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APRIL 1988

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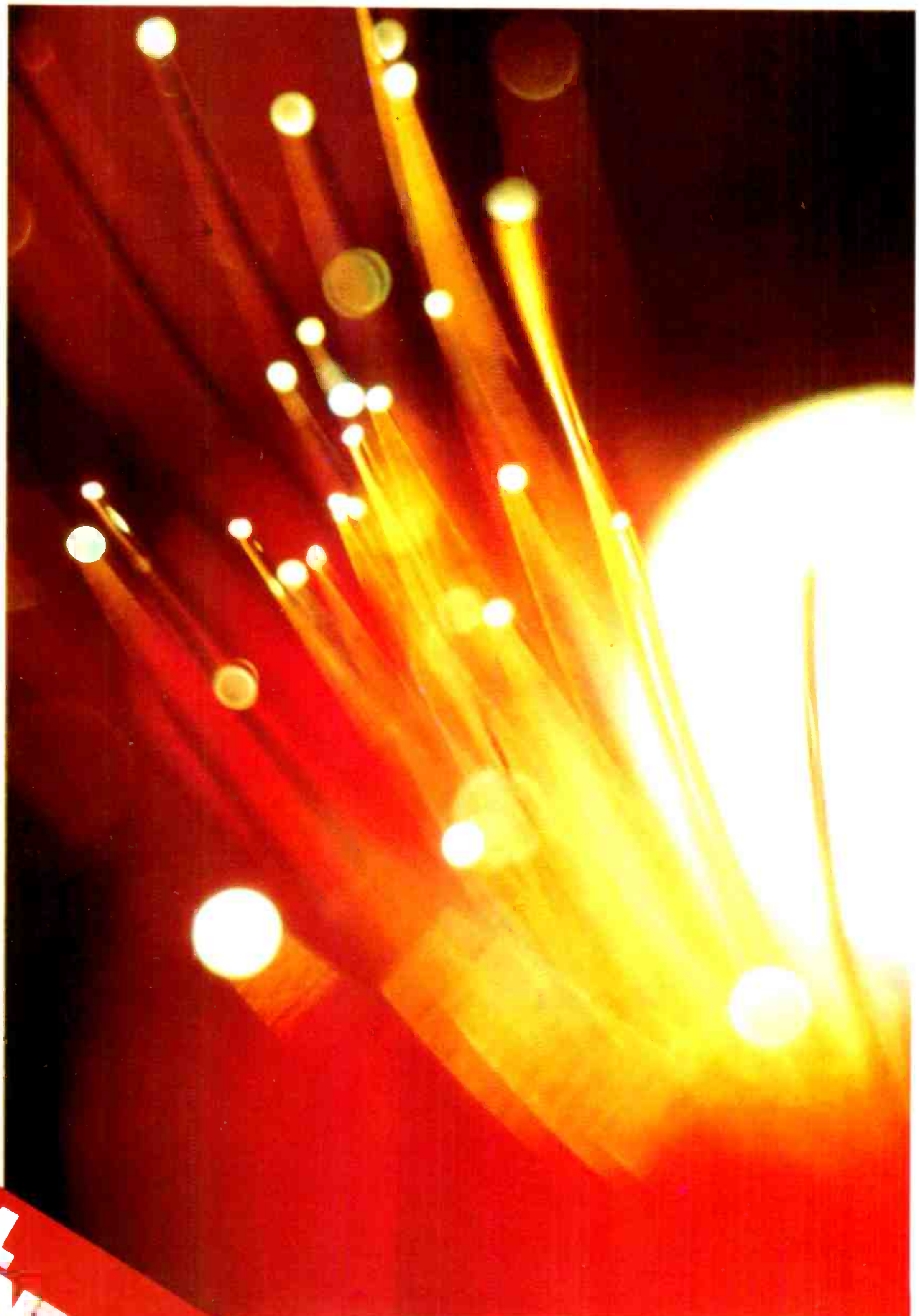
High-speed modem design

Random-input response of linear systems

Pioneers – optical fibres

Linguistics and data transmission

Harmonic extraction in lasers



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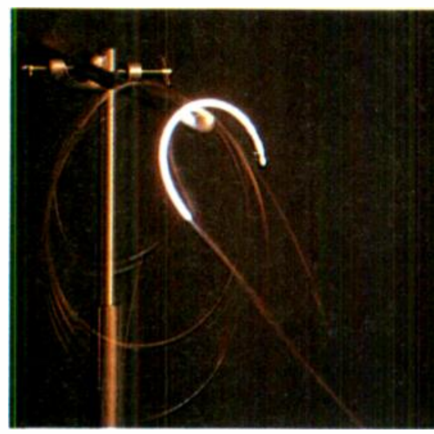
CONTENTS

APRIL 1988 VOLUME 94 NUMBER 1626

Insight No 2 focuses on developing technologies in communications from progress in fibre communications to advances in communications on the move.

FEATURES

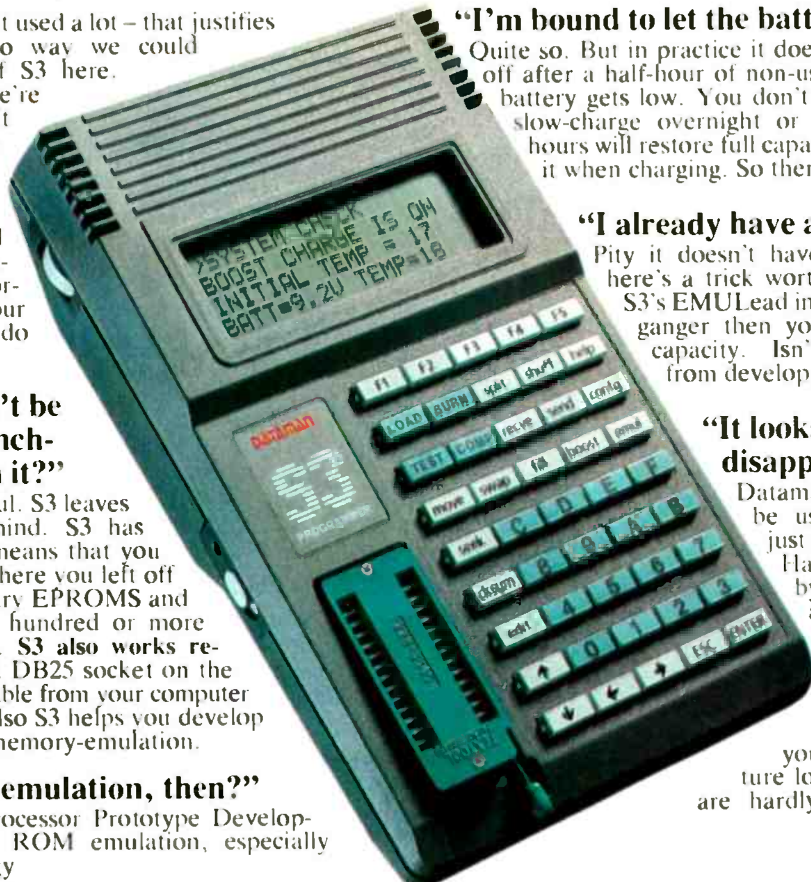


In Research Notes: destruction in a flash for an optical fibre.

REGULARS

"It's a pretty small battery-powered PROM programmer – so what?"

Tools which are convenient get used a lot – that justifies their existence. There is no way we could explain all the usefulness of S3 here. Instead, if you're interested we're going to let you see it, use it and evaluate it in your own workshop. We went to a lot of trouble to design S3 just the way it is – no other PROMMER is all CMOS and all SMT. So we must be convinced that S3 would be a formidable addition to your armoury. Now all we have to do is to convince you.



"Such a little thing can't be powerful, like a big bench-programmer – er – can it?"

Yes, it can. It is more powerful. S3 leaves other prommers streets behind. S3 has continuous memory, which means that you can pick it up and carry-on where you left off last week. S3 has a huge library EPROMS and EEPROMS. S3 can blow a hundred or more PROMS without recharging. **S3 also works remotely, via RS232.** There's a DB25 socket on the back. All commands are available from your computer (through a modem, even). Also S3 helps you develop and debug microsystems by memory-emulation.

"What's this memory-emulation, then?"

It's a technique for Microprocessor Prototype Development, more powerful than ROM emulation, especially useful for single-chip "piggy back" micros. You plug the lead with the 24/28 pin header in place of the ROM/RAM. You clip the Flying-Write-Lead to the microprocessor and you're in business. The code is entered using either the keyboard or the serial interface. Computer-assembled files are downloaded in standard format – ASCII, BINARY, INTELHEX, MOTOROLA, TEKHEX.
Your microprocessor can WRITE to S3 as well as READ. You can edit your variables and stack as well as your program, if you keep them all in S3.
S3 can look like any PROM up to 64K bytes, 25 or 27 series. Access is 100ns – that's really fast. Memory-emulation is cheap, it's universal and the prototype works "like the real thing".

"I'm bound to let the battery go flat."

Quite so. But in practice it doesn't matter. S3 switches off after a half-hour of non-use anyway, or when the battery gets low. You don't lose your data. Then a slow-charge overnight or boost-charge for three hours will restore full capacity. You can keep using it when charging. So there really is no problem.

"I already have a programmer."

Pity it doesn't have S3 features, eh? But here's a trick worth knowing. If you plug S3's EMULead into the master socket of a ganger then you get an S3 with gang capacity. Isn't production separate from development anyway?

"It looks nice. Will I be disappointed?"

Dataman tools are designed to be used by Engineers. Not just sold to Management. Have you ever been misled by some mouthwatering ad for a new product? Great artwork and exciting promises which feed your fancy? On impulse you buy and when the thing arrives you feel let down. The picture looked better. The claims are hardly justified; not exactly misrepresentation, just poor implementation. But you've bought it. And you're stuck with it. It stays in the cupboard, most of the time. **So how about this: buy S3 and use it for up to a month. If you're not still thrilled then you can have your money back.**

Softy3 is here!

S3 loads its working programs out of a PROM in its socket, like a computer loads from disk. Software expansion is unlimited. Upgrades will come in a PROM. Programs can be exchanged between users. How's that for upgradability?

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"Refund in the first month! How can you offer that?"

We trust S3 to fire your enthusiasm. We trust you not to use us as a free hire-service. We bet you won't send it back. How would you manage without it?

"These things cost a fortune and take months to arrive."

We wouldn't get you all excited and then let you down. It Costs **£495** plus VAT. That includes P & P, Charger, EMULead, Write Lead and a HELP program in ROM. S3 is in stock. Buy it today. Use it tomorrow. *(That's a fair promise. But please reserve product by phone or telex to make it come true).*

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Access

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COMMENT

Component or composite?

If we can disregard for a moment the battle over high-definition standards, then without doubt the most contentious issue in television technology at present is the question of recording formats. Improvements in camera performance have left the video recorder exposed as the weakest link in the broadcasting chain; and everyone agrees that the best way to sidestep its shortcomings is to go digital.

Already appearing in video production houses is the worldwide D1 digital standard, by which the luminance and colour-difference components are recorded on the tape separately. But D1's big advantage, that its cassettes can easily be replayed in PAL, SECAM, MAC or any other transmission standard, is offset by the rather serious drawback that it can give its best only in the expensive environment of an all-digital studio. For this reason, there has been no rush by the broadcasters to adopt it.

But now, to dismay in some quarters, comes Ampex with a new format, D2, where the signal to be digitized and recorded is the *composite* video waveform. A machine is to be demonstrated in the US at the forthcoming NAB show and PAL versions will be in Britain at IBC in the autumn. And Sony, which helped Ampex fine-tune the system, can be expected to unveil rival D2 machines.

Since it was Ampex which, with its quadruplex system back in 1956, made video recording workable, the company may be thought to have won the right to impose standards on the industry. But eyebrows have undoubtedly been raised by Ampex's tactic of presenting SMPTE (America's standards-making body) with a ready-made system, instead of adopting the more time-consuming approach of talking it through EBU (or other) working parties.

D2, according to Ampex, is likely to become the workhorse of studio operations and post-production, replacing not only the quadruplex machines still used for playing commercial spots but also the ageing C format. The new machines will offer a mass of attractive features, including low tape consumption, the ability to clone recordings digitally, and, most importantly, compatibility with existing analogue equipment.

What Ampex has done is to force an issue which others have for some years been pretending not to notice. For if, as seems almost certain, D2 is a commercial success, it will inevitably prejudice the adoption of D1, and with it the move to all-digital production. It will replace D1's universality with a recording format geared to an obsolescent transmission standard.

D1 may well survive as the first choice for high-quality work, such as in video graphics. But D2 could have far-reaching effects on the evolution of the ordinary television studio. For by giving managements the advantages of digital recording without the need to buy a whole digital studio, it may prevent us – possibly for ever – from attaining that most desirable goal, the general adoption of component coding. Inevitably it will hamper the introduction of new transmission methods such as MAC.

Purists need not worry too much, however. For even if D2 sticks, its lifetime could well be curtailed by moves towards high-definition television. And when a standard for h.d.tv is eventually thrashed out – if that day ever comes – we shall be able to reopen the debate on v.t.r. formats once again, with renewed enthusiasm.

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Designing a high-speed modem

Simple f.s.k. modems are no longer adequate for most professional communications requirements: more complex modulation methods and protocols are increasingly being adopted. This article shows how a V.22/V.22*bis* modem works. Subsequently the author will illustrate the implementation of these standards with a practical hardware example.

KEVIN J. KIRK

Because of the restricted bandwidth of national and international telephone networks, there is an upper limit to the data rates that modems can achieve. In most countries the recommendations of the CCITT (Comité Consultatif International Télégraphique et Teléphonique, an agency of the UN) are used as a basis for selecting frequencies and speeds.

The lowest speed commonly in use is covered by recommendation V.21, which is for an asynchronous f.s.k. system of up to 300 baud full duplex (i.e. capable of sending and receiving simultaneously at up to 300 bits per second). Frequencies used are 1180Hz (space) and 980Hz (mark) on channel 1 and 1850Hz (space) and 1650Hz (mark) on channel 2. The terms mark and space date from the very early days of telegraphy, when the pen either made a mark on the paper or left a space. Channel 1 is used by the calling (or originating) modem and channel 2 by the answering modem.

The highest speed available with simple f.s.k. is covered by recommendation V.23, which is an asymmetric duplex system with a forward channel capable of up to 1200 baud using 2100Hz (space) and 1300Hz (mark). This spread of frequencies leaves a small but usable bandwidth for a 'back' or engineering channel on 450Hz (mark) and 390Hz (space) having a maximum speed capability of 75bit/s.

Primarily, V.23 is used in half duplex systems where the back channel carrier is ignored and the clear to send (CTS) signal is merely a delayed version of the request to send (RTS) input, the delay being used to enable the channels to be turned around and settled ready for the new transmission. The exception to this is when the system is used in viewdata applications, such as British Telecom's Prestel service, where the 1200 baud forward channel is used to send pages of information out to the subscriber, who uses the 75 baud back channel to request page numbers or to call for information. When Prestel was first introduced a simple numeric keypad was sufficient. This included keys for 0 to 9 (for page number input) and ★ to precede page numbers or commands and # to terminate or execute commands. However, with the advent of extra services on Prestel and other viewdata networks, and more especially the use of two-way interaction via full alphanumeric keyboards (such as in telex traffic), the back channel has proved far too slow. In addition, many personal computers (such as the IBM and Amstrad PCs) cannot transmit and receive simultaneously at differing rates and so a software or hardware spooler is required to slow down the outward transmission. This has led to the provision of higher speed links of up to 2400bit/s full duplex – usually with error detection and correction, such as Vascom or T-link.

Many other databases are now capable of working at up to 2400bit/s. British Telecom's Packet Switch Stream (PSS) and International Packet Switch Stream (IPSS) services operate at up to 1200bit/s full duplex. BT Gold uses PSS and so is also capable of up to 1200bit/s full duplex; access at 2400bit/s has just been announced.

Although modems for these higher speeds cannot make use of conventional f.s.k., they must still produce a data signal that is capable of being accepted as 'speech' but stays within acceptable limits of errors and drop-outs.

This requirement led in 1979 to the CCITT's recommendations V.22 and later V.22*bis* (*bis* denotes a secondary related recommendation) which cover speeds of up to 1200bit/s full duplex (V.22) and 2400bit/s full duplex (V.22*bis*).

These recommendations have been adopted as standards in many countries including the United Kingdom and as such they form a benchmark for truly international communications.

However, to round out the picture the other main recommendations and their uses are summarized in Table 1.

DESIGN CONSIDERATIONS

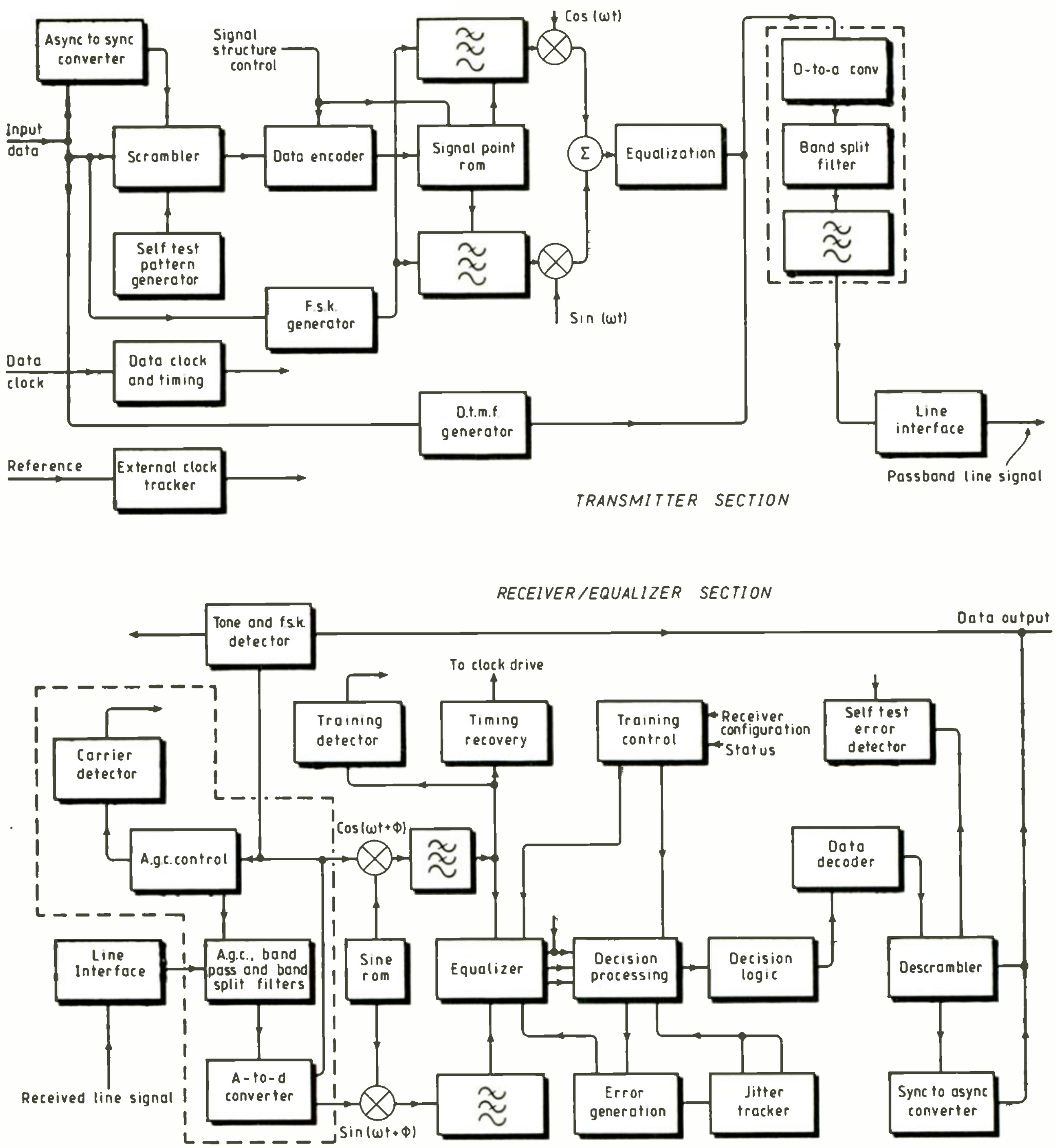
According to the CCITT recommendations for V.22, a modem will have the following characteristics:

- Full duplex operation on two-wire p.s.t.n. and point-to-point leased circuits.
- Channel separation by frequency division.
- Differential phase-shift modulation with

Table 1: main standards recommended on the CCITT for high speed data transmission. V.22 and V.22*bis* are dealt with in detail in Table 2.

V.26 (V.26*bis*)
2400bit/s asymmetric duplex (75 baud back channel) with fallback to 1200bit/s. Forward channel uses four-phase modulation of a 1800Hz carrier at 2400bit/s and two-phase at 1200bit/s. The back channel uses f.s.k. as for V.23. This modem does not contain a scrambler and is only capable of handling synchronous terminals. (US equivalent: Bell 201.)
V.27 (V.27*bis*, V.27*ter*)
V.27 and V.27*bis* provide 4800bit/s full duplex over leased lines with V.27*bis* having a fall-back to 2400bit/s. V.27*ter* provides 4800bit/s half duplex over public switched telephone network (p.s.t.n.) two-wire circuits with a fall-back to 2400bit/s. All have an f.s.k. back channel of 75bit/s. The forward channel uses eight-phase modulation at 4800bit/s and four-phase at 2400bit/s. V.27*bis* and V.27*ter* modems contain adaptive equalization with V.27 containing a manual equalizer; however, V.27 is recommended only for high quality leased lines meeting CCITT recommendation M1020. This modem contains a scrambler.
V.29
This standard allows 9600bit/s full duplex over leased lines and 9600bit/s half duplex over the p.s.t.n., with possible fall-back to 7200 and 4800bit/s. It uses eight phase modulation and amplitude modulation. At 4800bit/s the amplitude modulation is turned off, under which conditions it is similar to V.26. It may be multiplexed to provide one 7200 and one 2400bit/s channel, or one 4800bit/s and two 2400bit/s channels, or four 2400bit/s channels. It has a scrambler and adaptive equalization.
V.32
Full duplex 9600bit/s trellis-coded modulation over p.s.t.n. systems.
V.33
Capable of working up to 14.4kbit/s full duplex on four-wire leased lines using trellis-coded modulation.
V.35/V.36
Wideband 48kbit/s modem working over the 60-108kHz band.
V.37
Synchronous modem with a signalling rate exceeding 72kbit/s using the 60-108kHz band.

Note: V.22 covered formerly the standard signalling rates for p.s.t.n. modems (now V.5). V.22*bis* covered standard signalling rates for modems using leased lines (now V.6).



synchronous line transmission at 600 baud (nominal).

- Scrambler included.
- Test facilities included.

V.22*bis* is very similar except that in addition it uses amplitude modulation to double the data speed. To meet these requirements V.22 employs four-phase shift keying (d.p.s.k.) of a 1200Hz tone (originating modem) or 2400Hz (answering modem). In the latter case there is provision in the recommendation for an 1800Hz guard tone which ensures compatibility with the telephone network's requirements (it is transmitted at 4—6dB below the power level of data signals). Note that in certain countries (notably Sweden) a 550Hz guard tone may be used instead of or in addition to the 1800Hz tone. The CCITT does not specify a level for this guard tone.

Fig.1. Block diagram of the Rockwell modem chip set.

To meet total power transmission limits, the power level of the data carrier in the high channel will be about 1dB lower than the lower channel.

D.p.s.k. (delta phase shift keying) is a synchronous transmission system that uses phase changes on a carrier frequency to convey digital information.

This means that if the incoming data from the terminal is asynchronous then it first must be converted to synchronous form. This is achieved by using an elastic buffer which enables the modem to compensate for speed differences on the data train arriving from the terminal. Allowable error rates are 1200bit/s ±0.01% on the synchronous link (between modems) and +1% or −2.5% (or in certain circumstances +2.3% or −2.5%, the difference usually being selectable by a hardware or software link on many proprietary chip sets) on the asynchronous link to the terminal. The converter works by adding or subtracting stop bits at a maximum rate of one stop bit per nine consecutive characters. In addition if the converter detects between N and 2N+3 bits of start polarity (where N is the number of bits per character in the selected format) the converter will transmit 2N+3 start bits. If the converter detects more than 2N+3 start bits then it will transmit these all as start bits. This stream is passed on to the receiving terminal via RD (circuit 104 of the RS-232 link) to achieve synchronization. If the modems drop out of synchronization, they will regain it from the following stop to start bit transition. This is referred to as the break signal.

SCRAMBLING

After conversion, the synchronous bits are scrambled. This scrambling process is not for data security purposes, as it is self-synchronizing. Instead, it serves to ensure that the transmitted energy is spread throughout the passband, especially during quiet periods when no data is transmitted. This ensures that the receiving modem can demodulate the incoming signal coherently and recover the transmit clock. Also it allows the adaptive equalizer to update continously and lock on to the optimum equalization curves. A glance at Fig.2 will reveal that to all intents and purposes the scrambler and descrambler are identical: they consist of 17 shift register stages (tapped at stage 14) and a pair of half adders (exclusive-or gates). Therefore the data sequence is effectively divided by the generating polynomial in the transmitter, thus:

$$D_s = D_i \oplus D_s.X^{-14} \oplus D_s.X^{-17}$$

where D_s is the output data stream from the scrambler; D_i is the input data stream to the scrambler; $\oplus$ denotes modulo 2 addition and . denotes binary multiplication; and where mark=logic 1 and space=logic 0; and where the shift register clock rate is 1200Hz.

This means that if the number of shift registers is N then the resulting bit sequence representing a semi-random character will be 2N−1 bits long and the maximum number of identical sequential bits will be less than N. In addition, to ensure that remote loop 2 is not instigated by a scrambler lockup, circuitry must also be included to detect a sequence of 64 consecutive 1s at the scrambler output (D_s) and if detected the circuit must invert the next input bit to the scrambler (D_i). This circuit will be inoperative during handshaking (where detection of 1s is required for synchronization purposes) and during the instigation of a remote loop 2. In the interests of clarity this detection circuit is not shown in Fig.2.

Data is recovered in the receiver by multiplying the demodulated data sequence by the generating polynomial, thus:

$$D_o = D_s(1 + X^{-14} + X^{-17})$$

where D_o is the output data stream from the descrambler and D_s is the demodulated scrambler data stream. Note that some modem designers include a further circuit at point D_o to detect a sequence of 64 consecutive 1s at the descrambler input and then, if they are detected, invert the next output from the descrambler. This circuit must not begin to operate until after the handshaking process is complete and as such is best implemented in d.s.p.-based modems. This scrambling process suffers from one major disadvantage in that any single bit errors will be multiplied by three with the first error occurring during the recovered bit sequence, the second at the first shift register tap (14 clock pulses later) and the third at the end of the shift register chain.

MODULATION

After the scrambler chain the resultant data bits are paired to form di-bits 00, 01, 10 and 11, with the left hand bit of each di-bit being the one occurring first in the data stream. These di-bits will be used during modulation to form phase changes of 90° (00), 0° (01), 180° (10) or 270° (11).

Note that the phase to binary assignations do not follow the natural order (i.e. 0°=00, 90°=01, 180°=10 and 270°=11): this is to minimize errors due to phase inversion of one of the carrier oscillators.

V.22*bis* differs only in that the data chain is broken into four sequential bits, called quad-bits, with the first two bits being used to determine the phase changes as before (i.e. in relation to the preceding signal element) and the last two bits being used to modulate the amplitude of the carrier to form a further division of the quadrant. As this is essentially the only difference between V.22 and V.22*bis* a special training sequence is provided during the V.22*bis* connect sequence. Plain 600bit/s transmission in V.22 is carried out without di-bits, using a 90° phase change to represent 0 and a 270° phase change to represent 1.

However, V.22 and V.22*bis* are similar in that transmission is carried out at the optimum rate of 600 baud. Di-bits are passed to the complex modulator, which consists of two transmitters of identical frequency but 90° out of phase (in quadrature to each other). In mathematical terms, if we have two baseband signals $Vm_1(t)$ and $Vm_2(t)$ we can use a complex modulator (Fig.3) to produce modulated carriers:

$$V_1(t) = Vm_1(t)\cos\omega_c$$

$$V_2(t) = Vm_2(t)\sin\omega_c$$

where $\omega_c = 2\pi F_c(t)$, creating sum and differ-

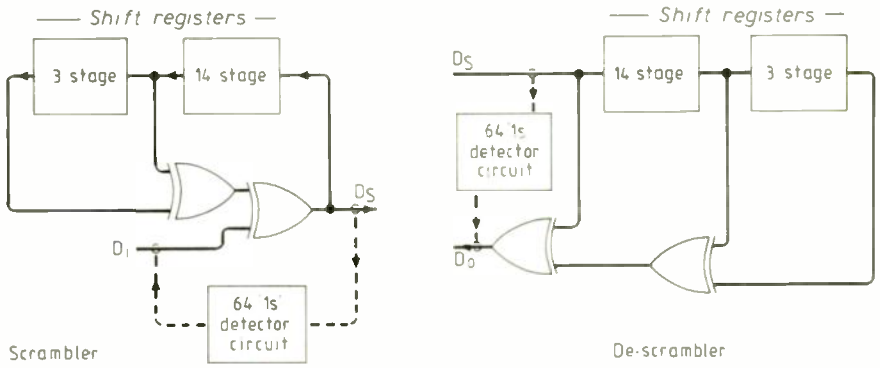


Fig.2. V.22 modems use a form of data scrambling to even out the transmitted energy spectrum.

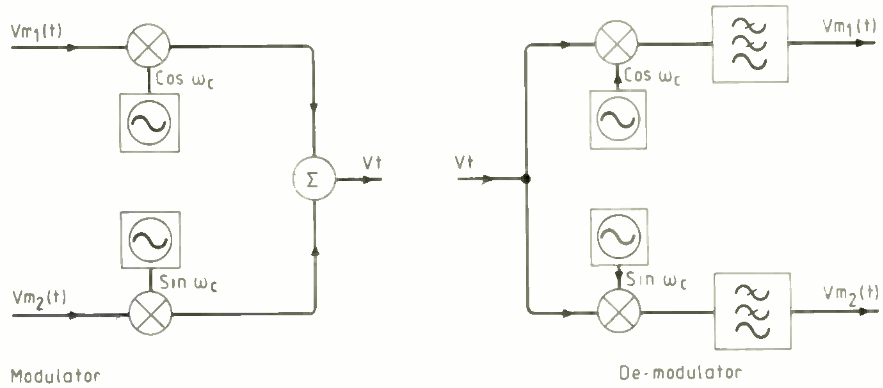


Fig.3. Quadrature-locked oscillators are used to permit product demodulation: this enables two baseband signals to occupy the same carrier space.

Table 2: CCITT V.22 modes

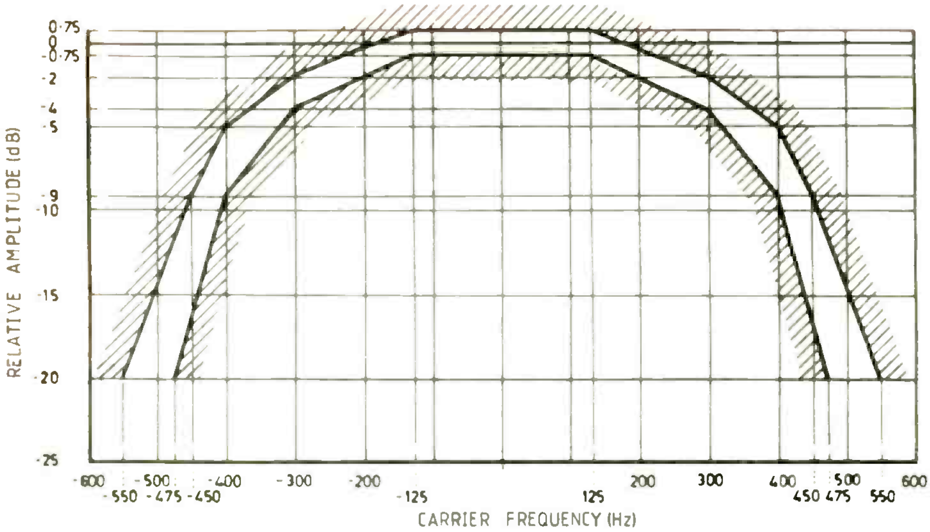
Mode	Speed
1	1200bit/s synchronous
2	1200bit/s start-stop (8,9,10 or 11 bits per character)
3	600bit/s synchronous
4	600bit/s start-stop (8,9,10 or 11 bits per character)
5	Asynchronous mode 1200 bit/s start stop or 300bit/s anisynchronous.

1 In mode 5 the modem always transmits data at a faster rate than it receives it from the terminal. Permitted rates are:
0-301bit/s and 1170-1204bit/s in to 1205bit/s
0-305bit/s and 1190-1221bit/s in to 1223bit/s.

2 A V.22 modem will normally offer either modes 1, 3 or 4 or a combination of modes 2 and 5, the required version being decided according to the handshake sequence on the p.s.t.n. link.

3 Bell 212A is the nearest US equivalent and differs in that it has no 600bit/s fallback, can only accept eight or nine-bit length characters and has only overspeed (+1% to −2.5%). However it has some additional features: for example, it can detect originating modems in answer mode and will automatically disconnect on receipt of a 'long space' (essentially a space lasting between 3.8 and 4.07 seconds). As a matter of interest, many computer bulletin boards running in the UK are using Bell 212A rather than V.22 (probably unbeknown to the system operator, since many higher speed modems automatically detect and select Bell 212). This means of course that true CCITT V.22-only modems (or those with hardware select lines), such as the Thomson 7515, will not work properly through no fault of their own. Symptoms of this condition are continuous errors, most noticeable during the quiet periods when every eighth bit is missing: depending on the receiving terminal, this usually produces ¼ or ¾ signs on the screen. For this reason our design will be capable of working on both Bell 212 and V.22.

Fig.4. Characteristics of the raised-cosine filter. This filter also removes unwanted harmonic content from the modem output.



ence frequencies about the carrier frequency, thus:

$$V_t = V_1(t) + V_2(t)$$

$$= Vm_1(t)\cos\omega_c + Vm_2(t)\sin\omega_c$$

Demodulation is a relatively easy matter because similar quadrature-locked oscillators are used to permit product demodulation to take place (Fig.3). The advantage of this system of modulation is that it enables two baseband signals to occupy the same carrier space. However, the disadvantage is that if phase lock is lost then severe crosstalk will occur between the two modulating signals.

The output of the modulator is usually fed to a low-pass filter (especially in d.s.p. based modems) to remove harmonic content and to a fixed compromise filter that performs a raised cosine function (Fig.4). This gives an output with a frequency spectrum equivalent to the square root of a raised cosine with 75% roll-off. Group delay characteristics are given as ±100μs over the frequency range 800-1600Hz (low channel) and 2000-2800Hz (high channel). In d.s.p.-based modems this is the point where digital to analogue conversion takes place. Similarly, in many single-chip V.22 modems this is where the signal is transmitted to a duplexer, sometimes referred to as the hybrid, which performs the four-wire to two-wire conversion (modem transmit and return, modem receive and return).

HANDSHAKING

For correct operation of adaptive equalizers, and to ensure synchronization, a handshaking sequence is called for in V.22.

This sequence

- detects carrier;
- adjusts automatic gain control circuits;
- sets timing synchronization;
- converges the adaptive equalizers, if fitted;
- synchronizes the descrambler.

This training sequence is crucial and must be strictly adhered to. Figure 5 illustrates the V.22 connection sequence: Fig.6 covers V.22*bis*. Note that the S1 bit pattern is the only difference between V.22 and V.22*bis* and so I shall describe only V.22 in detail.

ORIGINATING MODEM SEQUENCE

After 155ms (±50ms) of unscrambled 1s from the answering modem have been detected, DSR is turned on. The originating modem will then remain silent for a further 456ms (±10ms) after which it transmits scrambled 1s for equalizer convergence on the receiver. Similarly, the answering modem will transmit scrambled 1s, after which both modems will go into data mode.

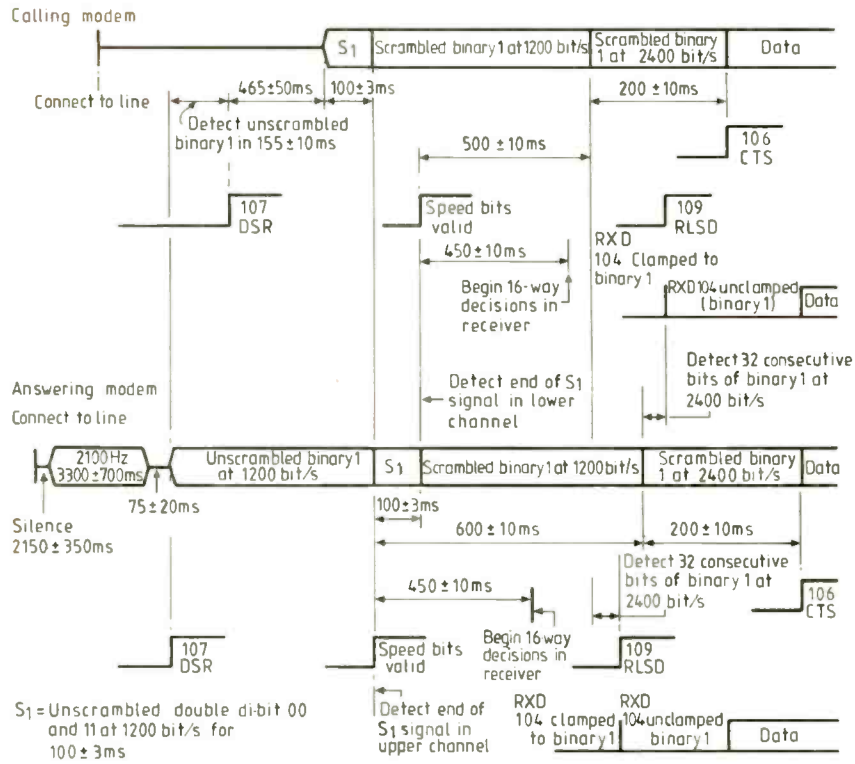


Fig.5 (above). V.22 modem connect sequence (1200bit/s). Three-figure numbers refer to RS-232 (now properly EIA-232) circuit numbers.

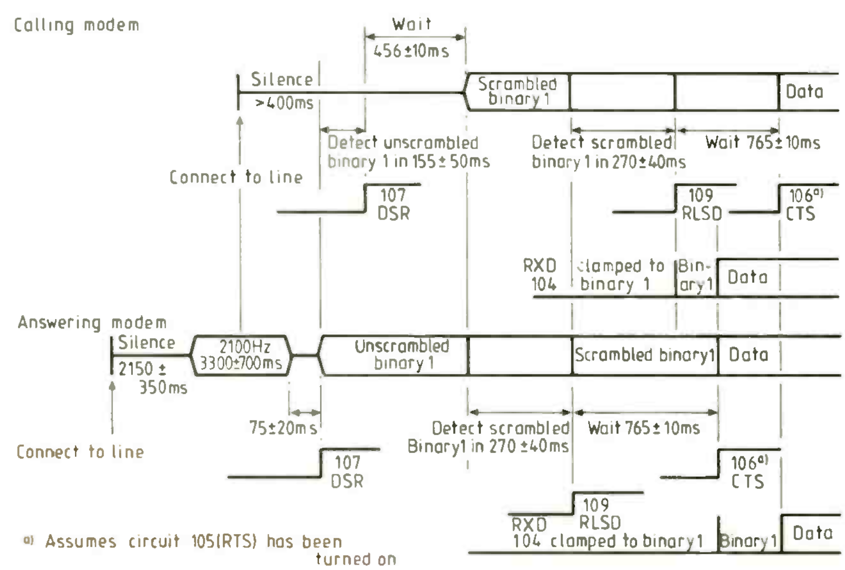


Fig.6. V.22*bis* modem connect sequence (2400bit/s).

ANSWERING MODEM SEQUENCE

On connection to the line the modem will transmit 2100Hz for 3300ms (±700ms) to disable echo suppressors. Following this it transmits unscrambled 1s to permit coarse timing and equalization convergence. It detects a chain of scrambled 1s for 270ms (±40ms) and then transmits its own chain of scrambled 1s. Lastly it waits for 765ms (±10ms) prior to raising CTS and going into data mode.

RECEIVING MODEM

Since many of the structures required for reception have already been covered in the transmit section, only the compensatory devices need to be described here: that is, the filters and amplifiers.

Following the line interface and hybrid, the first stage of reception depends on the actual modem device set being used. Ideally the stage would consist of a bandpass filter to exclude both low-frequency noise such as mains pick-up and high-frequency line noise, which will become more common as high frequency control signals are increasingly adopted: hence the requirement in BABT's regulations for high frequency spectral emissions below 1MHz to be at a level below −70dB. The filter must also be tight enough to limit the energy from the transmit section. It would be followed by a heavily damped a.g.c. circuit to compensate for line fading etc. The heavy damping should allow of course for the amplitude modulation of V.22*bis*. Thus any signals received over −43dB will be passed to the demodulator and any below −48dB will be damped, allowing 5dB of hysteresis.

The demodulator itself will recover the timing (probably using a phase-locked loop). It would be followed by (in d.s.p. modems) or preceded by (in many single chip devices) an automatic adaptive equalizer to help compensate for continously variable and fixed line amplitude and delay characteristics. Some devices (such as the Thomson 7515) offer only a fixed compromise equalization as this is all that is called for in V.22; however our design will feature both types. This equalization resembles that of a thermocouple linearizer: it produces a complement of the line amplitude and delay characteristics which when cascaded with the incoming signal will produce a flat response, which is why in d.s.p. based modems adaptive equalization is easier. The linearization algorithm may be continually applied or result codes may be fetched from look-up tables.

In his next article, the author will present a detailed description of an advanced 6501-based intelligent modem covering V.22/V.22bis.

Kevin Kirk received his basic training in the Royal Air Force. Having worked worldwide for a variety of computer companies, he is now senior design engineer with Anglo Computers.

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TEK 7844	400MHz Dual Beam Mainframe	£5700
TEK 7A26	200MHz Dual Trace Amplifier	£1250
TEK 7B10	1GHz Timebase	£895
TEK 7B53A	100MHz Dual Timebase	£650
TEK 7B80	400MHz Timebase	£595
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FEEDBACK

A.m. quality radio

I read with great interest the paper "Putting the quality back into a.m. radio" by J.L. Linsley Hood in the October 1986 issue. I want to make two comments.

In the paragraph referring to band-pass coupled i.f. transformer design, the author says (p.17) "...for critical coupling the coupling factor (k) should be the reciprocal of the mean Q value for the two coils". Actually, Q is not of the coil alone, but of the loaded tank. Q=100 is a typical value for a 455kHz i.f. coil, but the dual-gate mosfet output resistance can be of the order of the coil's parallel resistance, and the resultant Q may become, say, 65. In this way one designs a critical coupling and the result is under it.

Figure 2 (p.17) represents the amplitude response curves only for the circuit shown in (Fig.1(a)). If both resonant circuits are tuned on the same frequency f_0 and the coupling factor k is increased, then the circuits from Fig.1(b) to (e) behave like this: one peak of the amplitude response remains practically on f_0 while the other peak moves to the right(Fig.1(b)) or left (Fig.1(c), (d), (e)).

Tesu Ion-Constantin,
Polytechnic Institute of Iasi,
Romania.

Open letter to a school leaver

With regard to the possibility of our offering you employment, I regret that we are a very small company, specialising in industrial consultancy in the field of linear electronics, and we have no vaacancies at the moment.

However, if we had, bearing in mind the nature of our work, we would only be interested in engineers having a considerable degree of existing industrial experience, and able to make design contributions in such fields as identifying spectral distribution changes in noise; quantifying the ionic mobility characteristics of semi-colloidal fluids; or the reception of radio transmissions in the sub-microvolt level, with signal bandwidths down to a small fraction of a Hz – to take a random selection from recent design commissions.

Since our main effort in this case is a combination of background knowledge, inspiration, calculation and circuit design it would not be easy for you to help without a considerable amount more practical and theoretical training.

This brings me back to the point I most wish to make, as a piece of well meant advice. Get yourself some better qualifications. Turgid studies are a bore, but so is digging up a piece of uncultivated ground and a converting it into fruitful soil. You are still young enough to be able to embark on higher academic training, and acquiring useful scientific and technical knowledge is a vital task for you in the next few years. If you waste time it will soon be too late.

Sure, it is nice to earn a bit of money, but the amount you will learn in any company, doing the sort of bozo jobs which the young and unqualified hired hands are usually given, is not going to help you very much.

Believe me, I have spent fifty years in electronics and I have seen the realities of the work; young trainees don't learn as much as they hope – unless they are both inspired and inquisitive, and have tolerant employers – simply because the people who could tell them things are too busy doing their own thing to want to take time off explaining or answering questions.

Try to get to university, or some other higher training institution, and do a course in electronics, and aim for at least an upper second in a B.Sc., and then add an M.Sc., or Ph.D. to it. Then you will find jobs easy to get, you will be treated with respect and you will be allowed to do useful and challenging work, not just stuck with poking components into the holes of a p.c.b. whose function you do not know (and nobody will tell you) or fetching and carrying or tidying up behind some lordly young 'boffin' who thinks it a privilege that you are allowed to breathe the same air that he uses.

In the world of today, paper qualifications are everything. Whether you are useful or not only arises after that.

J.L. Linsley Hood,
Robins (Electronics),
West Monkton,
Somerset.

Neural simulation

Mention of both Pavlovian conditioning and electronic simulation of neural networks in John Wilson's January Research Notes ("Who wants a human computer?") brings to mind some early British work in this field long before the days of software and v.l.s.i.

In the early 1950s Dr W. Grey Walter, of the Burden Neurological Institute, Bristol, built a number of electronic functional models of neurophysiological processes to see if they gave any insight into what actually goes in the brain and central nervous system. As an example I enclose photocopies of some pages from his book The Living Brain (Duckworth, 1953) describing an electronic analogue of the conditioned reflex. The circuit uses three thermionic valves and a neon tube.

The device can be trained to give a response (relay operation) to a stimulus (a sound signal) which is not the natural or normal stimulus (a light signal) eliciting that response. In other words it learns that 'sound' means 'light'. Training is done by presenting the two stimuli more or less together (the sound before the light) about fifteen or twenty times. The resulting behaviour of the circuit is anogous to Pavlov's dogs being conditioned to salivate in response to the abnormal stimulus of a bell being rung, even after the natural stimulus to salivation – food – is no longer present.

To achieve this result the device uses three analogue memory functions with different decay times and one And gate.

Tom Ivall,
Staines,
Middlesex.

Flow charts

With Ross and Pratt's criticisms of Sweeney's flow diagrams (October and November Feedback) in mind, consider these examples which are some part of a larger machine. The examples could be called machine parts, assemblies, modules, processes, subroutines, programs or some such similar name.

Readers familiar with digital electronics will recognize Fig.1 as an RS flip-flop. Even when viewed from such a distance that the printed characters (R, S, etc.) are not clear, the figure is still readily recognizable by its characteristic shape. The viewer is using the same mechanisms that allow them to recognize a partly obscured person's face at a glance. In this case, I would guess that the recognition takes place in less than a quarter of a second.

Fig 1

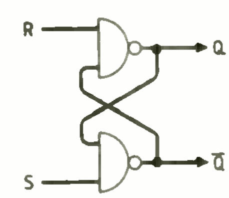


Fig. 2

```
DEFINE U1 AS 7400
BEGIN
  C := U1, 13
    Q := U1, 11/U1, 10
  A := U1, 9
    Q' := U1, 8/U1, 7
END
```

Now who has recognized what Fig.2 is? Well, it is a "pseudo-code" description of what would (almost) perform the same function as Fig.1. In my particular dialect I have chosen to call the inputs C for clear and A for assert. Did that throw anyone off? I don't think it would make much difference in Fig.1. And how about the fact that there is a bug in Fig.2; can Messrs Ross and Pratt find it inside of a minute?

A description of a machine part such as Fig.1, along with another one hundred similar parts, can be drawn on a single A4 size page and still be readily understood. A circuit diagram for a television set has about this density of information and is still

FEEDBACK

easily read. One hundred times Fig.2, listed as most programs are, would extend to over ten pages and be as clear as mud.

What I am saying is that real life practical experience has shown that for detailed work diagrams are more easily understood than verbal descriptions such as Fig.2. I have chosen a "hardware" example because hardware engineers are in no doubt as to what is the best way to communicate their information; they use diagrams such as Fig.1.

But should Ross or Pratt object that my hardware example is not relevant to software (i.e. computer programs, etc.) then consider that software is nothing more than a description of how to set up some particular piece of hardware. For instance, Fig.1 is a software description of a 1 bit variable, it has subroutines within it, the Nand gates, and it itself can form part of a bigger program, the whole machine.

Now Ross and Pratt suggest that this subroutine (Fig.1) is best described by a language "like English" (Pratt). But instead of writing the description as in normal English, they insist that by writing it in a wavy line down the page then suddenly, miraculously, it will acquire some "structure". The same structure, I guess, that makes it so recognizable in Fig.1. Well, looking again at Fig.2 you will see that I wrote it in a wavy line down the page but, to me at least, it still seems a lot less structured or recognizable than Fig.1.

The great tragedy of the computer industry today is that this cult of the wavy line holds an unwarranted influence over the development of the hardware. This is because the departments of wavy lines have always managed high profit margins, due to minimal capital overheads and the customer's general ignorance of wavy lines, and so have been favoured by the industry's captains over the hardware departments. This has lead to the present condition where the hardware's potential is fettered by the requirement to conform to the wavy line method of operation (i.e. the von Neumann bottleneck).

When computer designers realise that programming with wavy lines is just silly, and start instead to program with diagrams, I can guarantee that there will be an increase in the performance of the machinery.

A. Medes,
Dee Why West,
Australia.

Atomic fission

Thank you for publishing Carl D. Adam's article "Electromagnetically induced atomic fission" in the January edition of *EWW*. I look forward to seeing Adams' work progress from theory to reality.

I have been working in a somewhat different area to Adams, concentrating on the feasibility of 'electronically' interfering with the periodicity of radioactive decay rather than stimulating neutron fission.

As a physicist and electronics engineer, I am fully aware of the military implications of this field of research (Star Wars, for instance) but its potential for eradication of long-lived radioactive waste paralleled with the development of an extraordinary range of new power sources (particularly for space travel) cannot be put aside.

I believe radioactive 'avalanching' might be accomplished by the imposition of several 'keys' which exploit known atomic phenomena to elicit the required response. Naturally, I do not yet intend to reveal the specific procedures used to accomplish the desired result, but my keys involve the use of selected radioisotopes prepared in a number of specific configurations. These elements will be subjected to external excitation, partly electromagnetic – but other excitation keys will be inserted into the nucleus to initiate and control the avalanche!

I am well aware of the health problems posed by this project. The test rig alone requires thick shielding and monitoring apparatus. And the technique for preparing and installing the radiosotope poses some unique handling difficulties (albeit resolved).

As ever, the main difficulty is cost. The entire project will take more than a year to construct and require an investment of £400,000: a small price for a 'clean' planet and a ticket to the stars!

C. Bruce Sibley,
Waddington,
Lincoln.

Carl Adams, in his colourful article in *EWW*, January, 1988, p.15 suggests that an abundant and inexpensive energy source may soon be attainable if only we come to terms with the role the ether plays in causing atoms to have a stability characteristic related to standing wave conditions. By irradiating atomic nuclei with precisely tuned electromagnetic waves there is the possibility that fission can occur without the use of neutron bombardment.

Nuclear physicists will deride this idea, but there is an aspect that they will overlook, which I wish to mention by way of feedback on what Carl Adams says.

As *EWW* readers well know, EM waves at light and X-ray frequencies arise from electron regrouping in atoms. When we consider restructuring of atomic nuclei the EM waves produced are at the much higher frequency associated with gamma rays. In a sense, the tuning idea suggested by Carl Adams already features in tests using the Mossbauer Effect, but with an entirely different purpose in mind. In these tests gamma rays are emitted and absorbed by atomic nuclei and Doppler tuning caters for the recoil loss effects. We well know that radioactivity can be used to generate power, but so far this is not achieved by controlling the radioactivity by tuning an EM wave. The question, of course, is how this can be accomplished. Carl Adams' article aims at fostering research with this object in mind.

To add impetus to this proposition I remind readers of my article in *WW* October, 1982, p. 37 which speaks of an ether oscillating at the natural frequency at which wave energy creates particles in electron-positron pair form. This frequency is the limiting threshold frequency of gamma rays, being typically more than ten times that used in Mossbauer tests. The ether therefore can be said to be a source of ultra-tuned EM waves, which could interact resonantly with certain atomic nuclei.

From my own studies of resonant interactions betweeen a structured ether and matter, I came to realize that there are two species of atom that are driven into instability by the near-tuning of their standing wave modes with the ether oscillations. These are promethium (atomic number 61) and technetium (atomic number 43), which are singled out for resonance because these atomic numbers are close to 137 divided by $\sqrt{5}$ and by π, respectively. Note that 1/137 is the fine-structure constant and that the square of 137 is the ratio of the electron annihilation frequency to that of the motion of the electron in the hydrogen atom (atomic number 1).

Technetium and promethium are the two missing atoms in abundance tables. They are at least one thousand times more scarce than any element in the atomic number ranges 1 to 42, 44 to 60 and 62 to 83. Yet the rare earth samarium, which sits next to promethium with an atomic number 62, is ten thousand times more abundant than gold. In short, if the atomic elements represented radio stations each signalling at a different frequency, the transmissions from technetium and promethium are the ones that would be suppressed, owing to resonance with the channel reserved to the ether itself. The interaction would render these two elements unstable and divert their energy into forms operating at different frequencies.

I see this as support for the view expressed by Carl Adams, namely that the stability of atoms can depend upon their resonant interactions between the ether and EM waves developed within those atoms.

H. Aspen,
Department of Electrical Engineering,
University of Southampton.

FEEDBACK

Instrumentation amplifiers

In his article on instrumentation amplifiers (February, 1988, pp 123-5) Dr Lidgey provides a useful analysis of their properties. However, his conclusion, that an instrumentation amplifier has no significant advantage over the simple, standard, single-op-amp differential amplifier, is absurd.

In the real world, differential amplifiers are used to amplify differential signals in the presence of common-mode signals and interference. The signal sources involved are rarely considerate enough to have zero output impedance (indeed the commonest such source – the bridge sensor – has a substantial output impedance which varies with the value of the quantity being measured).

The gain and c.m.r.r. of the three op-amp instrumentation amplifier is barely affected by variations of source impedance whereas, as Dr Lidgey's own equations show, the gain and c.m.r.r. of the "simple, standard, single-op-amp differential amplifier" depend critically on the accuracy, and matching, of its input resistors – which cannot but be affected by the source resistances driving them.

Dr Lidgey's conclusion is so at odds with both basic electronic design (which seeks to minimize the effects that uncontrolled external variables may have on a circuit's performance) and with the everyday experience of instrumentation amplifier users that I am concerned about the failure of *Electronics & Wireless World's* technical referees to highlight the error before publication.
James M. Bryant,
St Marks,
Cheltenham.

F.J. Lidgey makes two serious omissions in his article contrasting operational and instrumentation amplifiers in your current issue. In discussing the problems of maintaining resistor matching to better than 1% over temperature, and the lifetime of the circuit, he ignores the ready availability of inexpensive amplifiers of both the types that he describes, manufactured in monolithic form with laser-trimmed resistors which have excellent accuracy and stability, and in concluding that the three-operational-amplifier instrumentation amplifier (INA) offers no significant c.m.r.r. advantage over the single operational amplifier circuit, he overlooks the drastic degradation of the latter's performance by even low values of signal source impedance.

For the last 6-8 years, this company (and others) have manufactured inexpensive monolithic INA's in which the critical resistors consist of laser-trimmed SiCr films deposited on the amplifier chip. These resistors, which are matched to 0.005% (50ppm), have temperature coefficients matched to about 1ppm and long-term stability better than 20ppm. Is it not excessively academic to discuss the problems of matching discrete resistors to 1% without mentioning such products?

Furthermore, in ignoring the applications of differential amplifiers with high c.m.r.r. – the majority of which involve signal sources, such as pressure cells and strain gauges, which have appreciable resistance – Dr Lidgey's conclusion that the three-operational-amplifier INA has no significant advantage over the simpler circuit, while true for amplifiers driven by stiff voltage sources, is dangerously misleading. The two circuits have comparable c.m.r.r. only when driven by very low impedances – in practical applications only the three operational amplifier INA, whose c.m.r.r. is substantially unaffected by the source impedance driving it, can be used.
R.E. Davies,
Senior Applications Engineer.

Moving-coil head amplifier

A new audio amplifier design in *EWW* is always of interest, so the moving coil head amplifier in the December 1987 issue is most welcome.

The circuit described showed a clever way to eliminate the large-value capacitor in the feedback loop. In the context of moving-coil amplifiers, the size of the capacitor is so large that electrolytics are the only practical solution. Every competent audio engineer knows that the inclusion of electrolytic capacitors in the audio signal path will seriously distort its sound quality due to dialectric absorption and other factors. In circuits where electrolytics have been used, it is often possible to improve their sonic performance by bypassing them with lower-value capacitors which will have much lower inductance. This measure can also be applied to power supplies, where the 10000μF reservoir might be bypassed by a better-quality 100μF electrolytic, a 1μF polypropylene and a 10nF polystyrene. Their effect is improved reproduction of the higher frequency part of the music.

I notice that the design makes no reference to the specification of components used. In my experience the quality of the cartridge loading resistor (e.g. R_1 in Fig.6) has a significant effect on the performance of the cartridge. A typical retail price of £10 for a pair of bulk-foil resistors with a temperature coefficient of 4 ppm/°C may at first seem a lot of money, but is small compared to the cost of some of the cartridges listed in Fig.1 of the article. In sonic terms, its effect may well be greater than that of spending an extra £10 on a higher-priced cartridge. Many people who have tried these resistors on my recommendation have been delighted with the improvements in sound quality.

I fail to understand the author's comment on the cost of the 2SB737. Its base resistance is only 2Ω, so one 2SB737 will replace three 2N4403s. I believe my business, Audio Kits Precision Components, is currently the only British supplier which advertises both devices. Curiously, in my latest list the price of the 2SB737 is *exactly* three times that of the 2N4403.

If any of your readers should be interested in building this head amplifier Audiokits will shortly be preparing a price list of parts used together with recommendation of how to improve the sound simply by fitting components manufactured to higher standards of quality and reliability.
Graham Nalty,
Borrowash,
Derby.

I should like to thank Mr Sage for his kind remarks about my article on moving-coil preamp stages. However, I would like to take issue with him on some of the points he subsequently raises.

There are good reasons for not quoting weighted and RIAA-equalized noise figures in dissertations on electronic design. Firstly, they tend to give an over-optimistic view of signal-to-noise ratios, and have a long and disreputable history of abuse in the field of hi-fi specmanship. Typically, RIAA equalization would improve the noise data quoted by roughly 13dB. (The maximum l.f. boost of an RIAA stage with respect to midband is actually a maximum of 18dB, not 30dB as quoted by Mr Sage).

Secondly, the resulting measurement is one step further removed from the results of Johnson-noise calculations. In low-noise design such calculations must be kept firmly in mind, usually by deriving a noise figure that shows how much noisier the circuit is than the theoretical minimum that the input source impedance allows. It is perhaps surprising that the concept of noise figure is not more widely used in audio design.

Thirdly, if there is doubt as to the frequency distribution of the noise being measured, weighting and equalization introduces a whole new set of possible inaccuracies. While I cannot speak for the BC650 or the ZTX655, I can assure Mr Sage that neither the 2N4403 or the 2SB737 show noise distributions with frequency that are markedly eccentric, and I do not understand his contention that unweighted measurements are not even usable for comparisons.

Moving on to the topic of using resistors as experimental source loads, I believe that, for

FEEDBACK

m.c. applications, this is valid. An m.c. cartridge consists of relatively few turns of very fine wire, and its electrical analogue is that of pure resistance plus a very small inductance. The latter can be neglected for setting optimum collector currents, as at these impedances noise is a very flat function of I_c, and there is no question of "fine-tuning" for minimum noise. My experience is that it is very difficult to obtain meaningful noise data when using a real cartridge as a source load, due to intractable problems of hum pickup, which are not completely solvable even with the liberal application of Mumetal.

I have not found myself that V_{ce} has a significant effect on noise performance in this sort of application. Linearity is certainly not a problem, as there is a negligible a.c. signal on the collector.

I was disappointed that, at the end of a constructive letter. Mr Sage disinterred the unhappy myth of sound degradation in electrolytics. I am at a loss to understand why he states that this has been demonstrated many times, when to my knowledge it has never been demonstrated at all.

Some members of the Subjectivist Tendency have exhibited "differential" test setups that have yielded the unsurprising information that capacitors have finite loss factors, but since this is a linear phenomenon no-one has ever been able to point out its relevance to audio design.* It is never helpful to make unsupported assertions, and I am still bemused as to why the standards of scientific proof should be so lax in the field of high-fidelity.

As to hypothetical t.h.d. degradation at very low levels, (presumably thought of as some sort of capacitor crossover distortion) the simple fact is that it does not happen. In a recent JAES paper[1]. I demonstrated that large-value electrolytics generate no trace of distortion (certainly less than 0.01%) at signal levels as low as 0.2 mV. This really is one of the great non-problems of all time.

To return to the m.c. head amp, the use of a large (220 μF) input capacitor is essential for minimal noise, and also to prevent time-constant interaction with the servo integrator. Bearing this in mind, adding local feedback networks for individual transistor biasing yields an unduly complex circuit, and also seems to give no benefit in ultimate noise performance. I realise that putting transistors in parallel and letting current-sharing take care of itself is not normally wise, but in this application it does work.

Finally, a word in defence of the TL072. It certainly makes a poor m.c. preamp, but it finds a niche in professional audio, giving moderate gain at medium impedances with moderate loads. The equivalent input noise is about −105dBμ under these conditions; in other words a TL072 operating at 10dB of gain would have an output noise of −95dBμ, comparable with the noise floor of 16-bit digital audio.

The use of TL072s in motorway construction is not recommended as the top of the dil package provides a poor grip in the wet. One solution, of course, would be to lay them upside down...

Douglas Self,
Forest Gate,
London E15.

*Enthusiasts of debate will enjoy the Great Capacitor Controversy of 1986, fought out in the correspondence columns of *HiFi News & RR* between August 1985 and July 1986. My own feeling is that I won this one on points.

Reference D.R.G. Self, "Ultra-Low-Noise Amplifiers and Granularity Distortion." *JAES* November 1987.

Words and pictures

Dear Editor – well read,
The nail – it could be said,
with neither fear nor dread,
was hit full-on the head!

What a timely and much needed editorial – please 'tilt' further. Send copies to all those who purport to be careers masters and lecturers whose responsibility it is to place graduates on the first rung of the industrial ladder but who, when requesting interviews, have the temerity to send out letters which typically consist of 10 or more single-sentence paragraphs, each of which takes a maximum of two lines on an A4 page.

Then there are the organisers of the local M.S.C. scheme, who write letters in which what is supposed to be the opening sentence is, in fact, a phrase. They have never been taught that a verb is a 'doing' word and that a sentence must possess one together with a subject etc.

The other problem is that typewriters – electric or manual – and word processors cannot spell. If, at school 'open nights' one has the audacity to ask the teacher of English why he or she did not correct the wrong spellings which occurred in so and so's essay the answer is usually that such criticism would only serve to demoralize the pupil. Whatever happened to the effective psychology of the edict "write-out 50 times!"

By coincidence, a letter from a college, a copy of which is enclosed (identity of source removed of course), arrived on the writer's desk at the same time as the *EWW* and, although it is one of the better examples of such missives, it does serve to illustrate your point, in that it is disjointed and has no 'flow'. If the writer of that letter spoke in the manner in which he wrote, he would probably sound something like a Dalek.

Allen Bennett,
Allen Bennett Controls Limited,
Sheffield.

Turing

In the November, 1986 issue of *EWW* you published an article by Tom Ivall on Turing's famous paper "On Computable Numbers,..."

In this paper there is a very disturbing contradiction between the *specification* for his machine on the one hand and its *attributed properties* on the other.

On p.230 his opening sentence read "The 'computable' numbers may be described briefly as the real numbers whose expressions as a decimal are calculable *by finite means.*" On p.231 he repeats this, adding "....the justification lies in the fact that the human memory is necessarily limited." On p.250 he refers to "....the physical system consisting of the computer and his tape."

We can see that what Turing is studying is the single physical system which may take on the following evolutionary forms:

(a) human computer with finite human memory;
(b) human computer with finite tape;
(c) mechanical computer with finite tape;
(d) electronic computer with finite storage.

His paper antedates (d) by some ten years. However, (d) gives useful confirmation that this system is finite in both parts; for who today would claim that he or she could build an infinite computer or provide it with infinite storage?

Unfortunately, and probably through defective maths, Turing goes on to deduce that irrational numbers, like e, are computable: that is to say computable *in full*, or expressible in positional notation with absolute precision. To do this, a Turing machine would certainly need an infinite tape, as is widely recognised; indeed, The Encyclopaedic Dictionary of Mathematics says "The tape is infinite in both directions."

In my view, the mathematics of Turing's day has included undetected error, as shown by this outrageous inconsistency as to the length of Turing's tape. If it takes fifty years to detect this one particular error, how long will it take present day mathematics to detect and correct them all?

H.L. Fisher,
Harpenden,
Herts.

Floating bridge

Will Mr R.M. Brady, who was at Trinity College in 1980, and who wrote an article on the floating bridge amplifier in the September and October issues of 1980, please contact the editor? – Ed.

Frequency measurement

Design of counter-time instruments has changed radically in recent years. The latest techniques used in frequency meters are described.

R. A. PAGE

In the past decade the humble frequency counter has quietly undergone a revolution. Ten years ago a typical instrument contained several boards of t.t.l. and a similar quantity of analogue circuitry. Products from many manufacturers looked and performed much the same, a neat row of push buttons for range selection sitting underneath six, seven or eight-digit l.e.d. display. The 1970s saw the introduction of simple, by today's standards, small-scale-integration, hotly pursued by l.s.i. and microprocessors in the 1980s. The range of products increased enormously as did the facilities offered.

Today, instruments can be grouped roughly into three categories, the simplest and least expensive offering basic frequency measurement only, instruments with both time and frequency measurement, and microwave counters.

To appreciate the benefits that modern technology has brought, it is helpful to review the operation of a basic frequency counter. The input signal, Fig.1(a), is first subject to a degree of conditioning (amplifying, filtering) before being applied to a Schmitt trigger with the intention of producing a well-behaved pulse train at the same frequency as the input, over as wide a range of input levels as possible. The main gating is controlled by a signal derived from the divided-down output of a reference oscillator, and the gated pulses counted by a chain of decade dividers whose contents are latched into the display at the end of the gate period. The lack of synchronism between the input and reference signals produces a ±1 count uncertainty in the measured total, Fig.1(b), and the effective resolution becomes the reciprocal of the gate time, i.e. a one second measurement will resolve the input to 1Hz.

For frequency measurement the input signal is counted for a fixed gate time. If the input signal is fixed, fed from a reference oscillator, the counter will display a measure of the gate pulse length, i.e. a time measurement, Fig. 1(c). For this reason, most general-purpose instruments can offer both frequency and time measurement for little increase in hardware complexity, and are known as 'universal counter-timers'.

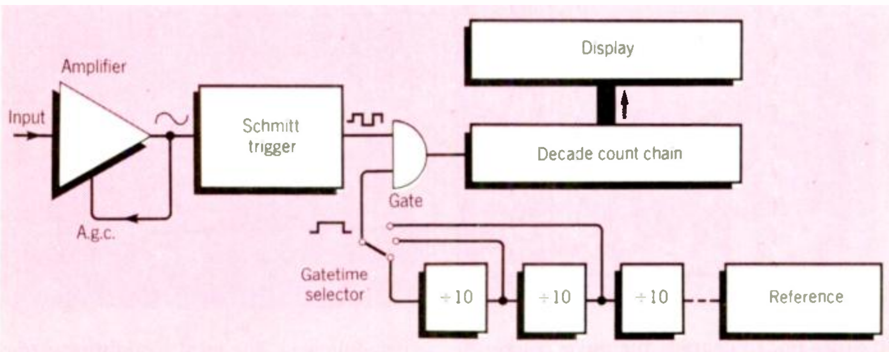


Fig.1(a). In the basic frequency counter, the input signal is squared up by the amplifier and Schmitt trigger and counted for a pre-determined gate time. Resolution is ±1 input cycle.

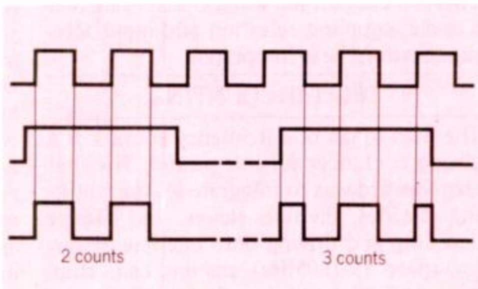


Fig.1(b). The accumulated total depends on the time relationship between the input and gate signals. In this example either two or three counts are recorded for a true input of two.

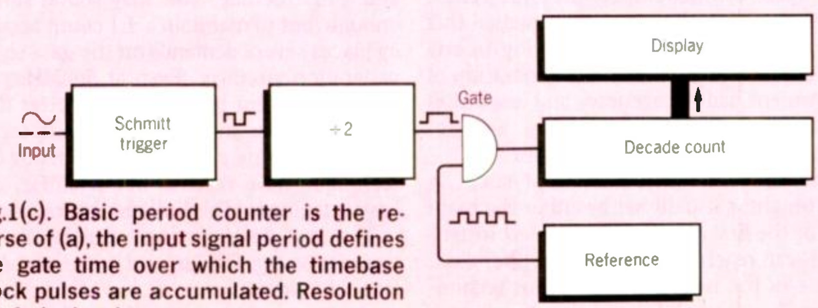


Fig.1(c). Basic period counter is the reverse of (a), the input signal period defines the gate time over which the timebase clock pulses are accumulated. Resolution is ±1 clock pulse.

SIGNAL CONDITIONING

The analogue input circuitry of a frequency counter has to meet a demanding specification From an input that can have virtually any waveshape, have frequency components anywhere from 10Hz to 500MHz or more, and range from less than 10mV to 250V, it has to produce a constant-amplitude pulse train with no extra transitions than those resulting from the input. No-one has yet produced one circuit to do this with any degree of success, and the usual solution is to split the frequency range into convenient bands, 'convenient' meaning those the designer would like rather than anything related to use or application. Typical ranges are 10Hz to 10MHz, corresponding to the operating limits of c.m.o.s. 5MHz to 100MHz (t.t.l. and e.c.l.), and 50 to 500MHz (highs-speed e.c.l.). Even so, switchable low-pass filters are often provided in an attempt to combat unwanted high frequency signals This noise can (and often does) ruin any attempt at measuring a "real" signal (as opposed to those that come out of signal generators).

To overcome the very wide dynamic range requirement, automatic gain control systems are commonly employed to amplify or attenuate the signal so that its peak-to-peak value is just greater than the hysteresis band of the Schmitt trigger. These work well and overcome many noise-related problems. On logic-derived signals, however, they may actually accentuate noise, as the effect of a.g.c. is to reduce the slew rate. In this particular case a clipping circuit would perform better. Also, most frequency-only counters are permanently a.c.-coupled, which causes problems with asymmetric waveforms such as pulses. The trigger point often ends up on the ringing and overshoot part of the signal. This is one instance where "progress" is not necessarily a good thing: there is not much you can do to an automatic counter that is obstinately measuring the third harmonic of your signal. Manual adjustment of the trigger level/sensitivity control of an older counter would usually produce the required reading. Counter-timers invariably have more comprehensive

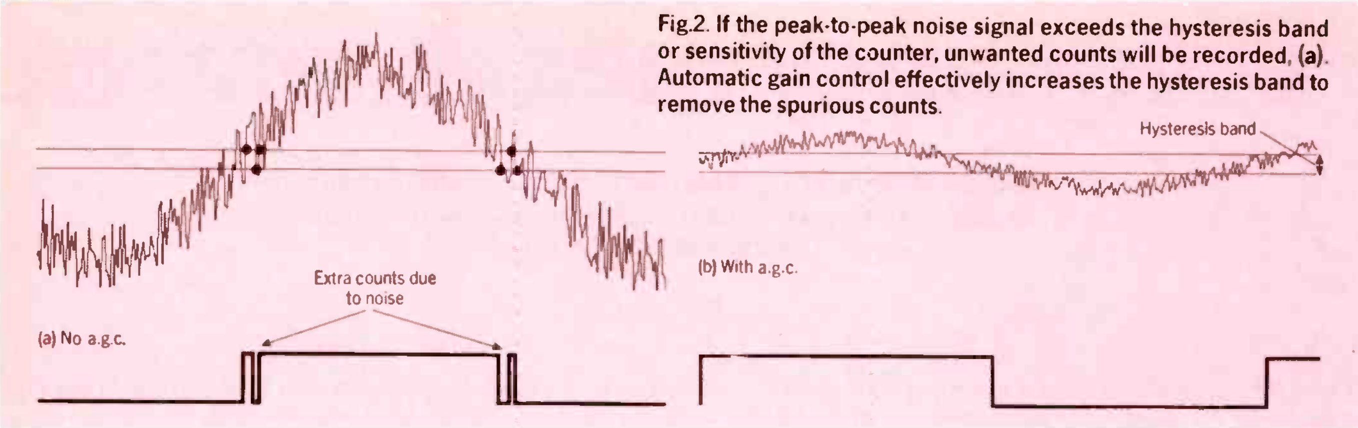


Fig.2. If the peak-to-peak noise signal exceeds the hysteresis band or sensitivity of the counter, unwanted counts will be recorded, (a). Automatic gain control effectively increases the hysteresis band to remove the spurious counts.

control of the trigger point, as accurate measurement of time intervals necessitates this.

SIGNAL CONDITIONING FOR TIMING MEASUREMENTS

The signal-conditioning requirements for timers demand a lot more flexibility than those provided for frequency measurements. For greatest accuracy it is vitally important that the input circuits trigger on the right part of the signal waveform. Most, if not all, timers feature a trigger level control that is used to position the trigger point anywhere within the input range of the instrument. The more comprehensive instruments allow this to be set digitally both via the front panel and remote programming. They may also allow the trigger circuits to act as digital voltmeters and measure the amplitude of the input signal. This leads naturally to the instrument being able to choose its own trigger levels, and make automatic measurements of pulse width, rise time, etc.

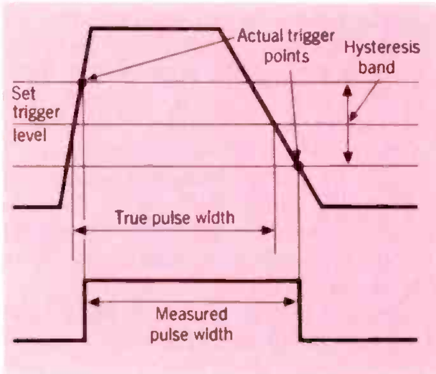
This is not the whole story, however. The actual trigger point depends not only on the trigger level set, but also on the slope of the input waveform and the hysteresis band of the trigger circuit (some hysteresis is always necessary to ensure noise-free transitions). This can lead to significant errors, Fig.3. One solution is to make the hysteresis band as small as practical, with all the attendant inaccuracies caused by noise, Fig.4. A more elegant answer is to use hysteresis compensation, Fig.5, which entails moving the trigger point setting depending on the slope of the input signal such that the actual trigger point occurs at the same voltage.

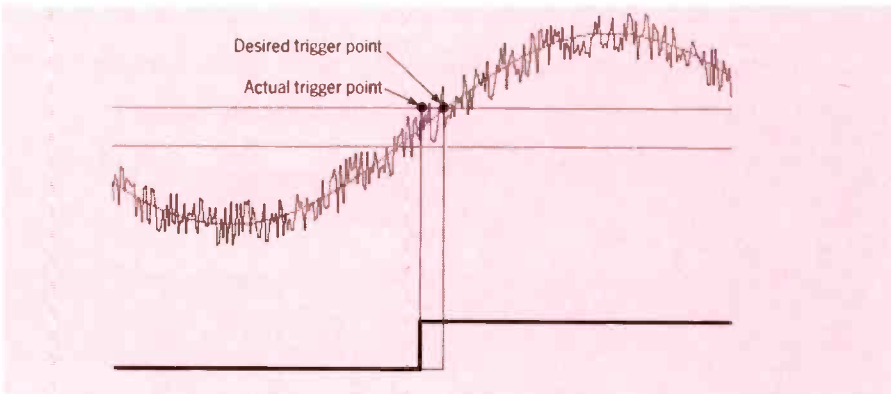
Many 'real world' signals are derived from mechanical systems with a lot of contact bounce. A 'trigger hold-off' feature disables the trigger circuits for a pre-set time after the first active trigger signal and prevents spurious edges from prematurely ending the measurement interval Fig.6.

Timing measurements often require two input channels, a start channel and a stop channel. For highest accuracy they must be identical and of as wide a bandwidth as possible. Modern instruments tend to use some form of hybrid circuit, usually thick film, as it is the simplest way to overcome variations due to layout and to minimize circuit strays. The input impedance of timing channels is standardized at 1M and it is essential to minimize the input capacitance in order not to degrade the pulse response. This is a difficult job when controls such as a.c.-d.c.-coupling selection and input attenuators must be incorporated.

Fig.3. For timing measurements, the hysteresis band must be kept small to avoid timing errors caused by the slope of the input signal. The trigger level is different for positive and negative-going edges.

Fig.4. Too small a hysteresis band introduces additional complications due to premature triggering on noise peaks.





DIGITAL COUNTING

The digital half of a frequency counter is a strong contender for integration. The first step forward was to integrate all the counting decades, division stages, and display decoding and driving onto one low power, low-speed (5-100MHz) custom l.s.i. chip. This had to be driven by a number of high-speed counter chips at the "sharp end". The major manufacturers had reached this level by the late seventies. Lacking in any sort of processing power, this generation of instrument had the accuracy and resolution limitations of earlier products, and remained unchanged for several years.

The upper frequency limit of such an instrument is usually set by either the main gate or the first decade. The simplest instruments can reach 100MHz, using either e.c.l. or one of the newer t.t.l. to c.mos technologies. To go much beyond this, two routes can be followed. The most straightforward is the prescaling technique, in which a high-speed divider chip (÷10 or ÷16) is placed in front of the main gate. This allows operation up to 1GHz and beyond. The emerging GaAs technology extends to at least 4GHz. The only penalty of prescaling is a loss of resolution (or an increase in measurement time) proportional to the division factor, which may or may not be important, depending on application. The resolution can, however, be improved by interpolation.

The second method is to use a faster gate and a first decade. This may sound simple enough, but to maintain a ±1 count accuracy places severe demands on the gate signal generation circuitry. Even at 500MHz, the gate signal must be accurate to better than 1ns, and its rise and fall times even faster. In practice, commercial instruments using this technique have reached 500-600MHz, and have remained at this limit for several years.

The next development, resulting in the 'counter on the chip' arrived in the introduction of microprocessors and much faster custom l.s.i. This allowed nearly all the counting circuits to be integrated, and processor control allowed the measurements to be manipulated in ways that increased resolution several times.

RECIPROCAL COUNTING

The ±1 count uncertainty in a conventional frequency measurement becomes an embarrassment at low frequencies; a 1-second gate time produces a resolution of 1Hz which at 100Hz is a 1% uncertainty. A reciprocal counter measures the period of the input and computes the corresponding frequency to a far greater resolution. For example, assume an instrument has the fairly common reference clock of 10MHz. A 100Hz input signal producing a 10ms gate time will result in the accumulation of $10^5 \pm 1$ clock cycles. Hence the resolution has increased to 1 in 10^5 and for a much shorter gate time. By averaging several input periods the resolution can be improved still further.

This ability, combined with processor control, has resulted in a new facility: the measurement time can be continuously varied to obtain the desired resolution, it is no longer necessary to select ranges in decade steps. Obviously, the resolution is a function of the ratio of input frequency to clock frequency; this technique is therefore limited to relatively low frequencies.

INTERPOLATION

The other method of increasing resolution is by interpolating between successive clock pulses to produce the same result as a much higher clock frequency. The technique requires the use of some very high-speed processing circuitry. The time difference between the opening and closing gate edges and those of the input signal define the charge time for a dual-slope integrator, Fig.7. This is then discharged at one-hundredth of the charge rate. The discharge time is measured by normal means and the processor does the necessary number-crunching to add each fraction of a clock cycle to the result measured in the normal way. To put some numbers to this, a basic 10MHz clock gives results equivalent to a 1GHz clock, i.e. nine-digits of resolution in one second.

FLEXIBILITY AND PROGRAMMABILITY

The advent of microprocessor control substantially changed the appearance of the modern counter. Most instruments sport a mini-keypad with enough function and facilities to satisfy everybody. Mathematical functions enable the display of not just frequency, but frequency offset, drift, either fractional or in parts per million, rotational speed, and even statistical data such as mean and standard deviation. Timers can compute pulse width, rise and fall time, duty factors, phase, frequency ratio, and even display the peak positive and negative voltages of the input signal.

The increasing use of automatic test systems, both in production and in the laboratory, has made remote programming facilities highly desirable. Most instruments today offer this in the GPIB format and some mate* – compatible instruments are becoming available. The speed of measurement of such instruments can become extremely important in an a.t.e. system, particularly in a production environment when many measurements have to be made and the overall test time has to be kept to a minimum. Even in the r&d laboratory, high-speed measurements allow a lot of statistical data to be accumulated, which the design engineer could not obtain in any other way.

MICROWAVE MEASUREMENTS

Instruments able to measure microwave frequencies are specialized pieces of equipment and are many times more complex and costly than low frequency counters. Indeed, all microwave counters contain at least one l.f. counter within them, and some as many as three.

TRANSFER OSCILLATOR TECHNIQUE

The transfer oscillator technique is probably the oldest method in use, Fig.8. In its modern form, operation is controlled by a microprocessor, but this is not essential. The basic system comprises a phase-locked loop that locks to a subharmonic of the microwave signal. The voltage-controlled oscillator typically 200-300MHz and sampling mixer combination effectively generate a comb of v.c.o. harmonics, one of which produces a beat signal in the i.f. band (about 100MHz). The i.f. signal is compared with a signal derived from the counter's main frequency reference and the error signal locks the v.c.b.

To find the harmonic number N, the input signal is simultaneously fed to another sampling mixer driven by a signal slightly offset from the main v.c.o. The resulting i.f. is mixed with the main i.f. to produce a difference frequency proportional to the harmonic multipler N, and the original offset frequency. The microwave input signal is then calculated by measuring the v.c.o. frequency by normal means, multiplying by the harmonic number N and adding or subtracting the i.f. To maintain resolution, multiplying by N means extending the gate time by the same factor. For example, a measurement at 20GHz using a v.c.o. at 200MHz takes 100 times longer than a conventional measurement.

Important specifications peculiar to microwave counters are sensitivity, a.m. and f.m. tolerance, multiple signal discrimination, acquisition and measurement time. Acquisition time is the time the counter takes to find the signal and prepare to make a measurement. High modulation tolerance and good multiple signal discrimination allow measurements to be made on fully loaded microwave links, it being undesirable to take the equipment out of service. The transfer oscillator counter offers the best sensitivity of any microwave counter (typically −40dBm), due to the main phase-locked loop having a narrow bandwidth, which rejects noise associated with the input.

Unfortunately, the f.m. tolerance is poor (less than 10MHz pk-pk), as the loop is unable to lock onto wide deviation signals.

* Modular automatic test equipment

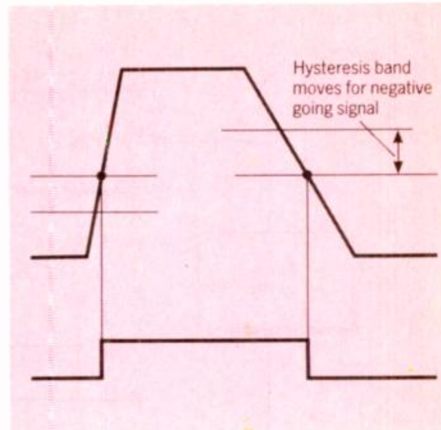


Fig.5. Hysteresis compensation is the solution to the problem in Figs. 3 & 4. By moving the hysteresis band automatically, the actual trigger level remains fixed.

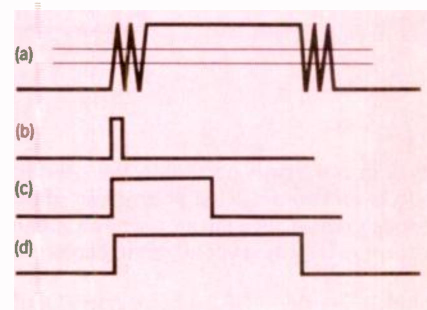


Fig.6. Trigger hold-off is used to overcome the problems of noise or contact bounce. Attempts to measure the signal shown at (a) will result either in extra counts or the short interval in (b). Trigger hold-off uses a monostable period, (c), to inhibit the signal during bounce time to produce the required measurement, (d).

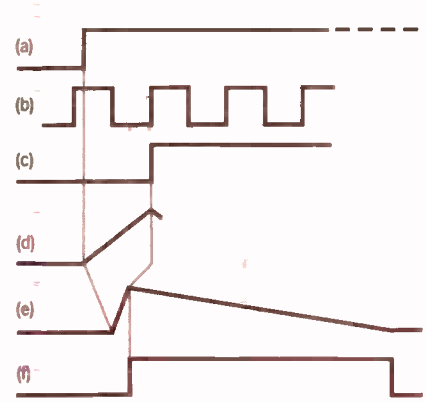


Fig.7. Analogue interpolation increases the resolution of a timing measurement to well beyond the natural limit of the timebase period. The time difference between the 'start' signal, (a), and the next active clock edge used to open the gate, (c), is converted into an analogue voltage by the integrator, (d), which is then discharged at 1% of the charge rate and the discharge time is measured, (f). The result is divided by 100 and added to the conventional measurement.

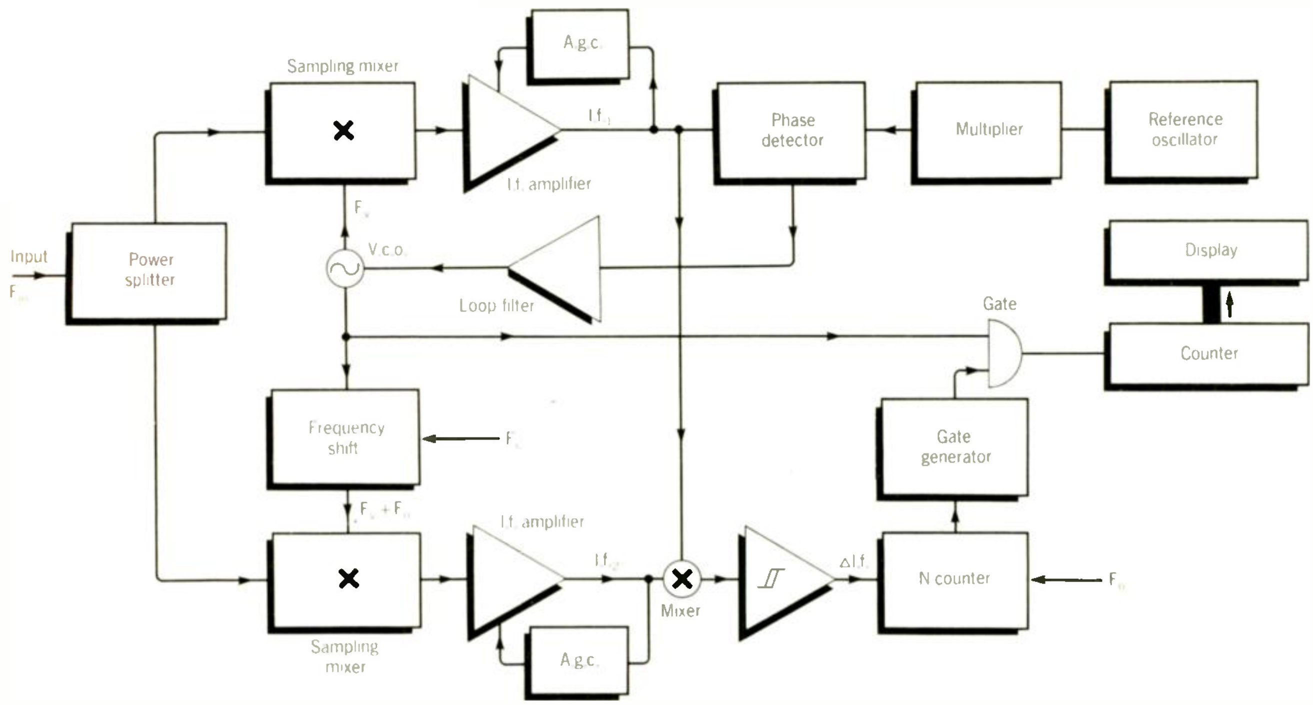


Fig.8. In a transfer oscillator, the primary loop is locked onto a subharmonic of the input signal and the harmonic multiplier is determined by the second mixing chain.

When locked, $F_{in} = NF_v \pm i.f._1$ **(primary loop)**
$= N(F_v + F_o) \pm i.f._2$ **(secondary loop)**

from which $N = \dfrac{|i.f._1 - i.f._2|}{F}$

Tolerance to a.m. and multiple signal discrimination can be very good, and depend on the a.g.c.

If the p.l.l. is replaced by a looser frequency-locked loop, the f.m. tolerance can be improved substantially at the expense of some loss in sensitivity, as the loop becomes more noise-sensitive.

HARMONIC HETERODYNE TECHNIQUE

Another popular architecture for microwave counters uses the harmonic heterodyne technique. The input signal is again mixed with a harmonic of the local oscillator, Fig.9, but in this case the l.o. is produced by a frequency synthesizer locked to the counter reference, and the i.f. is allowed to vary over a wide range (20-100MHz). In operation the l.o. is rapidly swept over its full range until the processor has calculated the best frequency to set the l.o. to, in order to give a suitable i.f. The harmonic number can be calculated in three different ways. One way is to use a second mixing chain in the same way as the transfer oscillator, as implemented in the 2440 series from Marconi Instruments. This results in a system with a very fast measurement time: as the l.o. is locked to the counter reference there is no need to increase the gate time. The i.f. signal is an exact down-conversion of the input.

A second method is to step the l.o. a small amount and measure the resulting i.f. shift. This appears to be the same as the first approach with half the hardware but with a small increase in measurement time due to the second (low resolution and high speed) i.f. measurement. Unfortunately, the penalty associated with the cost of savings of the single-mixer approach is loss of f.m. tolerance. Any hint of coherence between the input signal's f.m. and the l.o.'s stepping rate will result in an incorrect reading. To overcome it the l.o. must be stepped in a random or pseudo-random manner, and the i.f. shift averaged over a number of readings. Good f.m. tolerance to 50MHz can be obtained with acquisition time up to a second.

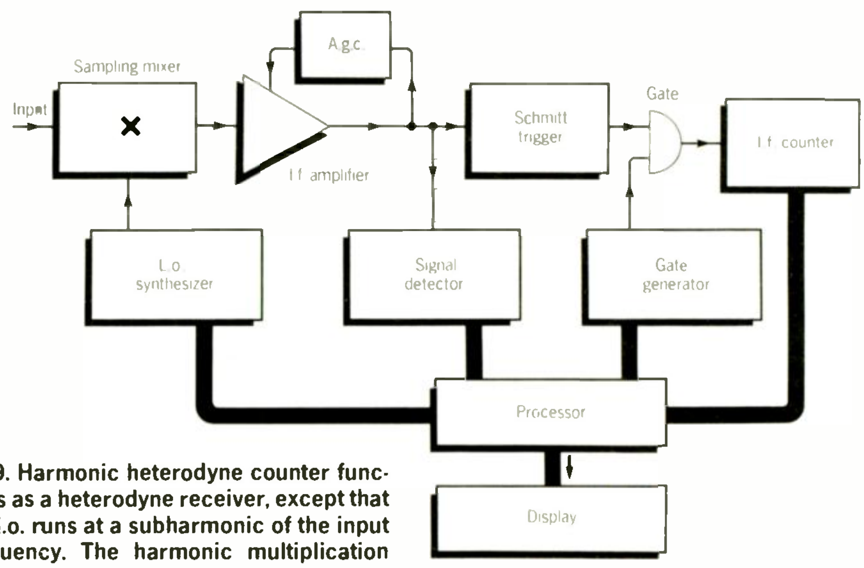


Fig.9. Harmonic heterodyne counter functions as a heterodyne receiver, except that the l.o. runs at a subharmonic of the input frequency. The harmonic multiplication factor can be determined by varying the l.o. frequency slightly and measuring the change in the i.f.

The third method of determining the harmonic number is to precede the counter with a tunable bandpass filter, usually implemented with yttrium-iron-garnet technology. A yig component is electrically tunable over the full band of interest with a bandwidth of about 20MHz. If the tuning voltage is generated by the processor, the input frequency is immediately known to within 20MHz and the processor can estimate the correct harmonic number. The technique is very powerful: it results in good acquisition time (200ms), automatic amplitude discrimination, and the possible programming of frequency limits such that the counter will look for a signal that may not be the largest in the band. The problems are high cost, weight, power consumption and a natural limit on f.m. tolerance.

Microwave counters can offer features not seen elsewhere, such as input power measurement and source locking. Input power is normally measured via the i.f. and tends to be rather inaccurate due to a high (and variable) input v.s.w.r. In source locking the counter is connected to the output of a low stability source and derives a control voltage related to the input frequency which is fed back into the f.m. input of the source. The result is a signal source with synthesizer-like stability.

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The observer in science

– too much taken for granted

TOM IVALL

A father said to his son, who suffered from double vision, "Son, you see two instead of one."

"How can that be?" replied the boy. "If I were seeing double, there would appear to be four moons up there instead of two."

This little story[1] illustrates two points about how we observe the physical realities of the world. First, it shows that we have difficulty in getting past our primary sense data. Consequently we consider that our own personal consciousness of the world *is* the world. There is an objective reality out there which is perfectly represented by our experience. Secondly, perception involves a rational process that always tries to organize and make sense of the raw data. In the story the son already possesses the *a priori* concept of number – an ability to count, the knowledge that four is twice two – and he applies this rational process to the sense data.

Psychologists study human perception in much detail but physicists and engineers tend to ignore it, even though perception is absolutely central to all their observations and discoveries. Or so it would seem, to judge from some of the discussions published in *E&WW* on the nature of physical phenomena like electromagnetism. The empirical data from experiments are generally agreed upon, and any inductive errors made in interpreting the data are usually exposed and eradicated, but it seems that the writers are not always aware of how far the subjective penetrates into the apparently objective.

For example, the primary fact of human consciousness, with its directive and intentional qualities, is generally so much taken for granted as to be almost eliminated from descriptions of what is going on. The French phenomenologist Maurice Merleau-Ponty puts it dramatically: "Scientific points of view, according to which my existence is just a moment of the world's existence, are always both naive and dishonest, because they take for granted, without explicitly mentioning it, the other point of view, namely that of consciousness. Through consciousness, from the outset, a world forms itself around me and begins to exist for me."[2]

Ths sounds a bit like a bad-tempered swipe at science, but it really draws attention to a fundamental problem in the whole philosophy of the subject. From the time of Galileo and Newton the so-called 'hard' sciences like physics have been spectacularly successful. This is because of their exactness. Natural phenomena can be precisely measured and described by laws or mathematical equations. Equipped with this deterministic body of knowledge, we can predict how man-made objects using matter and energy will behave. Thus the great edifice of modern technology arises. Its overwhelming presence, and ever-increasing list of achievements, is a permanent validation of the exact sciences that gave birth to it.

Measured on this scale, the life sciences (biology, ethology, anthropology, psychology, sociology etc.) have been less successful. Only where physics or chemistry have penetrated some way into biology – for example, molecular biology – have fundamental discoveries been made in this area. These 'soft' sciences are often accused of being too much inclined to woolly thinking, unsubstantiated theories and vague generalizations. Some physicists adopt a slightly sneering attitude to them. Reacting to this criticism, the life sciences have tried to justify themselves by accepting and borrowing the methodology of the exact sciences – introducing statistics and mathematical models, for example. Regrettably, this has sometimes been done for cosmetic reasons, to make the research seem worthy and solid through precision alone, even though precision may be irrelevant.

What Merleau-Ponty and other phenomenologists have been concerned to point out in this situation is that the 'hard' sciences with their precision do not have a monopoly on truth. The truth that characterizes the life sciences is in no way an inferior form of truth to that of the exact sciences.

You, dear reader, however much you may be devoted to the objective knowledge obtained by science and technology, would not consider it a superior truth to the facts of your own birth and inevitable death, your actions and experiences, your sensations, thoughts, feelings, desires and convictions. These are all intensely real. If you were desperately thirsty and somebody said to you objectively "It's just your body that requires liquid" you would be rightly affronted at this denial of, or decision to ignore, your intense awareness.

Life and consciousness are obviously prerequisites for knowledge. The life world that we experience is presupposed in the objective world that the physical sciences are working to reveal.

THE GREAT DIVIDE

But phenomenology is not just a defensive attempt to boost the truth of the life sciences at the expense of the others. It is much more genuinely a serious effort to bridge the gap between subjective experience and objective description, between empiricism and rationalism, that has complicated our search for true knowledge since the earliest times. Its founder, Edmund Husserl (1859-1938), was a mathematician who was also interested in psychology and philosophy. Thus he studied mathematical and logical structures (among other things) as they manifested themselves, as phenomena, to human consciousness. His method, appropriate to a mathematician, was to 'bracket' all existing presuppositions, theories and other conceptual apparatus for picturing the external world and to concentrate exclusively on directly experienced phenomena, attempting to describe these phenomena as accurately as possible.

Thus phenomenology was an attempt at a fresh start in the acquisition of knowledge. Boldly it claims that there is no division between appearance and reality (e.g. between the colours that appear to us and the 'colourless' electromagnetic waves that are the physical events responsible for them). Husserl and his followers considered that Kant's distinction between phenomena (what are perceived) and noumena (the things-in-themselves) was a pointless exercise. However, this rejection of the notion of things-in-themselves was not a denial of the objective reality of the world, only a rejection of this puzzling idea in the search for knowledge.

INTERPRETING SENSE DATA

In attempting to 'bracket' preconceptions and empty forms, the phenomenologists have recognized that mental interpretation gets to work at an early stage in our observation of the world. The observer can't help being an interpreter as well. This process occurs on two levels: the psychological and the epistemological.

After consciousness comes perception, in the ascent to objective knowledge. In perception the raw data from our sense organs is interpreted by the brain automatically, without any deliberate thinking. Here, a great many psychological studies of perception have demonstrated how bias and distortion can occur in this process. Such investigations have revealed the influence of motivation (both short- and long-term), interest and values, training, social and ethnic factors, success and failure in tasks, pain, taboos, anxiety, personality type and, of course, pathological mental states.

In specialists like scientific research workers, a particular problem is selectivity of perception. The British psychologist M. D. Vernon comments ". . . . the effects of knowledge and experience are in themselves liable to produce selective perception and the funnelling of attention to objects and events about which special knowledge and experience have been acquired. The consequence is that no two observers may perceive a given scene in exactly the same manner, and that they may disagree considerably as to its nature and contents."[3]

Figure 1 provides an example of the automatic interpretation and organization that the brain always tries to apply to raw sense data on the basis of existing knowledge. The drawing is deliberately perverse. It 'represents' an impossible object. We feel frustrated in trying to make sense of it because our past experience of real objects and perspective drawings is useless in the attempt at total recognition, even though there is a visual plausibility about the two ends of the picture.

In the practice of science, of course, any differences in perception between individual observers are screened out by rigorous methods of checking and repetition of experiments by different persons. The validity of a result therefore depends on consensus. But there is always the 'bottom line', the inherent characteristics of perception of *Homo sapiens*, which must be accepted as contingent and arbitrary, belonging to a particular stage of evolution. Logically there could be other modes of perception.

OBSERVATION AND EPISTEMOLOGY

On the epistemological level, the interpretation of what we observe in the world becomes a philosophical matter. Here we are confronted by the permanent divide, mentioned above, between the rationalists, who stress conceptual reasoning at the expense of direct experience, and the empiricists, who do the opposite. Both sides contain strong subjective elements and both have grave weaknesses.

Rationalism has a tendency to open-ended theorising without sufficient discipline from the brute facts. Empiricism, abjuring theory as much as possible, tends to end up with a rag-bag of disconnected empirical data which cannot be organized to make sense because of the absence of a conceptual framework, a unifying hypothesis, into which to fit them.

In modern science this fundamental dichotomy comes out in the difficulties of finding conceptual models that conform to the experimental data. There can be disputes about the validity of the conceptual model and about the reliability of the experimental data. See, for example, Dr Louis Essen's article on relativity in the February issue, pp.126-127. Ultimate truth is impossible in this approach to knowledge, simply because the world is one thing and a mental model is another: they can have a parallel congruence but never be identical. This is the division between subjective experience and objective description which phenomenology has tried to avoid.

Rationalism is generally considered to have started with Plato's theory of 'forms' or 'ideas', later to be called universals. The forms are entities known only to the mind. They are the only true realities and quite separate from the objects of sense perception, which are considered not to be real. Examples of forms are: red, animal, courage, motion. A form is single, immutable, common to all material objects called by its name (e.g. animal) and more perfect than any particular example. A form exists independently of human beings' knowing it. It also exists independently of particular examples, e.g. the form courage exists regardless of whether there are, or ever have been, any courageous acts. The form pre-exists the particular.

The things we actually perceive in the world have the properties they do because they 'partake' of certain forms. Thus a tomato 'partakes' of the forms: red, round, weight and others. Mathematics deals in forms such as number and set. These are universals because they are not particular entities found in the natural world.

This rationalist approach to knowledge was carried on and developed by Descartes, Spinoza and Leibnitz. Central features of their ideas were summarized in a previous *E&WW* article by the author[4]. In particular, Descartes was mainly responsible for the subject-object dualism which is characteristic of scientific thinking and procedure: the human observer outside of and detached from the thing observed.

Empiricism is totally different. Associated mainly with the British philosophers Locke, Berkeley and Hume, it stresses that all knowledge must come from experience. Here 'experience' means both perception through the sense organs and reflection or introspection on the raw data. For Locke, for example, things and events in the world give rise to 'ideas'. These 'ideas' – in contrast to Plato's – are the objects of sense experience and are applied to a mind which is like a "white paper, void of all characters, without any ideas."

The cul-de-sac which empiricism runs into is the consideration that if there are any entities other than those of sense experience we don't really know if they exist because we can't perceive them. A striking example of this dead-end in empiricism is Hume's famous analysis of causality. This has already been discussed in *E&WW*[5]. Hume's conclusion is that cause-and-effect do not belong in the physical world but are only a concept in the human mind. In nature things just happen. The observer sees a 'necessary connexion' between events which occur regularly together in time and space. But necessity is purely a mental concept. It operates, for example, in logical reasoning but not in nature. It cannot be perceived. Hume's analysis can't be faulted, even today, but it seems to go against common sense. It is a good example of subjectivity (here the notion of necessity) penetrating into, and being part of, the apparently objective (causality in nature).

Science uses both rationalism, in proposing hypotheses, and empiricism, in obtaining experimental data. Immanuel Kant is therefore rightly hailed as the foremost philosopher of science because he showed the possibility of a synthesis between the two[6]. At the time, in 1781, it was revolutionary. The mainspring of this revolution was Kant's proposal that, rather than deriving our concepts from observation, as was then commonly held to be the case, we actually make our observations conform to pre-existing concepts – that is, to *a priori* concepts independent of all sense data and experience. In short, we construct a world out of appearances. A more precise explanation of this constructivism is given in the box.

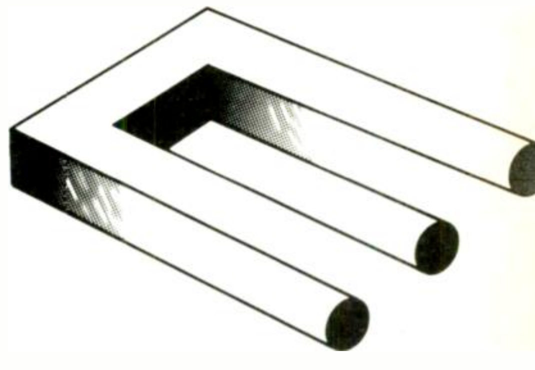


Fig. 1. This drawing demonstrates the automatic interpretation that normally takes place as part of perception – by deliberately frustrating it.

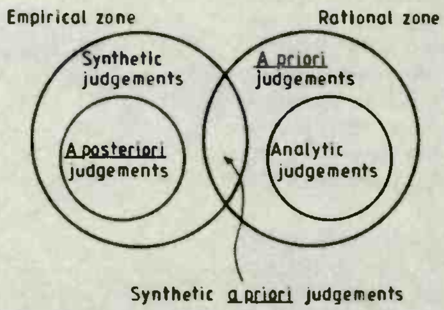
THE OBSERVER AS ACTIVE AGENT

What is important in the present context is the subjective content in Kant's approach to how knowledge is acquired. The concept comes first, as a product of consiousness. The observer uses it actively, as a possible structure into which he tries to fit evidence from the world, rather than passively waiting for nature to write something on Locke's "white paper" of a mind without concepts.

This insight may have been connected with the fact that Kant was also a great moral philosopher. He had been impressed by the laws of physics formulated by Newton and others, and he wished to believe in their objective validity. But, at the same time, as a believer in God and the existence of the soul, he also wished to maintain the primacy of free will, and the possibility of autonomous moral decisions, over the determinism implicit in the the laws of physics.

He therefore had a conflict of beliefs to resolve. In particular he wanted to attribute causality not to blind determinism but to a concept of the free human mind (see box). This internal conflict could have led, in some way, to the mental jump of proposing the then revolutionary idea that we make observations conform to concepts instead of the other way round.

Kant makes explicit what he thinks was happening instinctively or unconsciously in the minds of all scientists from the ancient Greeks onwards. At some early time, he thinks, there was an intellectual change from mere "blind groping" to producing properties of objects "by a positive *a priori* construction." After mentioning discoveries of scientists such as Galileo and Torricelli he says: "They learned that reason only perceives that which it produces after its own design; that it must not be content to follow, as it were, in the leading-strings of nature, but must proceed in advance with principles of judgement according to unvarying laws, and compel nature to reply to its questions.



CONSTRUCTIVISM. Kant showed the possibility of what he calls synthetic *a priori* judgements. In his scheme, statements which are rational but contain no new knowledge are called analytic judgements (e.g. "A>B so B< A" and "a bald man is a man"). These are represented as the small right-hand circle. They are tautologous re-arrangements, as found in logic. Being in no way dependent on sense perception of the world, they are also *a priori* judgements (large r.h. circle).

In contrast to this analytic *a priori* kind, there are other judgements which do depend on observation of the real world. These are represented by the small l.h. circle and are called *a posteriori* judgements. Because they are not analytic (internally self-validating as discussed above) they must be put together, or synthesized, from other, external knowledge and are therefore called synthetic (large l.h. circle) *a posteriori* judgements.

Kant's major contribution was to show that some judgements could be both synthetic and *a priori*, as indicated by the overlap of the two large circles. Being *a priori*, they have their own internal truth and don't depend on empirical observations for their validity, but they are nevertheless applicable to our sense perceptions of the world. As such, according to Kant, they give objective validity to our empirical observations. Casuality is one example of a synthetic *a priori* judgement: observations of related events conforming to an *a priori* concept of cause-and-effect. In this way we construct a world out of appearances.

For accidental observations, made according to no preconceived plan, cannot be united under a necessary law. . . . . . Reason must approach nature with the view, indeed, of receiving information from it, not, however, in the character of a pupil, who listens to all that his master chooses to tell him, but in that of a judge, who compels the witnesses to reply to those questions which he himself thinks fit to propose."[6]

Modern scientists also get answers which depend on those questions, put to nature through specifically designed experiments, that they think "fit to propose."

Nowdays in modern physics the interdependence of the observer and his/her experiment is well understood. The very presence and activity of the observer can modify what is observed. The physicist Pauli once commented: "I can choose to observe one experimental set-up, A, and ruin B, or choose to observe B and ruin A. I cannot choose not to ruin one of them." The idea of man split off from nature and observing it from outside is increasingly being seen as an artificial one. Rather, the activities of the observer and the things or events observed are seen as being linked together in a single on-going process or complex of matter and energy.

This view is very much in accord with the idea of *Dasein* advanced by the modern German philosopher Heidegger[7], a pupil of Husserl. *Dasein* can be roughly translated as 'being there' or 'presence in the world'. Instead of the observer being isolated and locked up inside his own skin and his own ego, he is already out there in the world, acting in it, whether he himself thinks so or not. His presence in the world is analogous to a field in physics, or to a discrete object with a boundary in the Newtonian sense.

In everyday terms *Dasein* is rather like our way of using a hammer or screwdriver, or some very familiar instrument or machine. We don't think explicitly and self-consciously of all our actions while handling it, that we are monitoring and controlling it through our sense organs, nervous system, muscles etc. The hammer becomes almost part of us while we wield it. Our 'field' encompasses the hammer and its effects. Indeed the psycho-physical feedback loop controlling it must necessarily pass through part of the world outside of us. Analogously our field of influence extends out into the world beyond the sharply-defined limits of the body and mind as traditionally understood.

So Heidegger's idea of *Dasein* destroys completely the old Cartesian dualism of mind distinct from body, subject from object, and observer from the thing observed.

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Network management through quality analysis

Many network protocols are so good that, with retransmission of corrupt data, there appears to be no fault on the network until there is a major breakdown. A new instrument is designed to overcome this by keeping a qualitative check on an Ethernet system. It does this by combining a network analyser with a waveform analyser and a digital time-domain reflectometer. This is claimed to 'reach the parts of a network that other instruments cannot measure'. Network Quality Analyser (NQA) can test a system or station while it is running. It measures such key parameters as network bias, jitter, d.c. and a.c. signal components, fall time and bit rate. These are graphically displayed on the instrument's screen, along with a comparison of the IEEE 802.3 network specification. It can thus diagnose and locate anomalies on the system before they become faults, and also indicate trends.

Automatic monitoring of the network is possible with the NQA setting off an alarm if a parameter drifts out of specification or any other defect arises.

Conventional network-analysis techniques monitor the system as a whole. They can quantify network and node usage and provide a network map of the traffic, perhaps indicating the source of any delays because particular stations are very busy. Indications of network efficiency can be gathered from analysis of the traffic. NQA includes such monitoring facilities but perhaps its *pièce de resistance* is the patented digital time-domain reflectometer which can be used on a 'live' system. This is particularly useful for diagnosing cable and cable-join faults, and again can identify potential trouble spots before they bring down the network.

Physically, all is housed in a desk-top unit with a c.r.t. and a floppy disc drive. All commands are entered through the touch-sensitive screen with a menu system. There are no front-panel controls. The price of £15,000 reflects the complexity of the equipment but Logic Replacement Technology, the manufacturers, claim that NQA is worth installing on networks with 20 or more stations. A saving in down-time at a bank or financial institutions could repay the cost of the instrument in a very short time.

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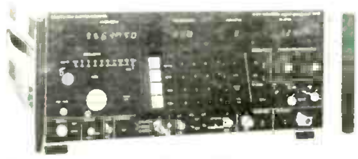

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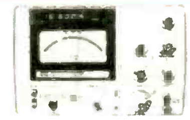

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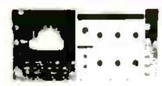

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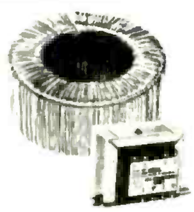

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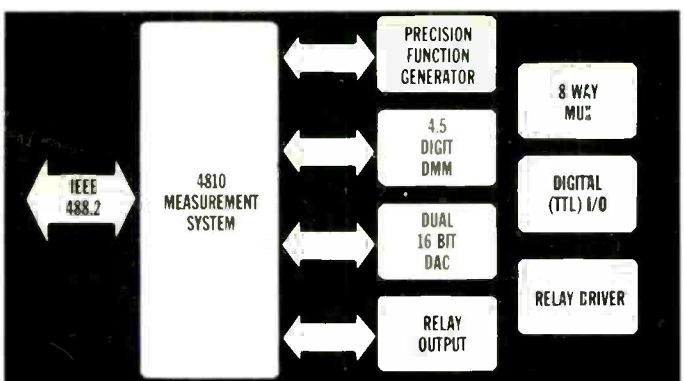

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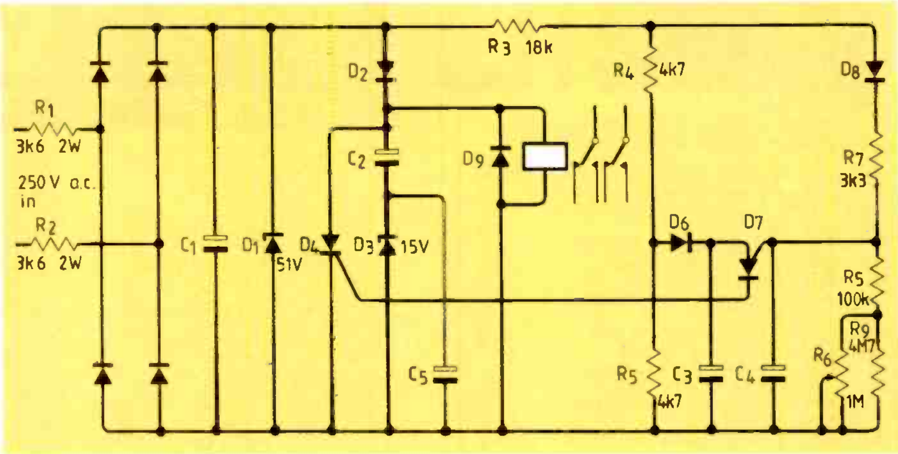
CIRCUIT IDEAS

Off-delay timer without auxiliary supply

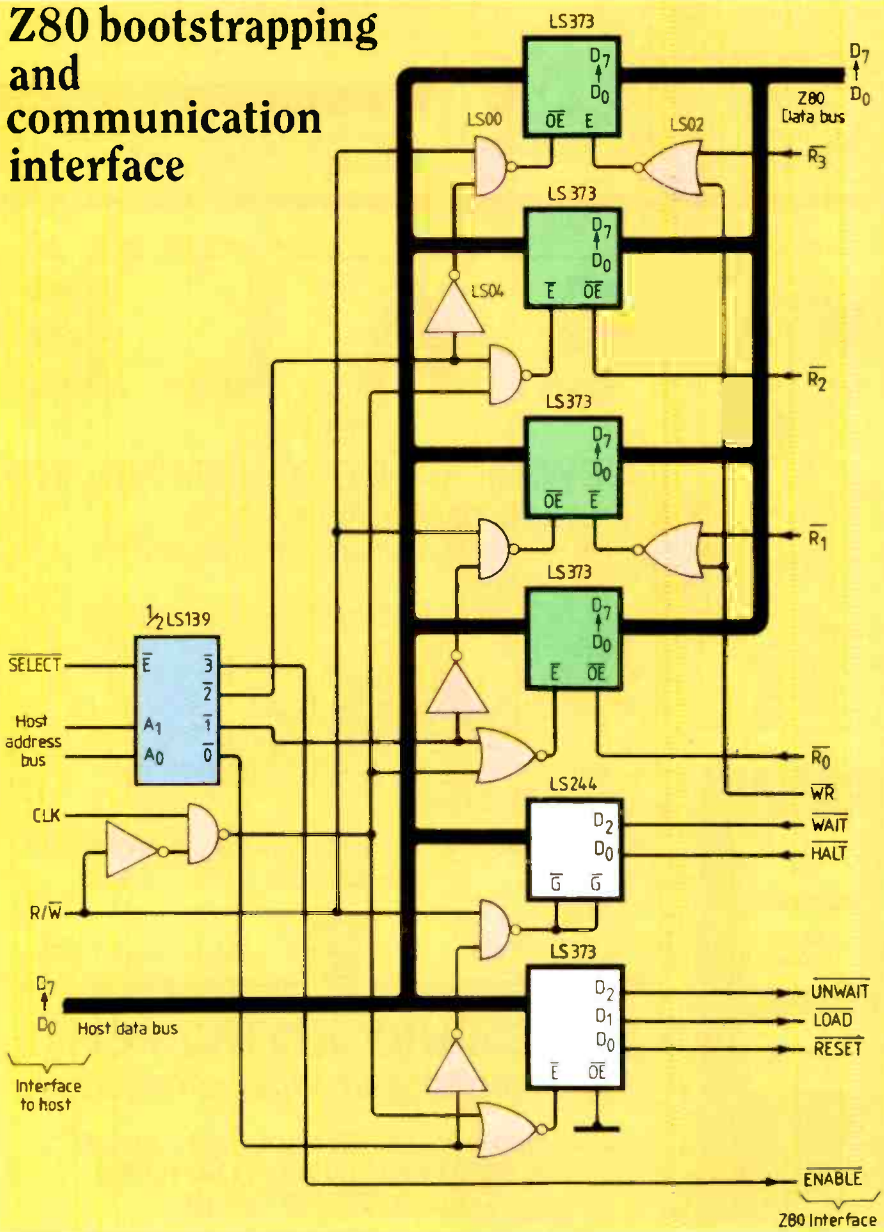


Delay timers that keep a relay held on for a short period after power has been removed normally require either an auxiliary power supply or special magnetic latching relays. But it is possible to keep a relay on for an accurately adjustable period of up to 15 seconds after power is removed without meeting either of these requirements.

Good linearity and repeatability of the time adjustment are obtained by using a programmable unijunction transistor to discharge C_2 through s.c.r. D_4. To achieve 3% linearity, discharge time through C_2 and the relay resistance should be at least three times the maximum delay required.

While power is on, C_2 is charged through D_2 and the relay is immediately energized through D_3. As C_3 charges through D_6 and C_4 charges through D_8, the unijunction transistor's anode and gate are brought to 8V and 16V respectively.

Z80 bootstrapping and communication interface



All microprocessors have some means of fetching instructions from a known address at reset. Normally, this address is in eprom, but instructions can be placed directly on the data bus at reset under control of another processor. The Z80 $\overline{\text{WAIT}}$ input makes this particularly simple.

By making Z80 read operations obtain data from another processor, but write operations write into the Z80's own memory, the memory can be loaded under software control of the other processor. I have used this method to interface a Z80 second processor to the 'Tube' of a BBC microcomputer.

On the host side, connecting to the BBC computer, there are three 8bit data latches and a control buffer, each with its own address. Since only four addresses are needed, the circuit can easily be used with other processors. Two data-latch pairs configured as four i/o addresses connect to the Z80 second processor; these form two read and two write data registers. A fifth data latch and buffer pass control and status lines.

By writing data to the control/status register, the host processor puts the Z80 second processor in load mode and resets it. On release of the reset condition, the Z80 zeros its program counter and attempts to read memory address zero. In load mode, this results in the $\overline{\text{WAIT}}$ signal being asserted and thus a Z80 read from data register R_0.

Monitoring $\overline{\text{WAIT}}$ through the control/status register, the host processor can now put the first program byte into data register R_0 and read R_3, causing strobe signal $\overline{\text{ENABLE}}$ to terminate the $\overline{\text{WAIT}}$ state. On leaving the $\overline{\text{WAIT}}$ state, the Z80 reads the byte in R_0 then attempts to read the next address, which causes the same sequence of events. Any write operation by the Z80 results in a write to the Z80 memory without $\overline{\text{WAIT}}$ being asserted.

During the $\overline{\text{WAIT}}$ state, the dynamic mem-

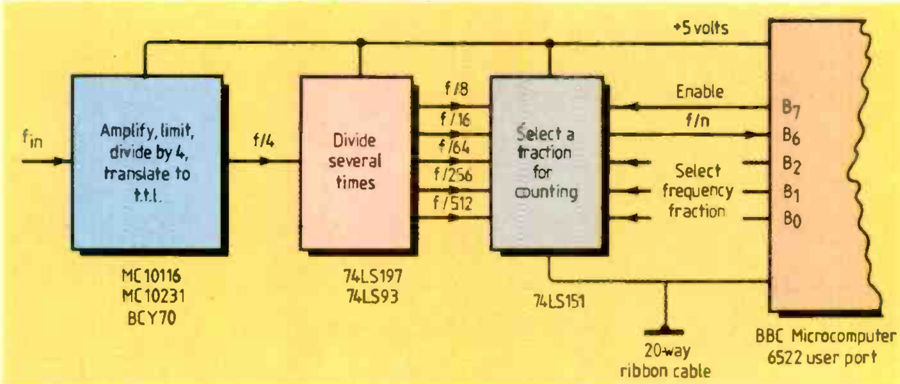
When power is switched off C_2 discharges through the relay coil. Potentially, the capacitor's charge can keep the relay energized for two thirds of the discharge time, at which point the drop-out voltage of the relay is reached, but after a third of the time constant, on-time becomes non-linear.

Potentiometer R_6 determines the discharge rate of C_4. When the p.u.t. gate reaches 8V, it turns on and draws current from C_3 to turn on s.c.r. D_4. On turning on, the s.c.r. discharges C_2 and turns the relay off at the set time before the non-linear region.

Linearity is within 0.5s and repeatability is fair. Timing capacitors $C_{3,4}$ should be high-stability low-leakage types.

T.S. Doraiswamy
Bombay
India

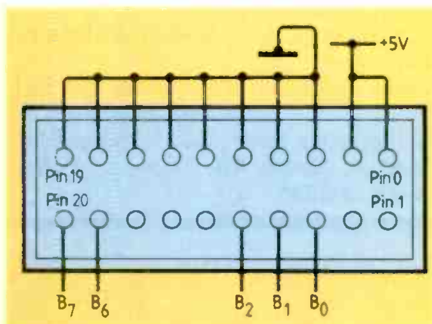
Frequency measurement interface



Using a computer to control, process and display readings greatly simplifies the design of a frequency meter. Only five i.cs are used in this circuit for interfacing to the v.i.a. in a BBC microcomputer, yet it works at up to 200MHz. Auto-ranging is easily done in software.

Input is amplified and limited then divided for counting by the 6522 versatile interface adaptor. Port B data lines of the v.i.a. communicate with the interface, its first timer gates the count period, and its second counts received pulses.

At the input* a fast e.c.l. line receiver i.c. amplifies and limits the signal. Next, an e.c.l. dual bistable configuration divides the signal by four and a transistor changes the level to t.t.l. Further division by 8, 16, 64, 256 or 512

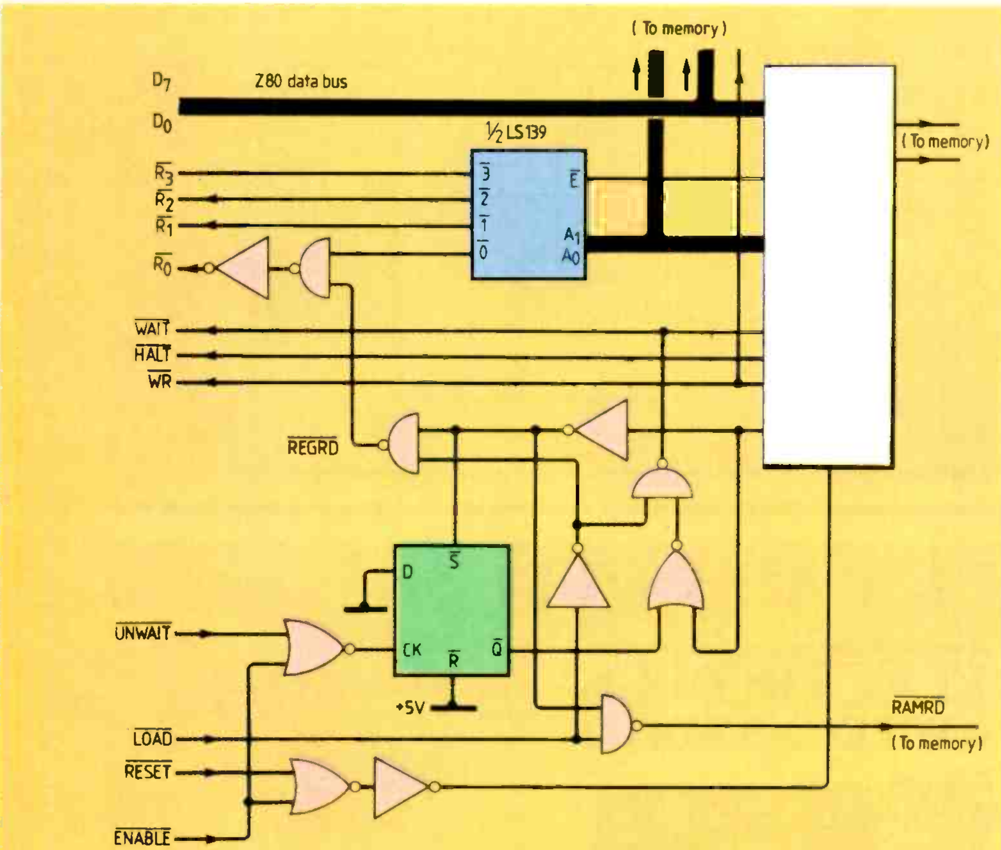


is then selected under computer control by addressing the 151 multiplexer.

Line B_6 from the v.i.a. carries the frequency fraction to the computer for counting. Control line B_7 sets the multiplexer enable input low when count pulses are to be allowed through; this happens during one or more programmed periods set using the v.i.a.'s first timer.

My software, in BBC Basic, makes about 100 readings per minute. It first prepares the screen, sets the second timer to count input pulses and sets the first timer to its monostable mode. It then measures by preparing the second timer, running the first and checking overflow.

If there is an overflow, resetting takes place; the divider is set to divide by 512 and a reading is taken using one gate opening per count. When no overflow takes place, the result is calculated and displayed and the system is rescaled, depending on the last reading, to select the frequency division and



ory is not refreshed. Since it needs refreshing once every 4ms, the bootstrap loading time must be minimized. In the prototype, a simple 58byte bootstrap program that transfers in about 4ms is used. To transfer it, the HL register pair is zeroed then repeatedly used as a pointer to indirectly load immediate data into Z80 memory as follows,

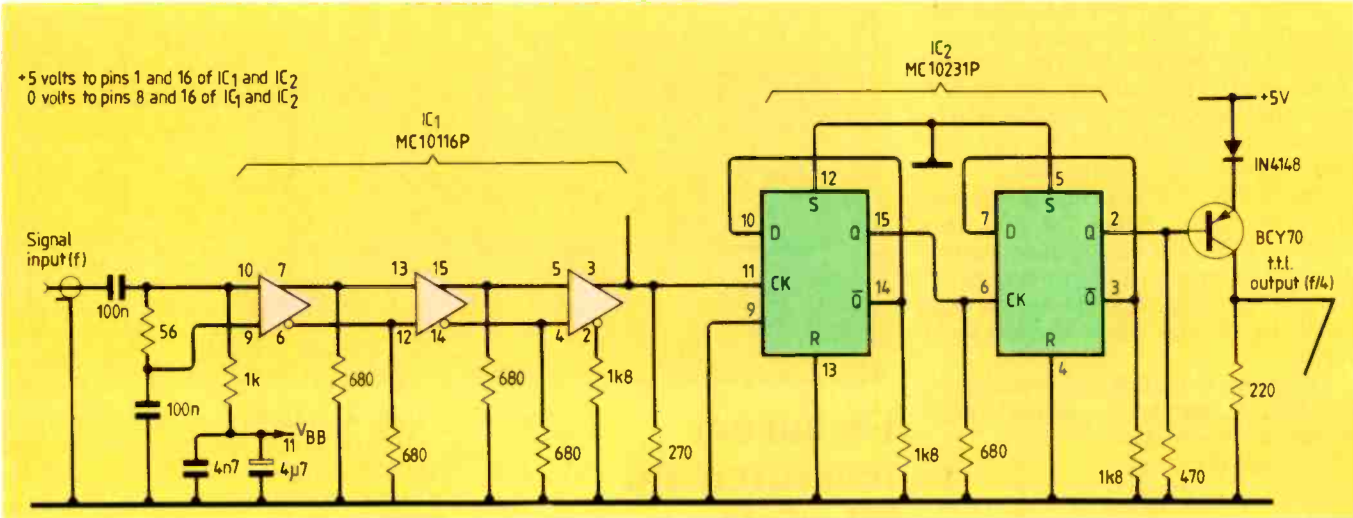
```
LD HL,#0
repeat:
LD (HL),‹byte›
INC HL
until done.
```

Once loaded, the short bootstrap program is started by RESET, allowing the Z80 to communicate with the host processor under its own control via the data registers.

My prototype Z80 second processor has 64Kbyte of dynamic memory whose eighth refresh bit is produced using a circuit similar to the one in Circuit Ideas, November 1987. With both host 6502 and Z80 processors running at 2MHz, transfer across the data registers under software control can be up to about 8Kbyte/s^{-1}.

John Cooke
Edinburgh

CIRCUIT IDEAS



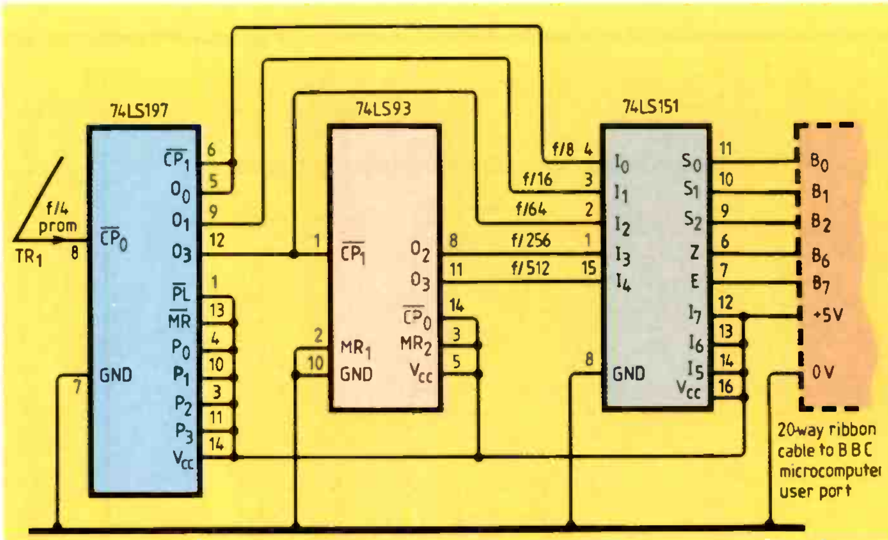
number of gate openings that will give good resolution.

Input impedance is 50Ω and coupling can be made either by holding a few turns of wire near the frequency source or directly through a suitable resistor. Tooley and Whitfield quote sensitivities of 3mV r.m.s. at 10MHz and 45mV at 200MHz. Screening is important and the p.c.b. must have a ground plane.

Neil Benton
Doncaster Yorkshire

*The input circuit was presented by Tooley and Whitfield in their frequency meter design published in the January and February 1979 issues.

Copies of the author's software and p.c.b. layouts can be obtained by sending an s.a.e. to Frequency Meter, *E&WW* Room L302, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.



NEXT MONTH

Pioneers – 17. In 1939, the pressure was on to find a source of high-power microwaves – the klystron was not able to provide enough for radar transmitters. J.T. Randall and H.A.H. Boot applied the resonator technique to the magnetron, designed by Hull in 1921, to obtain the cavity magnetron.

Sensitivity-based filter tuning. Computer-aided tuning of circuits such as filters, using sensitivity analysis. The process takes into account component errors and strays.

Multiple-spark ignition. Mosfet switching devices have made possible the development of high-energy, multiple-spark ignition systems. A practical circuit illustrates the design process.

Ampex's D2. Richard Lambley presents technical details of the new D2 digital video machines from Ampex, in which a controversial videotape format challenges the world D1 standard.

Optical time-domain reflectometry. A new approach to o.t.d.r. which uses spread-spectrum techniques to increase dynamic range and reduce measurement time.

Self-calibrating digital multimeter. Internal self-calibration, a novel a-to-d converter and some other clever circuitry gives the Datron 1281 an edge over the opposition.

Laser frequency multiplication

Multiplying the frequency of a laser involves a technique analogous to one widely used for r.f. multiplication.

CHARLES H. LANGTON

Radio-frequency multipliers using harmonic filters have existed since the days when high-frequency alternators first produced continuous waves for transmitters – and perhaps before.

With such multipliers, no matter what the power requirement and operating frequency, the basic multiplication principle is the same: a wave rich in harmonics is passed through a filter which selects the desired harmonic, Fig. 1.

Many waveforms, the most extreme example of which is a sine wave, do not contain the desired harmonic. To multiply such waveforms, they must first be distorted by a non-linear circuit or device to introduce the harmonic, Fig. 2. If the fundamental frequency of the input waveform is ω then the output sinusoid will have a frequency of $N\omega$, representing the Nth harmonic.

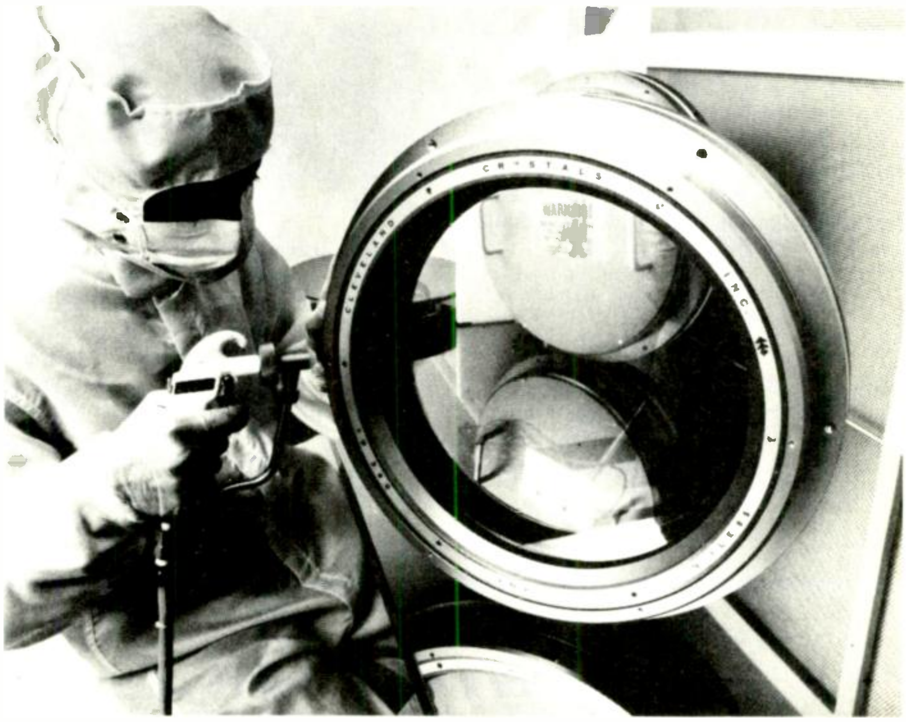
For many years it has been standard practice to use a suitably biased valve or semiconductor to introduce the distortion. Saturated cores have also been used for this purpose, not least in the high-frequency c.w. generators of pre-BBC times.

Principles similar to those used in r.f. multiplication also apply at the much higher frequencies of infrared and visible spectra.

NON-LINEAR OPTICS

High-power lasers have enabled experimental work in a field known as non-linear optics. Normally in optics work, it is assumed that the transmission of light through media such as glass, crystal and water, is linearly proportional. Doubling the intensity of incident light doubles the intensity of light at the other side of the medium.

At conventional light levels this is true, but when the intensity of the incidental wave reaches the extraordinarily high levels obtainable from high-powered lasers, the relationship becomes non-linear, Fig. 3.



The largest frequency doubler is used in plasma physics and laser fusion experiments with the world's largest lasers. This is a single perfect crystal that took 18 months to grow and polish. It has a working aperture of 36cm and the laser that is used with it is around 100m long. Picture courtesy of Optilas, Milton Keynes.

This is because light, being an electromagnetic wave, is at the mercy of the permeability and permittivity of the medium through which it propagates. When a ray of light passes from a low-density medium such as air or a vacuum, into a higher-density medium such as a transparent crystal, its propagation velocity is reduced.

The ratio between the velocities is the refractive index of the interface, n. If the wave's velocity through air or a vacuum is c and its velocity when travelling through the crystal is v then n=c/v. Velocity of the wave in the crystal is therefore v=c/n, but since,

$$n=\sqrt{\mu_r\varepsilon_r},$$

$$v=\frac{c}{\sqrt{\mu_r\varepsilon_r}}$$

where μ_r is relative permeability and ε_r is relative permittivity.

In a transparent crystal, μ_r is unity which simplifies the equation to,

$$v=\frac{c}{\sqrt{\varepsilon_r}}$$

If the incident wave approaches the crystal at right angles to the surface, the intensity I_2 of the wave as it crosses the boundary and enters the crystal is given by,

$$I_2=\frac{I_1 4cv}{(c+v)^2}$$

where I_1 is the intensity of the incident wave. However, $v=c/\sqrt{\varepsilon_r}$ so that by substitution in the above equation,

$$I_2=\frac{I_1 4\sqrt{\varepsilon_r}}{(\sqrt{\varepsilon_r}+1)^2}.$$

DUAL-FREQUENCY LASER IN METEOROLOGY

In meteorology, laser-frequency multipliers provide a means of calculating the size of water droplets in the atmosphere.

Two laser beams of different frequencies are transmitted into the atmosphere and reflected back to a detector at the laser station. By comparing the phases of the two beams, the size of droplets in the intervening space can be calculated, providing useful information for investigating the nature of fog or mist.

It is vital that both beams leave the laser station precisely in phase with each other. Frequency multiplication solves this problem; the laser's fundamental frequency provides one beam and its second harmonic provides the other.

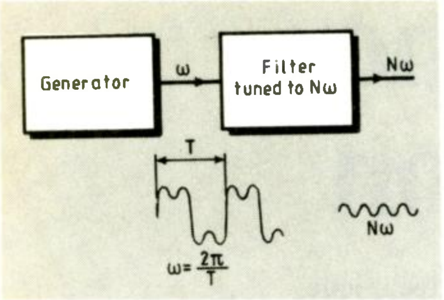


Fig. 1. Basic frequency multiplication process. Fundamental frequency with harmonics passes through a filter tuned to the desired harmonic.

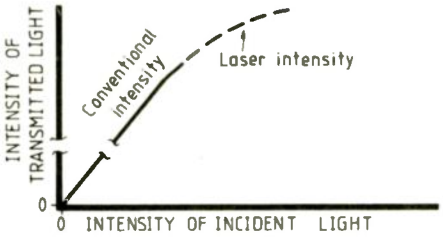


Fig. 3. At low intensity, light output from a given medium is linearly proportional to light entering the medium but when high-intensity laser light is used, transmission becomes non-linear.

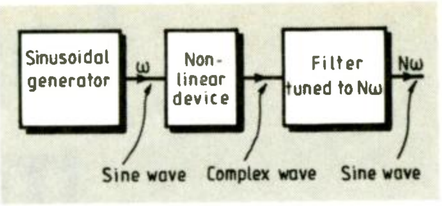
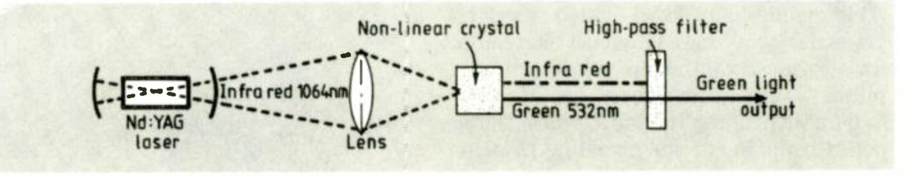


Fig. 2. To multiply some waveforms, a sine wave for example, a non-linear device has to be used to introduce the desired multiplication harmonic.

Fig. 4. Laser frequency multiplier. Compare this system with the one outlined in Fig. 2.



Therefore, intensity of the transmitted wave is a function only of the permittivity of the crystal. At normal light intensities, ε_r remains constant for a given frequency and I_2, being I_1 multiplied by a constant, is completely linear.

At the extraordinary intensities that exist in laser systems however, ε_r varies throughout each cycle and,

$$\frac{4\sqrt{\varepsilon_r}}{(\sqrt{\varepsilon_r}+1)^2}$$

depends on the instantaneous value of the incident wave. As a result, the equation becomes a non-linear function and the transmitted wave is no longer a perfect replica of the incident wave.

Being distorted in this way, the output wave now contains harmonics which were not present in the input wave and the desired harmonic can be selected by passing the output wave through an optical filter, Fig. 4.

In Fig. 4, the laser is a neodymium-yttrium-aluminium-garnet device (Nd-YAG) producing infrared light at a frequency of 2.82×10^{14}Hz (1064nm). Laser output passes through a lithium-iodate crystal which behaves non-linearly when subjected to high-intensity light. This non-linearity introduces a second-harmonic component of visible green light at twice 2.82×10^{14}Hz (532nm) into the wave.

Finally, the wave passes through a high-pass optical filter which absorbs the fundamental frequency but passes the second harmonic component of green light.

Rapid instrument repair and calibration

Perhaps one of the best compliments paid to the repair service at MSL is when customers complain that, after repair, their trusty oscilloscope doesn't work the way it used to. Usually this is because they have been so accustomed to using an instrument that is out of alignment, that when put right, it seems wrong! MSL guarantees to return the majority of instruments to the maker's specification, or even better in some cases. Oscilloscopes take up nearly half of the time. Out of the 27 to 30 thousand instruments repaired in a year, 10 to 12 thousand are oscilloscopes. The others range from Avo meters to computer hardware and microwave instruments. One example of their attention to detail is that they employ a watchmaker full-time to repair the bearings and springs in analogue meters. Normal servicing and testing takes between seven and fourteen days. There is also an emergency while-you-wait service. All equipment is fully tested and certified as 'up to specification'.

One milestone in the company's history was the acquisition of a calibration laboratory in Scotland, which is certified by the British Calibration Service and by the Defence Quality Assurance Board. Similar facilities were installed at their headquarters in Hitchin, Herts, which has standards calibration equipment conforming to the very stringent levels set by the National Physical Laboratory. It also conforms to national defence and Nato standards as well as BS 5750.

The company, with a staff of about 120, claims to be the leading independent calibration centre in Europe. It has over £2M in test equipment which is constantly being updated. One of its major customers is itself; keeping its own test instruments up to the highest standards in order to use them on customers' equipment. It also holds a comprehensive supply of spare parts and components for all the major test-equipment manufacturers which amounts to some £0.25M.

MSL undertakes contract servicing and calibration for some 1150 companies and national industries, ranging from GEC, Plessey, STC and Racal to British Gas, CEGB, UKAEA, and many research laboratories. About a third of their effort is related to defence and the Hitchin laboratory is also an RAF station holding in bond over 700 pieces of equipment ready for shipment.

Tempest is the generic term for protection against equipment that can eavesdrop on computers. By tuning-in to the emanations from a v.d.u. or even a laser printer, it is possible to decode what is being displayed/printed. MSL have become experts on such equipment, and on preventive measures against it. They formed a new division, MSL Secure Systems, to deal with it and with other 'sensitive' security systems. These include r.f.i. detection and prevention, secure optical fibre modems, multiplexers and isolation components. They have generators to simulate the electromagnetic pulse resulting from a nuclear explosion and so can test equipment's responses to such pulses. In these areas, MSL has become agents for a number of US companies and offer consultancy and full servicing and calibration.

A special secure laboratory houses such equipment and includes a screened room. The engineers, who all need security clearance, have been trained by the manufacturers of the equipment.

Such equipment is complex and expensive. There are few customers, though these are likely to be high-security establishments such as GCHQ. However, the main part of the business is in the non-security area; getting those trusty oscilloscopes back into action. MSL Calibration Centre, Wilbury Way, Hitchin, Herts SG4 0TA. Tel: 0462 31211.

The seven-per-cent rule

Ivor Catt believes that what appears to be a new rule of linguistics could have consequences in data storage.

IVOR CATT

My discovery of the seven-per-cent rule demonstrates how new academic disciplines can grow out of mundane technological advances, in this case the reduction in the cost of memory and of data processing.

In the past, data compression techniques involved replacing short strings like *ion, the, and* by a short code. There was an underlying assumption, valid at the time, that a 20,000 word look-up dictionary of words for conversion into shorthand was impracticable. An August, 1977 project report* suggested a dictionary of 200 strings, examples of strings to be compressed being *ion, the, and* and *ation*. At that time, a 20,000 word look-up dictionary in 200,000 bytes of memory would perhaps have cost £100,000. Huffman, Shannon and Fano were associated with the underlying theory of compression of three- or four-character strings.

The relations between cost, speed and size of semiconductor rom and ram recently passed the point where a look-up dictionary of 20,000 words became practicable, its price dropping to £100.

Since a text of 100,000 words is virtually all encompassed by a dictionary of 20,000 words, then if the average word length is six characters, we can today consider storing these (less than) two-character codes rather than the original longer words. The earlier, Huffman idea of character-by-character searching, looking for frequently recurring strings, seems to be obsolete.

The Lob Corpus** is a computer analysis of one millon words of text from diverse sources, and is invaluable for our purpose. We find that it would be possible, lacking systematically developed information, to make major errors – for instance to think that the average word is six characters long. Words in the Lob Corpus analysis are ranked in order of frequency of occurrence, and we find a number of interesting things. First, a form of text compression by word has already occurred in English, in that the most common words are generally substantially shorter than the less common words. Since these common words are so short, (the most common 64 words averaging 2.6 characters***, the next most common 64 words average 3.9 characters, and since more than half the words in the text come from these 128 words, it follows that the saving of the Space character which is implicit in text compression by word is one of the most compelling, but confusing, reasons for text compression by word. (With the inter-word space, 2.6 becomes 3.6 and the 3.9 becomes 4.9.) Possibly part of our system of word recognition when we read is that shortness tells us that the word is common, and vice versa. A word's length may be part of its informational content.

If the seven per cent rule were a law, then:
7% of the words in any long text would be *the*, the most common word in the language;
14% of the words in any long text would be *the* or *of*, the two most common words;
21% of the words in any long text would be *the, of, and* or *to*, the four most common words;
28% of the words would be *the, of, and, to, a, in, that* or *is*, the eight most common words.

Each time we doubled the catchment, we would account for 7% more of the words in the text. In 14 such steps we would have included 2^{14} = 16384 different words and accounted for 98% of the words in the long text.

In practice, the seven-per-cent rule only loosely controls the pattern initially, although you will see from the full table that, after the first four words, the 7% rule applies remarkably rigidly.

Analysis of word frequency in a text of 10^6 words. Figures in brackets are estimates.

Number of words, starting with the most common (catchment)	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192	16384
% of text that they represent	7	10	16	22	29	37	44	51	58	64	71	79	(86)	(93)	(100)
Average number of characters in words so far	3	2.7	2.6	2.4	2.4	2.5	2.6	2.8							(4.5)
Number of additional words	1	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
% of the text that the additional words represent	7	3	5	7	7	8	7	7	6	7	7	8	(7)	(7)	(7)
Average number of characters in the additional words	3	2	2.5	2.0	2.5	2.9	2.9	3.9			(5.1)		7.2		›7.6

It appears that something like a 7-bit[†] code for the most common 128 words, and one bit to indicate whether the code is 7 bit or 15 bit, would give efficient (×3 or so) text compression in a manner easy to effect with our hardware[††]. It would also not significantly interfere with text retrieval, although it would somewhat upset character-by-character search. It is 20% more efficient than using a 15-bit code for everything – 100 words consume 1200 bits instead of 1500 bits. There is a further small improvement down to 1100 bits for 100 words if four (or eight) different code lengths are used, requiring, of course, a 2- or 3-bit number to specify the code length used. Increasing the number of code lengths improves the efficiency by reducing the pattern length for words, but the improvement is more or less exactly cancelled by the waste involved in recording which code length is used.

The fact that use of two code lengths gives only a 20% advantage indicates that storing the look-up dictionary in ram and altering the "most common" 128-word set to suit experience with texts in real time will probably not be highly worthwhile, given that ram is more expensive than rom. However, such tradeoffs need to be discussed at great length. One large computer company with $4 billion turnover sells $1 billion worth of disc files each year. Although some of the file space will be taken by data, it is possible that text occupies a significant percentage of that $1 billion dollars' worth of hardware., This indicates that there is a lot of money available for effecting more efficient text compression. A similar argument could be used for text compression down telecommunication lines, by satellite and otherwise.

For the future, we have a fact (consistent 7%) without a theory. We will see whether other languages give us a consistent 7%.

Dr Eugene Winter, a language expert, is critical of the Lob Corpus, and I feel that further analysis should be of other bodies of text. Analysis should be by batch, 100,000 words at a time, and all the results delivered to me for accumulation, both to check on the main results and also to get a feel for variability – standard deviation – between different bodies of text.

If this remarkable 7% figure remained unknown until I stumbled on it, this would point to a gulf between the humanities (linguistics) and computer technology. It would mean that we have been misled by all the noise about structuralism in literary analysis into thinking that computers were now being used, whereas quite clearly they are not. However, perhaps this article will lead many students to go for fashionable computer-based Ph.D. research projects.

** Technical Memorandum No. C/R/087 by M. Sreetharan et al., "Text Compression with Property la." A report from a government-funded project at Brunel University Department of Electrical Engineering and Electronics to investigate the use of my computer architecture (UK Pat.1 525 048) in text compression.*

***K. Hofland and S. Johansson, Word Frequencies in British and American English, pub. The Norwegian Computing Centre for the Humanities, Bergen, 1982.*

****This is, of course, the average length of a word in the text coming from the most common 64, rather than the average length of these 64 words (which is 3.1 characters!); – an important distinction, difficult to describe.*

†This number seven can be varied between 5 and 10 with very little penalty – only 3% or so.

††The average length of uncommon words is seven characters.

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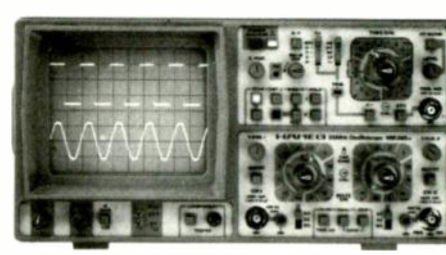

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Aeronautical data satcoms

Trials of the European Space Agency's experimental low bit-rate data communications system are going ahead on civil aircraft this year. This satcoms system will provide both in-flight public telex for passengers and airline business communications for the crews and ground staff operating the aircraft. It will also be used in an air traffic control experiment now being undertaken by European air traffic authorities.

As already reported, an airborne data terminal has been developed and manufactured by Racal-Decca Advanced Development Ltd. Five of these terminals have now been delivered for service trials of the Prodat System, as it is called. They will work on L-band frequencies to an existing ESA ground station at Villafranca, Spain, through Inmarsat's Marecs B2 communications satellite stationed at 26°W.

In engineering terms, this scheme can be seen as part of the current trend in exploiting the possibilities of low-speed data systems for satellite-based communications – notably the small requirements in bandwidth, r.f. power and signal/noise ratio (see December 1987 issue, p.1231). In operational terms, however, the Prodat scheme is an experimental approach in a worldwide intention to make use of satellites to provide more reliable communications for long-range flights – over the oceans, for example – than is possible at the moment.

For long-range communications, civil aircraft now depend on h.f. radio, which has well known problems arising from its propagation characteristics. In contrast, satellite communication appears to offer greater reliability. This, in turn, should improve operational efficiency and reduce costs to airlines and other civil aircraft users. The possibilities are widely understood – indeed, have been for about twenty years – by aeronautical organizations such as ICAO, ARINC and, more recently, SITA and Inmarsat. As a result, a number of service schemes are now in various stages of development.

ESA's low-speed satcoms system will send data messages from fixed to individual mobile users and vice-versa, and also from mobile to mobile. In addition it will 'broadcast' messages to multiple mobile users. Other facilities include paging, request/reply functions and periodical polling of mobiles. Here the word 'mobile' indicates that Prodat is in fact also designed for marine and land applications.

An outline of the aeronautical scheme is shown in Fig 1. Data in multiple channels is transmitted from ground station to satellite in the 6GHz satcoms band by time-division multiplexing. The carrier is modulated by binary phase shift keying. The t.d.m. frame has a duration of 1.024s and is divided into 64-bit slots.

Each of these time slots represents a channel, sending data to the user at a rate of 47bit/s. Other bits in the slot are used for the coding system. The Marecs satellite then relays this signal to the aircraft data terminal through a 1.5GHz downlink with a transponder e.i.r.p. of 24dBW. Lower-power operation is possible by the use of fewer slots per t.d.m. frame.

In the aircraft the radio signals are transmitted and received via separate transmit and receive quadrifilar helix antennas, each with a gain of 0dBi and a hemispherical radiation pattern extending from about 5° elevation up to the zenith. These are mounted in two small, low-drag, aerofoil blades 100mm high, installed in the top of the fuselage.

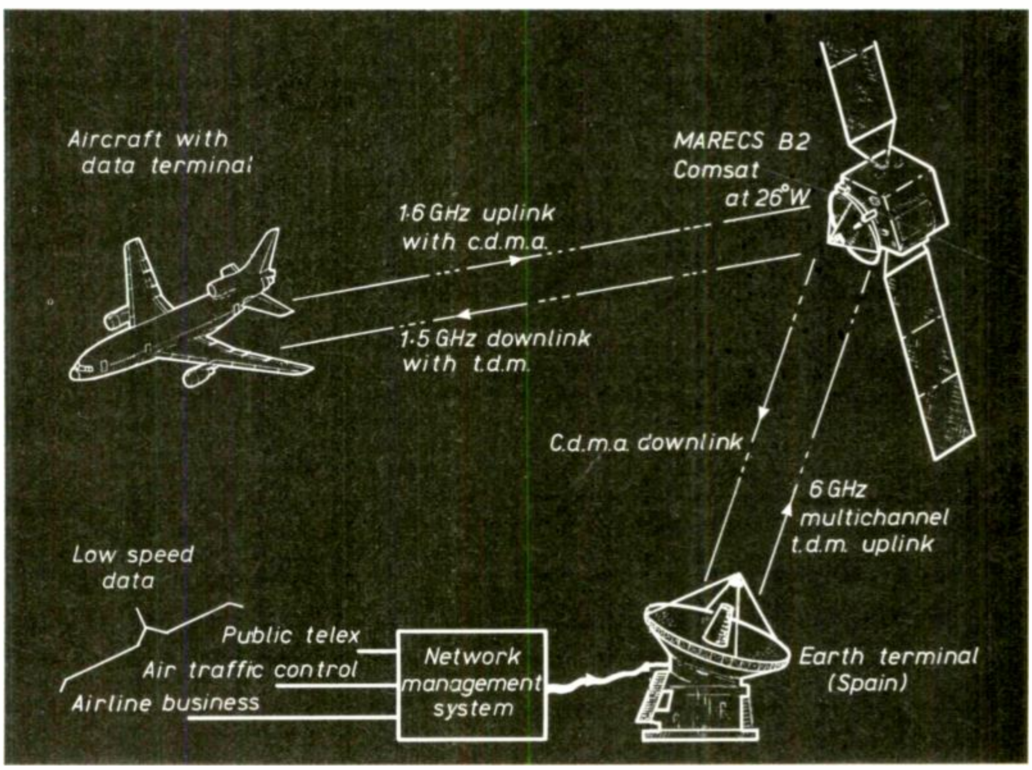
Data messages originating in the aircraft are uplinked at 1.6GHz to the satellite. Here again a multichannel transmission system is needed – actually 32 channels – by the multiplicity of aircraft using the satellite. But in this case the multiplexing of channels is done not on the time division principle but by code division, which uses spread-spectrum transmission. This method is called c.d.m.a. (code division multiple access), in conformity with the alternatives of f.d.m.a. and t.d.m.a.

Fig.1. Outline schematic of ESA's experimental low-speed data communication system for mobile satcoms, as used in current aeronautical service trials with civil aircraft and the Marecs B2 comsat over the Atlantic Ocean.

Here the 32 channels are transmitted by the same carrier frequency in all the aircraft terminals. Thus each transmission occupies the whole of the r.f. bandwidth available in the air-to-ground link, namely 650kHz. Transmissions are distinguished from each other by their individual spreading codes, each of which is a particular pseudo-random noise sequence (p.r.n.s.). Each code is b.p.s.k. modulated by a data message.

In broad principle this direct-sequence spread spectrum scheme is similar to that used in the GPS/Navstar and Glonass L-band satellite navigation systems (April 1987 issue, pp. 377-378). To prevent the 32 signals from interfering with each other the c.d.m.a. system needs a sufficiently large ratio of spread bandwidth to data bandwidth and a set of mutually orthogonal codes.

ESA chose this code-division transmission for the air-to-ground direction, as against the ground-to-air t.d.m., for several reasons of technical simplicity and low cost. One factor is that the transmitter e.i.r.p. of the aircraft terminal has to be kept very low. However, we understand that this choice of trans-



mission method is in fact a contentious matter in some radio engineering circles.

But there is no contention about the most important factor determining the choice of c.d.m.a. for this part of the system. It is the operational requirement that aircraft must be allowed to send their data messages whenever they want to. So all 32 channels must be permitted random access to the system. This means that the system has to be designed to cope with collisions between calls.

Theoretically f.d.m.a. could have been used for the air-to-ground link. But c.d.m.a. has the advantage over f.d.m.a. that it is more resilient in coping with multipath interference. This is important because, as mentioned above, Prodat is a system intended for land and marine use as well, and here multipath interference is a more serious problem than in the aeronautical application.

Spread-spectrum transmissions are often thought of as being prodigal in their use of frequency spectrum. In this particular case ESA says that, with a given number of channels, the spectrum requirement for c.d.m.a. is similar to that needed for f.d.m.a. But again this may be a debatable matter.

At the Villafranca ground station the received c.d.m.a. signals are separated from each other to recover the contents of the 32 air-to-ground channels. This is done by correlation with local p.r.n.s. codes corresponding to those used in the aircraft spread-spectrum transmissions. The result of cross-correlation is a despread signal.

Apart from the use of c.d.m.a., another technical feature of the Prodat system is a method of forward error correction (FEC) and automatic repeat request (ARQ) which is designed to suit the constraints of the low bit-rate system, such as long message transmission times.

Astra uplink

A new 9.5m parabolic dish antenna has been installed by Société Européenne des Satellites at its Betzdorf earth station in Luxembourg for the Astra television satellite.

The antenna will be mainly used by the company's network operations centre at Betzdorf, but will also be available as an uplink to Astra for any programme providers who may wish to feed in their television programme signals from that earth station. The antenna was built by ANT of West Germany. Details of the Astra satellite scheme were given in the June and August 1987 issues.

Harmless choppers

Whirling rotor blades do not interfere with L-band signals to and from helicopters, according to Inmarsat. This was one result from an experiment designed to see how effective low-speed satellite data transmission would be for automatically reporting the positions of helicopters operating in remote areas, or under low-flying conditions that would make v.h.f. radio systems unsuitable.

A helicopter carrying a compact transmission equipment flew a rectangular course of NE, SE, SW, NW from Great Yarmouth, Norfolk, and sent simulated position-report data via the Inmarsat Marecs B2 Atlantic Ocean satellite to BTI's earth station at Goonhilly, Cornwall. Good radio communication was said to have been obtained, except when the helicopter's fuselage obstructed the line of sight to the satellite.

From Inmarsat to Inmobsat

The International Maritime Satellite Organization was originally set up to provide communications and other services for sea-going vessels alone. But in recent years, as we have reported, it has been making decisions to allow its nine comsats to be used experimentally for aeronautical and land mobile communications as well.

Now Inmarsat is obviously thinking it might as well go the whole hog and declare itself a general satellite organization for all types of mobile communication. The West German government, through the Deutsche Bundespost, has just proposed amendments to the existing international agreements that would enable Inmarsat to provide the land mobile satcom services. One of these amendments is to change the name to International Mobile Satellite Organization, though the present acronym could remain. A decision to handle aeronautical services officially was made several years ago.

Olof Lundberg, director general of the international co-operative, has welcomed the German proposal. He recently commented, "If adopted, the amendments would enable Inmarsat to use its expertise and resources to bring recent developments in the production of small, portable satellite communications terminals to all those who need mobile communications – at sea, in the air and on land. The economies of scale this would achieve would benefit all users."

An international decision on whether to take on this more comprehensive role could well be made before the end of 1988.

Radio engineering terms in satellite links

In November 1987 we included a glossary of specialized terms used in describing satellite orbits. We now follow this up with a guide to the terminology of the radio links between satellites and earth stations. Many of the terms are familiar, from terrestrial applications. But we are putting them in the context of satellite applications, with suitable examples, to make this reference information more directly relevant to the reports appearing in "Satellite Systems".

For simplicity we will consider a one-way system, a downlink from satellite to ground. But the glossary applies equally well to uplinks and two-way systems. We assume that a frequency- or phase-modulated carrier is transmitted from the satellite in a channel of known bandwidth and that the link has a parabolic dish antenna at each end. The *channel capacity* of the link, measured in bit/s, is determined by its bandwidth and signal/noise ratio as given in Shannon's formula for maximum channel capacity. First we will look at the *signal power* and how it is affected throughout the link.

Signal power

Radio frequency carrier power from the satellite's transmitter, P_T, is fed to an antenna with gain G_T, which is a power density factor relative to an *isotropic radiator.* In general the gain of a parabolic antenna is given by $G=4\pi a\eta/\lambda^2$, where G is a power density factor, a is the aperture area, λ is the wavelength of the carrier frequency and η is the efficiency of the antenna (a percentage usually in the region of 60%). The antenna gain is normally expressed in dBi. To obtain this we find the logarithm of the power density factor and multiply by ten. Thus $G(dBi)=10\log_{10}$ (evaluation of formula).

It is common practice, in fact, to convert all r.f. powers, gains, losses and even bandwidth and noise power into dB. This is because communications engineers find it convenient to be able to calculate the effects of these various quantities (often involving many noughts) throughout a link by adding or subtracting their logarithms. The overall power calculation for a link is called the *power budget.* For example, transmitter carrier power is written not directly in watts but as dB(1W), usually abbreviated to dBW. Thus a transmitter carrier power of 100W is written as 20dBW.

When the r.f. power is radiated from the parabolic antenna it is concentrated into a beam of greater density with an *effective radiated power* of P_T+G_T (in dB). This power is normally expressed in terms of its equivalence to the much higher power that would have to be emitted from an isotropic radiator to achieve the same value as in the centre of the beam, namely, the *equivalent isotropic radiated power* (e.i.r.p.) The term *equivalent isotropic radiated power* is also in use. Thus, if 20dBW of r.f. power from the transmitter is fed to an antenna with a gain of 40dBi, the resulting e.i.r.p. is 20dBW + 40dBi = 60dBW (or 10^6 watts).

To be continued

Satellite Systems is written by Tom Ivall.

Linear systems and random inputs

In discussions of how linear systems respond to random inputs, the Wiener-Khintchine theorem, autocorrelation and cross-correlation are not always given the prominence they deserve.

HOWARD J. HUTCHINGS

In the detection of small signals, noise is the limiting factor. Many advanced signal-processing techniques used to recovering signals corrupted by noise have their origins in the analytical procedures developed by Gauss and others in the nineteenth century. The rapid growth of microelectronics and microcomputers has made such signal processing techniques routinely available.

Discussions in my previous articles have been restricted to finding suitable mathematical models of signals and systems in the time and complex frequency domains[1,2]. I will now demonstrate how mathematical representation can be used to determine the response of a linear system, when the input is a random signal rather than a deterministic one.

An attractive method of describing a system's behaviour is in terms of the impulse response h(t) transformed into the complex frequency-transfer function H(s) or frequency-transfer function H(jω). The fundamental attraction of this approach is that the output y(s) is related to the transfer function H(s) and input x(s) by the operation of multiplication.

When the input signal is a random waveform, this simple relationship no longer exists and the random characteristics of the input signal cannot be modelled in terms of transforms. To retain the operation of multiplication associated with complex frequency-domain analysis, it is necessary to recast the random input into an alternative form to make it transformable.

To ensure that a Fourier transform exists, it is necessary that,

$$\int_{-\infty}^{\infty} |x(t)e^{-j\omega t}|dt<\infty$$

Since $|e^{-j\omega t}|=1$, a sufficient condition is,

$$\int_{-\infty}^{\infty} |x(t)|dt<\infty$$

with one eye on the answer, this can be rewritten without any loss of generality in the form,

$$\int_{-\infty}^{\infty} |x(t)|^2dt<\infty$$

where the integral is finite as before.

Employing Parseval's theorem gives the frequency-domain model,

$$\int_{-\infty}^{\infty} f(t)g(t)dt=\frac{1}{2\pi}\int_{-\infty}^{\infty} F(\omega)G(-\omega)d\omega$$

Writing f(t)=g(t)=x(t), shows that the integral on the left is an expression for the mean-square power in the time domain,

$$\int_{-\infty}^{\infty} |x(t)|^2dt=\frac{1}{2\pi}\int_{-\infty}^{\infty} X(j\omega)X(-j\omega)d\omega$$

$$=\frac{1}{2\pi}\int_{-\infty}^{\infty} |X(\omega)|^2d\omega$$

$$=\frac{1}{2\pi}\int_{-\infty}^{\infty} P_{xx}(\omega)d\omega$$

It is particularly important to grasp the significance of this result, which shows how the average powers in the various components of the signal are distributed throughout the frequency domain. This concept is sufficiently important to be given a special name — the power spectral density function — symbolized by $P_{xx}(\omega)$. Figure 1 and reference 3 give further details.

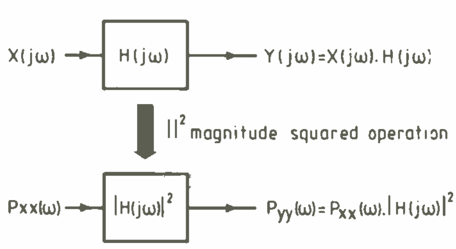


Fig.1. Using the magnitude-squared operation to model spectral power density as a transfer function.

Total average power contributed by all the frequency components is given by Parseval's theorem,

$$P_{average}=\frac{1}{2\pi}\int_{-\infty}^{\infty} P_{xx}(\omega)d\omega$$

The factor ½π is necessary since the units of average power are V^2, while $P_{xx}(\omega)$ has units V^2/Hz and the integration is with respect to dω which has units rad/s^{-1}.

An alternative description of the average power, P_{av}, can be deduced by recognizing that $P_{xx}(\omega)$ is symmetrical about the origin and the limits of integration are from $-\infty$ to ∞. This is simply twice the integral from 0 to ∞ so that,

$$P_{av}=\frac{1}{\pi}\int_{0}^{\infty} P_{xx}(\omega)d\omega$$

Fourier transforms describe the integral relationships between the time and frequency domains. Stated formally, the transformation from time domain to frequency domain is,

$$H(\omega)=\int_{-\infty}^{\infty} h(t)e^{-j\omega t}dt$$

while the inverse transformation is,

$$h(t)=\frac{1}{2\pi}\int_{-\infty}^{\infty} H(\omega)e^{j\omega t}d\omega$$

Figure 2 shows how the Fourier transforms relate to time and frequency domains. It is helpful to carefully consider the reality behind the abstraction of these last two equations. The first describes how energy of

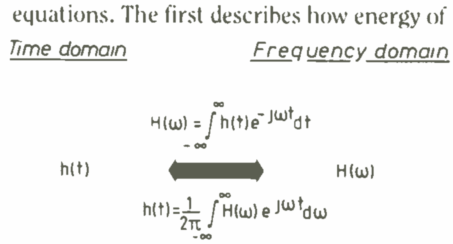


Fig.2. Summary of Fourier integral relationships between time and frequency domains.

h(t) is continuously distributed as a function of angular frequency in the range $\omega=\pm\infty$. In the second equation, the original time-domain function h(t) is recovered by reassembling the weighted frequency components by means of summation.

To acquire a little hands-on experience of using the power spectral-density function, consider the transformations required to express the decaying exponential $x(t)=Ae^{-\alpha t}$ in the power spectral density form, Fig.3.

WIENER-KHINTCHINE THEOREM

Using the inverse form of the Fourier transform with H(ω) replaced by $P_{xx}(\omega)$, the

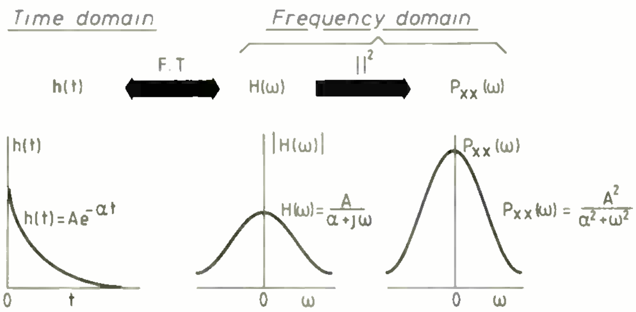


Fig.3. Transformations necessary to evaluate the power spectral density function $P_{xx}(\omega)$ of time-domain signal h(t).

autocorrelation function can be expressed as,

$$r_{xx}(\tau)=\frac{1}{2\pi}\int_{-\infty}^{\infty} P_{xx}(\omega)e^{j\omega\tau}d\omega$$

Recognizing that $P_{xx}(\omega)$ is an even function and that $e^{j\omega\tau}=\cos\omega\tau+j\sin\omega\tau$, the autocorrelation function, a.c.f., can be written in the equivalent form,

$$r_{xx}(\tau)=\frac{1}{2\pi}\int_{-\infty}^{\infty} P_{xx}(\omega)\cos\omega\tau d\omega+\frac{j}{2\pi}\int_{-\infty}^{\infty} P_{xx}(\omega)\sin\omega\tau d\omega$$

Notice that $P_{xx}(\omega)$ and $\sin\omega\tau$ are mutually orthogonal over the interval $\pm\infty$, so that the second integral is zero. Hence

$$r_{xx}(\tau)=\frac{1}{2\pi}\int_{-\infty}^{\infty} P_{xx}(\omega)\cos\omega\tau d\omega$$

Since $P_{xx}(\omega)$ is symmetrical about the origin, the autocorrelation function can be expressed in the form,

$$r_{xx}(\tau)=\frac{1}{\pi}\int_{0}^{\infty} P_{xx}(\omega)\cos\omega\tau d\omega$$

Additionally, the Fourier integral relationship expresses the spectral power density function $P_{xx}(\omega)$ in terms of its autocorrelation function,

$$P_{xx}(\omega)=2\int_{0}^{\infty} r_{xx}(\tau)\cos\omega\tau d\tau$$

Hence the a.c.f. and power spectral-density function are related as a Fourier-transform pair, Fig.4.

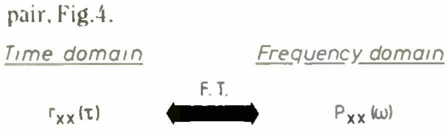


Fig.4. Wiener-Khintchine theorem relates the autocorrelation function in the time domain and the power spectral density in the frequency domain as a Fourier-transform pair.

Autocorrelation is a useful method of detecting signals in the presence of noise. The time-domain signal-processing operation applicable to aperiodic pulses or finite-energy signals is given by,

$$r_{xx}(\tau)=\int_{-\infty}^{\infty} x(t)x(t+\tau)dt$$

While the a.c.f. of continuous or finite-power signals is given by,

$$r_{xx}(\tau)=\lim_{T\to\infty}\left[\frac{1}{T}\int_{-T/2}^{T/2} x(t)x(t+\tau)dt\right]$$

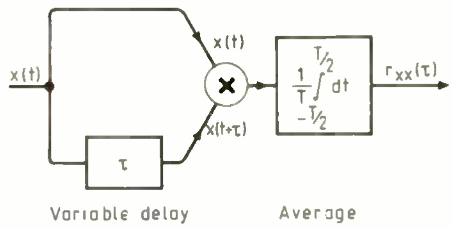


Fig.5. By making observation interval T sufficiently long and progressively varying the time shift τ, the signal-processing diagram provides a reasonable approximation to the finite power autocorrelation function.

Table 1. Properties of the autocorrelation function are such that all phase information present in the input signal is lost under the operation of autocorrelation. Amplitude information is retained although in a modified form. Periodic signals in real time retain their periodicity in parametric time. Substituting τ=0 gives the mean-square value of the signal.

Real time x(t)	ACF	Parametric time $r_{xx}(\tau)$
$A\sin(\omega t+\phi)$	⟶	$(A^2/2)\cos\omega\tau$
$A\cos(\omega t+\phi)$	⟶	$(A^2/2)\cos\omega\tau$
$A+B\sin\omega t$	⟶	$A^2+(B^2/2)\cos\omega\tau$
$Ae^{-\alpha t}$	⟶	$(A^2/2\alpha)e^{-\alpha\tau}$

Figure 5 is a model of the signal processing required to obtain the a.c.f. and Table 1 shows autocorrelation function properties.

EFFECT OF FINITE OBSERVATION TIME

It is interesting to examine the effect of the finite observation time T associated with the signal processing system shown in Fig.5. Consider the problem of calculating the a.c.f. of the signal $x(t)=A\sin(\omega t+\phi)$ over the interval [0,T]. Writing the a.c.f. as,

$$r_{xx}(\tau)=\frac{1}{T-\tau}\int_{0}^{T-\tau} x(t)x(t+\tau)dt$$

and substituting $x(t)=A\sin(\omega t+\phi)$, so that,

$$r_{xx}(\tau)=\frac{A^2}{2}\cos\omega\tau-\frac{A^2\cos[\omega(T-\tau)]}{4\omega(T-\tau)}\sin(\omega\tau+2\phi)$$

The first term is the theoretical a.c.f. while the other represents an error. Provided that observation time T is very much greater than the delay, the error will be small but as τ approaches T, the error becomes more and more significant[1].

CALCULATING DISCRETE AUTOCORRELATION FUNCTIONS

Sampled data sequences can be processed to obtain the discrete form of the autocorrelation function. This is probably best understood in terms of the autocorrelation coefficient. A sampled-data sequence of length 2N+1 samples has the autocorrelation coefficient defined by,

$$r_{xx}(k)=\frac{1}{2N}\sum_{n=-N}^{N} x_n x_{n+k}$$

The autocorrelation function is simply a graph of the autocorrelation coefficients. Consider the sampled data form of the sinusoid $x(t)=\sin\omega t$, sampled every T seconds. Figure 6 has the details (see over).

WHITE NOISE

A random signal in which all frequencies are present with equal weighting and random-phase, distribution is defined as white noise. Think of the analogy with white light, which has a constant spectral density over the visible spectrum.

Such a signal cannot exist physically since the mean-square value would be infinite. Despite this limitation it is a useful mathematical model which can be adopted with confidence provided the bandwidth of the random signal is very much greater than the bandwidth of the linear processor.

To evaluate the autocorrelation function of band-limited white noise shown in Fig.7 (see over) use the Wiener-Khintchine theorem so that,

$$r_{xx}(\tau)=\frac{1}{\pi}\int_{0}^{B} P_0\cos\omega\tau d\tau$$

$$=\frac{P_0}{\pi}\left[\frac{1}{\tau}\sin\omega\tau\right]_0^B$$

$$=\frac{P_0 B}{\pi}\left(\frac{\sin B\tau}{B\tau}\right)$$

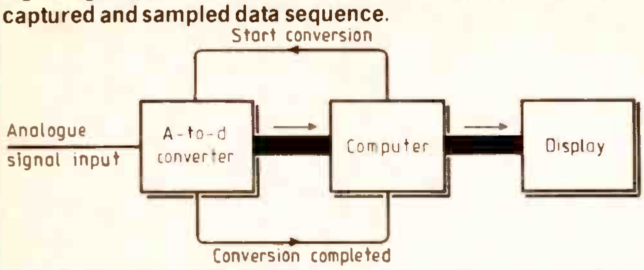
Sampling function sinx/x characterizes the autocorrelation function. Clearly the greater the upper angular frequency (B) of the band-limited model, the narrower will be the central pulse of the autocorrelation function. Treating this as a limiting process it can be concluded that as the noise bandwidth increases towards infinity, so the a.c.f. tends towards the weighted impulse centred on zero. By inspection the a.c.f. has a maximum value for zero delay, and as before $r_{xx}(0)$ equals the mean-square value of the random noise.

An example should help: consider the effects of applying wide-band noise with constant spectral density to the first-order low-pass system of Fig.8 (see over). Use signal-processing techniques to evaluate the total mean-square value of the filter-output.

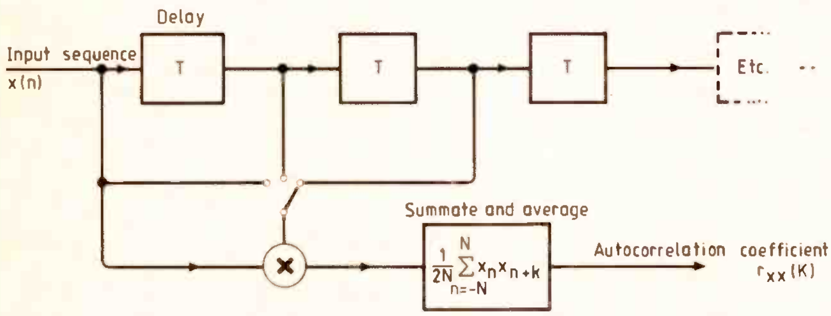
Method 1 — signal processing in the frequency domain. The transfer function of the system is given by,

$$H(j\omega)=\frac{k}{1+j\omega CR}$$

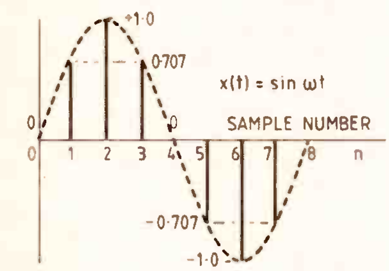
Fig.6. Signal processing necessary to generate the autocorrelation coefficients from a captured and sampled data sequence.

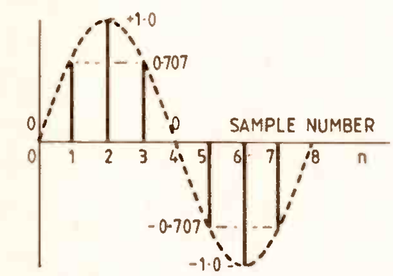


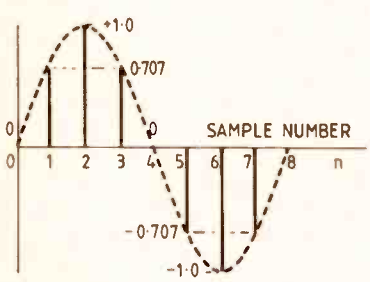
Signal processing diagram of the progressive shift, multiply and summate algorithim realized in software form.



Evaluating the autocorrelation coefficients.







To calculate $r_{xx}(0)$ align the samples as shown so that,

$$r_{xx}(0)=\frac{1}{8}(x_0x_0+x_1x_1+x_2x_2+x_3x_3+x_4x_4+x_5x_5+x_6x_6+x_7x_7+x_8x_8)$$

$$=\frac{1}{8}(0+0.707^2+1.0^2+0.707^2+0+0.707^2+1.0^2+0.707^2+0)$$

$$=0.5$$

To evaluate the value of $r_{xx}(1)$ shift the sampled waveform one place to the left so that,

$$r_{xx}(1)=\frac{1}{8}(x_0x_1+x_1x_2+x_2x_3+x_3x_4+x_4x_5+x_5x_6+x_6x_7+x_7x_8)$$

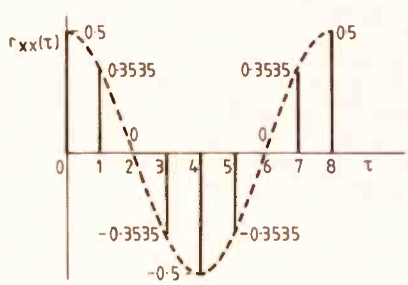
$$=\frac{1}{8}(0+0.707\times1+1\times0.707+0+0+(-0.707\times-1)+(-1\times0.707)+0)$$

$$=0.3535$$

The other coefficients follow by progressively shifting the sample of interest one place to the left until none of the samples overlaps. My results are,

$r_{xx}(2)=0$
$r_{xx}(3)=-0.3535$
$r_{xx}(4)=-0.5$
$r_{xx}(5)=-0.3535$
$r_{xx}(6)=0$
$r_{xx}(7)=-0.3535$
$r_{xx}(8)=0.5$

So that the autocorrelation function of the sampled-data sequence is $r_{xx}(\tau)=(V^2/2)\cos\omega\tau$ as expected.



Since the input is a wide-band white-noise signal, the spectral density of the output is given by,

$$P_{yy}(\omega)=P_0|H(j\omega)|^2$$

$$P_{yy}(\omega)=\frac{P_0k^2}{1+(\omega CR)^2}$$

To evaluate the mean-square value of the output signal, integrate using Parseval's theorem,

$$P_{av}=\frac{1}{\pi}\int_0^\infty P_{yy}(\omega)d\omega$$

$$=\frac{1}{\pi}\int_0^\infty \frac{P_0.100.d\omega}{1+(\omega CR)^2}$$

$$=\frac{P_0.100}{\pi}\int_0^\infty \frac{d\omega}{1+(\omega CR)^2}$$

Substitute $u=\omega CR$ and $du=CRd\omega$,

$$=\frac{P_0.100}{\pi CR}\int_0^\infty \frac{du}{1+u^2}$$

$$=\frac{P_0.100}{\pi CR}[\tan^{-1}(u)]_0^\infty$$

$$=\frac{P_0.100}{\pi CR}\left[\frac{\pi}{2}\right]$$

Using the data, substitute numerical values

$$CR=\frac{1}{2\pi\times5\times10^3}\text{seconds}$$

$$P_0=10^{-6}\ V^2/Hz$$

$$P_{av}=1.571\ V^2$$

Method 2 — signal processing in the time domain. The system's transfer function is,

$$H(j\omega)=\frac{k}{1+j\omega/\omega_0}$$

and in terms of s is

$$H(s)=\frac{k\omega_0}{\omega_0+s}$$

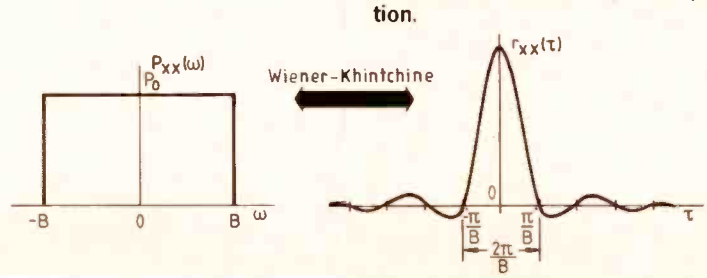


Fig.7. Increasing the upper angular frequency B of the band-limited model reduces the width of the autocorrelation function pulse. In the limit as the bandwidth becomes infinite the autocorrelation function is modelled by an impulse function.

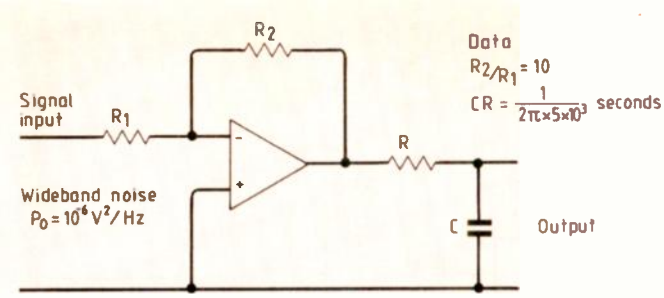


Fig.8. The linear signal processor is made up of a first order low-pass filter of 5kHz bandwidth connected in cascade with an amplifier of gain 10.

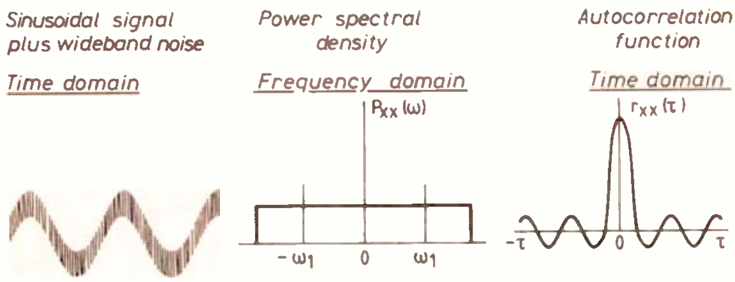


Fig.9. Autocorrelation function of a sinusoidal signal corrupted by wide-band white noise.

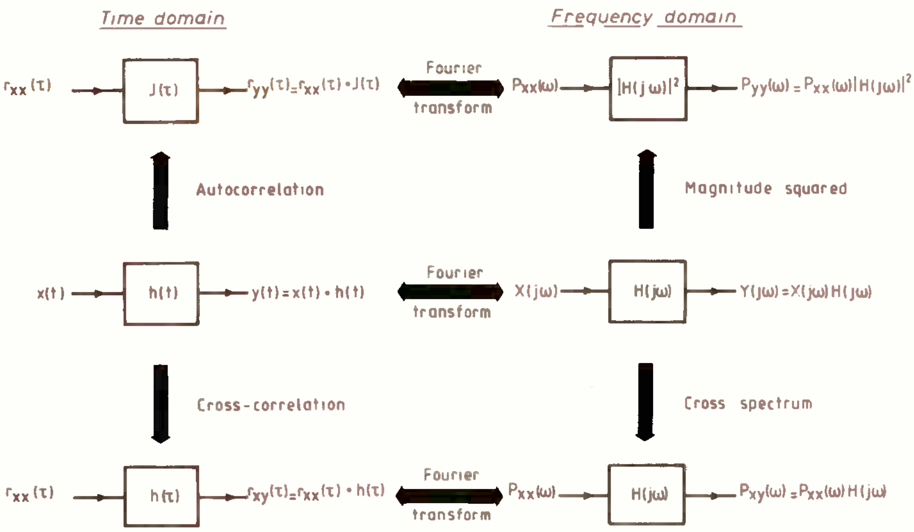


Fig.10. Summary of autocorrelation and cross-correlation signal-processing operations in time and frequency domains. Based on diagrams from Electronic signal processing, T326 Block IV pp.35,37, Open University Press.

Employing the inverse Laplace transformation to obtain the impulse response,

$$h(t)=10\omega_0 e^{-\omega_0 t}$$

Using Table 1, the autocorrelation function of h(t) can be determined,

$$J(\tau)=\frac{100\omega_0^2}{2\omega_0}e^{-\omega_0|\tau|}$$

The a.c.f. of the output signal is given by,

$$r_{yy}(\tau)=r_{xx}(\tau)*J(\tau)$$

Since the a.c.f. of the wide-band white-noise input is an impulse function, the operation of convolution is replaced by multiplication. To evaluate the mean-square value, put $\tau=0$,

$$r_{yy}(0)=P_0.J(0)=10^{-6}\,50\omega_0=1.571\ \mathrm{V}^2$$

This demonstrates the equivalence of time-domain and frequency-domain signal processing of random signals.

AUTOCORRELATION IN DETECTION OF NOISE-CORRUPTED SIGNALS

Detection of weak periodic signals corrupted by white-noise can be achieved using autocorrelation. Consider the signal processing implemented by the system in Fig.5 when the input signal consists of two components, x_1, a small-amplitude periodic signal and x_2, a random signal modelled as white-noise. The autocorrelated output is given by,

$$r_{xx}(\tau)=\lim_{T\to\infty}\left[\frac{1}{T}\int_{-T/2}^{T/2}x(t)x(t+\tau)dt\right]$$

and the noisy input $x(t)=x_1(t)+x_2(t)$ so that the autocorrelation function of the processed output will be,

$$r_{xx}(\tau)=\lim_{T\to\infty}\left[\frac{1}{T}\int_{-T/2}^{T/2}[x_1(t)+x_2(t)][x_1(t+\tau)+x_2(t+\tau)]dt\right]$$

$$=\lim_{T\to\infty}\left[\frac{1}{T}\int_{-T/2}^{T/2}x_1(t)x_1(t+\tau)dt+\frac{1}{T}\int_{-T/2}^{T/2}x_1(t)x_2(t+\tau)dt\right.$$

$$\left.+\frac{1}{T}\int_{-T/2}^{T/2}x_2(t)x_1(t+\tau)dt+\frac{1}{T}\int_{-T/2}^{T/2}x_2(t)x_2(t+\tau)dt\right]$$

hence,

$$r_{xx}(\tau)=r_{11}(\tau)+r_{12}(\tau)+r_{21}(\tau)+r_{22}(\tau).$$

The first and last terms represent the autocorrelation functions of the signal and noise respectively, and the two middle terms represent the autocorrelation functions of the uncorrelated signal and noise components. Since these signals share no common characterstic they may be equated to zero. It can then be concluded that the autocorrelation function of the sum of two uncorrelated signals is the sum of the autocorrelation functions of the individual components so that,

$$r_{xx}(\tau)=r_{11}(\tau)+r_{22}(\tau).$$

Figure 9 sums this up.

THE CROSS-CORRELATION FUNCTION

When a signal from a random process is applied to the input of a linear signal processor, the output will be related in some way to the input, in other words they will be correlated. Autocorrelation identifies similarities in amplitude and frequency although it fails to reveal the phase characteristics of the system.

This restriction can be overcome by modifying the autocorrelation function, and cross-correlating the input and output signals. Cross-correlation is defined as,

$$r_{xy}(\tau)=\lim_{T\to\infty}\left[\frac{1}{T}\int_{-T/2}^{T/2}x(t+\tau)y(t)dt\right]$$

where a time shifted version of the input signal $x(t+\tau)$ is multiplied by the processed output y(t) and the product integrated over all time. The cross-correlation function reflects the similarities of the amplitudes, frequencies and phase angles of all the components in the integrand. The operation of integration gives the long term average of the product.

The integral form of this expression is very similar to the operation of convolution discussed earlier[2]. Convolution, correlation and filtering are a triad of signal-processing operations and should be thought of collectively, rather than independently. This instructive approach will unify your perception of linear signal processing, Fig 10.

CROSS-CORRELATION IN FLOW MEASUREMENT

The basic principle is to use cross-correlation to time the passage of a particular signal between two transducers a known distance apart. Each transducer measures the conductivity of an unhomogeneous liquid or slurry, Fig.11.

As the particular conductivity profile or signal detected by the first transducer passes the second, the measured signal will have been corrupted due to turbulence in the liquid. By cross correlating the input and output signals the maximum correlation coefficient can be determined.

The time delay associated with the maximum coefficient is the average time taken for the liquid to flow between the two transducers, hence the flow rate can be established[5].

SYSTEM TESTING AND CHARACTERIZATION

The output of a linear signal processor in the frequency domain has been shown to be the product of the Fourier transform of the input signal $X(j\omega)$ and the transfer function $H(j\omega)$ so that,

$$Y(j\omega)=X(j\omega).H(j\omega)$$

and the transfer function is given by,

$$H(j\omega)=\frac{Y(j\omega)}{X(j\omega)}$$

Multiplying the top and bottom lines by the complex conjugate $X(-j\omega)$ (often denoted by $X^*(j\omega)$),

$$H(j\omega)=\frac{Y(j\omega).X^*(j\omega)}{X(j\omega).X^*(j\omega)}$$

$$=\frac{Y(j\omega)X^*(j\omega)}{|X(j\omega)|^2}$$

Identifying terms, recognize that $|X(j\omega)|^2$ is the input power spectral density function $P_{xx}(\omega)$ and $Y(j\omega).X^*(j\omega)$ is the cross spectral density function $P_{xy}(\omega)$ (Parseval's theorem may help here).

Note that the transfer function of the system $H(j\omega)$ is given by the cross-spectral density $P_{xy}(\omega)$ divided by the input spectral density $P_{xx}(\omega)$.

$$H(j\omega)=\frac{P_{xy}(\omega)}{P_{xx}(\omega)}$$

When the input signal is modelled as white-noise, the power spectral density has constant magnitude equal to the mean-square value of the noise, over the frequency range of interest. This provides an attractive method of system characterization. The frequency transfer function of the system is given by the cross-spectral density function divided by a constant,

$$H(j\omega)=\frac{1}{P_0}.P_{xy}(\omega)$$

The time domain model of the signal processing operation is obtained from the inverse Fourier integral relationship. Taking inverse Fourier transforms of both sides,

$$h(\tau)=\frac{1}{P_0}r_{xy}(\tau)$$

Clearly, dividing the cross-correlation function by the mean-square value of the random signal input gives the impulse response of the system, Fig.12.

This form of system characterization may be compared with the impulse response testing of continuous systems. Unfortunately it is seldom possible to identify practical systems in this way, since the amplitude of the impulse necessary to obtain a measurable response often overloads the system resulting in non-linear signal processing. Reducing the amplitude of the impulse may also be prohibited since the response will be obscured by system noise.

System characterization by white-noise input-output correlation has been used successfully in a variety of systems. These include chemical process control, the measurement and control of the dynamic characteristics of aircraft, the response of large buildings to wind buffeting, electronic circuit response, the dynamics of nuclear power plant and the dynamics of a diesel engine[6].

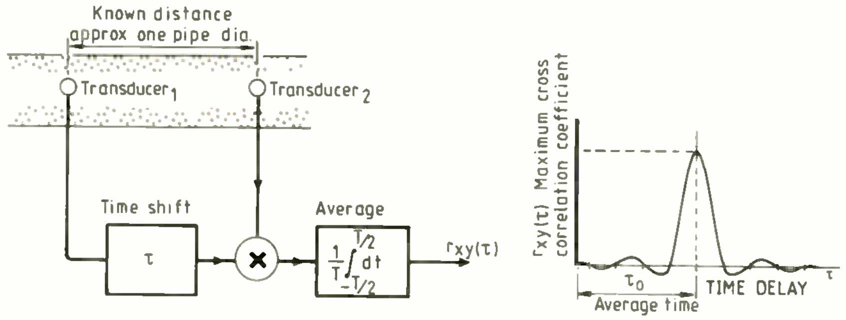


Fig.11. Use of cross-correlation techniques to measure flow-rate. Locating the transducers approximately one pipe diameter apart ensures measurable coefficients without causing prohibitively long signal-processing time (accuracy ±2%).

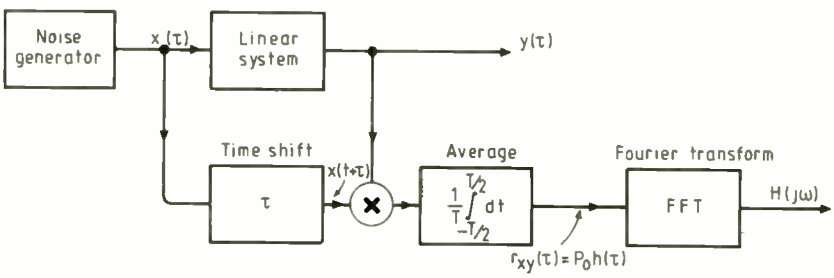


Fig.12. Signal-processing system diagram demonstrating how to obtain the time-domain impulse response h(t) and frequency-domain transfer function H(jω) by white-noise cross-correlation.

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BOOKS

World Radio TV Handbook edited by Andrew G. Sennitt. Billboard, 576 pages, £17.95. Indispensable guide to the world's broadcasting, for engineers and enthusiasts. This year's edition sticks to the customary format, though the television listings now include details of certain satellite broadcasts. The features section at the back includes articles on receiver specifications and active antennas, a review of the Lowe Electronics h.f. receiver (described in *E&WW* in April 1987) and a critical roundup of some of the latest portables. WRTH is available in the UK through Pitman Publishing.

A quarterly newletter is available direct from the publishers at £9 for four issues: this will provide news and updates to the short-wave frequency lists, schedule changes notified by broadcasters worldwide, equipment reviews and other features.

Dial-Search, fifth edition 1988/89, compiled by George Wilcox, 46 pages, £3.25. Listener's check-list and guide to British and European broadcasting, with lists of stations on l.f., m.f., h.f. and v.h.f., programme notes, tables and maps. A table of the UK v.h.f. band includes recent Geneva Plan changes of frequency and a number of foreign stations often audible in the UK. Dial-Search is available from the author at 9 Thurrock Close, Lower Willingdon, Eastbourne, East Sussex BN20 9NF (add 35p for postage).

TELECOMMS TOPICS

Fibre in the City

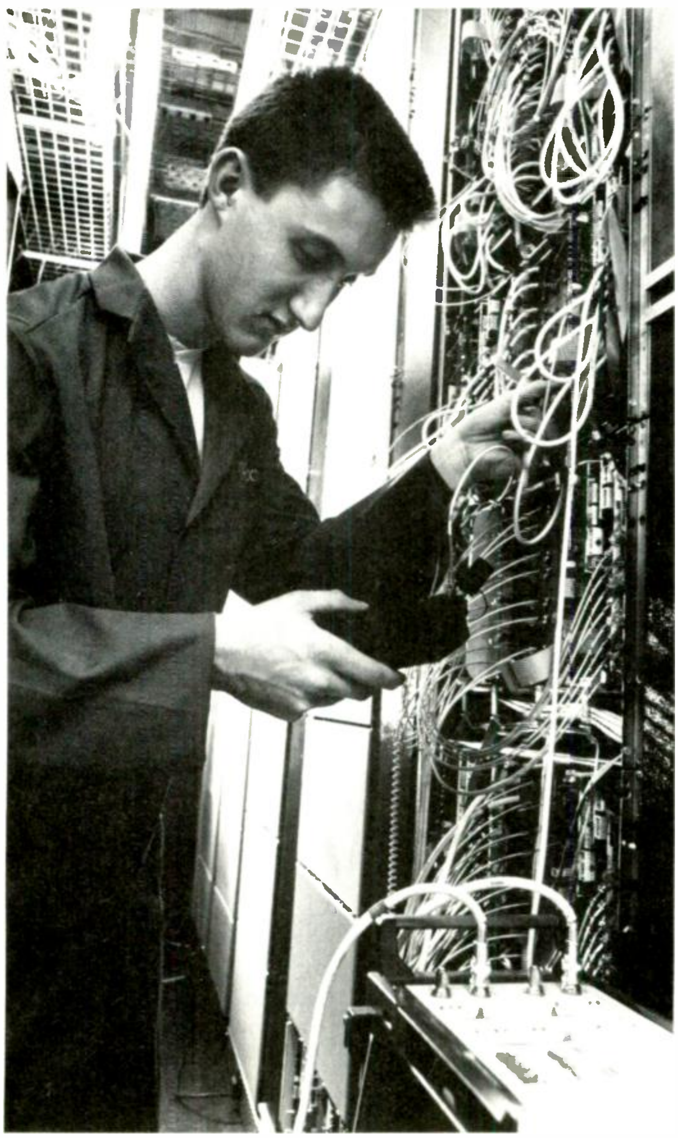
The City Fibre Network, a flexible access system (FAS) claimed to be the most advanced such system in the world, has been inaugurated by British Telecom in the City of London. Costing around £70 million, it uses single-mode fibres and allows the fast supply of new circuits, prompt circuit reconfigurations, rapid maintenance and high reliability.

FAS will allow new circuits to be set up more speedily or to be reconfigured by a simple software change at the service control centre, which can also monitor the status of any circuit, end to end, 24 hours a day, and so ensure high levels of reliability and maintenance. Standby circuits are incorporated into the network, ready to switch in automatically should a fault be detected, and centralized fault alarms will speed maintenance.

The first customers to benefit will be the 100 or so users of British Telecom's Dealerinterlink. This service enables customers to rent groups of private circuits – heavily used in the City to provide fast trading links – which are all connected to a central point. In this way a private speech circuit can be set up with any other Dealerinterlink user within 24 hours.

Eventually the total scheme is expected to run into several hundred million pounds and cover all the major business centres throughout the country.

Hub of the City Fibre Network is the exchange at Baynard House: here engineer Bryan Long is working in an area where the optical fibre cables enter the building.



...and on to Dockland

The system is to be further expanded to reach into London's dockland which is growing in importance as a business and financial centre. For this extension, Plessey has won an order valued at around £30 million. Plessey will have total responsibility for the project, and for the supply of the System X switching system and optical transmission equipment. But within this contract, STC will supply PDMX digital multiplexing equipment and related network management software to a value of £15 million.

Sweden's lead in data services

Sweden is to integrate its public data services with the public telephone network, using telephone exchanges to set up semi-permanent, private data links across the country. It claims that it is the first country in the world to take such an advanced step.

Televerket, the Swedish telephone administration, has just signed a contract with Ericsson to install digital leased line facilities operating at data rates from 2.4 to 64kbit/s in AXE exchanges in the network (the same switches as are System Y in the British Telecom network.) There is also an option for further orders that could include network supervision equipment.

It is Ericsson's first major contract for this recently introduced digital leased line function in AXE. It will enable semi-permanent leased data lines through the public telephone network to be set up or changed in a matter of minutes, entirely by command from an operator terminal. Ultimately, all 60 000 subscribers on the Swedish Datel data service will be served by links set up through these AXE exchanges.

Main benefits for users are expected to be speedier provision of data links in line with changing needs, higher service availability, and better transmission quality. The AXE exchanges will also supervise the data links end to end.

The equipment is expected to be handed over by the end of 1988. Teli, a subsidiary of Televerket, is supplying the data circuit terminating equipment that will be installed at each subscriber's premises.

At present, most telecommunications administrations provide private data circuits by hard-wiring links between incoming cables at the main distribution frame of each exchange along the transmission route. This takes time, and it is difficult to ensure end-to-end quality and continuity. It also makes it difficult to change data routes at short notice in line with the changing needs of companies.

The digital leased line facility enables AXE digital telephone exchanges to be used to set up these semi-permanent private data links through the public telephone network. It lets the telecommunications administration respond quickly to customer needs, with maintenance facilities that extend over the whole data route, right out to the subscriber terminals.

Irish spur to PTAT-1

Telecom Eireann, the government-owned public telecommunications operator in the Republic of Ireland, and Cable and Wireless have agreed to land a spur from the privately-owned PTAT-1 transatlantic fibre optic cable in the south of Ireland. The landing site will be at Courtmacsherry Bay, County Cork.

The announcement follows recent agreements reached by Mercury Communications, a wholly-owned subsidiary of Cable and Wireless, to lay fibre optic cables from the UK to France, Portugal and the Netherlands.

The PTAT (Private Trans-Atlantic Telecommunications) cable system is jointly owned by Cable and Wireless of the UK and PTAT Systems of the USA. Its first cable, PTAT-1, is scheduled to enter service in mid-1989 with PTAT-2 following in 1992.

Gordon Owen, managing director of Cable and Wireless said: "We are delighted to have reached agreement with Telecom Eireann, the first European PTT to demonstrate their financial commitment to PTAT. The installation of a new link will provide customers in Ireland with the first direct digital fibre cable access to the USA and a new fibre optic route to the UK."

European standards institute

The directors general for telecommunications of the Administrations of European Conference of Posts and Telecommunications Administrations (CEPT) have decided to establish an autonomous European Telecommunications Standards Institute in France at Sophia Antipolis near Nice, in conjunction with industry and users. They will progressively transfer to it the work on technical standardization hitherto undertaken by CEPT.

This is a step forward in the production of European telecommunications standards, providing for greater concentration of effort and the full participation of industry and users. It follows the proposal in the EEC Green Paper on the development of the common market for telecommunications services and equipment.

Offshore pay phones

Plessey payphones have been installed on the BP Forties offshore oil platforms. Telephones on the four platforms are linked to the British Telecom network by the Forties tropospheric scatter systems. Previously staff working on the platforms had to make costly reverse-charge calls to their families.

The payphones will report into a management system located some 110 miles away at the BP maintenance centre at Dyce, Scotland, where usage and performance will be monitored.

Worldwide Dialcom

British Telecom's value-added services division is restructuring its data services activities in an enlarged Dialcom group. The aim is to make the group, which will have initial revenues of around $100M, the worldwide leader in electronic mail and other value-added data services. It will have four marketing arms serving the United States, the United Kingdom, Europe, and other countries worldwide.

The new Dialcom group will be fully operational by April. It will combine Dialcom Inc.; Telecom Gold, UK's prime public messaging service; British Telecom's valued-added business services, which include Prestel, the British videotex service; and the computer network services division which provides technical support for the UK operation.

New look to fax

Interscan Communications Systems of Slough has launched "Signature", which it claims is a revolutionary development in facsimile transmission. It allows any make of fax terminal to be connected to any IBM-compatible computer and operates in full background mode enabling the PC to be used while receiving and sending fax messages.

By using the fax machine as a printer, printing is speeded up and quality is equal to, or better than, any Group 3 machine. The system adds facilities to even the most basic machine, and provides an upgrade to low-end machines with features such as extended autodialling, document storage, delayed transmissions, relay broadcasting and mailbox.

The growing popularity in fax has resulted in a large installed base of relativity new low-end machines. Signature provides a cost-effective upgrade path. Future developments of the system will allow Apple, DEC and other computers to be interfaced with fax. Interscan also expects to be the first company to offer fax in a Unix environment.

Interscan's approach is different from that adopted by other makers of fax cards (mainly US and Japanese). Japanese manufacturers are increasingly moving towards high-performance machines which communicate with PCs via RS-232 interfaces. On the other hand, while many of the other fax cards enable a facsimile to be sent directly from a PC, a scanner is necessary to send an image from hard copy.

Optical plastics

BT&D Technologies, the optoelectronic component joint venture between British Telecom and Du Pont has announced a homogeneous polymeric waveguide that is claimed to remain stable through a wide range of temperatures. Named Polyguide, the material is suitable for the manufacture of both simple and complex components. Waveguides based on the material are temperature stabilized to 125°C. Potential applications include passive multiport buried single-mode devices for coupling and splitting as well as multilayer buried waveguides and diffraction gratings for complex wavelength division multiplexing devices.

BT&D believes that it is the first optoelectronic component manufacturer to develop waveguides from such a photopolymer material.

Racal-Milgo in ISDN trial

Racal-Milgo is one of the vendors selected by Bell Canada to participate in the development of ISDN terminal adapters (TA) and applications.

A TA is a network access device that allows digital equipment – terminals and analogue devices such as modems, to be connected to multiple ISDN digital network services.

The trial allows Bell Canada to explore the productivity improvements and new opportunities provided by ISDN. It is using 144kbit/s basic rate access (2B+D) which consists of two 64kbit/s and one 16kbit/s all on a standard local telephone loop. The 64kbit/s channels can be used for voice and/or any form of data, and the 16kbit/s channel is used for signalling between the user and the network as well as for telemetry and user packets.

Later this year Bell Canada expects to add primary rate access services in Ottawa. In North America, because of the widely used 1.544Mbit/s T-1 channel capacity, this refers to 23 main channels of 64kbit/s plus one 64kbit/s channel for signalling purposes. The European equivalent of 30B + D is based on the 2Mbit/s channel.

BT chooses ICL's Oslan

ICL is to provide British Telecom with its Oslan bridges. These will connect multi-vendor computer equipment which controls electronic exchanges serving over 700 000 customers in the Thamesway district of Greater London. The order, worth £200 000, is for 20 remote Oslan bridges with a network management station and bridge management software.

The Oslan bridges will provide access to a DEC 8530 at BT's operations and maintenance centre at Woking, south-west of London. The equipment will allow 100 terminals in fifteen locations throughout the district to communicate as if they were sharing a single local area network.

The Woking centre will now be able to co-ordinate telephone exchange maintenance activity over an area of 600 square miles.

MNP Class 6 protocol

Microcom Inc. has introduced a further performance level of its Microcom Networking Protocol (MNP), the *de facto* industry standard for providing error correction and negotiation capabilities for dial-up modem applications (see p.1259, December 1987).

The new Class 6 service adds statistical duplexing and universal link negotiation features to earlier MNP modems to compare data transmission speeds available on each modem being connected and to select the highest possible speed common to both. A speed shift feature also may be enabled so that if the telephone line deteriorates during a data transfer, the modems can dynamically switch to a slower speed that is less vulnerable to line noise.

Class 6 service also enhances data transfer throughout by permitting the use of a half duplex V.29 "fast-train" physical connection and statistical duplexing to simulate full duplex communications.

Telecomms Topics is compiled by Adrian Morant.

ELECTRONICS & WIRELESS WORLD/NEC 1988 COMPETITION

ASSERT

(Assessments of the Social Significance of Engineering and Research for Tomorrow)

Win our writing competition and spend a week in Japan

You have until 30 June 1988 to let us have your entries for our writing competition, the initial announcement of which appeared last month. Three and a half months might seem ample time in which to compose 4500 words or so, but if you are of the same persuasion as the majority of writers the only compelling stimulus to the start of the pen-scratching or keyboard-tapping process is the sudden awareness of a deadline a couple of days away.

Of course, one has to spend a lot of time thinking about it, but it is a good idea to make a note of any points that occur along the way, so that the effort of putting it all down on paper does not get in the way of the ideas one wants to convey.

The name of the competition at the top of this page indicates the type of thing we are after, but we reproduce here the March leader, which might provide some food for thought.

In the eighty-odd years since radio and the wider area of electronics began to develop, we have all been beneficiaries in one way or another. There is hardly any field of human activity which has not been affected, where it is entertainment, communication, travel, medical research or industry in general.

All this is obviously greatly to be desired and the benefits of using electronics for these purposes cannot be gainsaid. But, nevertheless, one is sometimes conscious that there is, perhaps, an imbalance in the efforts applied to development. In recent years, the ingenuity of electronic engineers and capital investment have been directed to a constantly increasing extent to the development of space electronics, communications and 'defence' equipment which, if it achieves its aim, will never be used.

Communications apart, the majority of effort is wasted so far as direct benefit to mankind is concerned in the foreseeable future. In a world that is beset by deprivation of many kinds from the fundamental needs of life itself to the luxury of education, one could fairly hold the opinion that further developments in exotic electronics might at least be restrained in favour of a wider provision of more basic requirements.

The application of effort in our field of electronics might not seem immediately relevant to the alleviation of famine and pestilence but the attitude of mind that impels continuous investment of indulgent or lethal hardware is questionable. To expect companies throughout the world to turn down profitable development and production contracts would be naive, but a subsidized programme of development directed at more fundamental needs is perhaps possible.

Elsewhere in this issue appears the announcement of a competition in which readers are invited to set down their views on the way forward in engineering development. It may be that the admittedly idealized thoughts expressed above will be considered too ingenuous to be true, or that the existing regime is completely satisfactory. In any event, we expect to see a large number of thoughtful essays which should give rise to an interesting discussion, if nothing more useful than that.

Do, please, have a look at the announcement and let us have your thoughts – the prizes are very attractive and we are fortunate in that NEC, which has provided the main ones, is taking such a keen interest.

Bear in mind that engineering is international: narrow, nationalist politics are, of course, important but the aim of the competition is to elicit opinion on the larger question of the direction in which international effort in electronics might most usefully be directed.

Our intention is to publish a selection of the best essays, so that the length should not exceed about 4500 words, or three printed pages in *EWW*. Diagrams can be used if necessary, but the space they occupy will have to be deducted from the 4500 words.

The judging panel will be composed of respected names, both in and outside industry and the prize-giving ceremony will be in London.

NEC Electronics (UK) Limited have joined *EWW* in sponsoring the competition and have provided the first three prizes.

FIRST PRIZE

This is an all-expenses-paid week-long visit to Tokyo as guests of NEC, who will provide the winner with a tour of the NEC facility and Tokyo itself.

SECOND PRIZE

NEC will provide one of their newest PC-AT-compatible computers

THIRD PRIZE

An NEC digital video cassette recorder

EWW will present a number of further prizes for the runners-up.

Digital storage oscilloscope with 100 Msamples/s

A low-cost d.s.o. with many advanced features is introduced by Philips. Gary Burgess of Philips T&M describes its design and use.

G. BURGESS

While digital storage oscilloscopes are increasingly being preferred, their high cost has compelled many engineers to manage with an analogue instrument. However, a new dual-channel oscilloscope eliminates this remaining disadvantage – it costs only £2650, while still incorporating virtually all the features of the expensive models.

PM3350 is a combination instrument, and incorporates a 50MHz analogue oscilloscope. This brings engineers the best of both worlds. It provides a d.s.o's analytic capabilities, versatile triggering, and capacity to make accurate time and frequency measurements on a waveform without needing a separate time/counter. Further, it retains an analogue instrument's simplicity of operation, instantaneous response, and ability to capture high-speed single-shot events.

Although the PM3350 won't handle the signals that appear in circuits such as e.c.l. and c-mos asics, it will deal with the majority of microprocessor-based systems. Surprisingly, the main cost savings have not come from higher levels of integration (although these have certainly helped) but from consumer manufacturing techniques that have so far hardly penetrated to instrument manufacturers (see panel 'Production techniques'). Most importantly, the instrument doesn't cut costs by dropping out features.

ANALOGUE AND DIGITAL BANDWIDTH

The maximum bandwidth of an oscilloscope is an important parameter. Even when measuring 'slow' devices, it may be important to examine the switching edges and a typical power mosfet may have rise and fall times of 10ns or less, needing a 50MHz bandwidth or more to be able to capture them. Similarly, the capture of transients and single-shot signals in the digital section of the oscilloscope needs a sufficiently high sampling rate to make sense of the received signal. 100Msamples/s allows the capture of 10MHz signals as may be found in 16 and 32-bit processors. A very slow sampling rate can be useful for using the instrument as a chart recorder.

Sensitivity is another important factor. The eight-bit vertical resolution of the PM3350 gives a sensitivity of 2mV/div, which can be translated as a bit-sensitivity of 8μV, enabling very low voltage signals to be captured.

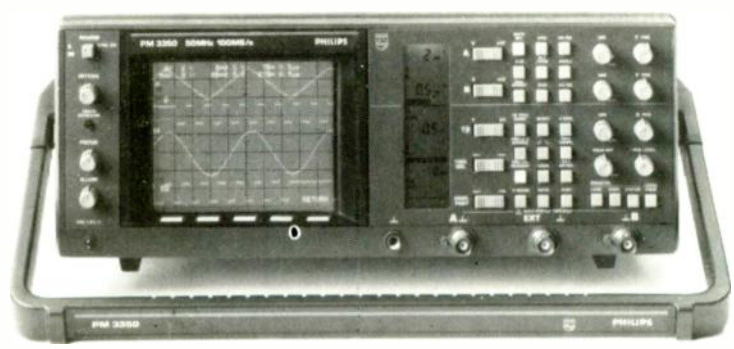


Fig.1. The PM3350 can compare two incoming signals against their corresponding reference frequencies, showing any measurements clearly on the screen.

SIGNAL CAPTURE AND CONVERSION

The PM3350 is built round a 68008 microcontroller, and a family of gate arrays (see panel 'PM3350 architecture'). Instead of expensive flash a-to-d converters, the new oscilloscope employs P^{2}CCD (profiled peristaltic charge-coupled device) memories to capture incoming analogue signals. These c.c.ds act as analogue shift registers, sampling and temporarily storing the incoming analog wave. The PM3350 has one c.c.d. per channel, allowing the oscilloscope to run at its top 100-Msample/s speed on both channels simultaneously.

The incoming waveform to a channel is continuously fed into the c.c.d. until a trigger pulse arrives. If the c.c.d. is stopped on the trigger pulse itself, the waveform held in the c.c.d. is actually the pretrigger information; this is particularly useful for capturing the leading edge of a transient (which is impossible on analogue instruments without additional delay lines). To capture post-trigger information, the contents of the c.c.d. are read out when the trigger delay elapses. The output from the c.c.d. is passed via a track-and-hold amplifier to an 8-bit a-to-d converter, which reads out the signal to the oscilloscope's main memory. This read-out can be done at a lower speed (known as fast-in slow-out, or fiso), allowing low-cost a-to-d converters and digital memories to be used. The memory capacity has – alongside the sample rate and bit sensitivity – traditionally been one of the major specifications of a digital storage oscilloscope. One of the disadvantages of a c.c.d-based oscilloscope is this relatively low record length, and the PM3350's memory depth indeed compares favourably with oscilloscopes costing much more. Each of the PM3350's two input channels is backed by 512 samples of memory, which means that, when working at the full 100-Msamples/s speed on both input channels, a waveform is described by at least 512 points. However, the effective memory size is larger than this, since the oscilloscope uses a specially-designed asic to make linear interpolations between adjacent points (dot-join mode), which doubles the number of points on the screen to 1024. This holds for time-base speeds from 0.5 s/division down to 2 ms/division. At lower timebase speeds (5ms/division down to 50 s/division), the a-d converter is fast enough to sample the waveform in real time. Here, the c.c.d. acts as a sample/hold circuit, which increases the memory to 2ksamples for dual-channel use, or 4 ksamples for a single channel.

Another general disadvantage of c.c.d-based oscilloscopes is the reduced resolution that can result from effects of transfer efficiency and leakage current within the c.c.d. Clever design, however, eliminates this drawback from the PM3350 (see panel 'Circuits compensate for transfer efficiency and leakage current effects'), and keeps the oscilloscope's effective resolution to as high as 7.5 bits. This ensures that the waveform on the screen is the same as that at the input.

DISPLAYS AND CURSORS

A common misconception about digital storage oscilloscopes is that they are less accurate than their analogue counterparts. This may be true in theory – the vertical resolution of a d.s.o. is, after all, usually limited to 8 or 10 bits, compared with an 'infinite' vertical resolution of an analogue oscilloscope. However, this is far outweighed by the accuracy of automatic measurements made using cursors, based on the d.s.o. timebase's crystal oscillator.

So when choosing a d.s.o. you should look closely at the cursor controls and readouts that are available, since these differ widely between oscilloscopes. One of the great advantages of a d.s.o. is that it can remove the need for separate instruments such as counter/timers and multimeters. Only one instrument has to be set up and operated, and the cursors clearly show those parts of the waveform that are to be measured.

The cursor facilities can show v, t, 1/t, peak-to-peak voltage levels, frequency, and rise time measurements on the screen. The oscilloscope can make all of these measurements while comparing a captured signal against a reference frequency, and displaying up to four waveforms on the screen simultaneously (Fig.1). A second set of cursors are automatically positioned during frequency, rise-time and peak-to-peak measurements to show clearly the exact points from which the measurements are being made.

These cursor controls are operated using 'soft' keys, which are also used to simplify the connection of peripheral equipment to the oscilloscope. The user can easily select (Fig.2) the analogue plot speed between 20 ms/sample point and 2 s/sample point, and the penlift level (active high or active low).

PM3350 ARCHITECTURE

A set of gate arrays in the PM3350 integrates the major sections of the oscilloscope, and keeps the chip count and manufacturing costs low. Four gate arrays mop up the majority of the display and timebase logic, and control circuits (see figure). The entire microcontroller logic, with serial bus interface and calibration unit, is contained on only 40 sq. cm. of p.c.b.

Firmware for the oscilloscope is stored on a 128-kbit eprom, and front-panel settings in 32 Kbytes of battery-backed r.a.m. Two timers update the oscilloscope's time-dependent functions, and there is a software 'watchdog' that resets the 68008 microcontroller in the event of a fault or a time-out. Thanks to this microcontroller, the PM3550 incorporates several 'intelligent' features. It can for example detect what type of probe is connected to the attenuator inputs, whether the front-panel potentiometers are at their calibrated positions, whether the IEEE-488 option has been installed, whether the timebase has been triggered. It also implements functions such as zoom and centre, and calculations such as for frequency, rise time, and peak-to-peak voltage.

The microcontroller communicates with the major circuit sections through the Philips I^2C bus, a serial bus which consists of only three wires (clock, data, and ground). At switch-on, the program initializes the oscilloscope hardware, and sets the 140-segment l.c.d. During use, the microcontroller scans the keyboard, and detects changes in potentiometer controls and probes, updating the l.c.d. accordingly. The front-panel settings of vertical display, trigger source and timebase mode are transmitted by the oscilloscope's microcontroller across to the display logic and control circuit. The microcontroller is automatically updated with the current positions of the channel switches, trigger switches and timebase selector.

The PM3350 uses an advanced domed-mesh p.d.a. (post-deflection acceleration) c.r.t. This tube has internal magnetic correction to automatically correct for small tolerances in the gun, which would otherwise result in astigmatism in the display. The trace itself has spot centring to within ±2 mm, and orthogonality (within 30'), both of which give a picture quality which is significantly better than previous low-cost 50+MHz oscilloscopes.

CIRCUITS COMPENSATE FOR TRANSFER EFFICIENCY AND LEAKAGE CURRENT EFFECTS.

The 512-cell c.c.d. in each channel is made up of two parallel sections, each 256 cells long. An incoming 100Msample/s analogue waveform is split into two 50Msample/s streams containing odd and even samples respectively. The two streams are passed along the cells of the c.c.d, which acts as an analogue shift register, sampling and temporarily storing the incoming analogue wave.

Unless measures are taken to prevent it, leakage current in a c.c.d. can reduce the resolution of d.s.os by causing the individual cells of a c.c.d. to lose electrons as the charge is passed on. Since this charge represents the voltage value that will be shown on the screen, this reduced resolution would be visible on an oscilloscope as a downward slope in the signal from left to right.

A simple circuit in the PM3350 compensates for the effects both of leakage current and transfer efficiency (which also results in electrons being lost as they are passed from one end of the memory to the other). The signals coming from the odd and even sections of the c.c.d. are subtracted (to cancel out the signal components), the result divided by two, and then inverted. The resulting signal gives the losses in a single section section of the c.c.d.. This signal is added to the original odd and even signals to give the corrected measurements.

All of these factors combine to allow the PM3350 to benefit from the low cost of c.c.ds, but without the reduction in resolution which they can bring.

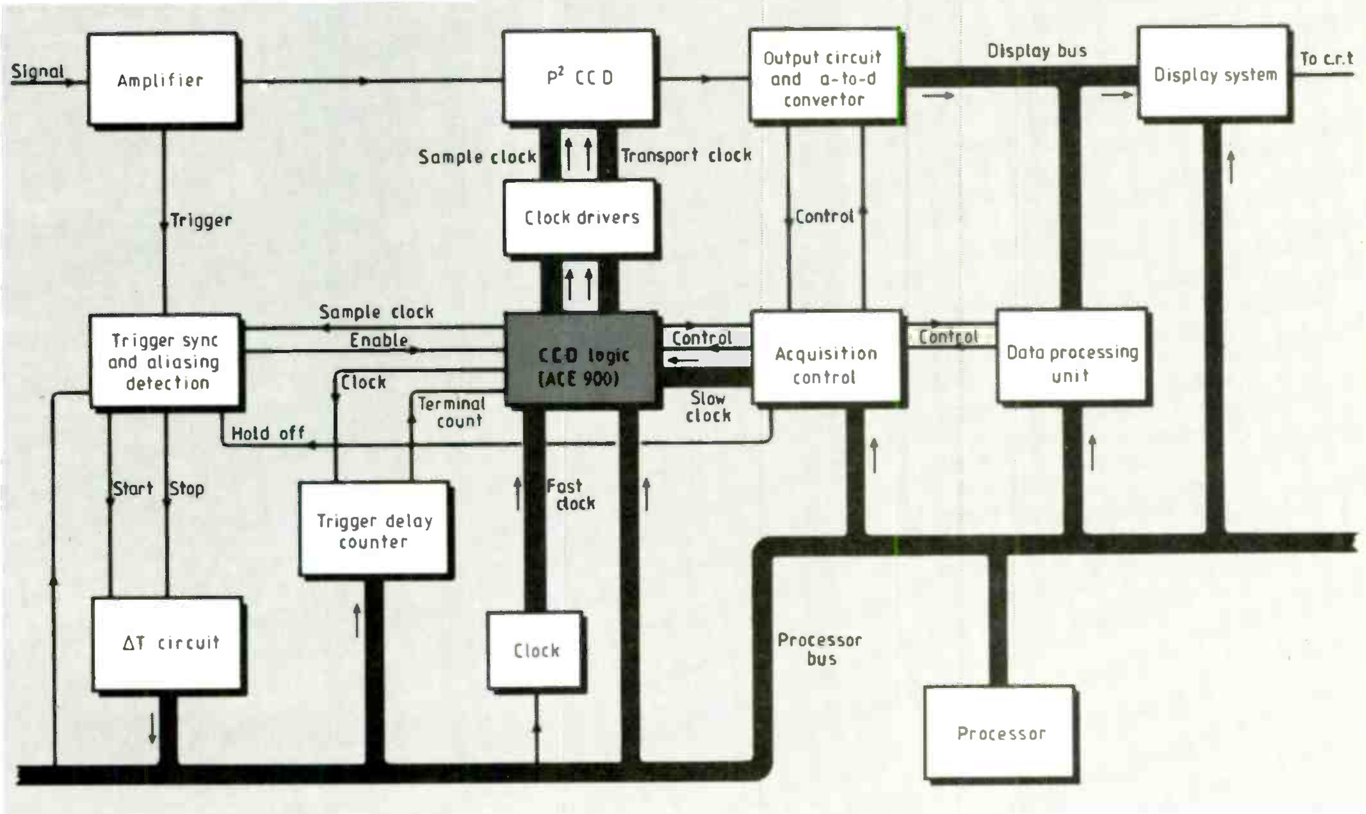
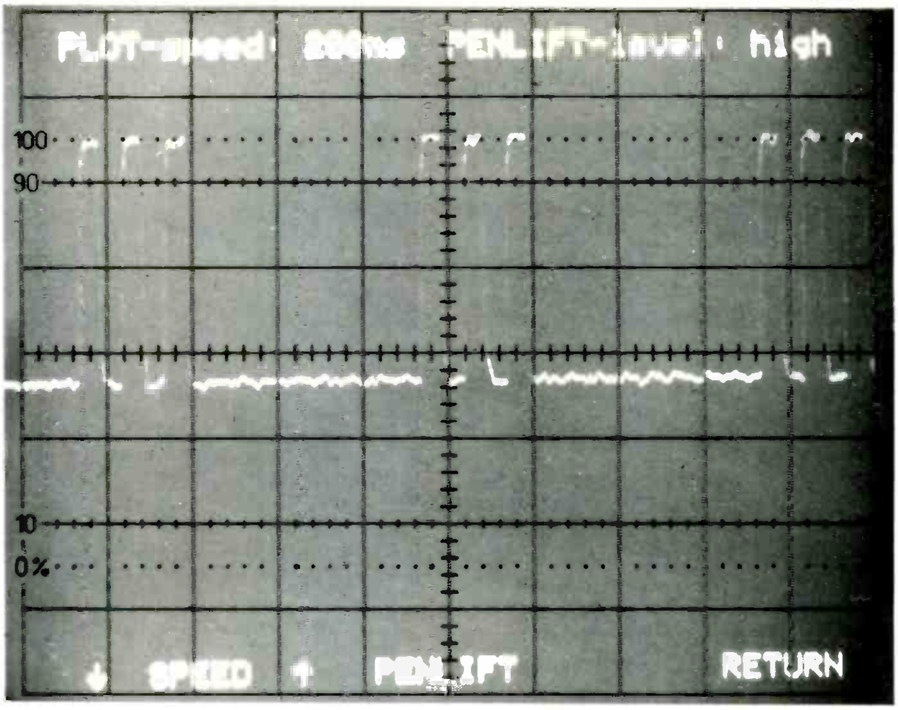


Fig.2. Obtaining hard copy from the PM3350 is simple using an X-Y recorder output. The plot speed and penlift level can be varied to make the oscilloscope compatible with any type of recorder.



The keys can also set the IEEE-488 addressing and mode (if the IEEE-488 option is included). The instrument can be set to talk and/or listen, and the address can be set between 0 and 30. The IEEE-488 option allows the scope to connect to any X-Y plotter that accepts HPGL or Philip T&M protocols – again selected using the soft keys. A screen plot can be taken by pressing a single button, thus eliminating the need to photograph the screen.

The PM3350's oscilloscope controls and the relevant displays are split into two separate areas (Fig.3), with the screen and its cursor controls on the left of the instrument. To the right of the screen are the rest of the oscilloscope controls. These settings are shown on a 140-segment l.c.d. display.

EASE OF USE

Many d.s.os are far from easy to work with and oscilloscope manufacturers have paid increasing attention to the problem over the last few years. The PM3350 is one of the easiest to operate. To display a signal, for example, a user just connects up the probes, and presses the 'autoset' button. This looks at the incoming waveform, initiates the software, and autoranges through the oscilloscope's settings, setting the attenuators and the timebase to that the input signals appear on the screen within a few seconds.

All keys on the front unit control several related functions, accessed by sequentially pressing that key. For example, the a.c./d.c. button toggles between a.c. coupling and d.c. coupling. This feature reduces the number of keys on the front unit, and simplifies operation.

USING THE INSTRUMENT

Oscilloscopes are normally used in one of two ways: to compare similar waveforms (such as in production testing and servicing), or to capture unpredictable data (such as in troubleshooting and debugging).

The basic demand for production testing and maintenance is programmability, either of the oscilloscope itself, or when it is connected to a computer. The PM3350's autoset button is useful here, too, since it makes the PM3350 particularly convenient for repetitive tests, where users often want to look at the same signal path in different sections of a piece of equipment. Oscilloscopes such as the PM3350 also allow complex routines to be performed without touching the front panel – in the case of the PM3350 across an optional IEEE-488 interface – which makes a dramatic difference to productivity.

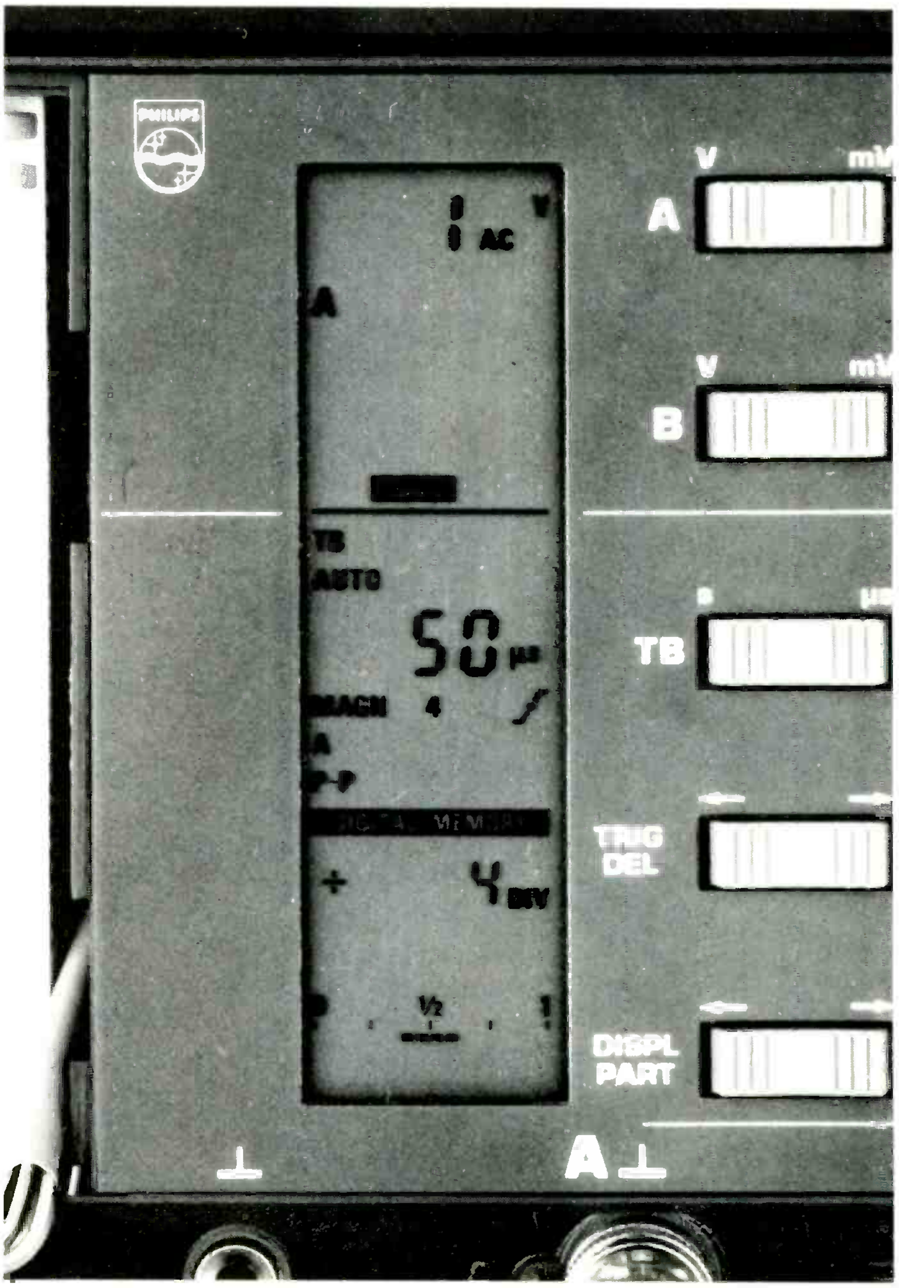


Fig.3. The PM3350 is divided into two sections: the screen and cursor controls, and a 140-segment l.c.d. which shows the settings of the rest of the scope's controls.

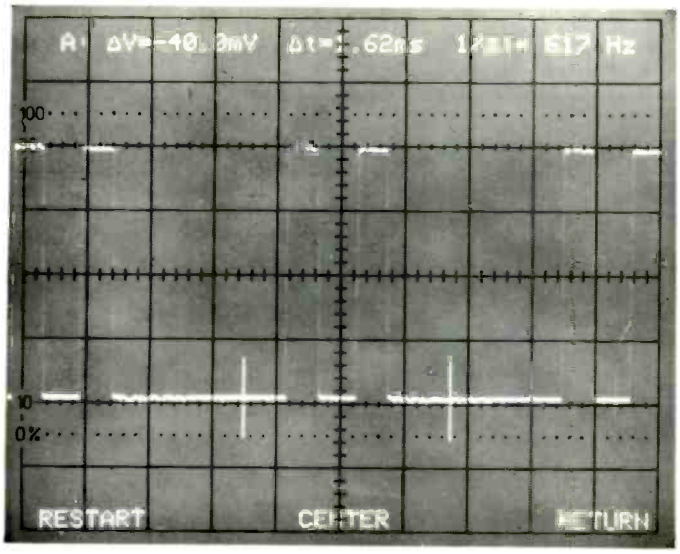


Fig.4. Pressing the 'zoom' (Restart) key automatically calculates the delay and the timebase settings, and....

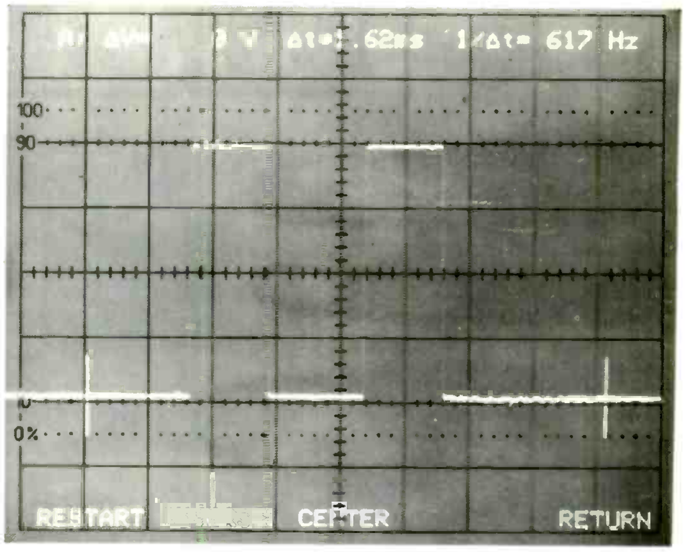


Fig.4b. ....draws an expanded trace (together with the relevant cursor positions) on the screen.

Debugging and troubleshooting have quite different requirements, since the oscilloscope must look for rogue signals such as race conditions and other intermittent faults. These signals need a high single-shot bandwidth, versatile triggering, extensive displays, and powerful cursor measurements.

Tracking down rogue signals during prototyping is particularly difficult because they occur infrequently or at random intervals, and individual transients usually have widely different amplitudes and periods. The bandwidth and voltage range are critical here. Also useful is the 'zoom' key (Fig.4). When pressed, the key automatically calculates the delay and the timebase settings, and draws an expanded trace (together with the relevant cursor positions) on the screen. This feature can be performed repeatedly to give (together with the 'centre' key) increasing detail down to the minimum resolution of the scope. Rather than simply magnifying existing data (which would yield no further information), use of the key re-acquires – at a higher sample rate, and therefore at a higher resolution – that part of the signal which falls between the cursors.

Finally on this topic, a specification that is often ignored is the triggering speed. Most oscilloscopes have a trigger speed equal to the maximum signal bandwidth. However, an oscilloscope *should* trigger at higher speeds, so that it doesn't miss fast pulses at a low repetition rate (where fast, stable triggering is essential). Correspondingly, the PM3350 has a full 100-MHz trigger bandwidth.

TESTING, SERVICE AND MAINTENANCE

Automatic test setups are highly significant for production testing and maintenance. The PM3350 has an optional IEEE-488 interface that allows it to be integrated in test systems, or connected directly to automated calibration systems. The link allows full remote control, including cursors and autoset function.

Checks can be carried out in use. A built-in, automatic checking procedure can be selected by the user, providing a ten-step routine that checks out the oscilloscope in about 30 seconds. The sequence tests the d.c.nd a.c. input coupling, alternated, chopped and added display, timebase magnifier, X deflection, triggering with both d.c. and peak-to-peak triggering.

PRODUCTION TECHNIQUES

Replacing the conventional assembled metal frame of oscilloscopes with a plastics carcase has led to considerable reduction in assembly costs. Philips went to considerable trouble to find the 'right' plastics and arrived at an 'alloy' of polycarbonate and ABS. This non-toxic material is non-inflammable and self extinguishing. Strong and rigid and yet lightweight, the material retains its properties down to very low temperatures. Integrated into the chassis are all the mountings for the p.c.bs and assemblies which slot and lock into place without screws. The case had already been made for other Philips oscilloscopes, so for this model there was no further tooling cost.

All modules are individually tested before assembly. Semi-automatic processor-controlled test and adjustment stations are to become fully automated. Final testing involves the complete instrument and consists mainly of such simple tasks as c.r.t. adjustment. All instruments are subjected to a burn-in process and are then retested. Further 'lifetime' tests are carried out on a randomly selected sample of instruments. Modular construction aids servicing. P.c. boards can be hinged out for access to both sides and they are connected by plug-in flat cable wiring which makes them easy to change.

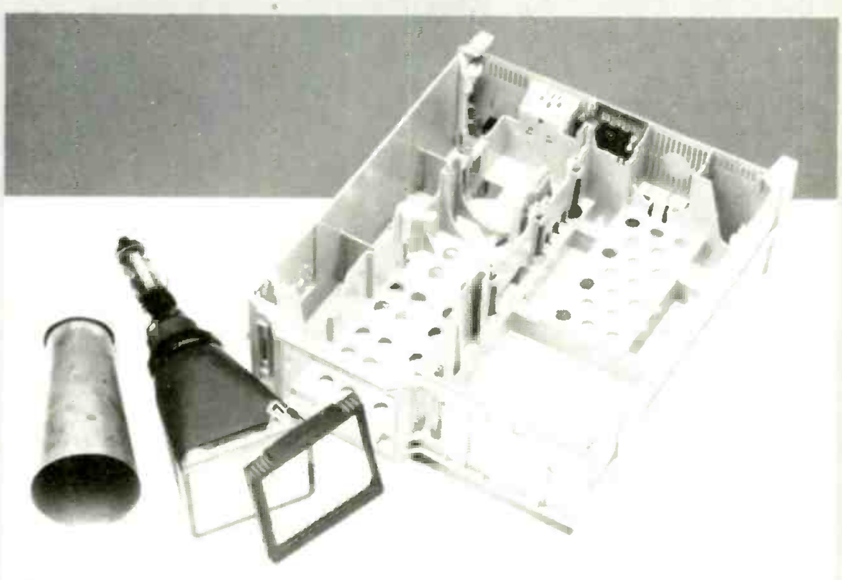
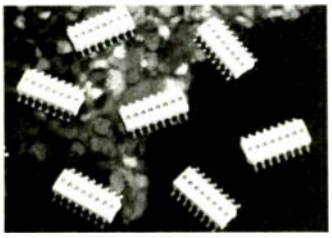


Fig.6. The PM3350's chassis is actually a one-piece injection-moulded frame made from a plastic 'alloy' of polycarbonate and ABS. The frame incorporates all 'click-fit' mountings and stops for p.c.bs and assemblies.

NEW PRODUCTS

Programmable links

Equipment often needs to be set up to interface with other items. This is usually a one-time operation, like the setting of the data rate on a printer, or the gain of an amplifier. Hitherto, such set-ups have been made with dil switches. Now it is possible to use surface-mounted shunts in packages of eight, which allow the selection of options simply by breaking the unwanted links.



Compatibility with the reflow methods of soldering makes the Greyhill 92 shunts easy to fit to surface-mounted p.c.bs. They offer high insulation resistance and can carry 1A with a maximum temperature rise of 20°C. Highland Electronics Ltd, Albert Drive, Burgess Hill, West Sussex RH15 9TN. Tel: 04446 54021.

Free cad software

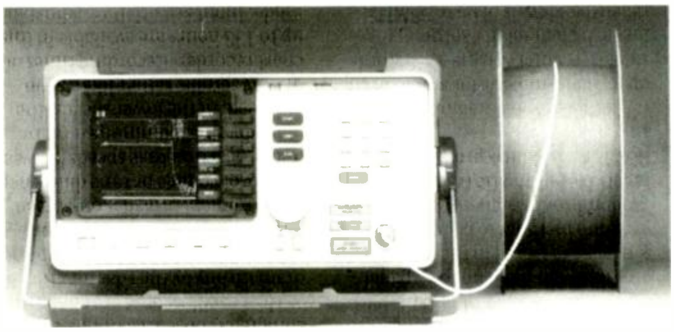
Software for a general-purpose cad system which runs on an IBM PC is being offered free by Pafec, a Nottingham software house which claims to be Europe's largest independent producer of cad systems.

PC DOGS, Personal Computer Drawing Office Graphics System, previously sold for £3000. It has all the functions of a two-dimensional drawing package and can cope with all but the largest drawings. According to Ian McKenzie, a Pafec director: "DOGS is ideal for the first-time cad user. The PC-based product can supplement a company's main cad system and also act as an introduction to the benefits of a more advanced installation."

Free copies of the software are available from Pafec or their agents. A small charge is made to cover the cost of the discs, of which there are fourteen, including screen and plotter drivers.

The manual is the equivalent of about 400 printed pages but it can be consulted on screen while using the system. An installation guide is included in the package.

Pafec's generosity has another motive: "We know from experience that many cad users who start with a PC-based package later find the need to upgrade to a more advanced system. We have those systems and that is where our growth lies," said Ian McKenzie. Pafec Ltd, Strelley Hall, Nottingham NG8 6PE. Tel: 0602 292291.



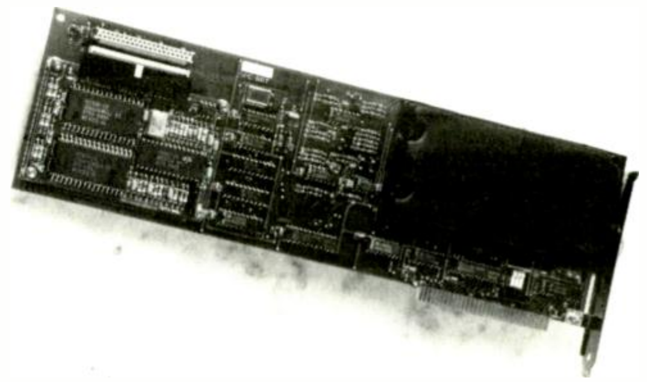
Tester for optical fibres

Considerable saving in time is claimed for the Hewlett Packard optical time-domain reflectometer. Testing of optical fibres is said to be more thorough and up to 150 times faster through the use of a special data-correlation technique, which increases the dynamic range of the HP8145A instrument to more than 28dB at a wavelength of 1300nm. The reflectometer has a distance range of 200km and can pinpoint a fault to within 1m with a dynamic-level resolution of 0.01dB.

For testing in the field, the instrument is battery powered and includes a plug-in, non-volatile memory module which can store over 100 traces complete with the related measurement information.

On the bench it is used for testing fibres and cables during production. Previous traces can be recalled for comparison with the current sample.

The instrument is easy to use, with keys that vary their functions according to the on-screen options present at the time. The keys can be programmed individually by the user and the instrument offers full HPIB communications. Alternative laser modules provide wavelengths of 1300nm and 1550nm and the reflectometer can be linked by four different standard connectors. Hewlett Packard Ltd, Eskdale Road, Winnersh Triangle, Wokingham, Berks RG11 5dZ. Tel: 0734 696622.



Fax modem for PCs

Facsimile messages can be sent from and received by an IBM PC-compatible computer by using a plug-in modem from Dowty. Text and graphics files can be transmitted without the need to print or scan them, saving time and improving the quality of the received message. In addition, features such as autodial, auto-answer, delayed transmission and automatic message distribution are all included.

A modem card, MicroFax, is combined with a software package to allow a PC to exchange fax messages with any Group 3 fax machine or with other computers with the same facilities. The modem is claimed to be the first of its type to win BATB approval.

Fax messages are generated by the software from an existing file produced on any software so that spreadsheets, word-processor files or images produced by graphic programs can be transmitted. The modem can operate in "background" mode, allowing incoming messages to be received and stored on disc while the computer is being used for other purposes. These can be viewed on screen and printed by a suitable graphics printer, if required.

Any IBM-compatible PC can be used to run the modem as long as a half-height expansion slot is available. Hard discs make the operation faster and easier and provide the large capacity to store messages. Dowty Information Systems Ltd, Steebek House, Newbury Business Park, London Road, Newbury, Berks RG13 2PZ. Tel: 0635 33009.

Safe developer for p.c.bs

Chemicals for developing positive-resist printed circuit boards have been made safer to use and easy to apply. Ready-mixed developer solutions are available in a sealed container with a built-in sponge which dispenses the correct amount of chemical to the board. An additional advantage is the possibility of developing a small area on a board, perhaps a modification added later.

Non-toxic chemicals, without any sodium hydroxide, are provided in the Seno applicator, which has a shelf life of two years and enough developer for about 70 boards of Eurocard size. Because of the safe chemicals, no special precautions are needed when disposing of an exhausted applicator. Mega Electronics Ltd, 9 Radwinter Road, Saffron Walden, Essex CB11 3HU. Tel: 0779 21918.

Data acquisition made easy

Full advantage of the windows system is taken in the Labtech Acquire PC-compatible software which has been specifically designed to be easy to use. There are no commands to memorize, since the system is menu-driven and it is claimed that the software can be put to good use after a few minutes of familiarization.

One menu is used to configure the input routines, specifying start-up procedures, data rate, duration, scales, limits and other parameters for display, storage and output.

Up to four channels of analogue data can be measured with one additional digital channel. Maximum data sampling rate is 50samples/s on each channel. Any signal-generating equipment with outputs that can be accepted by the computer's interfaces can provide the incoming data. Acquired data is displayed in real time in up to four windows. The colour of each signal trace can be selected so that multiple traces can be displayed and compared in a single window. Data can be stored while it is displayed along with elapsed-time records.

Additional software enables the data to be further manipulated in such spreadsheet analyses programs as Lotus 1-2-3.

Similar, superior, facilities are available in Labtech Notebook. The two programs share many features, so a user of Acquire can upgrade to Notebook while retaining the stored data and configurations. Available through Adept Scientific Micro Systems Ltd, 3 Letchworth Business Centre, Avenue One, Letchworth, Herts SG6 2HB. Tel: 0462 675352.

NEW PRODUCTS

VME workstation with risc processor

Although the main processor in the Torch VME32QX workstation is a 68020, it also has an OpenChip* risc-based controller to provide high-speed direct memory access. Other major components on the double Eurocard single board are a 68881 maths coprocessor and a 68551 paged memory management unit.

High speed is ensured throughout this Unix-based computer by the very high clock rate of 16.7 or 20MHz and 4Mbyte or on-board memory with the capacity to expand to 16Mbyte. Communication is also accented with a high-speed serial interface for peripherals, VMEbus, and Ethernet connections, and drivers for X.29 and X.25 communications.

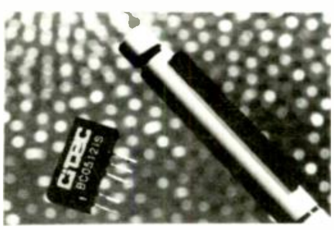
Full colour video facilities are incorporated. Screen resolution is up to 1024 by 768pels and each pel can be 4bits deep, providing a wide range of colours.

Icons and windows are used to operate the menu-driven system which allows easy access to an extensive range of Unix applications from Torch or from other suppliers. Strict adherence to standards ensures compatibility with the software for a number of other manufacturers' systems. Torch Computers Ltd, Abberley House, Great Shelford, Cambridge CB2 5LQ. Tel: 0223 841000.

* OpenChip is designed by Torch for their own use. High-speed memory access is provided by using application-specific instructions. This is the first use for the device. Other manufacturers have expressed interest in using the chip.

Miniature d.c. converters

Local, balanced power-supply voltages for analogue circuitry on such equipment as serial link interfaces are made easier by the use of miniature d.c. to d.c. converters from BICC-Citec. Auxiliary power



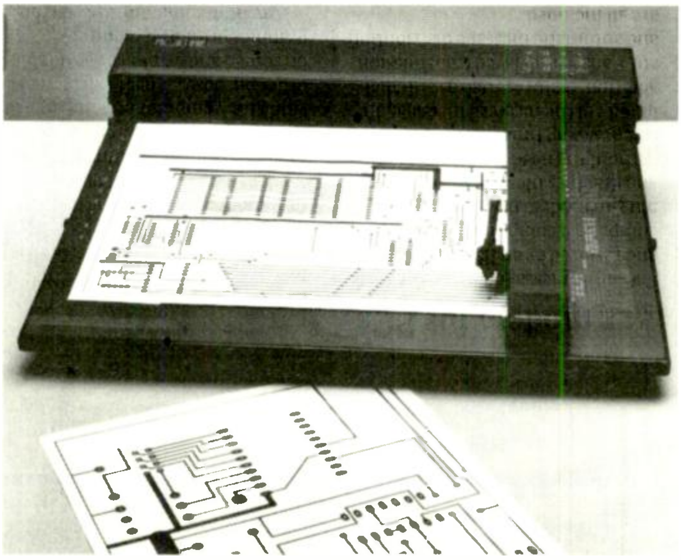
rails can be supplied by substituting a converter for the multiple-output switch used in such interfaces. Fully encapsulated and with no need for heatsinks, the units are rated at one watt and provide output voltages of ±5V, ±12V or ±15V. BICC-Citec Ltd, Westmead, Swindon, Wilts SN5 7YT. Tel: 0793 487301.

Low-cost p.c.b. designer

Many features normally associated with more expensive systems are available on the Lintrack PC printed-circuit design package for £160. IBM PC or compatible computers can be used to run the software which allows component pads and tracks to be laid on a 0.25mm grid on double-sided boards up to 480mm by 500mm.

Eight pad sizes are provided, as are eight track widths. Component layouts are selected from a pre-defined library; any outline designed by the user can be added to the library. Editing facilities allow any section of a circuit to be relocated, rotated, duplicated or erased. Either or both sides of the board can be viewed on the screen at four levels of magnification.

Output is to any HPGL compatible plotter at 1, 2, 4 or 8 times the finished board size. Further details from Linear Graphics Ltd, 28 Purdeys Way, Rochford, Essex SS4 1NE. Tel: 0702 541663.



Analogue-to-digital oscilloscope adaptor

Any single trace analogue oscilloscope can be converted into a two-channel digital storage instrument by using the DSA524 adaptor from Thurlby. It is connected to the oscilloscope by a single cable and the analogue instrument can have a bandwidth as low as 5MHz. Every front panel control on the adaptor is digitally programmable and up to 50 panel settings are stored in the internal program memory to be recalled randomly or in sequence for repetitive automatic testing. An RS232 serial link is provided. GPIB is an option.

The adaptor has a sampling rate of up to 20Msamples/s for single-event signals; memory size is 4096 words for each channel. It captures repetitive signals of up to 35MHz, using an equivalent-time sampling rate of up to 2Gsamples/s.

Non-volatile memory is used to store up to 16 waveforms for reference and comparison.

Mathematical algorithms enables digital interpolation to reconstruct a waveform from a minimum number of samples. For example, a near-perfect sine wave can be reconstructed from only four samples in a cycle. This gives the instrument a single-event bandwidth of 5MHz, much higher than most other instruments that sample at 20Msamples/s.

Digital summation averaging is provided for up to 256 recordings. This improves the signal/noise ratio for repetitive waves and allows the recovery of signals that are completely obscured by noise.

Host oscilloscopes are changed dramatically by the adaptor. Text and graphics are used to help set up and operate the instrument. Cursor measurement provides on-screen display of voltage or time differences. Reciprocal timebase speeds between 50ns/div and 200minutes/div are provided. At the lower speeds, the display scrolls, rather like a strip chart recorder. Recording times of up to 133 hours are available in this mode. Input sensitivity is adjustable between 2mV/div and 10V/div. Autoranging can be selected on either or both channels and an autoset system can select an appropriate timebase.

Hard copy can be made on a dot-matrix printer or a variety of plotters.

Small and lightweight the DSA524 costs £585 (+tax) in the UK. Thurlby Electronics Ltd, New Road, St. Ives, Huntingdon, Cambs PE17 4BG. Tel: 0480 63570.

Optical fibre cleaver

High accuracy is needed when cutting optical fibres as there can be much signal attenuation if the cut produces any reflections. With the Fujikura CT-03 cleaver, high-precision cuts are made purely mechanically: human error has been eliminated and no special training is needed for the operator.

A single blade can produce up to 24,000 clefts cut to within 1° from the rectangular. Single and multi-mode 125μm fibres can be handled. Centronic Sales Ltd, 275 King Henry's Drive, New Addington, Croydon CR9 0BG. Tel: 0689 47021.

Optical transmission of video signals

Transmission modules for sending signals through optical fibres at the 860nm wavelength have been developed by Siemens. They are thought to be of particular use in transmitting video signals from the remote tv cameras used in surveillance and road-traffic monitoring.

Transmitters and receivers are encapsulated in plastics packages and use 2.4mm pitch dil connectors

for electrical connections and either 2.5mm DIN or 3.175 SMA plugs for optical links.

Maximum transmission distance is 2km when used with 50μm graded-index fibre. Attenuation over this distance is less than 9dB. Repeaters can be used to extend the range.

All modules operate from a 5V supply and have a signal bandwidth of 7MHz. Output voltage is 1V peak-to-peak into 75Ω and can be connected directly to a colour monitor.

Siemens Ltd, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. Tel: 0932 785691.

NEW PRODUCTS

Miniature kilovolt power supply

Output from the K20/6 power supply, which operates from a 12V battery, is variable between zero and 20kV. Current consumption is less than 0.25A at full output. Output voltage is controlled by an external potentiometer.

Switching techniques are used to achieve a high output impedance of 100MΩ. This makes it suitable for insulation testing, electrostatic spraying and capacitor charging. A stabilized version for c.r.t. applications is planned. Small size is a feature of the unit, with the largest dimension being 115mm. Applied Kilovolts, 54 Benett Drive, Hove, East Sussex, BN3 6UQ. Tel: 0273 507973.

Highly stable oscillator

Temperature-compensated oscillators have been designed for high-precision military and professional equipment. STC claim a frequency stability of ±0.3p.p.m. in the temperature range −20°C to +70°C for the SQO3500 family of oscillators in a range from 2.5MHz to 20MHz.

Performance of the device can be tailored for specific requirements and there is a wide choice of output options, including t.t.l, c-mos, h.c-mos and clipped sinewaves. STC Components, Edinburgh Way, Harlow, Essex CM20 2DE. Tel 0279 26811.

IEEE-488 for PS/2

The first IEEE-488 (GPIB) interface for the new IBM personal computer family is the proud claim of Ziatech Corporation. It can control up to 15 remote instruments and is complemented by a range of software. INSTALL.488 allows existing application software for other systems to be run on the interface. Linkable device driver software has the advantage of addressing the interface directly, bypassing the computer's operating system, and is intended for high-speed applications.

Software configuration of the interface is provided by the Adaptor Description File which eliminates the need for jumpers and dip switches on the adaptor.

Hardware additions to the interface board include a watchdog timer, which regularly interrogates the devices connected and can transmit a warning if there no response. Available through Data Translation Ltd, Mulberry Business Park, Wokingham, Berks RG11 2QJ. Tel: 0734 793838.

Global positioning receiver

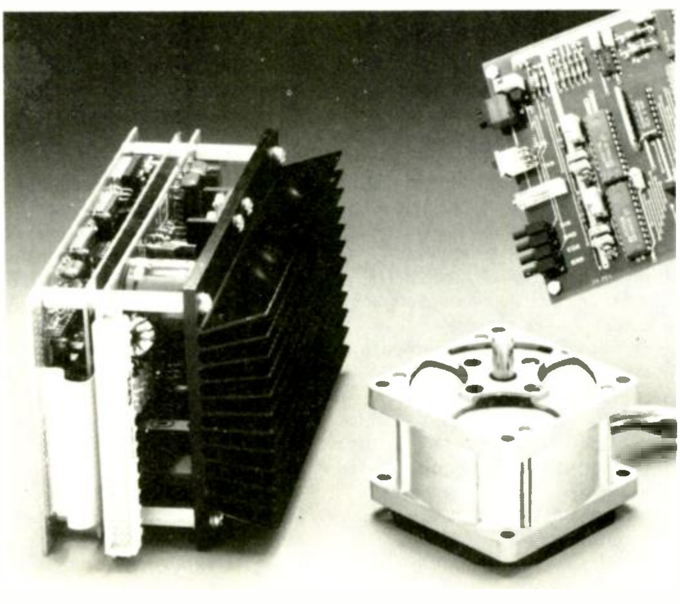
You can tell where you are to within 25m anywhere on the globe if you can decode the signals from the Navstar global positioning system (GPS) satellites. Navcore I is a receiver from Rockwell Collins that does decode the signals and can provide time and frequency standards as well as navigational information.

Coarse Aquisition codes are received so no special licencing is required to use the system. Even higher accuracy is available, through scrambled codes, to the US military and some of their favoured friends.

Applications include mapping, surveying and the setting and updating of atomic and quartz clocks. An improvement of some ten times is claimed to be achieved when compared with other standard methods. Available through the Steatite Group, 2 The Square, Broad Street, Birmingham B15 1AP. Tel: 021 643 6888.

Accurate motion control

Highly accurate positioning is claimed for the Portescap disc-magnet stepper motor with its associated control system. The two-phase motor has 200 full steps in a revolution, each of which can be further divided into up to 64 microsteps, giving a resolution of 12,800 positions or 0.028°. Error due to the motor is typically 0.045°, decreasing to 0.018° on a full step with both phases energized. The disc-magnet motor offers a linear torque: current ratio, low noise and smooth operation for speeds as low as a single revolution in a second. Other parts of the system are a pulse-width modulated, two-channel current source, a translator to convert motion commands into motor signals, and damping circuitry which suppresses mechanical oscillation within 5ms. Portescap UK Ltd, 55 Cobham Road, Wimborne, Dorset BH21 7RB. Tel: 0202 861500.



Higher resolution graphics

Another step on the way to even higher graphics resolution is provided by the Xcellerator 1600 range of 20in (508mm) display systems. Up to 1600 by 1200pels can be displayed and the system can interface with PC AT and PS/2 computer systems.

At the heart of the Xcellerator is the Texas Instruments' 34010 graphic system processor which is used to achieve high-speed continuous vector drawings with over 80,000vectors/s.

In its highest resolution, the display can select 16 colours from a palette of 4096. Mode 2 give a lower resolution 1024 by 768pels, but has 256 colours available from a possible 16.7 million.

Applications are thought to be found particularly in the cad/cam area, colour electronic publishing and graphic arts. With these particular applications in mind, the system is provided with 1Mbyte of display ram which can be expanded up to 8Mbyte.

To take full advantage of the increased resolution, software drivers have been made available to run Autocad, Microsoft Windows and DGIS, direct graphics integrated standard. Other links are being developed. Cambridge Computer Graphics Ltd, Convent Drive, Waterbeach, Cambridge CB5 9QT. Tel: 0223 863311.

High-voltage capacitor chargers

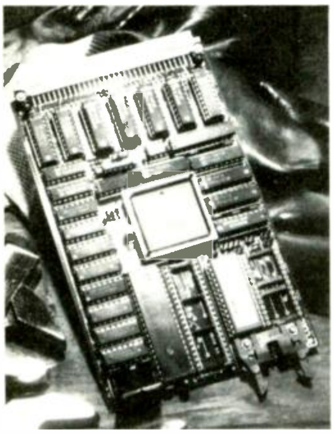
The 5000 series of capacitor chargers, which is suitable for use with pulsed lasers and in capacitor bank charging, uses a constant-power system with a switch-mode power supply. Eight models cover a voltage range from 1kV to 50kV, all with the same charging rate of 200 joule/s.

Particular attention has been paid by Hartley to safety and an emergency push-button activates a dumpswitch, which can also be triggered by external safety interlocks on the high-voltage equipment. Each charger is fitted with a display that shows the status of the charge – standby, charging or fully charged – and also the position of the safety dump along with the interlock status and output polarity. An output high-voltage meter indicates the presence of a voltage, even with the mains supply switched off. The chargers can be operated remotely if required. Hartley Measurements Ltd, 4 Bear Court, Daneshill East, Basingstoke, Hants RG24 0QT. Tel: 0256 56695.

NEW PRODUCTS

Industrial PC on STEbus

Software written for a standard PC can be run on a computer designed specifically for industrial use. By dividing the functions of a PC between four single Eurocards, and by incorporating a number of custom i.cs, Arcom has produced a flexible system which only needs to use the cards required. Many target systems might require the processor and i/o cards but have no need for graphic interfaces or disc controller. Compatibility is made possible by the similarity of the STEbus to the IBM PC's internal structure; both offer 8-bit data buses and 1Mbyte of addressable memory. This allows exact emulation of the PC's functions with all peripherals having the same addresses, so standard PC software

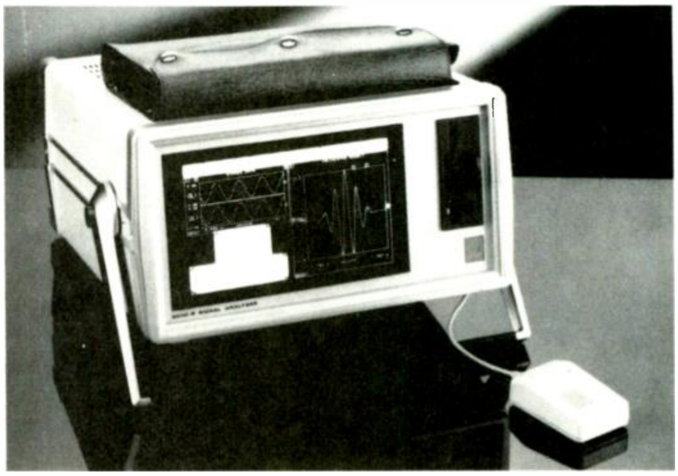


can be run without modification. Thus all PC languages and utilities can be used, with the additional advantage of having STEbus i/o interfaces already wired in. Expansion for up to 20 i/o boards is possible with the STE backplane. Arcom Control Systems Ltd, Unit 8 Clifton Road, Cambridge CB1 4WH. Tel: 0223 411200.

Breadboard card for PS/2

Protoyping circuits for use with the new series of IBM computers is possible with a p.c.b. from Brain Boxes that conforms to the Micro Channel Architecture (m.c.a.) backplane bus. 132 gold-plated edge connector fingers are linked to a matrix of plated-through holes on a 0.1in grid. In addition to the m.c.a. connector, the board includes a video extension connector.

As the board is completely blank, it could be used for anything, but some suggested applications are digital i/o, modems, memory extensions (up to 16Mbyte), network connections and co-processor boards. Brain Boxes, Unit 3G, Wavertree Technology Park, Wavertree Boulevard South, Liverpool L7 9PF. Tel: 051 220 2500.

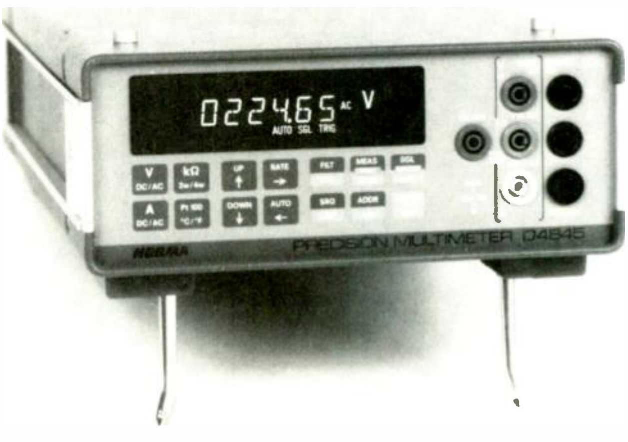


Portable signal analyser

No features have been left out by Thorn when converting the 2570 waveform analyser to a portable version. Indeed, it has been enhanced by the addition of spectrum analysis capabilities, signal filtering, and GPIB, RS232 and parallel printer interfaces.

Other features include a variety of input channels, a number of triggering options and programmable controls.

Operation of the instrument is through windowed menu options on the large electroluminescent screen, which are selected through the use of a mouse and remove the need for any front-panel controls. Sequences of operations can be programmed in by selecting the options and the setups can be stored on the built-in floppy disc, which is also used for storing recorded and processed data and for signal-processing software. A software package includes programs for mathematical manipulation of the signals and for such processing as Fourier analysis and wave smoothing. PC-DOS format is used, so it is easy to transfer data and programs to and from a computer. Thorn EMI Datatech Ltd, Spur Road, Feltham, Middlesex TW14 0TD. Tel: 01-890 1477.



Systems multimeter reads r.m.s

Full systems integration is possible with the Cropico Norma precision multimeter, D4845; it includes a GPIB interface. Different display modes, 3½, 4½ or 5½ digits, can be selected according to the precision required for a particular application. Basic d.c. error is 0.02% and the 2A range has a resolution of $10\mu A$. Voltage ranges are from 200mV to 1kV and the resistance ranges from 200Ω to 20MΩ can accommodate four-terminal devices. There is also the facility to use a Pt100 probe to measure temperature.

All alternating ranges give true r.m.s. readings and so can accurately measure distorted waveforms. The meter can recalibrate itself in the field and thus retain its accuracy when the environment changes. Measurement is simplified by the inclusion of mathematical functions, offsets and different triggering modes. Cropico Ltd, Hampton Road, Croydon CR9 2RU. Tel: 01-684 4025.

High-voltage alkaline batteries

Two additions to the range of Duracell alkaline batteries produce 15V and 22.5V. Respectively they are the MN154 with a nominal capacity of 50mAh and the MN122 with 80mAh. They are intended for use with such equipment as cameras and portable test instruments, though the 22.5V version is likely to find uses in some other applications, particularly radio transmitters. Duracell Technical Division, Church Road, Lowfield Heath, Crawley, West Sussex RH11 0PQ. Tel: 0293 517527.

Real-time clock for PCs

Standard timekeeping on IBM PCs requires a number of components which can all be replaced by a single device, the DS1287 from Dallas Semiconductor. Pin-compatible with Motorola's MC146818, the Dallas clock eliminates the extra components by incorporating a lithium power source. It is claimed to consume 300 times less power than its rival and lasts for more than 13 years in the absence of system power. The life of the device is much longer, since battery consumption is negligible so long as the computer is powered.

The 24-pin device has 50bytes of ram and 14 bytes of clock and control registers. It counts seconds, minutes, hours, days, months and years, remembers the days of the week. Joseph Electronics Ltd, 2 The Square, Broad Street, Birmingham B15 1AP. Tel: 021 643 6999.

Power resistors for sink mounting

Power resistors have been specifically designed to mount on heat sinks, are small and offer low inductance. Advances in thick-film technology have enabled the ceramic carrying the resistive film to be in direct contact with the heat sink, to allow increased power dissipation. RCEC resistors are rated at 250W at 100°C or twice as much at lower temperatures. Resistances range from 1Ω to 1MΩ, with a maximum working voltage of 5kV and isolation of 10^5MΩ. G.B. Electronic Products Ltd, Hoddesdon Road, Stanstead Abbotts, Ware, Herts SG12 8EJ. Tel: 0920 871077.

Analogue data radio link

We regret that the telephone number for Micromake in our February issue was transcribed. It should have read 073522 3255 and *not* 3522.

PINEAPPLE SOFTWARE

Programs for the BBC model 'B', B+, Master and Master Compact with disc drive

DIAGRAM II
– now also available for ARCHIMEDES

Diagram II is a completely new version of Pineapples popular 'Diagram' drawing software. The new version has a whole host of additional features which make it into the most powerful and yet quick to use drawing program available for the BBC micro. The new features mean that 'Diagram II' can now be used for all types of drawings, not just circuit diagrams. Scale drawings are possible and the facilities for producing circles and rubber banded lines together with the pixel drawing routines make any type of drawing possible. This advert has been produced completely using Diagram II.

Summary of Diagram II features:-

1. Works on all model BBC computers and makes use of Shadow memory if poss.
2. Rapid line drawing routines with automatic joins for circuit diagrams.
3. Rubber band line and circle drawing modes.
4. Makes use of the Acorn GXR rom to produce ellipses, arcs, sectors, chords and flood filling.
5. Pixel drawing mode allows very fine detail to be added.
6. Defined areas of screen may be moved, copied, deleted or saved to disc.
7. On-screen cursor position indication allows scale drawings to be made.
8. Keyboard keys may be defined to print User Defined Characters allowing new character sets to be used.
9. Wordprocessor files may be loaded and formatted into defined areas.
10. Up to 880 UDC's if shadow memory available, 381 without shadow.
11. Compatible with Marconi Trackerball and most makes of 'mouse'.
12. All 'Diagram Utilities' are included.
13. Completely 'scaleable' print routines allow any area of the diagram to be printed either horizontally or through 90deg. in scales that may be varied in 1% steps allowing up to 18 mode 0 screens to be printed on an A4 sheet (still with readable text).
14. Smooth scrolling over the whole area of the diagram.

Diagram II consists of a set of disc files and a 16k Eprom.
The disc is formatted 40T side0 and 80T side2. Please state if this is unsuitable for your system, or if you require a 3.5" Compact disc

DIAGRAM II – £55.00 + vat P & P free

MARCONI TRACKERBALL

For Model 'B' and B+ (with Icon Artmaster)	£ 60.00	+ vat
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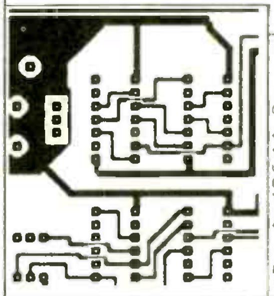
Bare Trackerball (no software)	£ 49.00	+ vat
Pointer Rom (available separately)	£ 12.50	+ vat
Trackerball to mouse adapters	£ 8.00	+ vat
Postage and Packing on Trackerballs	£ 1.75	

All orders sent by return

PCB

Pineapple's now famous PCB drafting aid produces complex double sided PCB's very rapidly using any model BBC micro and any FX compatible dot-matrix printer. The program is supplied on Eprom and uses a mode 1 screen to display the two sides of the board in red and blue either separately or superimposed. Component layout screens are also produced for a silk screen mask.
The print routines allow a separate printout of each side of the board in an expanded definition high contrast 1:1 or 2:1 scale. The print time is typically about 5 mins. for a 1:1 print of a 7" • 5" board. This program has too many superb features to adequately describe here, so please write or 'phone for more details and sample printouts.

£85.00 + vat — Plotter driver to suit most plotters £ 35.00 +vat



PCB AUTO-ROUTING

This brand new addition to the PCB program greatly increases the power of the software and speeds the design of PCB's even more.
A list of up to 190 connections may be entered in the form of a 'rats nest' and then the computer does the rest! You may specify which side of the board you wish a track to be on or you may leave the choice to the computer, and you may also say whether tracks should be allowed to pass between I.C. pins.
The program is in the form of a second Eprom and full features are available on a standard model 'B'.
Please write or 'phone for full details.

COMPLETE AUTOROUTE PACKAGE (Including manual Eprom) **£185.00** + VAT

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ADU is an invaluable utility for all ADFS users. It adds over 22 new •commands to the ADFS filing system as well as providing an extensive Menu facility with over 35 sub commands covering areas such as repeated disc compaction, saving and loading Rom images, auto booting of files and many more.
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6-2532/50ms	20-27256/21V	34-8741	48-63701V
7-2564/10ms	21-27512	35-8742	49-63701X
8-2564/50ms	22-27513	36-8041*	50-63705V
9-2758	23-87C64	37-8042*	51-63705Z
10-2716	24-87C256	38-8048*	
11-2732	25-8755	39-8049*	
12-2732A/10ms	26-8755A	40-8050*	
13-2732A/50ms	27-8355*	41-8751	
14-2764-50ms	28-8748	42-8752/21V	*READ ONLY

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APRIL 1988

INDUSTRY INSIGHT

Cellular radio's next phase: learning the lessons of digital cellular • networking in the nineties: how to move toward ISDN • whatever happened to Britain's cabling? • satellite service brings world mobile radio next year • how to blow a network • Charles Kao on fibre's future • data communication techniques • asynchronous working for synchronous networks • new battery system to revolutionize cordless communicators?

COMMUNICATIONS

EUROPE PUSH BROADBAND INFRASTRUCTURE

The expected changes in the European outlook for telecommunications start to happen this month with the establishment of a European Telecommunications Standards Institute in Nice by the Conference of Posts and Telecommunications Administrations. It is just one of a set of far-reaching Community decisions announced on 24 February as a result of the "widely welcomed" response to last year's Community Green Paper.

Intended to give shape and schedule to the re-defining of Europe's telecommunications regulatory framework, the Green Paper's follow-up proposals are off to a flying start with the blockbuster announcement from the telecom and information directorate in Brussels by the Commission's vice-president Karl-Heinz Norjes.

The market for telecommunications services is to open up progressively next year, to be followed by the market for satellite receiving antennas and, by the end of 1990, the complete opening of terminal equipment markets. The moves include economic and administrative support in the opening up of public procurement and independence of procurement decisions, application of full EC competitive rules, v.a.t. and progressive telecommunications tariffs, and mutual recognition of type approvals.

And there are further moves to come. There are other vital issues flowing from the concept of a Europe-wide market: like the regulatory questions relating to the development of satellite communications, developing dialogue in areas of social concern, and defining a European position on a whole range of telecom issues.

All these things need tackling in a rapid, orderly and effective way, says the directorate, to make the most of the new economic opportunities offered by advanced telecommunications technology.

But what of the issue of how to handle divergent national attitudes when trying to reach pan-European standards?

At a recent conference on digital cellular radio in Amsterdam Plessey's Professor Gosling warned that such a market for advanced cordless telephony may well be stillborn if a wider statesmanship does not prevail (page 380 focuses the problem). Though we now have the new ETSI it is not at all clear how it will resolve such conflicts.

● The technology side of all this is already under way; earlier this year the directorate adopted the Race programme, a set of 45 research and development projects in integrated broadband communications technology. It is designed to lay the foundations of the EC's digital communications infrastructure using optical fibres, satellite links and broadband switching nodes, beyond the nineties and into the 21st century.

INSIDE

Cover – see page 391

 Industry Insight is edited by Geoffrey Shorter and designed by Alan Kerr. Potential contributors to June's *Insight* on semiconductors should make immediate contact on 01-661 8639, send an outline by fax on 01-661 3948, or mail articles to Industry Insight, *Electronics & Wireless World*, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Potential advertisers contact Martin Perry on 01-661 3130 or James Sherrington on 01-661 8640.

COMMUNICATIONS

CELLULAR RADIO'S NEXT PHASE: CELLS ON THE HUMAN SCALE

Advanced cordless telephony is the latest technology to come forward which promises people more freedom of communications on the move. The market is already accustomed to high-cost cellular radio-telephones and low-cost paging systems. In between these two extremes are public call boxes, private mobile radio, radiophone, and now cordless telephones which can operate at short range in the home and in the office. Soon to come, we have the possibility of the advanced cordless telephone which can be operated in the public "telepoint" mode so that users can access the public telephone network via a public base station.

This development of technology means that everyone – businessmen, teenagers, housewives and communicators of all shapes and sizes – can enjoy low-cost telephony whether at home, on the move or in the office. In marketing terms this new service opportunity began by being described as an advanced public call box which gives pedestrians more flexibility, but its implications are far more revolutionary than this suggests, not least because it can also provide full ISDN services. Obviously the market potential is enormous. But it is bound to be a price-sensitive market, and the scale of the opportunity will depend on two things. First, Europe needs to organise itself to create a single market so that economies of scale in manufacture can be passed on to the customer.

The figure shows our estimate of demand

Standards legislators must not set back Europe relative to the rest of the world, says Plessey's technical director.

DIGITAL CORDLESS 1995

Installed base...	
UK	3.3m
Germany	2.9m
France	1.9m
Europe	10m

for digital microcellular cordless telephones in the UK, Germany and France. For products of this type these countries typically account for 80% of European demand so that we can postulate an installed base in the EEC of at least 10 million units by 1995.

The question is whether this demand will be satisfied by a multiplicity of standards or whether it will benefit from the economic advantages of a pan-European standard. In this respect we have already made a bad start.

A BAD START

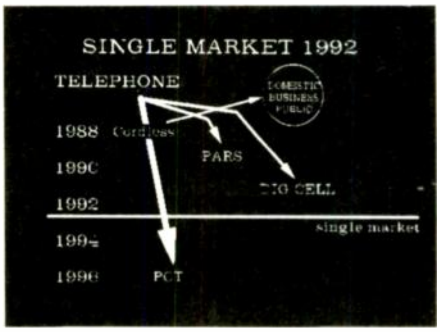
3 standards...
low volumes...
many prices...

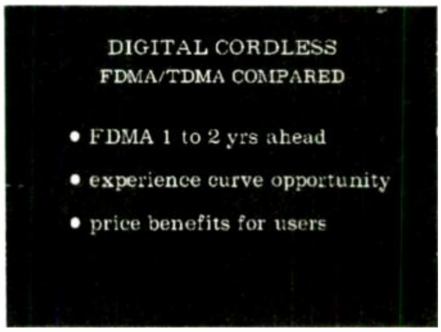
UK	£60
Finland	£700
Germany	£600
France	£200

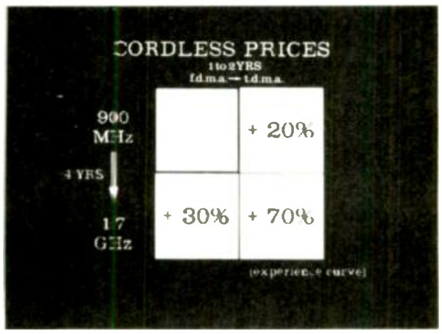
Three basic standards, plus variations, are in operation across Europe. So great is the spread of technology that the cheapest product sells in the UK for £60, while the most expensive is on sale in Finland for £700. The average cost in Germany is £600 and the cost in France is about £200.

The most conservative forecasts show that by 1992 the installed base of cordless telephones in Europe will be more than four million units. If we take the difference between the highest and lowest prices in Europe this represents a penalty of more than £500 million that consumers will have paid by 1992. But the story is even worse than this, because the cordless telephone is a price-sensitive market. In low-price Britain, penetration of microcellular telephones is six times greater than in high price Germany. If cordless telephones were sold all over Europe at UK prices then seven million more Europeans might enjoy the benefits of cordless telephony.

As Europe moves toward the single mar-







ket in 1992, a whole new set of mobile communications standards are emerging.

In 1988 the first contender for a pan-European cordless standard is ready. This proposal is based on f.d.m.a. at 900MHz and the first equipments will be submitted for type approval in the UK in the next few months followed by market launch before the end of the year. By 1992 the first digital cellular networks will be in operation and by 1996 we can anticipate the availability of the pocket telephone. By this I mean an inexpensive terminal costing perhaps £100 and the size of a cigarette packet, that is capable of transmitting and receiving telephone calls into the public network via the microcellular radio bearer.

In all of these cases, it is the duty of the standards legislators to focus on technology lead times and take a just view of what is ready for the market. Above all they must not hold up progress, which would set back Europe relative to the rest of the world in a way which would be subsequently beyond the possibility of recovery.

It is timely now to look at the situation in microcellular digital cordless technology. A number of proposals for a European standard have been proposed, including both a t.d.m.a. version and a f.d.m.a. version at 900MHz.

The f.d.m.a. proposal is up to two years ahead of the t.d.m.a. proposal and the technology is ready for the market. Both technologies are realisable at similar cost by the possibility of an earlier start with f.d.m.a. means that the experience curve can be exploited so that manufacturing cost benefits can be passed on to customers in terms of reduced prices. In line with theoretical predictions, there is little to choose between them, except that f.d.m.a. has distinct advantages of being able to accept speech from low-rate codecs without unacceptable time delays. The significance of this is that spectrum efficency is more assured in the long term with f.d.m.a. microcellular systems.

The standards debate is complicated by the shortage of frequency in some countries for cordless telephony at 900MHz. There is therefore talk of a pan-European standard at 1.7GHz, for t.d.m.a. or f.d.m.a. or maybe something else. But this spectrum cannot be made available until about 1993 at the earliest, which is so far away as to make it academic in terms of market development.

The experience curve argument for f.d.m.a. is compelling, and I am sure that the standard legislators would be the first to acknowledge that in this respect time is money.

Our estimate of the sensitivity of equipment prices to the experience curve is shown next. There is a matrix for f.d.m.a. and t.d.m.a. at either 900MHz or 1.7GHz. The frequency-division development programme is presently between one and two years ahead of the time-division development programme. Spectrum at 900 MHz is limited, so the higher efficiency of f.d.m.a. is an advantage, while spectrum at 1.7 GHz will not be available for at least four years.

The figures in the box show our estimate of equipment prices, taking account of the time differences, but assuming that both technologies are realisable at similar cost. The box suggests that t.d.m.a. at 900 MHz will always be 20% more expensive in the market than f.d.m.a. because it will lag on the experience curve. The 70% penalty for t.d.m.a. at 1.7GHz is a minimum, because in this band the technology may require expensive equalization which will never be required for f.d.m.a.

There can be no question that these arguments are compelling. But if we look at the current line up of support in CEPT we see quite a different picture (page 396).

At its meeting in November last year, the R22 Committee of CEPT, responsible for making a recommendation to the EEC about the cordless standard, demonstrated a set of deeply divided opinions. Faced with the overwhelming technical and commercial arguments that I have presented, and the evidence that the f.d.m.a. standard can give the market what it wants now and pass on

Turn to page 396

COMMUNICATIONS

TOWARD ISDN
Networking for the nineties

The communications world is on the brink of major change, one that poses extraordinary opportunity for the telecommunications industry. The change foretells an important leap forward in our ability to use information technologies to raise productivity and living standards, even international understanding. But this is by no means an assured result. Much depends on how well we manage the change – in particular, on how well the computing and communications industries work together in devising network solutions that optmize our total information system, rather than the piece parts.

What is the nature of this change? We often hear it described as the coming of the information age, but people usually think that just means the arrival of computers and robots. The change is more profound than that, because it means a drastic change in the way we control and organise most of the world's work. In a nutshell, the change is from a world where most work is directed and performed by humans, communicating by voice, to a world where much work is directed and performed by intelligent machines, communicating digitally.

Driven by evolving customer needs, technological progress and networking, the years ahead will be years of challenge and change for the telecommunications industry.

Why the communications change is profound

To understand how profoundly this change will affect our mission, consider how the telecommunications industry has evolved. From the outset, the purpose of our industry was to satisfy the age-old human need to communicate from person to person. And for the bulk of human history, the communication medium of choice has been the voice. But without the aid of technology, voice communication could only take place over short distances, within earshot. And it had to take place in real time; it made no sense to speak without a listener.

With the invention of writing, people began to use clay tablets, scrolls and books to communicate across time and distance. For more pressing needs, they devised the first telecommunications systems, messenger and postal services. It is interesting that for some limited uses, they also invented a few other clever technologies for long-distance signalling, using flags, bonfires, smoke puffs and mirrors. Some of these might qualify as the first digital lightwave systems! Later came the telegraph, the first electronic digital communications system, and, eventually, the telephone.

Prior to the telephone, most communications technologies were used simply as surrogates for the human voice. People used them because they had to; they couldn't use their voices. But when Alexander Graham Bell invented the telephone, that changed, and so for the budding telecommunications industry the customer need was clear. We concentrated our energies on providing Universal Telephone Service.

In pursuit of that mission, our industry exploited technology. But we didn't just use existing technology. Beginning with the telephone itself, we either invented or played a major role in developing *new* technologies, including the vacuum tube, the transistor, the laser and lightguide. And we brought this technology together in a vehicle created for meeting customer needs – telecommunications networking. Networking is a powerful tool that supports and couples evolution in customer needs and in technology.

Without networking and the systems engineering skills that support it, we could have made little headway toward Universal Telephone Service. Without networking, our voice communication systems would scarcely be so practical, economical, dependable and usable. Without networking, we would have and, in the early days of the industry, we did have, multiple terminals on peoples' desks. Without networking, we would have under-utilization of costly transmission facilities, little protection against equipment failure, little flexibility to accommodate evolving needs, and a proliferation of complex interfaces and protocols.

Thus, with great benefits, our industry has orchestrated three powerful forces; namely, evolving customer needs, technology, and networking. Technology made services possible, networking made it practical. And these forces interacted in beneficial, synergistic ways. The demand for economical long-distance telephony stimulated development of the vacuum tube, the transistor, and later the laser. The transistor, in turn, led to powerful stored-program controlled switches. And they gave rise to networking capabilities that stimulated the development of, and the demand for, new network services and features.

Until very recently, our focus on providing Universal Telephone Service was entirely proper. Almost all our features and services concentrated on voice, because most telecommunications traffic was among people, and voice was the communications medium of choice.

It is, however, true, since the industrial revolution began, a range of ever smarter machines have emerged, from the loom through lathes, cars, calculators, typewriters and most recently computers. But it has mainly been people who operated the machines, locally and in real time, who handled both input and output and who handled all necessary communications. So while they contained many machines, our workplaces remained highly peopled and paper-intensive.

Today, largely as a result of technical advances we are seeing a rapid and major change. Low-cost digital processing and low-cost digital transport are stimulating demand for a qualitatively different kind of communication – people-to-machine, machine-to-people, and machine-to-machine. There are many examples. Even at Bell Laboratories, for example, engineers design a circuit board at the console of a CAD system. Then the machine transmits the design data to the factory hundreds of miles away, where another machine receives it and transforms it into art masters. These are in turn fed as instructions to machines on the factory floor that make the product. No speech, no paper, and except at the very outset, just machine-to-machine communication.

But machine-to-machine data communication is inherently more complex

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ENTER 56 ON REPLY CARD

This article is based on remarks made by Dr Ian Ross at Globecom '87, held in Tokyo.

than people-to-people voice communications. People, after all, speak in one frequency band, at about the same speed; they signal which language to use, and when to start and stop talking. People all have about the same intelligence, at least by comparison with machines.

On the other hand, machines use different language or protocols; they transmit and receive and at greatly different rates; they often need to engage in conversation with many machines at once, rather than just one. They come with a wide array of "intellectual" capabilities, ranging from "dumb" terminals to supercomputers. They frequently don't speak one-to-one, but one-to-many, many-to-one and many-to-many. So a data network may need to sort, store and forward information, so that all machines do not receive the same information, nor receive it at the same time.

These differences amount to major new challenges for what has become known in the industry as Information Movement and Management. And for us in the telecommunications industry, they amount to a major expansion of our mission. We must turn our networking skills to data; we must network intelligent machines as successfully as we have networked people. Note, however, one thing should not change. We should still be orchestrating the same three forces: customer needs, technology and networking.

The role of ISDN

How are we responding to these new challenges? There is some very good news on that score. I am talking about the Integrated Services Digital Network, or ISDN. Strictly speaking, ISDN is not a network or a service offering, but rather a set of internationally accepted standards that our industry has created. It takes advantage of the major new digital capabilities that we already have, or are deploying in the world's telecommunications systems. It provides the blueprint for constructing end-to-end digital networks, and creating a whole new range of innovative services, especially services that will meet the needs of data users.

And that is just what we have begun to do: we are turning the ISDN plan into a reality. For example, last December McDonald's Corporation linked its corporate headquarters near Chicago to an AT&T 5ESS switch in an Illinois Bell central office some two miles away. It then began using ISDN services and equipment for digital telephone, voice/data terminals, fascimile and modem pooling. Data applications include using ISDN lines to access computer hosts from 3270-type terminals, which eliminates the need to string coaxial cable. Vendors from both the US and Japan are supplying the ISDN terminal equipment.

Other ISDN applications are planned or underway in twenty local exchange companies in the US, and we are gearing up to offer ISDN services over the inter-exchange network by the end of this year, and international the next. In addition, some 20 countries have ISDN applications, planned or underway.

ISDN is proving its worth. McDonald's and other users are attracted by just the advantages that flow from a genuine networking solution. ISDN offers them simplicity and integrated access to voice and data. It offers them the potential for a single terminal on the desk and a single network serving all their needs. It offers them a flexible, robust architecture with standard interfaces and protocols that will support a diversity of applications. It offers them a variety of formats – circuit, channel or packet. And it offers them a rich signalling system that will allow them to customise services provided by a public network.

The status of data networking today

But there is also some not-so-good news. The status of data-only networking today is not nearly so good as the status of voice networking. Yet data-only networks have become highly *strategic* to the operations of more and more companies. Already, financial networks or airline reservations systems can generate millions of dollars an hour for their owners. Yet for the most part, these networks do not take advantage of genuine networking solutions. One of the chief reasons is that until recently, the telecommunications industry did not offer such solutions to data users. So they had to build their own networks.

As a result, large data communication systems almost entirely bypass the intelligence and other resources of the public switched networks. Mainframe-based networks, for example, typically employ coaxial cable to link terminals and personal computers to cluster controllers. Point-to-point and multipoint private lines link the cluster controllers together and to the host computer's front end processor. Intelligence is concentrated at the peripheries of the network. In a mainframe-based network, in fact, the host runs virtually all major network operations within its domain, including security, routing, and sessions with other hosts.

For this and other reasons, today's data only networks have serious limitations. They are typically single-function, inflexible, difficult to evolve, to maintain, administer, reconfigure or back up. No one manufacturer can present the best solutions to the complex new needs that users are developing. So because different machines and networks use different proprietary protocols, users have tended to build multiple dedicated networks. When they have added an application, they have frequently had to add a new network. And when they seek to protect their networks against failure, they must almost always do it by adding redundant physical private lines and equipment. These are the penalties of not having good networking solutions available.

The situation offers striking parallels to the early days of the telephone industry, before we began to develop our networking skills. If you wanted to call a new customer, you often had to subscribe to a new service, and put an additional telephone on your desk. We have old pictures that show people with a half dozen instruments on their desks, much like the many terminals we now see where heavy data users work.

Next steps: migrating data networks to ISDN

What are the next steps toward providing real networking solutions for data users? Certainly, ISDN is critical. So one step must be to deploy ISDN as rapidly as possible. Like the telephone, ISDN will become more useful the more ubiquitous we make it. We must make ISDN features evolve, too – for example, to accommodate wideband access for local area networks and video.

Going beyond ISDN, we must pursue agreement on standards for the upper layers of the seven-layer Open Systems Intercon-

Turn to page 396

TEST AND MEASURING INSTRUMENTS FOR THE COMMUNICATIONS MARKET

INSTRUMENT DE MESURE ET DE TEST SUR LE MARCHE DES COMMUNICATIONS

PRÜF-UND MESSGERÄTE FÜR DEN NACHRICHTENWESENMARKT

INSTRUMENTAL DE PRUEBA Y MEDICION PARA EL AMBITO DE COMUNICACIONES

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COMMUNICATIONS

ELECTRONIC MESSAGE HANDLING FOR PC LANS

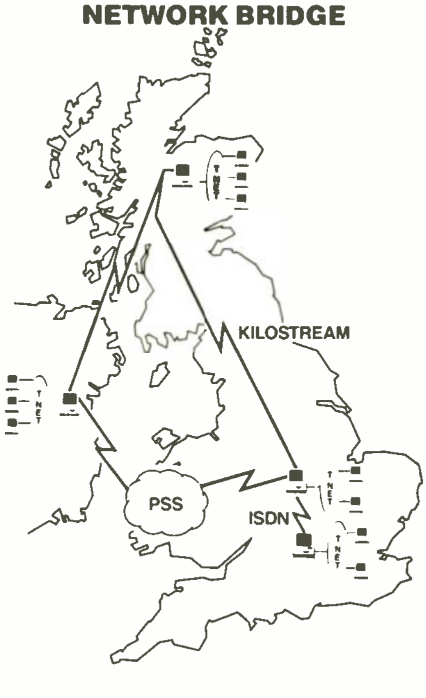
British Telecom is first with an X400 messaging system for microcomputer-based local area networks

Later this year British Telecom will begin to market the first microcomputer-based gateway for its public message handling service. BT's message handling service, Gold 400, is expected to go public this July, when the current pilot service comes to an end. It is based on X400 messaging, a CCITT standard designed to provide the architecture and support to enable PCs to access electronic mail, telex and facsimile, as well as computers. The development extends the T-Net 1000 series of local area network products announced last year by adding a PC400 gateway to give access to the growing X400 international 'open systems' messaging community.

The PC400 hardware consists of a Zenith M5000 series microcomputer (any other MS-DOS computer with 640K of ram would do) with an 'on-board' interface card that includes X25 protocols (to talk to Gold 400), its own 8086 processor and 256K of random access memory, loaded from the network file server. (A minimum configuration network would be PC400 + file server + workstation.)

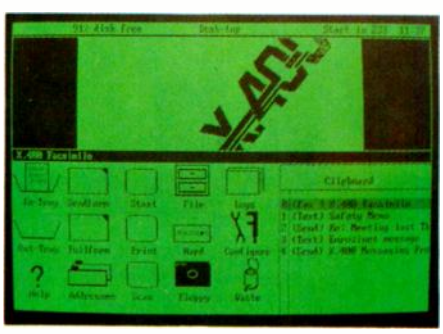
If you're not into the CCITT jargon, X400 may be something of a mystery. It's not particularly new; developed four years ago its aim is basically to combat incompatibility between electronic mail systems. X400 sets out to allow subscribers with the relevant interface transparent routing of person-to-person messages between users having nominally incompatible computer systems. This is in line with 'open systems interconnection' and the BT product is the first to address the o.s.i. reference model 'application layer' (layer seven). O.S.I. messaging is a secure store and forward system for transferring a wide range of (mixed) data formats: formatted documents, spreadsheets, facsimile, videotext, encrypted text, digitized voice, teletex, telex and electronic mail.

T-NET WIDE AREA NETWORK BRIDGE

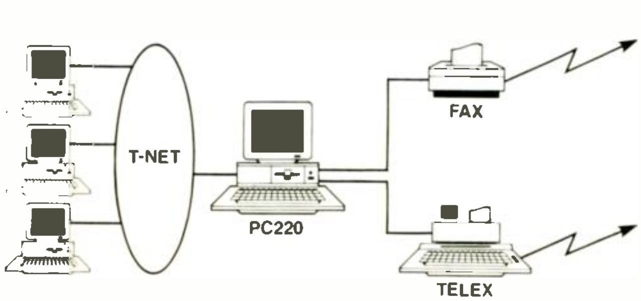


The X400 product follows BT's research laboratory wide-area network bridge announced last November, which using X21 or X25 protocols, it will operate through Kilostream, the packet switched service, ISDN or private lines to link geographically separate local-area networks, as the diagrams depict.

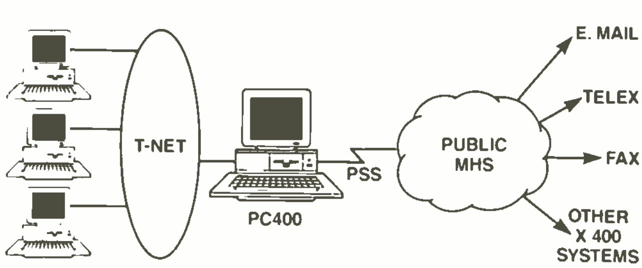
It joins the T-Net 1000 family of lan products, of which BT has so far installed around 100 systems. Two types of cabling are offered – Ethernet and Arcnet, and there are two corresponding boards available to plug into PCs intended for the network (costing around £350 and £280 respectively). Details of the range of products for T-Net 1000 are available from BT on freephone 0800 800 800, quoting reference ACQ153.



FAX/TELEX GATEWAY



X 400 GATEWAY



COMMUNICATIONS

DATA COMMUNICATION TECHNIQUES

Bob Dubery discusses the techniques of dial-up data networks and emerging trends in the industry, pinpointing common fallacies

Though modern techniques have revolutionized the way that modems perform, one factor has remained constant: the huge economies made possible by asynchronous data transmission – the original, and in the writer's view, the best, most efficient way of getting remote users to talk to a mainframe.

Asynchronous communication is in many ways synonymous with dial-up systems where acoustic couplers and terminals with built-in modems operating at 300 bit/s were the order of the day. Asynchronous line modulation rates are now more commonly 1200 and 2400 bit/s and no new system would today be implemented at 300 bit/s through a largish population of 300-bit users still exists.

Information service providers are often unwilling to force their users to change to the higher speeds. Here, education is needed as it is surprisingly common to hear it said that the slower speeds give the best chance of error-free traffic.

The growth of the personal computer as an indispensable tool to the modern business man has created a need to communicate to the office by means of dial-up links over often noisy and error-prone lines: factors that would initially seem contrary to the need for fast, reliable communication.

The writer has been associated with data communication sales for twenty years from the earliest days when speeds of 3300 bit/s were seen as the ultimate in synchronous transmission rates. Users have always been attracted to the highest speed modems in the often-mistaken belief that the maximum speed of the modem could be equated with the rate that data could be sent between two locations.

In very many cases the limiting factor in data transfer speeds is not the modem, but the characteristics of the protocol used and/or the efficiency of the computer terminal and front-end devices.

This trend continues today. Almost every popular journal carries press releases and advertisements for modems that continually claim to offer increasingly high data transfer rates. Although completely accurate in their claims, it is often fogotten that a modem is a very small part in any overall data communication system and the stated speeds will only result in data throughput at those rates if all other elements of the system have the same capability.

A suitable analogy would be the opening of a five-mile long, ten-lane wide section of the M25, with motorists expecting that their driving time around London would be dramatically reduced.

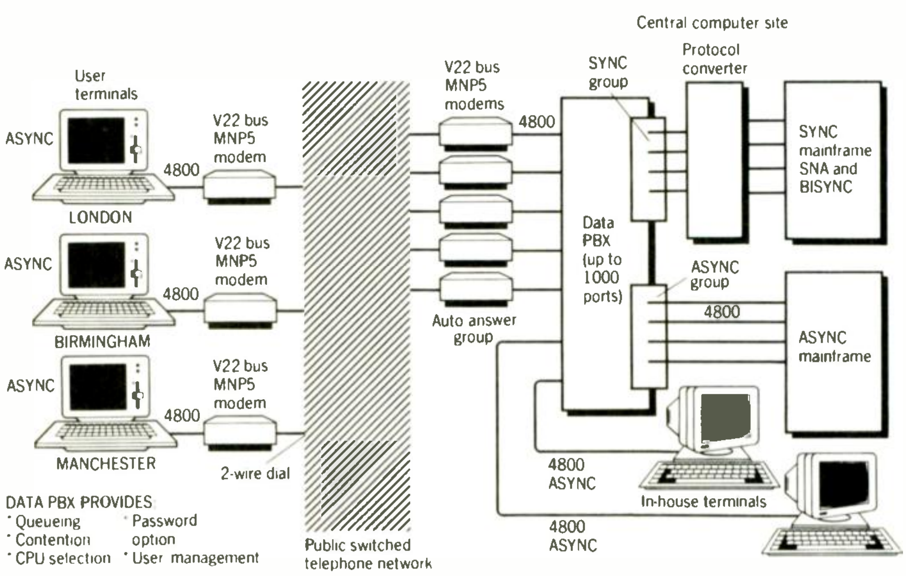
At one time, a remote data user equipped with a 'dumb' computer terminal set to a speed of, for example, 1200 bit/s could have typically resulted in throughput or 1200 bit/s or 120 characters per second. Most present day users have personal computers on their desks and when used on-line, connected to a data modem, some form of terminal emulation software within the PC enables it to duplicate and usually enhance normal terminal functions.

But there's a big difference between a PC-emulating terminal and a straight dumb-terminal situation. Although the emulating software has speed settings cover a range from 300 to 19,200 bit/s, the actual throughput of the PC is typically no greater than 3800 bit/s due to the processing time within the PC. A typical file reception is interrupted continuously by the sending of flow control characters back to the receiving modem as the internal PC buffers become full with data being processed prior to display.

So in deciding what speed of modem to use in a given system, the limitations of the sending and receiving software and hardware must be bourne in mind.

The writer's company market a range of modems that have the capability of sending error-free data at speeds around 5000 bits per second and as part of every sale we demonstrate the maximum operating speed, usually on the customer's premises. A lot of thought has to go into being able to demonstrate the full potential of the equipment.

We soon discovered that to achieve a maximized data transfer rate, the best type of data reception device was a relatively unsophisticated portable terminal that contained very little processing capability. With these terminals throughputs in excess of 5000 bit/s were possible. Using a 'sophisticated' terminal with multiple emulation characteristics dropped the throughput to around 4000 bit/s and worst of all, a PC runing a terminal emulator package resulted in a throughput averaging 3400 bit/s.



Asynchronous modems can lead to highest efficiency in synchronous networks.

In each case the terminal speed was set to 9600 bit/s.

In the asyncronous dial-up world, many standards are defined. These standards are determined by the CCITT and relate to the electrical characteristics of the digital interface as well as to the line modulation scheme and protocol used.

The most common standard used for new dial-access networks is V22bis. This is a full duplex two-wire system offering 2400 bit/s in synchronous or asynchronous formats.

Used in the asynchronous mode, the line modulation scheme is still a synchronous system with each modem including an asynchronous/converter. The data rate (the number of line signal transitions per second), is in fact 1200 baud but with q.a.m., in which the amplitude and phase sent to line is determined by a particular two-bit data pattern, the effective transmission rate can be 2400 bits per second.

Error correction and compression

Within the asynchronous conversion process further intelligence can be introduced to include two additional functions – error correction and data compression.

The error correction systems commonly employed entail splitting data into blocks or packets and adding checksum information at the end of the packet which, at the receiving end, is used to determine whether or not the packet was received without error. The size of the packet is set to be a compromise, based on the liklehood of an error ocurring on an average line.

Maximum throughput is obtained if the packet length is large thus making the packet acknowledgement (during which data flow is halted) a smaller percentage of the transmission time. However under noisy line conditions, a large data packet would statistically be more likely to suffer corruption than a small packet. This is especially true on dial-up lines where the line noise tends to be impulsive and randomized.

Data compression methods allow the incoming data to be stripped of all redundant data prior to transmission to line and for the stripped data to be reinserted at the receiving end. This is a normal function of the asynchronous to synchronous conversion process and such a conversion results in a compression of 20% given a ten-bit data character with stop and start-bit stripping.

A further refinement to the compression process is to examine the frequency of character occurrence and to assign a reduced-length data byte to the more commonly found characters.

Using a combination of this and run-length encoding, whereby a string of like characters is compressed to one character plus a character indicating the length of the string, compression factors of two-to-one can be obtained with ease on asynchronous data streams.

A further facility included in modems that feature data compression is the addition of a serial data buffer that allows the connected terminal to be set to say 9600 bit/s although the V22bis standard is nominally designed for 2400 bit/s operation. The serial buffer allows data to be entered from the terminal at 9600 bit/s and sent to line in a compressed format as fast as current line conditions will allow. Much use is make of flow control procedures to ensure that terminal transmission is held off if the buffer cannot be cleared due to temporary line noise situations.

Another advantage of this serial buffer is that a common terminal speed can be set and the "universal link negotiation" feature of the modem used to automatically adjust the modem speed to the speed of the answering data service.

The CCITT determine standards for modem characteristics and, as reported recently in the pages of this journal*, Study Group 17 failed to determine a specific standard for error correcting protocols when it met last October. The two protocols under examination were MNP (Microcom Networking Protocol) and LAPB (Link Access Procedure B).

The CCITT chose to allow them to co-exist, which causes no particular user problems as most large dial-up networks are nationally based and universal interconnection is often the least most sought after requirement in a modem network, given the existing problems of data security.

The Microcom protocol is offered as public domain up to class four and around 50 modem manufacturers worldwide offer this protocol within their modem product. Link Access protocol is already a standard in the X25 world and the proposed CCITT-acceptable version of this is LAPM which combines LAPM and LAPD for ISDN usage and adds some additional features.

The relative advantages of the two are virtually indiscernible from a users operational point of view, but clearly a common standard would have advantages for large public networks. An important point however is the idealized universality of a modem in being able to connect to any other modem using any error-correcting protocol. At the present time MNP offers the greatest flexibility in this respect.

MNP is available in a number of 'levels' and from time to time Microcom release enhanced versions which offer faster error correction and greater degrees of compression. The current most popular version is level five which offers Adaptive Packet Assembly, in which the length of data packet is dynamically adjusted according to the perceived line error rate, and also data compression algorithms that provide in excess of 5000 bit/s throughput whilst still using V22bis modulation.

Level six is also commercially available with claimed throughputs of up to 19,200 bit/s but at a significantly higher price. Such speeds are of little use unless the associated hardware can operate at similar speeds.

All the MNP levels offer 'universal link negotiation' which allows the originating modem to detect whether MNP is available at the distant answering device, and if so to automatically adjust to a common MNP level. Normal connections can be make to any V22bis standard modem that does not have any form of error correction but the advanced features are only brought into action when the initial 'link negotiation' recognises a similar modem at the end.

The key thing when considering asynchronous modems is not the speed indicated on the modem's front panel or within the manufacturer's literature, but rather the actual throughput achieved under live operational conditions.

*page 71, January 1988 issue.

In practical terms, data sent by a nominally 2400 bit/s V22bis modem with built-in error correction software to MNP level 2 will actually achieve a throughput of only 1900 bit/s. (This is easily measured by sending a file of known length and timing its reception). If the line is very noisy, thoughput can drop to less than 1000 bit/s.

The advent of MNP level five has allowed PC users to transmit files in half the previously obtainable time over average dial-up links and in many UK and international tests, throughputs of around 5000 bit/s have been typical.

Command sets

A further complication in modem selection is the type of command set used. In earlier generations of data modems, settings for operational speed and interface control were made by means of internal switches. Currently available 'state-of-the-art' data modems use a command set that uses the terminal connected to the modem to set the operational parameters.

This has the advantage that operating parameters can be set up from the software of a controlling personal computer or as is probably the original case for introducing command sets, the autodial feature of most V22bis modems can be programmed with the desired number from the user terminal.

The command set that is most widely accepted in industry is the Hayes set, originated by Hayes Microcomputers Products Inc of Norcross, USA. As is the case with the majority of good innovative ideas, the wide acceptance of this original command set format has ensured its inclusion in virtually every dial modem currently produced.

The Hayes command set is comprehensive and this tends to make its use complicated if the commands have to be set from the terminal keyboard. Because of this, many modem manufacturers include an alternative command set that is more user-friendly and features more easily remembered commands. For example the Hayes "AT" command to dial the number 01345 6789 is ATD 013 456789, whereas the Feshon set in the 6024 modem is D 013456789. Similar simplified alternative command sets are available from most modem manufacturers.

Asynchronous modems for synchronous systems

Users of existing or planned synchronous networks should seriously consider the use of protocol converters at the central site and the possibility of an access arrangement that consisted of asynchronous modems as described here and asynchronous terminals as the input/output device.

The advantages are very real:

- speed between the dial in user can be 4800 bit/s or greater
- error-correcting software within the modem is more efficient and faster than the normal sync software
- modems are capable of providing full duplex operation at the higher speeds; eliminating the turnaround delay of the older V26 standards
- advanced techniques in stored-number dialling can be terminal initiated
- standard asynchronous terminals can be used, with an attendant cost saving of up to 200% when compared to their synchronous counterparts
- use of asynchronous communication allows the use of highly efficient port contention and selection devices at the host site.

Such a system is shown on page 388, where all users have standard asynchronous terminals that operate at 4800 bit/s. They are connected to the serial port of an advanced MNP class five V22bis data modem. The built-in buffer and the data compression software within the modem still produce a line speed of 2400 bit/s to match the V22bis standard. One can dial any V22bis-compatible database but on connecting to a modem that has similar features the advantages of the high speed and efficient error correction become apparent. At the host site, a bank of auto-answer MNP class-five modems receive the incoming call and connect to the data PABX. This equipment can offer a menu selection of resources available and even provide additional password access protection if required.

For access to a DEC c.p.u. group, for example, would enter DEC at the destination prompt and IBM users, on entry of a suitable routing instruction, would be connected to the input of the protocol converter ports.

Such a system represents the ultimate in flexibility and perhaps offers an alternative to many organisations to interconnect systems such as X25 and other fashionable local area networking schemes.

Synchronous dial-up

The V22bis standard allows communication at 2400 bit/s in both asynchronous and sycnhronous modes. Unfortunately, all of the added features such as error correction and data compression are only available in the asynchronous mode. The majority of the asynchronous embellishments are, in fact, deviations of techniques that synchronous users have become accustomed to over the years.

In synchronous modes, error correcting is done within the protocol and to some degree, data compression is carried within the 'front-end' processor of large computer systems.

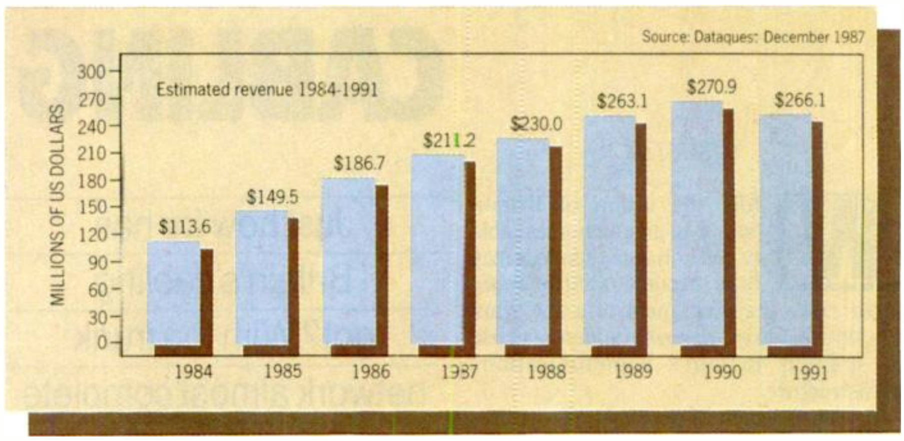
For the highest speeds over dial lines in synchronous modes, the V32 modem represents the latest means of achieving 9600 bit/s full duplex operation over the majority of two-wire dial lines.

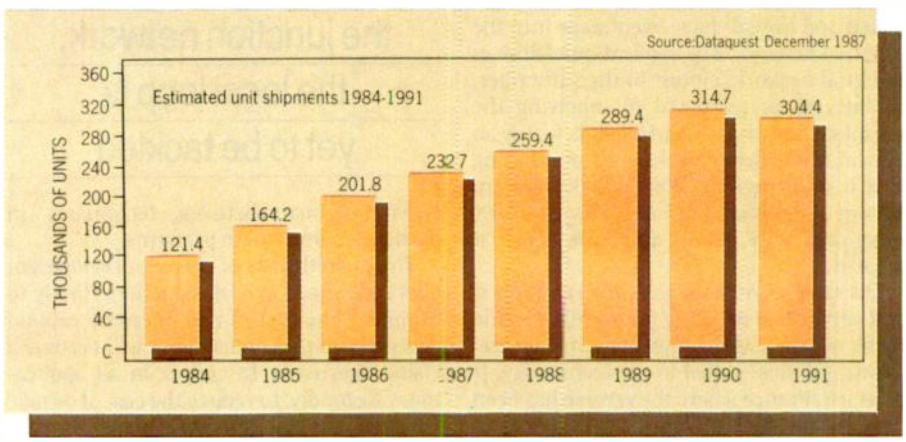
The V32 modems marketed by Feshon for

example, utilise trellis-coded modulation at 9600 bit/s. This error-correcting scheme uses 32 signal points coupled to an eight-state convolution encoder. At each baud time, the encoder generates a code bit that is combined with four data bits to select one of the 32 signal points for transmission. Each of these signal points represents a particular phase and amplitude combination.

At the receiving end a powerful Viterbi decoder examines the incoming data and selects the sequence of bits that most accurately represents the incoming data. This technique helps the Feshon 2265 to maintain substantially error-free performance over severely degraded lines. The modem also features an advanced adaptive echo canceller with a echo-delay estimator that gives a true long-haul perfomance over satellite and long-distance international links.

The V32 modem finds applications in providing a back-up service to leased lines and British Telecom Kilostream services. It has taken over from the old-style 9600 dial back-up system that necessitated dialling up two separate lines, one to provide a transmit pair and one to provide a receive pair, thus simulating the four-wire circuit that a V29 9600 full-duplex modem required. Automatic back-up systems utilising V32 modems are now available whereby the normal digital 9600 service is continually monitored, and if a failure condition is detected, the auto-dial sequence on the V32 is automatically initiated and the service restored via the public dial network.





Synchronous data compression

One of the most exciting developments in commercial data communications in recent years is the synchronous data compressor. Equipment now available will accept data from synchronous data sources, each operating at a true 9600 full-duplex rate and compress each source such that all the sources can be sent simultaneously over a single 9600 bit/s synchronous modem.

This device is not to be confused with a statistical multiplexer, which does really much the same thing, but the method of operation depends on looking for gaps in data streams and using those gaps for other users. The problem is that significant delays can occur to data flow whilst data is buffered waiting for user gaps to appear. A true data compressor reduces each data source such that it occupies around one third of its original data length and combined with the inherent statistical nature of data flow, compression efficiencies of up to four-to-one can be achieved.

In a practical terms this means that a large data communication user with four lines from London to New York can cancel two of those lines and route all users via the data compressor over the remaining two lines. In fact all the traffic could be put over one line, but generally users like to keep two lines active to safeguard against total loss of communication should one line fail.

Over 4000 of these data compressors are in use throughout the world. In the UK, the market for these devices is limited as the cost of data lines from British Telecom is amongst the lowest in the world. The problem of backing up high capacity >48,000 bit/s digital services is nevertheless one where the data compressor can be of great value.

A combination of a four-channel compressor and a two-wire dial modem can provide a total data throughput of 38,400 bits per second over a single dial link. Combined with automatic switching and line fault detection equipment, this combination can provide a truly effective means of backing up digital service connections.

Bob Dubery formed Feshon Systems Limited in 1980 to specialize in the supply and support of data communication equipment and networks. Feshon are on 0732 460088.

Cover story

Relatively minor impairments in digital radio links that could lead to reduced overall bit error-rate performance particularly during fade conditions can be detected using constellation analysis. Hewlett Packard's new 3709B dedicated analyser can monitor many of the in-phase and quadrature digital modulation formats, from q.p.s.k. at two bits per symbol to 256 q.a.m. at 16 bits per symbol, and 9, 25, 49 and 81 q.p.r., over the symbol clock range 1 to 80 megasymbols per sec. The analyser is connected to the receiver's demodulator to analyse the disturbances to phase-plane constellation patterns, detecting degradations arising in the transmitter, propagation path or receiver without disturbing radio traffic. The new analyser supersedes the earlier 3709A display-only unit, and is priced at £7,293 ex v.a.t.

With the current interest in replacing the f.d.m. radios of existing networks with digital microwave radios, HP say they expect that all new system additions will be digital by the end of the century. Enquiries to 0734 696622.

COMMUNICATIONS

PROGRESS IN OPTICAL CABLING

Just how far has Britain's cabling got? With the trunk network almost complete and inroads made into the junction network, the local loop is yet to be tackled

While the vision of Britain 'wired' to give all homes cable tv and enhanced services may have become a little more vague since the excitement of a few years ago, optical fibres are now in widespread use throughout Britain's communications infrastructure.

British Telecom is probably the world's single largest user of optical fibre cables. Its trunk network has now almost been completed and inroads have been made into the junction network. The application of fibre in the local network, closest to the subscriber, is likely to be restricted to supplying the business user whose requirements justify an optical fibre. British Telecom's purchasing level is in the region of 200-250,000 fibre-km or over 200 million metres, each year – 50% junctions, 25% trunk and 25% local at present.

Overseas, even in the USA, the emphasis is still very much on using optical fibre in the trunk network where high capacity requirements are most suited to the technology. It is only in France where the reverse has been true and emphasis has until recently been on placing fibre into the local network not the long haul trunk routes.

Other applications of fibre are still very much in their infancy and would comprise less than 10% of all fibre usage, with military and local area applications being the most popular non-telecommunication uses.

A key factor in the surge in the use of optical technology for communications whether for long-haul transoceanic transmission, intra-office communication, in automobiles, inside pipelines, or along electricity power lines, has been the dramatic fall in fibre prices from around £1 per metre, little more than ten years ago, to around 5p per metre now. The reduction has been achieved through two factors. Firstly, the opportunity for growth in requirements supporting volume production concentrated on single product line manufacture i.e. high quality single-mode acrylate-coated fibre. Secondly, the introduction of volume manufacturing techniques, in particular, long length preforms.

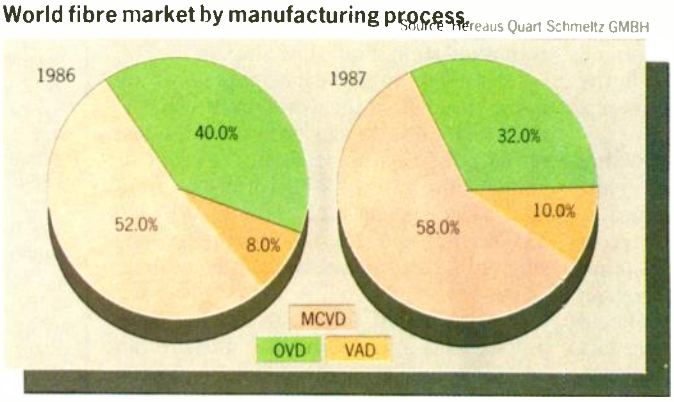
The main thrusts of current development effort are aimed at cost reduction. Firstly to minimize the cost of raw fibre and cabling processes so that optical fibre will become a viable alternative to copper in all applications. Secondly, to reduce the cost of ownership by improving fibre performance. Dispersion-shifted/low-loss fibre, where the 1550nm window is improved, can offer longer distances between repeaters which reduces overall system cost on long-haul links.

At present, British Telecom's introduction of fibre into the local loop has been restricted to the business market where capacity requirements justify fibre. London's City Fibre Network using STC's programmable digital multiplexers to provide a managed network is a case in point. Under normal circumstances, the demand from a domestic customer does not justify replacing the final copper cable drop with an optical fibre. In addition, most customers have shown little interest in the prospect of gaining access to more capacity through fibre to the home.

A few years ago cable tv was seen as a means of introducing a high-capacity network over fibre. But changes in the rules governing the provision of licences encouraged those companies successful in pilot projects scattered throughout the UK to minimize their initial investment and concentrate on the provision of basic tv channels rather than alternative services requiring the bandwidth potential of fibre.

Views are mixed as to the rapidity of introduction of fibre into the local loop. A recent market research report in the US indicated relatively limited application before 1995. With such a wide network of copper cables in place, it is perhaps predictable that the emphasis will be placed where the advantages are most obvious – down to the distribution point. In countries where the network is less well developed, or where competition supports an alternative network, fibre to the subscriber may be more likely. Mercury Communications have already installed the first part of their optical trunk network – the 'figure 8' linking major UK business centres. They have also installed hundreds of kilometres of high fibre-count cable into the City of London to address the business community's requirement for secure communications. Without an existing copper network, remote meter reading, security, data communications, cable tv and telephony, provided over

World fibre market by manufacturing process. Source Hereaus Quart Schmeltz GMBH



The world market for optical fibre has declined from a high in 1986 (1.8 to 2.0 million fibre-km) by about 10% in 1987 and is forecast to fall by a further 10% in 1988 before the growth in local loop application begins. In the USA, representing over 50% of world usage, this represented a fall in value terms from $774m to $701m 1986 to 1987. AT & T expansion accounted for much of the change in market share of the various fibre processes.

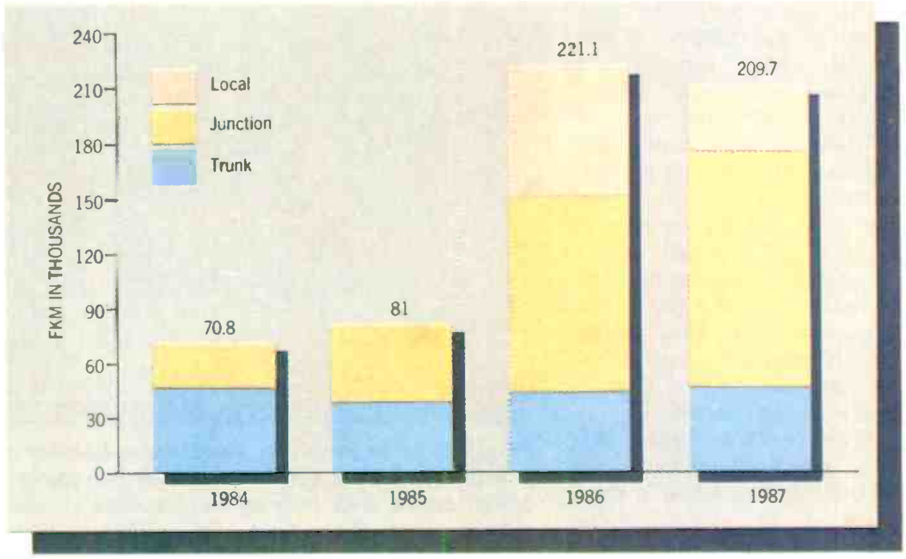
DATAFLO

STC Dataflo is a unique 'cable within pipeline concept' which allows optical fibre cables to be deployed in live pipelines over many kilometres without interrupting operations.

The cable is of rugged dynamic multi-fibre construction specially designed for the environment of pipelines. Single or multimode tightly buffered fibres are laid helically around a centre strength member and then sheathed. The outer sheathing material will be selected for liquid compatibility – water pipes, oil pipelines or other onerous environments. The cable is solid filled for hydrostatic pressure performance up to 70 bar if required (qualified to 150 bar).

The cable is introduced into the pipe through a special glanded entry system. A drag-inducing device, drawn by the fluid flow, guides the cable toward the previously prepared exit point, where it is accurately positioned, captured and retrieved through special seals.

Suitable for pipelines over 50mm in diameter, installation can be achieved at the rate of up to 3km/h including bends and vertical sections. This method offers major advantages for cable installation within built-up areas where the cost of civil works (typical quoted figure of £70/metre), is significant for duct instatement. With Dataflo, access is only necessary at entry and exit points to the pipeline. Two installations have been carried out in the South of England during 1987, involving deployment in water pipelines to provide communications and control circuits for local water boards.



British Telecom's demand for optical fibre increased almost threefold from 1985 to 1986. With requirements for junction applications growing apace, the procurement of high count cables for the recently inaugurated City Fibre Network created unprecedented demands. Cable suppliers, able to introduce large volume manufacture (STC's awards in 1987 were over 100,000 fibre-km) have been able to make dramatic reductions in fibre and cable costs.

optical fibres to the home, offers Mercury a major competitive opportunity.

Cable sub-system developments

The cost of installation of any cable-based network comprises a significant proportion of total cost, particularly within towns. Methods which minimize the distruption caused by civil works are likely to becoming increasingly adopted both for local and trunk applications.

STC's Dataflo for example can be installed within pipelines through a special glanded entry system and can be deployed in live pipelines over many kilometres without interrupting operations. As access is only necessary at entry and exit points, civil work and its associated disruption and cost is reduced.

British Telecom's blown fibre uses air pressure to carry fibre bundles through installed tubes, see page 399. As demand increases, additional bundles can be blown into vacant tubes so that initial fibre investment is minimized. This also offers further flexibility as cable can be withdrawn and re-installed along modified routes.

British Telecom and Mercury are also adopting an American process by installing Mini-duct, a pre-lubricated duct with a draw rope already in place. Thus cables can be installed much faster, and in longer lengths. Further opportunities exist in the use of Cablecon from Integral Corporation, where any type of cable can be inserted in its own duct prior to installation. While allowing rapid installation, it will also allow an easy, cost-effective path for fibre modification because the original cable can be pulled and replaced with a new cable without removing the duct.

Until recently two methods were available for installing optical cables using the power grids which dominate the world's countryside. Firstly, an optical cable lo-

FROM PREFORM TO CABLE

Fibres are manufactured by three methods: inside vapour deposition (MCVD), outside vapour deposition (OVD) and vapour axial deposition (VAD). In the UK these methods are used by STC, Optical Fibres and Pirelli General respectively, the last using a Japanese process. In the MCVD process, which is the most common and most flexible, a preform is produced using gasses deposited on a glass substrate, and the control of both rate of deposition and material content is of crucial importance. The collapsed preform is heated and drawn to produce an extremely fine strand of fibre. For single-mode fibre, the product manufactured in the largest volume, light is constrained to travel in a single path through the central core of the fibre measuring 9nm. This fibre is now being drawn in 43km lengths in volume manufacture by STC.

The fibre is cabled in any number of ways for use within buildings. The most common designs involve plastics tubes containing one or more fibres which can be stranded together to offer very high fibre counts: a significant volume of 96-fibre cable is installed in BT's City Fibre network in London. Other designs include tightly buffered fibres where the fibres are coated in plastics (currently used in tail cables to make the final link to the equipment), open channel designs where the fibres are located in the slots in a cartwheel design and ribbon designs where fibres are bonded together to form a ribbon and inserted into a tube or slot.

The fibre is generally required to operate at 1300 and/or 1550nm wavelengths where water absorbtion is minimized and signal strength can be maximized to allow long distances between repeaters.

Major Fibre Manufacturing Techniques

OVD	MCVD		VAD
Corning	AT & T	NKT	Sumitomo
&	Northern	L.M.Ericsson	&
Licensees	Telecom	Dawoo	Licensees
Lightwave	STC	AEG	
	Philips	GEC	
	Alcatel	Research	

Corning Glass Works have patents covering both outside vapour deposition (OVD) and some aspects of MCVD (inside vapour deposition). Key manufacturers in the US e.g. AT & T, Alcatel (previously ITT) and Northern Telecom have cross-licensing arrangements with Corning.

cated inside the earth conuctor at the summit of the towers, and secondly, a flexible cable wrapped around one of the conductors.

While the first necessitates replacement of the earth conductor and is, therefore, expensive, and the second will need to be replaced should subsequent restringing be necessary, both have one major drawback. They depend on a conductor for support and can only be installed with at least one power circuit off.

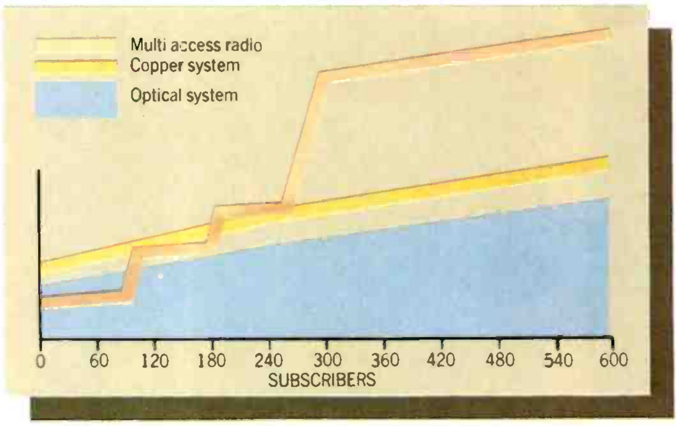
Self-supporting cables capable of spans of over 500 metres regularly found in most networks, are completely independent of the power distribution function of the grid. They are non-metallic and so can be installed safely without any interruption to the power network.

A Fibrespan cable has now been installed at Leatherhead for 18 months unaffected by the recent 100 mile/h winds. With tensile strength of 65,000N, three times the maximum operating level projected for worst-case wind and ice loading conditions, the cable is immensely strong.

The design involves a single glass-reinforced plastics rod pultruded with a longitudinal slot, into which fibre ribbons are laid. The cable is then filled with a hydrophobic gel to exclude moisture and prevent vibration but allow fibre movement. A cap then covers the slot and the cable sheathed with a specially formulated anti-tracking thermoplastic sheath to resist the degradation caused by the electrical environment.

Allowing up to 24 single-mode fibres to be contained (protected but easily accessible for splicing) in its fibre ribbons, Fibrespan can offer a communications network for an electricity board's own use or an alternative, cost-effective solution for a network operator.

Over the next six months cable will be installed in South East England as well as in Canada in extreme conditions where temperatures of 50% below zero are expected.



Proximity to an exchange, density of subscriber clusters and growth expectations all contribute to system choice. In general, optical cables, with their inherent bandwidth, are more cost-effective where the number of subscribers is high. In a rural application using optical cables and digital multiplex, while initial cost is higher than for a radio system, incremental costs of expansion for new subscribers and new services is much lower.

Edited from information supplied by Nick Bishop, market planning manager, STC Telecommunications Cable Products Division, Newport. Tel 0633 244244.

COMMUNICATIONS

OPTICAL FIBRE: PROGNOSIS AND ECONOMIC IMPACT

Twenty years on Charles Kao looks at how far his revolutionary idea has come, and where it's going

The prognosis for optical fibre is bright. As we progress into the post-industrial-revolution era we turn towards an information-intensive society where optical fibre is an essential component. Just as the motorways, autobahns or inter-state highways permitted the development of the modern transportation system, optical fibre will become our information arterial highway, providing the transport system for our information traffic. Fibre extends its usefulness into the design of sensors, transducers and processors. Fibre elements have the obvious advantage of being compatible with the transmission medium. Thus, as fibre performance continues to improve and the infra-structure of related technology continues to build up, the range of applications of optical fibre will continue to widen.

Fibre loss of silica fibre is close to its asymptotic value of about 0.14 dB/km at 1.55 µm wavelength. The fine tuning of this loss is aimed at achieving a practical single-mode fibre with low dispersion over a spectral region and which can be manufactured at a low cost. More basic work on an exact electromagnetic solution for waveguides with frequency-dependent and profiled index distribution will improve fibre design. The basic work on glass-material-formation mechanisms and its relationship to scattering, radiation hardness, refractive index and non-linear coefficients will substantially increase our ability to tailor the fibres to specific applications. Continuing work on new fibre-fabrication methods promises to reduce the basic cost further, so that single mode fibre cost will one day be less than the cost of a pair of copper wires.

The sol gel process, in which the glass-constituent material starts in liquid form, and the mechanically shaped preform technique, which starts with soot material in powder form, are both volume-production techniques requiring low capital investment and a high-efficiency usage of raw materials. They hold new promise in reducing fibre cost. On the other hand, the improvement of traditional techniques also indicates an improvement by a factor of 2 to 4 times through up-scaling, and an increase in fabrication speed and yield.

Silica fibre, with its excellent mechanical characteristics together with the abundance of the raw material necessary for its production, will constitute the bulk of transmission fibres; these will be single-mode type. Except for repeaterless applications where repeater spacing must be as long as possible, i.e. for inter-continental trunking, trans-oceanic links or inter-island links having an intervening space of greater than 200 km, silica fibre is adequate. For trans-oceanic and island-hopping applications a low-loss fibre with a repeater spacing-bandwidth product of $\sim$1000 GHz km is needed. This is indeed a challenge even if current materials work indicates that 10^{-3} dB/km is, in principle, possible for operation at 4 to 10 µm wavelength. Indeed, fluoride glasses, chacolgenide glasses and infra-red transmitting crystals should have the low losses as predicted if material structure can be controlled and impurities differentiated and removed. After that, the operating wavelength must be constrained to around the zero dispersion point with a nominally single-frequency source. The physical properties of the fibre must also be addressed. Most material is difficult to make, contains toxic components and is unstable, hygroscopic or susceptible to environmental attack.

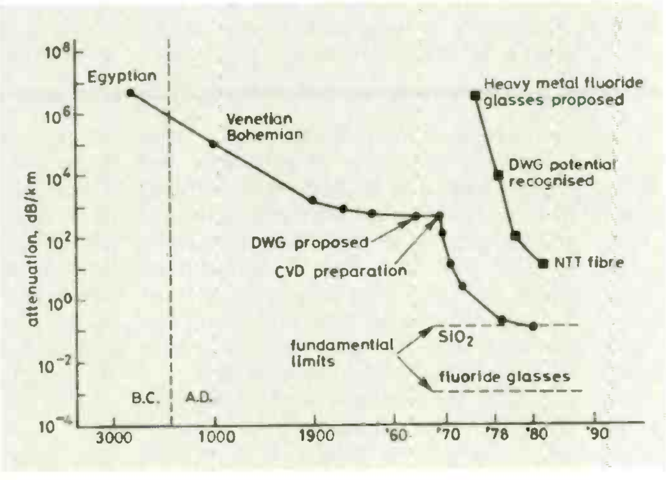


Fig.1 Fibre attenuation over the past and projected to the future

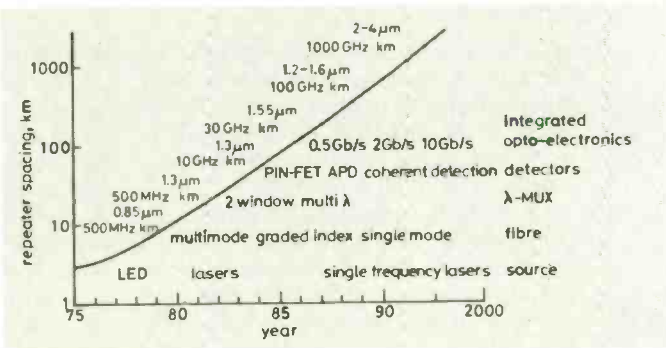


Fig.2 Key milestones for fibre-performance (spacing) projection

Fibre loss over the past, and projected to the future, is shown in Fig.1. The key milestones for fibre-performance projection expressed in bandwidth-repeater-spacing, together with the development of key components and techniques in associated technologies, is given in Fig.2.

It is appropriate to note that the bandwidth-distance product is capable of handling 1000 GHz over 1 km. This raises the issue that the signal-processing speed at the terminals should be very substantially increased in order to fully utilise, if needed, the bandwidth provided by the fibre. Currently fibre systems have been designed to handle signals up to 2·24 Gb/s. Highest bit-rate signal transmission demonstrated is below 10 Gb/s. Two pertinent questions are: (i) is 10^{12}b/s or terabit rate possible for future optoelectronic components; (ii) If 10^{12}b/s can indeed be attained, how should the design of signal-handling systems be changed to take the advantage of such high signal-

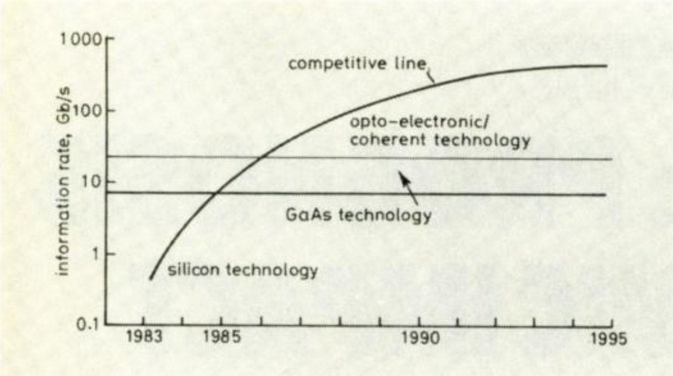


Fig.3 Projection of high information-rate technologies

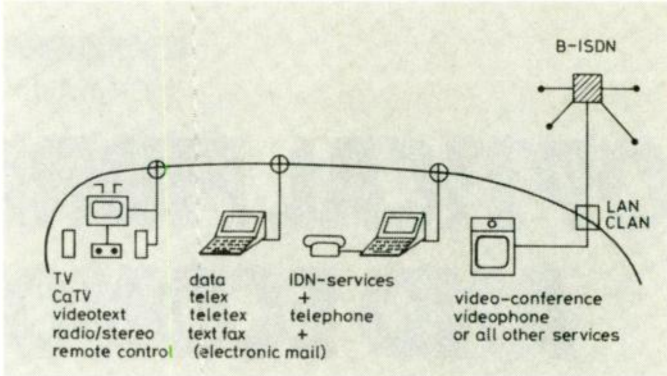


Fig.4 Broadband communication in integrated or separate networks.

processing speed. These questions are particularly timely since the transmission capabilities of the fibre are adequate to cater for these signalling rates. Moreover, several applications indicate that the demand on information capacity, transmission and processing rate can make use of such high signalling rates. For example, if video phones at 70 Mb/s per channel are as densely installed as telephones at 64 kb/s per channel today, the transmission requirement would be 1000 times the current trunk-systems transmission rates of 560 Mb/s; hence, 560 Gb/s are needed. Certainly one should also revise the strategy of all signal-processing methods, which hitherto have been designed to conserve bandwidth. With bandwidth available in abundance, signal-processing schemes which are wasteful in bandwidth, but which simplify the overall system design and are more cost effective, should be entertained.

Not surprisingly, optical fibre in an information society is stimulating research into high-speed optoelectronic components. It is speculated that the combination of electrons and photons used appropriately can result in effective signal-processing rates beyond what can be achieved in pure electronics for both silicon and GaAs technologies (see Fig.3).

The evolution of optoelectronics is taking place. Advances in electronic-material fabrication techniques, such as MBE and MOCVD, are making new semiconductors with 'tailored' properties possible. This is sometimes referred to as bandgap engineering. Study of the electron-transport mechanism in semiconductor material and the availability of ultra-fast optical-spectroscopy diagnostic techniques are together causing significant steps to be made toward realising truly integrated optoelectronic functions, which will evolve into system building blocks for ultra-fast systems. In the meantime broadband communication in integrated or separate networks is being promoted, particularly strongly in Europe. Fig.4 raises the scenario of B-ISDN, or separate networks.

Field trials are providing opportunities to rest not only technical feasibility, but also customer reactions to various experimental services. These activities will increase significantly in the near future when the benefit of such a system begins to be perceived, not in terms of the extension of conventional communication services such as telephones to video phones, data to ISDN etc., but in terms of new services based on fulfilling real information needs. Already stock-market information, instant banking transactions and legal search services have created a strong demand. New services backed by good interactive data bases can provide the competitive edge in doing business in all sectors. We must move closer to being able to master our data and knowledge resources.

Optical Fibres by Dr C.K. Kao, from which this article is adapted, will be published in June by Peter Peregrinus Ltd for the IEE, price £35.

Networking in the nineties from page 384

nect, or OSI, Reference Model. ISDN occupies the bottom three layers in the model. The upper level standards assure that, once computers are communicating, the machines can actually do useful work, no matter what the application or architecture.

But I want to leave you with an even more immediate challenge. And that is the challenge of developing ways for today's data users to migrate easily toward ISDN. Large data users have invested heavily in their existing approaches, because we have not been adquately meeting their needs. These data users could not switch right away, even if ISDN were already ubiquitous and fit all their needs. We must offer them products and services that let them taste the benefits of ISDN, without having to swallow them whole. We must offer them products and services that fit easily into their existing data networks, and that allow them to evolve their networks gracefully toward ISDN.

Clearly, the years ahead will be years of challenge for our industry. Yet despite all this challenge and change, let me remind you again about one thing that should not change. Just as it has for over a hundred years, our progress should be driven by the same three forces: evolving customer needs, technological progress, and networking. Our success will depend on how well we orchestrate all three to find solutions that are economical, dependable, flexible and usable. This is the lesson of our heritage, and the essence of our services to our customers and society.

Dr Ian Ross is president of AT&T Bell Laboratories, New Jersey.

Cellular revolution from page 381

ADVANCED CORDLESS
(CEPT Nov 1987)

TDMA	FDMA	EITHER	NO VIEW
Holland Germany Denmark Switz. Sweden Spain	Finland UK	France	Belgium Norway
6	2	1	2

price benefits, it would be a very great pity if CEPT were to divide up along lines of vested interest. Were this to happen, it would be an abuse of the standards process which it might not be too harsh to describe as a conspiracy against the consumer.

By using the example of cordless telephone and combining it with the lessons of digital cellular, I have tried to sound something of a warning that the single European market for telecommunications will be stillborn unless we recognise that a new climate of opinion in the world of radio affairs is absolutely indispensable.

If the conflict, mistrust and self-interest comes to dominate the standards process then it will discredit itself to the point where any progress becomes impossible. For an industry which is part of the critical path of the economy of Europe, I hope that I may be forgiven for suggesting that it is up to all of us to try and take a more statesmanlike view.

Professor William Gosling D.Sc. is technical director of the Plessey Company plc.

COMMUNICATIONS

BATTERY ADVANCE FOR CORDLESS COMMUNICATION

Alfred Tseung explains how a 'solar'-charged Ni Co battery could revolutionize power supplies for portable devices, given adequate funding.

The size and weight of mobile communication devices are undergoing a rapid miniaturization process. But the traditional nickel cadmium batteries, despite some developments in the past five years, have failed to keep pace. This article reveals the characteristics of a novel nickel cobalt battery being actively developed at The City University and the prospects of integrating this rechargeable battery into a photovoltaic system for powering mobile telecommunication devices.

The power demand for mobile radios is quite different to other applications. The power requirement in the receiving mode and transmission mode can vary by a factor of ten, therefore batteries should be capable of working at high current densities periodically. Nickel cadmium batteries fulfil this function, but they have a relatively low energy density, around 30Wh/kg. Moreover, since mobile radios are relatively costly, the battery cost is only a small fraction of the total, so it is feasible to consider the use of other couples which may be ruled out on cost grounds for other applications.

Ideally, the novel battery should provide improved energy and power density, and be able to replace the existing battery without any need for design changes in the mobile radio system.

On the other hand, some battery systems have different voltage and operational characteristics. It is therefore important to have extensive consultation with manufacturers and users before deciding whether to go ahead with the development of such batteries. This will involve a detailed technical economic analysis of the new design and substantial retooling of the radio system – mere consideration of battery cost and performance is not enough.

Nickel cobalt battery

The full reaction for a nickel cobalt cell is

$$Co + 2NiOOH + 2H_2O \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} Co(OH)_2 + 2Ni(OH)_2$$

Cell voltage: 1.28V

The electrochemical reaction involves oxidation of cobalt instead of cadmium. The theorectical capacity of cobalt is 0.909 Ah/g compared to 0.476 Ah/g for cadmium. Moreover, unlike the nickel cadmium type, the nickel cobalt cell can be recharged at 1.5 volts without gas evolution, and there is no need to provide excessive cobalt hydroxide to ensure the reduction of oxygen during the charge cycle. (In the case of Ni-Cd, up to 50% excess Cd might have to be added to the electrode.)

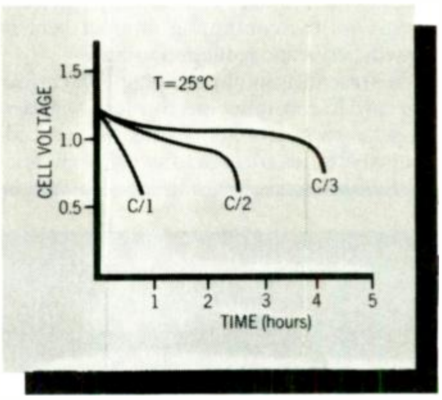
The energy density of a Ni Co battery is estimated to be 58Wh/kg compared to a maximum of 35 Wh/kg for Ni-Cd. Figure 1 shows the discharge curves of Ni-Cd at low C-rates and the discharge curves at high C-rates are shown in Fig.2. The cost of cobalt power ($15/kg) is significantly higher than that of cadmium ($2/kg). However, based on consideration of the capacity of the cobalt anode at 80% utilization, a cobalt electrode will have a capacity of 0.73 Ah/g as compared to 0.23 for the cadmium electrode (50% utilization). Therefore, the price difference for a 1Ah battery will be

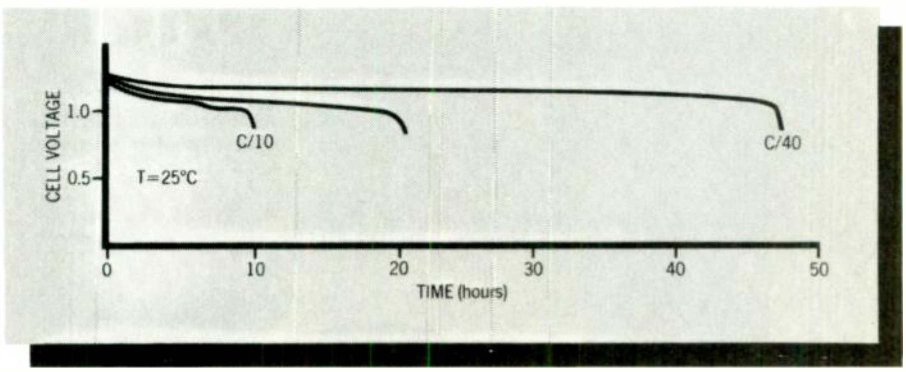
1.37g cobalt at 1.06 cents
4.35g cadmium Cd at 0.87 cents.

In addition, the manufacturing cost of Ni-Cd and Ni-Co batteries should be very similar and therefore it is not expected that Ni-Co batteries will be significantly more expensive than Ni-Cd batteries. Cobalt is more susceptible to self-discharge on open circuit than cadmium. However this would not be a problem in mobile radios since they are used and recharged almost everyday.

Thus, the Ni-Co battery has the following advantages:

- Similar working voltage to Ni-Cd battery and hence can be used in existing devices.
- Twice the energy and power density of Ni-Cd.
- Similar production cost and only marginal increase in raw material price.





Much development work needs to be done, especially long-term life tests and optimal design and individual cell components. However, it is not envisaged that these problems would present difficulties provided adequate funding is forthcoming.

Solar batteries to open up market

The Ni-Co battery is the most promising candidate for incorporation in a photovoltaic power system. It will provide for the first time a really practical system for the development of cordless devices where there is no need to recharge the battery from the mains. This will open up a completely new market.

The price of photovoltaic arrays is getting cheaper and their efficiency is improving. Table 1 lists some of the recent developments.

TABLE 1 Price forecast of different solar panels

	1985	1990	1995
Single-crystal silicon:			
Efficiency	11%	15%	16%
Profitable price ($/Wp)	6.5	4.5	3.0
Concentrators:			
Efficiency	14%	17%	20%
Profitable price ($/Wp)	5-6	3.3-4	2.5
Ribbon/sheet:			
Efficiency	10%	11%	14%
Profitable price ($/Wp)	7.5	3.3	2-3
Cast ingot:			
Efficiency	11%	13%	15%
Profitable price ($/Wp)	7	3.5	3.0
Amorphous silicon:			
Efficiency	5%	8%	10%
Profitable price ($/Wp)	5-6.5	5-6.5	2-3
Average mode price ($/Wp)	6.5	3.5	2.5

Source: Photovoltaics: 1983 Status – 1990 Forecast, by P.D. Maycock (11th Energy Technology Conference, 1984)

This suggests that the rapid cost reduction of the price of photovoltaic arrays in the next eight years will lead to their widespread use. This is borne out by the available world-wide statistics showing the growth in photovoltaic array production between 1982 and 1983 (Table 2).

TABLE 2 Growth of photovoltaic array production

	1982		1983	
	MW	%	MW	%
USA	5.7	61.3	13.1	66.4
Japan	1.8	19.3	5.0	23.0
Europe	1.6	17.2	3.3	16.2
Others	0.2	2.2	0.3	1.4
Total	9.3	100.0	21.7	100.0

The annual growth rate of photovoltaics is truly phenomenal – over 133%. The figures for later years were not available during our preliminary computer search but the growth rate is expected to be comparable, especially in view of the continuing improvement in the efficiency and reduction in cost.

At present, amorphous silicon solar arrays are used in consumer electronics – watches, cassette recorders and radios. Nickel cadmium batteries are used to store the electricity and provide power during heavy demand cycles. However, the relatively low energy and power density have precluded their widespread application to areas where the power requirement is more stringent, for example, mobile telecommunication equipment and portable computers. Since the efficiency of single-crystal silicon solar panels is expected to reach over 15% by 1990 with the price decreasing to $4.5/Wp, and assuming that such panels are used indoors, the amount of electricity produced by the panel may be reduced to one tenth of a watt. The basic power requirement for a portable cellular radio is likely to be 100mW for two hours a day and 10mW for 22h. Therefore, the total energy consumption is in the range of 0.42Wh/day. Since the solar panel should be capable of producing 0.8Wh during a working day, there should be sufficient electricity to recharge the nickel cobalt battery. Thus a completely cordless portable telecommunication device will become a practical reality.

Professor A.C.C. Tseung is director of the chemical energy research centre, City University, London.

COMMUNICATIONS

BLOWING A NETWORK

This novel technique from a British research laboratory simplifies optical fibre installation for in-building and local area networks. And attracts licensees.

Anyone who watched the Royal Institution Christmas Lectures televised a couple of years ago couldn't have failed to have been impressed by the demonstration of 'fibre blowing'. A hollow transparent tube 'laid' through the audience was visibly threaded with an illuminated fibre – blown by compressed air – for all to see in a matter of seconds. A most impressive demonstration of the way fibre technology continues to break new ground.

The novel technique demonstrates how easily and with relatively little care a blown fibre cable can be laid, a particular concern for data networks on account of damage that might be caused during installation, especially on a circuitous route. Fibres laid by BT Research Labs using this technique have been shown to experience very little strain on account of the distributed viscous nature of the installing force. One experiment using an optical phase delay method to monitor the strain during blowing along a 140 metre route with compressed air at 6 bar (90 psi) showed this to be as little as 0.03%. This enables engineers to guarantee the system for 25 years without the need for water barriers or cable pressurization.

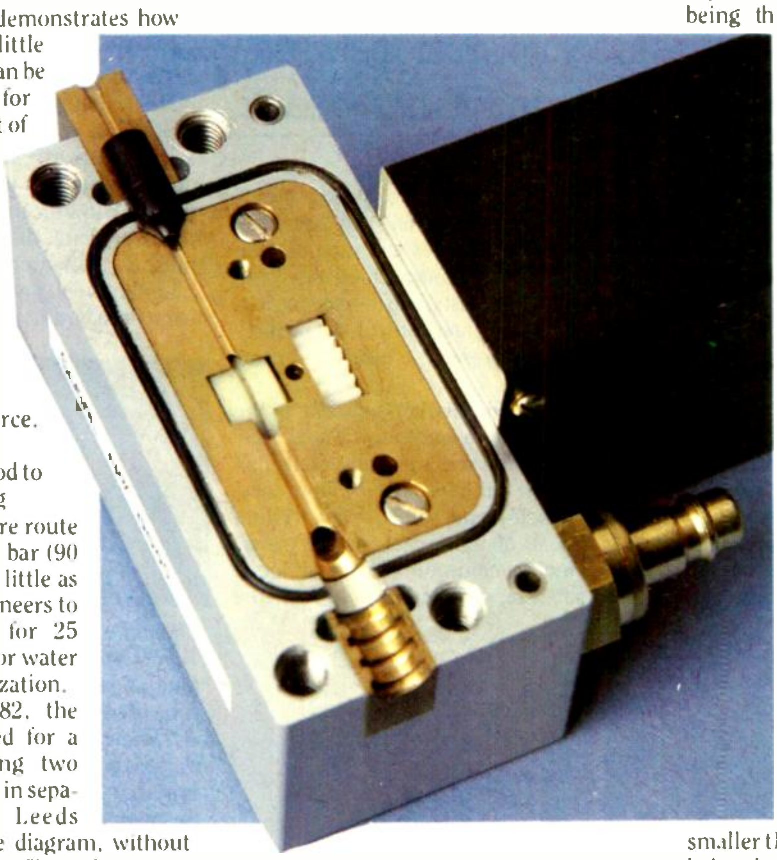
Patented first in 1982, the technique was first used for a trial system connecting two computer local networks in separate buildings to a Leeds telephone exchange, see diagram, without splices in the graded index fibre. The system has been in constant use since 1984 and has since been considerably extended using further multimode fibre. The latest addition, a junction link between Leeds, Basinghall and Hunslett exchanges in single-mode fibre 3.2km long, was installed last year – probably the longest spliceless link in the UK.

Since the Leeds trials many systems have been installed throughout the UK – Manchester, York, Bradford, Preston and other cities can now boast optical systems using this unique technology.

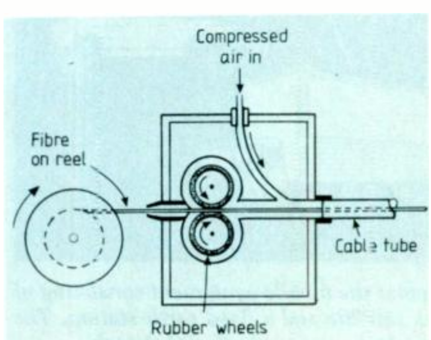
As BT's licensee Optical Fibres at Deeside increases the range of fibre types and bundle sizes available, BT will adopt the concept increasingly in its districts for local network distribution. They are currently installing a City Fibre Network in London using blown fibre links to major customers in the capital's square mile. Sumitomo in Japan and Corning in the US are also licenced by BT.

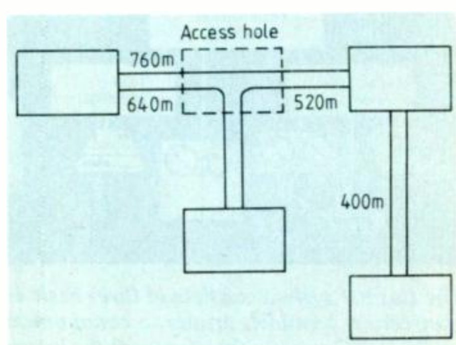
Another area of increasing interest to BT is the expansion of 'in-building' networks for dealer's desk-top terminal links to mainframe computers and multiplexers. The blown fibre technique, with field-terminable connectors, allows the 'spliceless-link' concept to be fully exploited, a major advantage being the speed of installation – up to 100m/min. The delicate fibre is the last link to be installed in the network, the tube system taking the brunt of the multi-discipline tradesmen's boots during the construction phase. No retro-splicing of expensive cable with this system. Blown in and working within minutes, the technique is unique in its degree of flexibility and 'future proofing'. Expansion, re-configuration and latest technology can all be offered within minutes and with minimal disturbance once the network tubes are installed.

● Earlier this year a trial installation around 130 dealer desks in the City using the Reuters Rich system was completed by Optical fibres and Architron Ltd under licence from BT. Announced at Frost & Sullivan's February seminar on fibre optics, Architron screen and keyboard cards are linked through 9mm SMA connectors by eleven 50/125μm fibres from each desk in runs up to 50 metres long. The 3.5mm i.d. tube is smaller than BT's 6mm type, its chief feature being the flexibility it offers in the number of fibres. An individually buffered fibre of overall diameter 0.5mm has been developed along with a new Venturi blowing head that will blow up to four fibres into the tube.



Rudimentary blowing 'head' used in the Leeds trial (below) is superseded by BT's patented design above, which enabled a spliceless link of 3.2km.





COMMUNICATIONS

WORLD-SCALE MOBILE DATA COMMUNICATIONS

Since it began operations in 1982, Inmarsat has revolutionized maritime communications. More than 6000 ships at sea are using the Inmarsat system to take advantage of high quality voice, telex and data links from virtually anywhere in the world. Six years later it still operates the world's only mobile satellite communications system and for the past few years there has been consistently growing demand for its use in both the aeronautical and land mobile contexts.

In the wake of last year's World Administrative Radio Conference in Geneva, the Inmarsat council has begun steps to broaden its charter to provide land mobile services as well. Inmarsat has already been accorded the institutional competence to offer aeronautical communications and the debut of those services is imminent.

The WARC decision was to permit land mobile communications in the L-band, that band of frequencies where Inmarsat currently offers maritime services. As a result, Inmarsat is planning a comprehensive range of new services designed to meet the needs of long distance and remote area travellers – trucks, container operators, trains, buses, businessmen and vacationers, explorers and adventurers. The services will include two-way satellite message communications, one-way message broadcasts, world-wide paging, remote monitoring and control, data collection and in the foreseeable future full voice communications.

From next year Inmarsat's new service will allow suitably-equipped vehicles to communicate between any two points on the earth

The land mobile market segment is the largest of all mobile communications markets. In 1984 there were, globally, some 365 million private vehicles, 102 million commercial vehicles and some seven million buses. Not all of these vehicles are candidates for mobile communications, let alone mobile satellite communications. At the present, however, there may be well over five million vehicles equipped with some form of mobile radio equipment, whether cellular, u.h.f., v.h.f. or private and public networks.

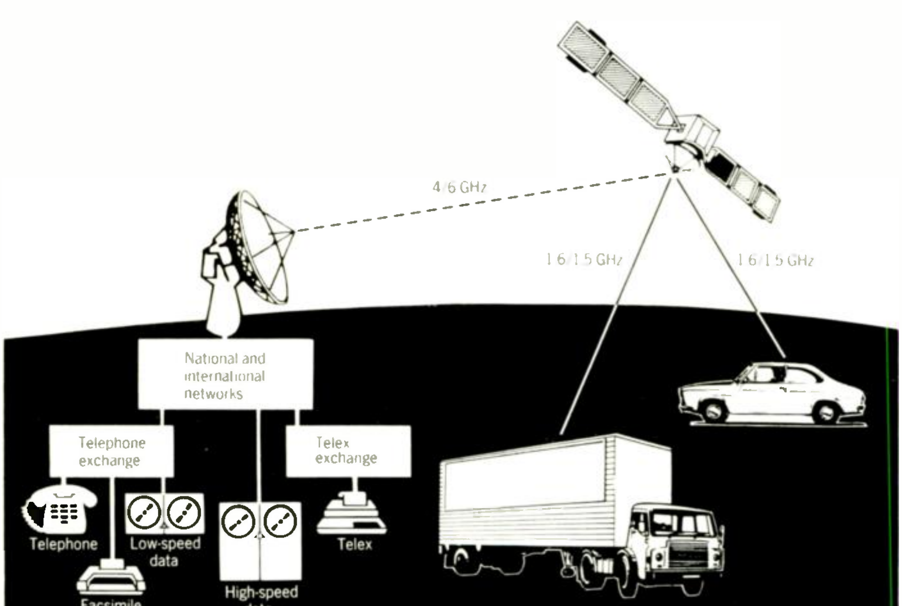
Vehicle cellular radio currently takes the major share of these markets, and though it is expected to grow further strongly, it will not be provided in all regions and areas where vehicles travel. Other forms of land mobile communications also have serious limitations (interference, lack of privacy, lack of spectrum). Further, current systems offer a rather low level of inter-operability, making comunications for vehicles operating over long distances or a wide area difficult, if not impossible.

Inmarsat will provide land mobile services using Standard-C, developed to meet a maritime need for low-cost text communication via small, light and inexpensive equipment. Adapting this system to the land mobile environment is a relatively minor task which is already well advanced.

The only thing which distinguishes the Toyota Spacecruiser Van that Inmarsat uses for land mobile trials is the omnidirectional conical antenna made by Denmark's Thrane & Thrane and mounted on a roof rack. One way trials have already been conducted, and two way tests start this month in Italy, Germany, Britain and Spain.

In cooperation with the telecommunications agencies of 12 European countries, Inmarsat is conducting trials of the Standard-C system throughout Europe. So far tests in the UK, Belgium, France, Spain, West Germany, and Netherlands have met with resounding success.

Standard-C communicates text messages to and from mobile terminals operating virtually anywhere. The messages can be in any type of text and be transmitted in a variety of modes – telex, electronic mail, packet-switched data and even graphics. It is an all-digital, store-and-forward system



The Imarsat system consists of three basic elements: the mobile equipment consisting of transceiver, terminal, printer, a communications satellite and a fixed earth station. The earth station provides interface with the international telecommunications network.

operating at 600 bits per second between the mobile, the satellite, and the receiving/transmitting earth station. One of 20 earth stations reformats messages into the chosen mode and transmits over the international telecommunications network to their destination.

The mobile equipment is tiny with the electronics unit itself no larger than the average car radio and a simple, omnidirectional antenna which could be flush-mounted or even hand-held. Its power requirements are minimal. Standard-C could be easily fitted to any vessel, vehicle or into a lightweight, portable briefcase or backpack unit. And with an RS232 interface it can work with personal computers, keyboards, printers and telex machines, as well as with automatic sensors.

The vehicle used so far in the trials is a Toyota Spacecruiser van fitted with an EGC terminal manufactured by Thrane & Thrane of Denmark. EGC, or Enhanced Group Call, is in fact a receive-only Standard-C designed for the distribution of marine safety and fleet management information. The antenna was mounted on a roof rack giving it a height above the road of approximately two metres.

Experimental results

Receiving continuous Standard-C messages, the mobile terminal is programmed to provide a printout approximately every 15 minutes, from which is calculated the number of received error-free frames per 100 transmitted. In addition, a lap-top computer connects to the receiver so that frame-by-frame results can be compared in real time to the environment.

The different landscapes encountered included many potential obstacles to a satellite communications link. Among those common to most principal routes were bridges and interchanges, landscaping, overhead lighting and gantries, tunnels, passing trucks and land barriers like mountains and places where roads have been cut into hillsides.

The most encouraging aspect of the results was that most of these potential obstacles seemed to have little or no effect on system performance. Because the Standard-C signal is based on an interleaved 8.64 second frame that can cope with maritime fades exceeding one second at a cruising speed of 90 km/h, very few of the obstacles caused packet loss.

The major loss of frames was due to tunnels, passing trucks which can obscure the satellite for periods longer than one frame and obscuration by land. With a higher, truck-mounted installation, performance would be improved. Nonetheless, on the open road reception was always well over 90% and often much higher or even perfect.

The fact that reception was sometimes less than perfect may not be particularly important because the trials were conducted using receive-only equipment. With a Standard-C terminal, which is expected to be a standard fitting for land mobile applications, the transmitting station is sent confirmation by the mobile of any messages successfully received.

In the absence of this acknowledgement, the message will be retransmitted several times. Thus the reception of Standard-C messages, regardless of terrain, is expected to be 100%. If at the end of this sequence there is still no acknowledgement, the sending party is informed that the message was unsuccessful.

● First trials with a Standard-C transceiver are scheduled for this March when Inmarsat takes a mobile home equipped with Racal terminal on a tour of Italy, West Germany and the UK. Commercial service is expected in the autumn of next year.

This Standard-C electronics unit measures 73 × 214 × 279mm and weighs in at 2kg. Any computer or printer with RS232 interface can be used. Inmarsat say that the cost of equipment will be less than US $5000; in full production it should be much less. Makers will be Racal, Danish company Thrane & Thrane, JRC in Japan and Sperry in USA.

WHAT IS STANDARD-C?

Essentially the Inmarsat Standard-C earth station is a fully digital microwave terminal featuring transmission and reception at a data rate of 600 bits per second throughout the bands designated for maritime communication (1.530-1.545 GHz downlink, 1.6315-1.6455 GHz uplink). To achieve this, it uses a system comprising five basic modules that fit into a package about the size of a car radio and which weighs less than 10 pounds.

Those five modules consist of a front end for signal reception and emission, a demodulator and decoder module for received messages, a modulator and encoder module for messages to be transmitted, an access control and message handling processor and user interface.

Signals are coded in a 1200 symbols-per-second format which corresponds to a transmission rate of 1200 bit/s bit-for-bit redundancy at the system's 600 bit/s data rate. In addition, data is interleaved to facilitate correction should the signal be subject to any fading during reception.

Data transmitted to a Standard-C earth station is initially received by a non-stabilized omnidirectional antenna with a minimum gain over noise temperature figure (G/T) of −24 dB/K amplified, demodulated, de-interleaved and decoded into a standard ASCII message. After transfer to a minimum capacity 32 kilobyte buffer memory in the system's access control and message handling processor, the message is transferred to a data terminal by way of a standard RS232-C interface. The user is free to choose any kind of data terminal; in the case of the Inmarsat prototype, a commercial lap-top computer with liquid-crystal display was pressed into service.

After outgoing messages are composed on the chosen equipment, pressing a transmit button sets into motion an interleaving, coding and modulating process the exact opposite of that used for reception. At the front end, the signal is amplified to 20 watts before transmission. A synthesizer automatically tunes the earth station in 5 kHz increments throughout the band for both transmission and reception.

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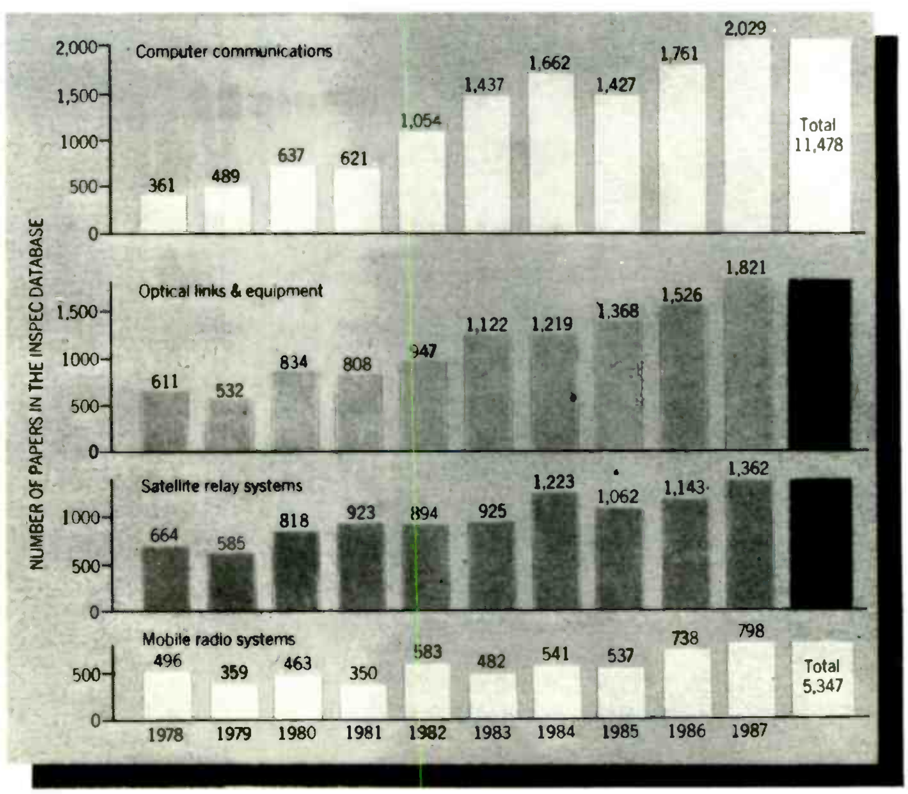
COMMUNICATIONS

COMMUNICATIONS BAROMETER

A ten-year look back on communications topics from the IEE's information services database, prepared exclusively for Industry Insight, shows the relative activity in areas of communications technology. Four areas – computer communications, fibre optic links, satellite communications and mobile radio – lead the field in electronic communications activity, pushing videotext, electronic mail and videoconferencing into the background. Videotext in fact registered 4,212 references, though last year's total of 436 papers was only half the peak activity of 1984 (831). And it's not really surprising that ISDN followed, with only 2,745, since it only became an issue in the eighties.

That is if the Inspec database is anything to go by. The source material for the database is the 4000 scientific and technical journals and 1000 conference publications scanned regularly by Inspec staff, and which produces about 250,000 new entries every year.

The database can be reached directly on-line by terminals connected to the public telephone network, or through ten on-line services around the world. For details of Inspec and how to consult the database, contact Inspec Marketing, IEE, Station Road, Nightingale Road, Hitchin, Herts, tel. 0462 53331.



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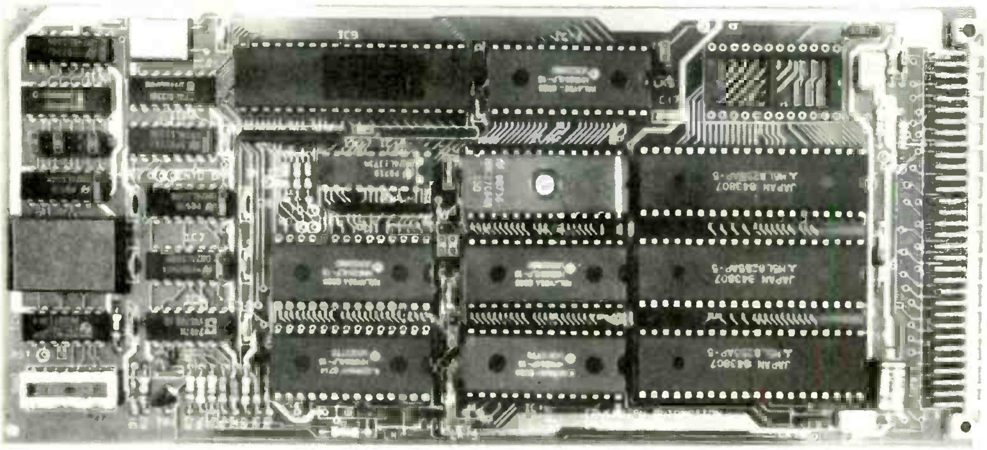

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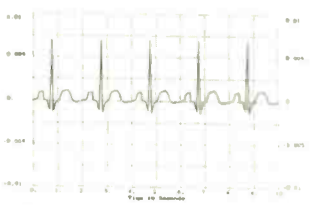
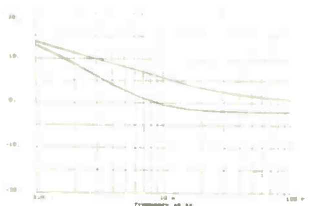


Waveform through switching circuit



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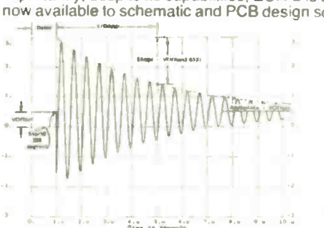
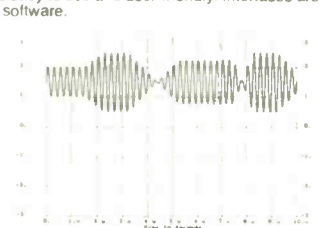


Internal generator programmed to produce sine wave with exponential amplitude decay



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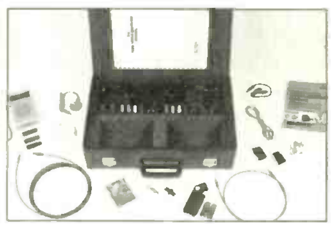

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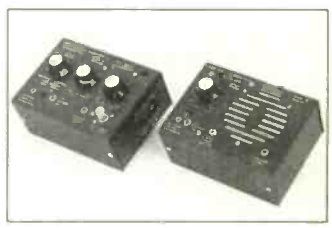

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Pioneers

16. Charles Kuen Kao, father of optical fibre communications

W.A. ATHERTON

Before the optical fibre era: heavyweight cable-laying in 1914 (STC).

In an age when satellite communications appear dominant it may come as a surprise that the cable-laying ships are at work in the Atlantic once again, following in the wake of the *Great Eastern* which laid the first successful Atlantic cable in 1866.

But optical fibre cables provide vastly more information-carrying capacity than conventional copper cables. They hold out the promise of the "fibred society". That is how many engineers see the near future, not least Charles K. Kao.

Until 1966, and the publication of Kao's paper written jointly with George Hockham on the possibilities of optical fibre communications, the business of communications was firmly limited to copper cables and the airways. That paper opened up a whole new world.

If an optical fibre with an attenuation as low as 20dB/km could be achieved, wrote Kao and Hockham, then optical cable communications would be feasible. Whilst existing figures were of the order of thousands of decibels per kilometre, they showed that, at least in theory, the 20dB figure was far from impossible. Four years later, Corning Glass in America achieved it and further reductions came quickly. Fibre-optic communications became a reality.

CHINA

Charles Kao was born on 4 November, 1933, in Shanghai. It was an ominous time and place to start life. Just two years earlier Japan had embarked on the conquest of Manchuria and the arrival of Japanese troops at Shanghai in January 1932 posed a threat to foreign concessions in China. The French concession in Shanghai, which was where the Kao family lived, was occupied after the attacks of 8 December, 1941 on Hong Kong, Malaya, the Philippines and Pearl Harbor. Against this background Charles Kao spent his childhood.

After the war the family moved to Hong Kong where British rule had been re-established. There, at St Joseph's College, Kao continued his secondary education. It was also at school (either there or in Shanghai) that Kao Kuen was given the name Charles, it being a common practice to give Western names to children learning English.

"The period up to around 1954 was a carefree time for learning in a congenial environment at an Anglo-Chinese Catholic school in Hong Kong", says Kao*. "The excellent education provided by the good teachers obviously gave me a very sound foundation in life."

For a sixth-form education, however, he left Hong Kong for London where he took A-levels at the Woolwich Polytechnic. This was followed by further study at the polytechnic for a University of London B.Sc. degree in electrical engineering which he received in 1957.

Kao then joined Standard Telephones and Cables Ltd (STC) at Harlow in Essex as a graduate trainee. Subsequently he became a research engineer at their laboratories (STL). STC was then part of the ITT Corporation, and Kao spent much of his working life being promoted around one or another part of the ITT empire in Britain, America and Germany. From 1961 to 1965 he studied for a Ph.D. at University College, London, whilst still employed by STL.

This easy movement around industry and between industry and university has been a characteristic of his life and one which he favours. From 1970 to 1974, whilst on "detached service" from STL, he was chairman and professor of the electronics department at the Chinese University of Hong Kong. Thereafter, at ITT's electro-optical products division in America, he rose to become chief scientist and director of engineering before moving to ITT's world headquarters as executive scientist. He even found time to spend a year at ITT's Standard Elektrik Lorenz subsidiary at Stuttgart in West Germany.

On 1 October last year he moved from ITT's Advanced Technology Centre in Connecticut back to the Chinese University of Hong Kong as vice-chancellor. One wonders what, at the age of 54, he will do next.

Whilst researching this article I asked Professor Kao whether he thought it important for university staff to move between academia and industry. He recommends it "if chance permits", and stresses the benefits of being involved in both teaching and administration as well as industrial activities including management. He writes from personal experience when he says, "These are ideal preparations to broaden one's perspective". This is a striking contrast to what is often seen as the career structure of engineering academics which frequently goes from student to research student to lecturer.

*Private communication.

STC

Telecommunications technology owed nothing to optical waveguides when Charles Kao joined STL in 1960. Through the 1950s the task had been to establish major transmission systems to cater for the increasing telephone traffic. As the new decade got under way research was aimed at establishing a long-distance microwave system using circular waveguides. Operating at millimetre wavelengths, this was seen as the big hope for the future as it would provide a very wide information bandwidth for telecomms traffic. Putting it into practice, however, was technically demanding.

However, not everyone at STL was working on millimetre microwaves. A research team led by Alec Reeves (inventor of pulse-code modulation) was studying a futuristic project to modulate the light output of hollow-cathode discharge lamps and find a way of guiding the light along the desired path. The opportunity offered by the wide bandwidth of optical communications was recognized. How to realise it in practice was not. Then in 1959 along came the laser.

"The subsequent invention in 1960 of the semiconductor laser light source," says Kao, "with its small size, ease of modulation, high output power, and prospective long service life really brought home the possibility of optical communication." Work began in earnest in Britain, Germany, France, Japan and the USA.

The problem definition was one with which telecommunications pioneers have been long familiar: to improve the signal source, identify the best transmission medium and make a better detector. E.H. Armstrong, A.G. Bell, Lord Kelvin, Charles Wheatstone, Samuel

Morse and even Stephen Gray back in 1729 had all battled with the same basic problem. No doubt a century from now others will be doing the same.

When the semiconductor laser arrived the previous favourite, the circular millimetre waveguide, faced an immature but lethal challenger.

Free air was the original idea for the transmission medium; but this suffers from bad weather and air density changes. Guided waves were soon considered, but just how to guide them was the question.

One method that people considered was to guide light waves through cylindrical pipes whose internal surfaces had been smoothed and given a highly reflective coating. Another idea was to guide the light along a straight path by using lenses arranged at regular intervals to refocus the light. Attempting to see the difficulty of a problem in retrospect, when one already knows the solution, is far from easy. As Kao has put it, "A good and convenient transmission medium was not obvious".

Kao was assigned to work with others on optical communications in 1963. By the following year it was apparent that "dielectric waveguides" (i.e. solids rather than pipes) had some potential advantages. They would be small, immune from atmospheric disturbances, and they might take light round corners without mirrors.

By that time, glass-fibre light conductors were available. Bundled by the hundred or thousand they could give small-scale illumination and convey images if arranged in a two-dimensional array. Later they were also used for ornamental lamps.

These light conductors had a transmission loss of about 3dB/m and that high loss was one of the main problems. They were made with a large circular-cross-section core with a concentric thin cladding around it. The refractive index of the cladding was much less than that of the core. That was fine for the applications so far, but was it the best arrangement for a communications cable?

These material and structural problems were the ones that Kao was addressing towards 1965. "What are the loss mechanisms and can these mechanisms be totally removed?" is how he has expressed the problem. "It appeared that no one had really asked this question before."

As work progressed, the worst absorption was found to be caused by impurities in the glass, especially iron. Happily the theoretical limit of scattering loss appeared to be only 1dB/km with a wavelength of 1m – a lot less than the 1000dB/km or so achieved in practice. "As I probed each point deeper the answer almost invariably was incomplete."

By the end of the year there was enough information to go into print and Kao wrote a paper jointly with fellow research engineer George Hockham. "Dielectric-fibre surface waveguides for optical frequencies" was published in the *Proceedings of the IEE* in July 1966. It concluded that "a fibre of glassy material constructed in a cladded structure represents a possible practical optical waveguide with important potential as a new form of communication medium".

Above: Professor Charles Kao (STC).

Main picture: laying TAT-8, the 280Mbit/s Atlantic optical cable (BTI).

The promise of greater information capacity and lowered costs has been fully realised in the years since 1966 and Charles Kao still burns with enthusiasm for the unfolding potential of fibre-optic broadband systems.

As lesser mortals enjoyed the World Cup football finals that summer, others were becoming equally, if not more, excited by the revelations given in the Kao and Hockham paper. The required fibre had been described and a target figure for the loss had been set at 20dB/km. The figure was, said the authors, "difficult but not impossible".

The paper had been reviewed for the IEE by John Bray, then director of research at the British Post Office research station. He initiated research at the Post Office laboratories (now British Telecom) and gave the lead for others to follow. Meanwhile Kao had established contacts with other researchers in Britain and Germany and had visited the United States and Japan.

In 1970, just four years after publication of the paper, Corning Glass in America achieved the target of 20dB/km. By 1976, 1dB/km had been reported and the first experimental optical fibre telecommunications systems were in operation. In all it has taken about 20 years to go from concept to large-scale application, and 25 years to the laying of an Atlantic cable.

THE FUTURE

Charles Kao has received honours from around the world for his work on optical fibre communications. He has published books on the subject and many papers and holds around 30 patents. He is very firm in his view of the bright future that optical fibre communications offers to an 'information society' hungry for voice, data, television and other communications.

Before leaving ITT's Advanced Technology Center to go to the Chinese University of Hong Kong he headed a widespread team seeking to achieve communication bandwidths measured, not in megabits per second, but in terabits per second (10^{12}bit/s). "These days", he said in an interview, "the opportunities to do research are great... the more we discover new things, the more we find that we have bits and pieces that we're not too sure of."

He sees optical fibres as vital to our future society and says, "I will be happy to be a participating member of that fibre society".

Next: John Randall, Harry Boot and the cavity magnetron.

Tony Atherton works at the IBA Harman Engineering Training College, Seaton, Devon. His book, From compass to computer, a history of electrical and electronics engineering, is available from Macmillan in paperback at £11.50.

TELEVISION BROADCAST

Powerful solid-state

One of the most difficult, yet pressing, decisions currently facing broadcast planning engineers is whether or when to opt for high-power solid-state transmitters in place of established tetrode or klystron units. Both the BBC and IBA are re-engineering major parts of their u.h.f. networks, with many new high-efficiency, pulsed-klystron transmitters at power ratings from about 10 to 40kW peak sync output. At present the highest power all-solid-state u.h.f. television installations in the UK are 200W units, with many tetrode and klystron transmitters at the one to five kilowatt levels. Klystron installations are costly but reliable, while recent improvements in u.h.f. power tetrodes have doubled operational lifetimes to around 14 000 hours and have improved reliability.

But today, Japanese firms, including NEC and Toshiba, are installing modular v.h.f. and u.h.f. all solid-state transmitters with total power outputs of up to about 30kW based on many hundreds of bipolar power transistors each providing up to about 100 or 200 watts output in Class AB, or alternatively for the v.h.f. bands using power mosfets, now capable of operation above 100MHz and with u.h.f. devices expected soon.

Planning engineers are thus faced with the possibility of extending solid-state installations by two orders of magnitude, from 200W to 20kW at a total "cost of ownership" that promises, on paper, to be highly favourable up to at least 5kW and debatably favourable at 10 or 15kW. Pulsed-klystrons or klystrodes remain clearly favourable only for the very highest powers such as the 40kW units at Crystal Palace or the 110kW u.h.f. installations widely used in the USA.

An all-day colloquium at the IEE, Savoy Place, "Advances in solid-state technology for broadcast transmitters" thus had unusual importance, with Peter Douglas (IBA) and Ivor Tupper (BBC) opening and closing the eight presentations with detailed cost analyses – which differed significantly in their conclusions and which were clearly based on advice they are offering for the next phases of the current re-engineering programmes – and with the possibility also of new fifth and sixth terrestrial television channels in the background.

Chairman Bob Wellbeloved (IBA) noted that the adoption of all-solid state for the highest (UK) powers is still seen variously as "a godsend or a gamble" but that after more than a decade of tetrode versus klystron controversy, the debate may soon shift to bipolar versus fet. The analysis of Peter Douglas suggests that installing solid-state rather than klystron transmitters for the next phase of the ITV transmitter replacement programme (u.h.f. powers between 7 and 20kW, but mostly 7 to 10kW) would result in financial savings of about 25%. Ivor Tupper was noticeably more conservative and his analysis could be summed up as a warning not to jump too fast, with the strong possibility that future, more-competitively-priced, klystron installations would offer a better option at powers of 10kW and above. All cost-of-ownership predictions depend to a considerable extent on informed crystal-gazing and risky extrapolation of reliability data, not to mention such questions as whether low-voltage equipment really will permit one-man maintenance visits rather than the mandatory two-man teams for high-voltage transmitters.

There is also the question of whether adoption of Class AB amplifiers would reverse the present use of combined (derated) vision and sound transmitters.

The NEC u.h.f. transmitters are based on the bipolar 2SC3660A device which can provide about 110W at u.h.f. Installations rated at 30kW (2×15kW) have already been sold to Australia. A novel feature is the use of jet air cooling of the output devices without any air- or water-cooled heat sinks. Toshiba have all-solid-state v.h.f. transmitters of up to 50kW output using 2SK410 mosfet devices (16 devices in 2×8 push-pull for 1.5kW amplifiers) but also up to 30kW on u.h.f. using 2SC3702 bipolar devices (2×10 in push-pull) in 1kW blocks. Toshiba suggested that fets can be expected to provide even higher reliability than bipolars and that these will be available for u.h.f. in the near future. An advantage of fets is the higher voltage rail (50 to 80V) than for bipolars (about 30V) and the less formidable current requirement.

SGS-Thomson Microelectronics described its new range of bipolar gold-metallized power transistors with an output per device of up to 240W (12dB gain) on Band I and 150W (8dB gain) on u.h.f. Bands IV and V. Gold metallization rather than aluminium is claimed to have greatly reduced the problem of metal migration in high-current devices. The Toshiba representative suggested that the components now having limited life are the electrolytic capacitors.

Stereo sound-in-sync

A digital stereo sound-in-sync system for broadcast television has been described by Soviet engineers at the A.S. Popov Scientific Research Institute (OIRT's *Radio & Television* 1987/6, pages 37 to 40) which highlights the weakness of the three analogue frequency-division multiplex systems in Japan, West Germany and the USA. The paper suggests that new breakthroughs have allowed broadcast systems with time-division multiplex to be designed, as used in the sound-in-sync distribution systems, the Czech TERI system and the MAC satellite systems. However, it points out that the MAC systems involve reduction and exclusion of synchronizing pulses, whereas terrestrial systems do not permit substantial shortening of the sync pulses. The authors suggest that in order to promote and speed up the introduction of a digital system for television sound, the USSR is interested in co-operative research on digital systems and in joint projects to produce components.

The paper, by G.I. Vlasov, director of the institute and others, sets out the requirements for stereo television sound as: general improvement of the quality of sound; the possibility to receive a stereo programme in mono (direct compatibility); the possibility for mono programmes to be received on stereo receivers (reverse compatibility); no interference between picture and sound; the possibility of transmitting an independent speech programme; and maximum possible technological compatibility with the equipment of an existing system.

Unlike the additional 728kbit/s digital carrier of the British Nicam 728 system, the Russians have developed a sound-in-sync system with 4μs bursts of data at 8Mbit/s in each line blanking period of their system D/K SECAM transmission standard (8MHz channels with 6.5MHz sound/vision carrier spacing). This provides a mean data rate of 488kbit/s. The proposed arrangement of the bit stream envisages each audio channel, including error protection, as having a bit rate of 192kbit/s, using sophisticated bit-rate reduction from the 448kbit/s rate of 32kHz sampling and 14-bit coding.

The authors point out that until recently none of the known compression techniques suitable for processing musical and artistic audio could achieve sufficient bit-rate reduction (but see MSC 256kbit/s stereo, February 1988, page 206). They claim to have developed an effective method of compressing high-quality audio signals by making use of the Zwicker critical bands of hearing. Zwicker discovered that within certain bands, the most powerful component conceals adjacent, less powerful components, including noise, making them imperceptible to the ear. Between 30Hz and 20kHz there exist 24 critical bands, their widths varying from 100Hz in the low-frequency domain up to 2kHz in the high-frequency domain. The dominant components have to be transmitted accurately, but other components within each of the critical bands may be transmitted digitally with a lower bit number, permitting the total bit rate to be reduced by three to seven times.

The experimental system reduces 448kbit/s to 150kbit/s, permitting efficient error protection with a rate of 192kbit/s per channel. Stereo decoders could be implemented with from four to seven l.s.i. chips, the more expensive models including an echo-corrector, a text synthesizer and a sound decoder for the independent channel.

Television Broadcast is compiled by Pat Hawker.

RESEARCH NOTES

Paper batteries

Ten years of research at Matsushita Electric and the Japan Synthetic Rubber Co. have led to a new paper-thin electrolyte for use in rechargeable dry batteries. The two companies claim that this could eventually lead to leakproof batteries less than 0.1mm thick, suitable for powering 'smart' credit cards. With a temperature range of −60 to +100°C they would also be suitable for use in space where present cells require extensive insulation.

The sheet electrolyte, of secret composition, is made into sheets by mixing it with a polymer dissolved in an organic solvent. The mixture is then coated on a sheet and dried.

Both companies are still studying what kind of metal electrodes will work best with the new electrolyte and say that, as a result, they don't expect a commercial cell to be available for at least one to two years. Nevertheless it is interesting to speculate on other possible new applications for a rechargeable cell so thin. One might imagine it as the middle layer of a self-powered printed circuit board. Or it could be moulded into the plastic case of a portable instrument. Perhaps that 'go faster' adhesive strip on flashy sports cars will actually be the battery?

Plugging into the human body

Curiously enough, one of the most difficult objects to connect lead-out wires to is not some exotic semiconductor but Man himself. Even temporary connections of the sort used for electrocardiograms are prone to all manner of interface problems. As for the more permanent connections of the sort that would be required for wiring up artificial sense organs, difficulties are legion. Contact resistance is but a minor problem, paling into insignificance compared to corrosion and biological rejection. For virtually any engineering material, the human body is one of the most hostile of all environments.

Now some of the first steps to overcome the scientific barriers between the living and the inanimate are being taken by Australian researchers who are looking for ways to improve replacement parts (or prostheses) and implants now used in the body.

One of the leaders in this research is Associate Professor Jak Kelly, of the University of New South Wales, who is experimenting with ion implantation. He has already succeeded in changing the way human tissue reacts to inanimate objects.

Professor Kelly, head of the university's physics department, works with a machine that removes electrons from atoms, leaving ions which are accelerated to high speed by electric fields. The ions are then fired into materials "like firing bullets into cheese" to alter their chemical make-up.

So far Professor Kelly has been able to encourage bone cells to grow on a silicon chip surface. In a report in *Australian Science Newsletter* (vol.14 no 12) he describes his work as "taking our lead from nature". "For instance, tendons have the ability to grow on to bones and take enormous loads. We need to convince tissue cells to grow on to ceramics and metals, and achieve the same kinds of bonds."

Professor Kelly believes technology could be used to promote cell growth on catheters and plastic tubes that must be lodged in the flesh for long periods during treatment. He also sees enormous applications in longer term man/machine interfaces. Controlling artificial limbs and thinking straight into a computer are but two obvious ones.

Machines with an eye to the future

Copying Mother Nature is a principle that doesn't always accord with good engineering practice. Aeroplanes that flap their wings have never been spectacularly successful. Caution based on that realisation is now leading some researchers away from the use of video cameras in the development of artificial vision systems. Although the traditional camera is in many respects analogous to the human eye, its strengths and weaknesses make it unsuited for applications in robotics and automation. A camera records a scene two-dimensionally in terms of changing brightness information which, even from multiple units, is difficult to translate electronically into shape and position. Our eyes can do it easily, not because they are the best input devices, but because they are interfaced with a set of powerful interpretive algorithms.

How then can an artificial vision system extract three-dimensional information without the need for such intelligent processing power? The answer, according to rival research groups in France, Japan, West Germany and USA is to use an 'eye' that provides more precise positional data, even if in the process it sacrifices brightness data.

The almost universal approach is to scan a scene with a laser beam and observe the reflected spot from a position away from the laser. Imagine, for example, what you would see when a laser beam makes a vertical traverse of a suspended sphere. From a viewing position at, say 90° from the beam, the observed spot would follow a c-shaped path, the size of the c depending on the plane of traverse. By controlling a laser beam to scan the whole of a complex-shaped object and by using a simple detector that needs only to be sensitive to the angular position of the reflection, it is possible in such a way to obtain 200 000 x, y and z coordinates of the object per second. These coordinates, which embody much less ambiguity, are far easier for computer processing than images obtained even from the highest resolution video camera.

Research groups at the Massachusetts Institute of Technology and at companies such as Siemens and Hitachi have already developed laser-based vision systems that are insensitive to ambient light and which are unaffected by the optical surface characteristics of the object being viewed. In different ways they can all reconstruct the shape of the object with infinitely less computing power and infinitely less ambiguity than would be the case if the input data had been obtained from video cameras.

Sticky light and optical tweezers

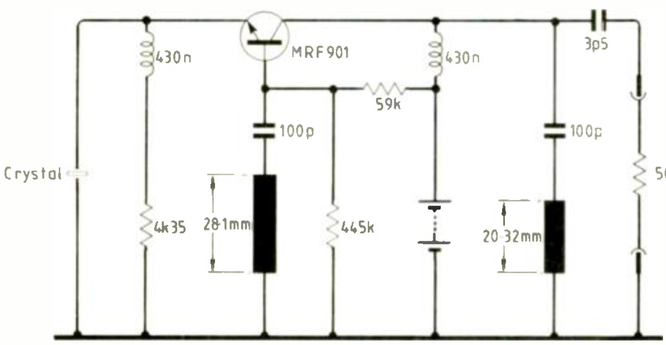
If you've ever had to struggle to repair your daughter's jewellery using fine tweezers and the smallest pencil-bit soldering iron, then imagine working to a scale a few orders of magnitude smaller. That's what's required to perform surgery on bacteria or to manipulate individual human cells for certain experimental or diagnostic purposes. Hitherto it has only been possible using geared micro-manipulators operating under a microscope. Even then it's hopelessly crude for some procedures.

A team from AT&T Bell Laboratories has now developed a manipulative technique that relegates tweezers to the Stone Age. It uses the radiation pressure of infra-red laser beams. Although radiation pressure is too weak for us to notice in everyday life, it is quite enough to push around particles from the size of atoms up to the size of living cells. Push is actually the wrong word because particles tend to move to regions where the light or infra-red is most intense. It's as if the beam were sticky.

This ability of i.r. beams to trap particles is now being used by the AT&T team in conjunction with a normal microscope to manipulate bacteria, yeasts and other micro-organisms in a way that was hitherto impossible. Perhaps the same technique will one day be used as part of a new fabrication technology for molecular-sized electronics?

Microwave crystal oscillators

What its authors claim to be the first report of a crystal oscillator working at a fundamental frequency in the u.h.f. and microwave part of the spectrum is published by two researchers at the University of Miami. G. Gonzalez and B. Avanic (*Electronics Letters* vol.23 no 25) explain the advantages of this technique for generating signals of high spectral purity with potentially low s.s.b. phase noise and low power consumption.



The crystal they use – an AT-cut unit resonant at 843MHz – was specially made by Piezo Technology Inc. of Florida, using chemical polishing methods. Although the Q of 6200 at the fundamental frequency is promising from the point of view of phase noise, there are nevertheless spurious resonances at higher frequencies, due to the extreme difficulties of manufacture. Quantity production is therefore likely to be many years away.

Because of the spurious resonances and the high frequency of oscillation, the circuit requires just a few more components than a comparable h.f. crystal oscillator.

The circuit (above) used by Gonzalez and Avanic uses a common-base layout with short-circuit stubs as resonant elements and the whole oscillator is constructed on microstrip board. It consumes only 0.9mA at 7.8V. In terms of s.s.b. phase noise, the authors say there is room for improvement, though the figures published are comparable to those of any conventional harmonic or multiplier-based u.h.f. oscillator. Nevertheless, as they point out, u.h.f. fundamental crystal design is still in its infancy and the room for potential improvement is considerable.

Low dimensional structures

The Molecular Beam Epitaxy Centre based at Nottingham University was formally inaugurated on 18 January, 1988 in the presence of Kenneth Clarke, Chancellor of the Duchy of Lancaster. One of four such centres investigating low dimensional structures (l.d.s.), Nottingham is undertaking experimental and theoretical work on electron-phonon interaction, quantum transport, quantum tunnelling, hopping and submillimetre and optical properties. Samples produced at Nottingham consist primarily of GaAs epilayers and GaAs/AlGaAs heterojunctions. Layers produced to date include one with the highest mobility ever produced in a university laboratory (2.1 million $cm^2V^{-1}s^{-1}$ at 4K). A number of structures including superlattices and resonant tunnel structures have been produced for the associated research groups and external collaborators.

This facility, together with three others in Hull, London and Warwick, provides the precise, complex semiconductor samples needed to explore the novel physical properties which arise when electrons in a solid are no longer free to move in three dimensions. Six such centres have been approved to date.

Already more than £12 million has been committed from SERC funds for l.d.s. research in 25 universities and a further £7.5 million has been included in the budget for the next two years.

The properties of l.d.s., which are formed from very thin layers of semiconducting materials, are varied and strikingly different from those of bulk semiconductors. New electronic, optical and magnetic properties are being discovered and many possibilities exist for technological exploitation.

SERC's science and engineering boards have agreed to develop a joint l.d.s. device programme in which the physics emerging from l.d.s. will be used to develop new semiconductor devices.

Optical catastrophe

Raman Kashyap and Keith Blow of British Telecom's Martlesham Heath research laboratories have discovered an entirely new guided-wave phenomenon that could result in the destruction of considerable lengths of optical fibre. The damage, shown in the picture, can propagate through several kilometres of fibre in a matter of minutes and requires no more than a watt or so of average laser power. That corresponds to a power density of $10MWcm^{-2}$. Hitherto it had been assumed that the safe limits for a fibre were roughly that of bulk silica, i.e. $>10GWcm^{-2}$.

All fibre damage is the result of non-linear processes taking place as the laser emission propagates from one end to the other. Effects such as Raman and Brillioun scattering, optical Kerr effect and the generation of solitons – solitary waves – have been well studied using high power lasers, though common to all of them are very high intensities or very long path lengths.

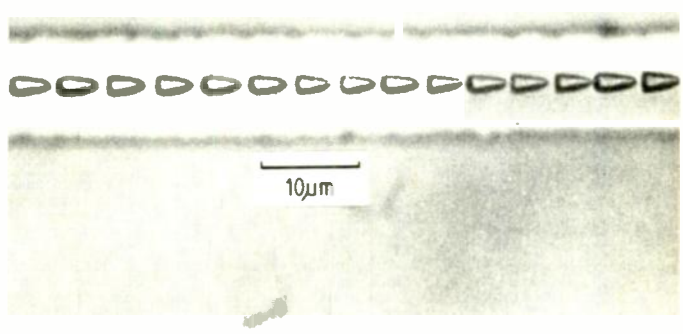
The newly reported phenomenon (*Electronics Letters* vol.24 no1) differs in that power levels are low and, once started, the destructive process carries on unimpeded from the distant end of the fibre back to the laser. The B.T. researchers describe it as 'self-propelled self-focussing' and the damage bears little relationship to normal laser damage at high power levels.

In the course of their experiments Kashyap and Blow fed two watts (average) from a c.w. neodymium:YAG laser into a short length of monomode fibre with a half-coupler block in the middle. This is a component of a standard directional coupler. When a mirror was brought into contact with the coupler, there was an intense flash starting at the coupler and propagating back to the laser. In less than a second the fibre had been totally destroyed.

Further experiments showed that the process could be triggered by a variety of factors, such as melting a small region of the fibre or dabbing a spot of paint on the end to absorb the emission. A final experiment destroyed 1.5km of fibre at a single go.

To start this catastrophic damage, the B.T. researchers say that the fibre core must be heated at some point to above its melting point of 1700°C. This probably happens over a very short length (~1μm) as a result of plasma heating. They theorize that the core then becomes highly absorbing, leading to a self-focussing effect which in turn causes the beam to collapse over a few wavelengths. This then creates a new high temperature region, and so on along the length of the fibre. As to why the breakdown is accompanied by intense visible emission, the team speculate that this is due to dielectric breakdown. They also – with some degree of understatement – point out that the newly-discovered phenomenon "may have serious implications for high average power guided-wave devices".

Research Notes is written by John Wilson of the BBC External Services science unit at Bush House.



Core region of a fibre after damage, showing oxygen-filled cavities a few wavelengths across.

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				BC204	0.25	BD124P	0.59	BD520	0.65	BF256LC	0.35	BFX86	0.25	BUY71	2.50	R2009	2.50	TI0142	1.75	2SC784	0.75
				BC207B	0.25	BD131	0.42	BD534	0.45	BF257	0.28	BFY18	1.35	BUV41	2.50	R2010B	1.45	TIP146	2.75	2SC785	0.75
AAY12	0.25	BC107A	0.11	BC208B	0.20	BD132	0.42	BD535	0.45	BF259	0.28	BFY50	0.32	MJ3000	1.98	R2322	0.58	TIP161	2.95	2SC789	0.55
AC126	0.45	BC107B	0.11	BC212	0.09	BD133	0.40	BD538	0.65	BF271	0.28	BFY51	0.32	MJE340	0.40	R323	0.66	TIP2955	0.80	2SC931D	0.95
AC127	0.20	BC108	0.10	BC212L	0.09	BD135	0.30	BD575	0.95	BF271	0.26	BFY90	0.77	MJE350	0.75	R2540	2.48	TIP3055	0.55	2SC937	1.95
AC128	0.28	BC108B	0.12	BC213	0.09	BD136	0.30	BD587	0.95	BF273	0.18	BLY48	1.75	MJE520	0.48	RCA16029	0.85	TIS91	0.20	2SC1034	4.50
AC128K	0.32	BC109	0.10	BC213L	0.09	BD137	0.32	BD588	0.95	BF335	0.35	BR100	0.26	MJE2955	0.95	RCA16039	0.85	TV106	1.50	2SC1096	0.80
AC141	0.28	BC109B	0.12	BC214	0.09	BD138	0.30	BD597	0.95	BF336	0.34	BR101	0.49	MPSA13	0.29	RCA16181	0.85	TV106/2	1.50	2SC1106	2.50
AC141K	0.34	BC114A	0.09	BC214C	0.09	BD139	0.32	BD695	1.50	BF337	0.29	BR103	0.55	MPSA92	0.30	RCA16334	0.90	ZRF0112	16.50	2SC1124	0.95
AC142K	0.45	BC115	0.55	BC214L	0.09	BD140	0.30	BD698	1.50	BF338	0.32	BR303	0.95	MRF237	4.95	RCA16335	0.85	2N1100	6.50	2SC1162	0.95
AC176	0.22	BC116A	0.50	BC237B	0.15	BD144	1.10	BD701	1.25	BF355	0.37	BRC4443	1.15	MRF450A	13.95	RCA16572	0.85	2N1308	1.35	2SC1172Y	2.20
AC176K	0.31	BC117	0.19	BC238	0.15	BD150C	0.29	BD702	1.25	BF362	0.38	BRY39	0.45	MRF453	17.50	S2060D	0.95	2N1711	0.30	2SC1173	1.15
AC187	0.25	BC119	0.24	BC239	0.15	BD159	0.65	BD707	0.90	BF363	0.65	BSW64	0.95	MRF454	26.50	SKE5F	1.45	2N2219	0.28	2SC1306	1.75
AC187K	0.28	BC125	0.25	BC251A	0.15	BD160	1.50	BDX32	1.50	BF371	0.25	BSX60	1.25	MRF455	17.50	T6021V	0.45	2N2626	0.55	2SC1364	0.50
AC188	0.25	BC138C	0.20	BC252A	0.15	BD166	0.95	BDX53B	1.65	BF394	0.19	BT100A/02	0.85	MRF475	2.95	T6027V	0.45	2N2905	0.40	2SC1413A	2.50
AC188K	0.37	BC140	0.31	BC258	0.25	BD179	0.72	BF115	0.35	BF422	0.32	BT106	1.49	MRF477	14.95	T6029V	0.45	2N3053	0.40	2SC1449	0.50
ACY17	1.15	BC141	0.25	BC258A	0.39	BD182	0.70	BF119	0.65	BF423	0.25	BT116	1.20	MRF479	5.50	T6036V	0.55	2N3054	0.59	2SC1628	0.75
AD142	2.50	BC142	0.21	BC284	0.30	BD201	0.83	BF127	0.39	BF457	0.32	BT119	3.15	OC16W	2.50	T9002V	0.55	2N3055	0.52	2SC1678	1.50
AD143	2.50	BC143	0.24	BC300	0.30	BD202	0.65	BF154	0.20	BF458	0.36	BT120	1.65	OC23	9.50	T9011V	0.75	2N3702	0.12	2SC1945	3.75
AD149	1.50	BC147B	0.12	BC301	0.30	BD203	0.78	BF158	0.22	BF467	0.68	BU105	1.95	OC25	1.50	T9015V	2.15	2N3703	0.12	2SC1953	0.95
AD161	0.50	BC148A	0.09	BC303	0.26	BD204	0.70	BF160	0.27	BF493	0.35	NU108	1.69	OC26	1.50	T9034V	2.15	2N3704	0.12	2SC1957	0.80
AD162	0.50	BC148B	0.09	BC307B	0.09	BD222	0.46	BF173	0.22	BF4995	0.23	BU124	1.25	OC28	5.50	T9038V	3.95	2N3705	0.20	2SC1969	2.95
AF106	0.50	BC149	0.09	BC327	0.10	BD223	0.59	BF177	0.38	BF4997	0.25	BU125	1.25	OC29	4.50	THY15/80	2.25	2N3706	0.12	2SC1985	1.50
AF114	1.95	BC153	0.30	BC328	0.10	BD225	0.48	BF178	0.26	BFR39	0.23	BU126	1.60	OC32	5.50	THY15/85	2.25	2N3708	0.12	2SC2028	1.15
AF121	0.60	BC157	0.12	BC337	0.10	BD232	0.35	BF179	0.34	BFR40	0.23	BU204	1.55	OC42	1.50	TIP29	0.40	2N3733	9.50	2SC2029	1.95
AF124	0.65	BC159	0.09	BC338	0.09	BD233	0.35	BF180	0.29	BFR81	0.25	BU205	1.30	OC44	1.25	TIP29C	0.42	2N3773	2.75	2SC2078	1.45
AF125	0.35	BC161	0.55	BC347A	0.13	BD236	0.49	BF181	0.29	BFR88	0.30	BU208	1.39	OC45	1.00	TIP30C	0.43	2N3792	1.35	2SC2091	0.85
AF126	0.45	BC170B	0.15	BC461	0.35	BD237	0.40	BF182	0.29	BFR90	1.50	BU208A	1.52	OC70	1.00	TIP31C	0.55	2N4280	3.50	2SC2098	2.95
AF127	0.65	BC171	0.09	BC478	0.20	BD242	0.65	BF183	0.29	BFR91	1.75	BU208D	1.85	OC71	0.75	TIP32C	0.42	2N4427	1.95	2SC2166	1.95
AF139	0.40	BC172B	0.10	BC527	0.20	BD246	0.75	BF184	0.35	BFT42	0.35	BU326	1.20	OC72	2.50	TIP33C	0.95	2N4444	1.15	2SC2314	0.80
AF150	0.60	BC173B	0.10	BC547	0.10	BD376	0.32	BF185	0.28	BFT43	0.35	BU326S	1.50	OC75	1.50	TIP34B	0.95	2N5294	0.42	2SC2371	0.36
AF178	1.95	BC174	0.09	BC548	0.10	BD379	0.45	BF195	0.11	BFW10	0.55	BU407	1.24	OC81	1.00	TIP41A	0.45	2N5296	0.48	2SC931D	0.95
AF239	0.42	BC177	0.15	BC549A	0.10	BD410	0.65	BF197	0.11	BFW11	0.75	BU408	1.50	OC84	1.50	TIP41C	0.45	2N5298	0.60	1SD234	0.50
ASY27	0.85	BC178	0.15	BC550	0.14	BD434	0.65	BF198	0.16	BFW16A	1.15	BU500	2.25	OC139	12.50	TIP42C	0.47	2N5485	0.45	2SD325E	1.65
ASY77	1.50	BC182	0.10	BC557	0.08	BD436	0.45	BF199	0.14	BFW61	0.60	BU508A	1.95	OC171	4.50	TIP47	0.65	2N5496	0.95	2SK19	0.55
ASZ16	1.75	BC182LB	0.10	BC558	0.10	BD437	0.75	BF200	0.40	BFW92	0.85	BU526	1.90	OC200	4.50	TIP48	0.65	2SA329	0.95	2SK33	0.55
AU106	6.95	BC183	0.10	BC639/10	0.30	BD438	0.75	BF240	0.20	BFX29	0.30	BU807	2.25	OC201	5.50	TIP50	0.65	2SA715	0.55	2SK105H	1.50
AY102	2.95	BC183L	0.09	BCY33A	19.50	BD510	0.95	BF241	0.15	BFX84	0.26	BUY20	2.15	OC205	10.00	TIP120	0.60	1SC495	0.80	3SK88	0.95

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						MB3756	2.50	SAS570S	1.75	STK415	7.95	TA7310P	1.80	TBA530	1.10	TCA830S	1.95	TDA2530	1.95	UPC1024H	1.50
						MC1307P	1.00	SAS580	2.85	STK435	7.95	TA7314P	2.95	TBA530Q	1.10	TCA900	2.50	TDA2532	1.95	UPC1025H	1.95
						MC1310P	1.95	SAS590	2.75	STK437	7.95	TA7321P	2.25	TBA540	1.25	TCA940	1.65	TDA2540	1.95	UPC1028H	1.95
						MC1327	1.70	SL901B	7.95	STK439	7.95	TA7609P	3.95	TBA540Q	1.35	TDA440	2.20	TDA2541	2.15	UPC1032H	1.50
AN103	2.50	AN7145M	3.95	LA4102	2.95	MC1327Q	0.95	SL917B	6.65	STK461	11.50	TA7611AP	2.95	TBA550Q	1.95	TDA1001	2.95	TDA2560	2.15	UPC1158H	0.75
AN124	2.50	AN7150	2.95	LA4140	2.95	MC1349P	1.75	SL1310	1.80	STK463	11.50	TA7629	2.50	TBA560C	1.45	TDA1003A	3.95	TDA2576	4.50	UPC1167C2	1.95
AN214	2.50	AN7151	2.50	LA4031P	1.95	MC1350P	1.75	SL1327	1.10	STK0015	7.95	TAA310A	3.50	TBA560Q	1.45	TDA1006A	2.50	TDA2581	2.95	UPC1181H	1.25
AN214Q	2.50	BA521	3.35	LA4400	3.50	MC1351P	1.75	SL1327Q	1.10	STK0029	7.95	TAA320A	3.50	TBA570	1.00	TDA1010	2.15	TDA2582	2.95	UPC1182H	2.95
AN236	1.95	CA1352E	1.75	LA4420	3.50	MC1352P	1.00	SN7414	1.50	STK0039	7.95	TAA350A	1.95	TBA651R	2.50	TDA1005	2.25	TDA2593	2.95	UPC1185H	3.95
AN239	2.50	CA3086	0.46	LA4422	2.50	MC1357	2.35	SN7421	0.85	TA7061AP	1.50	TAA550B	1.95	TBA673	1.95	TDA1035	2.50	TDA2600	6.50	UPC1191V	1.50
AN240P	2.80	CA3123E	1.95	LA4430	2.50	MC1358	1.58	SN76023N	3.95	TA7072	2.65	TAA570	1.95	TBA720A	2.45	TDA1037	1.95	TDA2610	2.50	UPC1350C	2.95
AN247	2.50	CA313EM	2.50	LA4461	3.95	MC1496	1.75	SN76110N	0.89	TA7073	3.50	TAA621	3.95	TBA750	1.95	TDA1044	2.15	TDA2611A	1.95	UPC1353C	2.45
AN260	2.95	CA3140S	2.50	LC7120	3.25	MC1723	0.50	SN76115N	1.25	TA7108P	1.50	TAA630S	2.95	TBA750Q	2.65	TDA1170	1.95	TDA2640	3.50	UPC1360	2.95
AN262	1.95	CA3140T	1.15	LC7130	3.50	MC3357	2.75	SN76131N	1.30	TA7120P	1.65	TAA661B	1.95	TBA800	0.89	TDA1180	2.15	TDA2655	4.50	UPC1365C	3.95
AN264	2.50	ETT6016	2.50	LC7131	5.50	MC3401L	2.50	SN76226DN	2.95	TA7129P	2.50	TAA700	1.70	TBA810AS	1.65	TDA1270Q	3.95	TDA2680A	2.75	UPC2002H	1.95
AN271	3.50	HA1137W	1.95	LC7137	5.50	MC14106P	2.95	SN76227N	1.05	TA7130P	1.50	TAA930	3.95	TBA810P	1.65	TDA1327	1.70	TDA2690	2.45	UPD2114LC	2.50
AN301	2.95	HA1156W	1.50	LM323K	4.95	MC14518CP	7.50	SN76228N	2.95	TA7137P	1.00	TBA120AS/B/C		TBA820M	0.75	TDA2002	1.95	TDA3310	2.95	555	0.35
AN303	3.50	HA1306	1.50	LM324N	0.45	ML231B	1.75	SN76533N	1.65	TA7146P	1.50		1.00	TBA820Q	1.45	TDA2003	2.95	TDA3510	3.50	556	0.60
AN313	2.95	HA1322	1.95	LM380N	1.50	ML232B	2.50	SN76650N	1.15	TA7176AP	2.95	SA/SB/T/U		TBA890	2.50	TDA2010	1.95	TDA3560	3.95	723	0.50
AN315	2.95	HA1339A	2.95	LM380N8	2.95	ML239	2.95	SN76660N	0.90	TA7193P	3.95	TBA231	1.30	TBA920	1.65	TDA2020	2.95	TDA4050	2.95	741	0.35
AN316	3.95	HA1366W	2.75	LM383T	2.95	MSM5807	8.75	STK011	7.95	TA7203	2.95	TBA395	1.50	TBA950/2X	2.35	TDA2030	2.80	TDA4600	2.50	747	0.50
AN331	3.95	HA1377	3.50	LM390N	3.50	SAA500A	3.50	STK014	7.95	TA7204P	2.15	TBA396	0.75	TBA990	1.49	TDA2140	3.95	TDA9503	3.15	748	0.35
AN342	2.95	HA1406	1.95	LM1011	3.15	SAA1025	7.25	STK015	5.95	TA7205AP	1.15	TBA440N	2.55	TBA990Q	1.49	TDA2150	2.50	TEA1009	1.35	7808	0.60
AN362L	2.50	HA1551	2.95	MS155L	2.95	SAA1251	4.95	STK018	7.95	TA7208	1.95	TBA480Q	1.25	TCA270	1.50	TDA2151	1.95	UPC41C	3.50	7805	0.65
AN612	2.15	LA1201	0.95	MS1513L	2.30	SAA5010	5.35	STK025	11.95	TA7222AP	1.80	TBA510	2.50	TCA270SQ	1.50	TDA2160	2.50	UPC566H	2.95	7812	0.65
AN6362	3.95	LA1230	1.95	MS1521L	1.50	SAA5020	5.75	STK032	7.95	TA7227P	4.25	TBA510Q	2.50	TCA650	2.50	TDA2521	4.50	UPC575C2	2.75	7815	0.65
AN7140	3.50	LA3201	0.95	MB3705	1.50	SAB3210	3.50	STK078	11.95	TA7228P	1.95	TBA520	1.10	TCA760	2.50	TDA2523	4.50	UPC1001H	1.95		
AN7145	3.50	LA4101	0.95	MB3712	2.00	SAS560S	1.75	STK085	8.95			TBA520Q	1.10	TCA800	6.95	TDA2524	1.95	UPC1020H	2.95		

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EBF93	0.95
EBL1	2.50
EBL21	2.00
EC52	0.75
EC70	1.75
EC81	7.95
EC86	1.95
EC88	1.95
EC90	1.50
EC91	5.50
EC92	1.95
EC93	1.50
EC95	7.00
EC97	1.10
EC8010	12.00
ECC32	3.50
ECC33	3.50
ECC35	3.50
ECC81	1.50
ECC81 SPECIAL QUALITY	2.25
ECC82	0.85
ECC82 PHILIPS	1.95
ECC83	0.95
ECC83 BRIMAR	2.15
ECC83 PHILIPS	1.95
ECC83 SIEMENS	2.50
ECC83S	3.50
ECC85	1.00
ECC86	2.75
ECC88	1.00
ECC89	1.50
ECC91	2.00
ECC189	1.95
ECC801S	6.95
ECC803S	6.95
ECC804	0.60
ECC807	3.95
ECC2000	7.95
ECF80	1.15
ECF82	1.15
ECF86	1.70
ECF200	1.85
ECF202	1.85
ECF801	0.85
ECF805	2.50
ECF806	10.25
ECH3	2.50
ECH4	3.00
ECH35	3.50
ECH42	1.50
ECH81	1.75
ECH83	1.00
ECH84	1.00
ECH200	1.50
ECL80	0.60
ECL82	0.79
ECL83	2.50
ECL84	0.74
ECL85	0.95
ECL86	0.95
ECL805	0.95
EF37A	2.50
EF39	1.50
EF40	4.50
EF42	3.50
EF50	2.50
EF54	4.50
EF55	4.95
EF70	1.20
EF73	3.50
EF80	0.55
EF83	3.95
EF85	0.50
EF86	2.25
EF86 MULLARD	4.50
EF86/CV4085	5.00
EF89	1.50
EF91	1.95
EF92	2.15
EF93	1.50
EF94	1.50
EF95	1.95
EF97	0.90
EF98	0.90
EF183	0.75
EF184	0.85
EF731	4.50
EF800	11.00
EF804S	19.50

EF805S	25.00
EF806S	25.00
EF812	0.65
EFL200	1.50
EFP60	3.50
EH90	0.72
EK90	1.50
EL32	0.95
EL33	5.00
EL34	2.95
EL34 MULLARD Matched per pair	15.00
EL34 SIEMENS	4.50
EL36	2.50
EL36 MULLARD	3.95
EL37	9.00
EL38	9.00
EL41	3.50
EL42	2.00
EL71	4.50
EL81	6.95
EL83	7.50
EL84 BRIMAR	0.95
EL84 MULLARD	3.50
EL84 SIEMENS	2.50
EL85	4.50
EL86	1.75
EL90	1.75
EL91	6.00
EL95	1.75
EL152	15.00
EL360	6.75
EL500	1.95
EL504	1.95
EL506	5.95
EL509	5.25
EL519	6.95
EL802	3.65
EL821	6.95
EL822	12.95
ELL80	22.50
EM34	12.50
EM83	1.65
EM84	1.65
EM85	3.95
EM87	2.50
EN32	15.00
EN91	1.95
EN92	4.50
EY51	0.80
EY70	7.50
EY81	2.35
EY82	1.15
EY83	1.50
EY84	5.95
EY86/87	0.50
EY88	0.55
EY91	5.50
EY500A	1.50
EY802	0.70
EZ35	1.00
EZ40	2.75
EZ41	2.75
EZ80	0.75
EZ81	0.75
EZ90	1.50
FW4-800	2.95
G55/1K	9.00
G180/2M	6.95
G240/2D	9.00
GC10B	17.50
GC10D	17.50
GC10/4B	17.50
GC10/4E	17.50
GC12/4B	17.50
GD86W	6.00
GDT120M	5.00
GN4	6.00
GN10	15.00
GR10G	4.00
GS10C	16.50
GS10H	12.00
GS12D	12.00
GT1C	14.00
GU20	35.00
GU50	17.50
GXU1	13.50
GXU3	24.00
GXU50SS	14.50
GY501	1.50
GY802	1.50
GZ32	2.50
GZ33	4.50
GZ34	2.50
GZ37	4.50
HABC80	1.50
HBC90	1.95
HBC91	1.95
HF93	1.50
HF94	1.95
HK90	1.95
HL41	3.50
HL90	3.50
HL92	1.50
KT8C	7.00
KT33C	3.50
KT36	2.00
KT44	4.00
KT45	4.00
KT61	5.00
KT63	2.00

KT66 USA	9.95
KT66 GEC	18.50
KT66R	15.00
KT67	9.00
KT77 Gold Lion	11.95
KT81	7.00
KT88 USA	10.95
KT88 Selectron	15.00
KT88 Gold Lion	22.50
KTW61	2.50
KTW62	2.50
KTW63	2.00
KTZ63	2.50
L87-20	95.00
LS9B	6.95
M508	195.00
M5143	155.00
M5199	295.00
M8079	6.00
M8082	7.50
M8083	3.25
M8091	7.50
M8096	3.00
M8098	5.50
M8099	5.00
M8100	5.50
M8136	7.00
M8137	7.95
M8161	6.50
M8162	5.50
M8163	5.50
M8190	4.50
M8195	6.50
M8196	5.50
M8204	5.50
M8223	4.50
M8224	2.00
M8225	3.95
ME1400	3.50
ME1401	29.50
ME1402	29.50
MHLD6	4.00
MP25	195.00
MS4B	5.50
MU14	3.50
N37	12.50
N78	9.85
OA2	1.50
OA2WA	2.50
OA3	2.50
OB2	1.50
OB2WA	2.50
OC3	2.50
OD3	2.50
OM4	2.50
OM58	3.00
OM6	1.75
ORP43	2.50
ORP50	3.95
P61	2.50
P41	2.50
PABC80	0.75
PC86	0.75
PC88	0.75
PC92	3.50
PC97	1.10
PC900	1.25
PCC84	0.40
PCC85	0.55
PCC88	0.70
PCC89	0.70
PCC189	0.70
PCC805	0.70
PCC806	0.80
PCE82	0.80
PCF80	0.65
PCF82	0.60
PCF84	0.65
PCF86	1.20
PCF87	1.25
PCF200	1.80
PCF201	1.80
PCF801	1.35
PCF802	0.85
PCF805	1.25
PCF806	1.00
PCF808	1.25
PCH200	1.50
PCL82	0.85
PCL83	2.50
PCL84	0.75
PCL85	0.80
PCL86	0.85
PCL805	0.90
PD500	5.95
PE1 100	69.00
PEN25	2.00
PEN40D	3.00
PEN45	3.00
PEN45DD	3.00
PEN46	2.00
PE06-40N	42.00
PFL200	0.95
PL36	1.75
PL38	1.50
PL81	1.25
PL82	0.60
PL83	0.52
PL84	0.78
PL500	1.10
PL504	1.15
PL508	1.75
PL509	4.85
PL519	4.95
PL802	6.00
PL802T	3.50
PL820	2.95
PY32	0.60
PY33	0.50

PY81	0.70
PY82	0.70
PY83	0.70
PY88	0.65
PY500A	1.95
PY800	0.79
PY801	0.79
QB3-300	72.00
QB3-1750	139.00
QB3.5-700	72.00
QB5-3500	595.00
QE08-200	145.00
QQE02 5	19.50
QQE03 12	7.95
QQE03-20	35.00
QQE06-40	45.00
QQV02 6	19.50
QQV03 10	5.50
QQV03-10 MULLARD	15.00
QQV03-20	25.00
QQV06 40A	27.50
QQV06-40A MULLARD	39.50
QQV07 50	55.00
QQZ03-20	45.00
QS75/20	1.50
QS95/10	4.85
QS108/45	4.00
QS150/15	6.95
QS150/30	1.15
QS150/40	7.00
QS1205	3.95
QS1213	5.00
QU37	9.50
QV03-12	5.75
QV05-25	2.50
QV06-20	29.50
QV08-100B	145.00
QY3-125	72.00
QY4-250	72.00
QY4-400	85.00
R10	4.00
R18	2.50
RG1-240A	14.50
RG3-250A	6.50
RG3-1250A	35.00
RR3-250	15.00
RR3-1250	35.00
S11E12	38.00
S104-2K	10.00
SC1/1300	6.00
SP61	3.50
STV280/40	11.95
TB2-5/300	85.00
TB2-300	195.00
TB3-750	95.00
TB3-2000	450.00
TBL2-300	395.00
TBL2-500	495.00
TD03 10/D/E/F	35.00
TT15	45.00
TT21	45.00
TT22	45.00
TT100	69.00
TY2-125A	85.00
TY4 400	85.00
TY7-6000A	600.00
TY8-600W	365.00
U19	9.50
U26	0.90
U35	3.50
U37	9.00
U41	6.95
U50	2.00
U82	3.00
U191	0.70
U192	1.00
U193	1.00
U251	2.50
U801	3.50
UABC80	0.65
UAF42	1.00
UBF80	0.60
UBC41	2.25
UBC81	1.50
UBF89	1.00
UBL21	1.75
UC92	1.20
UCC84	0.70
UCC85	0.60
UCF80	1.00
UCH21	1.20
UCH41	2.50
UCH42	2.50
UCH81	1.00
UCL82	1.75
UCL83	2.50
UF41	1.15
UF42	1.15
UF80	1.75
UF85	1.20
UF89	2.00
UL41	7.50
UL44	3.50
UL84	1.50
UL85	0.85
UU5	3.50
UU6	6.00
UU7	8.00
UU8	9.00
UY41	3.50
UY85	0.70
V235A/1K	250.00
V238A/1K	295.00

V246A/2K	315.00
V241C/1K	195.00
V453	12.00
VLS631	10.95
VP48	4.50
VP41	4.95
VR101	2.50
VR105/30	2.50
VR150/30	2.50
VU39	2.50
W21	4.50
W61	4.50
W77	5.00
W81M	4.50
W739	1.50
X24	4.50
X41	4.50
X66/X65	4.95
X76M	1.95
XC24	1.50
XC25	0.50
XFW47	1.50
XFW50	1.50
XG1-2500	75.00
XL628FT	7.50
XNP12	2.50
XR1/1600A	49.50
XR1/3200A	79.50
XR1-6400A	149.50
Y65	6.95
YD1100	75.00
YJ1060	265.00
YL1020	42.50
YL1060	195.00
YL1070	195.00
YL1071	195.00
YL1290	65.00
YL1440	450.00
Z77	1.20
Z300T	6.00
Z302C	12.00
Z359	9.00
Z520M	4.00
Z700U	9.50
Z759	19.85
Z803U	18.95
ZA1000	12.50
ZA1001	1.50
ZM1001	12.00
ZM1005	8.00
ZM1020	6.00
ZM1021	8.00
ZM1023	7.95
ZM1041	14.00
ZM1082	9.00
ZM1084	10.00
ZM1175	6.50
ZM1177	9.00
ZM1202	55.00
ZM1263	4.00
1A3	4.50
1AE4	3.50
1AX2	3.50
1B22	10.00
1B27	55.00
1B35A	45.00
1B63A	75.00
1K3	2.50
1N5GT	2.50
1P28	25.00
1R5	0.90
1S5	1.50
1T4	1.00
1U4	1.75
1U5	1.00
1X2S	2.50
2A3	16.50
2AS15A	11.50
2B7	2.50
2B22	69.50
2C36	70.00
2C39A	32.50
2C39BA	39.50
2C40	37.00
2C42	29.50
2C43	60.00
2C51	2.50
2CY5	1.50
2D21	1.95
2D21W	3.15
2E22	49.00
2E26	7.95
2J55	295.00
2K25	35.00
2K25 RAYTHEON	75.00
2K26	95.00
2K29	250.00
2K48	140.00
2K56	250.00
2X2A	5.00
3A/107B	12.00
3A/108A	9.00
3A/109B	11.00
3A/110B	12.00
3A/141K	11.50
3A/146J	7.50
3A/147J	7.50
3A/167M	10.00
3A3A	3.95
3A4	1.10
3A5	4.50
3A12	3.35
3B22	25.00
3B24	12.00
3B26	24.00

3B28	15.00
3BZ6	1.50
3C45	24.00
3CX3000A7	650.00
3CY5	1.50
3D21A	29.50
3E22	49.50
3E29	39.50
3EJ7	1.95
3H	0.40
3J.170E	1450.00
3J.187E	1450.00
3L	0.40
3Q4	2.50
4-65A	65.00
4-250A	79.50
4-400A	87.50
4-1000A	425.00
4B32	35.00
4B/551B	125.00
4BQ7A	1.75
4BZ6	1.95
4C28	25.00
4C35	145.00
4XC125C EIMAC	150.00
4CX250B	49.00
4CX250B EIMAC	59.50
4CX250BM	65.00
4CX250K EIMAC	115.00
4CX250R AMPEREX	125.00
4CX350A	100.00
4CX350F	95.00
4CX1000A	425.00
4CX1500B	398.00
4CX5000A	1000.00
4D21/4-125A	85.00
4D32	125.00
4GS7	2.25
4GV7	2.25
4J6A	2.95
4KT6	1.50
4X150A	35.00
4X500A	350.00
5A/102D	9.50
5A152M	9.00
5A163K	10.00
5A170K	6.25
5A-180M	9.00
5A-206K	10.00
5B-110M	10.00
5B-254M	14.50
5B-255M	19.50
5B-256M	15.00
5B-257M	15.00
5B258M	14.50
5C22	125.00
5CL8A	2.50
5J180E	2950.00
5JL8	2.95
5R4GB	5.50
5R4GY	4.95
5T4	5.95
5T8A	1.95
5U4G	2.95
5U4GB	4.50
5V4G	2.50
5X4	4.95
5Y3GT	1.95
5Z3	4.50
5Z4GT	2.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8	1.50
6AB4	3.50
6AC7WA	2.00
6AG5	2.50
6AG7	1.95
6AH6	3.50
6AJ4	3.50
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.60
6AM4	3.25
6AM5	6.00
6AM6	1.95
6AN5	4.50
6AN8A	4.50
6AQ5	1.75
6AQ8	1.00
6AR5	5.95
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	0.90
6AT8	1.75
6AU4GT	2.00
6AU5GT	4.50
6AU6	0.95
6AV6	0.90
6AW8A	3.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B4G	5.50
6B8G	1.50
6B10	1.95
6BA6	1.50
6BA7	4.50
6BA8A	3.50

6BC8	0.85
6BE6	1.50
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50
6BK4	4.00
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BN6	1.65
6BN8	3.95
6BQ5	0.95
6BQ7A	1.50
6BR7	4.95
6BS7	5.50
6BW6	5.35
6BW7	1.50
6BZ6	2.50
6BZ7	2.95
6C4	1.50
6C5	1.95
6C6	3.50
6C8G	1.50
6C9	4.95
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	1.95
6CD6GA	4.50
6CF6	1.95
6CG7	3.50
6CH6	6.95
6CL6	3.25
6CL8A	1.50
6CM7	2.95
6CS6	0.75
6CS7	0.95
6CW4	8.00
6DC6	2.35
6DJ8	1.00
6DJ8 SPECIAL	3.50
6DK6	1.50
6DQ5	8.50
6DQ6B	2.50
6DT6A	1.50
6DW4B	21.5
6E5	3.95
6EA7	2.50
6EB8	1.75
6EJ7	0.85
6EM5	2.50
6EM7	2.50
6EU8	1.75
6EV7	2.95
6EW6	1.50
6EW7	4.50
6F1	2.00
6F5	5.50
6F7	5.50
6F13	3.00
6F14	1.00
6F17	2.75
6F23	0.60
6F24	1.25
6F25	1.25
6F28	1.25
6F32	1.25
6F33	12.50
6FH5	6.50
6FH8	5.95
6FL2	4.50
6FQ7	3.50
6GE5	3.95
6GH8A	2.50
6GJ7	0.85
6GM6	2.65
6GS7	21.5
6GV8	0.95
6GW8	2.50
6GY5	3.95
6GY6	2.50
6H1	9.50
6H6GT	1.95
6HB7	1.95
6HF5	5.50
6HF8	7.50
6HM5	2.50
6HQ5	3.50
6HS6	4.95
6HS8	2.95
6HZ6	3.50
6J4	2.15
6J5GT	2.50
6J6	2.00
6J7	4.15
6J7G	4.15
6JB6A	5.50
6JE6C	7.50
6JM6	7.50
6JU8A	2.50
6JS6C	7.50
6K7G	2.00
6K8G	3.00
6KD6	7.50
6KG6A	6.95
6L1	2.50
6L6GC	2.95
6L6GC(G E)	5.75
6L6GC PHILIPS	6.50
6L6GAY	5.50
6L6GT	2.50
6L6WGC	5.50
6L7	3.50
6L15	3.15
6L19	3.95
6LJ8	2.50
6LD20	1.15
6LF6	7.50

6LQ6	7.50
6P28	2.00
6Q7GT	1.50
6R7	3.15
6RHH8	10.00
6S4A	1.50
6SA7	1.35
6SC7	1.50
6SG7	2.50
6SH7	1.35
6SJ7GT	1.20
6SK7	1.35
6SL7GT	1.95
6SN7GT	1.95
6SQ7GT	1.50
6SS7	1.95
6T8	1.50
6U6GT	3.50
6U7G	3.50
6U8A	1.50
6V6G	1.25
6V6GT	1.95
6W4GT	1.95
6Y6G	3.95
6X2N	1.00
6X4	1.50
6X5GT	1.00
6X5GTY	1.00
6X8A	2.25
7A6	4.50
7AU7	1.50
7B6	3.50
7B7	2.50
7D8	4.50
7J7	5.50
7K7	7.50
7L	1.50
7Q7	4.50
7Y4	2.50
8B8	2.50
8B10	2.50
8BQ5	1.95
8CW5	1.50
8EB8B	1.50
8FQ7	1.95
10CW5	1.50
11002	1.25
11ODE7	2.50
11ODX8	2.50
11OEB8	1.95
10EW7	2.95
10F1	0.75
10GK6	1.95
10P14	2.50
11E3	55.00
11R3	5.50
12A6	3.95
12AD6	1.50
12AE6	5.50
12AH7GT	4.95
12AL5	1.00
12AT6	1.25
12AT7	1.15
12AT7WA	2.50
12AU6	1.50
12AU7	0.85
12AV6	1.95
12AV7	2.50
12AX4GTB	1.50
12AX7	0.95
12AX7WA	2.50
12AX7S	7.95
12AY7	3.95
12B4A	4.50
12BA6	1.95
12BE6	1.95
12BH7A	2.95
12BL6	1.75
12BR3	1.95
12BY7A	2.75
12CB	2.50
12CA5	1.95
12CX6	1.20
12DQ6B	3.50
12DW4A	3.50
12DZ6	3.95
12E1	19.50
12E14	38.00
12FX5	1.95
12GN7	3.95
12GH7	3.95
12J5GT	3.95
12J7G	3.50
12JZ8	2.95
12K7GT	1.50
12K8Y	1.95
12KU7	1.95
12S7GT	1.50
12SA7GT	1.95
12SG7	4.75
12SK7	1.95
12SJ7	1.50
12SN7GT	1.85
12SW7	3.50
12SY7	4.50
12X4	1.95
13D3	3.29
13D7	3.20
13D8	3.20
13DE7	2.50
13DR7	2.95
13E1	145.00
13EM7	3.50
14B6	4.50
14R7	3.50
15E	5.50
16AQ3	1.95
16GY5	2.95
16H	0.40
16L	0.40
17AB	3.50
17AX4GTA	1.95

17BE3	2.50
17DW4A	2.95
17EW8	0.95
17JZ8	4.50
18D3	6.00
18GB5	3.50
19AQ5	3.50
19AU4GT	2.50
19BG6	3.50
19G3	19.50
19G6	9.00
19H4	35.00
19H5	33.50
20CV	9.50
20D1	0.70
20LF56	7.95
20L1	0.95
20P1	0.55
20P4	1.95
20P5	1.15
21JZ6	4.95
21KQ6	4.95
21LU8	3.75
24B1	39.50
24B9	39.50
25BQ6	1.75
25DQ6B	2.95
25L6GT	1.75
29C1	19.50
29KQ6	6.50
30C15	0.50
30C17	0.40
30C18	1.48
30FL2	1.35
30FL12	0.95
30FL13	1.10
30FL14	1.25
30L1	0.45
30L15	0.60
30L17	0.60
30P4MR	1.00
30P12	1.00
30P18	0.60
30P19	1.00
30P1	2.50
30PL13	0.60
30PL14	1.75
31JS6C	5.50
33A/158M	19.50
35A3	3.95
35A5	4.50
35C5	4.50
35L6GT	2.00
35Z3	1.95
35Z5GT	3.50
38HE7	5.95
40KD6	5.50
42	6.95
47	6.00
50A5	1.50
50B5	1.95
50C5	0.95
50CD6G	1.95
50EH5	1.50
50JY6	2.95
53KU	4.50
75B1	3.50
75C1	4.50
80	4.50
83	8.50
82A1	7.50
85A1	6.50
85A2	2.95
90AV	15.00
90C1	3.50
90CG	13.50
90CV	12.50
91AG	9.00
92AG	19.50
92AV	15.00
95A1	6.50
100E1	10.00
108C1	2.50
150B2	6.50
150C1K	9.00
150D2	2.50
150C4	2.50
185BT	1.50
211	25.00
230D	15.00
231D	15.00
250TH	150.00
307	5.00
328A	15.00
572B	59.50
723A/B	75.00
724A	275.00
725A	275.00
726A	75.00

801A	15.00
802	25.00
803	14.95
805	59.00
807	5.50
811	15.00
812A	35.00
813 Philips	35.00
813	27.50
829B	14.50
833A	95.00
845	45.00
866A	6.50
872A	20.00
873	60.00
954	1.00
955	1.00
1849	315.00
1927	25.00
2040	25.00
2050A	5.95
2050W	6.50
4212H	250.00
4471	35.00
4687A	9.50
5544	79.50
5559	55.00
5636	5.50
5642	9.50
5651	2.50
5654	1.95
5670	3.25
5675	28.00
5678	7.50
5687	4.50
5696	4.50
5702	3.50
5704	3.50
5718	6.15
5725	2.50
5726	2.50
5727	2.50
5749	2.50
5750	1.85
5763	5.75
5814A	3.25
5823	9.50
5829WA	6.50
5840	3.50
5842	11.00
5863	95.00
5886	13.95
5894	39.50
5899	4.50
5963	1.75
5965	2.15
6057	3.75
6060	2.25
6072	6.95
6080	8.50
6080WA	9.50
6132	10.50
6136	2.50
6146B	9.00
6155	72.00
6156	72.00
6157	2.50
6158	3.20
6201	6.45
6350	3.50
6360	4.50
6386	14.50
6463	7.50
6550	8.50
6550A GE	10.95
6550 RCA	15.00
6870	11.50
6883B	9.95
6973	7.95
7025	2.50
7025S	6.95
7027A	8.50
7119	9.00
7189	5.50
7199	7.50
7247	4.95
7360	15.00
7475	5.00
7486	155.00
7527	85.00
7551	8.50
7581A	9.95
7586	15.00
7591A	6.95
7815	59.50
7868	7.50
8950	10.50
18042	10.50

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Mobile radio spectrum woes

Some five years ago the Merriman Committee recommended that the UK should cease television broadcasting in v.h.f. Bands I and III thus overturning the long-established expectation, stemming from the now defunct Television Advisory Committee, that these bands would be re-engineered for 625-line television. The Government quickly accepted the Merriman proposals that these bands would be largely transferred to the land mobile services, apparently promising them even more spectrum space than they had been seeking over many years. For at least 25 years, the land mobile services had felt unfairly starved of spectrum. That neighbouring countries still regard Bands I and III as the prime bands for television seemed relatively unimportant, while the muted response of the British broadcasting authorities to being ousted from v.h.f. may well have been connected with their early-1980s fear of cable and their ambitions to get into space broadcasting in spite of many warnings of the financial risks of both.

Be that as it may, the mobile industry's drive into Bands I and III has been far from smooth, resulting in much grumbling about delays, ambiguities, uncertainties and system standards. Racal Vodafone, for example, still believes that an acute shortage of suitable mobile equipment, due to protracted disputes over standards and patents, is strangling the putative Band III network.

Cliff Dadson, chairman of the Network Operators Committee (Band III) has bitterly attacked the DTI/Home Office announcement that consideration is being given to possible limited use of Bands I and III for additional terrestrial television services, thus apparently reversing Merriman. On behalf of the committee he claims that the Government is acting in an "outrageous and irresponsible manner".

The committee has written to the DTI pointing out that "The members of this Committee have been working closely with your Department for the past five or six years, overcoming the problems, both political and technical, of sharing radio spectrum between the private mobile radio (PMR) services in this country with television services on the Continent and in Ireland. Just as we are going into operation with these new services, the Government issues a statement which completely undermines the Industry's confidence in the Department to give it the support which had been promised.... Presumably the broadcasting services have brought pressure to bear upon the Government to extend the present studies. If the Government cannot withstand such an approach, what hope has the less influential operator of radio services when deregulation comes into being?.... I must insist that as far as Band 3 studies are concerned, my Committee must be involved.... We will activate every means at our disposal to protect our investment and our future business in Band 3."

The anger of the Committee is understandable but in one respect possibly off target. The suggestion of re-allocating frequencies in Band III to television came not from the existing broadcasters, who have shown little enthusiasm for more competing terrestrial channels, but from the 214-page report on subscription television prepared for the DTI by Dr Charles Jonscher of CSPI (October 1987, page 1066). Most viewers in Britain are equipped to receive u.h.f. channels in the gap between Bands IV and V but not for v.h.f. television.

H.f. revival

The revival of professional interest in the h.f. spectrum is well reflected in the provisional programme of the IEE's four-day conference on h.f. radio systems and techniques, April 11-14 at Savoy Place, London where over 75 papers are due to be presented in 16 sessions, including a number of dual-stream sessions.

One recent development that seems likely to attract attention is the development of adaptive processors that permit the implementation of fully automatic 24-hour data links without any requirement for skilled operators. One that will be described has been developed by Plessey at Roke Manor and recently delivered to the Ministry of Defence (see "Easier h.f.?", October 1987, page 1067). The Plessey system is based on the use of two transceivers, one for traffic, the other as monitor, linked by an adaptive processor that seeks out a suitable channel among a menu of pre-set assignments, changing frequency when necessary on the basis of the error rate, with fall-back frequencies programmed in the event of contact being lost.

The use of adaptive processors, channel evaluation and frequency-hopping systems is also putting more emphasis on the need for transportable and ship-borne broadband antennas. Surveillance is being aided by the development of techniques for automatic signal identification and classification. Active receiving antennas and the use of phasing techniques for reducing co-channel interference are also the subject of papers. Engineers from the Royal Aircraft Establishment are reporting work on Blossom, the RAE's meteor burst communications system.

A less pleasing prospect for communications is the growing use of h.f. radars, reflected in nine papers including some from the UK, China, France, and Australia. Perhaps surprisingly there appears to be only a single (Marconi GEC) paper on digital signal processing receivers.

Power without wires

Over twenty years ago, in October 1964 at the Spencer Laboratory of Raytheon at Burlington, Massachusetts, a model six-foot helicopter climbed vertically up a guide wire to a height of 50ft, powered by microwave energy received on the model from 5kW of power generated on the ground. This was one of a series of experiments aimed at fulfilling the long-sought-after goal of Nikola Tesla to transmit electrical power without wires. The model helicopter project was part of a US defence project aimed at being able to drive a hovering vehicle from the ground as part of a laser communications system above the level of air turbulence. What eventually became of this project has escaped my notice.

Now, 23 years later, a Canadian Department of Communications project, "SHARP – Stationary High Altitude Relay Platform", is working along the same ambitious lines. A recent successful flight of an experimental microwave-powered model helicopter with a span of four metres has been reported. The model was taken up to about 100 metres with the aid of on-board batteries; these were then turned off and the model kept aloft by means of 2.5GHz energy beamed up from a dish antenna on the ground.

The model is only one-eighth the size of the planned operational helicopter platform which, when fully developed, is expected to be able to hover at heights up to 20km for months on end, as a low cost alternative to satellite communications or regional television services. This is expected to have a 36.5m span, a fuselage 24m long and to carry a 9.6m dish antenna set up behind the wings. The helicopter and its transponders will be powered from about 12 ground dishes, and it is estimated that up to about 10kW should be available for on-board communications or broadcast equipment which could have a service area of up to 600km diameter.

The Canadian Department of Communications plans to spend about ten million Canadian dollars on the model trials and another $20M on an operational model ($1M on the aircraft, $19M on the ground transmitters). Operating costs are put at about $250 000 annually. It is claimed that the power density of the up-going microwave beams will not be sufficient to affect birds, hang-gliders, ultra-light aircraft or balloons.

Radio Communications is written by Pat Hawker.

● *The Mobile Radio Users' Association's 1988 conference is to take place at Cambridge, 29-31 March. Details on 0223-323877.*

RADIO BROADCAST

Whither UK radio?

The long-awaited announcement on replanning UK radio, finally made by the Home Secretary, Douglas Hurd, in a written parliamentary reply on 19 January, seemed more concerned with adding to listeners' "choice" than worrying about the resulting programme or technical standards – a sort of "never mind the quality, feel the choice". Possibly the promised White Paper and subsequent legislation will remove some doubts about the multiplication of largely deregulated stations fighting for national and local advertising.

With the BBC virtually certain to lose a significant proportion of its audience by largely departing from medium wave national services, we may well see the UK heading for radio services based almost entirely on commercial recordings and d.j. chatter or the fully-automated cartridge play-out machines developed for low-cost, unattended commercial operations in the USA and now spreading in Europe. This is not to deny that there is a real place for genuine "community radio" or streamed "community of interest" stations.

The present key proposals appear to be for

- The BBC to continue to provide public service broadcasts but to relinquish the frequencies used for its Radio 1 and Radio 3 networks (or, if the commercial lobby gets its way) the superior Radio 2 frequencies.
- Frequencies to be allotted for three new national commercial networks, two on medium waves and one on v.h.f., with each expected to provide "a diverse and varied" programme service, although without any public service obligations.
- The phasing out of all duplication (simulcasting) of v.h.f. and medium wave broadcasting by national, local or community services (although the BBC is expecting to continue carrying Radio 4 on 198kHz for much of the time).
- Provision for up to 300 community/local stations in addition to the existing Independent Local Radio services.
- A new Radio Authority to license and regulate "with a light touch" all non-BBC radio. The IBA is to cease to be concerned with the regulation of radio, although its engineering division expects to be free to contract on a commercial basis for the provision of technical services.
- The possibility that once the Radio Authority has satisfied itself that applications for national commercial stations fulfil the basic requirement of promising diverse and varied programmes, licences would be allotted to the "highest bidder", presumably in terms of their offering a larger percentage of revenue which would pass to the Treasury.

These proposals have been criticised both on grounds of commercial viability of diverse programming and also from a regulatory viewpoint. Lord Thomson, chairman of the IBA, has written "I applaud your aims but denounce your means. Your proposals are radical and imaginative in their objectives but ill-thought out and potentially damaging in their effect not only on those engaged on independent broadcasting but on the audiences who listen to it..."

A.m. stereo or hi-fi?

In the February "Feedback" (page 134), Kerim Fahme suggests that rather than providing stereo on a.m. broadcasts he would prefer the added quadrature signal to carry the 5 to 10kHz audio components which are filtered out on most Region 1 broadcasts because of the narrow 9kHz channels and congested state of the band. Unfortunately, analogue phase-sensitive signals are subject to considerable crosstalk, in multipath conditions or where the encoder or decoder does not provide highly accurate phase quadrature over the full audio bandwidth. For example, in his system, a 6kHz signal would also produce some level of 1kHz tone in the output of the receiver and would almost certainly result in unacceptable distortion. Such crosstalk is far less worrying with stereo sum-and-difference signals. The effect might come near to resembling the "speech transposer for radio hearing aids" coincidentally described in the February issue and intended for those with severely limited hearing rather than as a means of faithful reproduction.

Another reader has questioned whether independent sideband techniques would not prove better than quadrature systems for a.m. stereo. In fact, i.s.b. is the basis of the Kahn/Heseltine a.m. stereo system which has battled, with diminishing success, for the prime place in the USA, where the Motorola system has been established as the market leader. Kahn has long argued that i.s.b. has many advantages and is less affected by the reflections, etc., that can degrade phase-sensitive systems. However this system did not show up well in the various field trials. The FCC refused to specify any one system but left it to the market-place to decide.

Pioneers depart

The death on December 11 of Dr George H. Brown added one more name to the list of eminent broadcast and communications engineers and scientists who died during 1987. These also included Arthur Collins, founder of Collins Radio, on 25 February, aged 77; Phillip H. Smith who, at Bell Telephone Laboratories, devised the Smith Chart for solving antenna and transmission line problems, on 29 August, aged 82; and Walter H. Brattain, co-inventor of the transistor for which he shared a Nobel Prize, who died in Seattle on 13 October, aged 85 (see also *E&WW* March, page 273).

George Brown, a frequent visitor to Europe, played a key role as RCA's director of research in the development of NTSC colour television and in the subsequent controversies in the USA and Europe on standardization. But it was his pioneering work on antenna design in the 1930s that has secured him a lasting place in the history of broadcast and communications technology. His 68 page paper "Directional Antennas" (*Proc. IRE*, January 1937) remains the classic text on the design of multi-mast m.f. and h.f. broadcast directional antenna design. It also directly inspired the development by radio amateurs of rotary close-spaced h.f. antenna arrays, including the 1937 driven arrays by Dr John Kraus, W8JK and the close-spaced Yagi array by Walter Van Roberts of RCA.

The development of the ubiquitous elevated groundplane antenna and the omnidirectional turnstile v.h.f. broadcast antenna was also due to George Brown, who was responsible for the antenna installations on the Empire State Building. He held 80 US patents and contributed over 100 technical papers.

Radiation hazards?

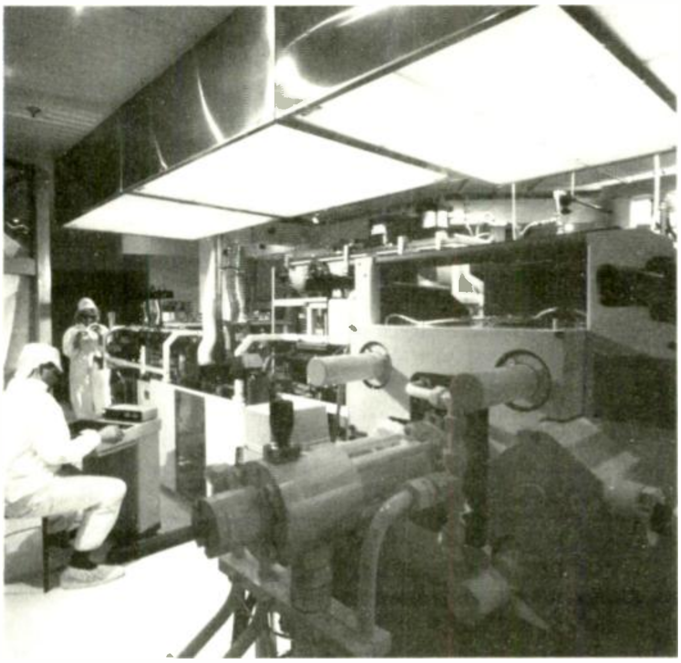
After 40 years of investigation into the possible hazards of low-level, non-ionized electromagnetic radiation, for example in the immediate vicinity of broadcast transmitters, scientists are now claiming that the field is still littered with inconclusive, ambiguous and controversial reports, impossible to evaluate fully, and that it is time to reconsider the need for more research.

The problem, they suggest, is not that too little is known about the biological effects of microwave, u.h.f., or lower-frequency energy. Rather, Kenneth R. Foster (University of Pennsylvania) and William F. Pickard (Washington University, St Louis) in a commentary "Microwaves: the risks of risk research" (*Nature*, 10 December, 1987) argue that "many of the thousands of papers. . . are concerned with heating of tissue, which, when excessive, is clearly hazardous. Yet, fundamental questions are still being raised about the very existence of hazards associated with low levels of exposure, and significant public concern remains". They do not suggest that low-level radiation *is* hazardous or take issue with the 1982 ANSI standard; rather they underline the difficulties involved in demonstrating the safety of environmental agents of all sorts, and believe that guidelines need to be established for halting risk research, concluding: "Granted, society must search for hazards of its technologies. But how to cope with the scientific noise that these studies produce? Such searches for hazards can go on too long, and guidelines for ending them must be established."

Radio Broadcast is compiled by Pat Hawker.

UPDATE

CD factory in a record shop



In the basement of Virgin Superstore in Oxford Street, London, is an area divided off from the rest of the shop by windows. Behind the windows, in view of the shop's customers is a compact disc pressing plant, the first on public view in the world. In front of the windows are a number of video displays which explain the processes on view.

Discs are mastered for Virgin by Nimbus Records in Wales to produce 'stampers' – moulds for the records. All other processes take place in the shop.

First in the production-line is an injection moulding machine where high-purity polycarbonate is squeezed into a mould containing the stamper. Highly polished, the mould also produces the optically flat surface through which the laser pick-up will operate. A reflective surface is added to the coded music side of the disc by sputtered deposition of aluminium in a vacuum chamber. A thin layer of protective laquer is coated on to the metal and cured under ultra-violet light. Finally the label is silk-screen printed onto the disc. All discs are checked by computer-aided quality control equipment and are produced at a rate of about one every ten seconds in the highly automated plant which includes the latest generation of CD-production machinery.

The 'factory' operates in a clean room atmosphere with filtered air conditioning. The staff enter through an air lock.

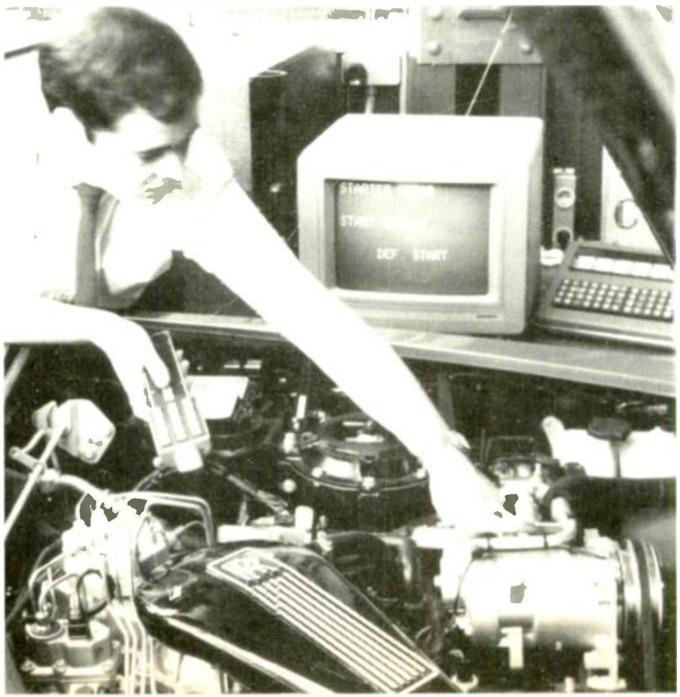
In-store production of compact discs was the brainchild of Richard Branson, Virgin's founder. Apart from offering a spectacle for the customers, the plant is especially useful for the production of short runs of discs and many producers are queuing to use the facility for 'limited editions'. Another advantage is that on promotional occasions, visiting pop-stars can sign discs 'hot off the press'. Commercially the plant is also a success and is expected to repay for its installation within a year.

Radio Show back after 22 years

It's 21 years since the BBC replaced the Home, Light and Third services with Radios 1, 2, 3 and 4. To celebrate the anniversary the corporation is going back to Earls Court, London 30th of September to 9th of October, to revive the Radio Show which was last held in 1966.

Inevitably there will be a nostalgic look back over the story of radio but also a look forward at some of the latest technologies including demonstrations of radio data services. Visitors will be able to meet some broadcasting celebrities, including story-tellers in a 'Listening Corner' for children. They can also watch, and maybe participate in, the making of programmes; and tour the stands of companies from the broadcasting industries.

Screen prompts guide an engineer through the final electrical check on a Rolls-Royce car. Siemens ECOS (electrical check-out system) automatically tests the voltage, current drain and resistance of every lamp, motor and electronic sub-system in turn This takes about 40 minutes, since there are 26 individual electric motors, about a mile of wiring, 2330 connectors and five main electronic sub-systems in each car. The resultant measurements are stored as part of the car's record for future reference.



After Chernobyl

More specialized research to cover permitted radioactivity levels in food and water, and the implications of a possible future accident within the European Community, are the concern of Euratom's Joint Research Centre (JRC).

As directed by the Commission of the EEC, the JRC is to redirect its efforts from more esoteric research into practical projects connected with industry and the environment.

The Community radiation protection research programme has had to be given additional funds as, before the accident, the budget had been reduced. New areas of research are the radiological consequences of the Chernobyl accident; the possible effects of future, hypothetical, accidents; and a number of other research studies including the evaluation of data on the transfer of radionucleides in the food chain, the improvement of practical counter-measures in the environment, and monitoring and surveillance after an accident.

Meanwhile, the Council of Ministers have agreed to set new limits of permitted radiation in foodstuffs in the event of a future accident. These are 1000Becquerels/kilogramme for milk products and 1250B/kg for other foods. However, the current limits of 370B/kg for milk and 600B/kg for others will remain in force for two more years.

Keep the talking books talking

If you like audio equipment and are willing to visit a handicapped person occasionally, Talking Books needs you. Some of the tape players sometimes go wrong and need fixing. You are not obliged to accept every request for a service call and you don't need any qualifications or even much experience; all is explained in a service manual sent to volunteers.

Send for an application form to Don Roskilly or Sheila Finch, The National Listening Library, Freepost, 12 Lant Street, London SE1 1QH, or telephone 01-407 9417.

Environmental test summaries

There is an enormous collection of national and international standards for testing the fitness of electronic and electrical equipment and components. The International Electrotechnical Commission (IEC) in its Publication 68 lists and specifies a whole series of environmental tests for international use. But publication 68 is actually a library of test procedures. 68-2 lists more than 50 test methods for a range of environmental conditions. These are further subdivided into individual tests. For example, Test Z/AFc (in Publication 68-2-50) describes the application of a cold test in combination with a sinusoidal vibration test.

This is all very well for those who actually carry out the procedures, but offers a forest of confusion to the specifier, who only needs to know which tests to apply.

Help is at hand in Publication 68-4: *Information for specification writers – test summaries*, which provides an introduction, definitions, cross references and 39 summaries of basic test procedures. It indicates which section of 68-2 the test was taken from, so the full test specification can be checked if necessary. The summaries are in loose-leaf form so that changes or additions can be easily inserted. The Commission stresses, however, that those who carry out the tests and assessments will still need the full specification. Full details from the IEC, 3 rue de Varembe, PO Box 131, 1211 Geneva 20, Switzerland, or from the British Standards Institute.

Wanted – emergency life-saving radio

Many lives could be saved at sea, or on mountains, if there were a miniature radio beacon that could be carried by an individual and picked up by a directional receiver. So says our sister magazine, *Yachting World* which is encouraging designers to create such a transmitter.

"What is needed," said Dick Johnson, editor of *YW*, "is a cigarette-packet sized transmitter that would be always carried by any crew member on deck. The device should float and, if not completely watertight, must be capable of operating in water for at least three hours."

Ideally it should also be able to transmit its exact location from signals it has received from navigational satellites, but the editor admits that there may be insurmountable problems in developing a device of that sort. More realistically, if it transmitted in the radio direction-finding waveband, the simplest receiver should be able to get a directional fix. A further target is that the price of the transmitter should be below £50.

As an incentive, *Yachting World* is offering £200 towards the further development of the most promising, working, equipment. Any company willing to produce the winning design will receive free advertising in the magazine.

"It cannot be beyond the wit of today's electronics wizards to come up with a simple device that would add immeasurably to the safety of the yachtsman," said Dick Johnson.

Who mends the p.c.b?

While promoting its own products, Schlumberger ATE's Winter edition of *Infotest* makes some interesting remarks about field-servicing electronic equipment.

In order to get a customer's installation up and running as quickly as possible, the field service engineer will replace a faulty circuit board with one from his/her kit. There is then often considerable delay, perhaps weeks if the engineer is busy, before that board is returned for repair. It may then be routed through a complicated pipeline until it actually reaches the repair shop.

The repairer will then have to diagnose the fault, perhaps with only a hastily scribbled report sent in by the, now very remote, engineer. Quite often there is nothing wrong with the p.c.b. but it still has to be tested.

How much more sensible, says Schlumberger, it would be if there were a number of local repair facilities, all equipped with their automatic test gear. There would need to be far fewer boards in the field or stuck in the pipeline and this could result in a much reduced inventory, say 30%, and consequently a reduction in capital costs.

Some advances towards DBS

In preparation for the launch of direct broadcasting by satellite, British Satellite Broadcasting (BSB) is inviting suppliers interested in the design and manufacture of domestic DBS receiving equipment to submit pre-qualification information. From the information supplied, BSB will select three companies to submit formal tenders for the production of the equipment. Each set will include an antenna and a receiver/converter which is likely to sit on top of a tv set. Technical guidelines have been sent to 50 companies from which the three will be selected. The small number was chosen to minimize the costs as there would be less capital outlay on each set than with multiple suppliers.

The receiver equipment will include access control, since one of the planned channels will be on a subscriber basis and the other three, pay-as-you-view. Each receiver will possess a unique identification code which can be used to activate (and presumably deactivate, if the bills aren't paid) signal reception. Codes will be issued to the three manufacturers.

Meanwhile, at the transmitting end of the chain, ERA Technology has been awarded a contract to provide uplink antenna systems for DBS. Two eight-metre dishes will be sited in the south of England. They will be the first to operate in the frequency band allocated by WARC77 for DBS: 17.3 to 18.1GHz uplink and 11.7 to 12.5GHz downlink. Both antennas will have the capacity to cope with five channels and will be fitted with tracking systems to maintain accurate alignment with the geosynchronous satellite.

ERA has designed the complete system and will manufacture the feeds between the various sections of the transmitting station. Larger structures, including the antennas are to be made to ERA's design.

Taylor meter recall

If you have a Taylor multimeter, model TD22 or TD23, you should return it to the company for a slight modification. It has been found that, in certain circumstances, the screw fixing the battery cover could become 'live' and therefore dangerous. The modification is free and instruments are returned as quickly as possible. Meters should be sent to Taylor Electrical Instruments Ltd, Parts and Service Centre, Archcliffe Road, Dover, Kent CT17 9EN. Packages should be clearly marked "For Modification."

Government backs super-conductors

High-temperature superconductivity is the target for a national collaborative research programme. It is designed to "keep Britain at the leading-edge of research," and is intended to stimulate companies into working together, pooling their resources with those of higher education and with European industries.

This initiative follows the discovery of ceramic materials that can conduct without resistance at temperatures as high as that of liquid nitrogen (88K or −185°C). There have been reports of experimental materials working at even higher temperatures, so the race is on to find materials that will superconduct at room temperatures. This is coupled with research into ways of using the materials in highly-efficient electric motors and electronic components.

The Department of Trade and Industry will fund half of the research. Coordinating the project for the DTI is Derek Howarth who can be reached at the Research and Technology Policy Division, DTI, Ashdown House, 123 Victoria Street, London SW1E 6RB.

PT 68K-2 SINGLE BOARD COMPUTER KIT

Designed around the powerful MC68000 microprocessor the PT 68K-2 is an easy to build single board computer kit.

When fully configured the PT 68K-2 becomes a full feature system that supports over 1M byte of memory, floppy and hard disk drives, serial and parallel I/O and provides extensive expansion capability.

User expansion of the PT 68K-2 is suported by way of six on-board IBM PC/XT compatible I/O ports. This gives access to a wide range of low cost PC add-on boards such as colour adaptors and Western Digital Winchester controller cards.

Two powerful disk operating systems are supported:

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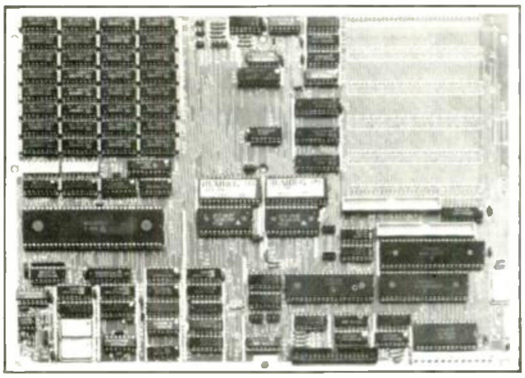

PT 68K-2 specification:

Processor	– MC68000 8MHz clock, optional 10, 12.5, 16MHz clock.
Memory	– 1024K DRAM, no wait states. 128K EPROM. 4K SRAM.
Floppy disks	– Four floppy disk drives. (WD1772 FDC) 40/80 track, single/double sided density.
Hard disks	– Winchester interface for WD1002A-HDO controller. PC/XT slots supports WD1002A-WX2 controller.
Serial I/O	– Four RS232 serial ports. (MC68681 DUARTS).
Parallel I/O	– Two 8 bit parallel ports. (MC68230 PIA) Interlocked handshaking. Two programmable interrupt timers.
RTC	– Battery backed real-time clock.
Expansion	– Six IBM PC/XT compatible I/O ports.
Power	– Requires 5V @ 2A and +/– 12V @ 20mA.
Size	– 12 × 8.5 inches.

The PT 68K-2 is supplied in kit form with all parts necessary to build a basic functioning 68000 computer. The user may then add additional parts to implement only those features required.

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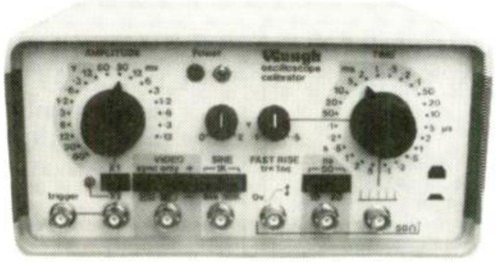

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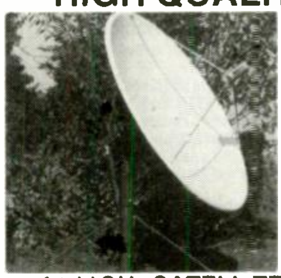

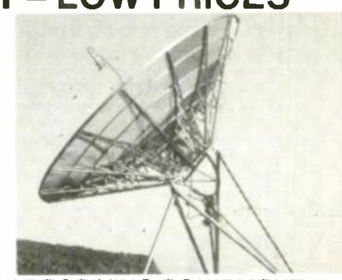

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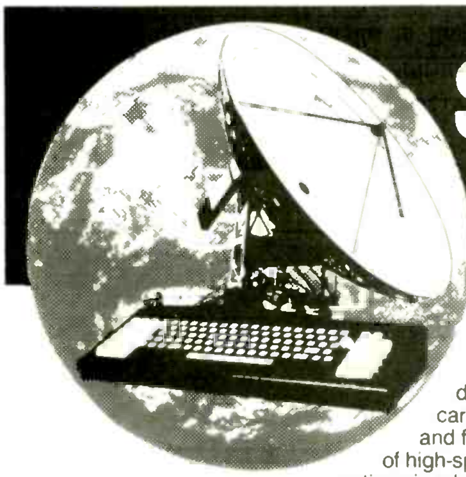

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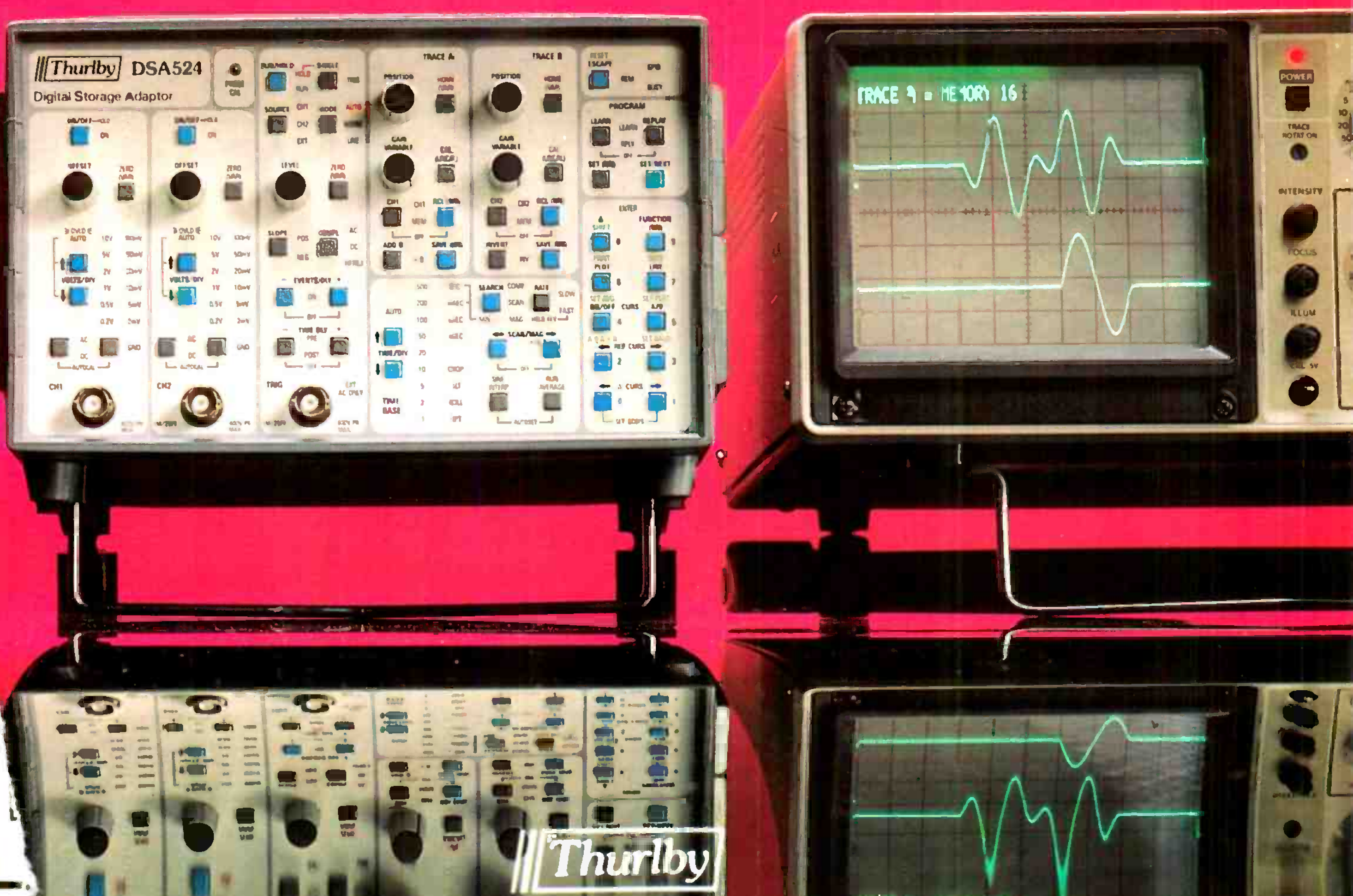

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