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SEPTEMBER 1987

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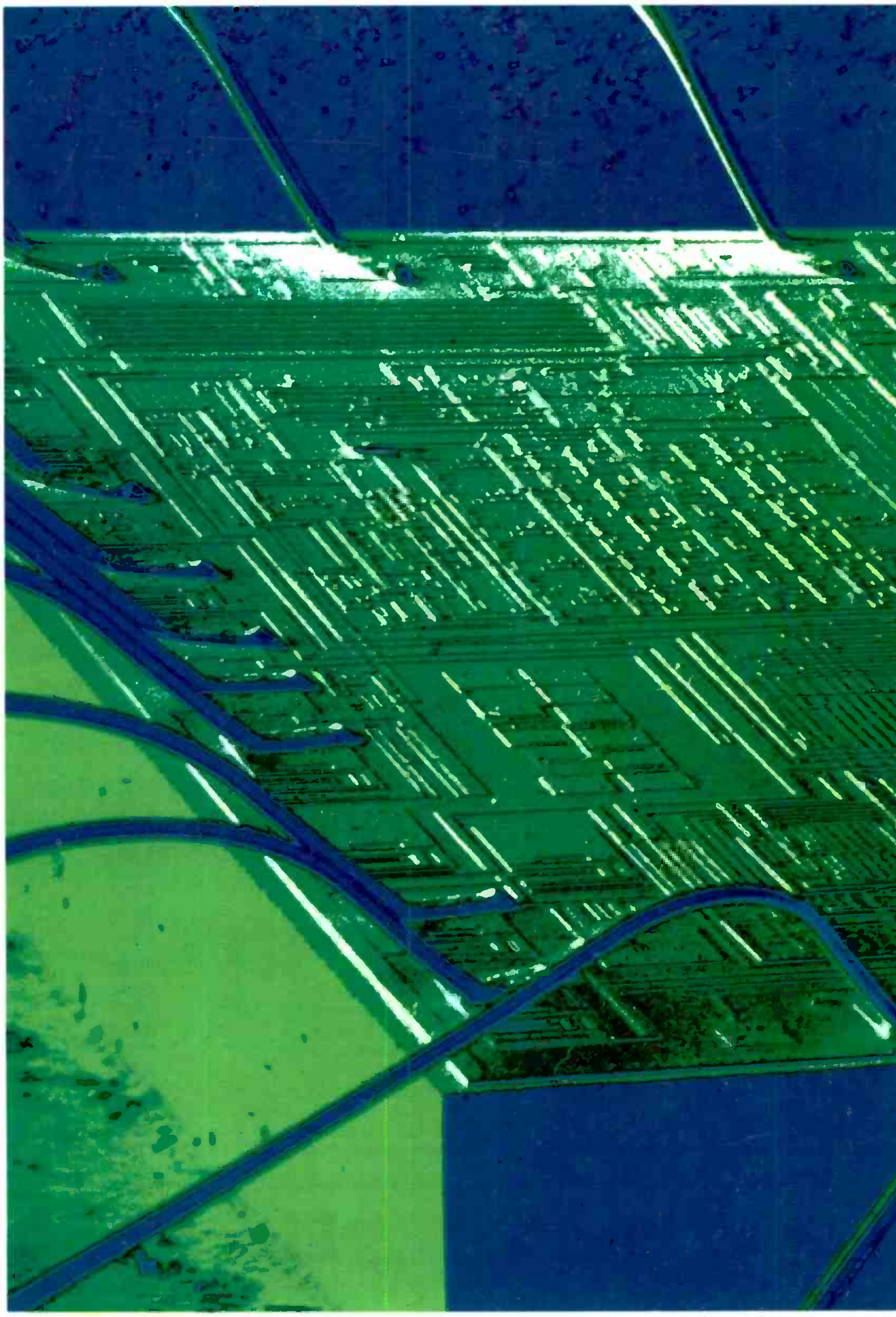

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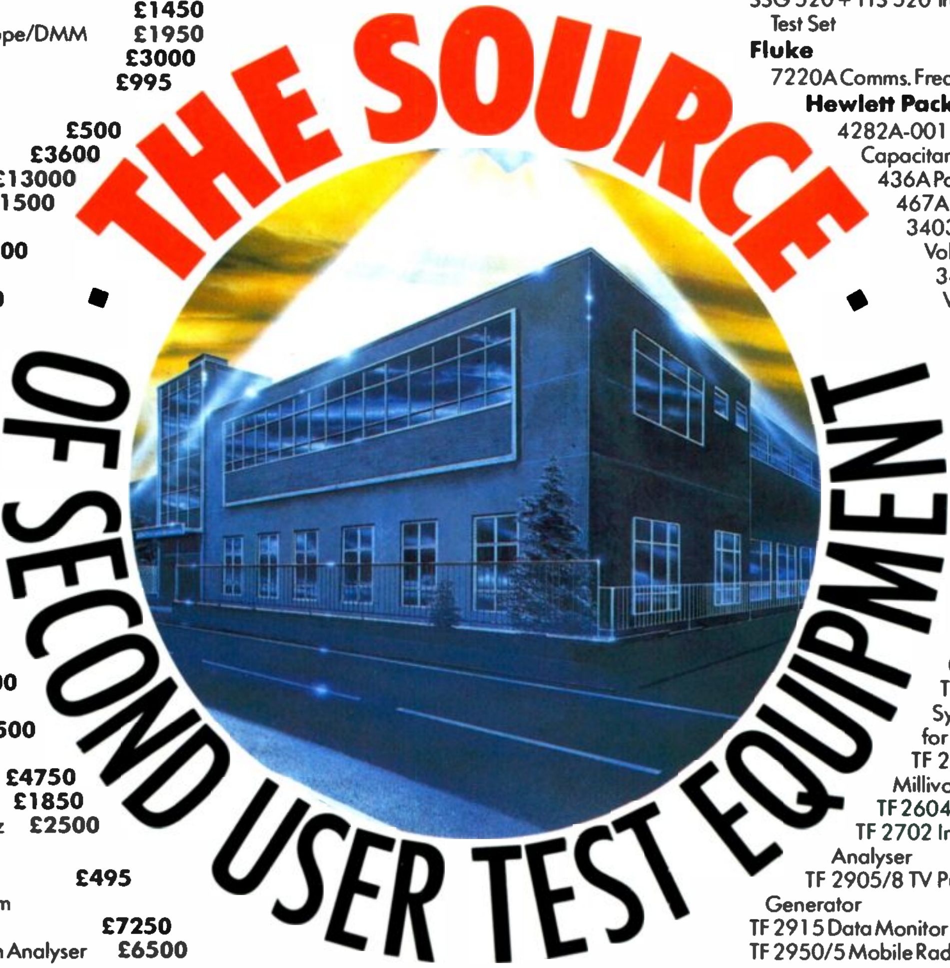


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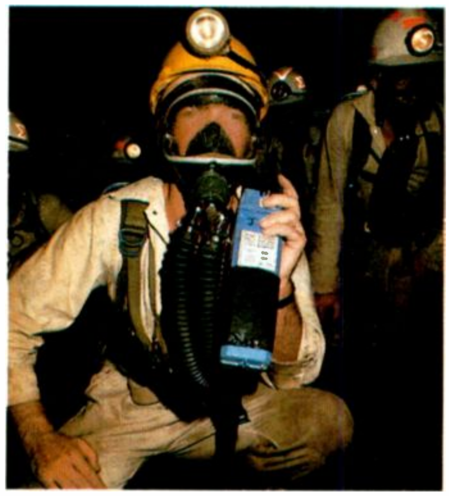

A miner using a personal transceiver to signal through rock in a South African mine. Dr Austin's article appears on page 943.



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REED BUSINESS PUBLISHING

## Sophocles and soap

Broadcasting could do something more for education in Britain than simply putting out more educational material. With many new programme sources becoming available through satellites and cable, there is now a technical opportunity to improve the aesthetic and intellectual diet of people who are living near the poverty line in this respect. The entertainments-industry ethos that permeates broadcasting would not be fundamentally opposed. It would be perfectly happy if ancient Greek drama proved as magnetic as soap opera, the *Incoronazione di Poppea* as compelling as *Coronation Street*.

At the time of the industrial revolution Britain's ruling class suddenly decided that the working class would have to be taught to read, in order to carry out the new kinds of instructions made necessary by factories and machines. What the authorities did not realise was that they were opening the doors to general literacy. People who could read technical instructions would also be capable of reading other, very different kinds of literature. Their knowledge, thoughts and views of the world would be expanded far beyond the instrumental requirements of work.

A parallel situation exists today. The government is worried because the UK's workforce is poorly educated and trained compared with those of our industrial competitors. But the qualities of knowledge, understanding and conceptual analysis required for excellence in modern technologies such as electronics cannot simply be taken off the shelf and injected when required like medicines. These qualities can only be supplied by people who are already well and broadly educated, able to adapt themselves not only to learn specialised techniques quickly but contribute to them as well. We need to grow more of such people.

But the soil is not right. It shows in everyday talk. Art, intellect and culture are as taboo in British conversation as religion, sex and politics are supposed to be. Art is too often misunderstood as entertainment, decoration or good taste. It may contain any of these, or none, but its essence is to illuminate, clarify and give meaning to human experience. Some countries revere their artists and intellectuals as fervently as we do our footballers and pop stars.

There is in fact no fundamental divide between, say, *Antigone* and *East Enders*. Both create drama from the conflict of passion and principles. The practical difference is that the entertainments-industry ethos has conditioned large masses of the population to the shallow and meretricious because this is the easiest route to ratings and money. Truth is sometimes too uncomfortable to be a marketable commodity. One result of this cynical manipulation of audiences which are uncritical because poorly educated is that the familiar assertion "I know what I like" really just means "I like what I know."

In UK broadcasting the best products of art and intellect are presented self-consciously, mainly through Radio 3, BBC-2 and Channel 4, in a way that makes them seem exclusive. Consequently many people see these networks as elitist cultural ghettoes and shy away automatically as if from contamination. The coming break-up of the old patterns in broadcasting could be an opportunity to heal this wound of misunderstanding in our society.

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# Memory in small computers

**Processors with 32bit buses address more ram than 16bit equivalents, but more significantly they are changing the way in which memory is used.**

RODNEY STUBBS

As personal computers have increased in performance, and the cost of ram has fallen, the size of user memory has increased from a few kilobytes to 640Kbyte for MSDOS systems and up to several megabytes for Unix-based computers.

But 32bit microprocessors are causing more than just an increase in the amount of memory that a computer can access; they are also changing the way in which memory is used. These processors and their co-processors are powerful enough to handle large programs requiring megabytes of memory. They can also coordinate multi-user, multi-tasking systems, again requiring expansive memories for efficient operation.

Addressing ranges of 32bit processors vary from about 16Mbyte to 4Gbyte and are usually linear, i.e. all address locations are continguous. Even with current low ram prices, using the whole addressing range with memory would be costly and probably unnecessary.

One approach is to use the full address range, but only part of it for ram. This is achieved by having virtual memory, which should not be confused with a virtual disc system. The approach is not new, having been developed several decades ago and used by IBM in their 360 series mainframes. It is currently used in some minicomputers.

In virtual memory systems, the bulk of addressable memory is not in ram but on hard disc. A floppy disc could be used instead but speed and capacity would be greatly reduced. To the user all the memory appears the same but in reality, only that part of the software currently being run is in ram; the remainder stays on the hard disc.

Transfer of code and data between disc and memory is done automatically by the computer system and is unnoticed by the user. For instance if the processor finds that the next instruction, or data to be operated on, is not in core memory (ram), it stops execution, returns to the operating system, saves a section of ram content onto disc and loads the required software section from disc. This process is known as swapping.

In reality this is not a very efficient process, although it is unlikely that the typical user would realize that it was taking place. In multi-user systems a co-processor known as a memory-management unit, which is sometimes built into the micro processor, relieves the main processor. When swapping is necessary for one user, the management unit takes over but instead of the processor waiting, it serves the second user whose data is in ram. This clearly makes more efficient use of processing time.

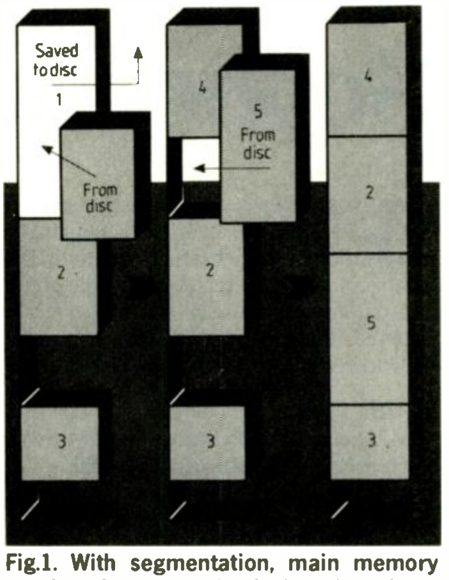


**Fig.1. With segmentation, main memory needs to be reorganized when there is no room for a large segment. At (a), memory reorganization is unnecessary when a large segment in ram is swapped for a segment on disc. But at (b), memory needs to be reorganized as in (c) in order to insert the large segment in ram. This reorganization requires complex algorithms.**

Matters are not quite so simple though. There are two main approaches to implementation of virtual memory – segmentation and demand paged. Segmentation has been in use longest and is easiest to implement. Demand-paged management needs extra hardware and more memory overhead but it is becoming more popular.

## SEGMENTED MEMORY

Segmentation appeared with the 8086 processor; later processors like the 80286, 80386 and Z8000 also handle segmented memory. The technique involves dividing addressable memory into a small number of generally large segments which may vary in size. These segments are swapped in and out of ram, onto disc as required; but if large segments are replaced by smaller ones, usable memory rapidly becomes fragmented.

Complex algorithms are needed in the operating system to match incoming segments with unused memory space, and even then a large segment needing to be swapped into the core can find insufficient contiguous free memory. The operating system has to totally reorganize the memory which is an inefficient process, Fig.1.

## DEMAND-PAGING

Swapping large segments into small gaps is not a problem with demand-paged management. This method uses a large number of relatively small and fixed-size pages; 512byte and 1Kbyte pages are not unusual. One may now has a very large number of pages but no memory fragmentation, complex swapping algorithms or memory reorganization.

Consider a 16Mbyte addressable memory area with 32 768 pages. To hold all these pages in ram would be wasteful so instead address-translation tables are held in ram. In the memory-management unit, there is a register that points to the start of the primary page table. This has for example 256 entries each four bytes wide, giving a total of 1024 bytes.

Each entry in the primary table points to the start of a secondary page table having for example 128 entries each four bytes wide, taking in total one 512byte page. Secondary page entries point to a page in memory so the entire memory map needs only a 1024byte primary table pointing to 256 tables of 512 bytes each. This takes only 132Kbyte, which represents less than 1% of the total address range, and most of that could be on hard disc.

In a multi-user system each user and/or program would have a primary table thus each program would have its own mapping to physical memory. Processors like the 80386 NS32000 series and Z8000 can handle demand-paging. With demand paging, the overhead is memory space, and not the complex algorithms needed for segmented memory.

Memory-management units still speed up the swapping process by marking only pages in ram that have been written to. Pages that have not been written to do not need to be saved on disc in the swapping process. Further flags attached to each page can be used to control access, such as read only and supervisor-mode access only, so that users cannot modify or overwrite critical code.

To summarize, 32-bit personal computers with their large addressing ranges allow more efficient use of memory, particularly in multi-user, multi-tasking systems, through the implementation of virtual memory. Paged and segmented virtual-memory techniques made practical by the increased performance of 32bit processors are now appearing in personal computers whereas previously they were only found in mainframe and minicomputers.

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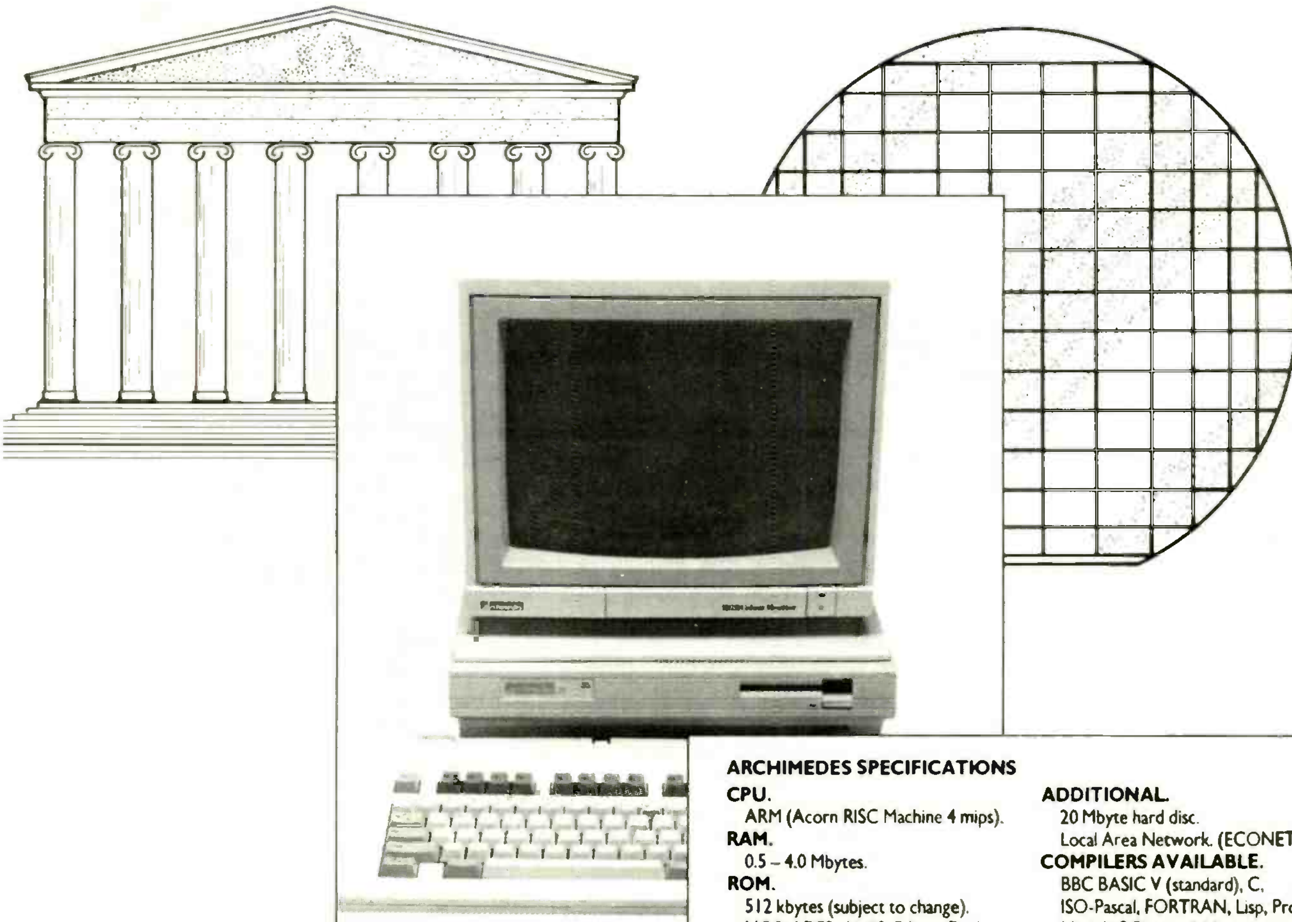

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# Microprocessor-controlled engine management

**Rising fuel costs and tighter emission control legislation have led to great advances both in engine design and in control systems.**

PAT JORDAN

Electronic components were finding their way into cars as long ago as the 1930s, in the form of valve radios. But only in relatively recent years has electronics begun to make an impact in the more critical areas of engine control and anti-skid braking. The main reasons behind this are, firstly, the reputation of reliability (or lack of one) which the early systems had; and, secondly, the high cost of the electronic module compared with that of the fairly basic mechanical system which was already proven to work reliably.

Indeed the environment in which the electronic modules have to survive is harsh, to say the least – voltage transients of ±300V with time constants of 100μs and load dumps of 100V with the time constant of 250ms. Further, the module has to be able to withstand a continuous 24V supply, even in a 12V system, to take account of boost starting. This puts very tight constraints on the design of the voltage regulator for the module. Indeed, any external input to the module must be protected against these excessive voltages.

On top of this, car manufacturers are, quite rightly, insisting on failure rates for any component of less than 100 parts per million so as to guarantee a reasonable mean time before failure for the module.

In recent years, however, enormous improvements have been made in semiconductor reliability and the requirements of the engine control system have changed dramatically. These changes are due partly to increasing fuel costs and a desire to develop more power but predominantly to government limits on permitted emissions from new vehicles which must be met throughout the life of the vehicle.

This has also created incentives for using unleaded petrol, which causes the engine to operate much closer to the detonation limit (pinking) and therefore requires much more accurate control. Detonation occurs when the mixture under compression ignites too early.

## IGNITION

Currently the most common use of electronics in engine control is in the ignition system. Systems can vary from the simplest transistor-assisted and capacitive discharge systems, which are available as retrofit units, to the most complex microprocessor-controlled digitally mapped system.

The transistor-assisted ignition (transistor amplifier between contact breakers and coil) offers no real advantage over a conventional system other than prolonged contact life and the ability to change to a higher energy coil (which extends the spark duration and helps break down fouled plugs). Capacitive discharge offers the ability to generate more ignition potential but at the cost of a shorter spark duration. This is an advantage at high engine speeds (e.g. in racing engines) but is a disadvantage for lean mixtures. However, it may improve starting, especially with fouled plugs.

The contacts can be replaced with some form of electronic switch, the most common types being the Hall-effect switch, the variable-reluctance (magnetic) transducer and the optical infra-red switch. The optical switch consists merely of an infra-red led and receiver with some form of vane interrupting the optical path between the two. This has never really proved popular, except in the retrofit market, because of the problem of dirt degrading the performance. The Hall effect switch is fairly well accepted in the industry and is currently used by a number of car manufacturers including VW and Ford.

By far the most widely used type of sensor is the variable-reluctance transducer which consists merely of a magnetic pole around which is wound a coil of wire. This transducer can be made to produce a pulse every time a tooth on a metal rotor or gear passes the pole of the transducer. This type of sensor is very cheap and reliable but has the disadvantage of producing output voltages ranging from 500mV to 80V, depending on rotor speed, and requires some fairly complex electronics to discriminate the signal from the noise. Figure 1 shows the type of waveform output by this kind of transducer.

The most common application of the variable-reluctance transducer is in conjunction with the timed turn-on (variable dwell) ignition system which is currently manufactured as an encapsulated hybrid module by AC Delco (GM), Lucas, Bosch, Ducellier, and others. It is currently fitted to at least one model in the range of virtually every European and US car manufacturer. This system is also known as breakerless ignition (i.e. there are no contact breakers). A major drawback of the conventional contact breaker system is that the fixed dwell angle causes the break current (and hence the kV generated by the back e.m.f. of the coil supply interruption) to drop off as engine speed increases and at low battery voltage the break current is again low (hence the use of ballasted coils to aid starting).

The timed turn-on system overcomes these problems, firstly by using a very low resistance coil which achieves the required break current very rapidly and maintains it by a current-limit circuit until the spark is required. Secondly, an electronic prediction circuit determines how far in advance of the spark the coil should be turned on (variable dwell) to minimize the power dissipation in the coil and module and yet still achieve the required break current under acceleration (Fig.2).

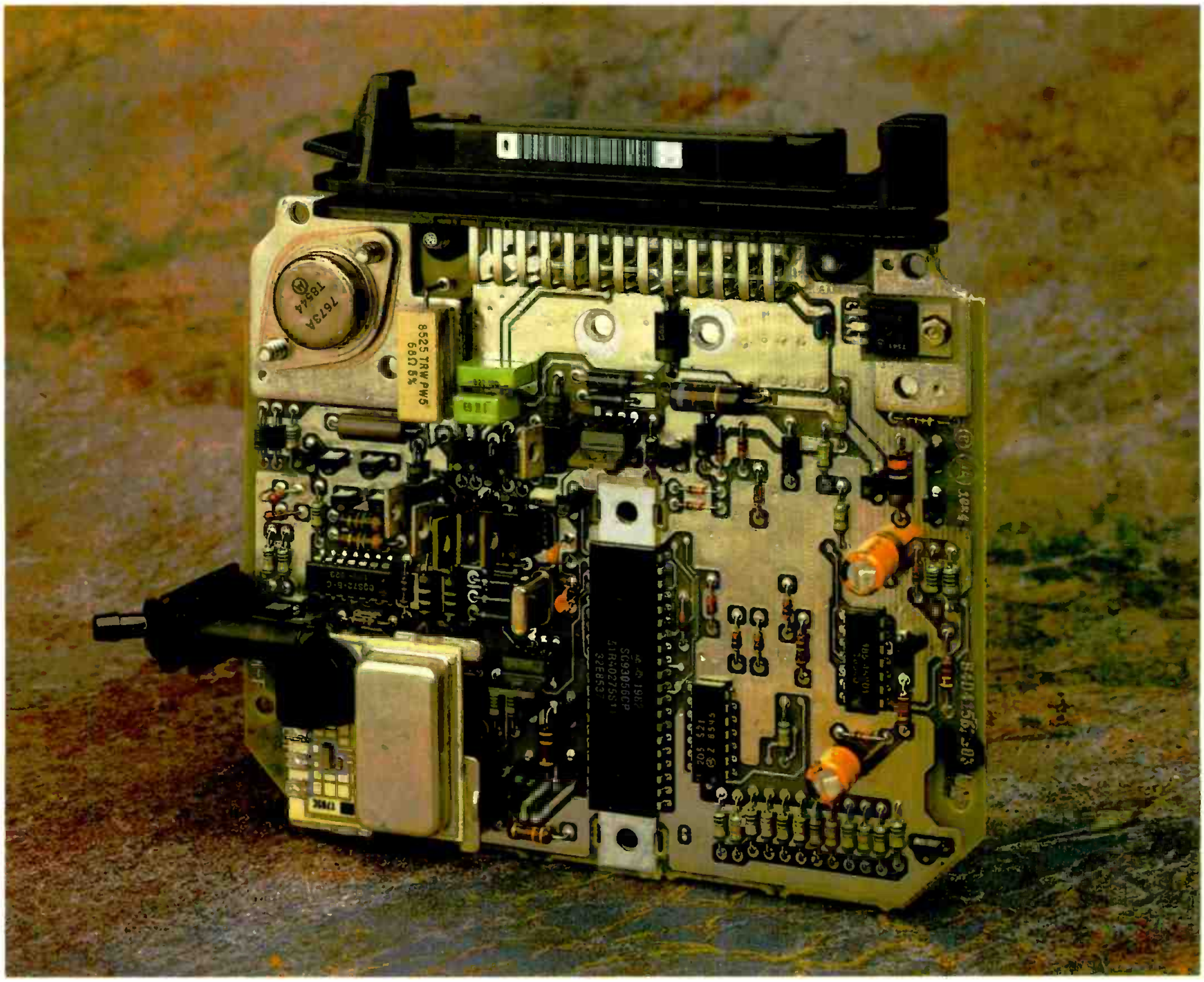
## DIGITALLY PROGRAMMED IGNITION

All the systems described up till now have depended on the mechanical distributor to determine the required spark advance as a function of engine speed and load. In the conventional distributor, the centrifugal advance (advance versus engine speed) is generated by two bob weights and two springs which cause the top half of the distributor shaft (contact breakers) to advance in relation to the bottom half (engine drive). This means that the most complex curve which can be generated has only two linearly advancing slopes.

Likewise the modification of spark advance with engine load is generated by the vacuum capsule which uses the depression in the manifold to drive a diaphram and spring. This allows an effective linear displacement of the centrifugal advance curve between two limits of depression. This crude but effective method of controlling spark advance has proved adequate for many years.

Recently, however, concern about the environment has led governments to impose legislation on emissions. The catalytic convertor has played a major role in controlling emissions but has deleterious effects on the efficiency of the engine and can only be used with unleaded fuel. The real solution, therefore, lies in better control of the engine by digitally mapping the ideal engine characteristics and storing the characteristic in the rom of the ignition and/or fuelling controller. The advantages of this are immediately apparent as we are no longer restricted to the dual slope curve of the distributor, but the complexity of the mapped surface (now a true three-dimensional surface) is restricted only by the amount of available rom and the resolution of the timer and a-to-d converter.

Negative slopes (decreasing advance with increasing speed) can also be produced to



**This programmable ignition controller designed for mounting in the engine compartment has an integral pressure sensor and ignition-coil drivers.**

avoid areas close to the detonation limit without compromising the rest of the curve. Figure 3 shows the most complex distributor curve possible; it should be compared with the far more complex digitally mapped characteristic for a typical engine in Fig.4.

Early digital ignition systems were based on custom i.cs and were ideal for specific high-volume applications. Unfortunately the custom approach lacked the flexibility which car manufacturers require to change engine characteristics at very short notice and to change the function of the system for different models of car. This is where single chip microcontrollers come into their own: their functions can be changed by simply altering the software, and the engine characteristics by modifying the rom data.

## TIME-BASED IGNITION

Microprocessor-based ignition systems fall into two basic categories which I will term time-based systems and angle-based systems.

In terms of the real-time tasks required from the micro, the time based system is certainly the simpler of the two. Generally it is based on a Hall-effect transducer mounted in the distributor or on the end of the crankshaft. The waveform output from the transducer is an electrical replica of the metal vane and is usually rectangular.

Figure 5 shows an example of a system where a 50:50 mark-to-space ratio was chosen. For a four-cylinder, four-stroke engine, the mark and space both correspond to 90°; and here the positive edge is chosen as the positional reference for the most retarded timing (top dead-centre is used for this example).

Engine speed can be derived by measuring the high period of the waveform or the period between edges, the inverse of which is equivalent to speed. For the former method, a timer structure with 'input gated' mode, such as that available on the Motorola MC6805S3, is ideally suited (see panel). In this mode the timer will count while the signal is high; and if this input is also connected to the interrupt pin the negative edge will indicate to the processor when to read the timer contents and calculate the engine speed. For the other method, the interrupt pin alone may be used and the timer read at every negative edge to determine the period. This has the drawback of the interrupt latency (time taken to stack machine status and begin execution of the interrupt routine) which affects the accuracy of the measurement.

A better solution is to use a timer with an

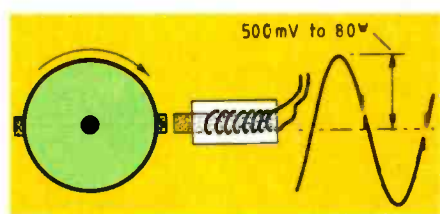



**Fig.1. Variable-reluctance (magnetic) transducers are the most common type of speed/position sensors used in engine control, but they have the disadvantage of producing an output which can range from 500mV to 80V peak to peak depending on engine speed.**

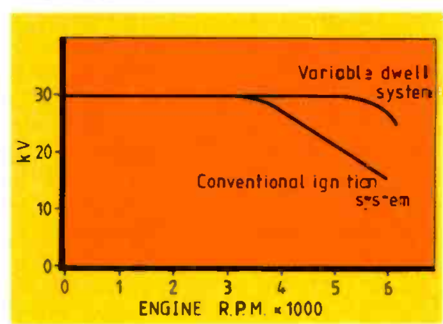
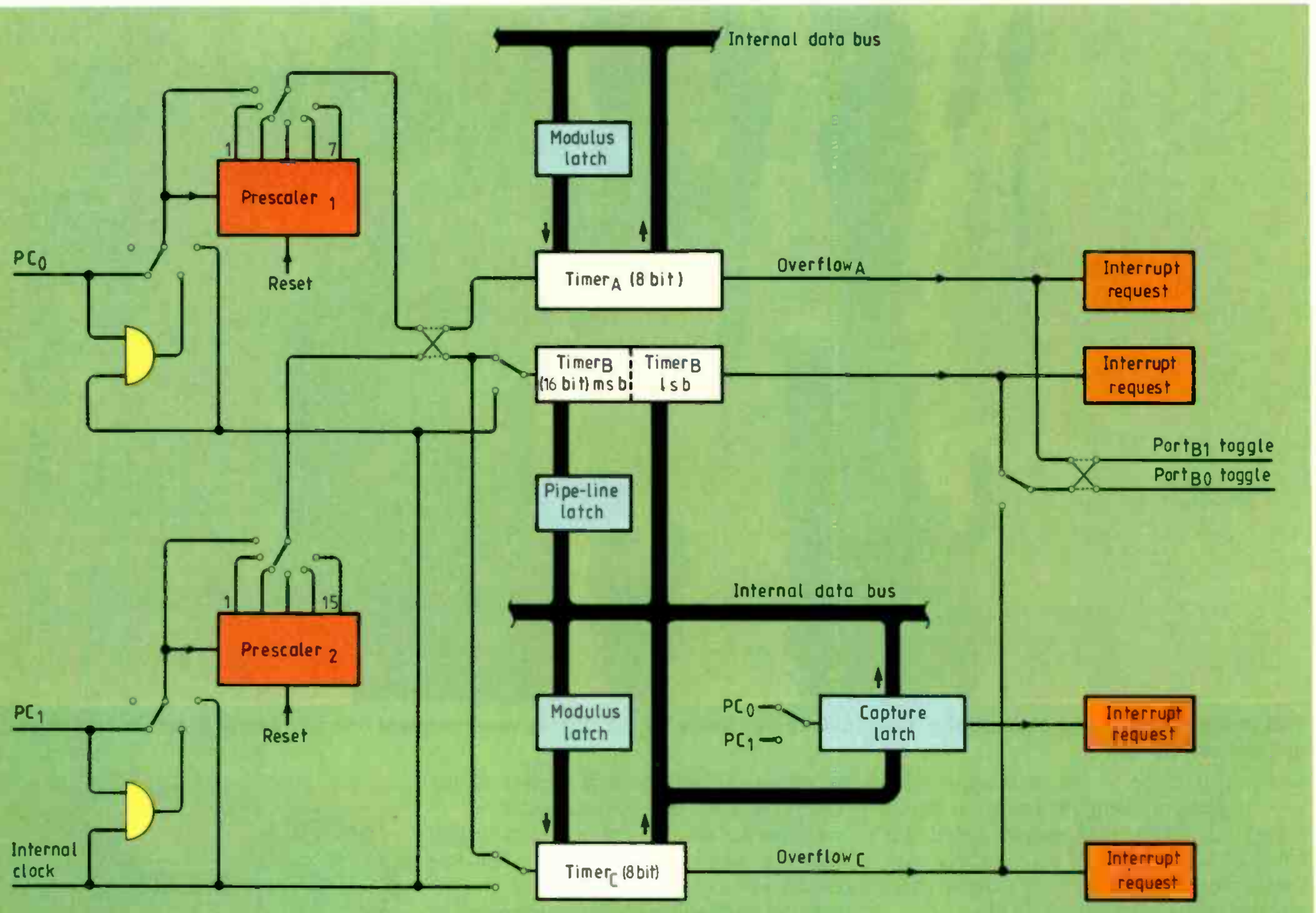



**Fig.2. Variable-dwell ignition significantly improves the available ignition potential at higher engine speed and during cranking.**

input capture facility, such as is available in the MC68HC05 family. This facility automatically captures timer contents on the occurrence of an external event and can be made to interrupt the processor. The other main input to the module is the load on the engine which is derived from the depression in the inlet manifold. This is generally measured by some form of silicon strain gauge pressure transducer, such as the Motorola MPX series which have on-chip calibration and temperature compensation. The analogue voltage dervied from this can then be used to drive directly the analogue inputs of the microcontroller's a-to-d convertor. Having yielded the engine speed and load, this information is used to point into a look-up table in rom which contains the corresponding advance angle for optimum performance. Owing to limitations on rom space the look-up table is generally constructed as a matrix of, say, 64 points on the speed axis by eight points on the load axis, making a total of 512 locations (or bytes). As the resolution of this matrix is inadequate by itself, interpolation is performed between the points in the matrix. Eight steps of interpolation on each axis would then give an effective matrix of 32 768 locations.

Once the desired advance has been determined, a timer function is required which will produce an output on one of the ports when programmed with the desired firing point relative to the most up-to-date reference point (the negative edge in our example).

There are basically two methods of doing this. The first is to load a timer at the negative edge with the time from that edge to the required firing point such that, when the timer decrements to zero, it will interrupt the processor or directly manipulate




**Powerful timer structure of the 680553 handles angle-based ignition with missing-tooth detection.**

This microcontroller, designed by Motorola for automotive ignition applications, includes three timers, an a-to-d converter, rom, ram, a serial peripheral interface, i/o and a watchdog timer.

Of the three timers, one is 16 bit and the other two are eight bit. The 16-bit timer has a pipeline latch to enable simultaneous reading of all 16 bits via the eight-bit bus. One of the eight-bit timers has a modulus latch which enables the timer to be set up to underflow to any programmed value, instead of $FF_{16}$. Associated with the other eight-bit timer are a modulus latch and a capture latch, which enables the timer contents to be latched when an edge occurs on an external pin.

The dynamic range required to measure the period for any engine speed (5 to 60ms) with a resolution of 16µs (<1° at 6000 rev/min) makes the 16-bit timer ideal for this task. The modulus latch is ideal for detecting changes in period such as with the missing tooth: on every tooth the timer is preset to the time for 1.5 teeth, and if it underflows then a tooth is missing.

Also, counting the number of teeth between references lends itself to the modulus latch technique. There the timer is loaded with the number of teeth and decremented by each tooth, to interrupt the processor at the point when the next reference is due. For measuring the period between teeth, (required for extrapolating to the coil firing point) the capture latch is ideal, as the timer value can be captured automatically and the processor interrupted to indicate that a value has been captured. The five-channel multiplexed a-to-d is essential for measuring the load on the engine (via the silicon strain gauge pressure tranducer), the engine temperature and air temperature from thermistors, and may also be used in the knock detection to compare knock intensity with background noise. With 3.7K rom and 104 bytes of ram, memory space is adequate even for the most complex ignition system. The synchronous serial interface may be used to communicate with a processor in the dashboard to pass information on engine speed and load (for an economy indicator light perhaps) or may be used to communicate with diagnostic equipment in the service centre. Input/output ports are available for digital inputs and coil drive, and the watchdog timer can force a hardware reset should the program run away becaue of noise.

the port. Timers A,B and C on the MC6805S3 allow direct control of the ports in this way, by means of the port-B toggle facility which automatically toggles one of the port pins when the time decrements to zero (see panel). The second method is to use the output compare facility (as on the MC68HC05B6), which will generate an interrupt and/or directly modify the port when the compare latch contents match the timer contents.

The coil 'on time' (dwell) must also be controlled. To achieve the same benefits as for the timed turn-on system, a very low resistance coil is used, with a current-limited driver stage. At low speeds it is sufficient to turn the coil on at the negative edge. However, at higher speeds, when the period is reduced, the coil must be turned on sooner, to guarantee achieving the required break current, by timing from the previous positive edge (assuming the previous period is known and no significant change in speed has occurred). At high speeds, data from the previous cycle is used due to the time required to calculate the new advance angle.

## ACCELERATION EFFECTS

Until now I have assumed that no significant change in engine speed has occurred between one cycle and the next. But in reality very significant changes can occur, and accelerations of up to 6000 rev/min per second have to be taken account of as well as almost instantaneous decelerations.

In the example, the period between sparks at 500 rev/min is 60ms and the processor would therefore measure the high time as 30ms. To generate a spark at zero degrees advance the processor would delay 30ms from the negative edge before producing the spark. In reality, however, with an acceleration of 6000 rev/min per second, starting at the negative edge, 30ms would actually equate to 160.2° from the negative edge (i.e. 16.2° after top dead centre). Similarly, the time at which to turn the coil on is predicted from the previous cycle: and with accelerations of this magnitude it is possible that the coil should be turned off before it is even on. Therefore, a balance has to be achieved between the risk of losing a spark and excessive power dissipation in the current-limit stage controlling the coil.

Various methods can be used to compensate for acceleration effects, including a second order differential filter of the form

$$T_{prediction} = A.t(0)+B.t(-1)+C.t(-2)$$

where t(n) is the current and previous periods and A,B and C are carefully chosen constants. This type of prediction may work very well but it can never compensate for the very first spark after the acceleration begins, and one spark may be lost. It is in this area that the angle-based system has a superior performance.

## ANGLE-BASED IGNITION

Angle-based systems generally use one or two variable-reluctance transducers as speed and position sensors. Where two sensors are used, one will produce the positional reference from two markers on the crankshaft pulley (180° apart for a four-cylinder en-

Fig.3. The most complex conventional distributor curve has linearly advancing slopes with only two break points.

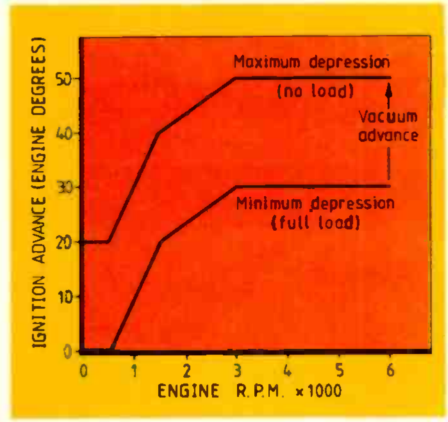
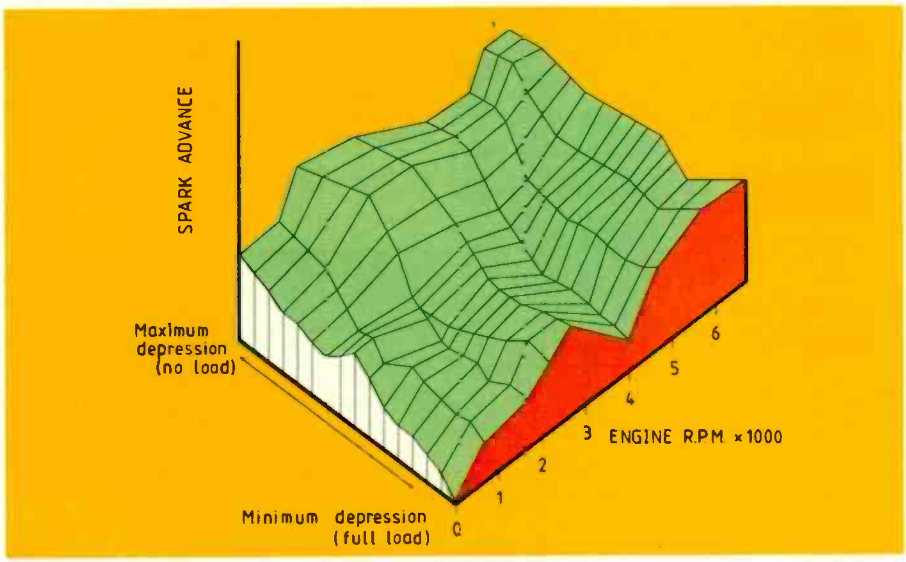



Fig.4. Complexity of a digitally-mapped engine characteristic is restricted only by the amount of available rom and the resolution of the a-to-d converter.



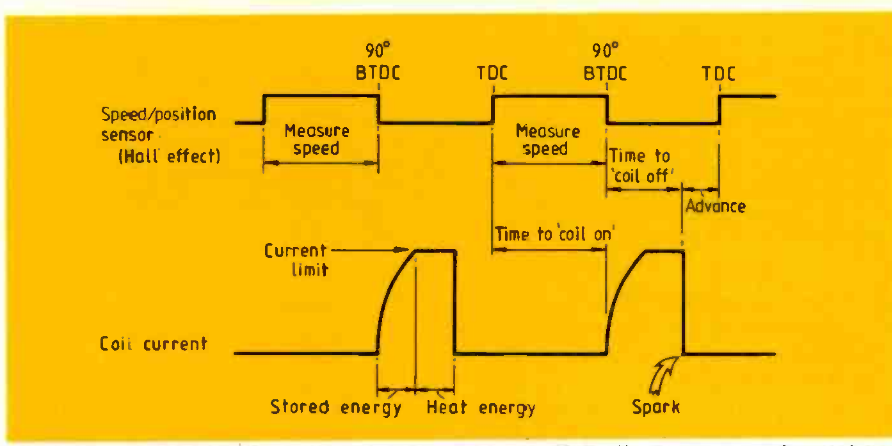




Fig.5. Time-based ignition systems normally use a Hall-effect sensor and metal vane mounted in the distributor or on the crankshaft. A current limit is required for the coil to provide variable dwell.

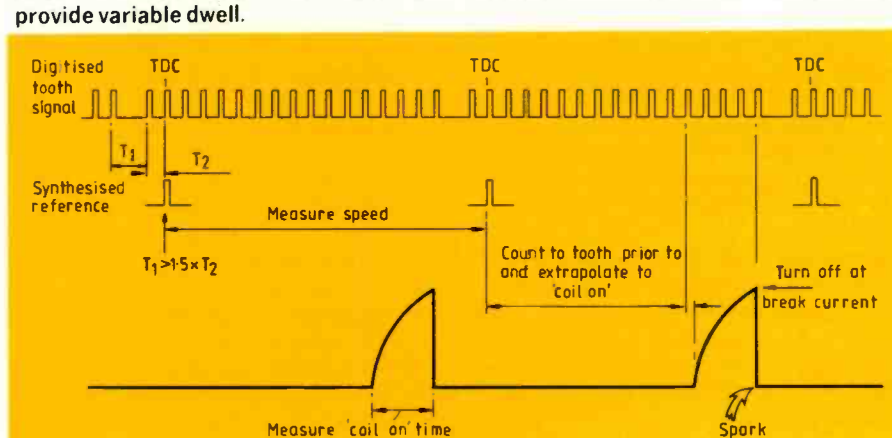
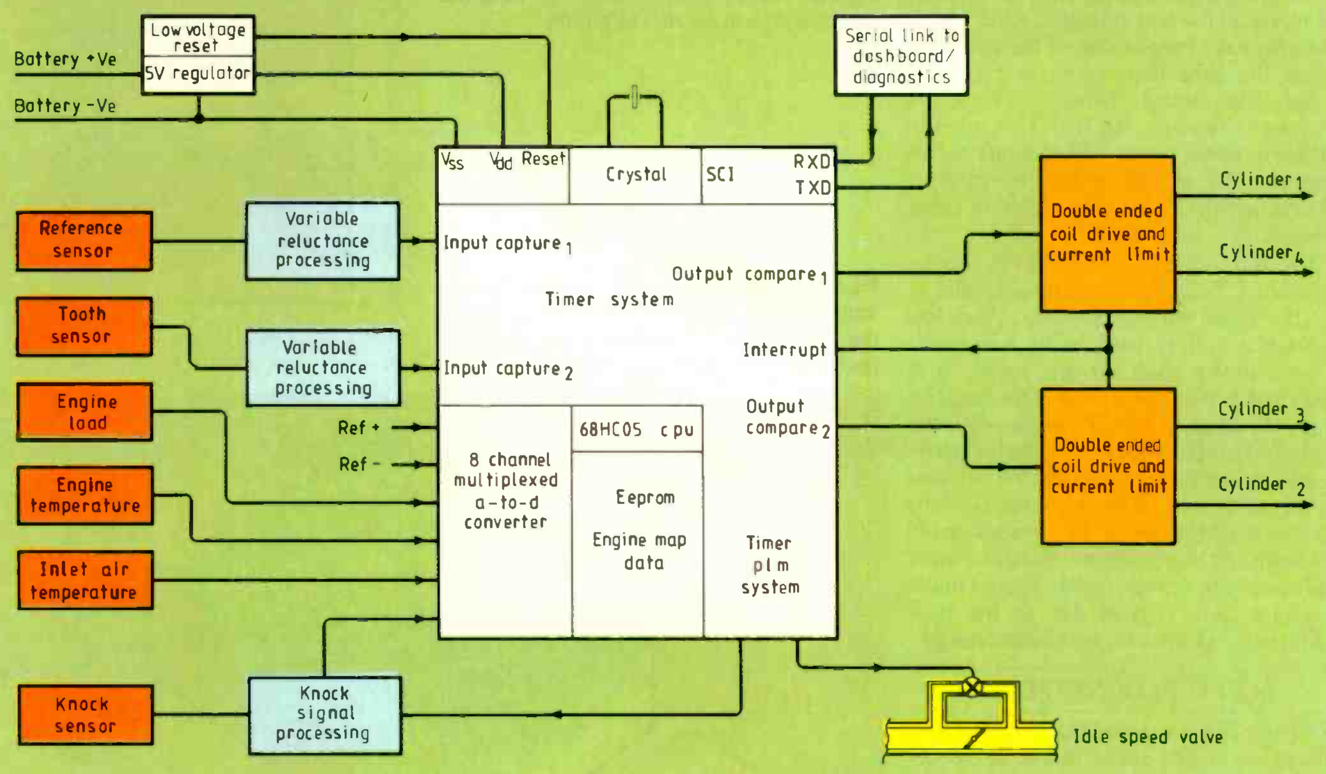



Fig.6. Angle-based ignition with missing tooth reference reduces cost of sensors and eliminates the need for current limit.




**New high-speed c-mos device controls distributor less angle-based ignition with idle-speed control.**

Built into another new microcontroller from Motorola is a powerful timer system which makes the device suitable for a distributorless angle-based ignition system. Included on the chip are an eight-channel multiplexed a-to-d converter, rom, ram, non-volatile eeprom, i/o and an asynchronous serial interface. In this case, the timer is a single 16-bit type, but associated with it are two capture latches and two output compared latches. The eeprom may be used to store calibration data for an individual module, or engine data which may change from one model to the next.

The diagram shows how an ignition system might be implemented with this device. No distributor is required for the h.t. because the output comparators control a double-ended coil: both cylinders fire simultaneously, one on the compression stroke and the other on the exhaust stroke. One of the two pulse-width modulated outputs can be used to drive the air bypass valve for idle-speed control.

Current consumption of the microcontroller, which is implemented in high-density c-mos, will be less than 10mA. The device will be available in 1988.

gine). The second sensor will monitor some form of toothed wheel (usually the flywheel) and produce more up-to-date information on engine speed and position.

In systems using only one sensor, a special toothed wheel must be used: usually it has two teeth missing (180° apart) to indicate the reference points. The missing tooth can be detected either by an analogue means of sensing the change in the shape of the waveform (voltage is proportional to rate of change of flux) or digitally by measuring the change of period from one tooth to the next (Fig.6). The effects of acceleration and deceleration on the period must also be considered when distinguishing the missing tooth reference.

Engine speed can now be determined easily by measuring the period between the reference points or the period over a number of teeth. Load is measured as before by a silicon strain gauge pressure transducer, and a look-up table is used to determine the desired advance angle.

I term this the angle-based system because the timing to the required firing point is done by counting the number of teeth from the reference, as these can be guaranteed to occur a fixed angle apart, irrespective of speed fluctuations. The teeth alone, however, do not generally give adequate resolution for the spark and so extrapolation is performed from the closest tooth prior to the firing point. Data stored in the rom can then be in engine degrees, instead of the time equivalent to the angle for that particular speed, as in the time-based system.

In a system such as this, if the information rate is high enough (i.e. less than 10° between teeth), it is possible to simplify the coil dwell control by controlling only the 'coil-on' point and turning it off automatically at the required break current. This requires that the coil rise time be measured on every firing so that it can be used to calculate the on-point for the next spark.

Unfortunately this is only half the story, as speed and load are not the only inputs required on modern ignition control systems. The ideal ignition timing will also vary with temperature, compression ratio and the octane and type of fuel used. For this reason, temperature sensors are generally mounted in the air inlet manifold and in the engine coolant and are used to produce an offset to the mapped timing. The hotter the engine, the higher the compression ratio and the leaner the fuel, then the closer to the detonation limit is the engine likely to be operating. This is especially true of turbo-charged engines which compress and heat the mixture even before it enters the cylinder, and of engines using on unleaded fuel.

For this reason, most modern ignition systems incorporate knock detection circuits which retard the ignition on detection of knock and bring it back slowly again towards mapped timing. Knock detection is based on a piezo ceramic sensor mounted on the engine block and tuned to around the characteristic knock frequency (approximately 7kHz, depending on the engine). The output from the sensor is then processed by electronic filters and its amplitude compared to a background reference to determine whether knock occurred.

---

*Pat Jordan B.Sc., is manager for single-chip microcontroller units with Motorola's microprocessor applications engineering department.*

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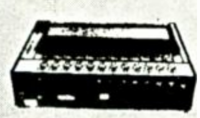

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# Transistors in parallel

**Two potential solutions exist to the problems of providing high currents at high voltages – large dies or parallel high-voltage transistors. This article analyses the latter, with reference to current sharing.**

SUE CAIN and RAY AMBROSE

The increasing complexity of user applications has led to demand for increasingly high powers from convertor and invertor circuits and therefore to the need for high-voltage devices with ever increasing current ratings. For these criteria to be met by a single device, extremely large dies are required. For example, a transistor with $V_{CEO} > 400V$ and $V_{CE(sat)}$ at $20A/4A < 1.5V$ would require a die with an area greater than $90Kmils^2$ (> 300mils × 300mils) {> 7.5mm × 7.5mm}.

The difficulty of producing a die attach capable of withstanding power cycling without reverting to expensive molybdenum bases means that large area dies tend to be extremely expensive and unreliable. An alternative solution is to connect more than one high-voltage device in parallel. This will produce the required high voltages at relatively low cost, and without loss of reliability.

## EQUALIZATION OF COLLECTOR CURRENT DURING SATURATION

The most important electrical parameter in the saturated operation of parallel connected power devices is $V_{CE(sat)}$. Unequal splitting of the current in the different parallel branches results from the different $V_{CE(sat)}$ of the transistors. In addition, variation of $V_{BE(on)}$ and $V_{BE(sat)}$ may have some effect since, if one device carried a higher current, its $V_{BE(sat)}$ would tend to increase, so diverting more base current to the other device. Where two transistors have base currents high enough to keep them in the saturated area, the saturation voltage for each is expressed by $V_{CE(sat)} = I_C \times r_{CE(sat)}$.

When two transistors have to carry an overall current, $I_L$, $I_{C1}$ and $I_{C2}$ may be calculated from the equivalent circuit shown in Fig.1. It follows that

$$I_{C1} = \frac{V_{CE(sat)}}{r_{CE(sat)1}}$$

$$I_{C2} = \frac{V_{CE(sat)}}{r_{CE(sat)2}}$$

$$\text{where } V_{CE(sat)} = I_L \times \frac{r_{CE(sat)1} \times r_{CE(sat)2}}{r_{CE(sat)1} + r_{CE(sat)2}}$$

A possible equalization may be achieved by connecting, to the emitters of the transistors, resistances whose values are high when compared to the saturation resistance $r_{CE(sat)}$; in this way, the equalization of collector currents is improved by a factor $R_E/r_{CE(sat)}$.

An evident limitation for this kind of equalization is the power dissipated in the emitter resistances. For each transistor the following is true.

$$P_{RE} = SI_E^2 \times R_E$$

where S is the duty cycle.

When N transistors are connected in parallel, N × $P_{RE}$ has to be significantly low when compared to the useful power, so that the overall efficiency is not decreased too much.

Figure 2(b) shows the behaviour of the collector currents with emitter resistors and Fig.2(a) without emitter resistors. $Tr_1$ has a $V_{CE(sat)}$ of 0.4V at 10A/2A, and $Tr_2$ $V_{CE(sat)}$ of 1.5V at 10A/2A. From these diagrams it may be verified that the delta $I_C$ of 3.2A in the unequalized condition is reduced to negligible values when two emitter resistances of 0.25Ω are used.

The dissipated power, calculated for S=0.5, is

$$P_d = 2 \times Sr_E \times I_E^2 = 2 \times 0.5 \times .25 \times 10^2 = 25W$$

As a general rule, a voltage on the sharing resistors of the same order of magnitude as $V_{BE}$ (1 – 1.5V) is sufficient to obtain good equalization in the saturation condition for all the devices.

In this case, the total $V_{CE(on)}$ becomes similar to the $V_{CE(sat)}$ of a high-voltage Darlington, which has a much better current capability for a given silicon area. The use of a Darlington could, in some cases, avoid the need to parallel transistors. For example, one SGSD310 offers twice the $I_{C(sat)}$ of a standard device for a smaller silicon area.

The experimental tests have been performed using 2 or 3 samples connected in parallel and considering in each case one or two transistors respectively at the upper $V_{CE(sat)}$ limit.

The measuring conditions considered for many commonly used devices are:

$V_{dc}$ = 300V
$I_C$ = 10A for each branch of the parallel connection
$I_{B1}$ = 2A
$I_{B2}$ = −2A

## EQUALIZATION OF COLLECTOR CURRENT DURING SWITCHING

With the parallel connection of high-voltage transistors, the proper operation of the devices during switching is of fundamental importance.

This problem is not significant at turn-on, since the faster transistors tend to carry all the load current; the consequent exits from saturation would determine a limitation of the current flowing through them. This special feedback effect allows a good sharing of the current in the parallel branches during turn-on.

During turn-off, however, the currents in the individual transistors can no longer be controlled. Once the faster transistors have been turned off, the devices with longer storage times have to carry all the current forced by the load.

During turn-off, high-voltage transistors are normally subject to special base conditions (high reverse base current required for fast switching) which limits the maximum energy that the devices can dissipate during this time ($E_{s/b}$). During this operating phase the slower transistors, having to switch high

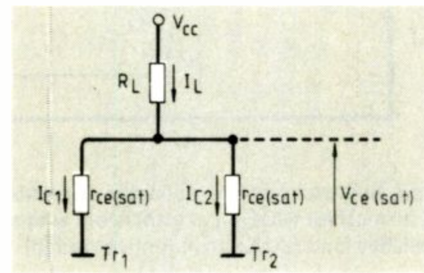


**Fig.1. The behaviour of two transistors carrying an overall current $I_L$**

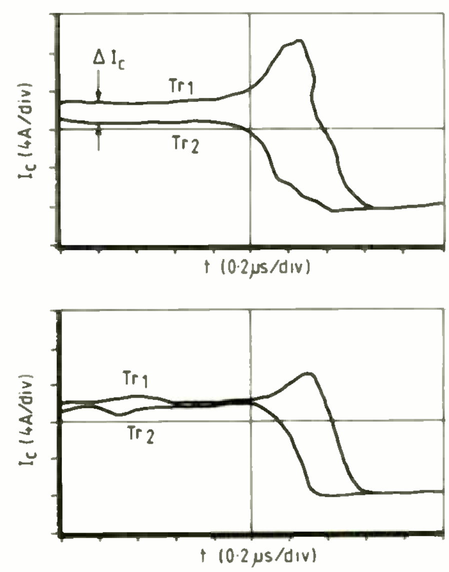


**Fig.2 The behaviour of the collector currents of two transistors without (a) emitter resistors and (b) with emitter resistors**

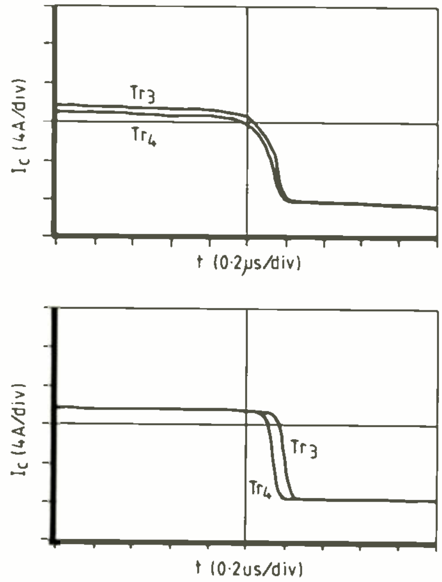


**Fig.3. Behaviour of the collector currents at turn-off for two typical transistors with a resistive load (a) and an inductive load (b)**

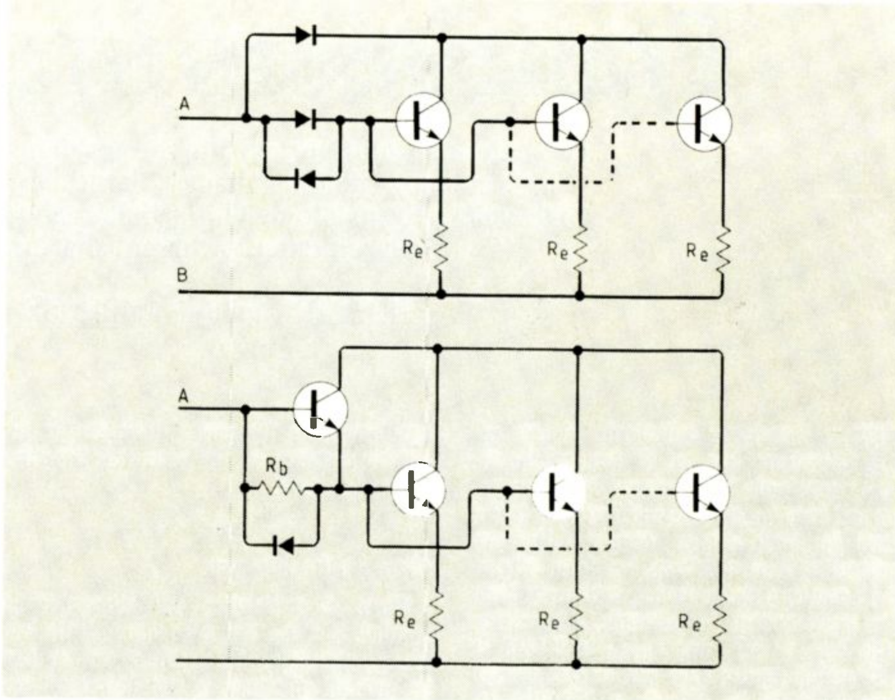


**Fig.5. Two possible circuit precautions enabling a good sharing of current in saturation and switching conditions**

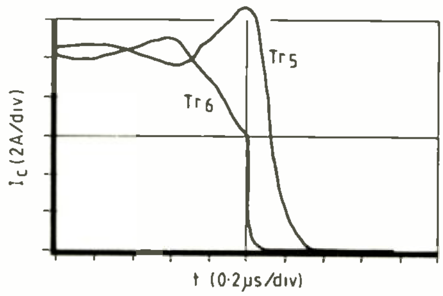


**Fig.4. Turn-off currents for two typical transistors**

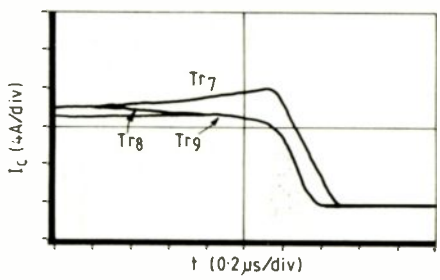


**Fig.6. Behaviour of the collector currents for an inductive load of three transistors.**

current peaks, are subjected to especially heavy voltage – current combinations, and consequent dangers of operation outside the safe reverse-bias operating area limits.

The electrical parameters that more directly influence the turn-off ($t_{storage}$ and $t_{fall}$) in high-voltage devices are $V_{CE(sat)}$ at working collector and base currents, and $h_{FE}$ in the active area (closer to the current at which the peak gain occurs). The transistors used in the experimental work have therefore been selected not only for $V_{CE(sat)}$, but also for $h_{FE}$.

Figures 3(a) and 3(b) show the behaviour of the collector currents at turn-off for two typical transistors, both with a resistive load and with an inductive load (with "clamp"). The measuring conditions and the measured electrical parameters for both transistors are:

| *Measuring conditions* | *Parameters measurements* |
|---|---|
| $V_{dc}$ = 300V | $h_{FE}$ (4A, 5V) = 20.4 |
| $I_c$ = 10A for each of the parallel branches | $V_{CE(sat)}$ (10A, 2A) = 0.6V |
| $I_{B1}$ = 2A | $h_{FE}$ = (4A, 5V) = 20 |
| $I_{B2}$ = 2A | $V_{CE(sat)}$ (10A, 2A) = 0.5V |

From the current behaviour it is clear that because the transistors have been selected showing the same $V_{CE(sat)}$ and the same $h_{FE}$, a perfect equalization is obtained during switching with either resistive or inductive load, without any special precautions.

One the other hand, Fig.4 shows the turn-off currents for these two transistors, different both in gain and in $V_{CE(sat)}$. These waveforms have been obtained by equalizing the collector currents with emitter resistors, but without any special precautions during the switching phase.

The transistor ($Tr_5$), featuring an $h_{FE} > 80$ (at $I_C$ = 1A, $V_{CE}$ = 5V) and a $V_{CE(sat)}$ of 0.4V (at $I_C$ = 10A, $I_B$ = 2A) is significantly slower in "$t_{storage}$" when compared to transistor $Tr_6$, featuring, in the same conditions, an $h_{FE}$ of 20 and $V_{CE(sat)}$ of 1.4V. It is clear that the slower transistor ($Tr_5$) has to switch a high current peak and is, as previously mentioned, more heavily stressed during this phase.

Two possible circuit precautions enabling a good sharing of current both in saturation and in switching conditions are shown in Fig.5. These provide equalization of storage times even if the transistors have very different saturation and gain characteristics.

Improved collector current equalization at switching is obained by limiting the spread of storage times of the transistors. The easiest way to achieve this is to minimize the storage time so that the differences become negligible. When a transistor is prevented from going into hard saturation, i.e. with base-collector junction not forward biased, the storage time is inherently very low. In the case of three parallel-connected transistors, the devices have been selected so that two of them show a low gain and a high $V_{CE(sat)}$, therefore being much faster than the third one, the latter being featured by a very high gain and a low $V_{CE(sat)}$. This is the worst case, as the latter transistor has to switch practically all the load current.

Figure 6 shows the behaviour of the collector currents, for an inductive load on three typical transistors selected according to the previous criteria.

***Measured parameters***
$h_{FE7}$ (1A, 5V) = 50
$V_{CE(sat)7}$ (10A, 2A) = 0.45V
$h_{FE8}$(1A, 5V) = 20
$V_{CE(sat)8}$ (10A, 2A) = 1.4V
$h_{FE9}$ (1A, 5V) = 20
$V_{CE(sat)9}$ (10A, 2A) = 1.4V

To achieve high-current devices, manufacturers parallel transistor dies within a single package. No particular precautions are needed, as the dies used are neighbours from one wafer, so all their parameters are, by definition, well matched. The designer may thus treat these multi-chip devices as a single transistor in any circuit conditions.

The need for emitter ballast resistors is eliminated if a suitable safety margin is allowed in design. For good sharing the devices must be prevented from oversaturation. This is achieved by the Darlington connection of a driver transistor, with the added bonus of increased forward gain. The use of high-voltage Darlingtons in place of transistors is a distinct advantage, and when even higher currents are required the paralleling of Darlingtons will be less critical than transistors.

*Sue Cain is with BA Electronics and Ray Ambrose at SGS*

# Microstrip and s-parameter design

**This brief introduction to microstrip, s-parameters and simple amplifier design leads to a practical example of how to design a narrow-band microwave amplifier.**

S.A. CROSSON SMITH

The basic structure of a microstrip line consists of a grounded backplane and a narrower top conductor separated by a dielectric. In theory the groundplane should be infinite but in practice a width of several times the top conductor is sufficient. For the purpose of this article it is assumed that the thickness of the conductor is negligible compared to the thickness of the dielectric. For most practical situations this is the case.

When making reference to a transmission line structure it is common to consider it in terms of lumped elements representing the capacitance per unit length and inductance per unit length of the structure. In this way distributed characteristics may be represented in a manner easily acceptable to most engineers. It is possible, at least conceptually, to treat a microstrip line in a similar manner. Figure 2 demonstrates the concept of treating a microstrip line similarly to most other transmission line structures and from this it can be seen how it is possible to represent the microstrip very basically with a similar lumped element network.

The characterstic impedance of this network is found from the familiar relationship $Z_o = \sqrt{L/C}$. Consider for the moment only the field within the dielectric. The wider the strip the greater will be its capacitance per unit length but also the smaller the inductance per unit length. Conversely, the narrower the strip becomes the greater the inductance but the lower the capacitance. The geometry of the line thus determines the L and C values of the lumped model. Likewise, the greater the thickness of the dielectric the lower the capacitance but the higher the inductance and the thinner the dielectric the higher the capacitance but the lower the inductance. It transpires that the ratio of the width of the strip to the thickness of the dielectric (W/h) determines the impedance of the line for a given dielectric.

This all assumes that there is a homogenous medium surrounding the line and that the structure supports transverse electromagnetic waves (t.e.m.) similar to, say, a coaxial structure. This is not the case as can be seen in Fig.3. The electric field is distributed between the dielectric and surrounding air. This distribution of field is a function of the line width and frequency, and gives rise to an effect known as dispersion whereby the line behaves differently at different frequencies. This will not be considered in detail here. The distribution of the fields in the air and dielectric give rise to longitudinal modes, hence the structure does not support true t.e.m. propagation.

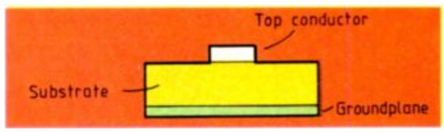


**Fig.1. Structure of a microstrip, consisting of the conductor, dielectric and backplane.**

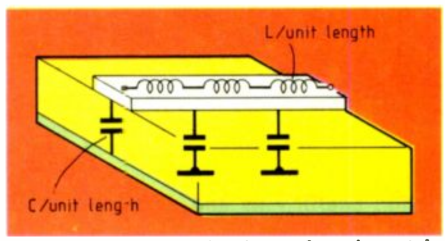


**Fig.2. Analogous behaviour of a microstrip with inductance along the length and capacitance through the substrate.**

**Fig.3. Electrical field surrounding a microstrip. The distribution of the field generates dispersion which varies with frequency.**

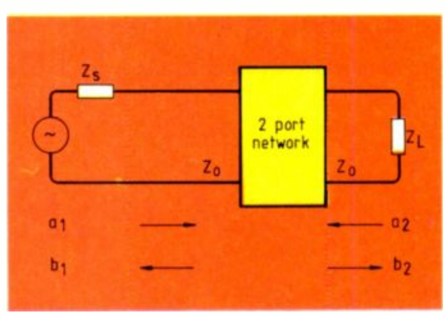


**Fig.4. Incident and reflected waves in a transmission line.**

The full relationship between the impedance of the line and its geometry requires extremely complex analysis but a number of researchers have worked on closed-form expressions derived by assuming a number of conditions.

One such set of expressions have been put forward by Gupta, Garg and Chada* and are reproduced below.

For the synthesis of a microstrip line of given impedance:

$$A = Z_o/60[(k+1)/2]^{1/2} + (k-1)(k++1)(0.23+0.11/k)$$

$$B = 60\pi^2/Z_o\sqrt{k}.$$

Then for $A > 1.52$:

$$W/h = \frac{B \exp A}{(\exp 2A)-2}$$

and for $A \leq 1.52$:

$$W/h = 2/\pi\left\{B-1-\ln(2B-1)+(k-1)/2k\,[\ln(B-1)+0.39-0.61/k]\right\}$$

where $Z_o$ is the characterstic impedance of the line required and k relative dielectric constant of the dielectric.

This is largely an empirically derived set of formulae assuming that the conductor thickness is negligible and that there are no surrounding conductive walls. The originators estimate their formulae to be accurate to about 2%, a claim I have found reasonable.

Due to the distribution of the fields between the air and the dielectric the apparent dielectric constant of the substrate material does not remain constant over any geometry line but varies with the W/h ratio. This gives rise to an "effective dielectric constant" and the same researchers have produced closed form expressions to calculate its value:

$$K_{eff} = (k+1)/2 + (k-1)(1+10h/W)^{-1/2}2.$$

To calculate the effective wavelength of a wave travelling down such a structure this value should be used instead of the more familiar k i.e.

$$\lambda_g = \lambda_o/\sqrt{K_{eff}}$$

where $\lambda_g$ is the wavelength within the microstrip structure and $\lambda_o$ is the wavelength in free space.

## S-PARAMETERS AND THE SMITH CHART

To lay the foundations for any consideration of active devices it is worthwhile introducing S-parameters and their relationship with the Smith chart. S-parameters are associated.

*Computer-aided design of microwave circuits. Artech House, Boston, 1981.

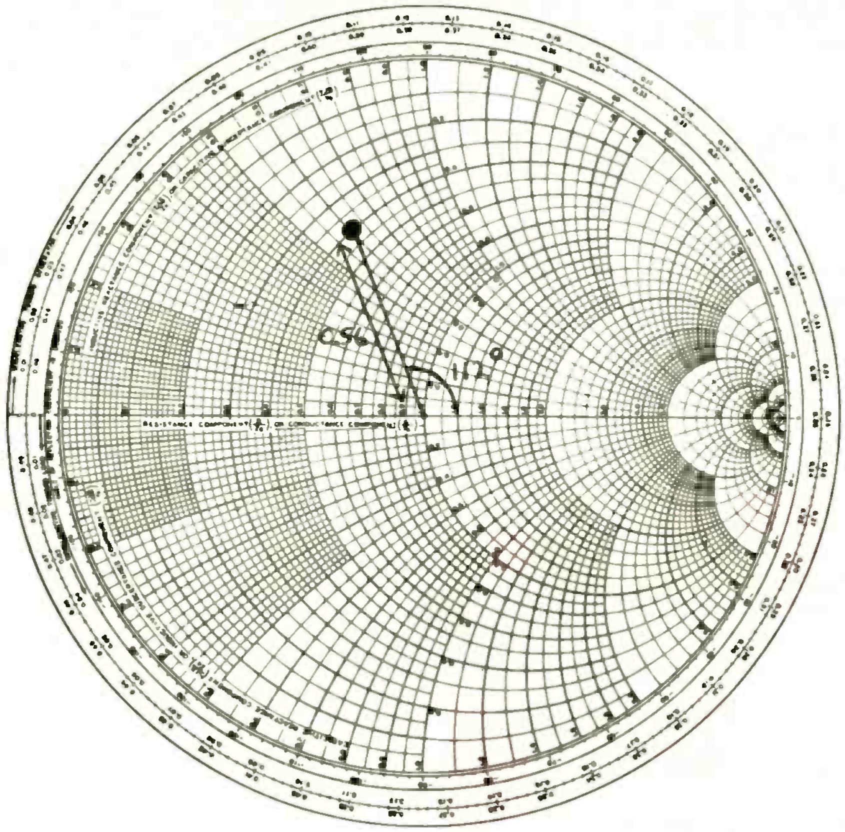

**Fig.5. Smith chart is used to calculate reflection coefficients and derive the input impedance and transfer characteristics of a device.**

with the transmission and reflection of waves rather than voltages or currents independently.

Consider any two-port network embedded into a transmission line system (Fig.4).

By convention waves travelling towards the network are labelled 'a' and waves travelling away from the network are labelled 'b'. Thus 'a' is considered as the incident wave and 'b' the reflected wave.

If one assumes that the two-port is perfectly matched to the impedance of the input and output transmission lines, $Z_o$, then there will be no reflected wave i.e. $b_1$ and $b_2$ will have zero magnitude and phase.

Assuming that the network is not perfectly matched to $Z_o$ but that its interaction with the incident waves may be described by four parameters $S_{11}$, $S_{21}$, $S_{12}$ and $S_{22}$ we could arbitrarily define a relationship as follows:

$$b_1 = S_{11}a_1 + S_{12}a_2$$
$$b_2 = S_{21}a_1 + S_{22}a_2$$

and hence define the parameters as

$$S_{11} = \frac{b_1}{a_1} \quad S_{12} = \frac{b_1}{a_2}$$
$$S_{21} = \frac{b_2}{a_1} \quad S_{22} = \frac{b_2}{a_2}$$

where $a_2 = 0$ implies that the output is perfectly matched to the external transmission line and likewise $a_1 = 0$ implies that the input is perfectly matched to the external transmission line.

From this $S_{11}$ is thus the input reflection coefficient of the network, $S_{21}$ is its gain, $S_{12}$ the reverse gain and $S_{22}$ is the output reflection coefficient.

The value of such a set of parameters is immediately obvious when one considers that to obtain, say, the maximum gain from a transistor its input and output ports must be conjugately matched to the surrounding transmission lines. The value of $S_{11}$ and $S_{22}$ convey the disparity between the line and the device i.e. they describe the reflection coefficients which must be matched out.

Reflection coefficients are represented on a Smith chart as vectors (see Fig.5).

Taking a totally arbitrary value of, say, $S_{11}$ as $0.56\angle 112$ (in polar form)

This is the input reflection coefficient of the device and hence, normalized to a 50Ω system:

$$S_{11} = 0.56\angle 112 = \frac{Z-1}{Z+1}$$

where Z is the input impedance of the device which may be read directly from the Smith chart as 0.4+0.6j (or 20+30jΩ). Working backwards:

$$\frac{(0.4+0.6j)-1}{(0.4+0.6j)+1} = \frac{-0.6+0.6j}{1.4+0.6j}$$

and converting to polar form:

$$= \frac{0.85\angle 135}{1.52\angle 23} = 0.56\angle 112.$$

Hence if $S_{11}$ is known then the input impedance of the device can be derived.

As S-parameters are found using wave techniques on transmission lines they are relatively easy to measure and hence the terminal impedances and transfer characteristics of a device may be found with comparative ease and accuracy.

*Steve Smith is with Castle Microwave Ltd, of Twyford, Berks*

## PRACTICAL EXAMPLE: DESIGN OF A NARROW-BAND 5GHz AMPLIFIER USING NE72084

The simplest way to introduce microstrip techniques into amplifier design is by way of single stub matching. This gives rise to a narrow band design but is, in fact, a technique often used.

The basic circuit is illustrated in Fig.6. The values of of $L_1$ to $L_4$ are required and are found as follows.

The input and output reflection coefficients ($S_{11}$ and $S_{22}$) may be found listed on the device data sheet. These are first plotted onto a Smith chart (see Fig.7) and the following processes are executed:

1. The constant v.s.w.r. circle is drawn from the centre of the chart such that the required value of $S_{11}$ lies on this circle.

2. A stub presents a parallel admittance to the device so it is easier to work in the admittance plane rather than with impedances. The conversion if done by drawing a radial line from the plotted value of $S_{11}$ to the opposite side of the constant v.s.w.r. circle. This point is labelled $S_{11}$'.

3. Continue the radial line to the outer "wavelengths towards the generator" circle and note the value so indicated; in this case 0.17 wavelengths.

4. Move around the constant v.s.w.r. circle to its nearest intersection with the unity conductance line (point A on Fig.7). Draw a radial line through this point to intersect the outer wavelengths circle and read off the value indicated. In this case 0.19 wavelengths. The difference between these values is the length of the line required in position $L_1$, ie 0.02 wavelengths.

5. The admittance at this point may be read from the chart directly as:

$$1+2.1j.$$

This susceptance of $+2.1j$ must be cancelled by presenting a negative susceptance of $-2.1j$ at this point. To find the length of line required to achieve this draw a radial line through the $-2.1j$ point at the edge of the chart ot the wavelengths circle and note the value (in this case 0.321 wavelengths).

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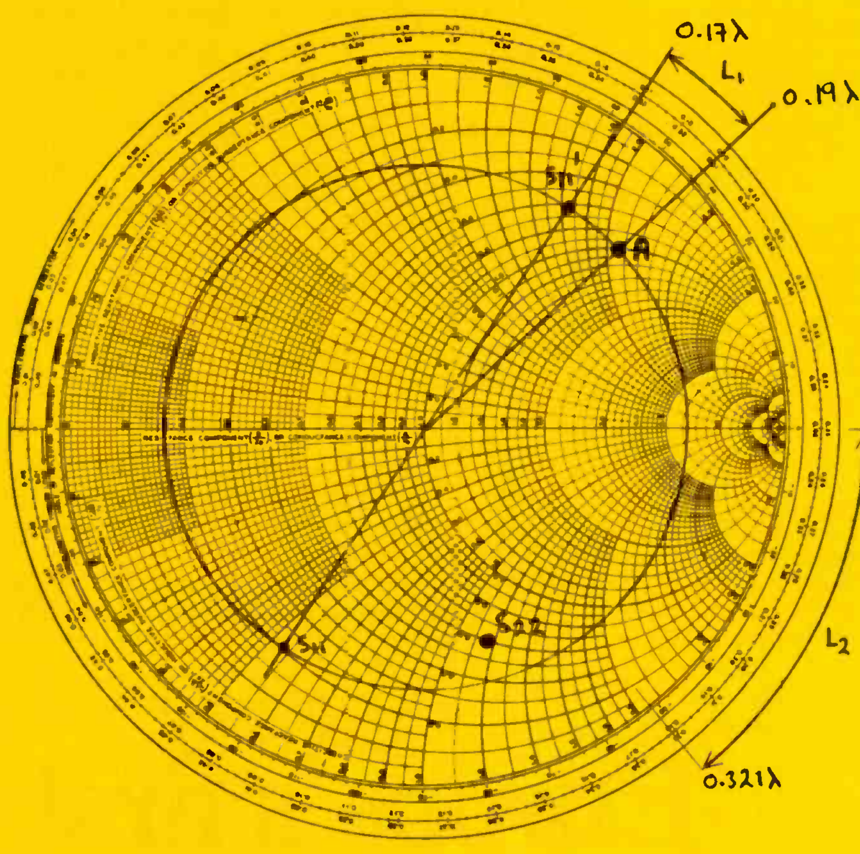



Fig.7. Calculation of a stub matching network. Reflection coefficients of the fet are used to find the required wavelengths.

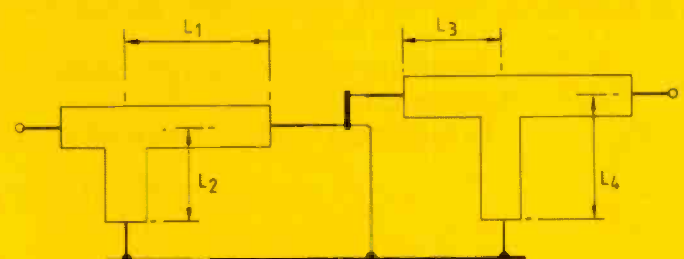



Fig.6. Basic construction of a single-stub matched amplifier.

A short circuit line presents an infinite conductance therefore to find the length of short circuit line required to produce the necessary admittance calculate the distance from the infinity conductance point to that found above. In this case 0.32 – 0.25 = 0.07 wavelengths = $L_2$.

Repeating this process for the output produces:

$L_3$ = 0.08 wavelengths
$L_4$ = 0.11 wavelengths

As calculated, all of the above line lengths are difficult to fabricate. One revolution around the chart is half a wavelength, arriving at the same admittance. If, therefore, multiples of half wavelengths are added to the stubs then their admittances will remain unchanged. Thus:

$L_1 = 0.52\lambda$
$L_2 = 0.57\lambda$
$L_3 = 0.58\lambda$
$L_4 = 0.61\lambda$

If the stubs are r.f. grounded with capacitors then this also makes a convenient point at which to introduce d.c. bias.

Converting to microstrip: Assuming RT/Duroid 6010 substrate material with a relative dielectric constant of 10.5 and thickness of 0.635mm and using the formulae described:

W/h = 0.91
∴ W = 0.58mm
and $K_{eff}$ = 7.12.

Thus: $\lambda_o$ = 6cm (wavelength in air)
and $\lambda_g = 6/\sqrt{7.12}$ = 22.5mm
hence: $L_1$ = 11.70mm
$L_2$ = 12.83mm
$L_3$ = 13.05mm
$L_4$ = 13.73mm

and the complete circuit is as Fig.8.

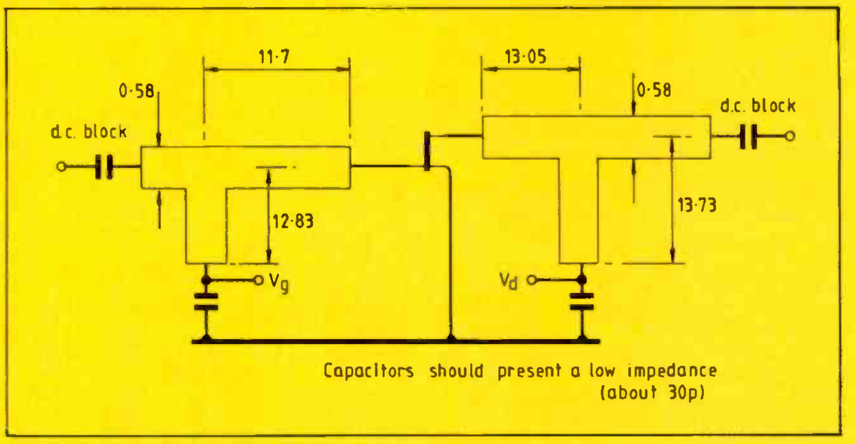



Fig.8. The completed amplifier. The NE72084 fet comes from NEC.

# Europe's first GaAs microwave foundry chip

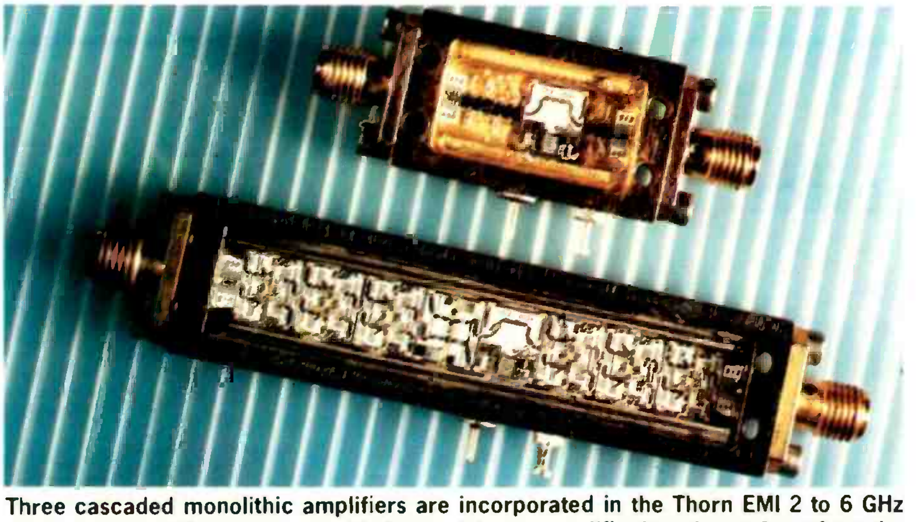
**Prototype gallium arsenide microwave amplifier shows how companies without their own fabrication facilities can benefit from foundry-produced monolithic technology.**

JONATHAN M.C. NICHOLAS

Because of the high investment needed to obtain competitive production costs for GaAs devices many companies are offering their process in a so-called foundry mode[1], which has been used successfully to produce silicon devices for several years. The fabrication company makes their design rules available to another company, which may not have a volume processing capability. The user has full responsibility for the design which he submits to the foundry for fabrication. Particularly if the user mounts and tests the devices himself, he can achieve custom devices to his own design at a very reasonable cost which, for volumes as low as a few hundred parts, can compete strongly with hybrid components. This route was used to produce a 2 to 6GHz gain block as a monolithic circuit.

## AMPLIFIER DESIGN

Design information was obtained from the foundry, Plessey Three Five Ltd. This consisted of data on the active devices and equivalent circuit models for the passive components which could be fabricated by the process. A specification for his device was based around our systems companies' requirements for a broad band gain block and



Three cascaded monolithic amplifiers are incorporated in the Thorn EMI 2 to 6 GHz microwave amplifier compared with the much larger amplifier it replaces. Apart from the reduction in size, there is a 30:1 reduction in the number of component bonds required, with a saving in both assembly time and cost.

are listed as follows:

| | |
|---|---|
| **frequency** | **2 to 6 GHz** |
| **gain** | **> 12dB** |
| **gain flatness** | **< ±0.5dB** |
| **noise figure** | **< 6dB** |
| **output power** | **> 13dBm at 1dB compression** |
| **vswrs** | **< 2.0** |
| **stability** | **unconditionally stable.** |

The 0.9μm fet offered by the foundry has a maximum available gain of about 10dB at 6GHz, the highest frequency required, but there is a considerable gain slope. It was decided that a two stage amplifier would be required with extensive feedback to achieve the gain and match performance.

A powerful feedback technique for achieving very broad band performance is described by Niclas[2]. They use a parallel feedback which consists of a resistor and an inductor in series. Because of the phase change of the feedback with increasing frequency, it is possible to implement negative feedback at low frequencies and positive feedback at the higher frequencies. Hence a flat gain can be achieved over a wide bandwidth, even if the transistor is near to cut-off. The effect of this inductor/resistor feedback is shown in Fig.1; the maximum available gain of the circuit shown is given for various values of the drain series line length, $\theta_D$, and for the fet alone. It can be seen that 200Ω of resistance in series with 30° of delay gives a maximum gain which is approximately flat.

The topology of the circuit is, essentially, fixed by the bias requirements for the transistors. In order to apply a bias voltage to the terminals of the fets it is necessary for there to be an r.f. path to ground from each terminal of the transistor, and a blocking capacity between each stage. Initial design of the circuit was performed quickly, using conventional amplifier design techniques and microwave cad software.

The detailed design largely followed the procedures outlined by Suckling[3]; care was taken to evaluate the full equivalent circuit model of each component realised in monolithic form. The diagram of the amplifier circuit is shown in Fig.2. Each of the lumped monolithic components enclosed by a box was in fact represented by an equivalent circuit model in the simulation file. The transmission line dimensions are shown; the electrical characteristics were calculated from information given in the design guide. In most cases the associated parasitics have an adverse effect on the amplifier performance and some re-optimization of the circuit element values was required. A large amount of the optimization was done manually by "tweaking" a few component values, rather than by using an optimizer. This was found to be more efficient as it reduced the possibility of producing a circuit which was highly sensitive or difficult to lay out. The sensitivity of the amplifier performance was checked to ensure that it would remain acceptable despite any process variations occurring during fabrication.

**Layout** The foundry provided cells containing active and passive devices which could be used as the basis for the layout. However, the layout and verification was carried out by hand on a simple graphics editor. The

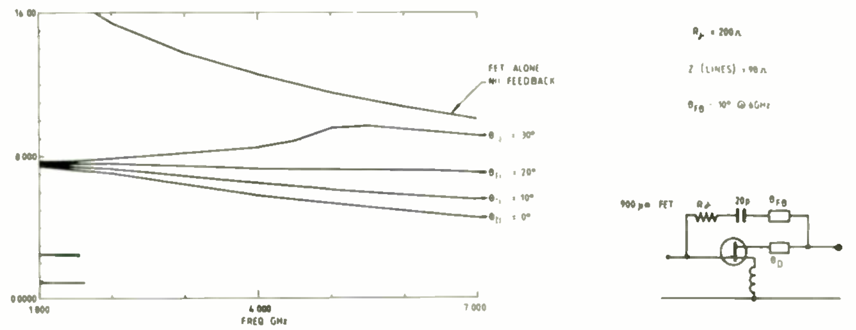


Fig.1. Gain against frequency for a field-effect transistor with feedback.

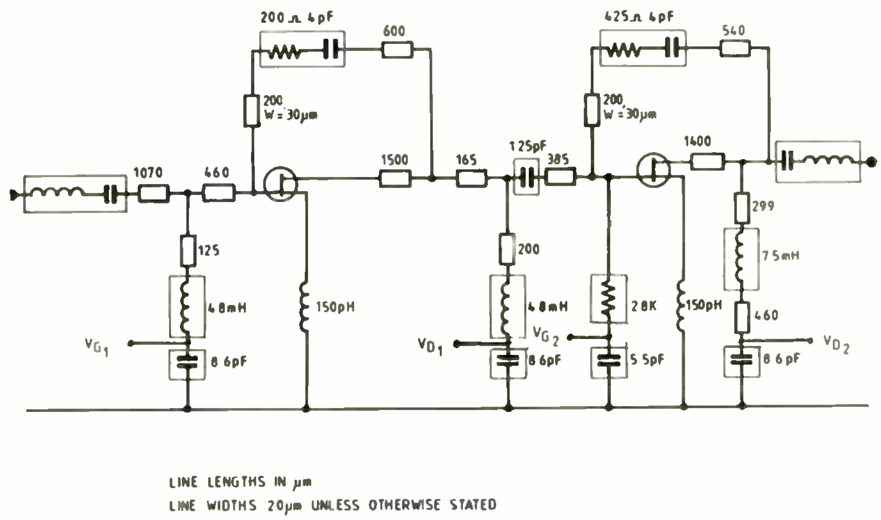



Fig.2. Circuit diagram of a wideband microwave amplifier. All components in boxes can be entered as circuit model elements in a computer-aided circuit design and simulation program.

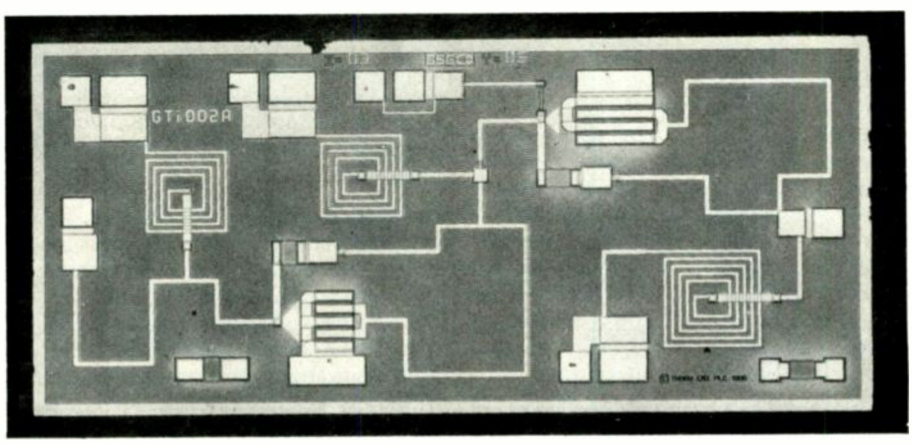



Fig.3. The completed amplifier layout. The gallium arsenide chip is only 1.4 by 3.2mm.

finished amplifier is shown in Fig.3; no attempt was made to condense the size of the circuit greatly at this stage so the circuit size is 1.4 × 3.2 mm. In addition to the process control monitors required by the foundry a variety of test patterns were included, both for possible debugging and for the design of future circuits.

## DEVICE FABRICATION

The tape, as supplied to the foundry, was checked for compatibility with the process design rules by a computer auto-checking routine. Process control monitors and alignment marks were added before mask making.

The process was developed specifically for m.m.i.cs and is based on direct ion-implantation into two-inch diameter l.e.c wafers. The depletion-mode recessed-gate fets had a minimum gate length of 0.9μm, and employed a two-level metallization scheme. The metal layers were separated by a composite polyimide/silicon nitride dielectric layer which enabled two types of m.i.. capacitors to be fabricated. The top level metallization, designed to exhibit low loss, was patterned by dry processing methods. Finally, wafers were passivated using a second layer of silicon nitride and thinned to 200μm before scribing and dicing.

## RESULTS

Initial d.c. testing by the foundry customer showed a high yield and a good uniformity across the wafer. Chips were selected on d.c. performance only for mounting and bonding into specially designed microwave test fixtures.

To date several samples have been tested at r.f. and all performed well; the performance was very close to what was simulated. A dip in gain at about 1.7GHz was due to an off-chip resonance in the bias supply on the test fixture and brings the amplifier slightly out of specification at 2GHz. In other aspects the device has met the required performance. Two hybrid modules have been constructed, each containing three cascaded devices and a minimum of external components. These modules give 30dB ±1.5dB of gain and have terminal matches of better than 2:1 over 2-6GHz. The 1dB compression point was nearly 16dBm at 6GHz.

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*Jon Nicholas is head of the c.a.d. v.l.s.i. department at Thorn EMI central research laboratories.*



This article is based on information first given at the IEE's colloquium on 'Multi-octave components and antennas,' 25 March 1987.


# Low-noise microwave transistors

**Increasing electron mobility in field-effect transistors allows increased gain while keeping noise-level down.**

High electron-mobility transistors are used in microwave applications. They have a noise factor of 0.9 to 1.2dB and a 10 to 12dB gain at room temperature. Intended for use in the 4 to 30GHz band, they find application in satellite broadcasting. They can replace mesfets and offer an enhanced performance in microwave amplifiers.

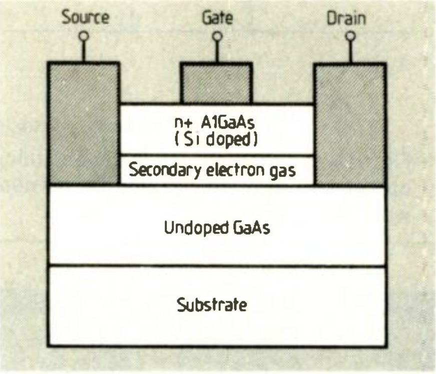
They are constructed in gallium arsenide using molecular-beam epitaxy or metal organic chemical vapour deposition. Several semiconductor manufacturers, notably Gould in the U.S. and many in Japan, are developing and producing the devices.*

Mesfets, despite improvements, appear to have reached the limits of their performances, and although the hem transistor is more expensive to produce, it is able to take over where the mesfet leaves off. It can offer lower noise, higher gain and larger mutual conductance ($G_m$) than a mesfet but these effects can be reduced by the effects on electron density caused by lattice vibration caused at higher (room) temperatures.

The greater $G_m$ of the hem transistor has not yet been fully explained. In a conventional fet the gate contact makes a Schottky barrier on the GaAs surface. A depletion layer is produced at the gate junction which is controlled by the voltage at the gate and in turn controls the flow of current from source to drain. $G_m$ is found by

$$G_m \propto \frac{u.n}{L}$$

where L is the gate length, u is electron mobility n is the carrier density. Larger $G_m$ can be obtained by shortening the gate length, increasing the electron mobility or making the carrier density larger. These last two options are mutually contradicting as the channel in which electrons move is the same as the carrier supply layer which decides the carrier density. A large amount of doping would promote higher electron diffusion and cause lower mobility.




**A concentration of electrons induced in the undoped layer of the hemt becomes highly mobile.**

The hemt has a gate layer of AlGaAs doped with donor atoms of silicon. Electrons freed by the ionization of this layer accumulate on the lower undoped side of this layer between it and the undoped GaAs channel layer. This induced electron concentration then acts as the carrier which is still under the control of the gate voltage. Unlike the conventional fet, a high level of impurity doping in the AlGaAs layer can ensure greater mobility.

An additional factor is the lattice structure vibration caused by temperature. Diffusion caused by such vibration can reach a level where it can equal the effect of the impurity level doped into the substrate. This reduces the channel electron density to that of a mesfet. The high mutual conductance is perhaps explained by higher electron mobility. Even with a high lattice vibration, the hemt offers an advantage due to the reduced level of impurity doping in the carrier channel. Reports have shown a 20% increase in mobility compared with that of a GaAsfet. The effect is further enhanced by careful control of the manufacturing techniques with the establishment of control over the impurity doping levels, leading to high yield, better reliability and lower cost.

Experiments are under way for replacing the AlGaAs doped layer with superlattice materials with a thin superlattice in the undoped buffer layer. Another possibility is the alternating of doped AlGaAs and undoped GaAs layers in a superlattice. Each layer would be very thin (1.5mm) and yet it is thought that this structure will improve the efficiency of the transistor and be easier to make using molecular-beam epitaxy.

Two particular areas are suitable for hemt application. High quality amplifiers in the 4 to 30GHz range; and, as the costs reduce, replacement of conventional fets. Sony, for example, are aiming at the second option while reviewing the higher performance versions. Mitsubushi is aiming at the high frequency application and has found the production of the devices not as expensive as they thought it might be. Many other manufacturers are planning to market the devices for satellite systems, including transmission in the Ka and Ku bands.

The transistor is now available as a discrete device, though both Fujitsu and Toshiba have engineering samples of an integrated amplifier constructed using hem technology. Fujitsu has produced a four-part amplifier with a noise figure of 1.66dB and a gain of 38dB: 17.7 to 19.7GHz at −55°C incorporating two hemts. Toshiba have also produced an amplifier in this band with noise <2dB and gain of 47.2 ±0.7dB, but built from six parts.

In the power microwave field, Gould (Litton) engineers have produced a device with multiple-feed gate structure which achieves a gate resistance a fraction of that of other devices, with a corresponding reduction in noise figures. It is expected that the device will operate to about 30GHz with 6dB maximum gain.

* Gould's microwave division has since been sold to Litton Industries, represented in the UK by March Microwave of Braintree, Essex.

# Pioneers

## 9. Guglielmo Marconi (1874-1937): father of radio

W.A. ATHERTON

For two minutes on July 21, 1937 the radio waves fell silent. In that unique way was commemorated the death on the previous day of Guglielmo Marconi, the international superstar of radio communication.

Marconi was born on April 25, 1874 at Bologna in Italy of a well-to-do Italian father and a Scots-Irish mother. He is said to have been a rather solitary child and much of his early education came from private tuition. He did not start school until he was twelve.

After a time at the Technical Institute of Leghorn (Livorno), he left full-time education without qualifying for a place at either the University of Bologna or the Italian Naval Academy, both of which were on his father's list of priorities for him. Father was not impressed.

By that time Marconi had developed an interest in physics which was not to be denied. At the University was Professor Augusto Righi. He was known to the family and he allowed Marconi access to his laboratories, lectures and books.

Righi is not very well known now. But he was a master scientist and, like Oliver Lodge in Britain, he was one of the few who really understood what Heinrich Hertz had achieved when he demonstrated the generation, propagation and reception of what had become known as Hertzian waves – i.e. electromagnetic or radio waves. Perhaps Marconi gained more from entering the university by the back door than if he had gone in through the front.

Hertz died in 1894 and Righi's obituary of him is said to have convinced Marconi that Hertzian waves could be used for communication. The basic requirements already existed but they needed to be brought together and have life breathed into them.

Although others had superior scientific understanding and were in a better position from which to achieve radio communication, it was Marconi who had the vision.

From Righi he learned how to generate, radiate and detect the waves. The usual receiving detector then available was the coherer, made of metal filings packed into a glass tube. It was invented by Edouard Branly in France and it became the main detector for the first ten years or so of radio communication. In London, Lodge gave it prominence in a lecture in honour of the recently deceased Hertz. That, and a subsequent lecture, were published and became well known. Lodge, by the way, had come very close to beating Hertz to the discovery of electromagnetic waves.

Working in his father's attic, and with little encouragement from the man who was paying for his tinkering, Marconi dramatically improved the performance of the coherer. He also improved on Lodge's and Righi's spark-gap transmitters and rediscovered the principle of earthing one side of his transmitter whilst using an elevated metal object to act as an aerial. This had been previously known to Amos Dolbear in America who had come tantalisingly close to radiotelegraphy (and telephony) a dozen years before Marconi even began.

With these improvements Marconi moved from the attic to the garden, and from the garden to the fields. There he achieved transmission over one and then two kilometres in 1895. The earth connection and the elevated aerial had moved him from short waves of a metre or less to much longer waves and greater distances.

It has often been said that Marconi excelled not so much at original inventions but at improving dramatically the inventions of others. That he most certainly did, but he coupled it with an ambition to achieve radio communication over ever increasing distances. It has been suggested that, in the early days, this drive may have been in part a desire to impress on his father that he could, in fact, do something other than fail to get into the university and the Naval Academy.

### MARCONI IN BRITAIN

The Italian telegraph authorities rejected an offer to take up the new invention and so Marconi turned to marine communications as being the obvious use for radiotelegraphy. With his mother's encouragement he set out for Britain, then the greatest maritime power.

He arrived in February 1896, and though his equipment was damaged by a customs inspection, his entrepreneurial spirit was not. A meeting was arranged with W.H. Preece, the chief engineer of the Post Office which held the monopoly on telegraphy. Preece had long entertained an interest in 'wireless' communication using induction (not radio), but this had proved to be impossibly cumbersome. After several demonstrations, including one over several miles across Salisbury Plain, Preece gave Marconi his considerable support.

With Preece's help Marconi began to gain publicity. On the whole engineering comment was favourable but initially Oliver Lodge was resentful. "One of the students in Prof. A Righi's class at Bologna," Lodge thundered, "being gifted, doubtless, with a sense of humour as well as with considerable energy and some spare time, proceeded to put a coherer into a sealed box and bring it to England as a new and secret plan adapted to electric signalling at a distance without wires."

Lodge was hardly being fair. Though the basic techniques were indeed well known, as Professor Slaby, one of the German pioneers pointed out, everyone else had got "just as far as 50 metres and no farther". Marconi had achieved miles and later Lodge was careful to give the Italian all credit due to him.

The British Post Office was slow in making an offer for the system and so, in July 1897, The Wireless Telegraph and Signal Company was founded. Marconi took £15 000 in cash, £60 000 in shares and a three-year contract at £500 per annum. It was not bad going for a man with a system but no customers.

The money had been provided by his mother's family and friends. It was no coincidence that in Britain lay his mother's extensive and wealthy family connections with the Haig, Ballantine and Jameson whisky empires.

At the start sales were non-existent. Some equipment was sold to the British Army in 1898 for use in the Boer War, but the expected market for ship-to-shore communications failed to materialize. Then in 1900 a contract with the Admiralty was signed to provide equipment and train operators. Maybe this was the key. After all, even Marconi could hardly expect to sell equipment to people who did not know how to use it.

A change of policy followed. Instead of selling equipment the company started to offer a radio communication service. Equipment would be leased, together with Marconi personnel who would operate and maintain it. This arrangement also overcame any possible infringement of the Post Office monopoly of wired telegraphy. A new company was formed, The Marconi International Marine Communications Co., and the original company changed its name to Marconi's Wireless Telegraph Company.

Shipowners now had access to a communications system that used standard equipment and techniques. Lloyd's of London gave that system its weighty approval with a contract in 1901. In practice this meant a virtual monopoly for Marconi's which lasted for seven years.

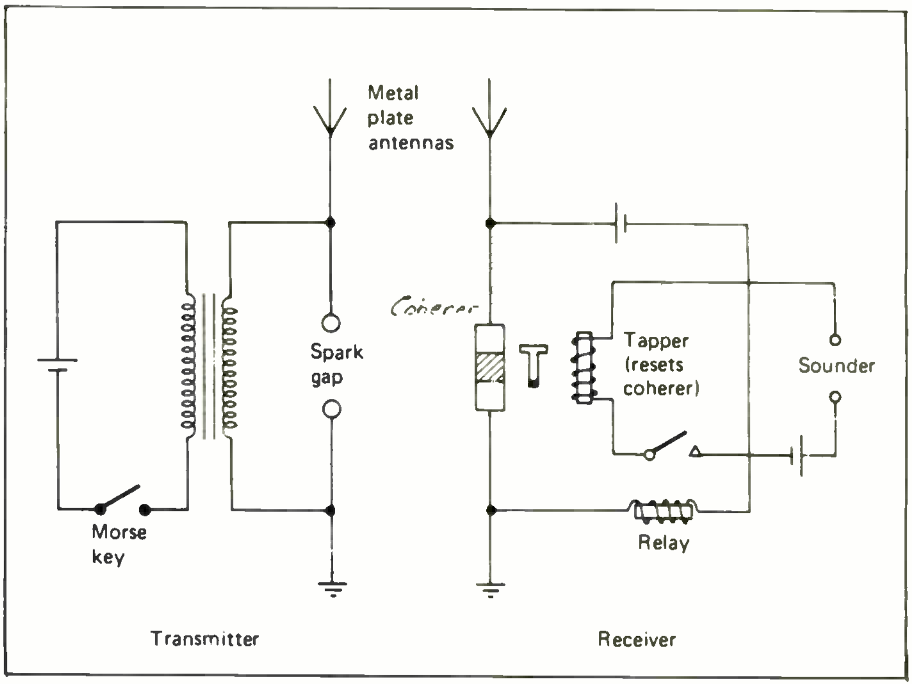
## BRIDGING THE ATLANTIC

Marconi himself felt there was another market: competition with the thriving submarine cable companies.

The first permanent installation was on the Isle of Wight from where messages could be sent to the mainland at about 12 rds per minute. It was from there that Kelvin sent the first paid radio telegram in 1898*. The following year a link was established across the English Channel, and after that the Atlantic became the target.

During more than a year of preparation, huge transmitting and receiving aerial arrays were constructed on both sides of the Atlantic – and destroyed by gales. At last the tests began, using a simplified aerial system at Poldhu in Cornwall and a receiving wire held aloft by a kite at St John's in Newfoundland.

*The telegram was reproduced in the June 1987 issue of *Electronics & Wireless World*, page 600.




**Marconi's untuned transmitter and receiver with ground and elevated aerial (1896).**

The transmission consisted of a single Morse letter S sent at specific times during the day. On December 12, 1901, during a blustering gale, signals were received and Marconi recorded in his diary, "Pips at 12.30, 1.10 and 2.20".

Reception was erratic and automatic receivers proved impracticable. Sceptics suggested that Marconi and his men were suffering from self deception and that the radio waves would have been lost into space. The local telegraph company in Newfoundland reacted by threatening legal action if tests contined. It had a monopoly to protect.

A month later all doubts were dismissed when automatic recording equipment recorded reception on board ship as Marconi sailed back to Britain. The difference in distance achieved between day and night was also noted: 700 and 1653 miles respectively. The Atlantic shipping lanes now promised a new market.

At the age of 27, Guglielmo Marconi had become an international personality, an engineering superstar.

His private life was soon to change also. In 1905, after two broken engagements, he (like his father) married an Irish girl: Beatrice (Bea) O'Brien. They had four children, one of whom died in infancy.

By 1912 the marriage was in trouble but the coupled averted disaster in more ways than one. As invited guests they were to sail on the maiden voyage of the *Titanic*. For business reasons, though, Marconi embarked on an earlier sailing. Bea avoided death by delaying her departure because their two-year old son was taken ill.

In an attempt to help their marriage they took a holiday in Italy. There was a head-on car smash and Marconi lost his right eye.

## ITALY AT WAR

When Italy entered the First World War on the Allied side in 1915 Marconi became adviser on radio communications to the Italian armed services, and he represented his country on official visits, to London and America for example. He was also an Italian delegate at the 1919 Paris peace conference.

In 1923, after much conscience searching, he joined the Italian Fascist Party. Mussolini was only too pleased to have the support of the famous Italian. Much later he was given the hopeless task of defending Italy's invasion of Abyssinia. In this he suffered the ignominy of being denied by the BBC the opportunity to broadcast in defence of the Italian action. Privately by then he had grave misgivings about Mussolini.

A year later his marriage to Bea ended in divorce. Another three years and he remarried, this time to a beautiful Italian girl less than half his age, Maria Cristina Bezzi-Scali. Marconi's position as a divorcee had created obstacles because of church law, but they were overcome with the cooperation of Bea, with whom Marconi was still on good terms Later Marconi himself became a Catholic and subsequently he personally supervised the installation of a short-wave transmitter in the Vatican.

From about 1934 he suffered several heart attacks. He was of course an international celebrity and had received many honours including the Nobel Prize (1909), honourary degrees, Knight of Italy (1902), Freeman of Rome (1903), and President of the Royal Italian Academy.

He died on the July 20, 1937 in Rome and received a state funeral. Following his own wish he was buried at Bologna, the scene of his childhood.

*Dr Tony Atherton is on the staff of the IBA's Harman Engineering Training College at Seaton in Devon.*

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# Tripos – life after the Amiga

**This real-time multi-tasking operating system designed for speed can be adapted for any 68000 family computer.**

LAURA GLEDHILL

**Tripos, the real-time multi-tasking operating system chosen by Commodore for their Amiga domestic/business microcomputer, is now being used in industry following the introduction of a porting kit last year. Laura Gledhill of Metacomco traces its history, explains its internal structure and looks at the future of Tripos in its new form.**

Tripos first appeared in January 1978 but the Cambridge University research project out of which it came started in 1976. The project, headed by Dr Martin Richards, was to design a portable operating system for minicomputers. With the exception of its kernel, Tripos is written in Basic Combined Programming Language (BCPL), a portable high-level language also designed by Dr Richards.

Originally Tripos ran on a PDP11. It was then ported to the Computer Automation LS14 and the Nova. It was not until Tripos was taken to Bath University in 1981 that work on the 68000 version began in earnest. Metacomco acquired the rights to 68000 Tripos from Bath University and continued its development to make it more commercially attractive. This task was assisted by Commodore-Amiga in March 1985 when Tripos was chosen by them for their new computer. In July 1985 the Amiga was introduced and Tripos emerged under a new name – AmigaDOS.

After the Amiga's introduction, Metacomco developed Tripos into kit form for porting to 68000-based computers. This kit, introduced in September 1986, includes a system generation tool, a 68000 assembler, a linker, system objects, source for a bootstrap rom and documentation. All that the user needs to do is to write device drivers in either assembly language or C following source-code examples from the kit.

A number of major contracts have been signed for Tripos in its new form and as a result, it will soon be available on two new 68000 family processors, the 68020 and 68070. The 68070, made by Mullard, is a highly integrated 16/32-bit processor consisting of a c.p.u., an $I^2C$ serial interface, an m.m.u., a reference timer, two independent programmable timers, an RS232 port and two d.m.a. channels. Negotiations are under way for STE bus support, adding to the existing range of VME cards supported.

## DESIGN PHILOSOPHY

Maximum response speed was a major design objective for Tripos. It is designed to have as few overheads as possible, resulting in a fast operating system suited to real-time systems where response speed is crucial. Three areas where this philosophy is clearly illustrated are scheduling, memory management and message passing.

The scheduler, discussed in detail later, adopts a strict task-priority system. There is no overhead for the time-slicing process required in systems using 'round-robin' type scheduling. A task which is allocated processor time continues to run until a higher priority task is ready to run or until it suspends itself.

In the area of memory management, kernel primitives are provided for allocating and freeing memory. No checking is done to stop a program using non-allocated space. By adopting this non-memory-management approach, all memory accesses can be executed as fast as the memory allows, avoiding any clock cycles inserted by a memory-management unit. Clearly, the applications software writer has to make sure that the programs are well behaved.

A similar philosophy is applied to the message-passing system. All communication within Tripos is done by sending and receiving 'packets'. These packets are areas of memory containing the information to be communicated and are passed by reference rather than copied. It is because of the Tripos memory-management philosophy that this method of message passing can be adopted, avoiding the unnecessary duplication of memory.

## INTERNAL STRUCTURE

Tripos is structured in concentric layers with the kernel at the centre. As these layers approach the kernel, they become more processor dependent. The kernel, written in assembly language, is 4Kbyte in object form.

Outer layers are written in BCPL and will transfer to a new processor provided that it has a BCPL compiler. This feature and the small kernel make Tripos a portable operating system, hence the suffix 'pos' of Tripos*. The outer layers are optional – only the required layers need to be installed. These layers are the 18Kbyte file handler, 5Kbyte console handler, 3Kbyte command-line interpreter, 18Kbyte debugger and libraries taking 17Kbyte. Libraries are needed if any of the outer layers are installed.

## PACKETS AND TASKS

Each function carried out by Tripos that can be allocated processor time is known as a task and each task has a priority level associated with it. Of the tasks ready to run, the task with the highest priority is allocated processor time. This method of allocating processor time is known as strict-priority scheduling.

All communication with the operating system is achieved by message passing and the message passed is contained in a structure called a packet. Structure of the packets varies depending on the type of message

*The prefix Tri in Tripos is not an acronym. The name was chosen because the operating system was developed at Cambridge University, where the word tripos originated. In days gone by, students would sit their final examinations on three-legged stools of that name. The examination name still holds but the stools are no longer in use.

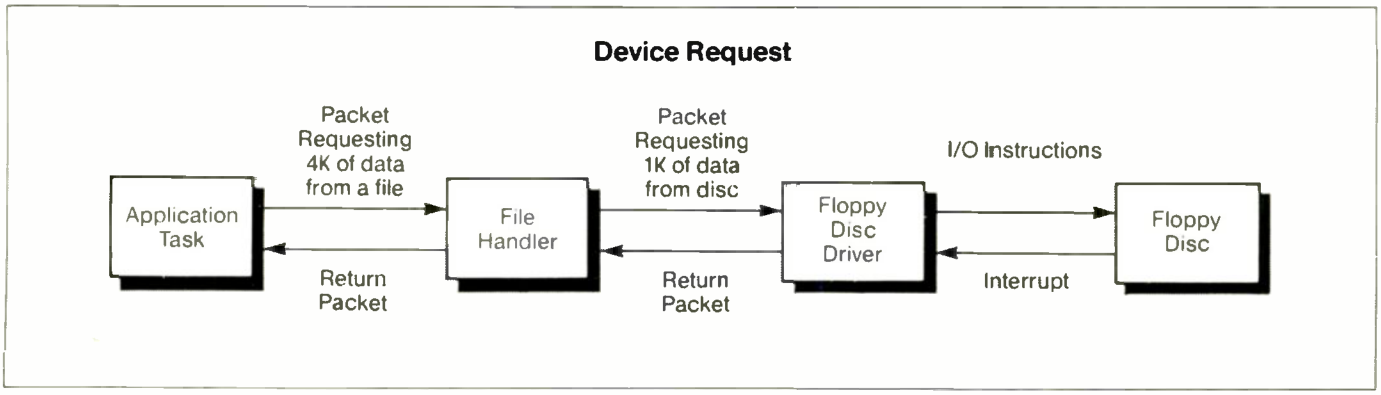



**Fig.1. The file handler forms high-level interfacing between the applications task and floppy-disc driver. Low-level interfacing between the file handler and disc is carried out by the disc driver. This technique facilitates device-independent i/o.**

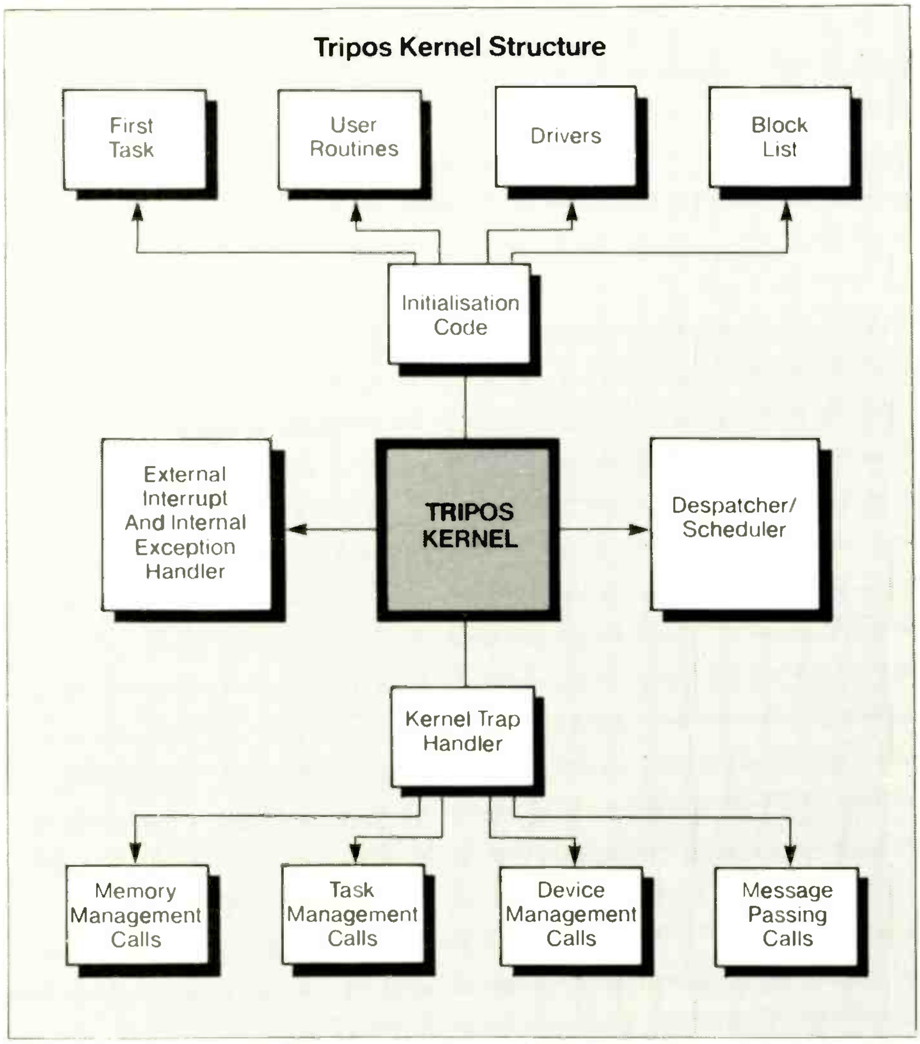



Fig.2. Tripos is structured in concentric layers. These layers become more machine dependent the nearer they are to the centre. Innermost is the kernel, 4Kbyte in size and written in assembly language.

being passed but all packets have these features:

- a link field pointing to the next packet in the queue
- an action-type specifier indicating the packet type
- a packet-destination pointer
- two result fields holding message replies
- argument fields.

When a message needs to be passed within the operating system, an area of memory is required to store the packet structure. Rather than passing the information within the packet physically to its destination, a pointer in the form of an address is passed to the packet structure. This pointer links the packet to a list called the destination work queue which contains entries for all packets waiting to be received by the destination code. A pointer to the next packet in the queue is held within the link field of each packet structure.

Two result fields hold replies to the message. Content of the first field is a number indicating whether the action requested in the message has been successfully executed. In the event of a failed execution attempt, the second field holds a number indicating the failure type. Information needed by the destination code for carrying out the message request is in the argument fields.

When a packet reaches the head of the destination work queue and has been serviced in the manner requested, it is returned to the sender. It is then the responsibility of the sender to release the memory allocated for the packet structure.

Packets are passed around the system at great speed. In a no wait-state system with a 10MHz 68010 processor a task can send and receive back 1250 packets each second.

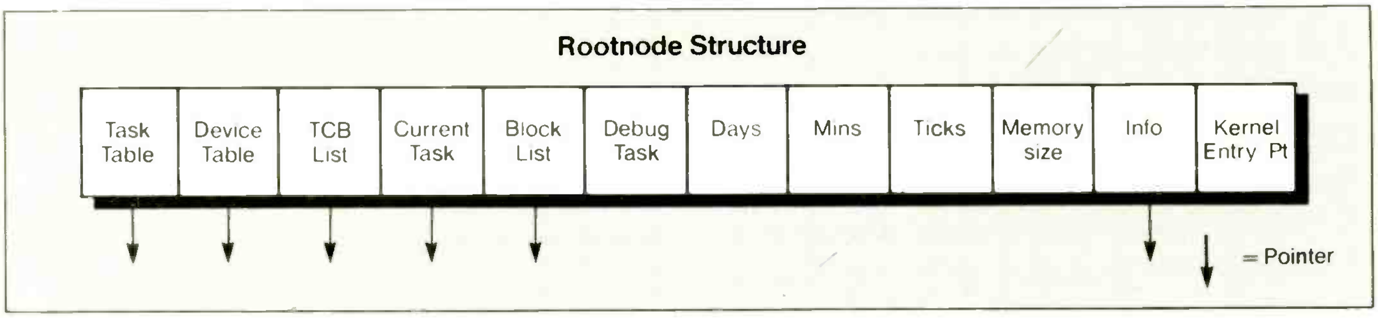



Fig.3. Root-node structure is used by Tripos to keep a record of all aspects of the system. This block is in a fixed position in memory.

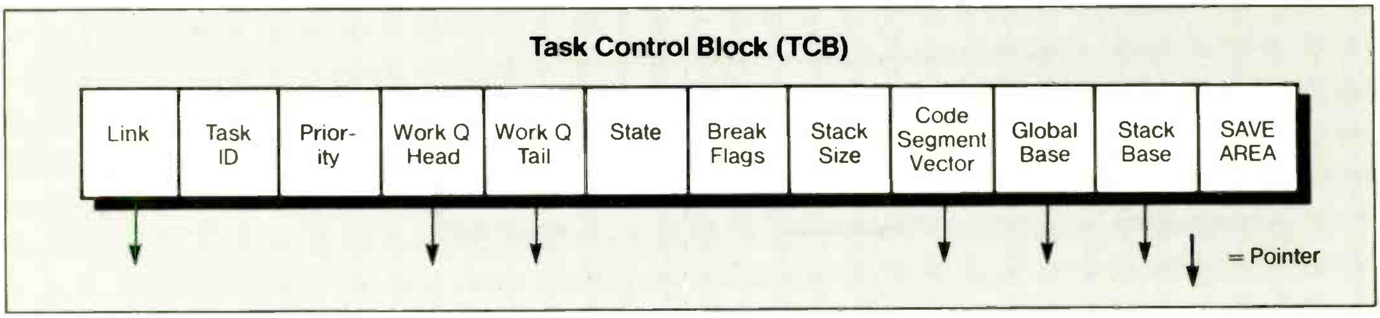



Fig.4. Each task within the system has an associated task-control block containing all information required by the system to manage the task.

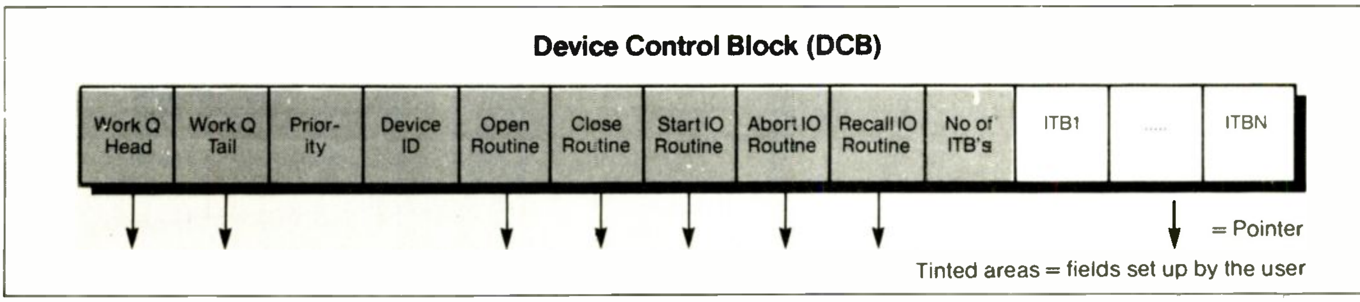



**Fig.5. One of these blocks is used for each device in the system. It contains information needed by Tripos to deal with device requests from tasks within the system.**

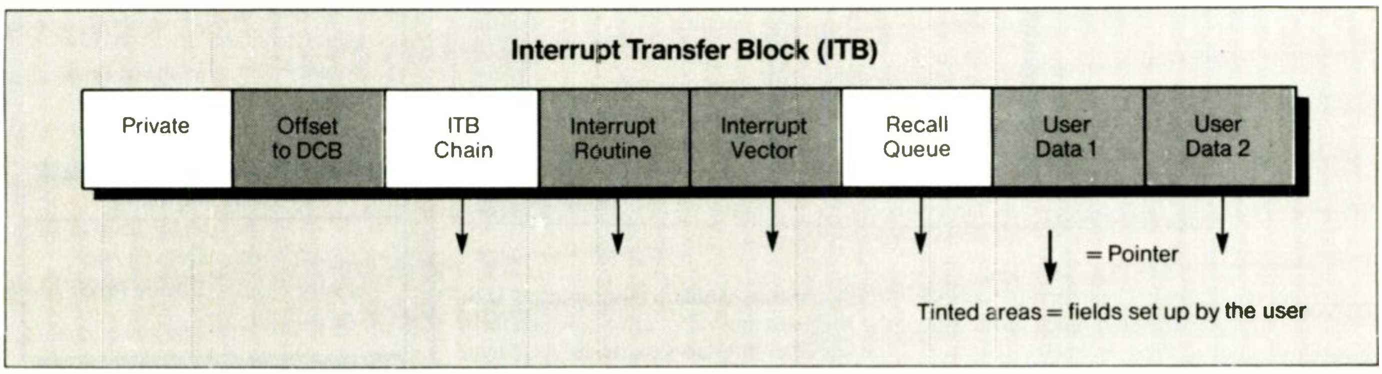



**Fig.6. This structure is used by the external interrupt handler to indentify the source of an external interrupt. Each block contains an interrupt routine responsible for servicing a particular kind of interrupt.**

## DEVICES

Peripherals capable of generating interrupts are called devices and each device has an associated handler and driver. High-level interfacing between tasks and the device driver is provided by the device handler. All requests from a task to a device are initially channelled to the device handler. This technique facilitates machine-independent i/o.

The device driver is the low-level interface between the device handler and the device. It deals with interrupts from the device, Fig.1.

## KERNEL STRUCTURE

There are four main sections in the kernel, Fig.2, the first of which is for initialization. During initialization, Tripos builds a list of all free and used memory areas known as the block list. Excluded from this list are the only two fixed items stored in memory – a root node and exception vectors.

The operating system uses the root node to keep an up-to-date status record of all aspects of the system. Exception vectors are pointers to routines which handle exceptions, both internal and external; external exceptions are called interrupts.

Within the root node, a field points to the task table containing pointers to the control block of each task, Fig.4. Information required by the system for task management is contained within the task-control block.

All task control blocks are also linked together in a list, in priority order, which is pointed to by the task control-block list field in the root node. This is used by the scheduler for allocating processor time.

Another entry the root node points to the device table holding pointers to the device-control block of each device, Fig.5. Device-control blocks contain information needed for carrying out task requests.

After building the block list, Tripos calls the user initialization routine, initializes the device drivers, then activates the first task.

Initiation of the next task ready to run is carried out by a section of the kernel called the dispatcher; a pointer to this task is passed by the scheduler. The dispatcher is entered whenever a task switch is necessary. Task switching is required when a packet is queued to a higher priority task than the current one, when a running task suspends itself while waiting for a packet to return, or when a task's priority is changed. Saving the state of a task and restoring the state of the next task, known as context switching, takes about 100μs.

Trap handling is carried out by the third main kernel section. The kernel trap handler performs various actions requested by the issuing of kernel calls, List 1. Task wait and QPkt are most important; these receive packets and queue them respectively.

Interrupt and internal exception handlers form the fourth main kernel section. Interrupts are requests for attention from devices connected to the system. An example of their occurrence is when i/o is requested by a task. Once the i/o has been initiated, it can take place independently of the processor, allowing processor time to be allocated to another task. When the i/o request is complete, the device issues an interrupt which is dealt with by the interrupt handler.

On the 68000 processor, an interrupt is either acknowledged immediately or left pending depending on the priority of the interrupt. When an interrupt is acknowledged, its interrupt vector is read. Interrupt vectors are stored in the fixed exception-vector area of memory. The vector contains the address of the first interrupt-transfer block associated with the vector, Fig.6. This transfer block is the head of a chain of transfer blocks, one of which is (hopefully) responsible for servicing the interrupt. The

### 1: Kernel Calls

**Task Management**

| | |
|---|---|
| Add Task | Change Pri |
| Forbid | Hold |
| Permit | Release |
| Rem Task | Set Flags |
| Super Mode | Test Flags |
| User Mode | Find Task |

**Device Management**

| | |
|---|---|
| Add Device | Rem Device |

**Message Passing**

| | |
|---|---|
| DQ Pkt | Q Pkt |
| Task Wait | Test Wk Q |

**Memory Management**

| | |
|---|---|
| Get Mem | Free Mem |

**Miscellaneous**

| | |
|---|---|
| Find DOS | Root Struct |

## 2: CLI Commands

| | | |
|---|---|---|
| Alink | End CLI | Prompt |
| Assem | Failat | Quit |
| Assign | Fault | Relable |
| Break | Filenote | Rename |
| C | Format | Run |
| Cd | If | Search |
| Console | Info | Set-serial |
| Copy | Install | Skip |
| Date | Join | Sort |
| Delete | Lab | Stack |
| Dir | List | Status |
| Diskcopy | Makedir | Type |
| Echo | Mount | Vdu |
| Ed | Newcli | Why |
| Edit | Path | |

## 3: DOS Calls

| File Handling | |
|---|---|
| Close | Create Dir |
| Current Dir | Delete File |
| Dup Lock | Examine |
| Ex Next | Info |
| Input | Io Err |
| Is Interactive | Lock |
| Open | Output |
| Parent Dir | Read |
| Rename | Seek |
| Set Comment | Set Protection |
| Unlock | Wait For Char |
| Write | |

| Process Handling | |
|---|---|
| Create Proc | Date Stamp |
| Delay | Device Proc |
| Exit | |

| Loading Code | |
|---|---|
| Execute | Load Seg |
| Unload Seg | |

| Miscellaneous |
|---|
| VDU |

interrupt handler calls the interrupt routine defined in each transfer block until the result of one of these indicates that the interrupt has been dealt with. If no transfer block is responsible for the interrupt, the debugger is entered so that the problem can be investigated.

While an interrupt routine is executing, no kernel calls may be issued. This restriction avoids unfortunate mishaps that can happen if another interrupt occurs while a kernel routine is queuing a packet for example. If this is allowed to happen the packet may be lost for ever with disasterous results.

To get round this problem a recall feature is provided. If an interrupt routine requires a kernel call, it requests to be recalled. While the recall request is being added to the recall queue, all further interrupts are disabled. When the recall request has been added to the queue, interrupts are enabled again.

Interrupts are turned off for at most about 20μs. On return from the interrupted routine, the first task on the recall queue is called; the exception to this is an interrupted kernal action, which must be completed first. All further recall requests are suspended during a recall until the current kernel action has been completed.

An internal exception is an error condition caused during a user's program. An example of an internal exception is divide-by-zero. If the user task does not have an exception routine defined for a particular exception, the debugging program is entered so that the user can find out why the exception occurred.

## COMMAND-LINE INTERPRETER AND CONSOLE HANDLER

Commands issued by the operator at the keyboard are handled by the command-line interpreter, c.l.i. Available interpreter commands are show in List 2. It is the console handler's responsibility, on request from the interpreter, to send lines of input from the keyboard back to the interpreter and echo keyboard input to the v.d.u.

The console handler communicates with the keyboard and v.d.u. drivers, which form the low-level interfaces to the devices themselves. It requests one character of input at a time, informing the v.d.u. driver when input is available to be echoed and adding each character to a buffer until a complete line of input has been received. On completion of a line, signalled by a carriage return, the handler informs the interpreter that the line is available and the appropriate c.l.i. commands are initiated.

## DISC OPERATING SYSTEM

Programs and data are stored in files organized in tree-structured directories. The directories are arranged in an hierarchical manner, each consisting of further directories and/or files. Each file has a file header block containing information about the file required by the file handler.

Directory information is stored in a directory block, also used by the file handler. At the base of the tree is the root block which is stored in a fixed position at the centre of the disc. Directories and files are chained either from the root block or a directory block. The only difference between the root block and a directory block is that the root block has no directory above it in the hierarchy.

**Tripos is the operating system chosen for Commodore's Amiga – a domestic/business computer with a 68000-family main processor and three coprocessors.**

A technique called hashing is used to link a new directory or file into the tree. An arithmetic function is applied to the name of the file or directory to produce an integer within a specified range. This integer is then used as an offset into a hash table, each element of which contains a disc block number. The block holds the new file header or directory block.

In the event of a collision, where two names indicate the same offset, the file headers or directories are chained. A string-matching process then identifies the matching name in the chain.

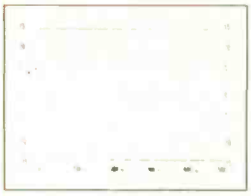
Disc operating system calls are shown in List 3.

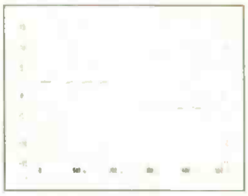
## CONCLUSION

Since the Amiga's introduction, Tripos has become a well established operating system with a large number of users. The range of high-level languages running under Tripos includes C, Pascal, Basic, Lisp and BCPL. Cross development support on PCs, Unix and Ultrix systems is also available for easy porting of Tripos and application development.

*Laura Gledhill is with Metacomco of Bristol*

# BANG





LOOK WHAT HAPPENED TO THE NICE CLEAN PWM SIGNAL WHEN THE LOAD WAS CONNECTED.

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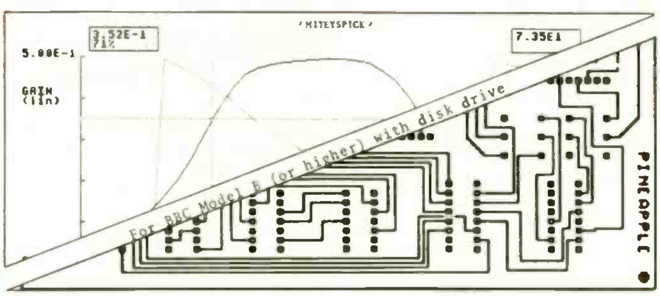


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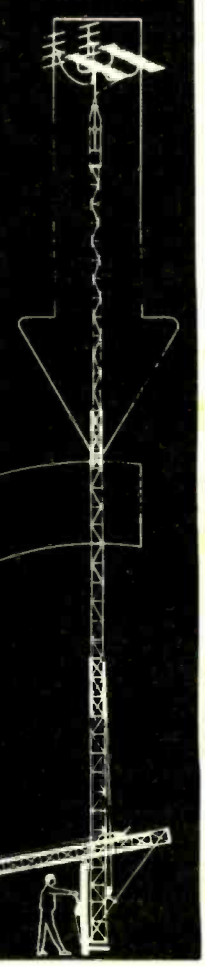

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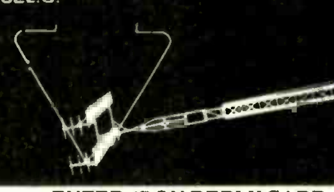

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# The diode as an energy-controlled, not a charge-controlled device

**The conventional notion of electricity as electrons jostling their way down a wire cannot, according to Catt's Anomaly, be the thing that arrives at and controls the operation of a diode.**

IVOR CATT

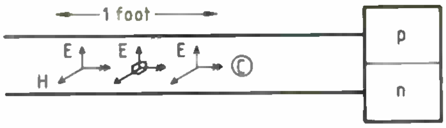
The traditional theory of operation of the diode is, for me, one of the many casualties of advances in electromagnetic theory during the last 25 years.

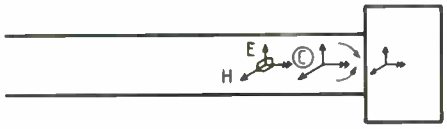
Whilst at Motorola, Phoenix, in 1964, work on the problem on how to interconnect high-speed (one nanosecond) logic gates led me to the same general conclusion as had been reached (unknown by me until 1972) by Oliver Heaviside a century before when he tackled the problem of how to improve undersea telegraphy from Newcastle to Denmark.

> "... (The electric and magnetic fields) are supposed to be set up by the current in the wire. We reverse this; the current in the wire is set up by the energy transmitted through the medium around it. The sum of the electric and magnetic energies is the energy...
>
> "... A line of energy-current is perpendicular to the electric and the magnetic force,..."
>
> – O. Heaviside, Electrical Papers vol.1, 1892, p.438.

Our conclusion was that what he called the "energy current" travelling down between the two conductors (i.e. the Poynting vector) guided by them as a train is guided by two rails, was the important feature of signalling, and not the electric charge and electric current in or on the wires. Twenty years later my view hardened when I came across an anomaly, explained in panel 1.

Let us deliver a 1ns-wide pulse down a long transmission line terminated by a diode. When the pulse reaches the diode, *it does not carry any charge with it;* Catt's Anomaly shows that charge could not have travelled fast enough to keep up with the pulse, which travels at the speed of light. If we are agreed that the diode will respond (for instance 'start to conduct') after a delay which is small (say 100ps) compared with the time delay down the transmission line delivering the pulse, then it must be responding to the *energy current*, that is the t.e.m. wave or pulse approaching it in between the two conductors. This t.e.m. pulse enters directly into the side of the crucial interface or surface between the p-region and the n-region which together make up the diode.




Note the phrase in panel 2: "Nothing ever traverses a capacitor from one plate to the other." Applied to the diode, this seems to say that nothing travels across the junction from the p-region to the n-region, or vice versa. The only travel is along the surface between the two regions, in a direction *at right angles* to the generally supposed direction of movement.

When the leading edge of the pulse reaches the near edge of the diode, it finds a change in characteristic impedance. As a result, most of it is reflected, but a very small portion continues forwards to the right, down the very narrow transmission line made by the surface between the p and n regions. It is possible that the effective dielectric constant $\epsilon$ is large so that the velocity of propagation, $(\mu.\epsilon)^{-1/2}$, from left to right along the p-n interface is very slow. At the speed of light in a vacuum, the round trip across the p-n interface of a diode a tenth of an inch wide would be 20 picoseconds but since the effective $\epsilon$ will be bigger than that for a vacuum, the delay will be greater.

When the step reaches the right-hand edge of the diode, it sees an open circuit and reflects back toward the left, so that the total voltage across the junction doubles. When it gets back to the front (left-hand) end, it reflects toward the right again (except for the very small portion which escapes across the $Z_0$ mismatch back into the transmission line leading away to the left). By this mechanism of zig-zag repeated reflections across the diode, the amount of energy

## 1: CATT'S ANOMALY

Traditionally, when a TEM step (i.e. a logic transition from low to high) travels through a vacuum from left to right (Fig.7), guided by two conductors (the signal line and the 0V lines), there are four factors which make up the wave:

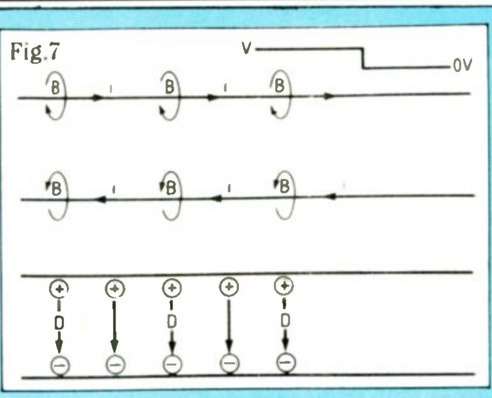
—electric current in the conductors

—magnetic field, or flux, surrounding the conductors

—electric charge on the surface of the conductors

—electric field, or flux, in the vacuum terminating on the charge.

The key to grasping the anomaly is to concentrate on the electric charge on the bottom conductor. During the next 1 nanosecond, the step advances one foot to the right. During this time, extra negative change appears on the surface of the bottom conductor in the next one foot length, to terminate the lines (tubes) of electric flux which now exist between the top (signal) conductor and the bottom conductor.




Where does this new charge come from? Not from the upper conductor, because by definition, displacement current is not the flow of real charge. Not from somewhere to the left, because such charge would have to travel at the speed of light in a vacuum. (This last sentence is what those "disciplined in the art" cannot grasp, although paradoxically it is obvious to the untutored mind.) A central feature of conventional theory is that the drift velocity of electric current is slower than the speed of light.

For further information on the Catt Anomaly, see letters in the following issues of *WW* 1981: Aug. 1982: Aug. Oct. Dec. 1983: Jan.

For what happens next, refer to my new model for the capacitor, panel 2.

(current) in the p-n surface increases 'exponentially' as indicated by the graph. When the energy density builds up beyond some critical level (0.7V), there is a 'snap', and the later advancing energy current sees a short circuit, and reflects with inversion.

Since no charge has been introduced into the p-n interface, it is totally inappropriate to explain the mechanism of the diode in terms of extra electrons. The explanation must be novel, in terms of the amount of electromagnetic energy present; that a level in excess of some critical value (0.7V) causes the t.e.m. wave travelling down the p-n interface to see a change in what is ahead of it, from open circuit to short circuit. That is, beyond that critical amplitude the p-n interface cannot accept more energy and rejects it.

This developing analysis of the behaviour of a diode is totally at odds with the traditional view, based on electrons, holes, energy barriers across the p-n interface that charges are trying to climb up. Why does this earlier theory succeed in correlating *at all* with experimental results?

"... if in conversation you insisted that your elder daughter was *identical* to your younger daughter, whereas in fact their "equality" only related to their parentage, every conclusion that followed this absurd assertion would not necessarily be absurd. For instance, if you knew the address of one daughter you might therefore know the address of the other. In the same way, it is possible for "valid" results to come from absurd postulates (like the absurd postulate that a diode is full of particles called electrons buzzing around trying to climb hills). "... the two non-identical daughters might have the same address. It is these 'echoes of truth' which masquerade as scientific truth today."
– I. Catt, Electromagnetic Theory vol.1, CAM Publishing, 1979, p15.

False theories, like the theory that the diode is a device controlled by charge, exist in the real world, and so are influenced, or somewhat directed, by the imperatives of the real world in which they find themselves, at least when it comes to the moment of truth: the checking of theory against experimental result.

# Semiconductor Centre

The Semiconductor and Microelectronics Centre, a combined research and development centre created by the University of Wales Institute of Science and Technology and University College, Cardiff, has recently opened in Cardiff. The centre will be especially looking at new semiconductor materials of the III – V group, possibly combined with material from the II – VI group.

UCC physicists have developed a wide range of techniques to build and examine semiconductors, while UWIST has a clean room facility to use construct transistors from the materials. Both groups work closely with industry to find applications for the new chips. Projects have already included the development of a thermoelectric generator for the US space programme, lasers for communications systems and high-speed devices.

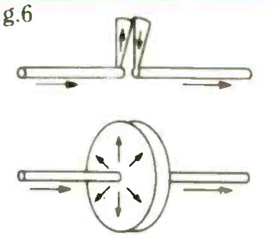
## 2: THE CAPACITOR

In the early 1960's I pioneered the inter-connection of high speed (1 ns) logic gates at Motorola, Phoenix, Arizona[12]. One of the problems to be solved was the nature of the voltage decoupling at a point given by two parallel voltage planes. I asked Bill Herndon about this problem, and he gave me the answer: "It's a transmission line"[13]. Bill learnt this from Stopper, whom I never met, who now works for Borroughs in Detroit.

The fact that parallel voltage planes, when entered at a point, present a resistive, not a reactive, impedance, was for me an important breakthrough. (It meant that as logic signal speeds increased, there would be no limitation presented by the problem of supplying +5V.) The reader should be able to grasp the reason why voltage plane decoupling is resistive by studying Fig. 6, which shows the effect of a segment only of two planes as they are seen from a point[14].

During the next ten years, with the help of Dr D.S. Walton, I gradually came to appreciate that, since a conventional capacitor was made up of two parallel voltage planes it also had a resistive, not a reactive (i.e. capacitive or inductive) source impedance when used to decouple the +5V supply to logic. Since the source impedance (= transmission line characteristic resistance) is well below one

Fig.6



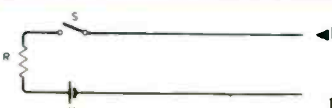
ohm, the transient current demand of logic gates approaching infinite speed can still be successfully satisfied with +5V from a standard capacitor of any type[15]. The reason why the myth has developed that the worst (low capacitance, 'r.f.') capacitors are the best in this role is discussed elsewhere[16].

The capacitor is an energy store, and when energy is injected, it enters the capacitor sideways at the point where the two leads are joined to the capacitor. Nothing ever traverses a capacitor from one plate to the other. This is clearly understood in the case of a transmission line. By definition, when a TEM wave travels down a transmission line, nothing travels sideways across the transmission line, or we would not have a transverse electromagetic wave.

**For further information, see the *Wireless World* articles dated December 1978 and March 1979.**

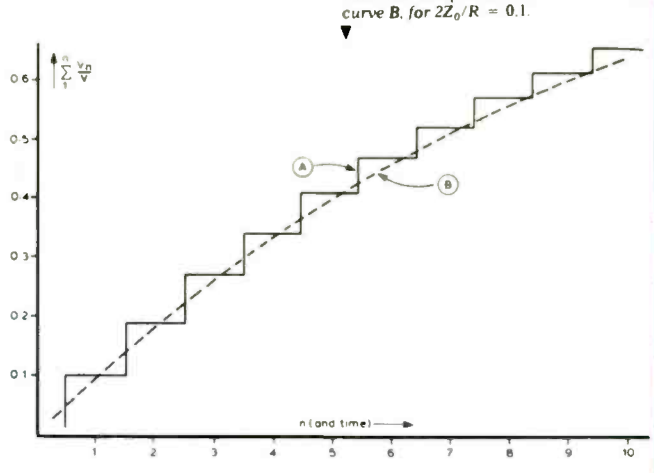
**Excerpts 1 & 2 are from Fundamentals of electro-magnetic energy transfer, by Ivor Catt, *Wireless World* September 1984.**

WIRELESS WORLD, DECEMBER 1978




◀*Fig. 2 An open-ended transmission line.*

*Fig. 3 Comparison of the transmission line model $1-(1-2Z_0/R)^n$ in the curve A with the lumped model $1-e^{-2Z_0 n/R}$ in curve B, for $2Z_0/R = 0.1$.* ▼



# Where is the short?

**How to locate short circuits without blowing your own fuse. State-of-the-art measurement techniques are brought down out of the clouds for the use of the average engineer with everyday lab equipment.**

LESLIE GREEN

On printed-circuit or wire-wrapped boards, a major problem seems to be the location of a short circuit between the power rails. Having seen the wild ramblings of others trying to locate the problem, I feel justified in setting forth the solution to the problem, which to me seems so easy. I must stress that this is a practical review based on the experience of finding such short circuits for others who were having difficulties.

The problem is easily stated. The board arrives in an area and, whether loaded with components or not, the power rails are tested for shorts. Oh dear! There is a short between +15V and 0V; where can it be? Now there are shorts and shorts. There may be a tantalum capacitor backwards across the supply, a diode backwards or a faulty ceramic decoupling capacitor if the board is loaded. Or on unloaded boards just plain track faults, solder blobs, wire-wrapped connections to the wrong pins or broken insulation faults. The component-fault shorts are usually easier to spot since they tend to smoke when you start turning up the power supply current limit. The other faults, however, are difficult to locate in this way.

First let me review a couple of the more neanderthal approaches to the problem, voiced by the uninitiated. How about putting on a really big power supply and blowing up the fault? Well, something would fuse certainly but there is a good chance that it would be something other than the fault. A bridged p.c.b. track can have a lower resistance than the rest of the track and can have a better heat dissipation rate as well. Hence the track peels off the rest of the board instead. On a wire-wrap board, if there is a real wire between +15V and 0V it is unlikely to fuse before any of the others. Of course, if it did start to get very hot the insulation on nearby wires would be damaged.

Here is a more technical one. How about spraying the board with aerosol freezer, passing an amp or so through the offending rails and seeing where the heat is dissipated by how fast the frost thaws? Well, it is great fun spraying a p.c.b. with freezer and watching it all go white as ice crystals form on the surface, but it just doesn't locate the fault. The heat generated may not be that great and it is spread by the p.c.b. material and the tracks. On wire-wrap boards you can't even get a good layer of frost because the wiring is up to a quarter of an inch off the board.

The real systematic solution is to cut tracks or links, bisecting the board each time until the fault is isolated. Not bad from an academic viewpoint but it sure makes a mess of that nice new p.c.b. The result, a patched up dissected p.c.b. with less good looks and lower reliability.

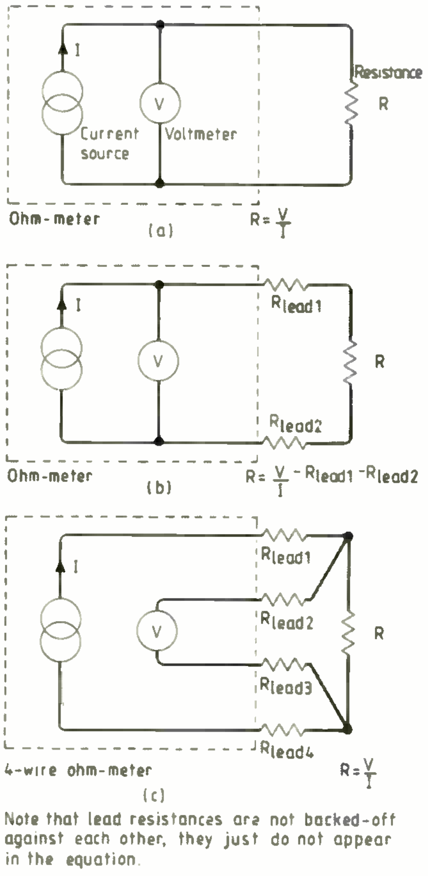




**Fig.1. Simple method requires only a bench power supply, a cheap d.v.m. and the standard four-wire resistance measurement technique.**

At this point cries of "If only I had an Acme widgetizer I could locate the fault just like that!" come up. All of this ululation is of course to no avail since we need to rectify the fault now – today – with existing lab equipment. To anyone with a background in high accuracy resistance measurement the answer is obvious. Unfortunately not many people really understand the basics of this, which are of course very simple provided you can grasp Ohm's law. First of all let us measure the resistance of a resistor. To do this we put a known current through the resistor and measure the voltage across it, Fig.1(a). Notice that this is a linear ohm-meter. The measured voltage is directly proportional to the unknown resistance. On moving-coil resistance meters it is usual to use a fixed voltage and measure the current. The current, being inversely proportional to the resistance, gives the familiar non-linear scale on the meter.

For lower resistances, however, the leads can not be neglected and the resistor reads higher than it actually is, Fig.1(b).

The solution is to use a separate pair of wires to sense the voltage across the resistor. Because there is no current in the sense wires the voltmeter reads the correct voltage. This is the four-wire ohms system used on precision digital multimeters.

This isn't a bridge measurement. In a bridge measurement a dummy set of leads is used to compensate out the lead resistance errors. In a true four-wire measurement the

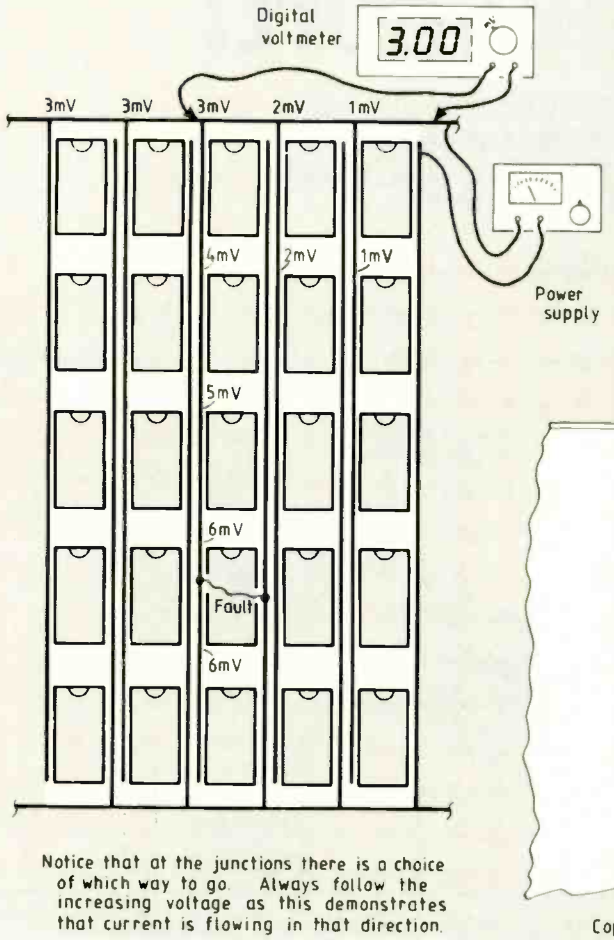
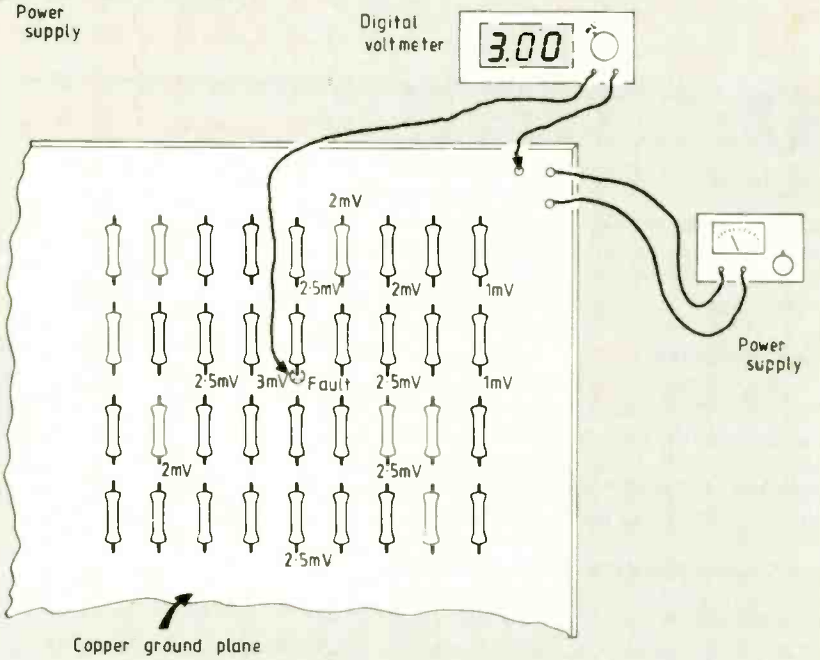



**Fig.2, left. Following the route that gives increasing voltage easily locates a short circuit. Either or both power lines may be used in this way.**

**Fig.3, below. Technique really pays dividends on heavily loaded boards where components obscure faults and a ground plane prevents use of a burn-out technique.**




lead resistance has no effect so long as the current source is adequately good and the voltmeter input impedance is sufficiently high. There is no requirement that the lead lengths or resistances be equal in this system. Fig.1(c).

Cries of "I know all about that, we did it once at college" appear from the ranks. "Of course we don't have a eight-digit multimeter so we can't measure it". Well if you had truely understood the theory you could immediately apply it to the problem at hand. The equipment required is a bench power supply and any cheap d.v.m. with say 0.1mV resolution. It is so easy it embarrasses me to have to explain it laboriously, and yet I have found it necessary.

Depending on the exact nature of the board under test, put the power supply across the shorted rails and wind up the current limit to say 1amp. Find those places on the p.c.b. which should be connected to one of the power rails. By following these points with a d.v.m. probe, the other probe being stationary at the power input, it is possible to locate a point which has more voltage on it than any other. You can get this easily by following changes in voltage. If the voltage is increasing in the direction you are moving the probe, fine. If not, go in another direction. You can of course do the same thing from the other power rail as well and they will meet in either one point or one link that shouldn't be, and there is your short circuit.

Figure 2 is a sketch of a real fault that was encountered. The board was a wire-wrapped prototype digital assembly using in excess of 100 i.cs. The voltages marked are to illustrate the fault and demonstrate the practical application of the technique. On this board the fault was a power wire pulled too tightly past a grounded pin, which cut through the insulation and caused the short.

This technique also works on p.c.bs which have ground planes, since the current will try to get at the short circuit from all sides to a certain extent. Figure 3 is another real fault sketched out. It is easy to have a short to the ground plane and a visual inspection may not reveal the fault as a component may be physically obscuring it. Trying to burn-out this track fault would have failed hopelessly since the ground plane would have run away with all of the heat.

In this example the board was loaded with some 700 components and a close visual inspection had revealed nothing. Using the technique described the fault was found in five minutes and turned out to be a p.c.b. short hiding under the silk-screened component overlay.

Now I know that you already knew all of this and that it is all obvious – but it is nice to see it written down, and it may help all those others!

*Leslie Green is senior design engineer at Gould Electronics.*

# Technical Change Centre closed

The independent Technical Change Centre, which advises government and industry on the adoption and impact of new technology, is closed. Core funding of £400,000 a year from the Economic and Social Research Council ceased from the end of June.

To survive in its present form, the Centre would need to become self-supporting in terms of overheads and salaries within three months of ESRC's decision rather than at the end of four years as planned.

The Centre had made strenuous efforts to secure the neccessary funds from other sources but, after reviewing the position, the Board did not believe that enough money could be raised in the time available. It therefore decided, with much regret, that the Centre should be closed at the end of July, making appropriate provision for the staff. The reasons for ESRC's decision to cut off core funding from the TCC are less than clear but the board believes the Centre has been most unjustly treated.

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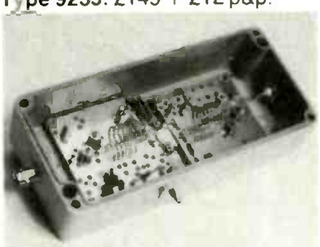
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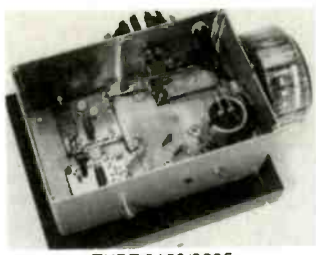
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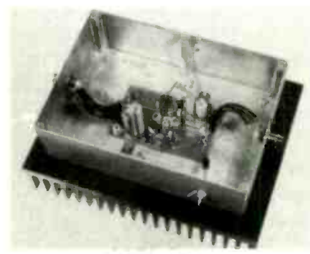
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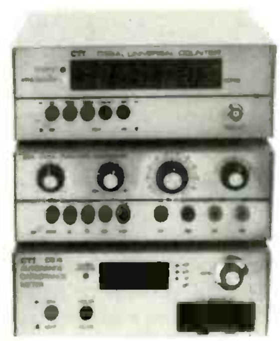

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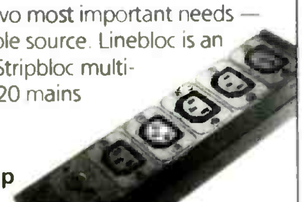

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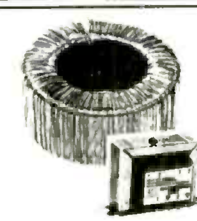

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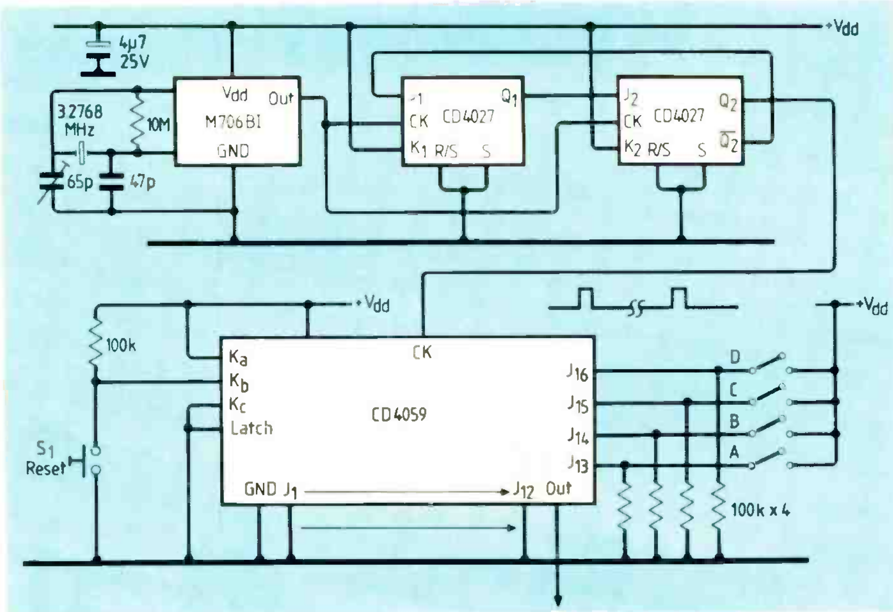
# CIRCUIT IDEAS

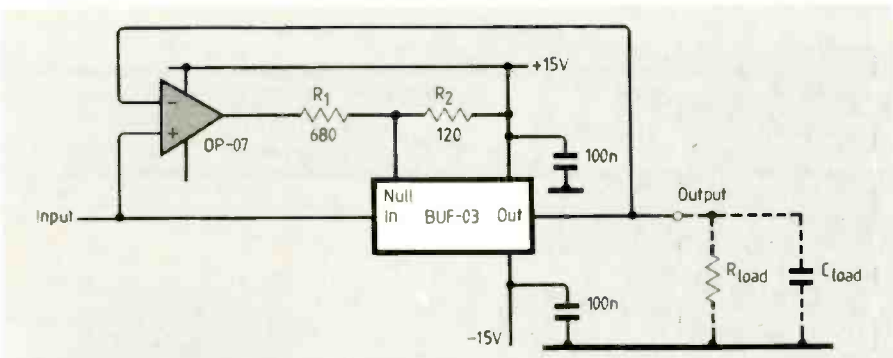
## Programmable 1-15 minute timer

A crystal controlled 50Hz timebase forms the reference in this timer but a mains derived clock is equally suitable. Timing is programmable in steps from one to fifteen minutes.

Frequency division of the 50Hz signal, ranging from 3000 to 45000, is performed by a series-connected modulo-three counter and a programmable divider in extended-count mode. Binary switch settings from 0001 to 1111 produce a positive-going 60ms output pulse at 1 to 15 minute intervals. Timing starts when the push-button is released.

N.E. Evans
Department of Electrical and Electronic Engineering
University of Ulster




## High-speed voltage follower gives 100mA output

Op-amps normally satisfy all the requirements for a voltage follower except speed. An alternative to searching for a faster device is to place a fast buffer in the op-amp feedback loop. This increases speed while maintaining the op-amp's accuracy.

The BUF-03 buffer is well suited to this configuration. Its 100mA peak output remains stable with any capacitive load whereas the OP-07 requires a 50Ω decoupling resistor for loads greater than 500pF.

Input signals of up to ±10V feed the buffer and op-amp non-inverting inputs. Gain error of the buffer is reduced by feeding op-amp output into its null terminal; voltage divider $R_{1,2}$ keeps op-amp output in its active region.

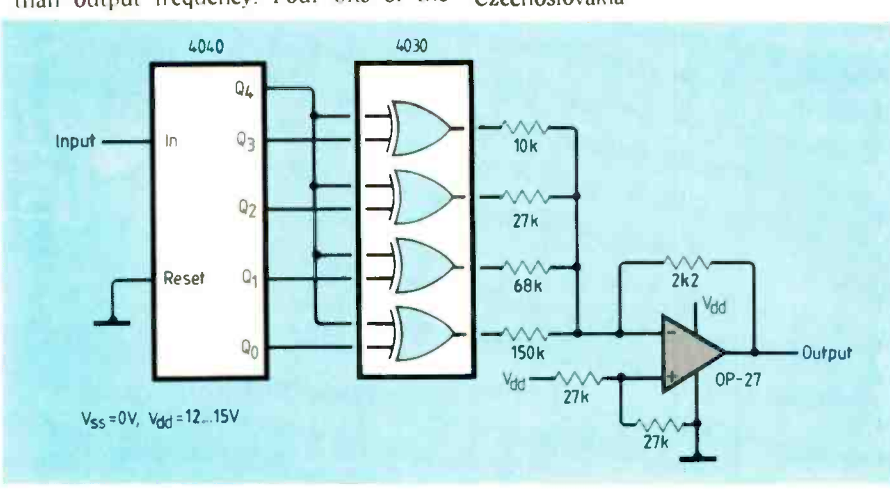
Frantisek Michele
Brno
Czechoslovakia

## Wide range digital sinewave generator

Three integrated circuits produce a digital sinewave generator with a frequency range of $10^8$:1. A resistor network shapes 32-step sinewaves from four counter bits so high and low-pass filtering is not necessary. Wave shape is changed by simply altering the resistor values.

Input clock frequency is 32 times higher than output frequency. Four bits of the counter feed the resistor ladder either in true or inverted form to give positive and negative half cycles; state of the fifth counter bit determines whether or not the four bits are inverted by switching one input of each exclusive-or gate.

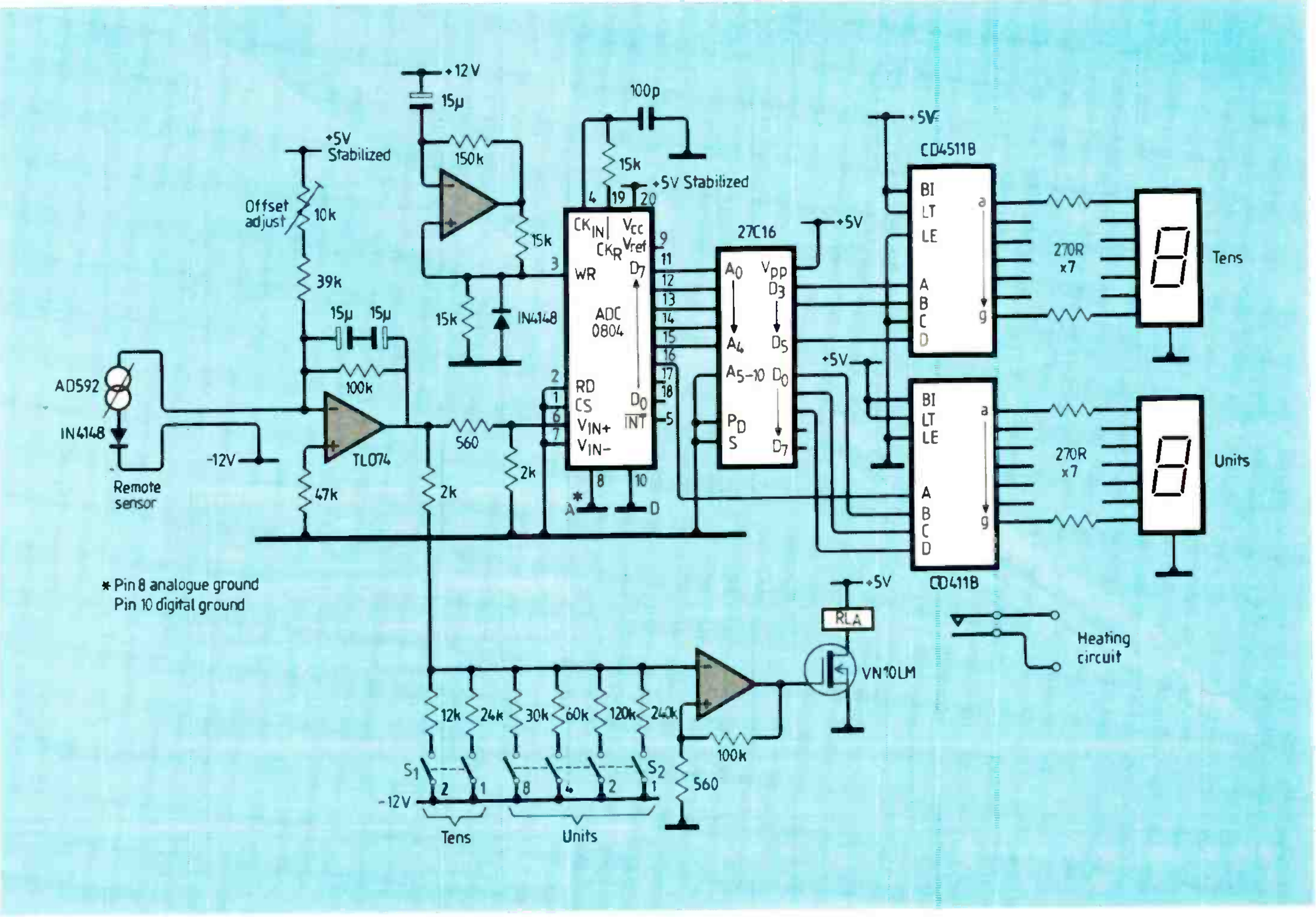
Frantisek Michele
Brno
Czechoslovakia




## Remote-sensing room thermostat

This controller replaces the conventional bimetallic heating thermostat to provide remote temperature setting and led temperature display. Extension of the circuit for detection of average or minimum temperature of several sensors is possible.

Existing wiring can be used to connect the remote sensor (Analog Devices) to the control/display unit located near the central-heating controller. Thumbwheel switches




set the temperature and the heating circuit is switched by a relay; the switch comparator provides around 0.5°C hysteresis. Range of the voltmeter is 0-39°C.

Regulation of the 5V supply is important, especially for the offset control and a-to-d converter. Resistors with 2% tolerance will give an error of better than 1%. To set the circuit, measure sensor current (273μA at 0°C rising by 1μA/°C) and adjust offset for the correct display.

With appropriate adjustment of input-stage gain, several sensors may be connected in series to register the temperature of the coldest, or in parallel to register average temperature.

B.V.W. Isaacs
Plymouth

Port and bit allocations.

| Port | Status | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| $P_{0A}$ | W | ← Eprom address low → | | | | | | | |
| $P_{0B}$ | W | sp | ← Eprom address high → | | | | | | |
| $P_{0C}$ | W | $V_{pp}$ control → | | OE | CE | sp | CLR | JAM | |
| $P_{0D}$ | W | ← PIO control → | | | | | | | |
| $P_{1A}$ | W | ← Time preset → | | | | | | | |
| $P_{1B}$ | R/W | ← Eprom data → | | | | | | | |
| $P_{1C}$ | R | sp | sp | sp | sp | sp | sp | sp | PROG |
| $P_{1D}$ | W | ← PIO control → | | | | | | | |

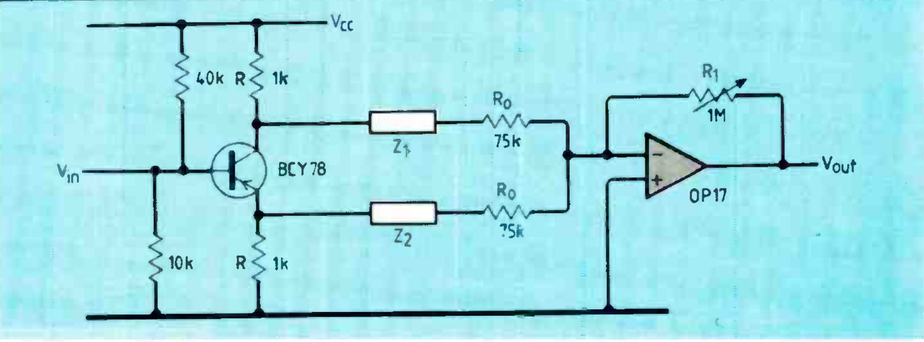
All output bits of port $P_{1A}$ and (potentially) $P_{1C}$ are set low when the data direction $P_{1B}$ is reversed. Spare lines are indicated by sp.

## Pass-band pilot filter

In frequency-division multiplexing, pass and stop-band filters are used to split pilot frequencies from telephone channels. Classical solutions require differential transformers that are difficult to design, especially for low frequencies.

We suggest this emitter-follower solution. In the pass band, impedances $A_{1,2}$ have different signs and attenuation ripple is ≤0.3dB; in the stop band, the two impedances have the same sign and attenuation is ≥40dB. Attenuation is

$$\frac{V_{in}}{V_{out}} = 20\log\left(\frac{R_0}{R_1}\right) + 20\log(Z_1+R_0)(Z_2+R_0)/R_0(Z_2-Z_1).$$




Using this equation for a pass band within $f_c \pm 4$Hz and stop band outside $f_c \pm 150$Hz, where $f_c = 20$kHz, gives an inductance of 1000H for quartz units $Z_{1,2}$; parallel capacitance is 20pF, loss resistance is 50kΩ and the two resonant frequencies are 19991 and 20005Hz respectively.

For narrower pass band and/or lower stop band attenuation, use a trimmer capacitor instead of $Z_2$.

Laka Jovan
Beograd
Yugoslavia

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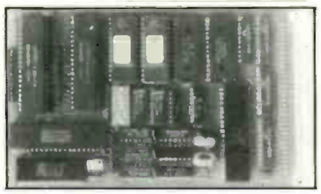

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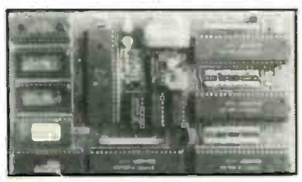

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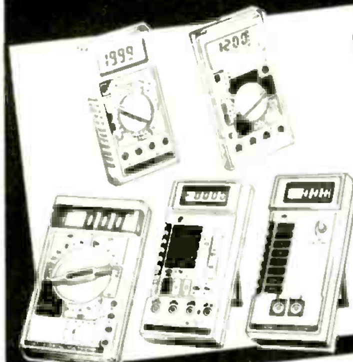

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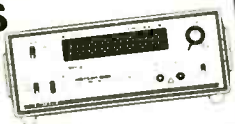

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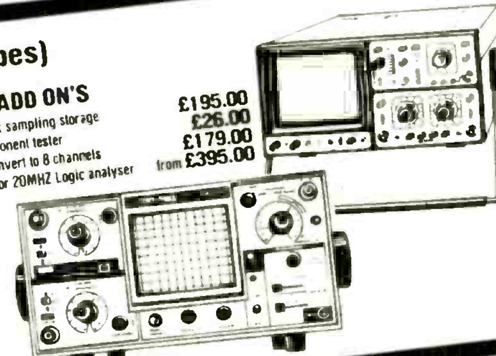

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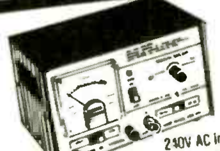

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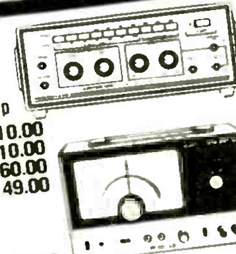

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# FEEDBACK

## Hugh Pocock

Hugh Pocock was much more than a name to me, for he encouraged me to write the first DIY book for the wireless amateur, published by the Wireless Press at Henrietta St in 1921. I never forgot the kindness which he showed to everyone with whom he came in contact, and his staff worshipped him.
Alan Douglas.

## Blood-pressure control

I read with interest the Research Note (July, 1987) concerning the closed-loop control system for blood pressure developed in Melbourne. It may be of interest to your readers that such a system has been in use in Glasgow Royal Infirmary Cardiothoracic Unit for the past two years. An initial assessment of our system confirmed the benefits of closed-loop control and I enclose a reprint of an initial study carried out by our Department of Anaesthesia.

Our most recent development is based on an Atari 520ST microcomputer and has the unique advantage of requiring no interaction with the keyboard. All input is achieved with a mouse-controlled arrow which the nurse uses to select from several options displayed on the screen. Nurses are not skilled in using a keyboard and we expect this feature to provide an important benefit in the routine use of computers in the clinical setting.
Gavin N.C. Kenny,
Department of Anaesthesia,
Glasgow Royal Infirmary,
Glasgow.

As a practising doctor and engineer involved in Medical Research I find the new improved *EWW* very useful for keeping up to date.

However, the article "Intensive care-biofeedback" in Research Notes (July 1987) highlights two problems which are probably worse in medicine than in most other disciplines – that of keeping up to date with journals of one's own specialty and of scanning the literature of other disciplines. There are approximately 2000 medical journals in the English language and probably 30 in which papers on clinical biofeedback could have appeared.

In fact, closed-loop control of blood pressure has been done by several groups in the past with software protection against artefacts. The first paper published in the UK was from the group at King's College Hospital in London using Simonsen and Weel monitoring equipment, an Apple II microcomputer and an Imed infusion pump with RS-232 remote control. (Closed Loop Control of Vasoactive Drug Infusion D.R. Potter, J.T.B. Moyle, R.J. Lester and R.J. Ware. *Anaesthesia* 1984 Vol 39 pages 670-677.)
John Moyle,
Consultant Anaesthetist and Bioengineer,
Milton Keynes Hospital.

## An oscilloscope problem

Long, long ago, when computers were young, I noticed a strange thing about troubleshooting glitches with an oscilloscope.

Displaying a culprit spike called for the fastest timebase, careful trigger adjustment and high intensity. Even so, the trace was dim and hard to see. Quite often, another person was unable to see the problem waveform.

Then, a few years later, I read with interest of some experiments on briefly presented images at Edinburgh and elsewhere. It turns out that some people can discriminate details of an image presented for microseconds, while others need tens of microseconds. This equipment is called a tachistoscope and is a favoured tool of experimental psychologists.

Emotionally charged material, it seems, can give rise to a perceptual block which calls for greatly extended presentation time to ensure visibility. More tendentiously, a relation has been offered between measures of intelligence and minimum times for perception.

If valid, this approach offers the long-sought 'culture-free' testing mechanism which could silence egalitarian concerns over racial discrimination, which have haunted the field of objective testing.

I went so far as to produce a black box which could flash one or two leds for a preset time and noted the differing minimum periods which subjects needed to discern the test pattern. I visualize the use of cheap and rapid pre-employment vetting, as an improvement on the time-consuming IQ batteries that employers like IBM used to (and perhaps still do) use.

My enthusiasm waned when I reviewed studies of IQ results of university professors, successful business people and some electricians. As you may have guessed, the electricians usually won the IQ tests, hands down.

So, acknowledging that success in life has to do with persistence, hard work and luck as much as intelligence, I laid the project aside.

But, when looking for an elusive spike with an oscilloscope, don't say you haven't been warned. If all else fails, use a logic analyser.
Brian Whatcott,
Gorland,
USA.

## Eastern promise

I recently came across the April 1987 issue of your magazine and read it from cover to cover. In particular, the editorial by Bob Giddy intrigued me to the extent that I was forced to reply.

The statement that the other European multi-nationals must give up some of their long-held territory is a very pessimistic statement. Why should the others give up the territory? Unless the British can demonstrate that they can take it over – well – the statement remains a pious hope!

Hawking British electronics to the USA – why cannot the British do it? The Germans are now doing it quite successfully! Reminds me of the 1950s: the British cars came to Canada, with lots of goodwill. But they refused to consider Canadian conditions and, within a few short years, they were knocked out of the market. It is a rare sight to see a British car in Canada.

The British have a good record for innovation and design, but not for production! How true! The cost of warranty repairs that have to be done by Canadian importers is staggering. We recently imported an instrument, which did not work. We checked, found it had not been tested at Canadian power voltage and frequency, despite the manufacturer's statement. We shipped it back twice before getting one that worked!

The idea of a partnership between the UK as designers and another country as fabricators is, I'm sorry to say – strictly for the birds! And a joint agreement with Japanese rather late in the day – I'd say! The third idea, of joint ventures with the Comecon – seems a little preposterous too!

My suggestion is that the industry should heed Margaret Thatcher's advice. Get out on your own. Britain can regain the dominant position she has had in science and industry. But Britain should not ride on joint ventures. She can do it on her own – if she has to.
Harry H. Schwartz,
President,
Electrodesign,
Quebec.

## Modern physics

I was very disappointed by the letter from Ivor Catt in the July issue: I have enjoyed many of his articles over the years. To use a scale like "hard to soft" implies some way of measuring position on the scale like the Rockwell test for the hardness of a material. When applied to disciplines of human knowledge I think that the analogy is inappropriate; they are not things to which a one dimensional measure can be applied. Also it has a pejorative air to it, as Ivor Catt says, "In a soft discipline, a model... is still

# FEEDBACK

of value *even* if it is imperfect, flawed" (my emphasis). I think that the only reasonable use of the term "hard science" is to describe those subjects where the theories and facts have precision quantitative measures as a dominant feature. Not all our experience can be encompassed by quantitative measures; if we go to a play by Shakespeare we may be interested in the statistics of word frequencies, but our experience of the play and sense of the truth which we see in it is not measured numerically or topologically.

Vituperative comments about careerist scientists adds nothing but 'soft subjectivity' to the argument. I know the world of science is just as full of self interest and politics as any other, but let us not mix up our frailties with the significance of the science. I hope that in any case we would complain of a situation where somebody loses a job because his theory is wrong – most (if not all) theories are wrong in some way. Of course some people lay themselves open to attack by presenting their ideas dogmatically to start with, but in all areas of human study we don't judge an individual by the wrong theories but by the contribution to the evolution of the subject. Remember Newton's comment about seeing further by standing on someone's shoulders.

Finally, the list. "Uncertainty": a very unfortunate nomenclature for the Heisenberg principle which is not uncertain at all. "Dualism": although the wave-particle model may seem inelegant in its explanations of systems in terms of the language we have been using in science for the past few hundred years, surely the prediction of the magnetic moment of the electron to 1 part in 1,000,000,000, as well as the theory's effectiveness in atomic physics in general, classifies it as "hard". "Observer and observed": this is one of many genuine attempts to come to an understanding of what quantum theory is about. It may not be the right direction but it has been analysed in quantitative detail. "Relativity": I know that *EWW* has much debate on this and there are many competing models, but the $E=mc^2$ which first came from Special Relativity is precisely shown in the atomic bomb, and the bending of light is predicted correctly in General Relativity; these are hard measurements, which may still of course be consistent with alternative models. "Statistics and probability": thermodynamics has worked for us precisely for hundreds of years, yet it can be derived from statistical mechanics which brings with it the possibility of calculating some thermodynamic parameters from more fundamental constants.

The only way science evolves is by the open contribution of a large community of people. I believe that although the flesh is weak, the spirit is willing, so let us keep to specific criticism of fact and not deal in subjective innuendo. I might add that I am a "hard" scientist with considerable misgivings about current interpretations of quantum theory and I argue consistently for theoretical pluralism as the best way to test our theories.

Robert D. Dyson,
Kidlington,
Oxfordshire.

## Relativity

I would like to question the version of Einstein's thought experiments summarized by M.H. Butterfield in the penultimate paragraph of his February letter.

Einstein's symbols A and B are two positions in the same system, not as Butterfield assumes abbreviations symbolizing an observer in one system A, exchanging data with an observer in another system B.

We can apply the rules governing the use of mathematical models to Einstein's original paper 'On the Electrodynamics of Moving Bodies' (1905). Firstly, find the problem, secondly, find the model of the Moving Bodies used to solve the problem, and finally, judge whether the model is realistic.

**Einstein's problem**. Clue: "...the unsuccessful attempts to discover any motion of the earth relatively to the 'light medium,'..." (Einstein's introduction).

**Einstein's model.** Clue: Einstein's first though experiment – "Let a ray of light start at the 'A time' $t_A$ from A towards B, let it at the 'B time' $t_B$ be reflected at B in the direction of A, and arrive again at A at the 'A time' $t_A$".

This is a modified Michelson-Morley experiment (MME), or rather the arm of the experiment headed directly into the ether wind, Einstein's problem and moving bodies. A is the position of the angled mirror, a clock, an observer, and the source of the ray of light. B is the position of the reflecting mirror, a clock and an observer. Einstein's "rod to be measured" is the distance between the mirrors and his "measuring rod" is a tape-measure. He defines his "stationary system" as "a system of co-ordinates in which the equations of Newtonian mechanics hold good." This is a fictitious stationary Newtonian MME in Newtonian time and space. (See N. Rudakov's Fiction Stranger than Truth.pp. 88-89.)

The first thought experiment (TE) is performed in a stationary Newtonian MME to synchronize clocks fixed to the angled mirror A and the reflecting mirror B. All clocks are first synchronized in pairs in a stationary Newtonian MME. Symbols A and B identify the positions of the mirrors, clocks and observers in the first and fifth TE's. Symbols $r_0$ and $r_2$ are substituted for position A and $r_1$ for position B in the last TE. The moving clock and observer are significantly absent from reflecting mirror $r_1$. Time at $r_1$ is not $r_2 - r_0$ divided by two.

TEs Nos 2, 3 and 4 are all performed in the same MME. The MME is stationary during No 2, and moving at 30 km/s during No 3, "operation (a)", and No 4, "operation (b)". The distance between the mirrors is measured with the same tape-measure during TE's Nos 2 and 3. The same solitary observer performs TEs Nos 3 and 4. TE No 4 carries a Mental Health Warning, THIS GIBBERISH MAY DAMAGE YOUR SANITY. Positions of artefacts are not identified by symbols in these three TEs. Observers in a stationary Newtonian MME do not exchange data with observers in a moving MME.

**Is the model realistic?** Clue: Art. 4 of his paper headed Physical Meaning of the Equations... After explaining by implication that the transverse arm of the MME is Newtonian and the other arm is not, Einstein confirms his conception of a realistic model. "...we shall, however, find in what follows, that the velocity of light in our theory plays the part, *physically*, of an infinitely great velocity." In other words, light acts instantaneously at a distance. The finite velocity of light is an essential measureable quantity in the Lorentz transformation.

Lorentz's model does not question L. Essen's measurement of light's velocity. Einstein's does, with a vengeance.

M.G. Wellard,
Kenley,
Surrey.

## Time and space

I enjoyed reading Scott Murray's article "If you want to know the time . . ." (December issue of *Wireless World*, p.28) but searched in vain for the rider "ask a relativistic policeman". Can it really be that clocks at the pole and at the equator can cooperate to prove Einstein wrong?

Such a proposition is outrageous and I have it on good authority. The editor of *Physical Review Letters* has drawn my attention to an experiment reported by NASA. It appears that in 1976 the NASA-SAO rocket-borne redshift experiment proved that the theory of relativity was correct and that over a 10,000km range from the Earth light speed was the same in opposite directions to within 3 parts in a billion. If this is true, then, as an antirelativist, I am defeated and Scott Murray should hoist the white flage as well. No longer can *Wireless World* entertain us by encouraging debate in this exciting arena or 'relativity'.

It would indeed be sad if *Wireless World* followed the example of *Applied Optics*. The editor of this journal, published

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by the American Institute of Physics, had occasion to write at p. 544 of the March 1977 issue: *'It was probably unwise for* Applied Optics *ever to have ventured into the controversial area of relativity theory (and the various optical tests for it). In that area even the experts carry long swords and enjoy duelling to the death. Unarmed editors of applied journals would be well advised to avoid that battelfield'.*

It appears that NASA did send a stable maser oscillator into space to test relativity. As a clock, it behaved as expected in slowing down as it returned to the stronger gravitational potential in its descent. This is just as Scott-Murray would predict. But what about the time dilation effect due to motion? Well, since relativity references motion on the observer, the speed of the rocket was referenced on the Earth frame and the time dilation terms were small enough to be ignored. The experiment performed by NASA had such small residual error that it could be said with confidence that the radio signals sent to the rocket travelled at the same speed as those sent back from the rocket. No evidence of motion through the preferred frame was found, and the range was 10,000km.

Now, what is fascinating about this experiment is that it was a major NASA project involving numerous scientists and aimed at testing relativity. It was seen as an experiment to detect motion through the aether, besides testing the effects of gravity. Yet, in the analysis the time dilation was calculated as reference on the Earth frame, whilst the resulting equation was used to estimate motion relative to the preferred frame. Could one really credit such an error? When the time dilation formula is referenced on the preferred frame the resulting equation contains no terms which would allow the anisotropy to be tested. The effects cancel out completely, making the test completely inconsequential so far as detecting our motion through space is concerned.

Such is the arena of debate on this question of relativity. The Establishment scientist wants to believe in relativity and no one seems to question results which support relativity. All the venom is directed at those who seek the truth and need convincing.

In conclusion, it is relevant to mention that the so-called time dilation formula has only been tested for atoms and particles moving at very high speeds, speeds far in excess of any expected motion relative to the preferred frame. The privileged role of the relativistic observer has not been tested in this context.

The NASA reference mentioned above is to a paper by Vessot and Levine, *Gen. Rel. and Grav., 10*, 181 (1979).

H. Aspden
Department of Electrical Engineering
University of Southampton.

## Class B crossover distortion

There appear to be many errors in this article by E. Margan (June 1987). While accepting that the circuit is experimental and not fully developed, I must point out that it cannot function in the non-switching Class-B mode, since the bias voltage is a fixed source. Sage Audio have found, during the development of their own amplifiers, that the bias voltage must have compliance – it must not be a voltage source such as two diodes or a $V_{be}$ multiplier. This is so that the upper transistor's base may be left biased just above $V_{out}$, whilst the lower transistor's base swings increasingly negative when supplying the negative output current cycle. The bias must be variable under signal control, varying in exact opposition to the increased volts drop across the lower emitter resistor.

Examination of all the recent Japanese n.s.b. circuits reveals this to be so, with the exception of Technics, who use a simplified Peter Blomley design. This is not a true n.s.b. system, but simply transfers the crossover region switching to an earlier

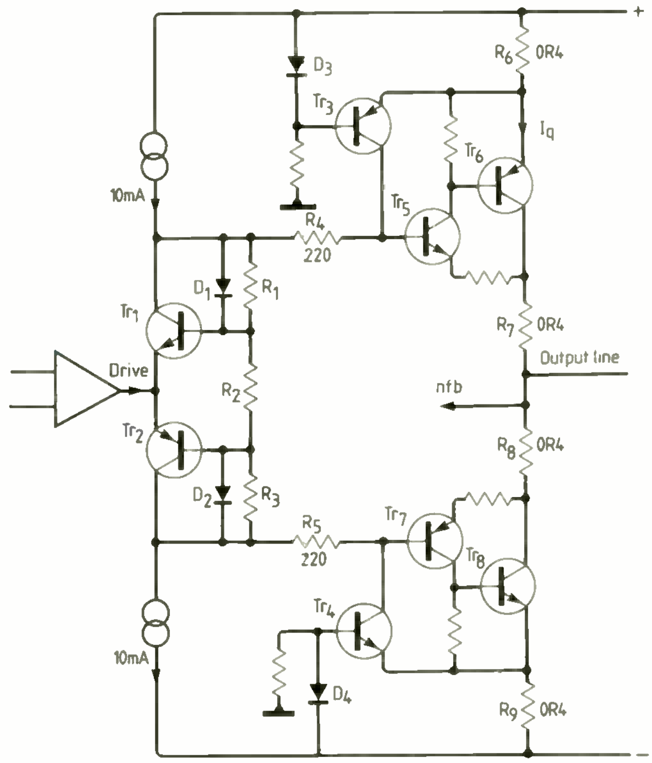



**Fig.1. Simplified Blomley amplifier in which $Tr_{1,2}$ alternately switch on and off but in which $Tr_{3,4}$ remain conducting due to $R_3$. Both circuits feature a fixed voltge-source bias; hence, some part of the circuit must switch if $I_{out}$ is to exceed $I_q$. A true n.s.b. system must include a dynamic variable bias working in opposite direction to the drive, giving bias voltage compliance.**

section of the amplifier: the output transistors are then biased continuously on with a small standing current via a resistor from the opposite supply, the driver transistors then being allowed to switch. Technics use the same idea, but replace the switching drivers with switching diodes. A skeleton diagram of the Blomley amplifier is in Fig.1, showing a fixed voltage, which means that something (in this case the drivers) must switch. Mr Margan's circuit is a failed attempt to develop the Blomley system further. I fear he has misinterpreted the Blomley compound output transistor configuration. For simplicity the skeleton diagrams for each system have been drawn with the same output configuration. It is clear that the Blomley amplifier drivers in Fig.1 are alternately switched on and off in driving the output transistors. However, with a fixed trickle current via $R_3$, the output transistors will remain conducting. This is only part way towards non-switching – driver-transistor switching pulses are still detectable, but

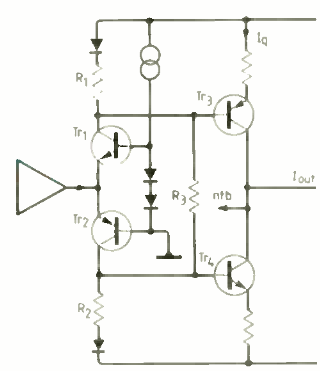



**Fig.2. Skeleton circuit of the Margan amplifier. This is very similar to the Blomley design, although the Blomley system does leave each output transistor permanently conducting, while allowing the drivers to switch off.**

much smaller due to lower storage charge in the smaller driver transistors.

In Mr Margan's circuit, the bias compliance offered is entirely due to $R_{4,5}$. This is better than standard Class AB, but is not a totally non-switching circuit.

Les Sage,
Sage Audio,
Bingley, Yorkshire

# Logic, intention and sexual equality

**Will 'equality of the sexes' bring about the demise of intentional logic symbols or will traditional values and teaching prevail? First, we must recognise the problem.**

J.E. KENNAUGH

The abstract world of electronic logic has no obvious connection with sex, but there are two sexes and there are two logic levels and, as I will show, the analogy is useful in considering mental attitudes and the way we think. The purpose of this article is to examine two different approaches to logic design and the fundamental attitudes which produce them. It will also clarify the reason for the conflict between, those who consider that the adoption of intentional logic symbols is the only way of putting meaning into logic diagrams, while others see the same logic symbols as utterly pointless.

I am not concerned with the wider mathematical subject of logic. The study of logical reasoning expressed in mathematical form has no doubt provided the prototype which in turn provided some of our terminology and has influenced the formulation of teaching methods. I am interested only in the conceptional process used by practical engineers in designing circuits and in describing the circuits they have designed.

It is clear from talking with other engineers that some, like myself, abandoned the classic approach which they may have been taught, either completely or partially in favour of what I will describe as the alternative approach. This brings them in conflict with those who continue to think in the classical manner. Both sets of devotees seem unaware of the nature of their differences, let alone analysed its cause. The difference could not be more fundamental. It is whether you accord to logic 1 and 0 the equivalent of sexual equality or whether you consider 1 to be the dominant and 0 the subservient sex.

## THE CLASSICAL VIEW

The classical view is strictly sexist. The logic 1 is the assertive, active, true state. The logic 0 merely indicates that the 1 is not present. From this standpoint and- and or-functions are described purely in terms of logic 1:

If A & B & C = 1, the output = 1

If A or B or C = 1, the output = 1.

The and-function is likened to multiplication, and the or-function to addition:

$$1.1.1 = 1 \text{ and } 1+0+0 = 1,$$

from which follows identities such as

$$A.(B+C) = A.B + A.C.$$

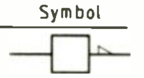
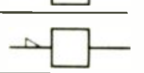
This reinforces the essential difference between and and or. In mathematics it is always clear whether you are multiplying or adding. Confusing the two would be disastrous so in the classical view they must be distinguished one from another. The question as to which is taking place is a necessary and valid one.

In practical terms we have two voltage levels designated HI and LO. As LO is usually near to 0V it seems tidy to make HI = 1 and LO = 0. This would be fine if the engineer could choose hardware to exactly match his or her mental concept. If this simple approach is adopted then the truth table of an inverter is

| Input | Output |
|---|---|
| 1 | 0 |
| 0 | 1 |

This may seem straightforward enough but to the classical view it just cannot be. Logic 1 is the true, assertive state. A gate cannot simply swallow it, never to appear again, neither can it create one where previously one did not exist.

Something has to give and it is the simplistic concept of HI = 1 which has to go. An assertive state is an assertive state, and if an assertive state enters an inverter, an assertive state must leave. Hence the classical approach leads to the following truth tables for the inverter

| Input | Output | Symbol |
|---|---|---|
| 1 (HI=1)<br>0 (HI=1) | 1 (LO=1)<br>0 (LO=1) |  |
| 1 (LO=1)<br>0 (LO=1) | 1 (HI=1)<br>0 (HI=1) |  |

There are two truth tables requiring two logic symbols, depending on whether the assertive state (logic 1) is HI or LO at the input. In the real world nand and nor gates predominate so engineers have to live with inversions at every gate. Those who stick with the classical approach overcome the problem by the use of intentional logic symbols. I recommend readers unfamiliar with them to study the article 'Mixed logic' by M.B. Butler, *Wireless World* July 1983, which is quite comprehensive.

Essentially there is no such thing as a logic inversion, merely a change from positive logic (HI=1) to negative logic (LO=1) or vice versa. What makes this complicated is that if a gate performs an and-function in positive logic, it will perform as an or-gate for negative logic and vice versa. Intentional logic symbols allow you to describe the functions of a gate at every point in the circuit and whether the function occurs in positive or negative convention.

Although the symbols allow the maintenance of intellectual integrity, it is at a price. There are at least twice as many symbols needed, two physically identical gates may have different symbols and because of the process of Boolean rationalisation, a single line may be assertive HI to one input and assertive LO to another, requiring the use of a symbol with no physical counterpart.

To summarise, the factors which epitomize the classical view are that 1 and 0 have unequal significance and that and and or are essentially different. The alternative view rejects both of these concepts.

## ALTERNATIVE APPROACH

In the classical approach, the logic 1 is the assertive state. There is no question of sexual equality and yet 1 has no meaning without 0. In my experience the thing which invariably catches new engineers is the open-circuit input, for it seems reasonable that if you connect nothing to an input, you cannot be asserting it. They soon learn that unused inputs must be tied either to logic 1 or to logic 0 and that a connection to logic 0 is just as important as that to logic 1.

Now consider a simple switch. If one was to ask whether a particular switch in a system is primarily intended for switching something on or off, then one's sanity would be put in question. Switches do not perform two independent functions called 'on' and 'off': they perform a composite on/off function. The only reason for putting one in circuit is that sometimes you want them 'on' and sometimes 'off'.

Now consider the following two definitions:

**A switch** is on if and only if it is up; it follows therefore that if it is down it is off.

**A gate** gives out a 1 if and only if A and B and C = 0; it follows therefore that if A or B or C = 1 it gives out a 0.

The similarity is obvious. Just as a switch performs a composite on/off function so a gate (in this case a so-called nor gate) performs a composite and/or function just as it was meaningless in the case of the switch to ask whether it is primarily for switching on or off, so it is meaningless to ask whether the gate is intended to perform an and or an or function. The answer is that it performs both just as with the switch. Every time this gate gives out a 1 it is because A and B and C = 0, it is performing an and-function. Every time it gives out a 0 it is because A or B or C = 1, it is performing an or-function. Both functions are necessary otherwise there would be no point in putting the gate in circuit. The and/or functions are no longer separate but are alternative descriptions of the same composite function, and this is a direct result of according equal status to 1 and 0.

In describing the conventional view the essential difference between and and or was highlighted by comparison with add and multiply. Whereas

$$A.(B+C)=(A.B)+(A+C)$$

seems to indicate the truth of this, the following equation which is equally true, raises doubts

$$A+(B.C)=(A+B).(A+C).$$

If the same equations are written using another convention

$$A \cap (B \cup C)=(A \cap B) \cup (A \cap C)$$
$$A \cup (B \cap C)=(A \cup B) \cap (A \cup C)$$

then it is obvious that 'and' and 'or' are no longer as different as multiply and add. They are merely two sides of the same coin, mirror images if you like.

Using this concept we can tie HI=1 and LO=0 permanently. We need half as many symbols each of which ties up on a one-to-one basis with its physcal configuration and the inverter is a valid concept in that it mererly changes one logic state to the other of equal significance.

The assertive state plays no part in the mental process, both states being equally assertive. If 1 enables, 0 disables, the input is an enable/disable. If 1 lets the signal through, 0 blocks it. After all, which is more assertive, a red traffic light or a green? I want to stop the traffic – assert red. I want the traffic to move – assert green. The unanimous decision of a jury deprives a man of his freedom (and function). A man's rights are protected by a single jury man refusing to condemn (or function). Which is more assertive, to vote guilty or refuse to vote guilty? Hence, even away from the completely artificial realm of electronics logic, the concept of assertive state is difficult to justify.

To the classical thinker there is no such thing as a toggle switch: all switches are biased one way or the other. So it is reasonable to ask whether a switch is for switching on (biased off) or for switching off (biased on).

It is clear from reading past contributors of *Wireless World* that while both thought processes are evident, the people concerned may not be aware of the difference. M.B. Butler, in his article entitled 'Mixed logic' (*WW* July 1983) states: "Classical logic synthesis procedures tend to generate unreadable circuit schematics". He has a genuine problem. He designs circuits using concepts which are not physically realisable (at least not economically). He then uses Boolean algebra to convert the circuit into a realisable form. During this process many of his concepts disappear. He can no longer understand how the circuit works. He cannot now produce a circuit description which describes the physical circuit. His solution is the use of intentional logic symbols with which he can, to a fair degree, redraw the circuit in such a way that it again bears some resemblance to his original intention.

Ian Kampel on the other hand is an alternative thinker but probably doesn't know it. Faced with producing an article to explain the new British standard logic symbols ('The new logic symbols' *WW* March 1985), he is clearly in great difficulty to understand why anyone should want to confuse the isue by using a negative logic convention. The best he can come up with is "The only real justification in using a negative logic convention is where a negative supply is used for logic devices". He notes that if polarity indicators are used, negation symbols disappear, but seems confused as to why anyone should want to use them in desperation, suggesting that they form an elegant solution "...at the interface between two manufacturers equiment" (one using a negative supply perhaps).

I fully sympathize with Ian Kampel. Until I analysed the problem I considered my mental process to be the norm and couldn't understand why any sane person would wish to make life so complicated. It was a surprise to me therefore when my analysis indicated that classical thinking was not on my side.

It must be more efficient and result in a more economical design if a designer thinks directly in terms of the actual devices he has at his disposal, rather than first think in terms of hypothetical devices and translate into the available hardware. Something is bound to get lost in translation. In any case, when actually involved in design, one not only has to take into account the range of devices available, but also the fact (say) that you have used one gate of a three-input nor gate and therefore have two left within the package.

There is a further reason for keeping as close to the hardware as possible. Consider the circuits shown, column 3. They are Boolean equivalents and yet the waveform from Fig.1 is guaranteed glitch-free, whereas that of Fig.2 is not.

An engineer who thinks directly in terms of the hardware has no difficulty in describing how the circuit works in his or her terms. It would however be impossible to describe the circuit using intentional logic symbols as they describe a thought process which has not taken place.

One can take the alternative approach a stage further. Having established that both nand and nor-gates perform a composite and/or function there is a choice as to one's mental image of them.

There is only one unique combination of inputs (all ones) which will give a 0 out of a nand-gate and several which will give a 1. Likewise, there is only one unique combination of inputs which will give 1 out of a nor gate (all zeros) and several which will give a zero. If we describe this as the unique state then I find it easier when checking my design, analysing someone elses, or fault finding, to simply ask at each gate "is the unique state present?" Instead of thinking of the nand and nor as being nand/$\overline{\text{nor}}$ and nor/$\overline{\text{nand}}$ respectively I think of them as nand/$\overline{\text{nor}}$ and $\overline{\text{nand}}$/nor.

It was this thinking which lead to my suggestion of the truth-table logic symbols (*WW* letters Oct 1981). I apologise for not furnishing them with the intellectual justification for that suggestion until now.

I wish to stress that I have not invented a revolutionary new way of looking at logic circuits. On the contrary, I believe that it is the way used by a majority of the engineers who make their living designing logic circuits. My function has been merely to analyse it so that the nature of the problem can be understood.

*John Kennaugh, B.Sc(Hons) works as a design consultant in Cornwall. Previously he was R & D manager of Tektel, designing v.h.f. and underwater communication equipment.*

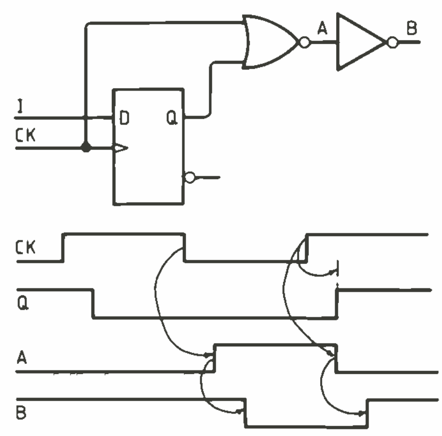



**Fig.1. An example of a circuit which gives a glitch-free output at B.**

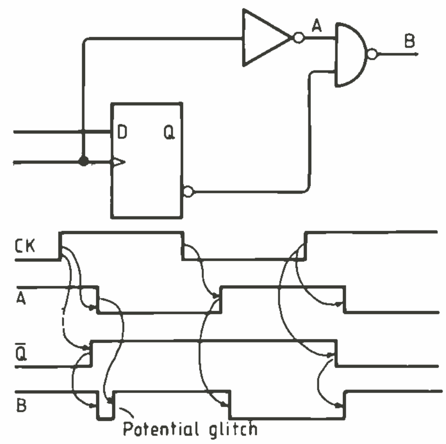



**Fig.2. This Boolean equivalent of Figure 3 circuit may produce a glitch at B.**

| Conventional name | Truth table Input | Truth table Output | Symbol |
|---|---|---|---|
| AND | All = 1 | 1 | 1 1 |
| | Else | 0 | |
| OR | All = 0 | 0 | 0 0 |
| | Else | 1 | |
| NAND | All = 1 | 0 | 1 0 |
| | Else | 1 | |
| NOR | All = 0 | 1 | 0 1 |
| | Else | 0 | |
| EXOR | Not equal | 1 | ≠ 1 |
| | Else | 0 | |
| EXNOR | Not equal | 0 | ≠ 0 |
| | Else | 1 | |

**Truth-table logic symbols first suggested by the author in 1981 are an extension of the alternative approach discussed.**

# Privatization of the radio spectrum

**The study for DTI by CSP International, on which we reported in our July issue, was supposed to consider the practicality of spectrum pricing. The report proposes radical deregulation, which was not explicit in the brief.**

DAVID RUDD

In 1983 the Merriman Report concluded that, for the future, regulatory procedures for licensing radio transmissions would have to include some capability for the making of value judgements, since demand may often exceed supply. But it did not say how that could be done. The authors had looked at a proposal from the Department of Transport (DTp) for a spectrum renting system and at other proposals for 'spectrum pricing', as it is called, and they thought "it may well be impracticable", but they recommended that, if the matter was to be further pursued, a feasibility study should be commissioned. Two years later, the Department of Trade and Industry commissioned such a study by CSP International, which has reported in March of this year – nearly four years after Merriman reported – under the title 'Deregulation of the radio spectrum in the UK'. '*Privatization* of the radio spectrum' would be a more descriptive title.

The change of emphasis from pricing to deregulation is significant. It hails two major departures from the original proposal from DTp. The first is to restrict the scope of the study, and so the scope of the pricing system, to civil uses of the spectrum (in other words MoD is to be let off again) and then to exempt television broadcasting as well, leaving only a rump of smaller users in the pricing system. The second is to allow revenue maximization to become the guiding principle in pricing the spectrum instead of the principle of matching the demand to the supply.

## BENEFITS OF PRICING WILL BE UNDERMINED

One may argue about whether spectrum renting or pricing is necessary (which it is not unless Merriman was right about demand often exceeding supply) or practicable or consonant with the British way of life. But what is certain is that the benefits of the price mechanism (see the box) will be seriously undermined if the largest users are exempt. Moreover, the leverage of the mechanisms now recommended, which will be increased by thus restricting its application, will distort the decisions of the paying users to the detriment of the whole economy if the fulcrum of revenue maximization is allowed to be inserted under it.

As well as the television and MoD giants, the police and fire services are to be exempted from at least the first and second rounds of Spectrum Management Licensing, by which spectrum pricing is to be selectively introduced. No reason is given for these two exemptions or the exemption of MoD, so one is left to guess what may be the instincts of the authors and recipients of the report.

The instinct to exempt the police and fire services probably arises from a subconcious, ill-considered dislike of the price mechanism as a sordid thing which has to be tolerated in industry and commerce but ought not to affect the provision of our vitally important 'safety-of-life' services. That is nonsense and even the report rebuts


"What's this 'spectrum pricing' then, boss?"
**"Well, it's to do with market forces and competition, y'know."**
"Oh, all that jazz! So can we bring in deregulation?"
**"Why not? Sounds great. Make that the main theme, Joe."**
"On my way, boss!"

## What are 'The Price Mechanism' and 'Trade-off Calculations'

**Whenever the price of something affects the quantity which you decide to buy or use, the price mechanism is at work. Sometimes it is simple; you buy only 2lbs of apples this week instead of 3lbs, although you like apples, because the price has gone up. On other occasions, especially in professional and commercial life, the mechanism is more complicated; you decide to move you office 150 miles, although the rent will be higher at the new site, because you expect to save more than that difference in transport and telephone costs and you hope to get some expert staff more easily at the new place. In that case the sums you did with rents, transport and telephone costs and your valuation of that expertise are known as trade-off calculations.**

**Together, we make billions of such decisions every week and cumulatively they both propel and direct the whole economy with an efficiency which no other mechanism can hope to emulate, for two reasons. Firstly the sum of all our decisions feeds back onto the price of apples (or offices) and thereby shares them out to users who value them most highly. Secondly, only you have the essential data for your decisions – how fond you are of apples and whether you are expecting visitors, or the amounts of your transport and telephone bills and the true worth of those experts. Consequently resource allocations which result from the operation of the price mechanism are effectively derived from a vast mass of essential information which is left out of account in any other method.**

it to some extent (on page 132), but the argument is not carried through. These services require and pay for a large range of equipment and materials. They also pay salaries and provide job security, which are at least enough to retain their work forces, and they trade off the costs of equipment and materials against each other and against the cost of personnel like any other employer. This commercial environment is generally beneficial to those services and raises their standards, compared with countries where the price mechanism is suppressed. Having to pay for spectrum would not undermine their ability to chase criminals and put out fires any more than having to pay for police cars and fire engines.

## NATIONAL SECURITY IN A NEW LIGHT

MoD relies on the mystery of national security to keep its immense allocations. But the armed forces do not get their tanks and aeroplanes and nuclear weapons without payment. On a much large scale they operate in just the same way as the police and fire services, and they benefit from the price mechanism to a correspondingly greater extent. In particular they have to pay for telegraph and telephone lines and their engineers trade off the cost of additional lines against the cost of more elaborate equipment, which would reduce the cost of the lines, like any other user. Whenever they have the choice between radio and land lines, other things being equal, they must of course choose radio because not having to pay for the spectrum makes radio cheaper. They would be falling down on their jobs if they did not do so. Theirs is not to try and guess the value of spectrum to other users, but to make the maximum use of a resource which comes free of charge.

As long as would-be users have to justify their applications for spectrum in terms of the detailed purposes for which they will use it, MoD can legitimately argue that its detailed purposes are secret and so its applications must be taken on trust. But if the armed forces are now told that they can have all that spectrum and they need not say what they want it for in detail – or at least not publicly – but that now they must pay for it, then the national security argument becomes irrelevant and there is no other legitimate reason for treating MoD any differently from any other user. That radical change in the status of MoD, if a thorough-going spectrum-pricing system were brought in seems not to have occurred to CSP International, or perhaps it did not occur to the officials who drew up CSP's terms of reference – or possibly they were simply determined to exempt the MoD allocation from any reform.

The television broadcasters rely on the assumed unpopularity of a 'spectrum tax', as it would probably be called – and that would not be a bad description. But public perceptions are not immutable. People can be voluntarily persuaded of the need for change if the case is explained with clarity. The report points out (page 142) that present management procedures can accommodate without difficulty the numbers of television channels allowed under the present Government policy for tv. But that is not a good enough reason to exempt television broadcasters and their engineers from the discipline of the price mechanism. If broadcasting policy were to come under review, as it might for reasons unconnected with spectrum management, the participation of tv broadcasting, including the BBC and the IBA contractors, in a spectrum pricing system would provide highly pertinent estimates of the scarcity value (or opportunity cost in the economic jargon) of the spectrum which would be taken up or released by any proposed changes.

Meanwhile, even under the present policy, some research engineers at an IEE conference a few years ago estimated informally that they could reduce the bandwidth of a colour tv channel from 8 MHz to 6 MHz without any loss of quality, but it would be "enormously expensive". Of course they had given no serious thought to the cost, nor to the scope for or cost of much smaller reductions which would nevertheless be highly priced by p.m.r. applicants who have been waiting for assignments in vain for years, or given up waiting years ago. But no-one can foretell how ingenious engineers can be until they have reason to give their minds to a problem.

If these public bodies had to pay rent for spectrum which they have previously had without payment, they would of course need a Government grant, or additional grant, to recompense them for those payments. So initially there would be a circulation of funds from the Treasury to the public body and back to the Treasury via the spectrum renting authority, which might seem rather pointless. But there is a very important point. After the initial running-in period, the 'spectrum' earmarks would have to be removed from the grants and the grants incorporated into the budgets of the public bodies, which would thereafter be subject to only the general reviews of funding which public bodies must undergo from time to time. So the public bodies would start from a position of no net change and then have the inducement to economise by using less spectrum.

## WHY THE GIANTS MUST BE INCLUDED

The reason for insisting on the inclusion of the large users in a pricing system is that a system which applies only to small users will induce them to restrict their bandwidths 'uneconomically' – in the sense that the exempted users could make equal or larger savings of spectrum at less cost but have no inducement to do so. That is the consequence of the trade-off calculations by which paying and non-paying users of any resource habitually decided how much of it they need. So much is explained in one of the references in the report's eight-page literature review of spectrum management from an economic standpoint. In fact, all the foregoing arguments have been rehearsed on previous occasions – and more than once – but the report has ignored them.

Turning to the other major departure from the original proposal, i.e. the substitution of revenue maximization for demand/supply matching as the guiding principle, chapter 3 of the report talks vaguely about "a huge number of market-oriented mechanisms for spectrum management" but it presents only two such mechanisms "in order to make the review of the alternatives simpler" and then confines its analysis to those two, namely delegation to private-sector organizations and one method of direct pricing by the DTI Radiocommunications Division (RD). The analysis exposes some difficulties RD would have in auctioning the spectrum and concludes immediately that spectrum management by private sector organizations is "likely to be superior".

## THE INDUCEMENTS TO COMPETE WILL BE TOO WEAK

Proceeding from that conclusion and from a tacit, but false, assumption that competition is necessary on both the buying and selling sides of the spectrum market, chapter 9 proposes to award spectrum management licences to a limited number of Frequency Planning Organizations (FPOs) in the private sector. However, neither these FPOs nor the existing users, such as the Joint Radio Committee in the p.m.r. bands, will have to pay for the scarcity value of the spectrum which they manage or use themselves; they will only pay a fee to reimburse RD's expenses. But they will be allowed to charge their users as much as they can get. So they will reap the scarcity value of the spectrum themselves, without having to pass it back to the original owners, the general public – a remarkable example of privatization by gift!

The authors of the report take the view that the market pressures generated by these arrangements will compel the FPOs to compete for the users' custom. But they omit to mention that the two main inducements to compete in a genuinely unrestricted market are the lure of expanding one's operations and profits by invading one's competitor's territory and the fear that one's competitors will invade one's own territory and force one to contract and perhaps go out of business. Those inducements will not feature in this market, which is really artifically restricted. Territorial invasion will be against the rules.

In theory there might be some residual competitive pressures, especially if Merriman turns out to have been wrong and demand does *not* often exceed supply. Then the would-be users will be free to shop around and get the best bargain. But in that case there will be no justification for pricing the spectrum in the first place and there was no need to commission this study or the Merriman Review or the numerous studies and reports which preceded it.

## THE REALITIES OF SPECTRUM SHORTAGE

Indeed, chapter 9 of the report goes so far as to assert that there is no prospect of a general spectrum shortage for the foreseeable future – say the next 10 or 20 years, although there will be local pockets of scarcity. But the authors are using the word shortage in a special technical sense, not the ordinary sense. Some technical restrictions on radio transmissions there must always be to prevent or minimize interference, like the rule of the road to prevent or minimize road accidents. But there comes a point where the cost of complying with ever more stringent technical restrictions and the concomitant delays in squeezing successive batches of users into ever more elaborate patterns effectively exclude large numbers of users altogether. That point was reached many years ago, when the waiting list for car telephones and other p.m.r. applications stretched into thousands and into years of waiting.

### The parameters of a spectrum renting tariff

**The six parameters on which the author suggested the rent of every user should be calculated, without regard to the user's purposes, were:**
**bandwidth**
**position in the spectrum (carrier frequency)**
**effective power**
**geographical location**
**direction(s) of transmission**
**duration of the licence.**


Cellular radio is the current technical solution to that problem but it is no criticism of cellular radio to point out that it confirms the existence of a spectrum shortage. Cellular radio is too expensive for thousands of would-be users, who would be delighted to have the much cheaper car telephones enjoyed by some motorists in the old days, if there was really no shortage of spectrum in the v.h.f. bands. Perhaps cellular radio makes more economic use of the spectrum than the other uses which were denied or delayed to get it started, although denying the competing systems access to the public telephone network for no better reason than to give cellular radio a leg up casts some doubt on that proposition. But nobody can know because the value of the spectrum did not enter the calculations.

It is that kind of shortage which necessitates value judgements and there is every prospect of a general spectrum shortage in that sense throughout the next 10 or 20 years and beyond. Merriman was right and in that situation the pressures on the FPOs to compete will be absent or slight. So is spectrum pricing doomed to failure or have the consultants or the steering group missed their way in the dark? Well neither; they have merely averted their gaze from the solution which was served up to them almost on a plate at the start of this study.

## WHY NOT THE SIMPLE APPROACH?

'Market-oriented' is a buzz-phrase and it is potentially misleading. If it means anything, there is not really a huge number of market-oriented mechanisms for spectrum management but there are more than two which are worth attention if you count different method of pricing as different mechanisms. Civil servants naturally favour auctions, perhaps because they place no responsibility on the auctioneer for the eventual price, but these are cumbersome method of buying and selling and they are not much used by ordinary people. For things like apples and cars and even houses, the normal method is simply to move the price up or down until the demand matches the supply as nearly as possible.

A simple method like that was presented to Merriman in one of the papers referred to in the literature review, and it was subsequently enlarged upon in an IEE paper in 1985, wherein the parameters of a suitable tariff were explained (see the box). But the precis in the literature review has cut out that part of the proposal to Merriman and it does not list the IEE paper.

Such a system of direct pricing by a central public authority would not preclude privatization of the spectrum, or part of it. There might well be room for spectrum management licencees, who would lease large blocks of spectrum from the authority, relieve RD of much of the burden and cost of detailed assignments, exercise their superior ingenuity in slicing up their blocks more cleverly than RD or their competitors and sub-let them piecemeal to the ultimate users. Spectrum management licencees might even become the only source of spectrum for small users, but the licencees should pay the going rate for the scarcity value of their blocks. Otherwise they will prosper, not by skill and enterprise but by squatting on a scarce public resource.

Whether or not one likes the general principle of spectrum pricing, which is like urban road pricing in some respects (in both cases the other options are draconian restrictions on access, or congestion and interference), the practical problems of introducing a central renting system are much smaller than they have been blown up to be. The obvious way is to retain a central organization, but in a slimmer form with different instructions. The participants should continue to deal with the *technical* questions which they have been accustomed to address and continue with the *technical* classifications of the users in so far as they affect their sensitivity to interference and the means of reducing it.

But the renting authority should be blind to the concerns of the users (commercial or social, industrial or trivial, military or civil) and they should attempt no value judgements, objective or subjective. Instead they should begin as soon as possible to charge all users rents, calculated at published rates on published parameters or spectrum usage, so that the users and the intermediate spectrum management licencees, if any, can understand all the calculations and tailor their applications to their own best advantage. The rents should then be gradually increased until there is an approximate balance between the demand for spectrum and its supply in all bands and all geographical locations. The only exceptions should be users who are in direct commercial competition with foreign concerns which do not have to pay for spectrum under international agreements.

By refusing to examine, or even mention, that kind of straightforward approach, the authors of this 'Deregulation' report have muddied the waters of spectrum management yet again and put back the realisation of the full benefits of radio communications for several more years.


*David Rudd, Ph.D., F.I.E.E., M.I.Mech.E., is a consultant engineer and economist. He gave a lecture on 'A renting system for radio spectrum' to the IEE in October, 1985 and it was published in Part A of the IEE Proceedings in January, 1986. At that time and until he retired, he was in the Department of Transport, but he was not concerned with the CSP study. His views are therefore entirely his own and not those of any government department.*

ENTER 23 ON REPLY CARD

# Good neighbourliness for personal computers

**Whilst manufacturers take steps to prevent signals escaping, economics dictates that some users will still be left with a problem. Here's how to reduce interference to v.h.f. and short-wave radio from computer systems.**

Frequencies used for the c.p.u. clock and v.d.u. character generator lie in the short-wave radio bands. Additional frequencies result from the digital nature of the circuits which introduces harmonics of these frequencies and a multitude of mixtures of sub-harmonics. Between them they contain energy at almost every frequency used for communication. The generation of this energy is almost inevitable, and interference can only be avoided by preventing its escape from the computer or keeping radio and tv receivers out of range.

In practice, computer hardware designers provide barricades such as filters on the power cable and metallic coatings on the inside of plastics cases. Such steps cost money, and the best that can be expected is that interference emission is reduced to just comply with the official standards – although such compliance is not yet obligatory in many countries.

The standards are based on the concept of 'protecting' radio and tv reception at a distance of 10 metres from domestic computers, and at 30m from industrial installations, see next page. Therefore computers designed to these standards may still give unacceptable emission when used too close to radio installations, or when weak signals are to be received. In these cases the computer emission must be further reduced or the computer and receiving antenna moved further apart.

## PROBLEM ANALYSIS

Emission can come from within the computer hardware itself and from its various interconnecting cables. In both cases wires are acting as transmitting aerials. To radiate efficiently such wires must be of significant length in relation to the wavelength of the radio signal to be emitted. A computer package whose longest dimension is, say 30cm, is unlikely to emit much interference with a wavelength longer than about 3 metres, that is, below 100MHz.

On the other hand, the connecting cables – power cable, printer cable and any network or modem cables – may be much longer and so able to emit interference efficiently over a much wider range of frequencies. The first step towards reducing the emission of a small computer is to reduce the emission from its cables. It is fortunate that this is something the user can do without invalidating the manufacturers guarantee! Signals from connecting cables that interfere most easily are the so-called 'common-mode' signals that can be visualized as travelling along the outside of the cable, either to be radiated into space or to return to their source via another cable. This mode is quite distinct to that of normal functional signals. Figure 1 shows the common-mode current that flows in the mains cable of an Amstrad 8512 intended for the UK market – the 8256 should be almost identical in this respect – plotted as a function of frequency. Measurement was made with a specialized current transformer and a spectrum analyser. The current is widely distributed across the spectrum. On a wider-range scan, the fifth harmonic of the computer clock 160MHz stood out clearly. Additional measurements made on the keyboard and printer cables showed similar spectra but reduced levels.

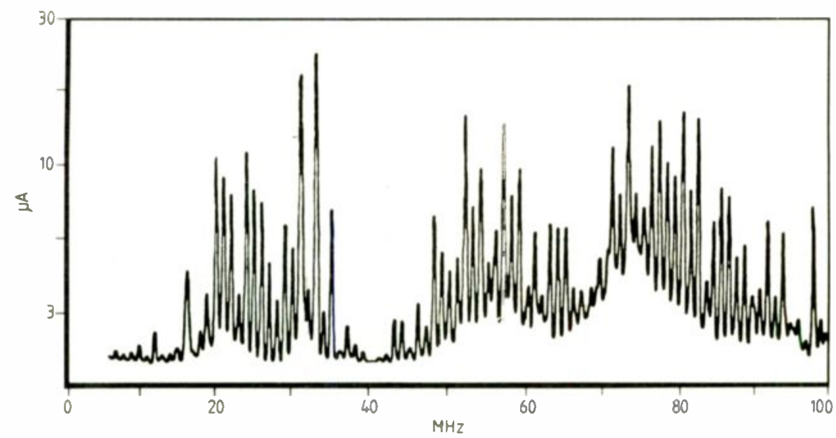



**Fig.1. The sharp edges of computer clock and data waveforms couple significant common-mode currents into the mains cable over a wide frequency range. This is a major route for interference emission.**

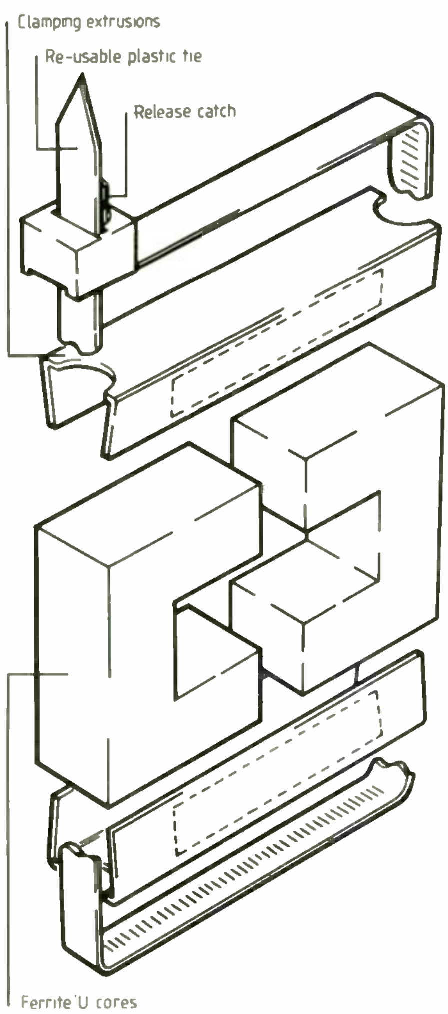



**Fig.2 This demountable construction allows a ferrite anti-interference choke to be fitted without rewiring connectors.**

## TREATMENT

Interference current can be reduced by the use of ferrite toroids, or more conveniently by clamp-on radio-frequency chokes.* These

## RF EMISSION STANDARDS FOR COMPUTERS

**International standards for the maximum radio-frequency emission from computers are all based on the concept of protecting radio and tv reception at a distance of 30 metres in the case of industrial computers (class A), or a distance of 10 metres in the case of domestic computers (class B). Such protection must make assumptions about received-signal field strength and the attenuation between computer and receiver antenna, and so has only statistical validity.**

**In the USA, FCC rule-making started in 1976, and by 1983 it was illegal to sell any computing equipment that did not conform to 'Part 15 Subpart J' requirements. This lead several other countries to introduce regulations to pre-empt the dumping of non-conforming US products. Nowadays the FCC buys samples, tests them, and prosecutes the manufacturers or importers where appropriate.**

**In Germany, conformance to VDE0871 (which covers a wider range of frequencies than most other standards) has been routine for many years. A British Standard 6527 was published in 1985 but has not yet been given legal force. However, an international specification, CISPR22, has now been technically agreed. Limits are as much as 7dB tighter than those of the FCC, reflecting the lower service field strengths used outside the FCC This standard is likely to be given legal force throughout the EEC within the next few years.**

**In Japan, a Voluntary Control Council for Interference has been set up, whose members intend to progressively reduce the emissions from exported products, reaching CISPR22 levels by December 1989.**

**None of these standards claims to reduce stray emission so much as to prevent electronic eavesdropping – but that is another story!**

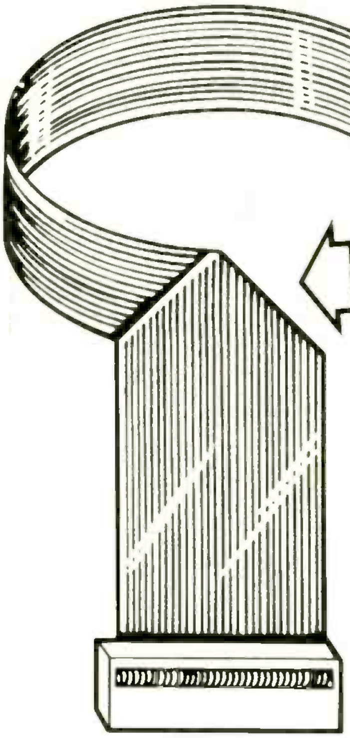


**Fig.3. Wide ribbon cables can be folded in half to allow fitting within a demountable ferrite core.**

devices have no deleterious effect on the function of the computer and may be installed without the need to re-wire any connectors. They do reduce the available cable length, however, and in the case of the Amstrad, it is subsequently necessary to have the printer on the right-hand side of the processor. Figure 2 shows an exploded view of the parts supplied.

Each cable must first be coiled to produce the requisite number of turns. The core-halves are then assembled round the coil and secured with the plastics parts provided. Details of the treatment of each cable may be seen in the photograph. The mains lead was wound five times around each of two cores, and the keyboard cable and printer power cable were each taken five times around a single core. Only the ribbon cable to the printer posed any real difficulty: it was necessary to fold this so that it could be accommodated in the core aperture. It could have been wound more neatly if the ribbon had been slit into two narrow ribbons, but this was avoided lest it invalidate Amstrad's guarantee. There was only winding space for four turns of the folded ribbon, but this proved adequate in this application.

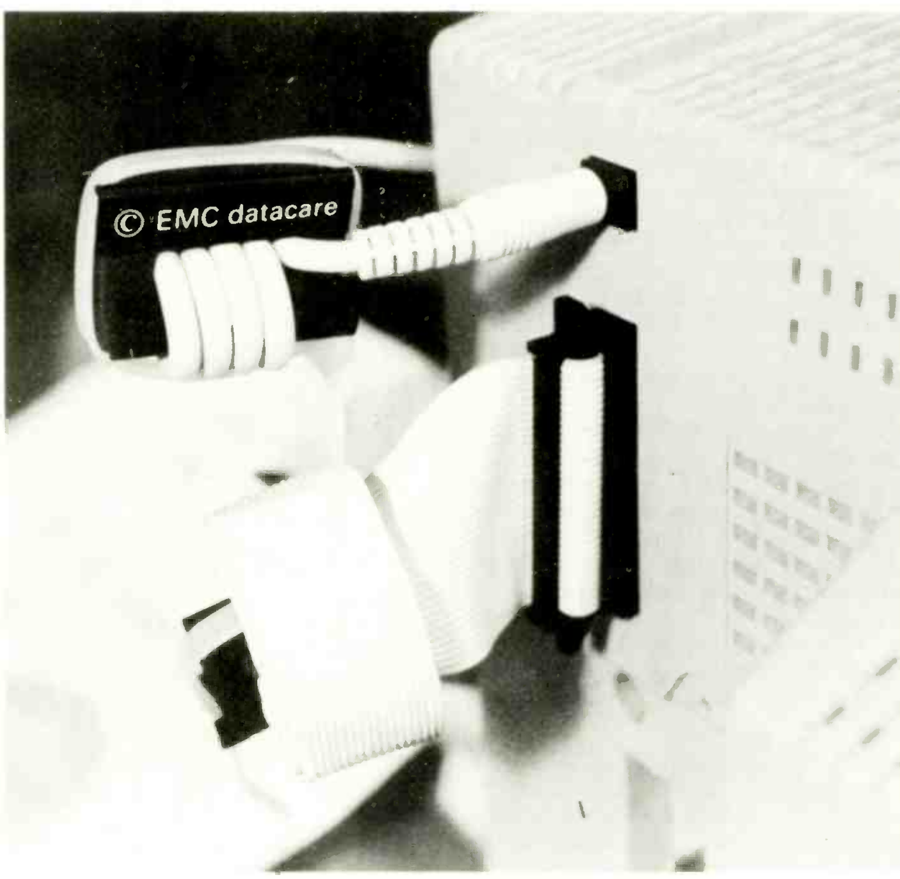
## RESULTS

The arrangement of clamp-on chokes described was chosen with the aid of a spectrum analyser to secure a ten-fold reduction in the power emitted in the v.h.f. f.m. broadcast band. The benefit gained at other frequencies varied because of resonance in the connecting cables and emission from the computer itself. We noted only a two-fold reduction in emission at 84MHz yet a twenty-fold reduction of the relatively strong emission at 160MHz.

The remedy completely solved the problem, and on theoretical grounds we would expect it to allow untroubled reception at one-third of the distance from the computer as was possible originally.

Interference paths are two-way, so there is also the less tangible but nevertheless real benefit of increased freedom from data errors and program lock-up due to external disturbances.

* Clamp-on choke kits are available from Verospeed of Stansted Road, Boyatt Wood, Eastleigh, Hants, SO5 4ZY, from AKD at unit #5, Parsons Green Estate, Boulton Road, Stevenage, Herts, SG1 4QG and from Texpro Manufacturing, 4087 Harvester Road, Unit #10, Burlington, Ontario, L7L5M3, Canada.




**Interference may be reduced by the choke action of a few turns of cable on a suitable ferrite core.**

The theory underlying this article was outlined in a series of articles entitled 'Earthing, shielding and filtering problems' by RC Marshall in *Wireless World* vol.82 1976 Aug, Sept, Nov and Dec issues (nine pages total).

*Richard Marshall, M.A., F.I.E.E. who read his first copy of* Wireless World *in 1947, is technical director of Protech Instruments and Systems Ltd. at 241 Selbourne Road, Luton, Beds.*

# RESEARCH NOTES

## Heavy things drop faster

Which drops faster, a cannon ball or a tiny ball bearing? If you were among those ridiculed in school physics lessons for making the 'mistake' of assuming that the heavier object falls faster then here's your opportunity for having the last laugh.

Long before Newton formulated his universal law of gravitation, by dropping two dissimilar-sized objects from the top of the leaning tower of Pisa. Every schoolboy (or should it now be schoolperson?) now knows that if you conduct the experiment on the airless surface of the moon where the viscosity of the medium can be ignored, then even a feather will fall as fast as a lead ball. Well, almost...

John Donoghue and Barry Holstein of the University of Massachusetts have been doing some calculations based on quantum field theory that show that, even if one supposes the earth's gravity to be constant, there is still a small difference in the acceleration of free falling objects.

The variation is due to what Donoghue and Holstein (*Eur. J. Phys.* Vol 8 No. 2) believe to be a tiny difference between the gravitational mass of an object and its inertial mass. Although these are considered equivalent as far as Newtonian physics and General Relativity are concerned, things are different in quantum mechanics.

In quantum theory it is assumed that each subatomic particle is constantly emitting and re-absorbing photons. This in turn changes the inertial mass, a consequence of the equivalence of mass and energy. Applying Dirac equations, Donoghue and Holstein conclude that there is a reduction in the inertial mass of heavy objects which causes them to respond more readily to the pull of gravity. Heavy objects therefore do indeed fall faster.

If that just seems like a blinding glimpse of the obvious, a scientific vindication of commonsense, then another prediction from quantum theory may prove a bit harder to swallow. Photon emission is temperature dependent, so if heavy objects fall faster than light ones, then cool objects must also fall faster than hot ones. Similarly if two mirror nuclei are dropped simultaneously then the one of smaller charge will reach the ground first. But before you book a holiday to Pisa and get arrested for heating up or charging a cannon ball, it's perhaps worth pointing out that the effect is immeasurably small. The researchers say that their 'effect' would change the acceleration of an electron by 3 parts in $10^{17}$, that's roughly five orders of magnitude smaller than the accuracy limits of state-of-the-art experiments!

## Glasses improve your hearing

When psychologist Mike Kelly wrote to *New Scientist* asking if anyone shared his impression that spectacles improve one's hearing, he expected little more than ridicule. Instead he was surprised by the number of people who apparently share his experience. What they all say is that glasses make it easier to extract speech from a noisy background. So whatever lies at the bottom of the phenomenon, it's clearly real.

An obvious thought is that glasses help people with defective vision to lip-read, though this can't be a whole or even partial explanation because, according to Mike Kelly, the improvement is evident even when using the telephone. The phone, incidentally, destroys another theory that glasses push the ears forward slightly thus collecting more sound. The effect persists when contact lenses are used instead of spectacles.

If lenses of any sort improve the signal-to-noise ratio of the auditory system, it seems most probable that the explanation lies in the way the brain processes different sets of sensory stimuli. Although sights and sounds have a considerable measure of separate processing, the brain does have common areas where interpretation is carried out. This is how lip-reading helps clarify indistinct speech. It also explains why we tolerate poor sound on tv.

So if the eyesight is bad without glasses, the brain may have to work harder to interpret the outside world. That in turn might divert processing power from the aural system, making hearing worse. Of course it's possible to argue the other way round and say that clear sight gives the brain more data to process in the first place!

Perhaps the answer is not to be found in information theory so much as in psychology. Could it be that if our glasses make us see better, then subconsciously we expect all our senses to improve?

Experiments could easily be devised to verify or disprove many of the possibilities. Does a hearing aid, for example, improve a person's ability to read the optician's chart? Do spectacles with plain non-magnifying lenses improve hearing?

Perhaps readers of *E & WW* might solve this mystery once and for all by sharing their own experiences by doing a few simple tests and letting the Editor have the results?

## High mobility semiconductors

Nottingham University's multi-million pound NUMBERS project, which aims to have a major influence on the next generation of devices and computers, has taken an important step forward.

The heart of the project, centred in the University's Department of Physics, is the growth centre where extremely thin layers of semiconductors are grown and processed under clean room conditions for research projects at extremes of temperature and magnetic field.

The standard measure of quality of the material is the mobility of electrons at low temperatures when they move in a two-dimensional sheet inside a specially prepared heterostructure. Material with a mobility of $2\times10^6 cm^2v^{-1}s^{-1}$, which is approaching the highest grown anywhere, has now been produced. This is believed to be higher than any material previously grown in a university laboratory.

Major support is being provided by the Science and Engineering Research Council which so far has invested £2.5million, by the University itself and by companies including Philips and Plessey. The University of Nottingham's Department of Electrical and Electronic Engineering has recently been awarded more than £45,000 from the Science and Engineering Research Council to work on layers of semiconductors.

## Radiation-resistant alloys

Designing materials suitable for use in nuclear reactor cores is not easy. Most commonly available materials absorb neutrons which alters their physical properties resulting in deformation or cracking. Of the commonly available metals, beryllium and magnesium are among the least absorbent of neutrons though, in other respects, their properties don't always make them suitable as structural materials.

Research into radiation resistant structural alloys is now being undertaken at Loughborough University of Technology, the UKAEA Harwell University of Technology, the UKAEA Harwell Laboratory and at the US Department of Energy Research Laboratories at Argonne.

Computer studies are being employed to model the damage processes that occur when steels are subject to neutron bombardment. In particular, the studies will examine the effects of radiation on the movement of impurity atoms within the lattice structure of the material. Migration of impurity atoms is one of the prime causes of structural failure of materials undergoing neutron bombardment.

Following the computer simulations, practical tests will be undertaken using high energy particle accelerators at Argonne. It is hoped that this work will lead to commercial nuclear reactors that are both safer and more reliable.

## Chip testing in a flash

One of the problems facing the makers of GaAs chips capable of working faster than 100GHz is quite simply how to test them. For meaningful results the test equipment should have a bandwidth at least an order of magni-

# RESEARCH NOTES

tude greater than the chip itself, that's more or less into the infra-red part of the spectrum. Such test gear doesn't exist in any practical form. Current continuous-wave test gear is limited to around 26GHz. Another problem is how to make connections to the chip under test. Crocodile clips or even automated test probes simply aren't on at 100GHz.

Research involving Stanford University and AT & T Bell Laboratories has come up with a novel approach that gets round the speed problem and the connection problem all in one. It makes use of the fact that gallium arsenide is an opto-electronic material that will change its electrical characteristic when illuminated with pulses of light. So to get a fast pulse on the input of a chip under test all that's necessary is to bombard it with picosecond laser pulses and observe the resulting changes in the chip's characteristics.

Such testing is in the time domain rather than the frequency domain and can achieve response speeds as fast as 200 femtoseconds. The US Aerospace Corporation has now built test jigs to characterize GaAs fets destined for military space hardware. It uses optical pulse generators and detectors built into microstrip transmission lines.

## Optic fibre break detector

Current methods of detecting breaks in optic-fibre cables are complex and tedious, relying on a technique known as optical time-domain reflectometry (OTDR). Before this approach is put into practice the individual fibre must be demounted from its sender or receiver and connected into special equipment designed to measure the transit time of an IR pulse along the fibre to the break point and back again.

BT Research Laboratories at Martlesham are now pioneering a new system that is built into the transmission network and gives an instant readout. (*Electronics Letters*, Vol.23 No 9). It's based on a duplex system in which there is an independent transmitter and receiver at each end of the fibre. Each receiver is equipped with a 'light-fail' detector and a precise timer/recorder. When a cable fault occurs it is thus recorded independently at both ends, each record representing the time of the break with a small amount added to allow for the flight time of the last working pulse. A comparison of the recorded times can then be used in conjunction with other known parameters, such as propagation velocity and cable length to calculate the precise position of the break.

One theoretical objection to this technique is the fact that a real-life break occurs over a finite time, typically a few nanoseconds. The point at which transmission loss occurs may thus differ between the commonly-used duplex wavelengths of 1300nm and 1500nm. This is due to microbending. The BT group calculate that in practice, however, this should not result in an additional location error significantly greater than 10m.

Practical experiments have been carried out on a 34Mbit/s link over a path length of 24km which have demonstrated a worst-case detection spread of 30.8m. This is more accurate than a conventional OTDR and will also work over any length of cable that will permit a practical transmission path. OTDR equipment is limited by the reflection loss at a fibre break and is often too insensitive to detect a mid-span break in a long cable.

## New auroral radar probes

The Sweden and Britain Radar Aurora Experiment (SABRE) is a two-station coherent system designed primarily to probe the behaviour of the E-region radio aurora. One station operates on 153.2MHz at Wick in Scotland; the other at Uppsala uses 142.6MHz. Peak pulse power of the transmitters is 50kW. The receiving system consists of 16 towers, each carrying four eight-element Yagi antennas matrixed so that eight different beam directions can be monitored simultaneously.

The systems are currently being used for a number of different ionospheric and magnetospheric studies ranging from simple measurements of auroral activity through to detailed investigations of pulsation events and electric field vectors. The latter can be calculated by combining measurements taken from both stations.

Correlation with data from other projects is also proving valuable. These include EISCAT (the European Incoherent Scatter Project) and various satellites (VIKING, HILAT, AMPTE).

The British station is operated remotely by telephone line from Leicester University, where the data is retrieved and processed each day.

Writing in *SERC Bulletin* (Vol.3, No.8) Professor T.B. Jones of the Department of Physics describes the SABRE system as being one of the most powerful and cost-effective tools for studying both the geophysics and plasma physics of the upper ionosphere. So much so that a new 1GHz coherent radar called COSCAT will now be built in Finland as a joint venture between Leicester University, Oulu University and the West German Max Planck Institut für Aeronomie. Further transportable v.h.f. systems are also envisaged.

## Whistling in the Ionosphere

'Whistlers' are well-known radio frequency phenomena that are generated by lightning and which then normally propagate through the waveguide formed between the earth and the ionosphere. When picked up on an e.l.f. receiver they sound like a rapidly sweeping tone – hence the name.

A report (*Nature* Vol.327, No 6121) by W.C. Armstrong of Stanford University, California draws attention to a strange new whistler interaction that occurs when an r.f. burst travels from one hemisphere to the other along the lines of the earth's magnetic field. What apparently happens is that some of the whistler energy passes through the ionosphere and is then directed along the lines of the magnetosphere through ducts of plasma. On its way it then undergoes amplification by cyclotron resonance with energetic electrons – a sort of repeater in the sky.

After this 'one hop' trip around the earth, the whistler is then reflected back along exactly the same path into the midst of the thunderstorm whence it was born. High in the atmosphere this returned r.f. energy causes secondary ionization which in turn triggers off another lightning strike, resulting in yet more whistlers. Armstrong shows that this second, upward lightning strike and the secondary whistlers occur approximately 5s after the original stroke.

This theory is intriguing and elegant, though not without its complications. One problem is the need to explain how the relatively un-energetic 100keV electrons of a whistler can penetrate back through the ionosphere to the top of a thundercloud, which extends no more than about 15km from the earth's surface. Unassisted, such electrons would not penetrate below 80km altitude. Even if one calculates the level of bremsstrahlung X-radiation produced when such electrons decelerate, it still wouldn't be enough to ionize the air below 30km.

Another problem is the timing. Five seconds is somewhat longer than the calculated transit time of the electrons along the lines of the earth's magnetic field. So is there some delay inherent in the process that triggers the secondary whistler?

As yet, there's no definitive answer, though Armstrong proposes a trigger mechanism based on laboratory experiments with electric fields applied to fluids and crystals. What is also interesting is the thought that man-made e.l.f. transmissions could trigger whistler-mode signals that might in turn induce lightning eleswhere in the world. If so, it could provide the litigious with far more ammunition than acid rain ever did!

*Research Notes is written by John Wilson.*

# Remote control of comsats

As soon as a communications satellite parts from its launching vehicle, whether rocket or shuttle, it becomes an independent spacecraft relying on remote control by radio from the ground. The sub-system for remote control, known in the trade as tracking, telemetry and command (t.t.c.), looks after two main functions. One is the navigation of the satellite as a whole – its injection into orbit and positional control (attitude and orbit) when on station. The other function is to control mechanical and switching equipment to make the space payload operate as a radio relay station – for example, extending antennas and solar panels, and switching transponders and antenna feeds to meet changing transmission requirements.

The satellite therefore carries a special sub-system for t.t.c., which provides two-way communication. The telemetry side monitors and measures what is going on in the spacecraft; the telecommand side makes control adjustments in response to this information. For the two directions of signals there are special receivers, transmitters and antennas. The ground control station has a corresponding two-way radio system.

There are several frequency bands allocated by the ITU specifically for 'space operations'. For example, v.h.f. downlink and uplink bands are allocated at 137 and 150 MHz respectively, u.h.f. uplink and downlink bands at 2 and 2.2 GHz respectively, and other frequencies at s.h.f. for use with C-band and K-band satellites (e.g. see diagram in May issue, p. 528).

Examples of current technology are provided by the t.t.c. systems of two European Space Agency comsats already discussed in these pages, the Olympus and the European Communications Satellite (ECS). Overall these systems operate by digital data transmission. Olympus uses S-band radiocommunication within the uplink band of 2025 – 2120 MHz for command signals and within the downlink band of 2200 – 2300 MHz for telemetry signals. Transmitters and receivers are in the form of transponders which work through an axially-slotted antenna mounted on a mast or tower.

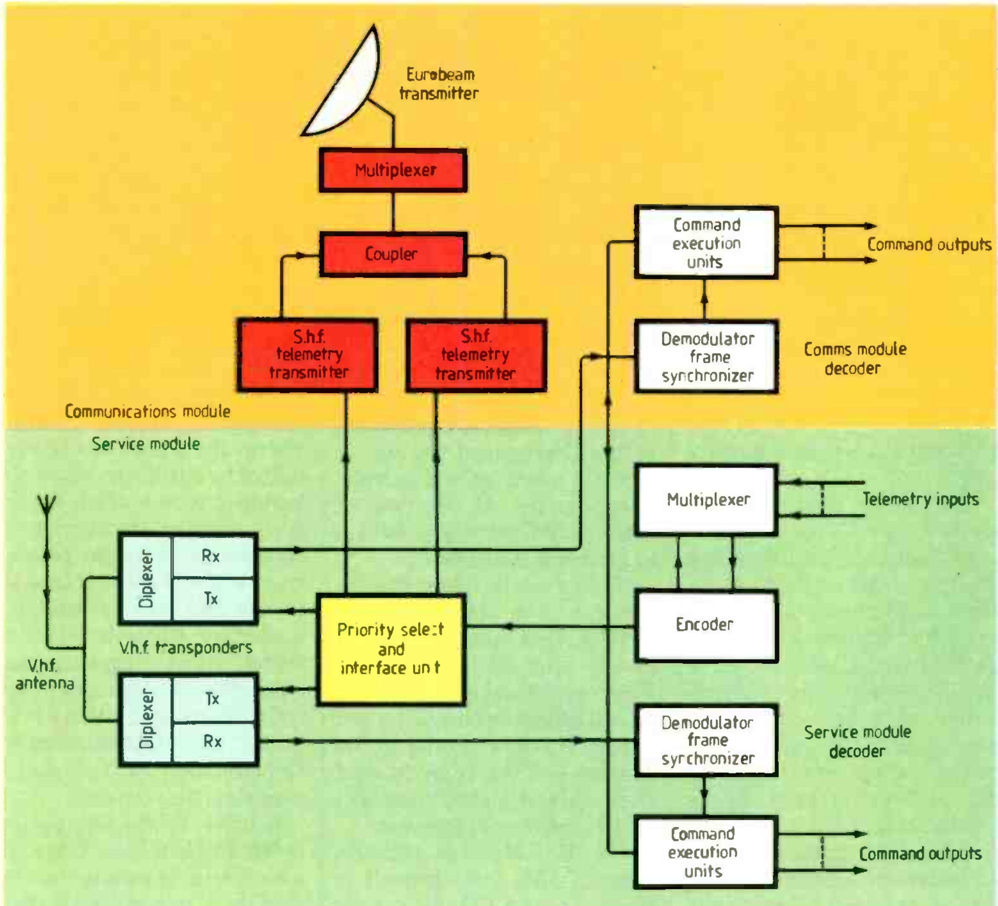



**Fig. 1. Spacecraft equipment in the tracking, telemetry and command system used for remote control of the European Communications Satelite.**

The Olympus command (uplink) digital signals have a data rate of 500 bit/s and are transmitted on an 8-kHz subcarrier. In the spacecraft this channel provides 263 different command output signals. There are also outputs for synchronization of the t.t.c. system. Telemetry information from the spacecraft to ground is carried on a higher frequency subcarrier of 65.5 kHz. This is modulated by telemetry data at a rate of 256 bit/s, using split-phase p.s.k. Altogether there are 512 telemetry inputs of different kinds from the spacecraft. Some take the form of 8-bit serial words; others convey single bits. Processing of both telemetry and command digital data is done by c.m.o.s. logic circuits.

ECS, being a smaller, special-purpose comsat relative to the multipurpose Olympus, has a smaller t.t.c. system. It uses 384 telemetry inputs and 443 command outputs. As can be seen from Fig. 1, some other t.t.c. equipment is housed in the spacecraft's communications module (described last month) and some in its service module. The main Eurobeam transmitter and antenna (see last month) are one means for sending the telemetry signals to ground. This is done on a frequency of 11.45 – 11.7 GHz sub-band containing one group of the ECS main communications channels.

Another transmitter is also used for sending telemetry signals – a v.h.f. downlink on 137.2 MHz – but this operates only during the initial period of manoeuvring the spacecraft into its orbit, that is, from launcher-satellite separation till the end of the transfer orbit (see below). The Eurobeam 11-GHz transmissions provide the permanent telemetry channel to ground when the comsat is finally on-station in its geostationary orbit. As can be seen from Fig. 1, the telemetry signals are first multiplexed, then encoded before being sent to a priority select and interface unit which passes them to the v.h.f. or s.h.f. transmitters.

Commands to the ECS are transmitted from ground on a v.h.f. uplink working at 149.39 MHz. These are received and pass through a branching unit to twin diplexers feeding two receivers in v.h.f. transponders. The output of one receiver goes to a decoder in the communications module. Here the serial digital data is separated into frames by synchronizer units and distributed to the various command outputs. All the command data, as well as that for telemetry, is formatted in accordance with standards laid down by ESA.

Perhaps the most crucial role of a t.t.c. system is the initial navigational task of guiding the satellite so that it is correcly injected into orbit and properly oriented after leaving the launching by ESA's Ariane rockets. The normal procedure is to launch the spacecraft first into a highly elliptical orbit, where one focus of the ellipse is the same point as the centre of the Earth. In this orbit the point farthest from the Earth, called the apogee, is close to the desired satellite altitude for a circular, geostationary orbit 35,800 km above the equator). Here, too, the speed of the satellte is at its lowest.

At this point a command signal from the ground fires a large reaction-propulsion motor, called an apogee (kick) motor. This generates an additional force which, applied in a suitable direction relative to that of the existing inertial force given to the satellite, accelerates the spacecraft into the geostationary orbit.

The actual manoeuvring, however, is much more complicated than this outline of the principle might suggest. It involves an intermediate, or transfer orbit, spinning and despinning of the satellite to ensure the right direction of acceleration at apogee, numerous measurements of orbital parameters and spacecraft attitude, and positional corrections by reaction propulsion in response to these measurements. All the necessary measurements and commands are sent through the t.t.c. system.

During the transfer-orbit phase, before the satellite has become geostationary, there is a continuous relative movement between the spacecraft and the earth. This allows orbital measurements to be made by tracking the comsat from the ground, using a beacon transmitter on the satellite as a signal source. Orbital measurements thus obtained are accurate enough for control purposes in manoeuvring the spacecraft into its final circular orbit.

Once the comsat is on-station in the geostationary orbit it is no longer stabilized by spinning its body but controlled in three axes by means of momentum wheels running at about 4,000 r.p.m. Attitude and orbit errors are detected by using sun sensors, infra-red Earth sensors and gyroscopes to measure the spacecraft's position with respect to fixed references. In response to these detected errors small reaction thrusters apply positional corrections to the spacecraft. Although this stabiization process runs automatically, the electronics of the system also receives command signals from the ground.

## D-MAC for Britain's d.b.s.

Two engineering decisions made at about the same time have defined the UK's future d.b.s. service more precisely. British Satellite Broadcasting (BSB), the consortium awarded the licence by the IBA (February 1987 issue, p. 198), has chosen the established Hughes HS 376 satellite design. The IBA, together with BSB and the Cable Programme Providers Group, are proposing to the Government the use of D-MAC/packets as a transmission standard. At the time of writing the Government has yet to approve this standard.

Hughes will be responsible for providing two satellites, launching both of them into geostationary orbit at 31°W, making them operational and arranging launch insurance cover. The first is expected to be in orbit by the autumn of 1989, ready to start television and teletext broadcasting by Christmas of that year.

The HS 376 will transmit three 27-MHz f.m. channels in the 11.7 – 12.5 GHz d.b.s. band allocated at WARC 77: channel 4 (11785.02 MHz), channel 8 (11861.74 MHz) and channel 12 (11938.46 MHz). Each transponder will have an r.f. output power of 110 watts. Already widely used throughout the world, this Hughes design is a cylindrical, spin-stabilized satellite with a diameter of 2.2m and a height of 6.3m in orbit. A telescopic cylindrical solar array system collapses the height to 2.9m when the spacecraft is stowed in the Delta launching rocket. Power generated by the solar array is 1054 watts at the beginning of its life. Weight of the satellite is about 640 kg.

D-MAC/packets is one of a family of transmission standards based on the broad principle of time-division multiplexed analogue components (MAC) for the vision signal, plus packets of data for digital sound and other purposes. The C-MAC/packets standard is already well known, having been officially adopted by the EBU as early as 1983. B-MAC was described in the December 1986 issue, p. 65, and the March 1987 issue, p. 263. The D2-MAC/packets version has emerged mainly as a system for satellite-delivered cable services.

IBA and BSB engineers have chosen D-MAC/packets because it "provides the best realisation" of three criteria: (a) overcoming limitations of existing systems; (b) making the most efficient use of channel capacity available; and (c) allowing maximum freedom for compatible future developments.

For example, under (a), D-MAC/packets is considered better than the technically optimum C-MAC/packets system because it allows the use of simpler and lower-cost receivers. In the C system the digital data is transmitted by quaternary phase shift keying (q.p.s.k.), which requires fairly complex circuitry in the receiver for optimum performance, whereas in the D (and D2) system this data is sent by a duobinary (three-level) coded signal which frequency modulates the 12-GHz carrier along with the analogue vision components. Thus straightforward f.m. demodulation of the data is possible at the receiver.

Relative to the D2 version, D-MAC/packets has twice the sound/data transmission rate (like the C system) and is therefore superior to D2 in meeting criterion (b) above.

Details of the proposed d.b.s. transmission standard were given by Brian Salkeld and Chris Daubney of the IBA at the recent European Satellite Broadcasting Conference at Brighton. They said that the f.m. MAC vision signal will have pre-emphasis and d.c. restoration. For digital sound/data the duobinary coded signals will be sent in packet form at a clock rate of 20.25 Mbit/s, frequency-modulated like the vision signal. Each data packet will contain 751 bits. With duobinary coding the 20.25 Mbit/s data rate requires a baseband width of about 8.5 MHz.

Of the 206 data bits carried in each tv line, the first eight will be used primarily for vision line sync. purposes. The remaining 198 bits will be arranged in two equal sub-frames, to facilitate transcoding into the D2-MAC/packets standard. The entire satellite channel could be used for data when tv programmes are not being broadcast.

Incidentally, 20.25 Mbit/s was chosen as a clock rate for the MAC C and D versions because it fits in with the sampling rates of the CCIR world digital coding standard for studio equipment. It is the sampling rate necessary for the time-compressed, and therefore higher bandwidth, luminance and colour-difference components in the MAC signal; that is, 3/2 times the 13.5-MHz luminance component sampling frequency and 3/1 times the 6.75-MHz colour component sampling frequency.

Thus, a 64-μs tv line in the 625-line system contains 1296 clock periods. Each of these will allow transmission of 1 bit of information, which can be used to carry either one data bit or one sample of an analogue vision component.

Sound channels will be stereo or mono, with 15-kHz bandwidth. Up to eight of these channels can be transmitted in the data part of the signal. Teletext will also be carried in the data multiplex.

All the vision signals will be encrypted, whether intended for free reception, subscription or 'pay-per-view' services. This is, of course, already becoming common practice with the satellite tv programmes now being distributed by 11-GHz comsats in the Fixed Satellite Service (see, for example, March 1987 issue, p. 263).

The D-MAC/packets vision signal is compatible with existing 625-line PAL colour tv receivers. It, and a single sound signal, will be delivered to receivers' aerial sockets through set-top units which will perform all the necessary demodulation and decoding.

## Transmission R&D

The possibility of transmitting at least three high-quality television signals through a 41-MHz global beam transponder is being investigated in the USA by Comsat Laboratories for INTELSAT. Advanced techniques being utilized include a combination of analogue compression, digital video processing and time division multiplexing.

After initial R&D work to select the best technique INTELSAT will assess the results and, if promising, will give Comsat the go-ahead to design and produce a signal processor.

*Satellite Systems was written by Tom Ivall.*

# TELECOMMS TOPICS

## Telecom Gold interconnects

British Telecom's electronic mail service, Telecom Gold, is expanding its range of facilities with the introduction of the Gold 400 message handling service and has also produced improved user documentation. It will be the first public service implementing the agreed X400 standard for message handling.

It will interconnect different public and private electronic mail systems, and permit messages to be sent between them and the telex and facsimile services. The system and software for Gold 400 were supplied by a north American BT subsidiary, Dialcom, Inc. Through Dialcom, BT is now able to supply X400 message handling software to all Dialcom licencees, which operate in 17 countries.

## Chinese telecom support

The Plessey Company has set up a technical support centre at Factory 520 in Shanghai to provide locally-based service and support for the growing number of latest-generation telephone systems in the People's Republic of China.

It has installed a fully working i.s.d.x. (integrated services digital exchange) switch at the centre to enable Chinese technicians to provide technical support for their colleagues from other provinces of the country which have ordered this fully-digital telephone system.

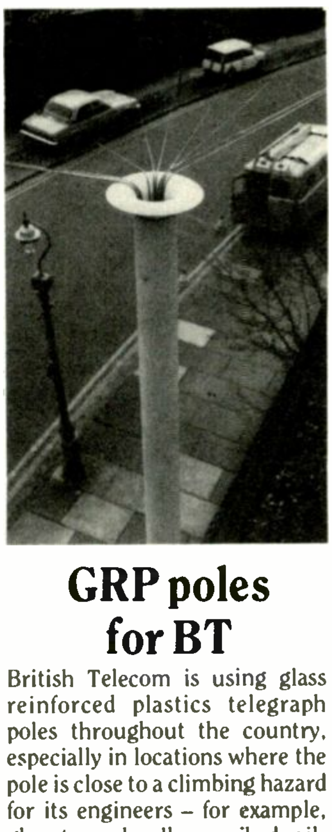
A number of Chinese technicians from this factory have already been trained by Plessey.

## First national value-added network

Digital Equipment Company is to set up the UK's first national value-added network to allow insurance companies, banks, building societies, other financial institutions and financial advisers to carry out transactions on-line.

The network will be controlled by two VAX 8550 clusters set up on adjacent sites in Berkshire. The dual clusters will ensure that the network has the necessary resilience, flexibility and capacity to provide consistent and reliable service. The regional centres, based on MicroVAXes, will provide local access to organisation throughout the UK. Users of the network will be able to connect most types of electronic office equipment to the network.

The system has been designed with an architecture (financial services architecture) which integrates the major software components at the design level so that new facilities can be added without disruption to the service.



## GRP poles for BT

British Telecom is using glass reinforced plastics telegraph poles throughout the country, especially in locations where the pole is close to a climbing hazard for its engineers – for example, glass topped walls or spiked railings. The wiring running through the centre of the pole can be safely accessed via a reinforced door at the base.

Permali Gloucester Ltd has won a two year contract to supply these poles to BT's Materials Executive at Swindon. As well as being lighter and consequently easier to handle and erect, they are less likely than steel, wooden or concrete poles to cause serious injuries and damage in a road accident when a vehicle leaves the road.

## European satellite to Americas for testing

The Space and Communications Division of British Aerospace has competed the assembly and integration of the multi-purpose Olympus 1 satellite. This, the world's largest and most powerful civil three-axis-stabilized communications satellite, is now in Pasadena, California, to undergo solar simulation tests at NASA's Jet Propulsion Laboratory. The tests have been designed to prove that the thermal design of the spacecraft copes with the severe temperature extremes encountered in space. From there it will go to the David Florida Laboratories in Canada for further environmental testing and will be ready for launch in September 1988.

The Olympus 1 was built under contract to the European Space Agency by a multinational consortium led by British Aerospace.

## Cellular installation problems

The cellular communications division of Ericsson Information Systems Ltd has introduced a nationwide installation service for car telephones that it sells directly to its customers. According to Derek Saunders, the division's national sales manager "We decided to offer this service because nearly all the problems reported were the result of incorrect installation by unqualified engineers and the absence of test equipment". This is in keeping with the Cellnet experience. According to marketing director, Peter Waller, the wrong siting of the antenna can result in a loss of up to 30% of antenna gain. He explains that the ideal place would be centre roof, closely followed by front or rear window mounting. Roof mounting is not popular with users because of convenience (impeding a roof rack) and aesthetics and, unfortunately, not all fitters are as competent as is desirable. Fitters frequently adopt the far more quick and convenient rear wing position – especially if the vendor is offering "free fitting" – which means they do not have to disturb roof linings etc.

## Telex for air travellers

The first live demonstration of Prodat, a satellite-based telex and data transmission system for air travellers, was carried out by Racal-Decca Advanced Development Ltd in conjunction with the European Space Agency at Le Bourget Airport during the Paris Air Show. It consisted of messages being transmitted via satellite from a Prodat terminal and antenna installed on an aircraft to a ground station at Villafranca and onward to the public telex and data networks.

Prodat is a development satellite communications relay system for data transmission between mobile users on land, at sea, and in the air. It will, in particular, allow for aircrew data communications and passengers telex facilities via ground data networks throughout a flight, without resorting to often unreliable h.f. radio links.

Manufactured by RDAD in conjunction with Racal Avionics, the airborne data terminals and antenna equipment to link aircraft with ground stations via satellite will be used in the service trials scheduled by the Societe Internationale de Telecommunications Aeronautiques (SITA), the Paris-based, airline-owned, aeronautical communications company.

The trials will be conducted later this year in cooperation with ESA using the Inmarsat space segment. Such a satellite link offers the only reliable method of communicating an aircraft's position and other information from the aircraft to the ground once it is out of range of radar or v.h.f. radio.

Transmissions at 1.5 and 1.6GHz are employed between mobile terminals and the satellite, with reliance on specialized modulation and error correction techniques, tailored antennas for airborne use, and adaptive synthesizers to compensate for Doppler shift resulting from aircraft movement. The r.f. elements result from a collaborative programme with the French company SNEC of Bretteville L'Orgeuilleuse in Normandy.

## Key and lamp comes up to date

Norton Telecommunications, Telephone Rentals and Austin Taylor join forces to bring a new electronic key and lamp system to a market worth in excess of £120 million. According to Norton's sales and marketing director, Martin Cawood, "Key and lamp systems are used in 30,000 organisations throughout the UK. For more than twenty years customers have used the same electromechanical equipment incurring heavy cost penalties when they wanted to move or change equipment around."

Traditionally organisations use key and lamp units to enable a number of staff to answer incoming calls on a group of lines. These include police, fire and ambulance services, stockbrokers, travel agents, estate agents, the insurance industry, telesales and mail order houses. The Austin Taylor design includes two major advances over the old key and lamp systems – visual indication of the call which has been waiting the longest, and an intercom facility between desk units.

## One-to-One sold to Comtext

Electronic mail company One-to-One has been sold to Comtext International Ltd by its owner, Pacific Telesis International. One-to-One is believed to have around 15,000 mailboxes, the second largest in the country. It provides a range of electronic messaging facilities to business and personal users, gateways to information databases, cellular phones, radio paging and courier deliveries and links to national and international telex networks.

Comtext entered the telecommunications industry at the end of 1986 when it acquired BFT Communications Ltd one of Europe's large international telex and cable refilers. Both companies use similar Tandem computer-based technology.

British Olivetti Customer Support Group is to provide a viewdata network for a major travel operator, Pickford Travel, under a three-year contract worth over £500,000. The contract involves installing the cabling as well as installing and commissioning Acorn Communicator terminals in over 300 Pickford brances throughout the UK.

In addition to the installation work, project managed by a team from Olivetti's CSG, the Pickford's terminals and network will be maintained for three years by CSG engineers who, once the system is fully installed, will be able to respond to most calls within four hours. Eventually a total of 1,500 terminals will be installed.

## Telecoms UK in Coventry

The Telecommunications Industry Association, which arose like a Phoenix from the short-lived Telecom Dealers Association, will be one of the sponsors of a new event designated Telecoms UK. To be held on October 31 and November 1 at the Crest Hotel, Coventry, it will combine a conference, exhibition and an awards dinner. According to TIA chief executive, Richard Woollam "We are now a fast-growing mature industry and Telecoms UK is the forum needed, both for exchanging views and to give a platform for those major players in supplying and manufacturing."

For years Coventry hosted the TMA (Telecommunication Managers Association) annual Covention, until that event outgrew the available facilities and moved to Brighton.

## Radiopaging by satellite

Trials of the worlds's first satellite radiopaging service are to start at the end of the year. It will enable drivers of long-distance lorries to be contacted immediately by their companies while they are on the road – particularly those of road haulage firms operating on routes across Europe, the Middle East and Africa.

Customers taking part in the trials will make their satellite paging calls in exactly the same way as an inland paging call. Messages will be routed via BTI's Goonhilly Down satellite earth station to an Inmarsat satellite. The signal returned to/from the satellite will be received by a small "patch" antenna mounted flush with the roof of the lorry cab. A Message Master alphanumeric pager in the cab will display the message and a printer will provide hard copy.

## InterCity Trainphones

**Trainphones, supplied by British Telecom Mobile Communications, have entered service on the British Rail London-Cardiff InterCity trains. The first 31 units, out of the 200 ordered, have been installed. They operate on the Cellnet cellular radio system, using the standard green BT pre-payment Phonecard.**

**British Rail estimates that 500,000 calls a year will be made from Trainphones.**

## Digital 934MHz short-range radio by 1990

The Department of Trade and Industry and the Electronic Engineering Association have embarked on a programme aimed at the introduction of a digital short range radio service by the early 1990s. A working party is to be set up by the DTI to finalize the performance specification for the service.

The Department will also be responsible for steering the specification through the CEPT (Conference of European Post and Telecommunications) where the draft specification has already attracted a great deal of support from other member nations.

Short range radio is a low power (less than 5 watts) service having a range of around 5km. It will utilise 80 channels of 25kHz arranged as one control channel which scans and selects a clear channel from 79 speech channels.

The use of all-digital techniques for voice and data is a UK first in this field because CEPT has developed a draft specification based on analogue technology. The EEA alternative utilises the more advanced digital technology and provides additional features such as data transmission. The DTI will not be licensing any service for three years. This time interval will allow the digital specification to be developed as an alternative to the analogue one.

## Telecoms Green Paper

The European Commission has approved its Green Paper of Telecommunications setting forth proposals aimed at unifying telecommunications across Europe. After an initial policy discussions in October, the Commission will move on to discussion aimed at producing consensus which it is hoped will produce a number of more formal proposals before the end of the year.

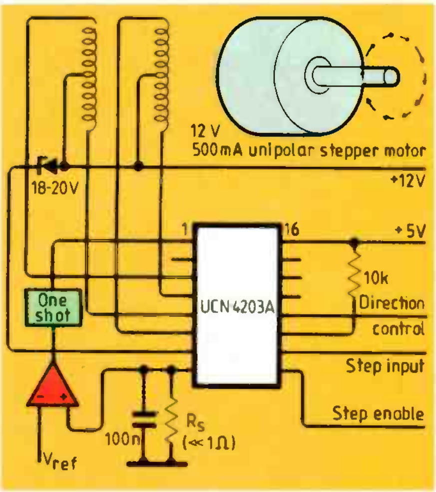
*Turn to page 000 for further details.*

# APPLICATIONS SUMMARY

## Chopped stepping-motor driver

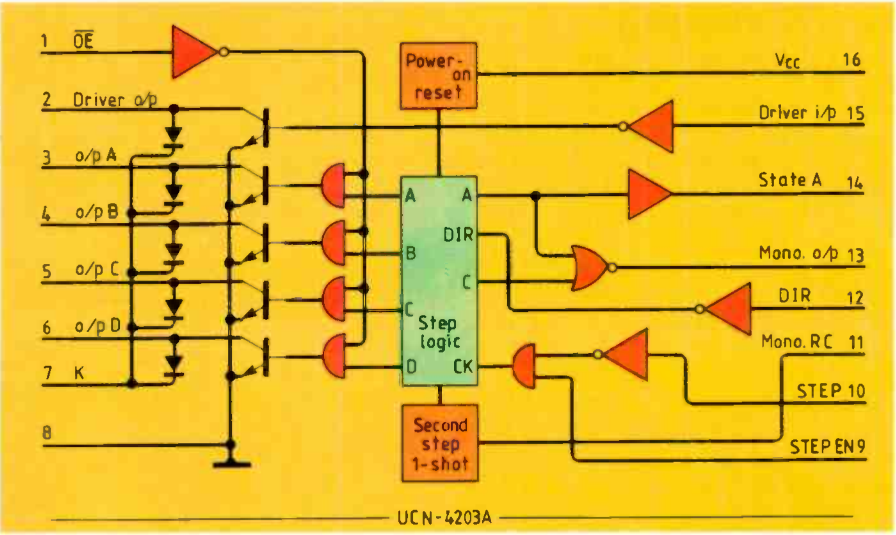
One i.c. decodes step and direction signals into 500mA stepping-motor drive signals. This i.c., the Sprague UCN4202, accommodates full-step or double-step operation and has built-in reset and transient suppression circuits. It also has a spare driver that can be used for the head-load solenoid in disc-drive applications.

Apart from this chopper drive circuit for 12V 500mA unipolar stepper motors there are four other circuits in the UCN4202 Engineering bulletin. They are two-phase




bipolar drivers for 500mA and 2A motors, an a.c. driver for 2A motors and a unipolar two-phase driver for 500mA motors. Brief specifications of fourteen small stepping motors from five North American manufacturers are given.

Special-purpose logic for disc-drive applications is built into the 4202. When output A is activated, pin 14 is high and its state can be combined with other drive logic to form the track-zero signal. An 'on-track' output can be taken from pin 13, which is low when outputs A or C are active. On-track is one of the conditions that must be met before writing is enabled.




ADDRESSES

ITT Semiconductors
145-147 Ewell Road
Surbiton
Surrey KT6 6AW
01 390 6578/9

Sprague Electric
HB Electronics
Lever St
Bolton
Lancashire BL3 6BJ
0204 386 363

Motorola
STC Electronic Services
Edinburgh Way
Harlow
Essex CM20 2DF
0279 442971

Intel
Accent Electronic Components
Jubilee House
Jubilee Road
Letchworth
Hertfordshire SG6 1TL

or

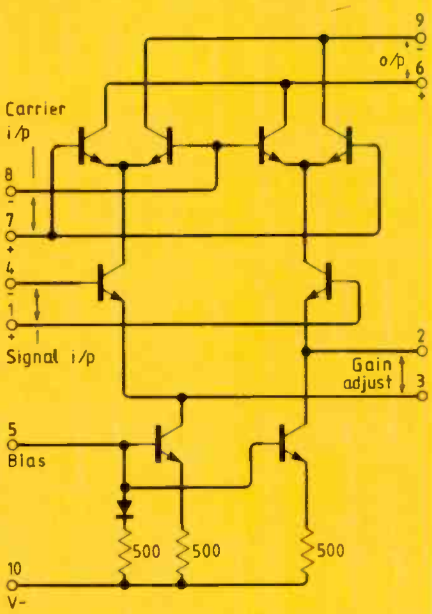
Jermyn Distribution
Vestry Estate
Otford Road
Sevenoaks
Kent TN14 5EU
0732 450144

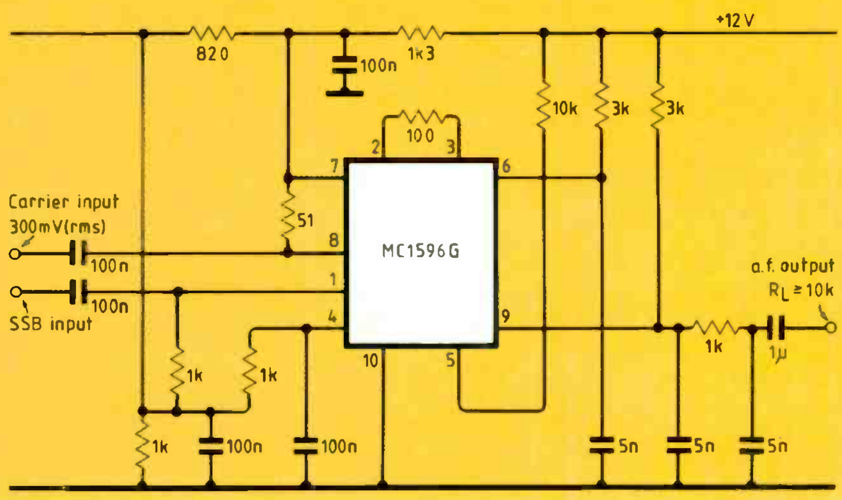
## Product detection without transformers and tuned circuits

A general description of the MC1596 balanced modulator, its gain equations, biasing information and six circuits form Motorola application note AN531. The 1596 functions as a broadband d.s.b. s.c. balanced modulator without transformers or tuned circuits.

In this s.s.b. product detector operating from a single 12V supply, all frequencies except the desired demodulated audio are r.f. and are thus easily filtered at the output. As a result, carrier-null adjustment is not essential.

Carrier level is 100 to 500mV, s.s.b. input is up to 100mV, and the circuit works from v.l.f. up to 100MHz. Sensitivity for a 9MHz s.s.b. input signal and a 10dB signal-plus-noise-to-noise ratio at the output is 3μV. With 0.5μV r.f., an s.s.b. receiver with 50Ω input impedance would require only 12dB overall power gain from antenna input terminals to the 1596 product detector.



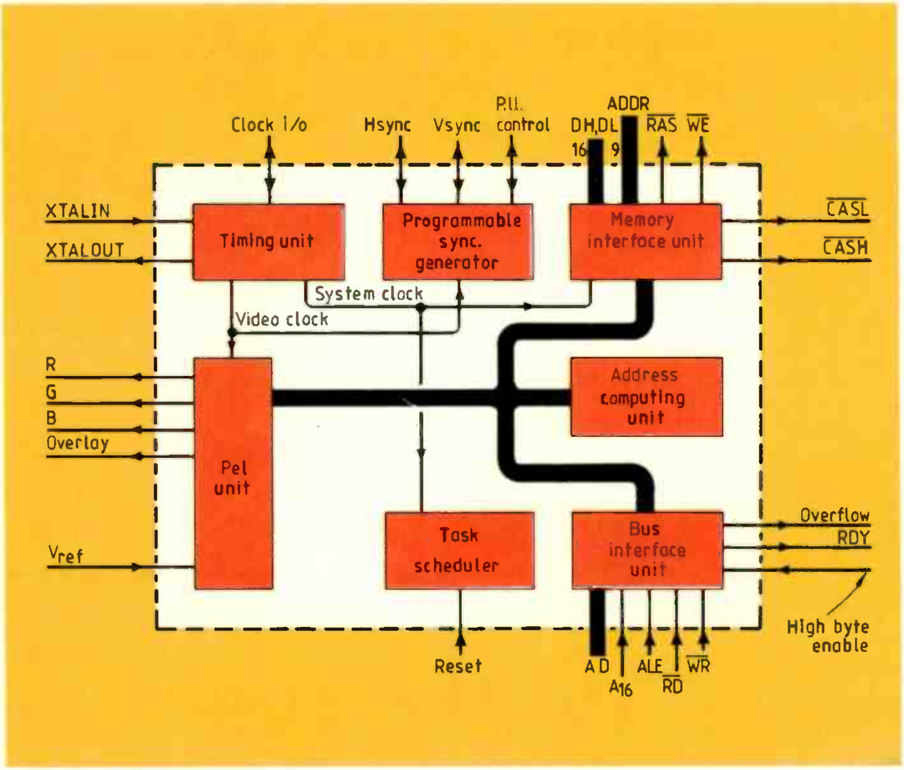



## High-integration graphics system

Seven i.cs and an 82716 video storage/display device form a colour-graphics controller with a resolution of 640 by 400 pels at 4bit/pel. When interfaced to an 80186 microprocessor no further control logic is needed.

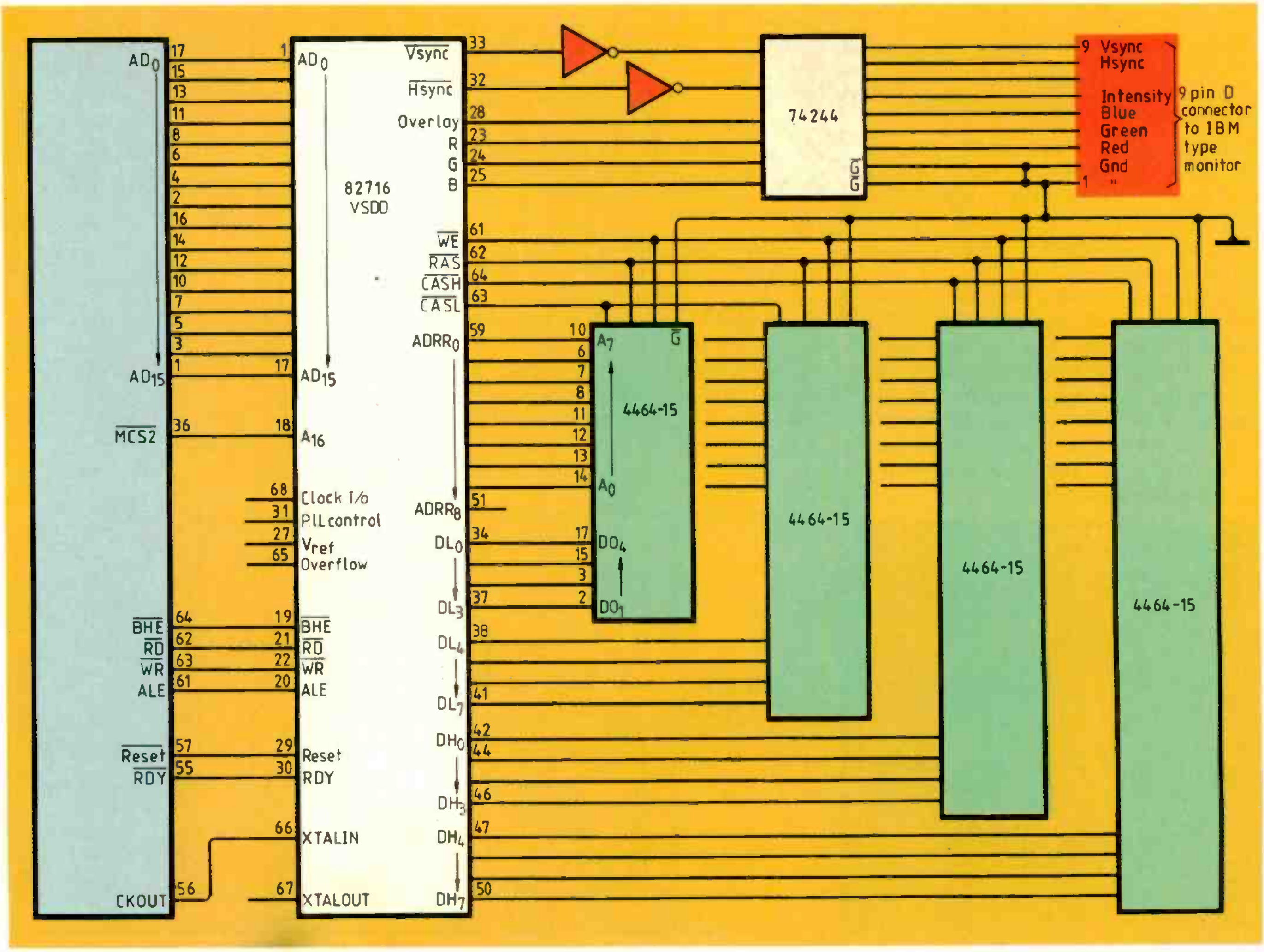
Inside the 82716 are a d-ram controller, a task scheduler, sync generators, a 16/4096 colour palette and video d-to-a converters. Although only 128Kbyte of d-ram is used here, the controller can handle up to 512Kbyte.

The Intel application note describing this controller includes assembly-language software details and video timing information for output to an IBM colour monitor.

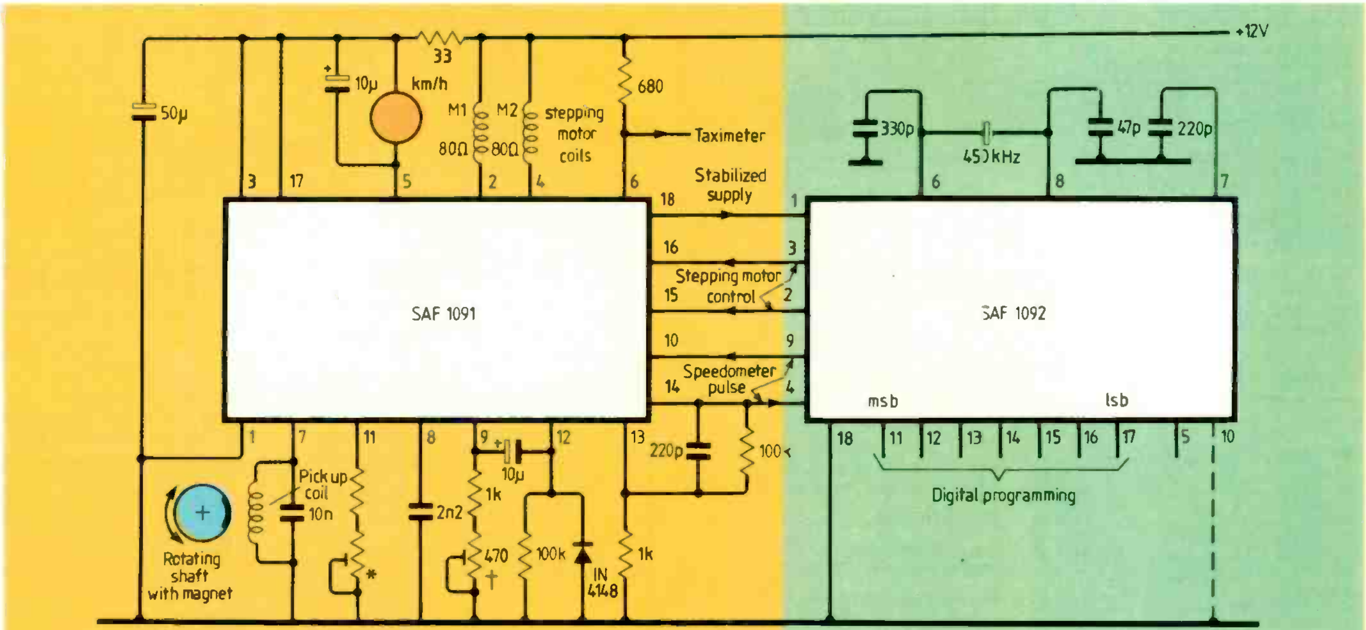



### Led driving considerations

Illustrations 4 and 5 from this application note described in the July issue were transposed but the table entries were correct. In the last two table entries, R is not quoted because it does not affect consumption; it is a low value used to limit current at power up.



# APPLICATIONS SUMMARY

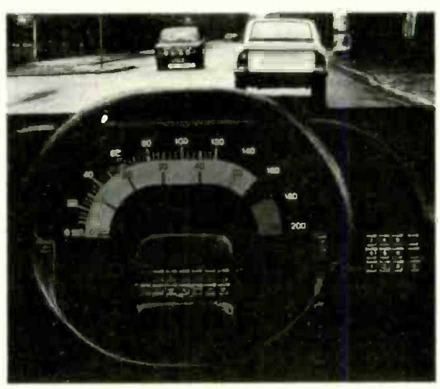


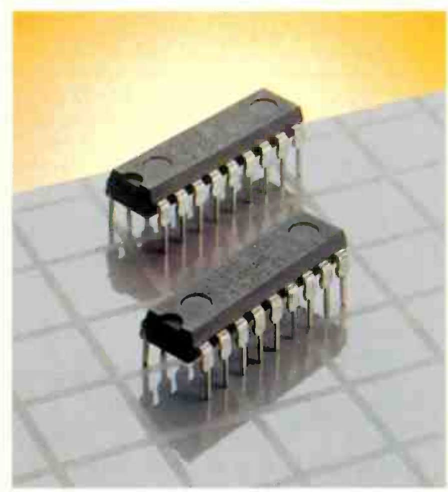

* Meter current † Input sensitivity

## Programmable speedometer and mileage indicator

A general-purpose digital speedometer i.c. needs to be programmable for different tyre diameters. In the SAF1091/92 i.c. pair, a programmable interface i.c. produces timing signals for a second i.c. which drives a speedometer, odometer and taximeter.

Few external components are needed, as this application example from ITT publication 6251-287-1E shows. Pulses from a proximity switch drive the speedometer. Two output pins drive the small stepping motor of an odometer and a further pulse output drives the speedometer; speed pulses are averaged by the meter's mechanical inertia.

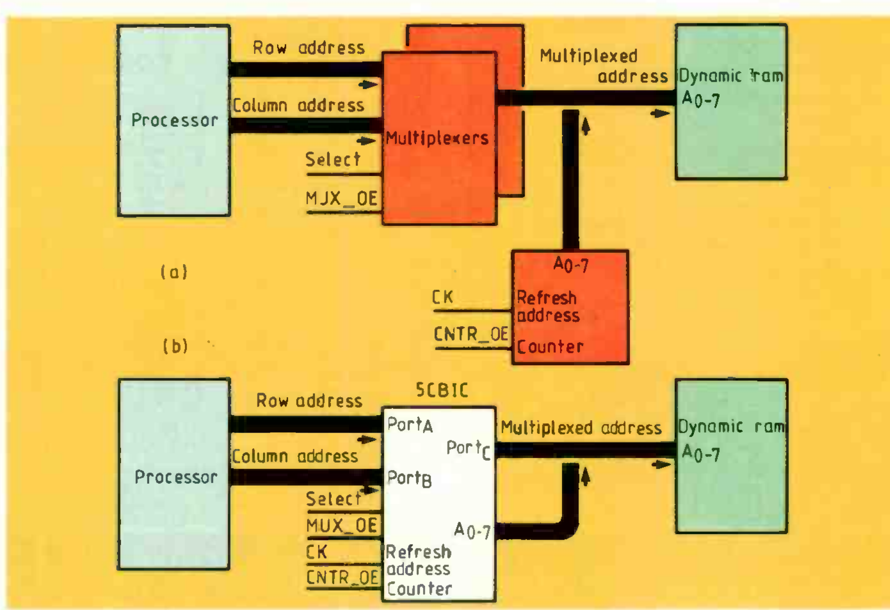




## Lower chip count for d-ram control

Most dynamic ram applications need multiplexers for row and column addresses and an address counter for refresh. Note AP309 from Intel describes how the 5CBIC programmable logic i.c. can replace the address counter and multiplexers. Design equations are given for the iPLDS II programmable-logic development system.

Three other recent notes relating to the 5CBIC describe configuring the device (AB17), dual-port memory control (AP305) and microprocessor bus demultiplexing (AP308).



# 01-208 1177 TECHNOMATIC LTD 01-208 1177

## BBC Computer & Econet Referral Centre

AMB15 BBC MASTER ( · free software £346 (a) ........ AMB12 BBC MASTER Econet £315 (a)
AMC06 Turbo (65C – 02) Expansion Module ........ £99 (b)

| | | | | | |
|---|---|---|---|---|---|
| ADC08 | 512 Processor | £195 (b) | ADJ24 | Advanced Ref Manual | £19.50 (c) |
| ADF14 | Rom Cartridge | £13 (b) | ADF10 | Econet Module | £41 (c) |
| ADJ22 | Ref Manual Part 1 | £14 (c) | ADJ23 | Ref Manual Part II | £14 (c) |
| | | | | BBC Master Dust Cover | £4.75 (d) |

**BBC MASTER COMPACT**
Free bundled software within price
SYSTEM 1 128K Single 640K Drive and bundled software £349 (a)
SYSTEM 2 System 1 with a 12" Hi Res RGB Monitor £399 (a)
SYSTEM 3 System 1 with a 14" Med Res RGB Monitor £549 (a)
Second Drive Kit £99 (c) Extension Cable for ext 5.25" drive £12.50 (d)

**ARCHIMEDES**
Limited quantities of these new computers are now available. Place your orders now to ensure early delivery.

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ACORN Z80 2nd Processors £329 (a) ........ Universal 2nd Processor Adaptor £75 (b)
MULTIFORM Z80 2nd Processor £289 (b) ........ ACORN IEEE Interface £265 (a)
TORCH Z80 2nd Processor ZEP 100 ........ £229 (a)
TZDP 240: ZEP 100 with Technomatic PD800P dual drive with built-in monitor stand ........ £439 (a)

**META Version III** – The only package available in the micro market that will assemble 27 different processors at the price offered. Supplied on two 16K roms and two discs and fully compatible with all BBC models. Please phone for comprehensive leaflet £145 (b).

We stock the full range of ACORN hardware and firmware and a very wide range of other peripherals for the BBC. For detailed specifications and pricing please send for our leaflet.

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PS400 400K/640K with integral mains power supply ........ £115 (b)
**5.25" Dual Drives 40/80 switchable:**
TD800 800K/1280K ........ £185 (a)
PD800 800K/1280K with integral mains power supply ........ £209 (a)
PD800P 800K/1280K with integral mains power supply and monitor stand ........ £229 (a)
**3.5" 80T DS Drives:**
TS351 Single 400K/640K ........ £75 (b)
PS351 Single 400K/640K with integral mains power supply ........ £99 (b)
TD352 Dual 800K/1280K ........ £134 (b)
PD352 Dual 800K/1280K with integral mains power supply ........ £152 (b)
PD853 Combo Dua 5.25"/3.5" drive with p.s.u. ........ £209 (a)

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| 80 T SS DD | £11.50 (d) | 80 T DS DD | £13.25 (d) | 80 T DS DD | £19.50 (d) |

## FLOPPICLENE DRIVEHEAD CLEANING KIT

FLOPPICLENE Disc Head Cleaning Kit with 28 disposable cleaning discs ensures continued optimum performance of the drives. 5¼" £12.50 (d)
3½" £14.00 (d)

### DRIVE ACCESSORIES

| | |
|---|---|
| Single Disc Cable £6 (d) | Dual Disc Cable £8.50 (d) |
| 10 Disc Library Case £1.80 (d) | 30 × 5½" Disc Storage Box £6 (c) |
| 50 × 5½" Disc Lockable Box £9.00 (c) | 100 × 5½" Disc Lockable Box £13 (c) |

## PRINTERS & PLOTTERS

**EPSON**
LX800 ........ £229 (a)
FX800 ........ £315 (a)
FX1000 ........ £439 (a)
EX800 ........ £409 (a)
EX1000 ........ £595 (a)
LQ800 (80 col) ........ £439 (a)
LQ1000 ........ £609 (a)

**TAXAN**
KP815 (160 cps) ........ £269 (a)
KP915 (180 cps) ........ £369 (a)

**JUKI**
6100 (Daisy Wheel) ........ £319 (a)

**NATIONAL PANASONIC**
KX P1081 (80 col) ........ £159 (a)
KX P 3131 (37K buffer) ........ £249 (a)
KX P 3132 (32K buffer) ........ £249 (a)

**STAR** NL10 (Parallel Interface) ........ £209 (a)
**STAR** NL10 (Serial Interface) ........ £239 (a)

**BROTHER** HR20 ........ £349 (a)

**COLOUR PRINTERS**
Integrex Jet Printer ........ £549 (a)

**Dotprint Plus** NLQ Rom for Epson versions for FX, RX, MX and GLP ........ £28 (d)

**PLOTTERS**
Hitachi 672 ........ £495 (a)
Plotmate A4S ........ £370 (a)
Plotmate A4SM ........ £450 (a)
Plotmate A3M ........ £569 (a)

## MONITORS

**RGB 14"**
1431 Std Res ........ £179 (a)
1451 Med Res ........ £225 (a)
1441 Hi Res ........ £359 (a)

**MICROVITEC 14" RGB/PAL/Audio**
1431AP Std Res ........ £199 (a)
1451AP Std Res ........ £255 (a)
All above monitors available in plastic or metal case.

**TAXAN SUPERVISION 620**
12" – Hi Res with amber/green options.
IBM compatible ........ £269 (a)
Taxan Supervision 625 ........ £319 (a)

**MONOCHROME**
**TAXAN** 12" HI-RES
**KX117** Hi Res green screen ........ £85 (a)
**KX118** Hi Res long persistence ........ £90 (a)
**KX119** Hi Res amber ........ £90 (a)
**PHILIPS** 12" HI-RES
BM7502 green screen ........ £69 (a)
BM7522 amber screen ........ £75 (a)
BM7542 white screen ........ £79 (a)

**ACCESSORIES**
Microvitec Swivel Base ........ £20 (c)
Taxan Mono Swivel Base with clock ........ £22 (c)
Philips Swivel Base ........ £14 (c)
BBC RGB Cable ........ £5 (d)
Microvitec ........ £3.50 (d)
Taxan £5 (d) ........ Monochrome £3.50 (d)
Touchtec – 501 ........ £239 (b)

## PRINTER ACCESSORIES

We hold a wide range of printer attachments (sheet feeders, tractor feeds etc) in stock. Serial, parallel, IEEE and other interfaces also available. Ribbons available for all above plotters. Pens with a variety of tips and colours also available. Please phone for details and prices.
**Plain Fanfold Paper with extra fine perforation (Clean Edge):**
2000 sheets 9.5" × 11" £13(b) 2000 sheets 14.5" × 11" £18.50(b)
Labels per 1000s: Single Row 3½" × 1 7/16" £5.25(d) Triple Row 2-7/16" × 1 7/16" £5.00(d)

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UV1T Eraser with built-in timer and mains indicator. Built-in safety interlock to avoid accidental exposure to the harmful UV rays.
It can handle up to 5 eproms at a time with an average erasing time of about 20 mins. £59 + £2 p&p.
UV1 as above but without the timer. £47 + £2 p&p.
For Industrial Users, we offer UV140 & UV141 erasers with handling capacity of 14 eproms. UV141 has a built in timer. Both offer full built in safety features UV140 £69, UV141 £85, p&p £2.50.

## EXT SERIAL/PARALLEL CONVERTERS

Mains powered converters
Serial to Parallel ........ £48 (c)
Parallel to Serial ........ £48 (c)
Bidirectional Converter ........ £105 (b)

## MODEMS

All modems carry a full BT approval

**MIRACLE TECHNOLOGY WS Range**

**WS4000 V21/23** (Hayes Compatible, Intelligent, Auto Dial/Auto Answer) ........ £149 (b)

**WS3000 V21/23 Professional** As WS4000 and with BELL standards and battery back up for memory ........ £295 (b)

**WS3000 V22 Professional** As WS300 V21/23 but with 1200 baud full duplex ........ £495 (a)

**WS3000 V22 bis Professional** As V22 and 2400 baud full duplex ........ £650 (a)

***The price of WS4000 and WS3000 modems includes a COMMSTAR II ROM and BBC Data Cable.***

**WS2000 V21/V23** Manual Modem ........ £95 (b)
DATA Cable for WS series/PC or XT ........ £10 (d)
Auto Dial Card ........ £27 (d)
Auto Answer Card ........ £27 (d)
WS2000 SK I Kit ........ £5 (d)

***This offer can only apply if it is specified at the time of placing your order for the modem.***

**RT256 3 PORT SWITCHOVER SERIAL INTERFACE**
3 input/1 output or 1 input/3 output manual channel selection. Input/output baud rates. Independently selectable 7 bit/8 bit, odd/even/none parity. Hardware or software handshake. 256K buffer, mains powered ........ £375 (b)

**PB BUFFER**
Internal buffer for most Epson printers. Easy to install. Inst. supplied.
PB128 128K ........ £99 (c)

### Serial Test Cable

Serial Cable switchable at both ends allowing pin options to be re-routed or linked at either end — making it possible to produce almost any cable configuration on site.
Available as M/M or M/F £24.75 (d)

### Serial Mini Patch Box

Allows an easy method to reconfigure pin functions without rewiring the cable assay. Jumpers can be used and reused. £22 (d)

### Serial Mini Test

Monitors RS232C and CCITT V24 Transmissions, indicating status with dual colour LEDs on 7 most significant lines. Connects in Line. £22.50 (d)

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This low cost intelligent eprom programmer can program 2716, 2516, 2532, 2732, and with an adaptor, 2564 and 2764. Displays 512 byte page on TV — has a serial and parallel I/O routines. Can be used as an emulator, cassette interface.
Softy II ........ £195.00(b)
Adaptor for 2764/2564 ........ £25.00

## SPECIAL OFFER

2764-25
27128-25
27258
27612
6264 LP-15

All prices on application

## CONNECTOR SYSTEMS

### I.D. CONNECTORS

(Speedblock Type)

| No of ways | Header Plug | Receptacle | Edge Conn |
|---|---|---|---|
| 10 | 90p | 85p | 120p |
| 20 | 145p | 125p | 195p |
| 26 | 175p | 150p | 240p |
| 34 | 200p | 160p | 320p |
| 40 | 220p | 190p | 340p |
| 50 | 235p | 200p | 390p |

### D CONNECTORS

No of Ways

| | 9 | 15 | 25 | 37 |
|---|---|---|---|---|
| **MALE:** | | | | |
| Ang Pins | 120 | 180 | 230 | 350 |
| Solder | 60 | 85 | 125 | 170 |
| IDC | 175 | 275 | 325 | — |
| **FEMALE:** | | | | |
| St Pin | 100 | 140 | 210 | 380 |
| Ang Pins | 160 | 210 | 275 | 440 |
| Solder | 90 | 130 | 195 | 290 |
| IDC | 195 | 325 | 375 | — |
| St Hood | 90 | 95 | 100 | 120 |
| Screw Lock | 130 | 150 | 175 | — |

### TEXTOOL ZIF

SOCKETS
24-pin £7.50
28-pin £9.10
40 pin £12:10

### EDGE CONNECTORS

| | 0 1" | 0 156" |
|---|---|---|
| 2 × 6-way (commodore) | — | 300p |
| 2 × 10-way | 150p | — |
| 2 × 12-way (vic 20) | — | 350p |
| 2 × 18-way | — | 140p |
| 2 × 23-way (ZX81) | 175p | 220p |
| 2 × 25-way | 225p | 220p |
| 2 × 28-way (Spectrum) | 200p | — |
| 2 × 36-way | 250p | — |
| 1 × 43-way | 260p | — |
| 2 × 22-way | 190p | — |
| 2 × 43-way | 395p | — |
| 1 × 77-way | 400p | 500p |
| 2 × 50-way (S100conn) | 600p | — |

### EURO CONNECTORS

| DIN 41612 | Plug | Skt |
|---|---|---|
| 2 × 32 way St Pin | 230p | 275p |
| 2 × 32 way Ang Pin | 275p | 320p |
| 3 × 32 way St Pin | 260p | 300p |
| 3 × 32 way Ang Pin | 375p | 400p |
| IDC Skt A + B | 400p | |
| IDC Skt A + C | 400p | |

For 2 × 32 way please specify spacing (A + B, A + C).

### MISC CONNS

21 pin Scart Connector 200p
8 pin Video Connector 200p

### AMPHENOL CONNECTORS

36 way plug Centronics (solder 500p (IDC) 475p
36 way skt Centronics (solder) 550p (IDC) 500p
24 way plug IEEE (solder) 475p (IDC) 475p
24 way skt IEEE (solder) 500p (IDC) 500p
PCB Mtg Skt Ang Pin
24 way 700p 36 way 750p

### GENDER CHANGERS

25 way D type

Male to Male ........ £10
Male to Female ........ £10
Female to Female ........ £10

### RS 232 JUMPERS

(25 way D)

24" Single end Male £5.00
24" Single end Female £5.25
24" Female Female £10.00
24" Male Male £9.50
24" Male Female £9.50

### DIL SWITCHES

| | | | |
|---|---|---|---|
| 4-way | 90p | 6-way | 105p |
| 8-way | 120p | 10-way | 150p |

### RIBBON CABLE

(grey/metre)

| | | | |
|---|---|---|---|
| 10-way | 40p | 34-way | 160p |
| 16-way | 60p | 40-way | 180p |
| 20-way | 85p | 50-way | 200p |
| 26-way | 120p | 64-way | 280p |

### DIL HEADERS

| | Solder | IDC |
|---|---|---|
| 14 pin | 40p | 100p |
| 16 pin | 50p | 110p |
| 18 pin | 60p | — |
| 20 pin | 75p | — |
| 24 pin | 100p | 150p |
| 28 pin | 160p | 200p |
| 40 pin | 200p | 225p |

## ATTENTION

All prices in this double page advertisment are subject to change without notice.
ALL PRICES EXCLUDE VAT
Please add carriage 50p unless indicated as follows:
(a) £8 (b) £2.50 (c) £1.50 (d) £1.00

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## 74 SERIES

| | |
|---|---|
| 7400 | 0.30 |
| 7401 | 0.30 |
| 7402 | 0.30 |
| 7403 | 0.30 |
| 7404 | 0.36 |
| 7405 | 0.30 |
| 7406 | 0.40 |
| 7407 | 0.40 |
| 7408 | 0.30 |
| 7409 | 0.30 |
| 7410 | 0.30 |
| 7411 | 0.30 |
| 7412 | 0.30 |
| 7413 | 0.50 |
| 7414 | 0.70 |
| 7416 | 0.36 |
| 7417 | 0.40 |
| 7420 | 0.30 |
| 7421 | 0.60 |
| 7422 | 0.36 |
| 7423 | 0.36 |
| 7425 | 0.40 |
| 7426 | 0.40 |
| 7427 | 0.32 |
| 7428 | 0.43 |
| 7430 | 0.30 |
| 7432 | 0.36 |
| 7433 | 0.30 |
| 7437 | 0.30 |
| 7438 | 0.40 |
| 7439 | 0.40 |
| 7440 | 0.40 |
| 7441 | 0.90 |
| 7442A | 0.70 |
| 7443A | 1.00 |
| 7444 | 1.10 |
| 7445 | 0.70 |
| 7446A | 1.00 |
| 7447A | 1.00 |
| 7448 | 1.00 |
| 7450 | 0.36 |
| 7451 | 0.35 |
| 7453 | 0.38 |
| 7454 | 0.38 |
| 7460 | 0.55 |
| 7470 | 0.50 |
| 7472 | 0.45 |
| 7473 | 0.45 |
| 7474 | 0.50 |
| 7475 | 0.60 |
| 7476 | 0.45 |
| 7480 | 0.65 |
| 7481 | 1.80 |
| 7483A | 1.05 |
| 7484A | 1.25 |
| 7485 | 1.10 |
| 7486 | 0.42 |
| 7489 | 2.10 |
| 7490A | 0.55 |
| 7491 | 0.70 |
| 7492A | 0.70 |
| 7493A | 0.55 |
| 7494 | 1.10 |
| 7495A | 0.60 |
| 7496 | 0.80 |
| 7497 | 2.90 |
| 74100 | 1.90 |
| 74107 | 0.50 |
| 74109 | 0.75 |
| 74110 | 0.75 |
| 74111 | 0.55 |
| 74116 | 1.70 |
| 74118 | 1.10 |
| 74119 | 1.70 |
| 74120 | 1.00 |
| 74121 | 0.55 |
| 74122 | 0.70 |
| 74123 | 0.80 |
| 74125 | 0.65 |
| 74126 | 0.55 |
| 74128 | 0.55 |
| 74132 | 0.75 |
| 74136 | 0.70 |
| 74141 | 0.90 |
| 74142 | 2.50 |
| 74143 | 1.30 |
| 74144 | 2.70 |
| 74145 | 1.10 |
| 74147 | 1.70 |
| 74148 | 1.40 |
| 74150 | 1.75 |
| 74151A | 0.70 |
| 74153 | 0.80 |
| 74154 | 1.40 |
| 74155 | 0.80 |
| 74156 | 0.90 |
| 74157 | 0.80 |
| 74159 | 2.25 |
| 74160 | 1.10 |
| 74161 | 0.80 |
| 74162 | 1.10 |
| 74163 | 1.10 |
| 74164 | 1.20 |
| 74165 | 1.10 |
| 74166 | 1.40 |
| 74167 | 4.00 |
| 74170 | 2.00 |
| 74172 | 4.20 |
| 74173 | 1.40 |
| 74174 | 1.00 |
| 74175 | 1.05 |
| 74176 | 1.00 |
| 74178 | 1.50 |
| 74179 | 1.50 |
| 74180 | 1.00 |
| 74181 | 3.40 |
| 74182 | 1.40 |
| 74184 | 1.80 |
| 74185A | 1.80 |
| 74190 | 1.30 |
| 74191 | 1.30 |
| 74192 | 1.10 |
| 74193 | 1.15 |
| 74194 | 1.10 |
| 74195 | 0.80 |
| 74196 | 1.30 |
| 74197 | 1.10 |
| 74198 | 2.20 |
| 74199 | 2.20 |
| 74221 | 1.10 |
| 74251 | 1.00 |
| 74259 | 1.50 |
| 74265 | 0.80 |
| 74273 | 2.00 |
| 74276 | 1.40 |
| 74278 | 1.70 |
| 74279 | 0.90 |
| 74283 | 1.05 |
| 74742 | 3.20 |
| 74290 | 0.90 |
| 74293 | 0.90 |
| 74298 | 1.80 |
| 74351 | 2.00 |
| 74365A | 0.80 |
| 74366A | 0.80 |
| 74367A | 0.80 |
| 74376 | 1.60 |
| 74390 | 1.10 |
| 74393 | 1.20 |
| 74490 | 1.40 |

## 74LS SERIES

| | |
|---|---|
| 74LS00 | 0.24 |
| 74LS01 | 0.24 |
| 74LS02 | 0.24 |
| 74LS03 | 0.24 |
| 74LS04 | 0.24 |
| 74LS05 | 0.24 |
| 74LS08 | 0.24 |
| 74LS09 | 0.24 |
| 74LS10 | 0.24 |
| 74LS11 | 0.24 |
| 74LS13 | 0.34 |
| 74LS14 | 0.50 |
| 74LS15 | 0.24 |
| 74LS20 | 0.24 |
| 74LS21 | 0.24 |
| 74LS22 | 0.24 |
| 74LS24 | 0.50 |
| 74LS26 | 0.26 |
| 74LS27 | 0.24 |
| 74LS28 | 0.24 |
| 74LS30 | 0.24 |
| 74LS32 | 0.24 |
| 74LS33 | 0.24 |
| 74LS37 | 0.24 |
| 74LS38 | 0.24 |
| 74LS40 | 0.24 |
| 74LS42 | 0.50 |
| 74LS43 | 1.50 |
| 74LS48 | 0.90 |
| 74LS49 | 1.00 |
| 74LS51 | 0.24 |
| 74LS54 | 0.24 |
| 74LS55 | 0.24 |
| 74LS73A | 0.30 |
| 74LS74A | 0.35 |
| 74LS75 | 0.45 |
| 74LS76A | 0.36 |
| 74LS78 | 0.42 |
| 74LS83A | 0.70 |
| 74LS85 | 0.75 |
| 74LS86 | 0.35 |
| 74LS90 | 0.48 |
| 74LS91 | 0.90 |
| 74LS92 | 0.35 |
| 74LS93 | 0.54 |
| 74LS95B | 0.75 |
| 74LS96 | 0.90 |
| 74LS107 | 0.40 |
| 74LS109 | 0.45 |
| 74LS112 | 0.45 |
| 74LS113 | 0.45 |
| 74LS114 | 0.45 |
| 74LS122 | 0.70 |
| 74LS123 | 0.80 |
| 74LS125 | 0.50 |
| 74LS126 | 0.50 |
| 74LS132 | 0.65 |
| 74LS133 | 0.55 |
| 74LS136 | 0.45 |
| 74LS138 | 0.55 |
| 74LS139 | 0.55 |
| 74LS145 | 0.95 |
| 74LS147 | 1.75 |
| 74LS148 | 1.40 |
| 74LS151 | 0.65 |
| 74LS152 | 2.00 |
| 74LS153 | 0.65 |
| 74LS154 | 1.60 |
| 74LS155 | 0.65 |
| 74LS156 | 0.65 |
| 74LS157 | 0.50 |
| 74LS158 | 0.65 |
| 74LS160A | 0.65 |
| 74LS161A | 0.75 |
| 74LS162A | 0.75 |
| 74LS163A | 0.75 |
| 74LS164 | 0.75 |
| 74LS165A | 1.10 |
| 74LS166A | 1.50 |
| 74LS168 | 1.30 |
| 74LS169 | 1.00 |
| 74LS170 | 1.40 |
| 74LS173A | 1.00 |
| 74LS174 | 0.75 |
| 74LS175 | 0.75 |
| 74LS181 | 2.00 |
| 74LS183 | 1.90 |
| 74LS190 | 0.75 |
| 74LS191 | 0.75 |
| 74LS192 | 0.80 |
| 74LS194A | 0.75 |
| 74LS195A | 0.75 |
| 74LS196 | 0.80 |
| 74LS197 | 0.80 |
| 74LS221 | 0.90 |
| 74LS240 | 0.80 |
| 74LS241 | 0.80 |
| 74LS242 | 0.90 |
| 74LS243 | 0.90 |
| 74LS244 | 0.70 |
| 74LS245 | 0.90 |
| 74LS247 | 1.10 |
| 74LS248 | 1.10 |
| 74LS249 | 1.10 |
| 74LS251 | 0.75 |
| 74LS253 | 0.75 |
| 74LS2457A | 0.70 |
| 74LS258A | 0.70 |
| 74LS259 | 1.20 |
| 74LS260 | 0.75 |
| 74LS266 | 0.60 |
| 74LS273 | 1.25 |
| 74LS279 | 0.70 |
| 74LS280 | 1.90 |
| 74LS283 | 0.80 |
| 74LS290 | 0.80 |
| 74LS292 | 14.00 |
| 74LS293 | 0.80 |
| 74LS295 | 1.40 |
| 74LS297 | 14.00 |
| 74LS298 | 1.00 |
| 74LS299 | 2.20 |
| 74LS321 | 3.70 |
| 74LS322A | 3.90 |
| 74LS323 | 3.00 |
| 74LS324 | 3.20 |
| 74LS348 | 2.00 |
| 74LS352 | 1.20 |
| 74LS353 | 1.20 |
| 74LS356 | 2.10 |
| 74LS363 | 1.80 |
| 74LS364 | 1.80 |
| 74LS365 | 0.50 |
| 74LS366 | 0.50 |
| 74LS367 | 0.52 |
| 74LS368 | 0.50 |
| 74LS373 | 0.70 |
| 74LS374 | 0.70 |
| 74LS375 | 0.75 |
| 74LS377 | 1.30 |
| 74LS378 | 0.95 |
| 74LS379 | 1.30 |
| 74LS381 | 4.50 |
| 74LS385 | 3.25 |
| 74LS390 | 0.60 |
| 74LS393 | 1.00 |
| 74LS395A | 1.00 |
| 74LS399 | 1.40 |
| 74LS445 | 1.80 |
| 74LS465 | 1.20 |
| 74LS467 | 1.20 |
| 74LS490 | 1.50 |
| 74LS540 | 1.00 |
| 74LS541 | 1.00 |
| 74LS608 | 7.00 |
| 74LS610 | 25.00 |
| 74LS612 | 25.00 |
| 74LS624 | 3.50 |
| 74LS626 | 2.25 |
| 74LS628 | 2.25 |
| 74LS629 | 1.25 |
| 74LS640 | 2.00 |
| 74LS640-1 | 3.00 |
| 74LS641 | 1.50 |
| 74LS642 | 2.50 |
| 74LS642-1 | 3.00 |
| 74LS643 | 2.50 |
| 74LS643-1 | 3.00 |
| 74LS644 | 3.50 |
| 74LS645 | 2.00 |
| 74LS645-1 | 4.00 |
| 74LS668 | 0.90 |
| 74LS669 | 0.90 |
| 74LS670 | 1.70 |
| 74LS682 | 2.50 |
| 74LS683 | 3.00 |
| 74LS684 | 3.50 |
| 74LS687 | 3.50 |
| 74LS688 | 3.50 |
| 74LS783 | 16.00 |

## 74S SERIES

| | |
|---|---|
| 74S00 | 0.50 |
| 74S02 | 0.50 |
| 74S04 | 0.50 |
| 74S05 | 0.50 |
| 74S08 | 0.50 |
| 74S10 | 0.50 |
| 74S11 | 0.75 |
| 74S20 | 0.50 |
| 74S22 | 0.50 |
| 74S30 | 0.50 |
| 74S32 | 0.60 |
| 74S37 | 0.60 |
| 74S38 | 0.60 |
| 74S40 | 0.50 |
| 74S51 | 0.60 |
| 74S64 | 0.45 |
| 74S74 | 0.70 |
| 74S85 | 5.50 |
| 74S86 | 1.00 |
| 74S112 | 1.50 |
| 74S113 | 1.20 |
| 74S114 | 1.20 |
| 74S124 | 3.00 |
| 74S132 | 1.00 |
| 74S133 | 0.60 |
| 74S138 | 1.80 |
| 74S139 | 1.80 |
| 74S140 | 1.00 |
| 74S151 | 1.50 |
| 74S153 | 1.50 |
| 74S157 | 2.00 |
| 74S158 | 2.00 |
| 74S163 | 3.00 |
| 74S169 | 5.50 |
| 74S174 | 3.00 |
| 74S175 | 3.20 |
| 74S188 | 1.80 |
| 74S189 | 1.80 |
| 74S194 | 3.00 |
| 74S195 | 3.00 |
| 74S196 | 3.50 |
| 74S200 | 4.50 |
| 74S201 | 3.20 |
| 74S225 | 5.20 |
| 74S240 | 4.00 |
| 74S241 | 4.00 |
| 74S244 | 4.00 |
| 74S251 | 2.50 |
| 74S257 | 2.50 |
| 74S258 | 2.50 |
| 74S260 | 1.00 |
| 74S261 | 3.00 |
| 74S283 | 2.70 |
| 74S287 | 2.25 |
| 74S288 | 2.00 |
| 74S289 | 2.25 |
| 74S299 | 4.50 |
| 74S373 | 4.00 |
| 74S374 | 4.00 |
| 74S387 | 2.25 |

## 74C SERIES

| | |
|---|---|
| 74C00 | 0.70 |
| 74C04 | 0.50 |
| 74C08 | 0.70 |
| 74C10 | 0.70 |
| 74C14 | 0.50 |
| 74C20 | 0.70 |
| 74C32 | 1.00 |
| 74C42 | 1.50 |
| 74C48 | 1.50 |
| 74C73 | 1.00 |
| 74C74 | 1.20 |
| 74C76 | 1.00 |
| 74C83 | 2.00 |
| 74C85 | 2.25 |
| 74C86 | 0.50 |
| 74C90 | 1.90 |
| 74C93 | 1.50 |
| 74C95 | 1.60 |
| 74C107 | 1.00 |
| 74C150 | 5.00 |
| 74C151 | 2.00 |
| 74C157 | 2.50 |
| 74C160 | 1.80 |
| 74C161 | 1.80 |
| 74C162 | 1.80 |
| 74C163 | .80 |
| 74C173 | 1.00 |
| 74C174 | 1.50 |
| 74C175 | 1.50 |
| 74C193 | 1.50 |
| 74C194 | 1.50 |
| 74C195 | 1.50 |
| 74C221 | 2.50 |
| 74C244 | 2.25 |
| 74C245 | 2.25 |
| 74C373 | 2.25 |
| 74C374 | 2.25 |
| 74C902 | 1.20 |
| 74C911 | 9.00 |
| 74C912 | 4.50 |
| 74C922 | 6.00 |
| 74C923 | 6.50 |
| 74C925 | 6.50 |
| 74C926 | 7.50 |

## 74ALS SERIES

| | |
|---|---|
| 74ALS00 | 0.45 |
| 74ALS02 | 0.45 |
| 74ALS04 | 0.50 |
| 74ALS08 | 0.50 |
| 74ALS10 | 0.45 |
| 74ALS20 | 0.45 |
| 74ALS32 | 0.45 |
| 74ALS74 | 0.70 |
| 74ALS138 | 1.50 |
| 74ALS139 | 1.50 |
| 74ALS244 | 4.00 |
| 74ALS245 | 4.75 |
| 74ALS573 | 2.60 |
| 74ALS574 | 4.50 |
| 74ALS580 | 2.60 |

## 4000 SERIES

| | |
|---|---|
| 4000 | 0.20 |
| 4001 | 0.24 |
| 4002 | 0.25 |
| 4006 | 0.70 |
| 4007 | 0.25 |
| 4008 | 0.60 |
| 4009 | 0.45 |
| 4010 | 0.60 |
| 4011 | 0.24 |
| 4012 | 0.25 |
| 4013 | 0.36 |
| 4014 | 0.60 |
| 4015 | 0.70 |
| 4016 | 0.36 |
| 4017 | 0.55 |
| 4018 | 0.60 |
| 4019 | 0.60 |
| 4020 | 0.80 |
| 4021 | 0.80 |
| 4022 | 0.70 |
| 4023 | 0.30 |
| 4024 | 0.48 |
| 4025 | 0.90 |
| 4026 | 0.40 |
| 4027 | 0.60 |
| 4028 | 0.75 |
| 4029 | 0.35 |
| 4030 | 1.25 |
| 4031 | 1.25 |
| 4032 | 1.00 |
| 4033 | 1.25 |
| 4034 | 2.50 |
| 4035 | 0.70 |
| 4036 | 2.50 |
| 4037 | 1.10 |
| 4038 | 1.00 |
| 4040 | 0.60 |
| 4041 | 0.55 |
| 4042 | 0.50 |
| 4043 | 0.60 |
| 4044 | 0.60 |
| 4045 | 1.00 |
| 4046 | 0.60 |
| 4047 | 0.60 |
| 4048 | 0.55 |
| 4049 | 0.36 |
| 4050 | 0.35 |
| 4051 | 0.65 |
| 4052 | 0.60 |
| 4053 | 0.60 |
| 4054 | 0.80 |
| 4055 | 0.80 |
| 4056 | 0.85 |
| 4060 | 0.70 |
| 4063 | 0.85 |
| 4066 | 0.40 |
| 4067 | 2.30 |
| 4068 | 0.25 |
| 4069 | 0.24 |
| 4070 | 0.24 |
| 4071 | 0.24 |
| 4072 | 0.24 |
| 4073 | 0.24 |
| 4075 | 0.24 |
| 4076 | 0.65 |
| 4077 | 0.25 |
| 4078 | 0.25 |
| 4081 | 0.24 |
| 4082 | 0.25 |
| 4085 | 0.60 |
| 4086 | 0.75 |
| 4089 | 1.20 |
| 4093 | 0.35 |
| 4094 | 0.90 |
| 4095 | 0.95 |
| 4096 | 0.90 |
| 4097 | 2.70 |
| 4098 | 0.75 |
| 4099 | 0.99 |
| 4501 | 0.36 |
| 4502 | 0.55 |
| 4503 | 0.36 |
| 4504 | 0.95 |
| 4505 | 3.60 |
| 4506 | 0.90 |
| 4507 | 0.35 |
| 4508 | 1.20 |
| 4510 | 0.55 |
| 4511 | 0.55 |
| 4512 | 0.55 |
| 4513 | 1.50 |
| 4514 | 1.10 |
| 4515 | 1.10 |
| 4516 | 0.55 |
| 4517 | 2.20 |
| 4518 | 0.48 |
| 4519 | 0.32 |
| 4520 | 0.60 |
| 4521 | 1.15 |
| 4522 | 0.80 |
| 4526 | 0.70 |
| 4527 | 0.80 |
| 4528 | 0.65 |
| 4529 | 1.00 |
| 4531 | 0.75 |
| 4532 | 0.65 |
| 4534 | 3.80 |
| 4536 | 2.50 |
| 4538 | 0.75 |
| 4539 | 0.75 |
| 4541 | 0.90 |
| 4543 | 0.70 |
| 4551 | 1.00 |
| 4553 | 2.40 |
| 4555 | 0.36 |
| 4556 | 0.50 |
| 4557 | 2.40 |
| 4560 | 1.40 |
| 4566 | 1.40 |
| 4568 | 2.40 |
| 4569 | 1.70 |
| 4572 | 0.45 |
| 4583 | 0.90 |
| 4584 | 0.48 |
| 4585 | 0.60 |
| 4724 | 1.50 |
| 14411 | 7.50 |
| 14412 | 7.50 |
| 14416 | 3.00 |
| 14419 | 2.60 |
| 14490 | 4.20 |
| 14495 | 4.50 |
| 145000 | 6.50 |
| 14599 | 2.00 |
| 22100 | 3.50 |
| 22101 | 7.00 |
| 22102 | 7.00 |
| 40014 | 0.48 |
| 40085 | 1.20 |
| 40097 | 0.36 |
| 40098 | 0.40 |
| 40100 | 1.50 |
| 40101 | 1.25 |
| 40102 | 1.30 |
| 40103 | 2.00 |
| 40104 | 1.20 |
| 40105 | 1.50 |
| 40106 | 0.48 |
| 40107 | 0.55 |
| 40108 | 3.20 |
| 40109 | 0.80 |
| 40110 | 2.25 |
| 40114 | 2.25 |
| 40147 | 2.80 |
| 40163 | 1.00 |
| 40173 | 1.20 |
| 40174 | 1.00 |
| 40175 | 1.00 |
| 40192 | 1.00 |
| 40193 | 1.00 |
| 40194 | 1.00 |
| 40244 | 1.50 |
| 40245 | 1.50 |
| 40257 | 1.80 |
| 40373 | 1.80 |
| 40374 | 1.80 |
| 80C95 | 0.75 |
| 80C97 | 0.75 |
| 80C98 | 0.75 |

## LINEAR ICs

| | |
|---|---|
| AD7581 | 12.00 |
| ADC0808 | 11.90 |
| AM7910QC | 25.00 |
| AN103 | 2.00 |
| AN-1-5050 | 1.00 |
| AY-3-1350 | 3.50 |
| AY-3-8910 | 4.90 |
| AY-3-8912 | 5.00 |
| CA3019A | 1.00 |
| CA3020 | 3.50 |
| CA3028A | 1.10 |
| CA3046 | 0.70 |
| CA3059 | 3.25 |
| CA3060 | 3.50 |
| CA3080E | 0.70 |
| CA3085 | 1.50 |
| CA3086 | 0.60 |
| CA3089E | 2.50 |
| CA3090AQ | 3.75 |
| CA3130E | 0.90 |
| CA3130T | 1.30 |
| CA3140E | 0.45 |
| CA3140T | 1.00 |
| CA3146 | 2.25 |
| CA3160E | 1.50 |
| CA3161E | 2.00 |
| CA3162E | 6.00 |
| CA3189E | 2.70 |
| CA3240E | 1.50 |
| CA3280G | 3.00 |
| D7002 | 6.00 |
| DAC1408-8 | 3.00 |
| DAC0800 | 3.00 |
| DAC0808 | 3.00 |
| DG308 | 3.00 |
| HA1366 | 1.90 |
| ICL7106 | 6.75 |
| ICL7611 | 0.95 |
| ICL7650 | 4.00 |
| ICL7660 | 2.50 |
| ICL8038 | 4.00 |
| ICM7555 | 0.90 |
| ICM7556 | 1.40 |
| LC7120 | 3.00 |
| LC7130 | 3.00 |
| LC7131 | 3.50 |
| LC7137 | 3.50 |
| LF347 | 1.20 |
| LF351 | 0.60 |
| LF353 | 0.90 |
| LF355 | 0.90 |
| LF356N | 1.10 |
| LF357 | 1.00 |
| LF398 | 4.00 |
| LM10CLH | 4.50 |
| LM301A | 0.30 |
| LM307 | 0.45 |
| LM308CN | 0.75 |
| LM310 | 2.25 |
| LM311 | 0.60 |
| LM318 | 1.50 |
| LM319 | 1.80 |
| LM324 | 0.45 |
| LM334Z | 1.15 |
| LM335Z | 1.30 |
| LM336 | 1.50 |
| LM339 | 0.40 |
| LM348 | 0.60 |
| LM358P | 0.50 |
| LM377 | 3.00 |
| LM380N-8 | 1.50 |
| LM380N | 1.50 |
| LM381AN | 1.70 |
| LM381N | 3.00 |
| LM383 | 3.25 |
| LM384 | 2.20 |
| LM386N-1 | 1.00 |
| LM387 | 2.70 |
| LM391 | 1.80 |
| LM392N | 1.10 |
| LM393 | 0.85 |
| LM394CH | 4.00 |
| LM709 | 0.35 |
| LM710 | 0.48 |
| LM711 | 1.00 |
| LM723 | 0.60 |
| LM725CN | 3.00 |
| LM733 | 0.65 |
| LM741 | 0.22 |
| LM747 | 0.70 |
| LM748 | 0.30 |
| LM1011 | 4.80 |
| LM1014 | 1.50 |
| LM1801 | 3.00 |
| LM1830 | 2.50 |
| LM1871 | 3.00 |
| LM1872 | 3.00 |
| LM1886 | 6.00 |
| LM1889 | 4.50 |
| LM2917 | 3.00 |
| LM3302 | 0.90 |
| LM3900 | 0.80 |
| LM3909 | 1.00 |
| LM3911 | 1.80 |
| LM3914 | 3.50 |
| LM3915 | 3.40 |
| LM3916 | 3.40 |
| LM13600 | 1.50 |
| M51513L | 2.30 |
| M51516L | 4.50 |
| MB3712 | 2.00 |
| MC1310P | 1.50 |
| 1413 | 0.75 |
| MC1458 | 0.45 |
| MC1495 | 3.00 |
| MC1496 | 0.70 |
| MC3340P | 2.00 |
| MC3401 | 0.70 |
| MC3403 | 0.65 |
| MF10CN | 4.10 |
| MK50240 | 9.00 |
| ML902 | 5.00 |
| ML922 | 4.00 |
| NM6221A | 3.00 |
| NE529 | 2.20 |
| NE531 | 1.20 |
| NE544 | 1.90 |
| NE555 | 0.22 |
| NE556 | 0.60 |
| NE564 | 4.00 |
| NE565 | 1.20 |
| NE566 | 1.50 |
| NE567 | 1.25 |
| NE570 | 4.00 |
| NE571 | 3.00 |
| NE592 | 0.90 |
| NE5532P | 1.50 |
| NE5533P | 1.60 |
| NE5534P | 1.50 |
| NE5534AP | 1.50 |
| OP-07EP | 3.50 |
| PLL02A | 5.00 |
| RC4136 | 0.55 |
| RC4151 | 2.00 |
| RC4195 | 1.50 |
| RC4558 | 0.55 |
| S50240 | 9.00 |
| SAA1900 | 16.00 |
| SFF96364 | 8.00 |
| SL490 | 3.00 |
| SN76013N | 3.00 |
| SN76023N | 3.00 |
| SN76115N | 2.15 |
| SN76489 | 4.00 |
| SN76495 | 4.00 |
| SN76660 | 1.20 |
| SP0256AL2 | 7.00 |
| SP8515 | 7.50 |
| TA7120 | 1.20 |
| TA7130 | 1.40 |
| TA7204 | 1.50 |
| TA7205 | 0.90 |
| TA7222 | 1.50 |
| TA7310 | 1.50 |
| TBA231 | 1.20 |
| TBA800 | 0.80 |
| TBA810 | 0.90 |
| TBA20 | 0.80 |
| TBA820M | 0.75 |
| TBA920 | 2.00 |
| TBA950 | 2.25 |
| TC9109 | 5.00 |
| TCA210 | 3.50 |
| TCA220 | 3.50 |
| TCA270 | 3.50 |
| TCA940 | 1.75 |
| TDA1004A | 5.00 |
| TDA1010 | 2.25 |
| TDA1022 | 4.50 |
| TDA1024 | 1.10 |
| TDA1170S | 3.00 |
| TDA2002 | 3.25 |
| TDA2003 | 1.90 |
| TDA2004 | 2.40 |
| TDA2006 | 3.20 |
| TDA2020 | 3.20 |
| TDA2030 | 2.50 |
| TDA2593 | 5.00 |
| TDA2653 | 7.00 |
| TDA3560 | 7.50 |
| TDA3810 | 7.50 |
| TDA7000 | 3.50 |
| TEA1002 | 7.00 |
| TL061CP | 0.40 |
| TL062 | 0.60 |
| TL064 | 0.90 |
| TL071 | 0.40 |
| TL072 | 0.70 |
| TL074 | 1.10 |
| TL081 | 0.35 |
| TL082 | 0.55 |
| TL083 | 0.75 |
| TL084 | 1.00 |
| TL094 | 2.00 |
| TL430C | 1.20 |
| UA759 | 3.20 |
| UA2240 | 1.20 |
| UCN5801A | 6.00 |
| ULN2001A | 0.75 |
| ULN2002A | 0.75 |
| ULN2003A | 0.75 |
| ULN2004A | 0.75 |
| ULN2068 | 2.90 |
| ULN2802 | 1.90 |
| ULN2803 | 1.80 |
| ULN2804 | 1.90 |
| UPC575 | 2.75 |
| UPC592H | 2.00 |
| UPC1156H | 3.00 |
| UPC1185H | 5.00 |
| XR210 | 4.00 |
| XR2206 | 4.50 |
| XR2207 | 3.75 |
| XR2211 | 5.75 |
| XR2216 | 6.75 |
| XR2240 | 1.20 |
| ZN404 | 1.00 |
| ZN414 | 0.80 |
| ZN419P | 1.75 |
| ZN423E | 1.30 |
| ZN424E | 1.30 |
| ZN425E8 | 3.50 |
| ZN426E8 | 3.00 |
| ZN427E8 | 6.00 |
| ZN428E8 | 4.50 |
| ZN429E8 | 2.25 |
| ZN447E | 9.00 |
| ZN448 I | 7.50 |
| ZN449E | 3.00 |
| ZN450E | 7.50 |
| ZN459CP | 3.00 |
| ZN1034E | 2.00 |
| ZNA1040 | 6.60 |
| ZNA134H | 23.00 |
| ZNA234E | 9.50 |

## VOLTAGE REGULATORS

1A FIXED VOLTAGE PLASTIC TO220

| +VE | | | −VE | |
|---|---|---|---|---|
| 5V | 7805 | 0.45 | 7905 | 0.50 |
| 6V | 7806 | 0.50 | 7906 | 0.50 |
| 8V | 7808 | 0.50 | 7908 | 0.50 |
| 12V | 7812 | 0.45 | 7912 | 0.50 |
| 15V | 7815 | 0.50 | 7915 | 0.15 |
| 18V | 7818 | 0.50 | 7918 | 0.50 |
| 24V | 7824 | 0.50 | 7924 | 0.50 |

1A FIXED VOLTAGE PLASTIC TO92

| | | | | | |
|---|---|---|---|---|---|
| 5V | 78L05 | 0.30 | 5V | 79L05 | 0.45 |
| 6V | 78L06 | 0.30 | 12V | 79L12 | 0.50 |
| 8V | 78L08 | 0.30 | 15V | 79L15 | 0.50 |
| 12V | 78L12 | 0.30 | | | |
| 15V | 78L15 | 0.30 | | | |

## OTHER REGULATORS

FIXED REGULATORS

| | | |
|---|---|---|
| LM309K | 1A 5V | 1.40 |
| LM323K | 3A 5V | 3.50 |
| 78H05KC | 5A 5V | 5.40 |
| 78H12 | 5A 12V | 6.40 |
| 78P05 | 10A 5V | 9.00 |

VARIABLE REGULATORS

| | | |
|---|---|---|
| LM305AH | | 2.50 |
| LM317T | TO-220 | 1.20 |
| LM317K | TO3 | 2.40 |
| LM337T | | 2.25 |
| LM350T | 10A+VAR | 4.00 |
| LM396K | 10A+VAR | 15.00 |
| LM723N | | 0.50 |
| 78HHO5KC | 5A 5V | 5.75 |
| 78HGKC | 5A+VAR | 6.50 |
| 78GUIC | 1A+VAR | 2.25 |
| 79HGKC | 5A–VAR | 6.75 |
| 79GUIC | 1A–VAR | 2.50 |

SWITCHING REGULATIONS

| | |
|---|---|
| ICL7660 | 2.50 |
| SG3524 | 3.00 |
| TL494 | 3.00 |
| TL497 | 2.25 |
| 78S40 | 2.50 |
| RC4195 | 1.50 |

## COMPUTER COMPONENTS

### CPU

| | |
|---|---|
| 1802CE | 6.50 |
| 2650A | 10.50 |
| 6502 | 4.50 |
| 65C02-2MHz | 12.00 |
| 6502A | 6.50 |
| 6502B | 8.00 |
| 6800 | 2.50 |
| 6802 | 3.00 |
| 6809 | 6.50 |
| 6809E | 10.00 |
| 68B09 | 10.00 |
| 68B09E | 12.00 |
| 68000-LB | 36.00 |
| 8035 | 3.50 |
| 80C35 | 6.00 |
| 8039 | 4.20 |
| 80C39 | 7.00 |
| 8080A | 7.40 |
| 8085A | 3.00 |
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# 'j' – real thoughts on the imaginary axis

**There is nothing imaginary about j. Anyone doing anything with electronic circuits should still master complex numbers.**

JOULES WATT

"Surely everyone can handle calculations using j nowdays?" I surmised. But no. Either familiarity has made it all boring, or students still trip up over the term imaginary – and when you look into it, a surprising number of quite senior engineers and technicians also tend to avoid complex numbers if they can, when working out problems.

People in this unfortunate situation have to face the fact that Fourier and Laplace transforms, Bode plots, poles and zeros, frequency and phase response, many differential equations, Smith charts – and even common old impedance itself all remain a closed book.

The arguments about the meaning of j started with people solving algebraic equations. How do you find their roots? Girolamo Cardan discussed this issue in his *Ars Magna*, published in 1545. He noticed that if you allow $\sqrt{-1}$ to come into the picture, all equations have roots. Some have real number answers, others have complex roots, yet others have a mixture of real and complex ones. He proved that complex roots always occur in pairs. Cardan called numbers containing $\sqrt{-1}$ *sophistic*, meaning 'intriguing but not very useful!'

We can illustrate the kind of thing this early author said by using a quadratic together with our modern notation. For example, w = 3 or w = 5 satisfy $w^2 - 8w + 15 = 0$. As you know, we call 3 and 5 the real roots of this equation, (try them in and see...). Root means 'from where the equation comes.'

But a whole bunch of quadratics have no such roots, however hard you search along the real axis at all the infinite number of points on it that represent the integers, rational numbers and irrational numbers which make up the real number system. We all yawn at the familiarity of the explanation in Fig. 1, where the parabolic curve of the quadratic either cuts the real axis at two points (a) to give the real roots, or it remains too high up (b) ever to get to the axis and therefore, with no axis intersection, no roots.

"Ah!" you say, "I don't sketch all these pictures, I use the formula and a pocket calculator..." Yes, we know the general

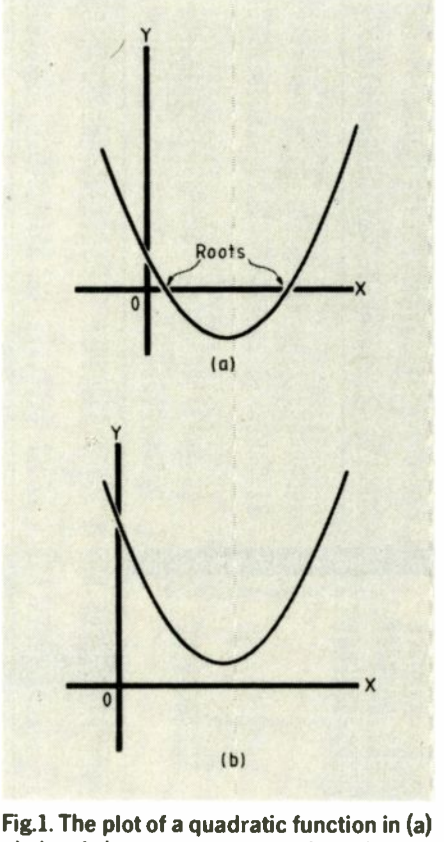



**Fig.1. The plot of a quadratic function in (a) obviously has two answers at the points on the 'x' axis where 'y' equals 0. In (b) the parabola never reaches a value of y equals 0, so we say there are no roots. If we admit complex numbers, then (b) has roots.**

quadratic equation $ax^2 + bx + c = 0$ has the well known formula for its solution.

$$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where $x_1$ is the '+' root solution, $x_2$ the '−' root one. And we see the problem that arises, for example, in trying to solve $x^2 - 8x + 25 = 0$.

The formula gives,

$$x_{1,2} = \frac{8 \pm \sqrt{-36}}{2}$$

Minus 36 is $-1 \times 36$, so the square root comes down to finding $6\sqrt{-1}$. The problem always is, "What is the square root of minus one?" If you try it on your calculator, you get 'error', or if $\sqrt{-1}$ turns up in your computer program, the same thing occurs, or the run crashes. Try as you might, no real number multiplies by itself to give $\sqrt{-1}$. But nevertheless, (as we do all have some knowledge of algebra!) if it did exist we could give it a symbol, j say, and define, $j^2 = -1$. So, using this j the equation has two roots, complex now, $x_1 = 4 + j3$ and $x_2 = 4 - j3$ and away we go with a whole lot of new numbers – the complex numbers that I am talking about. You can see why Cardan called them 'sophistic'.

## TRIGONOMETRY BECOMES COMPLEX

A most interesting little tit-bit of history turns up in the work of James Gregory who, in his maths textbook of 1667, gave the infinite series expansions of sinθ and cosθ, (see box). In his other book, he described the two-mirror reflecting telescope, which we still call the Gregorian system in memory of him.

This all became relevant when Leonhard Euler took up these series expansions and showed they related to the exponential series expansion for $e^{\theta}$, where e is that peculiar irrational number 2.71828... This relationship worked, as Euler showed, if the index of e was an imaginary number iθ, where he used the letter i for $\sqrt{-1}$, and introduced the term 'imaginary unit' for it. His decision to do this was rather unfortunate as there is nothing imaginary about the subject. Our forebears, the electrical engineers, wrote 'j' for $\sqrt{-1}$ instead, soon after i had become standard for electric current. The Euler's identity we are talking about, (see the box),

$$e^{j\theta} = \cos\theta + j\sin\theta$$

developed into a very important relation for our field of work.

## GEOMETRY BECOMES COMPLEX

Other mathematicians thought along different lines. Once again, the independent growth of new ideas occurred together. Just before the turn of the 19th century a Norwegian surveyor, Caspar Wessel, published a geometrical representation of complex numbers. He was struggling with vectors and noted that 'the unit in the positive line direction is +1, that in the negative direction is −1 and ε is the unit perpendicular to the + direction and has the same origin...

Wessel's ε is equivalent to j. Unfortunately, hardly anyone read his paper on the subject for about 100 years.

At about the same time (1806), J.R. Argand published a paper showing Descartes' famous graph axes now labelled 'real' along the x axis and 'imaginary' along y. Posterity immortalized Argand via this geometry; nevertheless the whole subject crystallized around the early 1800s with Wessel, Buée and a little later, Mourey and Warren all publishing treatments of complex numbers. So did Gauss and, as a result of his work William Hamilton struggled for half a lifetime with 'complex numbers in three dimensions' – to invent Quaternions. Although no longer heard about, quaternions led to Vector Analysis via Clerk Maxwell[1], Willard Gibbs and Oliver Heaviside. The unit vectors **i**, **j**, **k** of space analysis are therefore not a thousand miles from $\sqrt{-1}$. As you know, vector analysis has an enormous power of explanation in electromagnetic theory, but that is another story[1].

## OPERATIONS

Modern teaching seems to have reduced the emphasis on the operational meaning of j. Older readers will smile with recognition at this, while younger students nearly always say, "Operator j, what do you mean *operator* j ...?" Following Argand and Wessel we do

## A Short mathematical story

Leonhard Euler noticed a relationship between the infinite series expansion of the exponential function and the two expansions for sin and cos, as found earlier by James Gregory.

Following the way these mathematicians thought, we say, "Suppose a function of θ, say, can be expanded in a *power series*." This means that we assume,

$f(\theta)=a_0+a_1\theta+a_2\theta^2+a_3\theta^3+a_4\theta^4+...$

is true if we take enough terms and insert the appropriate constants, $a_0$, $a_1$ etc.

If we know $a_0$ and $a_1$ for instance, we get the straight line approximation to the curve of f(θ). This is the tangent at the point about which we are expanding the function. We often do this to 'linearize' the curve of a non-linear device over a little bit of its characteristic. This means that the series and f(θ) agree at least in the region of one point. If we know $a_2$ also, then we are fitting a parabola onto the curve and a wider range of agreement occurs around the point – and so on.

Now proceed to differentiate. We let f'(θ) be the first differential coefficient, f''(θ) the second, etc.

$$\therefore\ f'(\theta)=a_1+2a_2\theta+3a_3\theta^2+...$$
$$f''(\theta)=2a_2+2.3a_3\theta+3.4a_4\theta^2+...$$
$$f'''(\theta)=2.3a_3+2.3.4a_4\theta+3.4.5a_5\theta^2+...$$

Now suppose we have a look at what is happening at the origin, as Colin McLaurin did.

This means $f(0)=a_0$ (i.e. the 'y' intercept is at $a_0$)

$$f'(0)=a_1$$
$$f''(0)=2a_2$$
$$f'''(0)=2.3a_3$$
$$f''''(0)=2.3.4a_4$$

So that $f^n(0)=2.3.4...na_n$

You might recognise 1.2.3.4. ... n as 'factorial n'. We write it as n! ("n shriek", as my old maths teacher called it.)

This means we know the $a_0$, $a_1$, $a_2$, etc. for the "expansion of f(θ) about the origin." And this is precisely what McLaurin did, so after him, the series is called the McLaurin expansion.

$$\therefore f(\theta)=(f(0)+f'(0)\theta+\frac{f''(0)}{2!}\theta^2+\frac{f'''(0)}{3!}\theta^3....$$

Now try it on cosθ, sinθ and $e^\theta$ as typical functions (certainly of interest in our trade).

All you have to remember is that

$$\frac{d(\cos\theta)}{d\theta}=-\sin\theta \text{ and } \frac{d(\sin\theta)}{d\theta}=\cos\theta \text{ together with } \frac{d(e^\theta)}{d\theta}=e^\theta$$

This last result shows that the exponential function has a slope that equals itself at all points.

$$\therefore\ \sin\theta=\theta-\frac{\theta^3}{3!}+\frac{\theta^5}{5!}-...$$

$$\cos\theta=1-\frac{\theta^2}{2!}+\frac{\theta^4}{4!}-...$$

$$\text{and}\quad e\theta=1+\theta+\frac{\theta^2}{2!}+\frac{\theta^3}{3!}+\frac{\theta^4}{4!}+\frac{\theta^5}{5!}...$$

Now the *piece de resistance*. Put jθ equal to the original θ in the above exponential series:

$$\therefore\ e^{j\theta}=1+j\theta-\frac{\theta^2}{2!}-j\frac{\theta^3}{3!}+\frac{\theta^4}{4!}+j\frac{\theta^5}{5!}...$$

(Remember that $j^2=-1$, $j^3=-j$ and so on...)

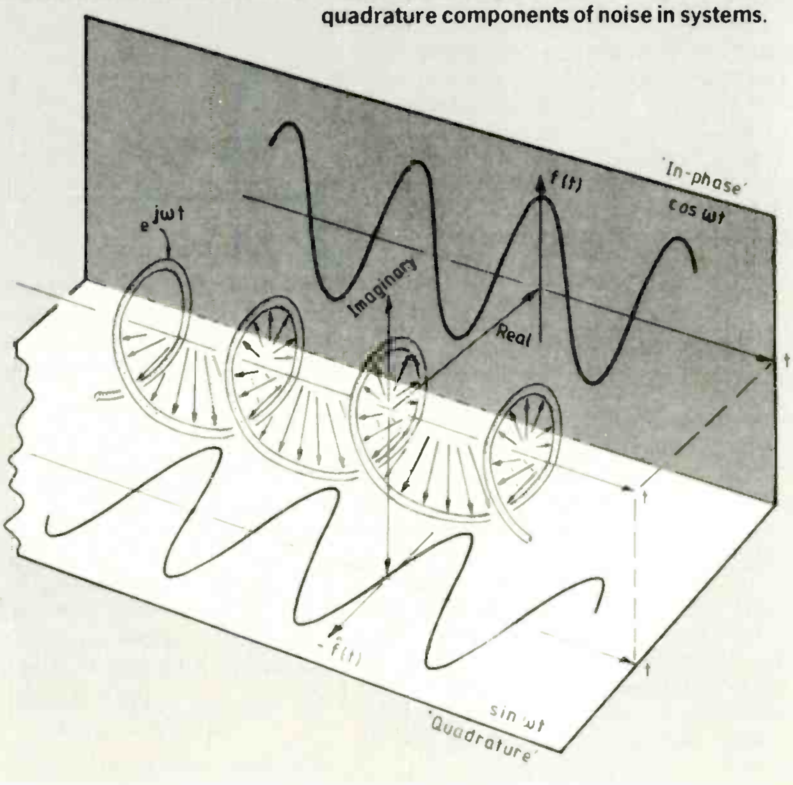
We now put this into the form A + jB,

$$e^{j\theta}=(1-\frac{\theta^2}{2!}+\frac{\theta^4}{4!}-...)+j(\theta-\frac{\theta^3}{3!}+\frac{\theta^5}{5!}-...)$$

Straightaway you see that,

$e^{j\theta}=\cos\theta+j\sin\theta$ which is Euler's famous identity.

**The rotating phasor $e^{j\omega t}$ can be resolved into the two planes at right angles I have shown here. One component forms the real part, the other forms the imaginary part of Euler's relationship. Of some interest, other people call $e^{j\omega t}$ the *analytic function* made up from f(t), the in-phase component and $-j\hat{f}(t)$ the quadrature component, where $\hat{f}(t)$ is known as the Hilbert transform of f(t). This interpretation facilitates work in modulation theory – especially theory of s.s.b. and in-phase and quadrature components of noise in systems.**



not look on j as a number at all. Instead look on it as operating on a number, like + or − does. Operate on +4 with − and the direction of 4 is turned through 180° from pointing to the right along the real axis, to pointing along the left, or negative direction.

As operating with − is equivalent to operating with j, then j again, because j×j = −1, then operating on a number with just one j might take you only half way on the journey, i.e. 90° Figure 2(a) shows the operation. The imaginary number axis contains all the j numbers. When j = 0, we obtain all the real numbers. Therefore the real numbers are just a subset of the complex numbers, namely all those on the x axis along which j=0. When we look along, say, the horizontal line through j4, as shown in Fig.2(b), another subset of numbers turns up. This time we have a particular selection of complex numbers. The whole set of complex numbers contains every point in the plane.

This real/imaginary plane referred to 0 and the two axes through it is the Argand Diagram. Often, authors call this picture the complex plane or simply the z plane. All the points have two parts, the horizontal magnitude or real part and the vertical magnitude, or imaginary part.

Take another look at the second quadratic with its two complex roots,

$$x_{1,2} = \frac{8+j6}{2} = 4 + j3$$

One is x = 4 + j3, the other is the conjugate complex number x = 4 − j3. All equations with complex roots have them turn up in conjugate pairs. Conjugate to something means 'its opposite number', as it were. In complex numbers it simply means, 'put −j where +j was, and you get the conjugate'. The conjugate of any complex number on the Argand diagram is easy to see in all cases. It is the reflection in the real axis, as you can see in Fig.3.

Conjugates have interesting (and useful) properties. Their sum is a real number; e.g. if we have z = a + jb, then z* = a − jb and z + z* = a + jb + a − jb = 2a. Their product is a real number, $zz^* = a^2 + b^2$. If z is the complex number $e^{j\omega t}$, then its conjugate z* is $e^{-j\omega t}$ and, using Euler's identity on both of these, you can see that z + z* is real. zz* easily shows its real nature, because,

$$e^{j\omega t}e^{-j\omega t} = \frac{e^{j\omega t}}{e^{j\omega t}} = 1$$

## VECTORS OR PHASORS?

From all the historical connections of complex numbers with vectorial ideas, you might be tempted to look at the Argand diagram and say, "The complex number z has a magnitude (out from 0) and a direction (angle θ to the real axis). Therefore, it represents a vector." Well, yes – if you look into old treatises, z was called a vector. Yet we multiply modern vectors in an entirely different way to complex numbers. We divide complex numbers, but division has no meaning at all for vectors. Because of these differences, we now tend to label complex number representation of directed lines as phasors.

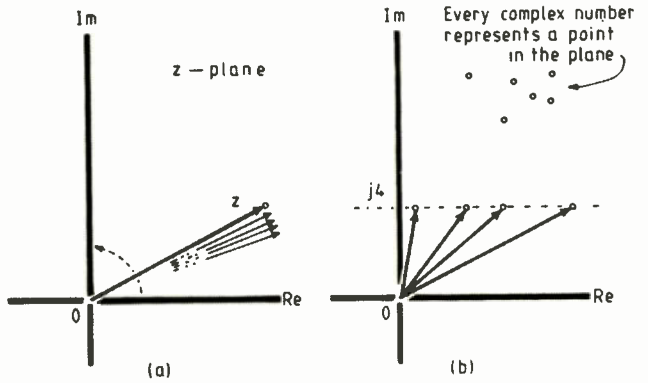



**Fig.2. The construction in (a) is called the Argand Diagram. You can think of the arrowed line ('phasor') turning from the 'Re' axis to pointing along the 'Im' axis when operated on by j. All the points on the horizontal line j4 in (b) represent a subset of the complex numbers. In general, the complex numbers describe all the points in the z plane.**

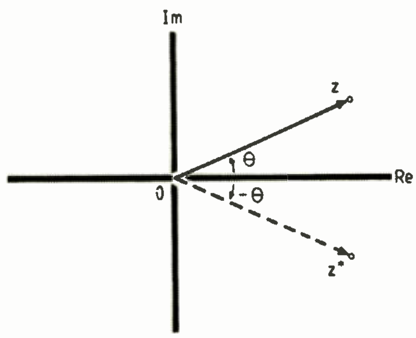



**Fig.3. The complex conjugate is the mirror image of the original complex number reflected in the real axis.**

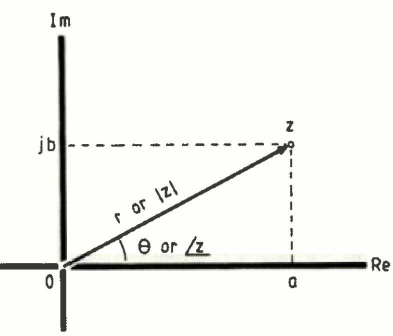



**Fig.4. The bits of a complex number (or to be more refined – its 'components') make up trigonometrical/geometrical possibilities for a variety of definitions, as shown here.**

## STANDARD FORM AND SOME OPERATIONS

First we notice the obvious fact that a real number can never equal an imaginary one. Therefore when two complex numbers are equal, their real parts and imaginary parts must equate separately, a fact I used in the discussion of Euler's work in the box.

$$\therefore \text{ if } R_1+jX_1=R_2-jX_2$$
$$\text{then } R_1=R_2 \text{ and } X_1=-X_2$$

In discussing the subject, A+jB is called the Standard Form of a complex number. They can all be written in this form. Adding and subtracting is simple.

$$z_1+z_2=(r_1+jx_1)+(r_2+jx_2)$$
$$=(r_1+r_2)+j(x_1+x_2)$$

This is in standard form and shows that complex numbers do add like vectors.

Multiplication is easy too:

$$z_1z_2=(r_1+jx_1)(r_2+jx_2)=(r_1r_2-x_1x_2)$$
$$+j(r_1x_2+r_2x_1).$$

Division is a little trickier:

$$\frac{z_1}{z_2} = \frac{r_1+jx_1}{r_2+jx_2}$$

Remember the properties of the complex conjugate,

$$\therefore \frac{z_1}{z_2} = \frac{r_1+jx_1}{r_2+jx_2}\cdot\frac{r_2-jx_2}{r_2-jx_2}$$

$$= \frac{r_1r_2+x_1x_2}{r_2^2+x_2^2} + j\,\frac{r_2x_1-r_1x_2}{r_2^2+x_2^2}$$

All of these show standard form, 'real part plus imaginary part'. You can see clearly that $z_1z_2$ is neither a scalar product nor is it a vector product of two vectors[1]. The result of $z_1z_2$ is in fact another complex number lying in the z-plane. So is $z_1/z_2$.

My earlier statement that complex numbers do not obey the rules of vector algebra receives vindication in these standard results. Therefore you should support the move to call them phasors, when their magnitude and directional properties come up for discussion. Some authors call the length or magnitude of a complex number, its amplitude, which corresponds with the name we give to the peak value of a sine wave. This is not surprising, as complex numbers and the resulting phasors are most fruitful in describing a.c., waves, and oscillations. The angle made by the complex number anticlockwise round from the real axis, we term its phase.

## AMPLITUDE AND PHASE

The two quantities, magnitude and phase angle, arise very often and we should be able to find them in any given problem. Resorting to geometry on the Argand diagram helps. Notice on Fig.4 that z=a+jb has a magnitude written |z| or r. This shows that, by simple trigonometry,

$a = |z|\cos\theta$ and $jb = |z|\sin\theta$

$\therefore \quad z = |z|(\cos\theta + j\sin\theta)$

Using Pythagoras,

$$a^2 = |z|^2\cos^2\theta \text{ and } b^2 = |z|^2\sin^2\theta$$

so that,

$$a^2+b^2 = |z|^2(\cos^2\theta+\sin^2\theta) = |z|^2$$

so that the magnitude of any complex number is 'real part squared, plus the imaginary part squared, and take the square root'.

$$\therefore |z| = r = \sqrt{a^2+b^2}$$

The phase angle from the same trigonometry,

$$\tan\theta = \frac{b}{a}$$

$$\therefore \quad \theta = \tan^{-1}\frac{b}{a}$$

We can also write the phase in good old engineering notation as $\angle\theta$, which we read as 'angle $\theta$ of z'. You can also write it as $\angle z$, meaning simply 'the angle of z'. This means that the complex number z is $r\angle\theta$, or $|z|\angle z$ in polar coordinate form with this notation.

## AVOID TEDIUM!

I have seen many students tediously multiplying or dividing out complex numbers, to get them into the standard form R+jX presumably, then going on to find the magnitude and phase angle, according to the above rules.

What they did not seem to realise was that $|z_1z_2| = |z_1|\ |z_2|$. In other words, 'the amplitude of the product is the product of the amplitudes'. Similarly the phase $\angle z_1 z = \theta_1+\theta_2$ which is, 'the angle of a product is the sum of the angles of the factors'.

Therefore if $z_1 = a+jb$ and $z_2 = c+jd$ then,

$$|z_1z_2| = \sqrt{a^2+b^2}\cdot\sqrt{c^2+d^2}$$

$$= \sqrt{(a^2+b^2)(c^2+d^2)}$$

and $\angle z_1z_2 = \tan^{-1}\frac{b}{a} + \tan^{-1}\frac{d}{c} = \theta_1 + \theta_2$

You might like to show similar rules for the quotient, i.e. show that,

$$\left|\frac{z_1}{z_2}\right| = \frac{|z_1|}{|z_2|} \text{ and } \angle\frac{z_1}{z_2} = \theta_1 - \theta_2$$

Also you might enjoy applying these results to z and its conjugate, z* as an exercise to see what happens.

## SPINNING PHASORS

We see now why complex numbers turned out to be so useful in radio and electronics theory. To see some of this, make the point z rotate anticlockwise so that the phase angle $\theta$ radians continually grows. For simple cases, keep the amplitude constant. How fast we make $\theta$ increase gives us a number we call the angular velocity. We write this as $\omega$ radians per second so that the angle $\theta$ after t seconds is $\omega t$ radians.

The horizontal, or real component is $r\cos\omega t$ and the vertical, or imaginary part is $jr\sin\omega t$. If we plot out either of these we get the sinusoid of the oscillations we are talking about (mostly current or voltage variations in our work). We work through a problem, then at the end take the real part (cos) or the imaginary part (sin) as the solution of the 'a.c. theory' piece of work.

## FIXED PHASORS

Many people talking about this subject define the phasor as the 'frozen' directed line – stopped as it would be in a snapshot. Mathematically, this amounts to removing the time variable, working the problem, then re-inserting the $e^{j\omega t}$ at the end. You can see this from the exponential form describing the oscillation,

$$Ve^{j(\omega t+\theta)} = Ve^{j\theta}e^{j\omega t}$$

Removing the time varying factor $e^{j\omega t}$ leaves the 'fixed phasor' $Ve^{j\theta}$ with its amplitude V and phase angle $\theta$ to march on through the problem. The procedure is to apply the complex number theory I have revised to deal with a few of these 'frozen phasors' in action together. In other words, we use them to handle the summing and product operations on a number of sinusoids in such applications as modulation theory, network analysis and so on.

## PHASOR TRANSFORMS

The unique property an exponential function has of reproducing itself when differentiated or integrated, means that we can transform a differential equation – generally hard to solve – into an algebraic equation – much easier to solve. The condition on the differential equations is that they describe phasor motion. In other words, we can solve those equations which apply to circuits driven by sine waves. Very many of the problems arising employ just this situation.

consider $\quad v = Ve^{j\omega t}$

then $\quad \frac{dv}{dt} = j\omega Ve^{j\omega t}$

but the 'reproducing' property of the exponential means we can replace the last couple of factors with the original variable v.

$$\therefore \frac{dv}{dt} = j\omega v. \quad \text{Similarly} \quad \frac{d^2v}{dt^2} = -\omega^2 v$$

This shows differential replaced by complex number algebra, which we have discussed at length.

**Reference**

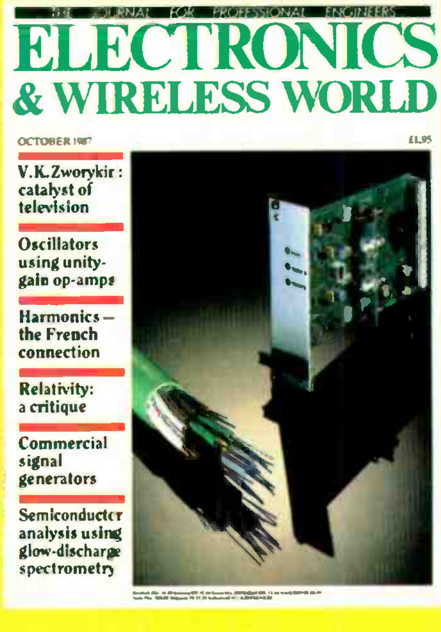
1. Joules Watt. Maxwell's e.m. theory revisited. *Electronics and Wireless World*, July 1987, pps 697-699.

# NEXT MONTH

**CD rom.** The compact disc overcame the major drawback of analogue audio recording by storing digital audio in a durable medium convenient for duplication. Its success brought down the cost of the player and has made it attractive as a computer peripheral.

**R.F. signal generators**. Our latest industry survey concentrates on high-frequency signal generation, investigating up-to-date design techniques and some applications for the new generation of instruments, which offer facilities far in excess of the traditional "sig. gen".

**Vladimir Kosma Zworykin.** A Russian, living in the United States and working mostly at RCA, Zworykin was the inventor of the early television camera tube, the Iconoscope. According to his obituary notice in *The Times*, his work was the basis for all later technical advances. He can fairly be said to be the Father of Television.




**Harmonics – the French connection.** Joules Watt invokes the Baron de Fourier in a piece on the construction and analysis of periodic waveforms. He also sets a puzzle and, somewhat rashly, offers a prize for its solution.

**Mains signalling.** A report of work done, using computer simulation techniques, on using the electricity mains to carry signals. The investigation centres on the reduction of required bandwidth and the reduction of interference.

**Glow-discharge mass spectrometry.** Seen as a natural successor to spark-source mass spectrometry, g.d.m.s. is being used in the semiconductor industry to measure both deliberate and inadvertent impurities in, for example, cadmium telluride and silicon.

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# Radio communication through rock

**Electromagnetic waves do propagate through rock. Their ability to do so is a complex function of frequency, geological criteria (both electrical and physical), and antenna characteristics. This article reviews the work done over many years to solve the problems of transmission without having to rely on wave-guiding devices such as leaky feeders.**

B.A. AUSTIN

The need for effective communications in underground mines has led to a considerable amount of research effort being directed at radio-based techniques[1,2]. Unfortunately, much of the published material has ignored the significant contributions made in the field of non-guided radio systems operating at medium frequencies (300kHz to 3MHz). This article is an attempt to redress the imbalance by presenting some of the research findings and by describing some of the equipment developed specifically for this purpose.

## THE EARLY WORK

As early as 1925, almost at the dawn of radio, *Wireless World* carried an article on the use of radio as an aid to life saving in mines.[3] The ideas first raised there are remarkable in that they predict very accurately the sorts of systems which are employed today. No mention is made of the frequency used, but a glance at the photographs in that article shows an abundance of multiturn loop antennas and the text alludes to the very high rates of attenuation which occur through the rock and to the fact that any metal conductors within the mine would assist in propagating the signal. These facts clearly indicate that the radio frequencies used must have been at the lower end of the spectrum, in keeping with the technology of the day. By 1947, when the problem was once again given some attention, radio science has made considerable progress. The man commissioned to report on the feasibility of radio communication through rock was Trevor Wadley, recently demobilized from the South African Corps of Signals, where he played a significant part in developing radar equipment, along with similar efforts in England and other Commonwealth

**Fig.5. By mounting the modern synthesized SC100 transceiver on the flexible, multiturn loop antenna, the miner is given considerably more freedom of movement. Ergonomic factors played a major part in the design of the modern generation of radio equipment. In addition it is intrinsically safe thus allowing it to be used in flammable areas.**

nations. Wadley was later to become very well known as the inventor of the famous "triple-loop" method of frequency synthesis and probably even more significantly, of the Tellurometer, a method of precise distance measurement by microwaves.

He wrote a report for the Transvaal and Orange Free State Chamber of Mines in which he showed that signal attenuation through rock increased almost exponentially with frequency. When the radiation efficiency of electrically small antennas (necessary in the confined tunnels and working areas of a mine) was considered as well, then an optimum frequency existed for communication over a given distance. The curves Wadley produced to illustrate these effects are shown in Fig. 1.

They are based on the simplifying assumptions of a homogeneous and isotropic rock medium and that the performance of the antennas was not affected by the presence of the rock. Initial tests using these results confirmed that radio communication was indeed feasibile at these frequencies over ranges of a few hundred metres, directly through the rock. The presence of electric power cables, water pipes and even rails was shown to assist in propagating the signals over even greater distances – the so-called "wired wireless" referred to more than twenty years earlier.

However, the limiting factor in all of this was the valve technology available. Calculations showed that a total system loss of some 140dB could be accommodated by semi-portable equipment operating at about 300kHz. Whereas a receiver sensitivity close to the theoretical limit could be achieved and transmitter powers of 10W were quite feasible, the problem of size and weight of the equipment made it impracticable for use in day-to-day mining. It had a role to play, however, during mine emergencies and this very important application provided some impetus for further development. This was some time in coming: it was not until 1961 that a significant amount of progress was reported by Vermeulen and Blignaut in a paper to the South African Institute of Electrical Engineers.[4] Their system operated at 335 kHz and consisted of an all-valve transmitter/receiver with an output power of 2 watts into a tuned-loop antenna which was encapsulated into a rigid carrying strap containing the loudspeaker. This hardware was "worn" by the miner along with the obligatory breathing apparatus during fire-fighting and rescue operations undergound.

The equipment was a considerable encumbrance, but the communication that it provided with the "fresh-air base", some few hundred metres from the scene of operations, was a major step forward. It should also be noted that the miner wore a snorkel-type of breathing apparatus, plus nose-clip. These were vital when fighting a highly noxious underground fire. They prevented any voice communication by the miner though and so a system of coded signals, transmitted by a key-switch, was devised. These signals were the responses to carefully phrased, unambiguous questions asked by the operator at the base station, using

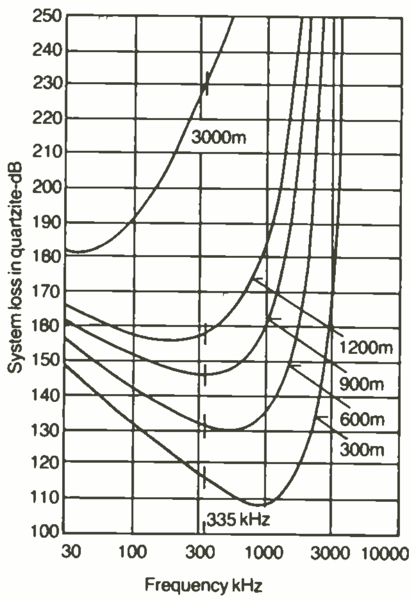



**Fig.1. For any communication distance through a lossy dielectric medium like rock there is an optimum transmission frequency. Fig.1 shows, in theory, how that frequency decreases as the required range is increased. In addition, the attenuation through the rock and the inefficiency of electrically small antennas both contribute to the overall system loss.**

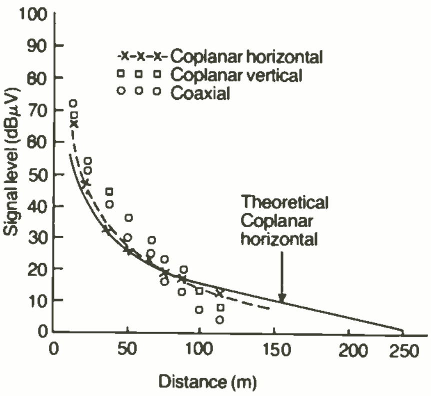



**Fig.2. In a stratified medium the relative orientation of the transmit and receive antennas can have a significant effect on the received signal level. Figure 2 shows the signal passing through a near-field/far-field transition as indicated by the change in orientation from coaxial to coplanar horizontal of the loop antennas.**

telephony – a tall order during the heat of operations!

The base-station equipment was of more conventional design. It delivered about 5 watts to a 1.1m diameter, 6-turn loop antenna which resembled a wagon wheel in its rigid housing. Amplitude modulation was used and the power source was a motor car battery. The total weight of this apparatus was 35 kg. Clearly this equipment was not suitable for day-to-day use by unskilled operators. If radio was to be introduced into mining there was a need for miniaturization and this of course meant transistors and the use of modern plastics and battery technology.

## MODERN DEVELOPMENTS

Again there was a lull in the development of radio systems for general applications. A period of some eleven years elapsed before work was resumed in earnest. As will be seen later this was to be a repetive feature of this research and the ribald suggestion that sunspots affected even underground radio was made from time to time! Both the maturity of solid-state technology and the developments in single-sideland modulation were factors in the next generation of equipment to be produced. Both meant greatly improved performance. Ten watts of peak-envelope-power in manpack-size equipment was readily obtainable. The operating frequency, confirmed by numerous underground tests, was 335 kHz. However, world-wide interest in mine communications were now evident and the considerable research resources in the United States particularly, were being brough to bear on the problem under the auspices of the US Bureau of Mines, (USBM).

Attention was also being focused on the propagation path and on the antennas. Reference to the original Wadley curves in Fig. 1 shows that communication ranges of some 300m through rock should be possible at frequencies around 1MHz with system losses about 10dB lower than at 335kHz. This was exploited very successfully with the design and manufacture of large quantities of handheld 1W p.e.p. transceivers operating at 903kHz. The actual frequency, being close to the optimum for short range work, was the result of using inexpensive 455kHz ceramic filters in a simple s.s.b. transceiver configuration.[5] The loop antenna was still used, but it was now made flexible and was hung over the miner's shoulder and across his chest. This improves the ergonomics of the equipment considerably and led to the introduction of a radio communication system in daily use at a depth of 3000m in a gold mine. Two-way voice communication was now the feature of this system and was, of course, vital for its adoption as a day-to-day tool.

Whereas the original simplifying assumption of rock homogeneity had demonstrated the feasibility of radio communications underground it was clearly inadequate to describe the real-world situation. In fact, calculations based on a knowledge of typical stratified rock conditions, using applicable values of electrical conductivity, , and permittivity, , were most pessimistic and yet experimental results in a variety of mines confirmed the validity of previous reports. The modes of propagation of electromagnetic energy through rock were obviously more complicated than suggested by a simple homogeneous model. Two significant papers which shed considerable light on the problem appeared during this time. The first was a combined French and American publication[6] which helped greatly to quantify the effects of frequency and rock electrical characteristics. It was shown that, in theory at least, two so-called communication windows exist: these being dubbed the low-frequency and the high-frequency windows.

## ELECTROMAGNETIC THEORY

The low-frequency window was defined for all frequencies below some cut-off, $f_c$, a characteristic of the particular rock medium, and is given by

$$f_c = \sigma / 2\pi\epsilon$$

Also defined was a maximum communication range, $r_m$, which was a function of $f_c$ and the bandwidth, B, required. Not surprisingly the range is dependent upon the skin depth, , within the rock and was given by

$$r_m = 3.85\,\delta\,\sqrt{f_c}/B$$

Using values of bulk conductivity and permittivity typical of gold mines ($= 10^{-3}$ Sm$^{-1}$ and $_r = 10$) we find that $f_c = 1.8$ MHz and $r_m$ = 1120m for a 3kHz bandwidth. Both are about an order of magnitude greater than experimental results had shown but were indicative of the type of performance to be expected.

The high-frequency window, by contrast, implied that frequencies above about 180 MHz would provide communication over 175m in that same environment. There had never been any experimental evidence to support this result, however, and the reason was clear from the paper. The concept of a high-frequency window is dependent upon the rock characteristics of , and being constant and independent of frequency. There is a wealth of evidence which shows that only is likely to satisfy this requirement and then not in every case. We are left therefore with the conclusion that only the lower radio frequencies will support the propagation of electromagnetic energy directly through rock. Also of particular interest is the result, attributable to Wait, that a small magnetic loop antenna performs better than its electric dipole equivalent, when surrounded by a lossy dielectric medium as rock. The reasons for this fascinating behaviour will not be elaborated upon here, other than to say that they are due to the near-field phase relationships of the field components generated by the two antenna types. However, there is considerable practical significance in this finding because loops have always been the preferred antennas for mining radio systems when used in confined spaces in view of their more convenient geometry compared with loaded whips.

The second paper of note appeared in 1976[7]. It contained a model of the propagation mechanism which helped explain many of the measured results which had puzzled researchers up to that time. Using medium frequency equipment, including one of the South African versions, the USBM personnel had achieved ranges in coal mines which greatly exceeded those predicted theoretically. In addition there were marked polarization effects which had been noted and these certainly suggested that any homogeneous model would be in error. The new model which fitted the experimental data extremely well, see Fig.2, assumed that a cylindrical TEM mode within the rock was guided between two layers of more highly conducting strata.

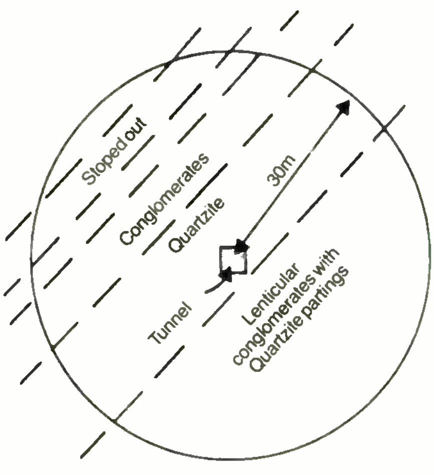



**Fig.3. The inclined strata of a particular test site are shown. A two-plate waveguide of quartzite bounded by higher conductivity conglomerates existed and confirmed a theoretical model which showed how increased range could be achieved by exploiting this natural wave-guide.**

## EXPERIMENTAL RESULTS

The best fit[8] between calculated and measured results occurred when the boundary layers had a conductivity of $10^{-3}$ Sm$^{-1}$ and that of the 15 m thick bounded region was $10^{-4}$ Sm$^{-1}$. It is interesting to note that the actual orientation of the stratified rock. In the case shown here in Fig.2 the terms "vertical" and "horizontal" are somewhat arbitary. In fact, maximum signal strengths were received when the strata themselves would be inclined and this was borne out by a sectional view of the mine geometry in the area of the test site, shown in Fig.3. It is interesting to speculate on the use of such electromagnetic techniques for remote sensing.

## ROLE OF EXISTING CONDUCTORS

A frequent finding, commented upon even in the earliest metal conductors in the mine. Theoretical analysis of the coupling and propagation mechanisms involved is complicated and really beyond the scope of this article. However, for the sake of completeness it should just be noted that essentially two modes of propagation exist: the monofilar or unbalanced mode and the bifilar or balanced node. A single conductor like a power cable or water pipe in a mine tunnel can have currents induced in it easily from a nearby transmitting antenna. The induced energy propagates along the conductor with an attenuation rate that is primarily a function of the electrical conductivity of the tunnel walls. Essentially this mode is similar to that in a coaxial transmission line, with the walls playing the part of the outer conductor.

By contrast, a radiating antenna close to two parallel conductors only induces signals into them if they are a reasonable distance apart and are not twisted. However the rate of attenuation is considerably less than in the monofilar case because this bifilar mode is, to a first approximation, independent of the surrounding lossy rock. At v.h.f. and above use is made of so-called "leaky feeders", based on these principles, to provide mine-wide communications. These are usually coaxial cables with holes or slots cut in the outer braid or are balanced two-wire transmission lines containing "mode-converters" which unbalance the lines at regular intervals and so enhance the coupling in and out[9]. It should be noted that these systems only allow communications to take place when the radio equipment is within some metres of the leaky feeder. Very little energy at the v.h.f. frequencies will actually propagate independently in the tunnels because they behave, on their own, as very lossy waveguides. For the same reason power cables and water pipes are not effective transmission lines at v.h.f. but perform very acceptably at the lower frequencies of the "through-rock" radio systems. An intriguing example of this is described below.

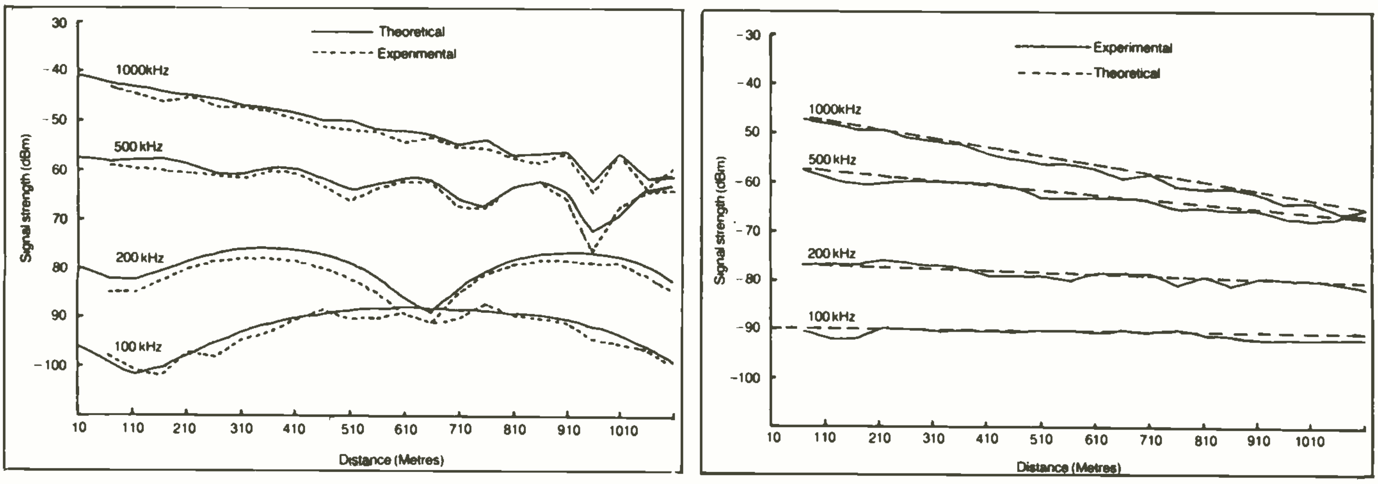
## AN UNEXPECTED CONDUCTOR

As part of a research programme to understand and quantify these various propagation phenomena, a 1400m length of cable was strung up in a gold mine tunnel 300m underground[10]. The test site contained no other metallic objects of any sort and so was an ideal area for investigating the monofilar mode. However, measurements of signal attenuation with distance at frequencies from 100kHz to 1MHz produced attenuation rates which were far lower than were predicted for this mode. By measuring the standing waves on the conductor it was possible to calculate the effective conductivity and permittivity of the "transmission line" which was guiding the energy. Both were considerably lower than one would have expected had there been a true monofilar system in operation. In fact the average value of $_r$ was only 1.65 which suggested that the energy was propagating within the air dielectric of the tunnel and not returning through the surrounding rock. The question was: "Where was the second conductor? The only possible candidate was the highly mineralized water in a trough which ran the length of the tunnel. Its measured conductivity was some 600 times higher than that of distilled water. On that assumption the characteristic impedance of this two "conductor" transmission line was calculated as being about 500ohms. The rest was easy. Terminating the end of the cable and the water trough below in 500ohms flattened out the standing waves almost completely, as can be seen when comparing Figs. 4(a) and (b), thus confirming the mechanism at work.

This result was both novel in view of the unexpected transmission line which was identified and most useful because it confirmed a somewhat similar model which had appeared in the literature [11]. In that case a railway line, embedded in a tunnel floor, had been shown to function most effectively as the second conductor with an overhead trolley wire in a bifilar system.

## DAY-TO-DAY APPLICATIONS

With the greater understanding of the propagation mechanisms which these various




theoretical and experimental programmes had provided, serious consideration was given to producing equipment suitable for day-to-day mining use. As with all communication systems there was a need for frequency planning and allocation in order to prevent mutual interference with other users in the area. It will be appreciated of course that no such interference would occur either to or from communication services on the surface because of the high rate of attenuation through the overburden. Voice communication was not the only area of application of radio in mines. Considerable success had been achieved with both remote control and telemetry systems provided by medium-frequency radio. It was vital therefore to be flexible in the use of the spectrum and so the next generation of s.s.b. equipment, produced in 1978, provided multi-channel capabilities, synthesized in 10kHz steps from 100kHz to 1100kHz. The SC100 transceivers, shown in Fig. 5, (p.943) were manufactured to military specifications in order to be able to withstand the very rugged and corrosive environment encountered in deep, hard-rock mines. In addition they had to satisfy stringent intrinsic safety requirements to prevent any possibility of ignition of flammable gases, should these be encountered underground.

In mining emergency situations, particularly underground fires, all electric power to the affected areas is switched off. This has the immediate effect of eliminating all electrical noise generated by plant and machinery. Under normal circumstances this impulsive noise interferes seriously with radio communications and the early generations of equipment were not designed to discriminate against it. Two options were then open: either the use of f.m. rather than s.s.b. or the incorporation of noise blanking into the receiver to remove the interfering noise pulses. Both were investigated and it is a moot point which is the better approach to follow. F.m. would seem to offer the advantage of less complicated circuitry in achieving its objective though recent advances in signal processing techniques, incorporated into the latest version of the s.s.b. equipment being developed at the time of writing (Fig.6), would appear to have more than satisfied the operational requirements.

This article has reviewed some of the history of radio communications underground at medium frequencies. It is worth noting that probably only radio communications with submerged submarines provides a set of environmental conditions and electromagnetic issues which are more challenging to the design engineer. One can only speculate on the next generation of equipment to see service in mines.

**Fig.4(a) shows a single, unterminated 1400m cable in a mine tunnel has noticeable standing waves induced on it when excited at various frequencies. A simple theoretical model predicted those standing waves very accurately. The necessary second conductor was found to be highly conducting run-off water flowing in a ditch within the tunnel. (b) shows a calculation of the characteristic impedance of this inadvertent transmission line. When terminated by that value the standing waves disappeared just as expected. The increased losses at the higher fequencies are also evident from these two figures.**

**Fig.6. The most recent s.s.b. medium-frequency underground radio equipment, using a throat microphone. The unit contains a noise-blanking system.**

The author would like to acknowledge the team effort of his former colleagues in the Research Organization of the Chamber of Mines of South Africa.

**The author**

Brian Austin, Ph.D, FIEE, worked in industry on underground radio communications problems for ten years before becoming a senior lecturer at the University of the Witwatersrand in Johannesburg. He is now in the Department of Electrical Engineering and Electronics at the University of Liverpool.

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# Handshaking state diagrams ease design of your own m.s.i.

**Multiple state diagrams with handshaking interconnections provide a self-documenting technique for m.s.i. chip design using field-programmable logic sequencers. All you need is a low-cost logic programmer, a PC and suitable software.**

DAVID BATCHELER

Regular readers of *Wireless World* will be familiar with the logic design techniques expounded so effectively by D. Zissos and B. Holdsworth and these methods* apply well to the growing family of field-programmable logic sequencers which are increasing in size and power each year. With FPLSs design engineers can make their own m.s.i. chips tailored to individual needs but the design of the state diagram needs care and can be time consuming if many interacting states are involved.

It is sometimes easier to break the problem into small parts each with its own state diagram and have the different diagrams interact in a handshaking mode to quickly produce a chip design that is easy to understand.

A recent opportunity to use this technique occurred when I had to design a circuit to measure the difference between two currents one at 2000 volts and the other at 4000 volts. The currents were turned into two pulse trains X and Y whose frequencies were proportional to the respective currents. The difference frequency X−Y was now required to give an accurate measure of the difference current. The mark space ratio of the pulse trains changed with frequency but we knew that X>Y under all conditions.

## DRAWING THE STATE DIAGRAMS

The general approach would be to use the standard sequential techniques to produce a single state diagram, see panel. This proves to be rather difficult because the state diagram must divide into two at every state after the first, to take account of the fact that the next edge to come along could be an X or a Y. We must allow for both possibilities if we are to have freedom of mark: space ratio for both pulse trains.

The technique I adopted for this problem has proved generally useful namely to split the problem into simple functions that can be represented on a state diagram and have all such systems interact with each other on a handshaking basis. Using this technique a system to produce a difference frequency from the two pulse trains X and Y breaks down into a three-state diagram problem with an X register, a Y register and a difference counter, as shown in Figs 1,2 and 3. All these state diagrams have four states, each being represented by a unique binary code 00, 01, 11 or 10 and, in contrast to one big state diagram, each of these is easy to understand.

## HOW THE SYSTEM WORKS

Refering to Fig.1 an X pulse will cause the X register to move from S0 (A0, B0 = 00) to S1 (A0, B0 = 01) during the following clock pulse and the X pulse is then latched in. This causes two things to occur, the Y register (Fig.2) moves from S4 to S5 so that it is ready to register a Y, and the difference counter (Fig.3) moves from S8 to S9 counting the X. When the difference counter moves to state S9 it 'handshakes' back to the X register causing it move from S1 to S2. The X register will return to S0 whenever X goes to zero and be ready to register a further X. The difference counter moves to state S12 during the clock pulse after the X register moved to state S2 and it now waits for the next pulse to be registered. If the next pulse is a Y the difference counter moves from S12 to S8 and the external counter is not affected, but if the next pulse is a further X, the difference counter moves from S12 to S11 and a difference count is now recorded.

In detail, if the difference counter is in state S12 and a further X is registered in state S1, the next clock pulse moves the difference counter to S11. A further clock pulse counts a pulse from S11 into an external difference counter and moves the X register from S1 to S2. The clock pulse after the X register moves into state S2, the difference counter is clocked back into S12

* As found in
Logic Design Algorithms by D. Zissos. Oxford 1972.
Logic Design-5: Clock driven circuits, by B. Holdsworth and D. Zissos. *Wireless World* June 1977.
Digital Logic Design, by B. Holdsworth, Butterworth 1982.

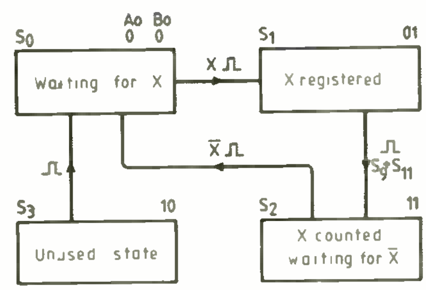
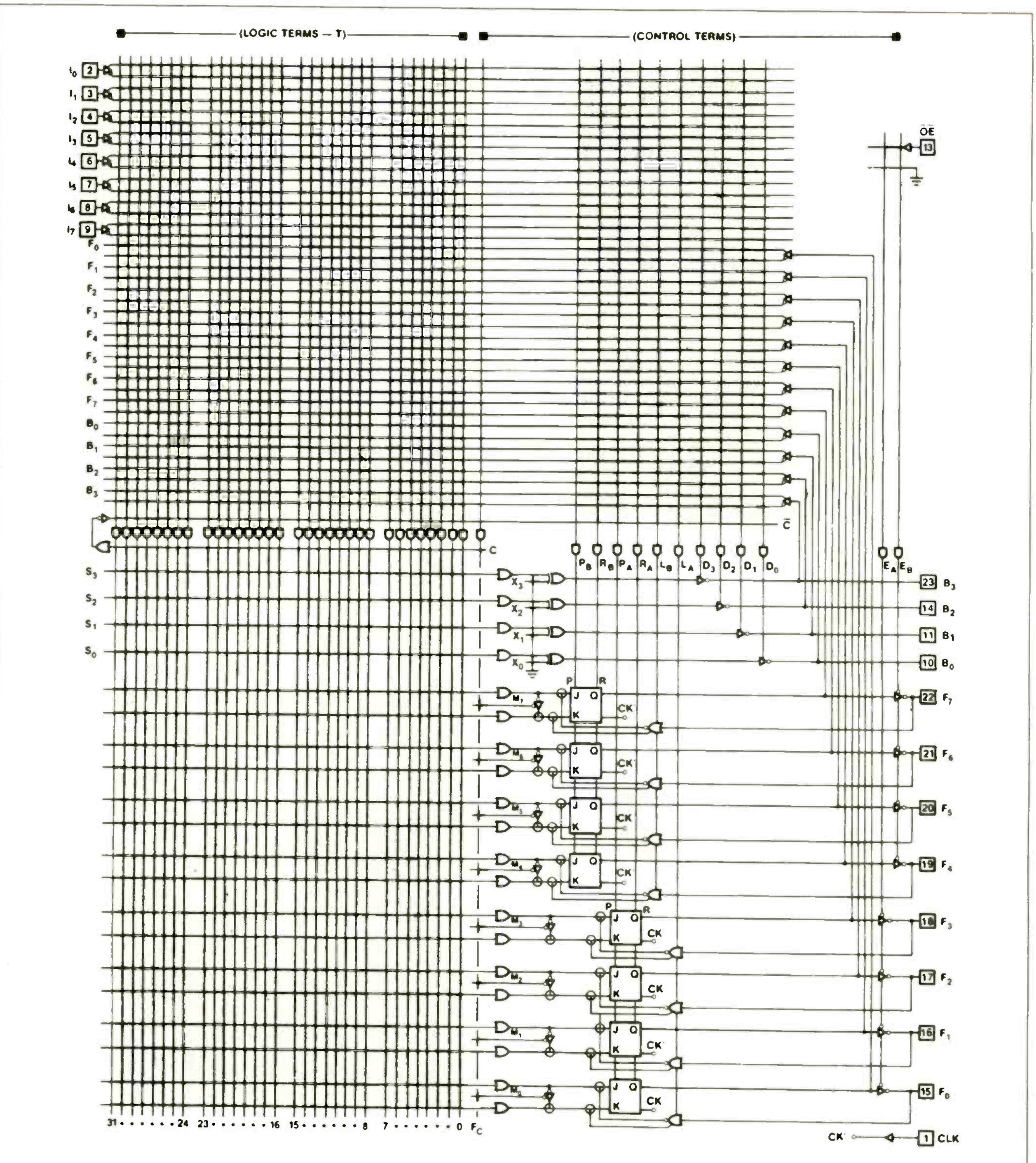



**Fig.1 State diagram describes the action of the X register circuit which stores an X pulse by a state change from S0 to S1. When the difference counter enters either state S8 or S12 it counts the X pulse by moving to state S9 or S11. The difference counter then clears the X register by moving it from S1 to S2.**

### 1: DESIGNING SEQUENTIAL SYSTEMS

A sequential logic system consists of a circuit which is latched at any given time into a stable condition waiting for some event to occur to move it into the next stable state. In any system there must be $2^N$ states since the addition of a bistable latch will double the number of available stable states. Unused states must be defined so that they do not become latch-up states at switch-on or during a burst of noise.

One diagrammatic way to represent sequential logic systems is with a state diagram, in which a box is used to represent the latched states and an arrowed line is used to show transistions from one state to another. The boxes are given a unique binary code and the conditions which will cause a transition to take place are put by the arrow. The box can be used to give a written description of the state of the system and the order of the binary code can be freely chosen to give convenient output signals if the system is clocked. Event-driven systems must follow a Grey code sequence at all times to avoid race conditions. Clocked systems do not have this limitation.




1. All OR gate inputs with a blown link float to logic "0".
2. All other gates and control inputs with a blown link float to logic "1".
3. ⌒ denotes WIRE-OR.
4. Programmable connection.

waiting for yet another X or a Y. Each X pulse to occur before a Y will be registered in the same way, until a Y occurs, which will cancel the first X register and reset the difference counter to state S8.

A Y pulse is registered in the Y register by a movement from S5 to S6 and after being counted by the difference counter the handshaking effect will move the Y register from S6 to S7 where it will remain until Y goes to zero.

Notice that every change of state in the difference counter is caused by a state being entered in the X or Y registers and after each change the difference counter handshakes a change back to the registers.

## DERIVING BOOLEAN EQUATIONS

The Boolean equations are derived simply and directly from the state diagram by looking for all the conditions which turn a given state on or off.

In Fig.1 the states are defined by A0 and B0. A0 is turned on (i.e. from 0 to 1) when we move from state S1 to S2 and under no other condition. The movement from S1 to S2 occurs after the difference counter enters either state S9 or state S11. So we can say

Turn-on condition for A0

$$=S1^*(S9+S11)$$

$$=\overline{A0}^*B0^*(S9+S11).$$

However as we are using J-K flip-flops, $\overline{A0}$ ($\bar{Q}$ in J-K nomenclature) is internally added

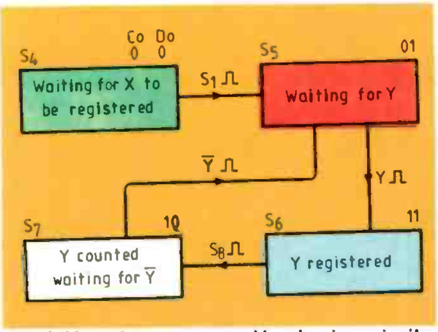



Fig.2. Y-register stores a Y pulse in a similar manner to the action of the X register. At the start of each sequence however it waits in state S4 until the X pulse has been registered before storing a Y. This synchronizes the two registers.

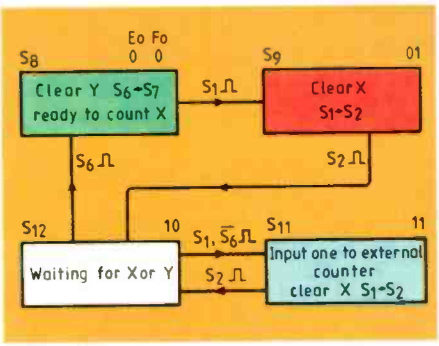



Fig.3. Difference counter counts the first X by moving from state S8 to state S9. When the X register has been cleared, counter is moved to S12 where it waits for either an X or a Y to be stored in the registers. Every X stored before a Y will cause the difference counter to move to S11 producing one difference pulse. A Y will cancel the first X and return difference counter to state S8.

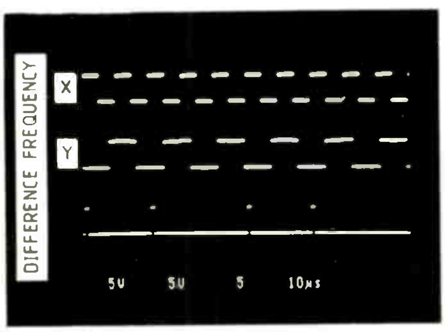



Fig.5. Oscilloscope picture shows a train of X pulses, a train of Y pulses and the resulting difference pulse train from pin 10 of the integrated circuit.

into the $J_{A0}$ input and we can say

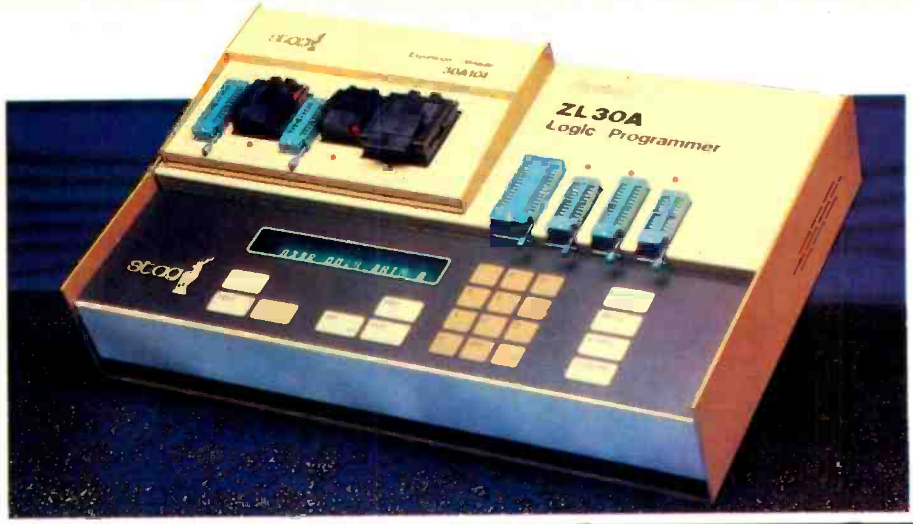
$$J_{A0} = B0^*(S9 + S11).$$

Now looking at S9 + S11 we see from Fig.3 that $S9 = \overline{E0}^*F0$ and $S11 = E0^*F0$, so $S9 + S11 = \overline{E0}^*F0 + E0^*F0 = F0$.

And we have a final expression for the J-input to the A0 flip-flop: $J_{A0} = B0^*F0$.

In a similar way we derive the turn-off conditions for A0. There are two conditions which bring about the turn-off of A0. From Fig.1 these are the transition from S3 to S0 and from S2 to S0. These conditions are

$$= S2^*\,\overline{X} + S3$$
$$= A0^*B0^*\,X + A0^*\,\overline{B0}$$




This Stag programmer together with PC and Signetics Amaze software are all that is needed to produce the a wide variety of m.s.i. chips. With an expansion module it will also cater for Mullard's new PML macro logic devices. Details of Signetics programmable logic devices and Amaze software from Paul Whicker on 01-580 6633. Stag are on 0707 332148.

Now in a J-K flip flop A0 is internally added into the $K_{A0}$ input and so

$$K_{A0} = B0^*\,\overline{X} + \overline{B0}.$$

In the Signetics software the two equations for $J_{A0}$ and $K_{A0}$ are represented as follows:

$$\text{a0:}\quad j = b0^*f0;\qquad k = b0^*\overline{X} + \overline{b0};$$

The remaining j and k equations for b0, c0, d0, e0, f0, are all derived from the state diagrams exactly as above.

$$J_{B0} = \overline{A0}^*\,X$$
$$K_{B0} = A0^*\,\overline{X}$$
$$J_{C0} = \overline{D0}^*Y$$
$$K_{C0} = \overline{D0}^*\overline{Y}$$
$$J_{D0} = \overline{C0}^*\overline{A0}^*\,\overline{B0} + C0^*\,\overline{Y}$$
$$K_{D0} = C0^*\,\overline{E0}^*\,\overline{F0}$$
$$J_{E0} = \overline{F0}^*\,A0^*B0$$
$$K_{E0} = \overline{F0}^*\overline{C0}^*D0$$
$$J_{F0} = \overline{E0}^*\overline{A0}^*\,B0 + E0^*\,\overline{A0}^*\,\,B0^*\,\overline{(C0^*D0)}$$
$$K_{F0} = A0^*\,B0$$

The difference frequency output occurs wherever state S11 is entered i.e. when $E0^*F0 = 11$.

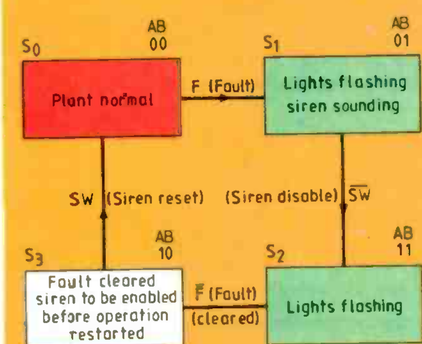
## FREQUENCY LIMITATIONS

The use of multiple state diagrams gives a system that is easy to understand and implement but the handshaking takes up clock cycles. The sequence for counting X and resetting is S0 to S1, S8 to S9, S1 to S2, S9 to S12 and S2 to S0, i.e. five clock cycles are required to count and reset an X pulse so the frequency of the clock pulse must be at least five times that of X.

This circuit was used to replace two a.c.-to-d.c. converters and an analogue comparator and from conception to having a working chip in the circuit took only a few working hours, because of the availability of FPLSs. The device used was a Signetics PLS179 and Fig.4 (page 969) shows the Boolean inputs derived from state diagrams and the pin configuration as presented by Amaze software. Fig.5 shows the chip in action.

## 2: EXAMPLE

**The alarms for a chemical plant may consist of a siren and flashing lights. When the maintenance crew arrive on the scene they may throw a switch to turn the siren off but the lights may continue to flash until the fault is fixed. Finally the switch that disabled the siren must be restored before the plant can be started again. The state diagram of the alarm system shows the conditions during the states within the boxes and the event that causes the state to change on the line by the**




**arrow. Under normal conditions the alarm system is in state S0 but when a fault F occurs the alarm moves to state S1 until the switch is operated when it moves to S2. When the fault is cleared the system moves to state S3 where it waits until the switch is returned to the on position before returning to S0.**

**Descriptions within the state boxes show conditions that exist when the system is in that state. Descriptions by the arrows show the conditions that will cause a change of state to occur.**

The logic diagram of the PLS179, opposite, contains eight J-K flip-flops configured so that both the J and K inputs can be programmed with sum of products expressions. The outputs Q and $\overline{Q}$ can also be routed to any of the inputs internally, making it a versatile device for use in clocked sequential systems with many as 256 states on a single device.

This technique has been used to reduce more complex state diagrams to a system of simple state diagrams in circuits of more specialized interest.

*David Batcheler, M.Sc. M.I.E.E., is engineering design support manager at Venus Scientific, Inc., a Ferranti company, on Long Island, New York.*

# NEW PRODUCTS

## Computer-controlled oscilloscope

A suite of utility software from Tektronix enables their 1100 series of oscilloscopes to be controlled from an IBM PC. Two versions cover different oscilloscope models.

The software allows the computer to be used to control routine tasks, such as the acquisition, storage, graphic representation and transmission of test setups, waveform and measurement data.

The system is menu driven from the computer. Source code, compatible with the IBM Basic compiler or Microsoft QuickBasic (2.0 versions of both) makes it possible for the user to add additional specific utilities to the software. Measurement data can be loaded into analytical data base programs such as Asyst, Lotus 1-2-3 and Framework. Tektronix UK Ltd, Fourth Avenue, Globe Park, Marlow, Bucks SL7 1YD. Tel: 06284 6000.


## Universal counter/timer

A wide range of measurement modes including frequency, period, period average, time interval, time interval average, frequency ratio, and totals are available on the Thandar TF1000 series of universal counter/timers.

Two inputs are provided each with a d.c. to 100MHz bandwidth, a.c. or d.c. coupling, slope selection, and a 1:1 or 10:1 attenuator. Channel A also has a high frequency filter. Both channels have trigger level controls with three-state trigger indicators. A trigger hold-off control is used in time interval measurements and a display time control allows display times of 100ms to infinity. The instruments also feature an 8-digit display with six additional function indicators. The rear panel has an internal/external clock switch and socket, low frequency monitors for channels A and B for probe calibration, and d.c. trigger level outputs for each channel. The monitor output is used for the indication of start and stop points when in time-interval mode; the output has three states when trigger hold-off is selected.

The Model TF1000 has an extra input (Channel C) to allow frequency measurements to 1GHz. Both instruments have a high-stability timebase option based upon a 10MHz crystal oscillator.

Available from Electronic Brokers Ltd, 140 Camden Street, London, NW1 9PB. Tel: 01-267 7070.

## Digital clamp meter

A meter measurement of current and voltages in power cables is the Model 620 from Global Specialties. The hand-held digital clamp meter has eight functions including direct volts, alternating volts, a.c, resistance, continuity, data hold, diode test, and peak hold.

The 620 has a 3½-digit liquid crystal display with automatic indications of negative polarity, over-input, and low battery. the nominal measurement rate is 2.5 measurements per second. It is powered by a single 9V battery. The instrument is supplied with a pair of test leads, a battery, a carrying case, and an instruction manual. Global Specialties, Shire Hill Industrial Estate, Saffron Walden, Essex. CB11 3AQ. Tel: 0799 21682.

## Fast recovery rectifier diodes

Three new fast recovery rectifier diodes from Semikron, feature reverse recovery times as short as 250ns.

The diodes are packaged in either stud or capsule form, depending on current rating. They are suitable for applications in switched mode power supplies, inverters, a.c. motor controllers, uninterruptible power supplies, and as inverse diodes for g.t.o. and asymmetric thyristors.

The fastest of the three, at 250ns, is the SKN 3 F 20 stud diode. It has an RMS forward current of 41A and a 375A. Reverse voltages range from 600 to 1200V. The second device, the SKM 2 M 100 stud diode, has a maximum reverse recovery time of 2μs and a forward current rating of 190A. Voltage ratings vary from 400 to 1400V.

Designed for high-power applications, the SKN 2 M 400 capsule diode has an average forward current of 400A. Its recovery time is 4μs and voltage ratings are available in the range 800-1500V. Semikron Ltd, 4 Marshgate Drive, Hertford SG13 7BQ.

## Low drop voltage regulator

A 5V/1A three-terminal voltage regulator, type L4941 from SGS, exploits a new bipolar power technology to achieve a very low dropout voltage 450mV at 1A) and very low quiescent current (35mA). In place of the lateral PNP transistor normally employed as the series-pass element in low drop regulators this i.c. uses a new isolated collector vertical PNP structure which offers gain and speed performance much closer to those of NPN transistors.

The L4941's low dropout is particularly useful in post regulation and battery supply applications. In post regulation schemes the device allows a much lower intermediate voltage between the main regulator and post regulators; increasing system efficiency. And in battery-powered equipment the low dropout prolongs effective battery life – an L4941 will continue to provide a stable 5.8V for conventional low drop regulators and 6.5V for standard regulators. Performance is guaranteed right down to the minimum input voltage.
SGS Semiconductor Ltd, Planar House, Walton Street, Aylesbury, Bucks.
Tel: 0296 5977.

## Small 100MHz oscilloscope

Claimed to be the smallest of its type, the Hitachi V-1065 oscilloscope is 275mm wide, 130mm high and 360mm deep. An internal processor provides automatic calibration of the timebase and sweep circuit diagnostics. Cursor measurement on the c.r.t. display include △V1, △V2, △T and 1/T and also displays several system parameters. 'Sensitivity' is 2mV to 5V/div in 11 calibrated steps with an accuracy of ±3% across the full bandwidth. Rise time is 35ns and a signal delay facility enables the examination of the leading edge. Delay sweep allows the expansion of cursor-marked areas for closer inspection. Sweep time on the main timebase is 50ns to 0.5s/div; the delay timebase has 50ns to 50ms/div. The timebase can lock automatically to an incoming signal and trigger lock prevents false triggering when faced with multiple pulse bursts. Hitachi Denshi UK Ltd, 13 Garrick Industrial Estate, Hendon, London NW9 9AP. Tel: 01-202 4311.

# NEW PRODUCTS

## Unified switch sets

A range of switches and 7-segment l.e.d. displays can be plugged together and mounted on a p.c.b. The result is a considerable reduction in production costs and an improvement in both reliability and appearance. The TT type is for sideways plugging into a vertical p.c.b. Decades of thumbwheel switches have varying lead lengths so that those furthest from the p.c.b. are pinned through the nearer switches. The range is complemented by momentary contact or toggle switches, l.e.d. indicators, fuse holders, and locking switches.

A further range may be mounted on a horizontal p.c.b. and the TPS range is specifically designed to be used with surface-mounted boards, having a separate base into which the switches plug after reflow soldering. Data Precision Ltd, Fromson Building 1, Canada Road, Byfleet, Surrey KT14 7JL. Tel: 09323 53879.

## Coder for radio data service

A radio data coder can insert an inaudible extra signal into an f.m. broadcast for use with new radio sets to display channel and programme information, and some other services.

A computer sets-up the message content which is stored in non-volatile memory not only to retain it but also to allow it to be changed rapidly when required to do so.

The RE531 coder offers a carrier and unwanted-signal suppression of >90dB, it incorporates a v.r.f. coder, and the 19 to 57kHz phase is selectable –0 or 90°. It can be programmed to give single or chained lists and may be synchronized externally. The signals and coding principle conform to the EBU technical document 3244 supplement 2, and can optionally provide radio-paging, alarm and status signals.
R.E. Instruments Ltd, Sherwood House, High Street, Crowthorne, Berks RG11 7AT.
Tel: 0344 772369.

## Fast plotter for computer output

A large (240K) buffer memory permits the transfer of complex drawings at high speed to the Advance Bryans Colourwriter 6400 plotters. This frees the host computer for other tasks. The 6400 is a series of plotters including one that takes A4 paper size with seven pens and an A3 plotter with ten pens. A roll paper holder (optional) allows the automatic plotting of up to 105 consecutive drawings. Each plotter accepts commands in the Hewlett Packard graphic language and additional built-in commands ensure compatibility with a range of commercial software enabling the production of pie charts and filled areas. There are three character sets provided and seven different types of line. Advance Bryans Instruments Ltd, 14 Wates Way, Mitcham, Surrey CR4 4HR.
Tel: 01-640 5624.

## Repair kit for surface mounts

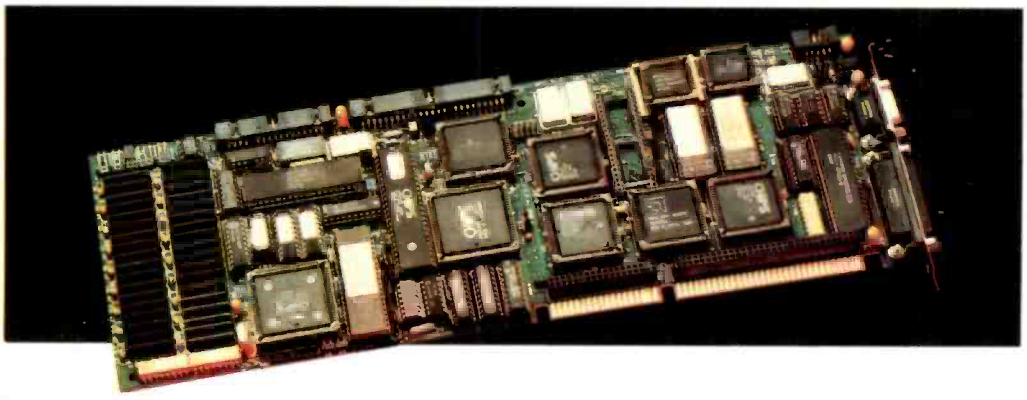
Contained in a plastic carrying case, the Multicore SMD solder repair kit provides all the materials necessary to replace faulty surface-mounted components. These include; solder wick to remove excess solder after a component has been removed; halide and rosin-free liquid flux with a brush to apply it; solder cream; low melting-point solder wire and a solvent cleaner to remove any flux residues. All parts of the kit may be re-ordered individually. Multicore Solders Ltd, Kelsey House, Wood Lane End, Hemel Hempstead, Herts HP2 4RQ. Tel: 0442 233233.

## IEEE-488 for PCs

Housed on a half-size plug-in card the Brain Box offers full IEEE 4888 (GPIB) interfacing for an IBM PC (XT or AT) and most compatibles. The interface features data transfer rates of 250kByte/s, a complete controller with 'listen' and 'talk' ability. It is supplied with comprehensive software which includes user-defined 'End of Sequence' terminator and time-outs, and can redirect any of the outputs through the GPIB port. Support is provided for a variety of high and low-level languages as well as Tektronix standard codes. At less than £200 the British-made card and associated software offers many features costing much more on imported products. Aditi Electronics, 46B High Street, Hurstpierpoint, W. Sussex BN6 9TT. Tel: 0273 833124.

## PC/AT computer on a single board

Compatible with the IBM/AT computer the single-board computer from Databasix has been designed to offer systems integration and for industrial automation. The board has all the functions of the AT computer with some additional facilities, including 1MBytes of ram and 128KBytes of eprom. It includes controllers for hard and floppy discs, parallel and serial i/o ports, a SCSI controller and a clock/calendar. A maths co-processor may be fitted optionally. Cmos components ensure a low power consumption and applications for this QPC-5152 board are likely to be found in process control, computer-aided design, and built-in to other products. Databasix Ltd, Old Bath Road, Newbury, Berks RG13 1NG. Tel: 0635 37373.



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| MARCONI TF1066B AM/FM 10MHz–470MHz | £350 |
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| MARCONI TF1313 Universal Bridge | £100 |
| H.P. RF MILLIVOLTMETER 411A 500KHz–500MHz | £60 |
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| AVO 8 Complete with batteries and leads from | £50 |
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| TEST LEADS suitable for AVOMETERS Red & Black with 2 Croc Clips and 2 Prods (p&p £2) | £5 |
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| Real Time Third Octave Analyser Type 3347 | £3.000 |
| Heterodyne Analyser Type 2010 | £1.750 |
| Level Recorder Type [illegible]307 | £1.400 |
| Beat Frequency Oscillator Type 1022 | £400 |

| | |
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| DISK DRIVE PSU 240V in 5V 1.6A & 12V 1.5A Out Size W25mm | £10 ea |
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# NEW PRODUCTS
COMPUTING

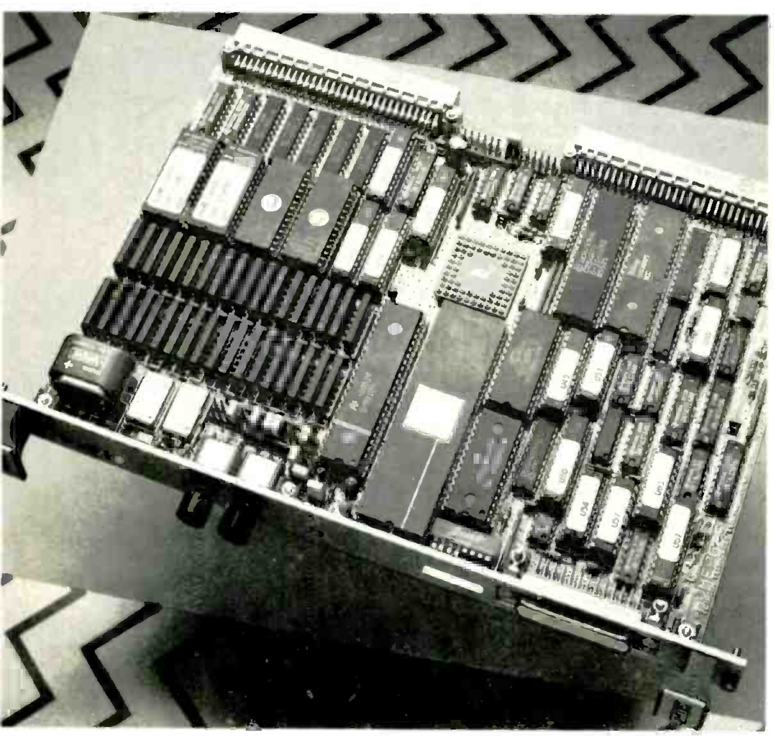
## Transputer graphics evaluation

Rapid Silicon have put together a high-speed graphics demonstration package based on Inmos transputer products.The equipment includes Inmos' multi-transputer evaluation boards, the IMSB003, which contains four 32-bit T414 transputers to provide a processing system which can run at 40 mips. The high-performance graphics card, the IMSB007, can display high-resolution, real-time animated images with ray-traced reflections and similar effects. The disc processing card, IMBB005, itself with two T212 transputers, can be fitted, with a hard disc, into a small volume and offers considerable space saving over other systems. Further details from Rapid Silicon, Denmark Street, High Wycombe, Bucks HP11 2ER. Tel: 0494 442266.

## VME-bus computer board with SCSI

Built around the 68010 processor, the HVME-SB86S is a single board computer with a SCSI interface. It is intended for use in realtime computing and has an i/o bus particularly suited to disc drives, graphics and other back-up peripherals. Applications include engineering workstations, multi-user systems, development and target systems. The 68010 runs at 10 or 12.5MHz with no wait states from on-board 512K or 1Mbyte d.ram. The addition of a v.d.u. terminal and power supply enables the card to run as a standalone computer. Units can be linked together in a multi-processor system. Through the VME bus the board supports three levels of bus arbitration and has a seven-level bus handler with bus clock and reset facilities.

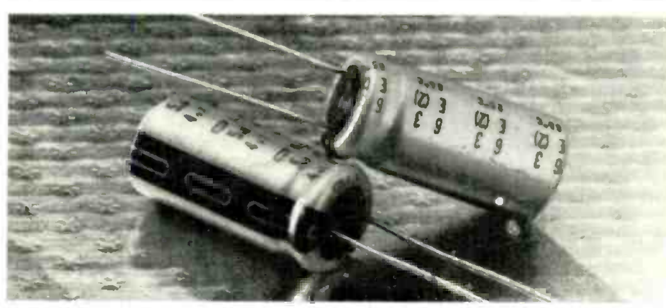
In addition to VME and SCSI bus controllers, the board has two serial ports and a parallel printer port. Four sockets allow up to 256Kbytes of eprom and an additional 8Kbyte s.ram is battery backed to retain data on power down.
High Technology Electronics Ltd,
303 Portswood Road,
Southampton SO1 1QL.
Tel: 0703 229041.



## Transputer card for PC

An add-on board for IBM XT or AT personal computers or compatibles from Systems West includes one or two 32-bit transputers and up to 16 Mbyte of ram. The board runs at up to 30 mips, depending on the number and types of transputer included. This offers a performance, comparable with super-mini and mainframe computers. For even faster performance, up to three boards can be fitted to give 90 mips, or the system with one or more upgrade cards can be networked with another computer. It can also be used to control an even more powerful transputer-based system from the same makers.

Tasm, the transputer assembler software set is provided but high level languages, Fortran, C, Pascal and Occam are optional extras. These languages generate code that runs completely on the transputers. libraries of interfacing programs running on the host system under DOS, with maths and graphics tasks undertaken by the upgrade boards, support high-speed data tranfer between host and transputer using interrupts and d.m.a. Software currently runs under DOS 3.2 but DOS 3.3 and OS 2 systems will become available in about a year.
Systems West, Suite 110, Southgate, Whitefriars, Lewins Mead, Bristol BS1 2NT.
Tel: 0272 277332.



## Capacitors for memory back-up

The new SB series of aluminium electrolytic capacitors from ECC Electronics have been specially designed for memory back-up applications. Using a new foil etching technique and a special electrolyte, the capacitors are claimed to offer a superior performance to batteries in terms of operating temperature range of −25 to +85°C and a guaranteed load life of 1000 hours at 85°C, with good holding voltage characteristics. The SB series is available in capacitance values ranging from 2.2 to 47 mF to meet the requirements of extremely low current flow memory back-up applications. Maximum operating voltage is 5.5V and surge voltage rating is 6.3V.
ECC Electronics UK Ltd, 9 Blenheim Road, High Wycombe, Bucks HP12 3RT.
Tel: 0494 36113.

# NEW PRODUCTS

COMPONENTS

## Forth systems development toolbox

A design system called FORCE (Forth-optimized risc computing engine) has been developed by Harris and is based on the Novix Forth processor risc architecture. Readers may recall the feature on this device recently in *E&WW*. It differs from most other processors by running the high-level language Forth directly as its operating language; this results in high speed and easy programming. The end products will be standard and semi-custom i.cs incorporating the risc chip with additional macrocells and logic gates. The high speed of the devices is likely to find particular application in real-time control and digital signal processing systems. Macrocells under development include a 16-input interrupt controller, an integrated memory stack controller, a 16 by 16-bit multiplier and various counter timers. The first standard i.c. will be a control processor incorporating all of these functions along with the processor, available towards the end of the year. Application-specific i.cs will become available early in 1988. Harris Semiconductor, Eskdale Road, Winnersh, Wokingham, Berks RG11 5TR. Tel: 0734 698787.

## Fast 16-bit and 24-bit multipliers

The high-speed performance demanded by array processor, super-mini computers and other devices can be met by two new bipolar digital multipliers from Analog Devices. The ADSP8018 is a 10kHz e.c.l.-compatible 16 by 16-bit multiplier with a maximum multiply time of 19ns. ADSP-7018 is a t.t.l.-compatible version with a maximum multiply time of 19ns. The devices use 2μm bipolar geometry with gate delays of 300ps and lower power dissipation than the slower e.c.l. rival devices. Each multiplier has a 32-bit output port so that the 32-bit product of a 16 by 16-bit multiply can be read in one clock cycle.

The same company has produced a 24 by 24-bit c-mos multiplier with a maximum multiply time of 95ns. The ADSP1024A is designed to bridge the gap where 16-bit multipliers are not accurate enough but floating-point i.cs are too expensive, especially in d.s.p. and graphics applications. The device has two inputs and one output. The most significant and least significant products are multiplexed through the output port in a single clock cycle, producing a full 48-bit product without throughput delay. Analog Devices, Station Avenue, Walton-on-Thames, Surrey KT12 1PF. Tel: 0932 232222.

## Optical proximity sensors

It is now possible to obtain an 18mm photocell with optical proximity sensing up to 150mm, using the new option introduced to its RC photocell range by Datalogic. The increased distance, claimed to be some 50% above the norm for this type of sensor, has been achieved without any change in the size of the unit which, at 18mm length, is compact.

A second option is upgraded frequency from 175 operations per second to 1500 op/s. At a frequency of 1.5kHz, the M18 barrel unit gives a higher response accuracy for machine timing and product detection.

Particularly suited to the production line, packaging machines, conveyors and control, the RC Range of 256 photocells uses modulated infra-red radiation. They have built-in amplifiers and incorporate an l.e.d. to indicate that the unit is switching. D.c. versions are protected against short-circuits and inverse polarity connection. Included in the range are 24 fibre optic versions for installation in awkward or hazardous areas.

Versions of the Datalogic M18 Barrel Unit available are: Retro-reflective, optical proximity, diffused and focussed, through-beam and fibre optic, all in a.c. and d.c. The higher frequency is available on d.c. models and extra direct detection distance on both types. Datalogic (UK) Ltd, Redbourn Industrial Park, High Street, Redbourn, St. Albans, Hertfordshire AL3 7LG. Tel: 0582 85 4344.

## Fast static rams

Manufactured in c.mos by MMB Semiconductor, the AAA16K4 is organized as 4096 by 4 bits. It has been optimized for speed while offering low power consumption. Maximum current used is 120mA when active and 20mA on standby, with an access time as fast as 25ns. The device is automatically held in standby mode whenever it is not selected. This reduces the power requirement further and the need for cooling. Inputs and outputs are t.t.l.-compatible which leads to the simplification of system design. Three versions offer differing access times and all are in standard 20-pin dil packages. Available through Mogul Electronics, Central Court, Knoll Rise, Orpington, Kent BR1 0JA. Tel: 0689 77919.

## Linescan camera with processor control

A low-cost, self-contained linescan camera requires only the addition of a light source for operation. The camera, called Autoscan, could have widespread application in non-contact measurement and monitoring functions. It contains a 128-byte eprom to set data storage. The use of microprocessor control provides easy function and setting selection using pushbuttons and a backlit liquid crystal display. Full multi-input/output capability is provided and includes a 12-bit d to a output (4 to 20mA), four relay outputs, two opto-isolated inputs for 'read now' signals and an RS485/422 bidirectional data port. Autoscan features a 2048-element linear detector array scanned at 2MHz. The standard camera is available at less than £1200 and supplied with a 50mm F1.8 variable-focus lens: other lenses are optional. Uses include edge tracking, width and height measurement, strip centre monitoring, hole and tear detection. Integrated Photomatrix Ltd, The Grove Trading Estate, Dorchester, Dorset DT1 1SY. Tel: 0305 63673.

## Programmer for logic arrays

An expansion module for the Stag ZL30A logic programmer as used in the design on page 916, can be used for Signetics programmable macro logic gate arrays. These arrays can be rapidly programmed to provide "instant" application-specific i.cs. Based on fuse programmed arrays, current devices (PLHS501) have the equivalence of up to 1600 gates. The Stag module used with their programmer allows the programming of both surface-mount and d.i.l. packages. The ZL30A programmer can now be used with over 750 programmable logic devices. Stag Electronic Designs, Tewin Court, Welwyn Garden City, Herts AL7 1AU. Tel: 0707 325136.

## Subminiature fuses

A subminiature fuse called Microtron is an axial-lead device with enhanced short-circuit performance. Rated at 125V alternating, the fuse can interrupt a 50A fault current in circuits with 97% power factors. Comparable units have similar short-circuit ratings, but at a 100% power factor, a condition that rarely exists in the real world. At 125V direct rating, the fuse can interrupt a 300A fault. The fuse is available in 1/16A steps through to 10A.

The same company has recently announced a range of subminiature surface-mount fuses. Busman UK, 1 Drumhead Court, Chorley, Lancs PR6 7BX. Tel: 02572 69533.

## Low-noise high-speed quad op-amp

A noise figure of 11nV/Hz$^{-2}$ at 1kHz, a slew rate of 8V/μs and a gain bandwidth of 6.5MHz are offered on the "new generation" OP-471 op-amps from PMI. In addition to low noise and high speed, the device is claimed to offer precision performance with very low input offset voltage and voltage drift. Open-loop gain is >500,000, ensuring gain accuracy, even in high-gain applications. Common-mode rejection is >105dB. The monolithic design ensures parametric matching and temperature tracking between all four amplifiers makes it especially suitable in multiple op-amp applications including gain blocks, low-noise instrumentation amplifiers, audio equipment, and active filters. The device has the same pin-out and can be used as a direct replacement and upgrade for a number of quad op-amps. Bourns Electronics Ltd, 90 Park Street, Camberley, Surrey GU15 3NY. Tel: 0276 692392.

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# NEW PRODUCTS

## Thermistors for protection

A comprehensive range of surge-suppression thermistors is the SK range from STC is designed to satisfy a wide variety of applications including inrush current limiting in switch-mode power supplies, time delay of relays and solenoids, and the protection of lamp filaments. Produced from semiconducting ceramic materials, the devices have an insulating coating with resistance greater than 10MΩ at 750V. Maximum operating voltage is 265V r.m.s, maximum body temperature is 200°C and standard resistance tolerance is ±20% at 25°C. There are 20 standard devices in the SK range and 'specials' can also be provided. STC Components, Edinburgh Way, Harlow, Middlesex, CM20 2DE. Tel: 0279 26811.

## Versatile video framestore

A wide range of options allows the FS768 framestore from Oggitronics to be used is a variety of applications. Apart from capturing a single video image, it can be used to view the 'live' incoming image and record a specific frame when required while continuing to view. It can be synchronized with a strobe flash to capture fast moving events. Low-level images can be captured by cumulatively adding to the picture, rather like a long exposure in a photographic camera. This can be done by modifying the camera to hold off the beam while the image is building, or by using the framestore to sum consecutive frames.

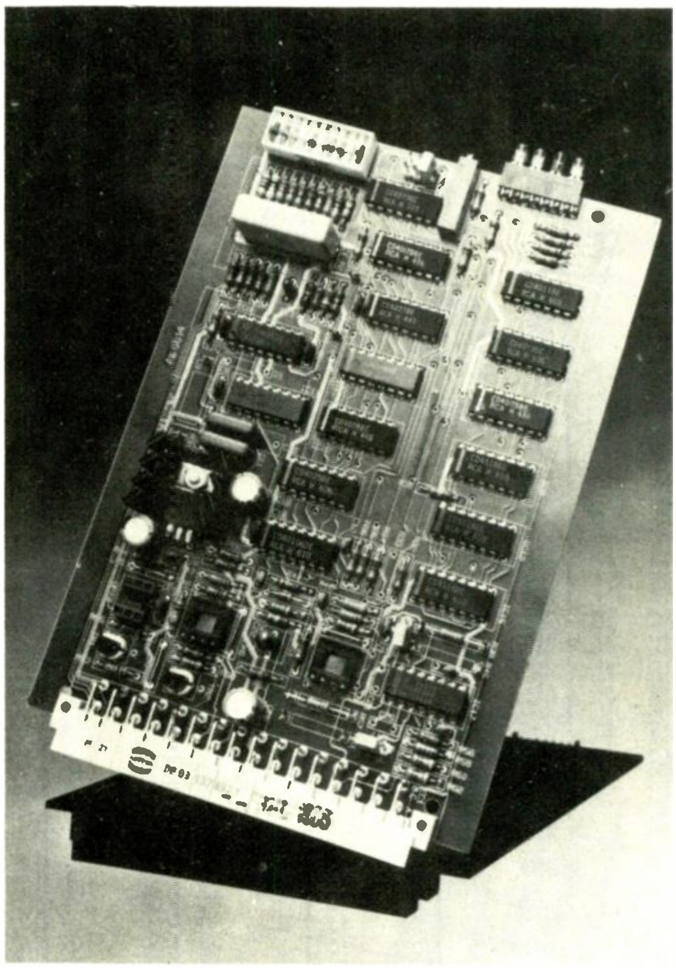
One particular use for such a store is the translation of non-standard video images for display on a tv monitor or storage on a video recorder. The FS768 can be adapted to accept the polar coordinates of radar and sonar images and convert them to the tv raster. Slow-scan input from electron microscopes or i-r detectors, or fast scans from c.c.d. and photodiode arrays can also be accepted. Such operation is transparent to the user and no interference with the screen image is seen while it is being updated.

Successive images may be averaged to reduce spurious noise; up to 256 images can be summed. A video mixer allows images to be compared and various logical operations can display the areas that are the same or are different. False colour can be added to an image by the use of a look-up table and the grey-scale can be manipulated to enhance the contrast of the image. Oggitronics, Poole House, 37 High Street, Maldon, Essex. Tel: 0621 50378.

## Low light-level camera

An ultra-high sensitivity video camera has been developed for imaging at extremely low light levels, typically those encountered in luminescence and fluorescence applications. Employing a high performance two stage MCP image intensifier, the camera, Hammamatsu C2400 VIM, provides extremely low noise and wide dynamic range extending from visible light to single photon levels.

A choice of image pickup tubes allows the camera to be optimally configured for conventional analogue or photon imaging. The system is available with a spectral response range of either 280 to 650nm or 280 to 850nm. Standard features include overload protection circuitry and bias lighting. Optional features include Peltier cooling, shading correction, gamma correction, polarity inversion and external synchronization control. Hakuto International UK Ltd, Eleanor House, 35 Eleanor Cross Road, Waltham Cross, Herts EN8 7LF. Tel: 0992 769090.

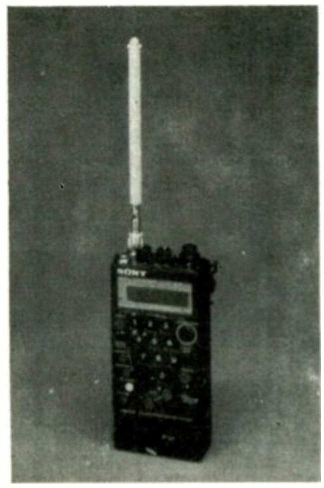


## Stepper-to-servo converter

This module allows d.c. servo motors to be driven from digital stepper motor control systems. Designers can now mix d.c. servos with stepper systems without changing the existing controller. This provides great expansion possibilities for existing stepper systems, both simplifying the control requirements and avoiding the higher costs normally associated with d.c. servo controllers. MC16 module comes on a single Eurocard. It provides the d.c. servo control function by taking the existing stepper clock and direction outputs, comparing these with feedback signals from an optical encoder attached to the motor shaft, and generating a 'torque demand' signal. Arranged like this, the d.c. drive is used purely as a torque amplifier, with the MC16 providing the required gain. Therefore, no tacho generator is necessary, further reducing overall system costs. Digiplan also offer the MC16's capabilities in the form of ready-built three-axis (or more) control systems, in a standard 19in rack. PKS-Digiplan Ltd, 21 Balena Close, Creekmoor, Poole BH17 7DX. Tel: (0202) 690911.

## All-band radio

The Sony ICFPRO80 has continuous tuning from 115kHz to 223MHz. Its memory can cope with up to 40 preset stations. Frequencies can be selected directly from its keyboard and there are several methods of scanning the memory or the r.f. spectrum, or selected parts of it, to find a channel.



Another new radio from Sony is the ICF7600DA which offers an analogue dial in addition to the digital display, and includes a clock and timer. It offers 12 s.w. bands along with v.h.f., m.w., and l.w., with up to 15 preset stations. More details from Sony UK Ltd, South Street, Staines, Middlesex TW18 4PF. Tel: 0784 67000.

## High-voltage insulation testers

Capable of uncovering defects which could cause breakdown in low voltage applications, these insulation testers can also be used as M Ω meters. The Danbridge, JPI2A and JP30A are non-destructive high voltage testers suitable for a very wide range of applications – from component testing to motors and aircraft installation. Test voltages are applied to an insulated test probe through a coaxial cable. The JPI2A (12kV) probe is equipped with a high-tension switch, and is terminated with a 4mm straight tip. JP30A (30kV) has a similar probe and an additional ball-tipped probe for use in the higher voltage ranges. The meters have two and three ranges respectively with meter readouts for voltage in kV and current in μA. Output current is a maximum of 300μA, limited to protect the user. As well as the meter indication there is an audible output which signals ionization in an insulator. Available through Wavetek Electronics Ltd, Tag Lane, Hare Hatch, Reading, Berks RG10 9LT. Tel: 073522 4121.

# NEW PRODUCTS

COMPUTING

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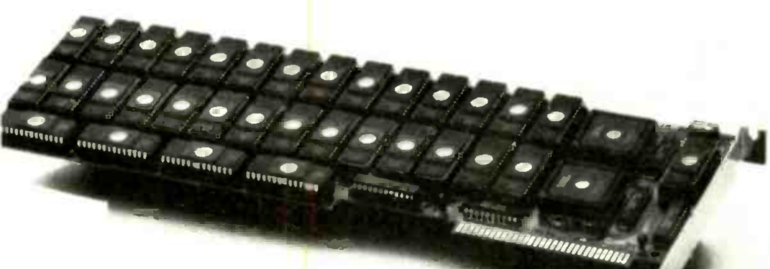
Appearing to a PC-DOS or MS-DOS as a standard disc, the QPC add-on boards for IBM compatible PCs provides a combination of ram, rom, eprom or battery-backed ram which is rugged and resistant to vibration, heat or dust as may be found in an industrial environment. Such solid-state 'discs' can retain system configurations permanently and be used for permanent program storage as well as temporary data retention. The P-5211 can hold up to 2Mbyte of prom or eprom, or 1Mbyte of eeprom. QPC-5212 has a capacity for 512Kbyte of ram, plus 1Mbyte of rom. The QPC-5213 holds 1Mbyte of ram. All ram sockets on the 5212 and 5213 are lithium battery-backed for non-volatile memory. Up to four boards can be used in a PC system giving a total of up to 8Mbytes. Databasix Ltd, Strawberry Hill House, Bath Road, Newbury, Berks RG13 1NG. Tel: 0635 37373.




## Toshiba launches super TN displays

Liquid crystal displays of the super-twisted nematic kind offer higher contrast and wider viewing angles than previous l.c.ds. Toshiba UK launch seven graphics l.c.ds ranging in size from 640 by 640 dots to 128 by 128. The displays use a multiplexing ratio of up to 1:200 to enable a high-contrast, high-definition image to be retained over the large matrix of dots. Three types are available: W-ST (blue on a white background), Y-ST (blue on a yellow background), and B-ST (white on a blue background). The last-mentioned is best used with an electroluminescent back-light.

Super-TN modules are particularly suitable for the larger displays such as those in work stations, word processors, electronic typewriters, photocopiers and facsimile machines, as well as portable computers as illustrated by Toshiba's own Rupo word-processor. Toshiba UK Ltd, Electron tube and device division, Frimley Road, Frimley, Camberley, Surrey GU16 5JJ. Tel: 0276 62222.

## Whose frequencies?

The destabilization campaign directed at British broadcasting by sections of government, politicians, advertising and media interests in the name of "deregulation" seems likely to reach a climax when a White Paper and subsequent new Broadcasting Bill are published next year under the aegis of the Home Office broadcasting policy unit. But it is questionable whether future plans can be formulated realistically until more is known about the way in which broadcasting frequencies will be allotted and regulated in view of the DTI-sponsored CSP International report "Deregulation of the radio spectrum in the UK". To many broadcast engineers the separation of responsibility for administration of the radio spectrum from broadcasting policy matters has always seemed rather like saying that one government department should be in charge of the railways but that the provision of the tracks should belong elsewhere.

Curiously, the industry was invited to respond by June 30 to both the Home Office document "Radio: Choices and Opportunities" and to the CSPI Report. Yet it is difficult to see how a realistic response can be made to either in isolation. It is clear that while there is at least some common ground on the Home Office consultative document, there are strong feelings about the radical proposals made by CSPI, and DTI claim that other concepts are still being considered.

The CSPI report assumed that the BBC and IBA would become "major users" forming, in effect, a special form of the Frequency Planning Organizations set up as commercial undertakings to manage specific blocks of the spectrum. The major users would manage their own blocks to serve their own needs, but would be free also to act as FPOs if they wished, selling spare frequencies from within their blocks to individual users. However, the FPO concept is based firmly on the idea that each FPO should have exclusive rights to a part of the spectrum and that there should always be at least one other competing FPO in a position to offer a suitable frequency from within its own block. For this concept to apply to broadcasting would pose questions that cannot be answered sensibly until more is known about the directions to be taken in the new Broadcasting Bill.

For example, on m.f. and television bands 4 and 5, specific channels are used by both the BBC and IBA in different parts of the country; only on Band 2 v.h.f./f.m. is the concept of sub-bands coming into existence. This would suggest that there might need to be a joint BBC-IBA "major user FPO" but then where does that leave the concept of competitive pricing? Or, for that matter, the concept of a virtually de-regulated radio? The IBA has stated that it believes that it is in the interest of the listening public to retain a public-service broadcasting element in independent radio but seems prepared to agree to a much more relaxed form of "control". It does recognise a class of "not for profit" stations that could maintain some vestige of the original concept of community radio, although it becomes increasingly difficult to distinguish between what is planned for the new tier of local or community of interest stations and the stations wishing to churn out "Top 40" playlists. The major debate seems to be over the question of national commercial services, with "Choices" suggesting three such services, the IBA wanting only two, and some of the existing ILR stations remaining opposed to any. Meanwhile the BBC seems to be gradually extending its World Service input to UK listeners, not only in the form of news bulletins on Radio 3 but most recently by carrying World Service for an extra 20 minutes on the 200 kHz Droitwich transmitter between 5.30 and 5.50 a.m. Many people would welcome the World Service programmes on a national Band 2 network as a logical and economical extension of choice, but that raises questions of Foreign Office funding.

What could develop into virtually a new national commercial service for the UK is being planned by Radio Luxembourg using a long-wave (254 kHz) transmitter to be built near Dublin. This is a frequency allocated to Ireland on a shared basis but never used by Radio Telefis Eireann. It is claimed that, with a power of 500 kW, it will serve most of the UK during daylight without excessive co-channel interference from the long-wave stations located in Algeria and Finland. The UK similarly has an unused long-wave allocation shared with Warsaw. This was originally intended to provide a long-wave service for Scotland, but the BBC were convinced that it would suffer too much co-channel interference.

## Spectrum and physical abuse increases

The Radio Investigation Service of the DTI seems to be fighting a losing battle to put the broadcasting pirates off the air. The latest blow has been the decision of the House of Lords that the Wireless Telegraphy Acts do not permit RIS to seize (with or without a court order) the disc and tape records of illegal broadcasting stations on the grounds that these do not constitute part of the "apparatus". Since recordings are often the most valuable and most difficult to replace assets of such stations, this is a serious blow.

At a recent joint IERE/DTI colloquium on Frequency Planning Miss Dilys Gane, director of RIS, brought up to date the current work of the service beyond that disclosed in the first Annual Report of the Radiocommunications Division of the DTI. She claimed that unlicensed broadcasting remains a particularly difficult area, with the number of stations increasing again and with the supporters of some of the stations increasingly willing to show violence and threatening behaviour towards RIS teams: "We are in a box with complaints from aeronautical and public utility services, and from the public who find BBC reception wiped out. RIS would prefer not to be in battle with organized violence". The RIS has increasingly had to call on police help in dealing with the pirates.

Following the introduction in 1985 of charges made to householders seeking RIS visits to help trace the cause of interference to their radio and television reception, there has been a big drop in complaints. But the public can still register complaints of interference without charge and many of these complaints have helped RIS to target its enforcement work against misuse of transmitters. Complaints have numbered 4,372 with only 715 people paying the £21 fee for personal visits.

The RIS however has not been idle. In particular it has stepped up its inspections of radiocommunication installations. During 1986-87, 9000 existing and 1500 new private mobile radio (p.m.r.) stations were inspected. There has also been 1300 inspections of small-craft installations, a previously neglected area. It has been found that a number of users were apparently unaware of the need to hold certificates of operating competence in addition to the transmitter licences.

Of the 9000 inspected existing p.m.r. stations, 40 per cent were found not to be fully conforming with their licences (23% in the case of new stations). About 16 per cent of allotted frequency channels were no longer in operation but had not cancelled the licence, 8 per cent were using excess e.r.p., 6 per cent had more mobile units than were being paid for, 5 per cent of the base stations had been moved without notifying the DTI, some by more than 25 miles, and 5 per cent were using non-approved equipment.

A problem with unlicensed broadcasting stations is the increasing use of "link" programme feeds to unattended transmitters using less predictable frequencies, that come to light only when they cause interference to other services.

While British Telecom appear to be gradually moving towards the introduction of the CT2 u.h.f. cordless telephones and with the sale of unapproved types banned since May, there appears to be little falling off in the number of conversations that can be accidentally heard when tuning across 1.7 MHz. Some of the signals seem to travel very much farther than the 100 m range often specified. Nor does the average user seem to realise that his private conversations are being so widely broadcast.

*Radio Broadcast is written by Pat Hawker.*

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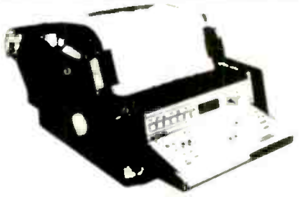

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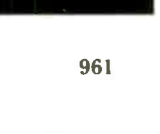

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## Tape revolution

Two-inch tape and quadruplex transverse video recorders remained supreme for broadcast applications for over 20 years from 1956 to around the end of the 1970s. The 1-in helical-scan format which replaced the quadruplex is already under challenge after a bare decade of operational use. The decision by Thames Television, following in the wake of NBC, to opt for the new half-inch M.II cassette format developed by Matsushita (Panasonic), initially for portable single camera (p.s.c.) applications but later extending to many studio operations, seems certain to set a UK trend. NBC, earlier this year, claimed that their first batch of production models of the new metal-particle-tape M.II machines had produced results exceeding expectations and promptly ordered a further batch of 236 units for delivery early 1988. For its major new studio centre in New York, NBC have chosen the M.II cassette format for all broadcast operations. It seems increasingly likely that in time 1-in reel-to-reel and the 0.75-in U-matic cassette formats may follow 2-in quadruplex virtually into oblivion.

The Thames Television decision is a blow for the rival half-inch metal-particle-tape Betacam-SP machines and could represent a serious set-back for the Sony company that in recent years has been a dominant force in broadcast studio equipment. Thames Television engineers have stated that M.II was preferred to Betacam-SP because of the 90-minute playtime and the p.c.m. digital stereo sound, but the low capital and running costs of half-inch cassette machines must also have been a powerful incentive to change formats once again to take advantage of the continuing improvement in the packaging density of magnetic tapes.

An unusually wide-ranging history of video recording has been published in the March, 1987 *SMPTE Journal* by Julia and Michael Stanton, covering almost a century of development from the initial ideas on audio recording of Oberlin Smith and Valdemar Poulsen through to the M.II and the enormous growth of the consumer video cassette market. It notes the suggestion by R.T. Firiebus in 1929 of using a light beam as the reproduction mechanism for video disc recordings, the 1927, British patent of Boris Rtcheuoloff covering recording the video image on one side of the an undefined magnetic material, the outline in 1932 by Dr Fritz Schroeter of video recording principles essentially similar to modern practice and some of the many attempts to make fixed-head machines at tape speeds of up to 30ft/s in the years before Ampex gave a first in-house demonstration of quadruplex transverse-scan recording on March 2, 1955, when it was decided to press ahead with the project. It led to a demonstration to CBS on April 4, 1956 a few days before its public appearance at the 1956 NAB Chicago exhibition.

## George Walton – tv pioneer

The recent revival of interest in the remarkable Scophony 405-line mechanical television receiver of 1938-9 (*E&WW*, May 1987, pages 515-7) reminded readers of the work of J.H. Jeffree in developing a light valve based on the diffraction of light by ultrasonic waves. But it should not be forgotten that the original Scophony company, set up in 1930 by Solomon Sagall, was primarily formed to exploit the work of the Lancashire-born engineer George William Walton. His ideas on mechanical television in the early 1920s, in collaboration with the enterprising Canadian-born (Sir) William Stephenson, were unquestionably far in advance of the early Baird work.

Recently Frank Boysen, a retired power engineer who was with the Cox-Cavendish firm making electro-medical equipment at Harlesden in the early 1920s, has told me how Walton and Stephenson, both then also with Cox-Cavendish, became associated and jointly filed patents on the synchronization of television pictures, television systems including the transmission of colour by means of beam splitting and triple interlace of red, green and blue images – all before Baird filed his first crude patent outline of a Nipkow disc system, with no indication of how synchronization could be achieved (Patent 222604 dated July 1923).

Stephenson, who was later to head the wartime British Security Coordination operation with offices in Rockefeller Centre and the telegraphic address "Intrepid", seems to have pulled out of the television and picture-telegraphy work of Walton fairly early on.

Cox-Cavendish had set up a subsidiary, General Radio, making "wireless sets" in kit form sold through Woolworth's at 6d a go, with Stephenson in charge of a new test room for this operation; George Walton, whose choice of language was often "fruity", was in charge of the firm's main test room. While Walton received financial support from Lord Northcliffe in the development of his ideas on picture telegraphy, he seems to have lacked financial backing for his television ideas until he wrote to Solomon Sagall in 1929. Yet it is interesting to note that many of the Baird systems between 1923 and 1929 seem to bear an uncanny resemblance to the systems described and illustrated in the Walton/Stephenson patents.

Patent 213,654 (Electric synchronous movements) noted that "Moving bodies at a transmitting station and a receiving station are synchronized e.g. for purposes of picture transmission or television, by modulating the electromagnetic waves emitted by a wireless or wired-wireless transmitter by an alternating current of a low frequency dependent on the movement at the transmitting station, and using such modulation to set up an alternating current of the same frequency to maintain the movement at the receiving station." Applied for December 1922.

Patent 218,766, applied for in April 1923, and including colour transmission noted that: "In picture-transmission apparatus of the type embodying at the transmitting station two members moved continuously to cause light from successive areas of the picture to be directed in rapid succession on one or more light-sensitive elements, or embodying at the receiving station two members similarly moved to cause a source of light to illuminate successively each of the recording surface or viewing screen, (1) either member may be adjusted in relation to the other to ensure correct framing of the picture, i.e. correct arrangement of the areas of the received picture to correspond with those of the transmitted picture, (2) when the members are rotating discs provided with narrow-continuous slits, such slits are shaped and inclined to each other that the picture is explored in successive parallel lines at the same speed in all parts of the picture."

Although Walton's practical development work must initially have concentrated on picture-telegraphy, there is no doubt whatsoever that he was thinking just as much in terms of the transmission of moving images. The replicas of Baird's equipment at the Science Museum and at the (now closed) IBA Television Gallery show a scanning system far closer to that illustrated by Walton in his patent than the straightforward Nipkow disc of the original Baird patent. The Walton patent also illustrates a mechanical triple-interlace scanning arrangement for colour with parallel horizontal scanning lines.

Solomon Sagall has recalled that after seeing a demonstration of low-definition television in Berlin by Denes Von Mihaly in March 1929, he returned to the UK and formed British Telehor Ltd to exploit the British rights of the Mihaly system. The announcement of this company brought him a letter from George Walton proposing a novel optical-mechanical method of large screen television. The concept impressed Sagall as being ahead of and far more promising than the tv methods used either by Mihaly or John Logie Baird. The result was the formation of Scophony Ltd in 1930 with stockholders including Gaumont British (already becoming owners of Baird Television), Ferranti Electric and Oscar Deutsch of the Odeon chain of cinemas. It became a public company in 1936. It seems unfortunate that while Baird is widely thought of as "the inventor of television," few people have heard of George Walton.

*Television Broadcast is written by Pat Hawker*

## Spectrum deregulation?

The problems posed for radio communications services, rather than for broadcasting, should the CSPI Report "Deregulation of the Radio Spectrum in the UK" be implemented in part or in its entirety, dominated the recent joint IERE/STI colloquium on Frequency Planning.

It is clear that the CSPI recommendations find little or no support, even among the land mobile users, who for many years were the prime source of discontent with the existing UK spectrum management procedures and what they regarded, with some justification (at least until the 1983 Merriman Committee report), as a niggardly allocation of spectrum, and excessive red tape on the part of an entrenched bureaucracy. But even this group have reacted strongly against what they see as changes certain to lead to a steep rise in cost of spectrum usage in some areas, far above existing licence fees. Since they have read the CSPI recommendations there has been a significant decrease in complaints. UK licences may have been slow and difficult to obtain, but the fees have traditionally been set at levels intended primarily to recover administrative costs rather than as a form of revenue collection. The proposed Frequency Planning Organizations would be free to charge what the market would stand and would be run for profit.

Major users such as British Telecom and British Telecom International also have strong reservations about, and objections to, the CSPI recommendations. One BTI delegate considered the whole CSPI concept as more suited to real estate management than spectrum management: "Real estate involves fixed fences; the spectrum fences can be moved."

There is also a view, even within the DTI, that too rigid a new system could inhibit further technological development. Engineers see the trend in short-distance radio communication with the so-called universal pocket radio of the future as being firmly towards multiple-access systems under computer control able to search for and seize free channels within a wide spectrum block rather than depending on specific channel assignments to individual users. Others consider that problems could arise if the competing private FPOs gradually merged or came under foreign ownership.

It was also pointed out that CSPI proposes that FPOs would be responsible for monitoring their own blocks of spectrum but would not have the powers of legal enforcement at present exercised by the DTI's Radio Investigation Service.

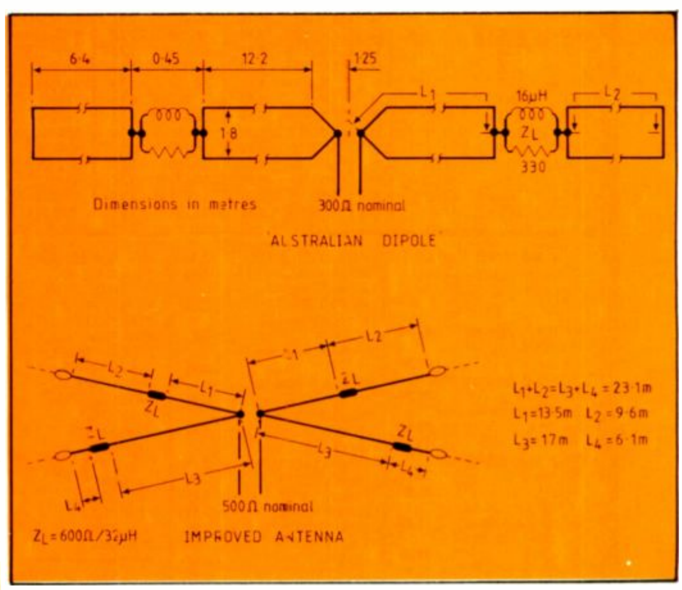
Michael Bate, an RD Deputy Director with responsibility for technical and policy matters, had the uneviable task of describing to 150 largely hostile delegates the main points of the CSPI report. He felt constrained to add a questionmark to his paper "A place for market forces in the management of radio frequencies?" and to point out that he was not there to defend or sell the CSPI report but rather to explain its background, its main conclusions and to consider "where do we go from here".

It is important to note, he insisted, that the choice is not simply *status quo* versus the CSPI proposals; there are other models to be considered, among them the US approach of private sector frequency planning organizations without exclusive rights to particular bands of frequencies. Another scheme might be to permit trading of frequency assignments. He explained that DTI's Radiocommunications Division is continuing to crystallize its own views not only on the basis of the CSPI report but also on other options that have been canvassed. There was a need to consult with Government, users and manufacturers. The DTI then propose to prepare a package of proposals possibly in the form of a Green Paper or some less formal document. It was recognized that the US system has the advantage that it can be seen working whereas the more radical CSPI scheme has not been tried anywhere in the world. He hoped that submissions would not just criticise the CSPI proposals but would consider better ways of shaping and making more intensive use of the radio spectrum and recognize the need for more flexibility in those allocations that can be changed without international co-ordination: "It is an opportunity to make a constructive response and to show that Government departments do not always know better. I would make the most of this opportunity."

Although submissions from users and the industry had been asked for by June 30, later submissions would be considered.

## Improved h.f. broadband antenna

Recent years and the continuing revival of interest in h.f. communications have seen an increasing need for transportable wideband antenna systems suitable for such applications as tactical medium-distance military communications, amateur radio etc. and able to cope with fast frequency hopping, or frequency changes over a large part, or preferably all, of the h.f. spectrum while presenting a reasonably constant feed impedance to the transmitter and at the same time achieving good radiation efficiency even at the lower frequency end of the h.f. spectrum. A dipole equivalent, so to speak, of the large rhombic antennas used for point-to-point communications since their development in the early 1930s by E. Bruce of Bell Telephone Laboratories.




Dr Brian Austin, now of the University of Liverpool, but until recently at the University of the Witwatersrand, Johannesburg, has reported developing, in association with Andre Fourie, a post graduate student, an improved h.f. broadband wire antenna (*Electronics Letters*, 12 March 1987 and personal correspondence) following investigation of earlier resistive loading techniques including the so-called "Australian dipole" due to R.J.F. Guertler and G.E.Collyer in 1974. Whereas the Australian "fat" dipole used twin-wire elements loaded with resistance and inductance, the new version achieves better matching and greater flexibility by using diverging (bow-tie) wire elements each loaded with 600-ohm resistors in parallel with 16-microhenry inductances, in an inverted-vee configuration.

This can result in an antenna with a 46-m span that covers the entire range 3 to 30 MHz with a v.s.w.r. not greater than 2.5:1 and a radiation efficiency of better than 40 per cent even at the 3 MHZ low-frequency end when fed from a 500-ohm transmission line. The single-pole, inverted-vee configuration makes this a readily transportable form of wire antenna and would also probably be suited to ship installations.

Dr Austin has stressed the need to consider both v.s.w.r. and radiation efficiency when evaluating loaded antennas. Simulations using a method of moments computer code has made this possible and experimental results have confirmed the validity of this approach.

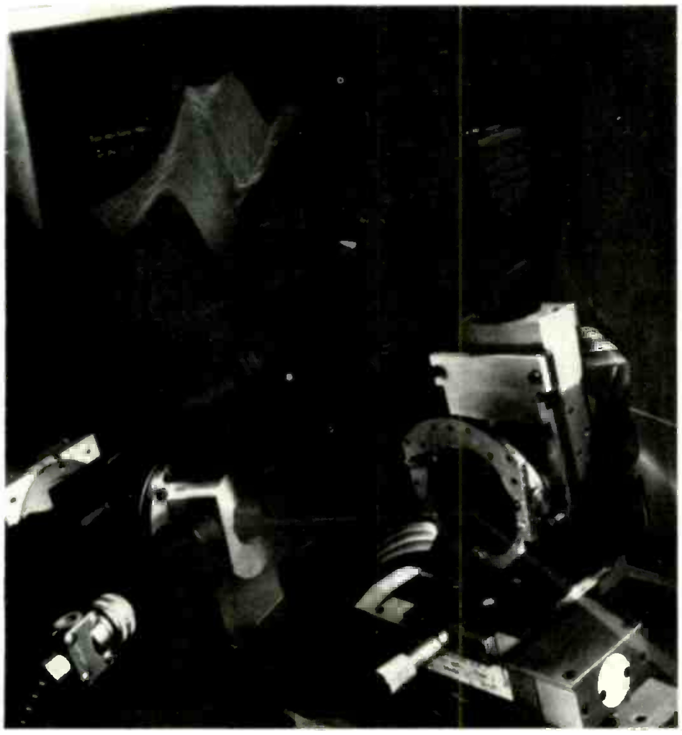
*Radio Communications was written by Pat Hawker.*

## Quicker than a flash

IBM researchers say their claim to the world's shortest electrical pulses is an important step toward designing ultrafast computers. Using a laser and fast switch pulses lasting one half of a picosecond ($0.5 \times 10^{-12}$s) have been generated by a switch consisting of a transmission line constructed on a silicon substrate.

The transmission line is two parallel one-micron-wide aluminium strips two microns apart. A pulsed laser beam, split into two by a mirror, provides a pulse that strikes the silicon between the two aluminium lines, shorting them and creating an electric pulse that travels down the transmission line. This short change in the voltage in the aluminium is sampled by an optical switch. The other half of the beam, delayed by a longer optical path, drives the sampling switch which measures the pulse. The time delay (i.e. the length of the optical path) needed to collect the pulse determines the duration of the pulse.

The fastest silicon logic devices can switch on and off in about 30ps, GaAs devices in 10ps.



Ellispometry, in which a finely focused beam of polarized monchromatic light is used to analyse a surface, can be combined with spectroscopy to provide a two-dimensional scan or a reflected energy measurement, or both. It can provide a profile of a slice of semiconductor material with an accuracy of an atomic monolayer in depth with a lateral resolution of 10microns. The technique is seen in action in an experimental set-up at the Laboratories d'electronique et de physique appliquée, part of Philips Research.

## Electronic components show revived

Since the old RECMF show has absorbed some years ago by the giant British Electronics Week, the components industry has had no UK show of its own. Nutwood Exhibitions hope to fill the gap with their Components in Electronics show, which they intend to stage for the first time in London next March.

What they plan is a show for engineers rather than salesmen. Manufacturers will get the opportunity to promote their technology to individual designers and buyers, leaving the business of selling to their distributors. Supporting the exhibition will be an international conference and a cinema, where – again – the emphasis will be on information and education about the latest developments, rather than on sales pitches.

Nutwood say they have already received enquiries about stand space from several dozen manufacturers, including big names such as Ferranti, MEDL, Mitsubishi, Plessey, Siemens, Sprague and STC Semiconductors. The show will be held at the new Islington Business Design Centre, 8-10 March 1988. Details from Nutwood Exhibitions at Godalming on 04868-25891.

Another London show date for the new year is British Education and Training Technology '88, to be held at the Barbican Centre, January 20-23. This event, formerly known as the High Technology and Computers in Education show, has gained the sponsorship of the Education Secretary, Kenneth Baker, who was evidently confident of surviving the general election. For the first time all four halls at the Barbican will be in use, and a programme of seminars will be offered. The organizers say they will promote the show extensively overseas and they stress its potential as a showcase for exports. Details from Emap International Exhibitions on 01-608 1161.

## The cost of semiconductors

A study by ERA Technology reports that high-purity materials – the key to the successful production of microelectronic devices can account for up to 20% of the cost of a device. It recommends closer working relationships between the device manufacturers and the materials suppliers, in the light of increased demand for more complex products and fierce com-

### EXHIBITIONS & CONFERENCES

**28 August – 6 September**
**Funkausstellung:** International audio and video fair Berlin (incorporating MediaForum). International Congress Centre, Berlin. Details from AMK Berlin, Postfach 19 17 40, Messedamm 22, D-1000, Berlin 19, FRG.

**2 – 4 September**
**MediaForum Berlin '87** Congress and exhibition on telecommunications, including broadcasting. Details as above.

**8 – 10 September**
**Digital signal processing;** a short course at the Institute for Information Technology, University of Sheffield. Details from Mrs C. Scown. Tel: Sheffield 768555 Ext. 5100.

**9 – 11 September**
**Electrostatics summer school.** University College of N. Wales, Bangor. Tel: 0248 351151 Ext. 2749.

**15 – 18 September**
**Design Engineering** Show and conference, NEC, Birmingham. Cahners Exhibitions. Tel: 01 891 5051.

**EED 87,** electronics in engineering design. NEC, Birmingham. Cahners as above.

**Test and transducer;** international conference and exhibition. Wembley Conference Centre, London. Trident International. Tel: 0822 4671.

**22 – 23 September**
**Computer Networks;** short course at the IIT, Sheffield. See 8 September for details.

**23 – 27 September**
**PCW 87:** 10th Personal Computer World Show, Olympia, London.

**29 September – 1 October**
**NAV 87.** Navigation data, dissemination and display conference and exhibition. Heathrow Penta Hotel. Organized by the Royal Institute of Navigation. Tel: 01-589 5021.

**Semiconductor International;** design, assembly, test, materials and chemicals. NEC Birmingham. Cahners Exhibitions. Tel: 01-891 5051.

petition. The report presents an analysis of the market for material and chemicals in Europe and the UK. The UK consumption of these materials was worth about £116M and £546M for all Europe. The market for silicon wafers will be worth about £187M by 1990 compared with a £10M demand for gallium arsenide wafers.

The report "Materials and processes for microelectronics" is available from ERA Technology Ltd at Cleeve Road, Leatherhead, Surrey KT22 7SA.

## Faster telecom aparatus approval

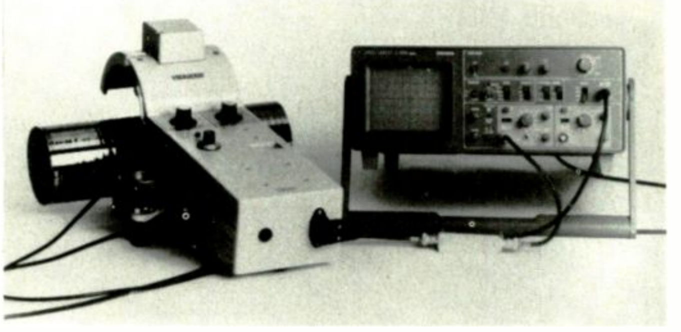
A pilot scheme has been devised to ease the log-jam of delays caused by the requirements for testing telecommunications equipment for approval by the BABT. Telephones, modems and apparatus for the disabled that includes either can now be tested by independent, approved by BABT, test laboratories. The laboratory will make a provisional assessment of the apparatus and only if there are any novel features will they refer the testing to the BABT. The laboratory will carry out all testing but it is still the BABT that must recommend the approval or rejection of the apparatus from the reports of the laboratory.

## Software projects gain government support

Three software engineering projects are to receive financial support from the DTI under the Software Engineering Demonstration Initiative, which aims to encourage the design and use of "engineered" software packages. Three companies are involved:

- Illingworth Morris, a textile group which will be using a new computing language – Progress – to develop an integrated business management system
- Fisher-Price Toys, for developing a sales and distribution system for its UK manufacturing site another 'fourth-generation' language, Genesis V
- Istel, a computer services company developing an integrated purchasing system for use by the Rover group and using the JSD method, another new-generation programming system.

The problems addressed by the projects will provide experience in the use of such software tools, and the results from such systems could be of wide interest, say the DTI. Other demonstrator projects are being considered for future support.



A non-contact test meter devised at Siemens to measure the minority charge-carrier life in a crystal silicon rod quantitizes the quality of the silicon rod by directly correlating the carrier life and the number of defects or impurities in the rod. The life of carrier pairs is determined from the decay in conductivity following application of a light pulse from a bank of 36 leds, and is found by the change in an h.f. resonant circuit coupled inductively by a coil surrounding the crystal. Because there is no externally applied current in the rod, measurement is not affected by high field strengths, internal p-n junctions, or, contact voltages. Carrier-life can be measured on rods of any diameter with a simple change of the coil size, with resistivity from one to thousands of ohm/cm. During measurement the high frequency pulses are first set to resonance. The decay time can be measured directly from the off-resonance setting by synchronizing the time base sweep with the flashing light sequence on an oscillograph.

## Towards high-temperature super-conductors

Vacuumschmelze, a subsidiary of Siemens in Germany, has been working on the production of ceramic super conducting materials, samples of which have been produced on a laboratory scale and tested successfully.

The focal point of the current work is to improve superconducting properties that to date have not always been adequate, for instance current carrying capability and the production of conductors in the form of wire and strip. It is estimated that it will take between five and ten years before a technically perfected superconductor is available whose properties and reliability are suitable for the construction of magnets.

The new superconductor materials are based on oxidic materials like lanthanum strontium oxide and yttrium barium copper oxide. At present new transition temperature records are frequently being reported, and mean transition temperatures of about −170 to −180°C are predicted. First signs of superconduction at −20°C have been reported although no material is known to be completely superconductive at this temperature. The actual maximum transition temperature for these materials will not be established for months, if not years, say the company. Irrespective of this, the unexpected discovery is a step forward for basic research, opening up entirely new aspects for superconductors. Since these novel superconductors can be

### EXHIBITIONS & CONFERENCES

**5 – 8 October**
**HDTV 87:** International colloquium, Ottawa, Ontario, Canada. Details from HDTV Coloquium, Journal Tower North, 300 Slater Street, Ottawa, Ontario K1A OCB, Canada.

**6 – 8 October**
**Internepcon** packaging show and conference. Metropole Hotel, Brighton. Cahners Exhibitions. Tel: 01-891 5051.

**13 – 15 October**
**Computer Graphics 87.** Wembley Exhibition Centre. Online International. Tel: 01-868 4466.

**27 – 30 October**
**BIAS '87** 21st international automation, instrumentation and microelectronics exhibition and conference. Milan, Italy. Exhibition Secretariat, EIOM, Viale Premuda 2, 20129 Milano, Italy.

**3 – 5 November**
**Comex 87;** mobile radio exhibition and conference. Sandown Park Exhibition Centre. Frametrack Ltd. Tel: 01-653 2657.

**17 – 19 November**
**Electronic Displays 87;** Kensington Exhibition Centre, London. Network Events. Tel: 0280 815226.

**23 – 26 November**
**Digital Information exchange;** professional digital audio seminar, at London Zoo. Details from Peter Woodcock. Tel: 0992 583557.

**14 –17 December**
**Land mobile radio;** Fourth International IERE conference. University of Warwick, Coventry. IERE. Tel: 01 388 3071.

**1988**

**29 February – 4 March**
**Electrex 88.** International electrical and electronic exhibition. NEC Birmingham. Electrex Ltd. Tel: 0483 222888.

**23 – 25 May**
**International conference on rural communications.** IEE Savoy Place, London WC2. Tel: 01 240 1871 Ext 272.

**23 – 27 September**
**IBC 88.** International Broadcasting Convention. Metropole and Grand Hotels, Brighton. Details from the IEE. Tel: 240 1871.

# UPDATE

cooled with liquid nitrogen at −196°C as opposed to liquid helium (−269°C) a technical breakthrough in the fields of electrical engineering and electronics is anticipated providing the new materials can be developed for large-scale industrial use.

● British company Basic Volume Ltd of West Norwood, London, claim a world first in fabricating a high-temperature superconducting cylinder or solenoid. Formed out of otherwise brittle and crumbling ceramic material, tubes of a 1-2-3 compound of yttrium barium copper oxide ($Y_1Ba_2Cu_3O_7$) have been made measuring up to 31mm in diameter and 120mm long, whilst superconducting at 88-93K. The company specializes in 'exotic' materials, such as those used for its solid-state chemical gas sensors – $La_2CuO_4$ for instance is available off the shelf.

British universities have produced their first electronic devices using the new superconductors. Birmingham and Strathclyde universities announced squids within days of each other, Strathclyde's operating at the higher temperature of boiling nitrogen.

## 24h voice recorder

Racal Recorders of Hythe, Southampton are set to double their turnover in the communications recorder market in the next four or five years, bringing their share up to 21 or 22% from 14%. They estimate the world market to be worth £65 million, made up of the emergency services (31%), financial services (26%), defence and security (20%), civil aviation and marine (18%), with the UK market amounting to £10million.

The machine that is going to help Racal achieve this is the new ICR64 a compact microprocessor-controlled voice recorder with a choice of 16, 32, 48 or 64 channels. Its compactness means that 256 channels are available from a single floor-standing cabinet. The micro processor-based design provides for built-in test programs, touch button controls and RS232C interfacing.

The machine has several unique features. As well as a mechanical lock, electronic locks prevent interruption of recording and of unauthorised access to monitoring and time clocks. An automatic check for clean tape prevents recordings being overwritten. The tap transport – which uses the closed-loop dual capstan approach that won the company a Queen's Award – is said to provide enhanced accuracy for digital data; simultaneous recording of a.t.c. and marine plot-extracted radar data extends up to 19.200bit/s.

In the replay modes, 'time-search' allows fast access to recordings made at specific times, while 'activitysearch' locates and plays any recorded passage on any selected channel. On record, a 'voice-operated' function can be pre-selected.

**Copy of print-out from Signetics Amaze software shows both logic expressions and device pin allocations. Note that TI is the reset input. Fig.4, carried over from page 949.**

```
######################## P I N   L I S T ########################

   LABEL     ## FNC ##PIN ---------- PIN## FNC ##     LABEL
CLOCK        ## CK  ##  1-!          !-24 ## +5V ##VCC
X            ## I   ##  2-!          !-23 ## /B  ##N/C
Y            ## I   ##  3-!          !-22 ## B   ##N/C
TI           ## I   ##  4-!    P     !-21 ## B   ##N/C
N/C          ## I   ##  5-!    L     !-20 ## O   ##/FO
N/C          ## I   ##  6-!    S     !-19 ## O   ##/EO
N/C          ## I   ##  7-!    1     !-18 ## O   ##/DO
N/C          ## I   ##  8-!    7     !-17 ## O   ##/CO
N/C          ## I   ##  9-!    9     !-16 ## O   ##/BO
DIFF         ## O   ## 10-!          !-15 ## O   ##/AO
N/C          ## /B  ## 11-!          !-14 ## /B  ##N/C
GND          ## OV  ## 12-!          !-13 ## /OE ##N/C
                           ----------

@LOGIC EQUATION
ao :j=bo*fo;
    k=/bo+bo*/x;
bo :j=/ao*x;
    k=ao*/x;
co :j=do*y;
    k=/do*/y;
do :j=/co*/ao*bo+co*/y;
    k=co*/eo*/fo;
eo :j=fo*ao*bo;
    k=/fo*co*do;
fo :j=/eo*/ao*bo+eo*/ao*bo*/(co*do);
    k=ao*bo;
diff=eo*fo;
```

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Salary scale: £8,557-£10,674.

For Job Description and Application Form, contact District Personnel Department, East Dorset Health Authority, Central Administrative Offices, Royal Victoria Hospital, Shelley Road, Boscombe, Bournemouth BH1 4HX

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Experienced contractors who wish to be considered for inclusion on a list of Tenderers should apply to the Director of Roads, Strathclyde Regional Council, 20 India Street, Glasgow, Scotland G2 4PF within two weeks of this advertisement and should provide details of similar contracts undertaken, together with a copy of this advertisement and the names, addresses and telephone numbers of persons to whom reference may be made.

**W. S. McAlonan**
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