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ELECTRONICS WORLD

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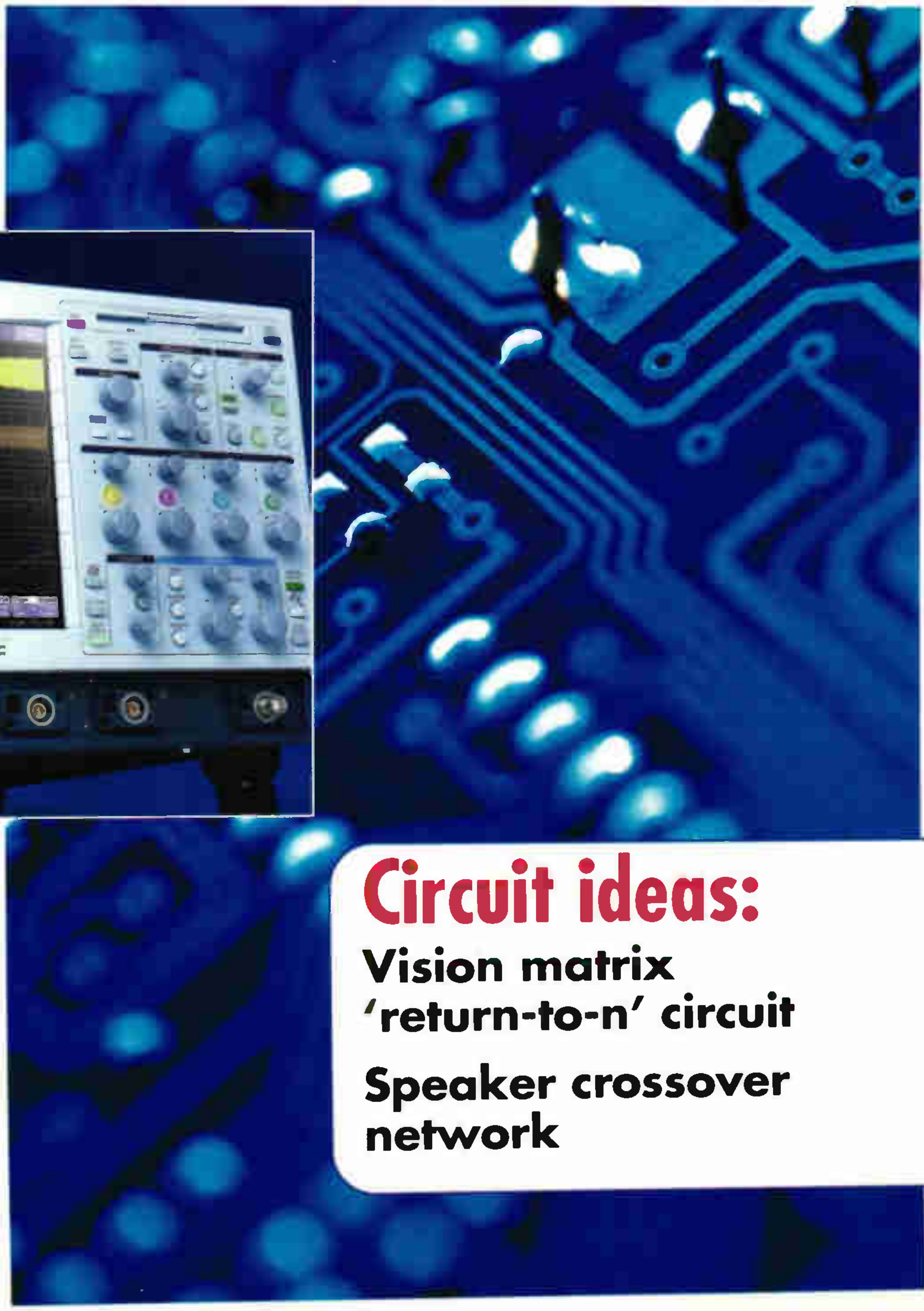
EMC - A fatally flawed discipline?



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Vision matrix 'return-to-n' circuit

Speaker crossover network

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Next issue, dated April on sale March 6th

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Mr. Catt returns

I've had quite a bit of correspondence in the last few months enquiring as to the whereabouts of Ivor Catt. Well, I am pleased to report that he is safe and well and living north of London. He still has some very clever ideas and is as anti-establishment as ever. This month, I offer readers his take on the EMC community and I am sure that his article will ensure a swelling mailbag, judging by some of his remarks. As always, your comments on this and any other issues raised in *EW* are always welcome and as regular readers know, your comments both good and bad will get published if they are deemed worthy. And for your information, there are very few letters that get binned or severely edited, as I think it important that your comments are given the space they deserve.

This month's issue (I think) is fairly balanced with items that I know are close to your hearts. For the audio buffs, John Ellis discusses the Miller capacitor and offers some design solutions, whilst the RF officiandos, we have a practical FM frequency synthesizer. For those who like serious equations, Fourier synthesis is discussed in great detail by Leslie Green and Alan Bate concludes his thoughts on impedance measuring.

Despite some heavyweight analysis that reckons we'll all be bouncing back in 2003, the short term still looks pretty bleak from where we are. They reckon the recovery will be fuelled by wireless handsets, wireless LANs and an increase in consumer electronics spending. I think that we still have a way to go in the downwards direction before we turn the corner. And kicking the guts out of a pretty defenceless middle eastern country, although good for the military electronics industries, will not do most of the rest of us much good. Thank you Mr. Bush.

Phil Reed

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Data transfer record broken by 6Pbyte tape store

The San Diego Supercomputer Center (SDSC) at the University of California has beaten the world record for data transfer from a tape store, claims the centre.
Its huge, updated tape storage system can now transfer data at 828Mbyte/s.

"Nobody in academia has such a fast data archive system," said Phil Andrews, program director at SDSC.

Data sets in scientific disciplines from anatomy and astronomy, to climatology and particle physics have grown over the past decade, from megabytes to gigabytes, to terabytes, said the centre. SDSC holds the 10Tbyte Digital Sky astronomy project and some data sets now exceed one petabyte.

The tape store, which can hold 6Pbyte, is housed in five silos where robots pick 200Gbyte tapes from racks and insert them into one of 24 30Mbyte/s StorageTek tape drives. This rate is roughly doubled by data compression.

From the silos, data is fed through a new data routing system to San Diego's 1.7Tflops IBM Blue Horizon supercomputer. "The combined effect the new technology has been a reduction - from days to hours - in the transfer of multi-terabyte data sets from the tape store," said the centre.

Between tape store and computer is a disc-based storage area network from Sun which allows multiple computers to share data and is due to be updated from 50 to 500Tbyte by the end of this year.

TeraGrid

The US National Science Foundation is putting $88m into 'TeraGrid' which, when it comes on stream this year, will be the largest, fastest, distributed infrastructure for open scientific research, claims the San Diego Supercomputer Center.

When completed it will include more than 20Tflops of distributed computing power, nearly one petabyte of disk storage and San Diego's 6Pbyte of tape capacity.

San Diego, together with the University of Illinois, California Institute of Technology, Argonne National Laboratory, and the Pittsburgh Supercomputing Center, will be connected through a 40Gbit/s network.

Magnets look fractal

Theorists at the Ohio State University suggest magnetic fields can take the form of fractals, if a magnet is made of plastic molecules that are stacked in parallel chains.

Professor Arthur Epstein was modelling magnets for future electronic structures that are so small the magnets no longer behave like three-dimensional objects.

"The materials currently used in magnetic devices - for example, hard discs or credit cards - behave like three-dimensional magnets," explained Epstein. "However, the decreasing size of these devices may one day require them to be considered one- or two-dimensional in nature. As the spatial dimensions decrease, the magnetic dimensions of the materials may take on fractal values."

The model was of a compound of manganese tetraphenylporphyrin and tetracyanoethylene, which can form polymer chains that are one-dimensional.

It showed that, as the material was magnetized by an external magnetic field and cooled, it began to behave as a special kind of glass.

At -267°C the magnetic field existed in 0.8 dimensions. Cooled further, it passed through one dimension and finally settled at 1.6 dimensions at –269°C.

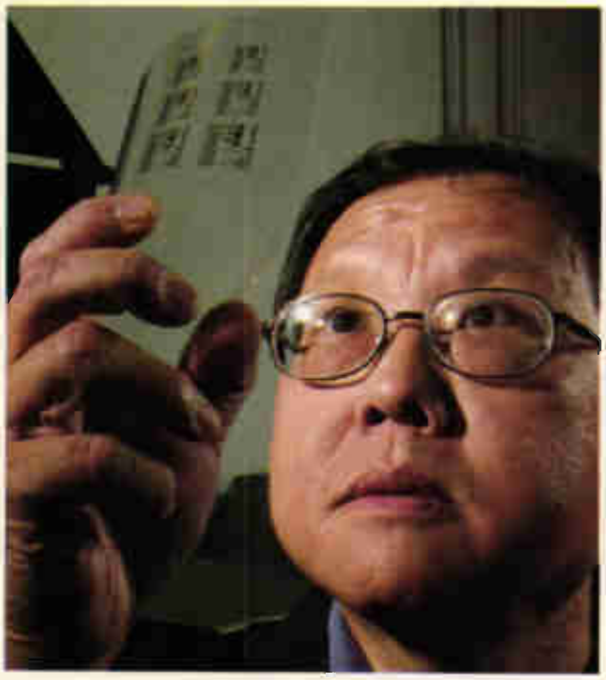
"Many magnetic fields sprouted out from the material like branches of a cactus. Tiny secondary magnetic fields then sprang out from the branches," said the university. Interlocking fractal growth gave the magnetic field a unique kind of order, said Epstein who has named the material 'fractal cluster glass'.

Electronics in Shannon still growing

Based in the Shannon Free Zone, Beta LAYOUT recently welcomed their 10,000th customer to the Shannon Facility.
On placing the 10,000 order, the customer became the grand prize winner. Based in Germany, Mr. Matthias Mayer is involved with a company who specialise in electronic measuring devices. Managing Director of Beta LAYOUT, Elizabeth Nolan, had this to say "Mr Meyer represents our profile customer. He is working in a small, but highly technical research and development company. We are delighted to offer this to such a valued customer."

Xerox develops air-stable conductive polymer

Canadian researchers have made a conductive organic polymer that is stable in air and can be printed into circuits on flexible plastic substrates using inkjet techniques. By combining many of the properties necessary for large-area electronics in an organic material that can be processed under ambient conditions, low-cost devices could be possible.



"Transistors can be made 150μm across, suitable for displays of almost 1,200dpi," said Beng Ong, the leader of the group at Xerox Research Center Canada in Ontario. Ong presented the work in a paper entitled 'High-performing semiconductor polymer designs for field-effect transistors' at the autumn meeting of the Materials Research Society in Boston in December.

Ong's material is a second-generation smectic liquid crystal, built via self-assembly. Chemically, it is a member of the polythiophenes, a group of unsaturated, sulphur-containing compounds that have been the subject of research into organic electronics for a number of years.

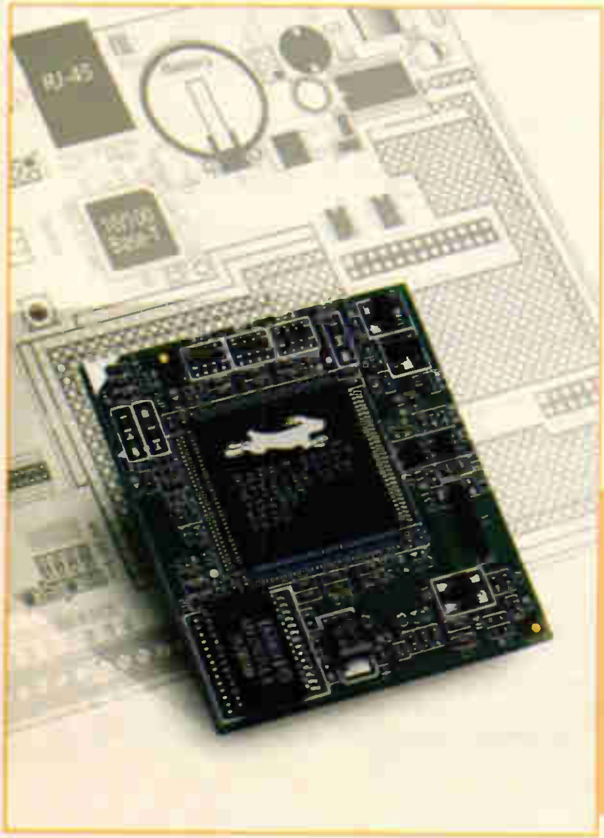
Ong's version has a field effect transistor mobility of up to $0.12cm^2/Vs$, up to an order of magnitude greater than other polymers measured in the same device architecture. It has a switching speed similar to that of the amorphous silicon already used in displays, and its ratio of electric conductivity in the on and off states is high - currently between 10^6 and 10^7. It also has good bias stress.

Ong said the material's development involved identifying the structural features in existing polymer materials responsible for limitations such as air-sensitivity, then designing a synthesis.

Xerox's polymeric electronics research is being carried out at XRCC and the company's Palo Alto Research Center, with help from Motorola Labs and Dow Chemical. Xerox is aiming to develop materials suitable for large-area electronic devices that could be printed onto flexible substrates, perhaps using cheap, high volume roll-to-roll processing. It is also developing processes to print complete active matrix arrays.

In the UK the field of polymer electronics is being led by Professor Richard Friend's firms Cambridge Display Technology and Plastic Logic. CDT recently acquired Oxford-based Opsys, which has developed promising light-emitting dendrimer chemistry.

Dendrimers are middle-weight molecules with chemically adjustable properties that combine the solution-processability of polymers with the design flexibility of small molecules.



Bluetooth hits the highway

Motorcycle helmet company Momo and Motorola have teamed up to design a Bluetooth-enabled helmet to allow bike riders to use personal audio and mobiles without removing their headgear. It is currently just a concept and may be available in the shops subject to demand, said Motorola.

A complete reference design for 10/100BaseT Ethernet has been fitted into a board measuring just 35 x 29 x 7.4mm.
Developed by Rabbit Semiconductor, the board combines an 8-bit processor with flash, SRAM, decoder, PWM outputs and five serial ports, and is the first of the company's cores to include analogue.
The RCM3400's processor runs at 29.4MHz. The clock has a spectrum spreading feature that the firm said will reduce electromagnetic interference.
The board is designed to mount on a user's existing motherboard. It is priced at $39 in 1,000 unit quantities, while a development kit costs $399.

Lords call for centre of excellence

A House of Lords report on the UK's electronics industry has concluded the country needs a national centre of excellence to maintain our world standing.

Britain's leadership in microprocessor architectures and system-on-chip design can only be maintained through such a centre, the Chips for Everything report argues.

"The research we are developing could be of vast advantage," said Lord Wade of Chorlton, chairman of the House of Lords Science and Technology Committee. "There is an opportunity for the UK to take a more important role in the future."

However, the country's R&D should focus less on chip manufacturing technology, such as CMOS, but more on innovative design.

Lord Wade argued chip manufacturing is too expensive and risky, especially considering a fab plant can cost upwards of £1bn.

"Current research funding is the wrong way around," he said. Lots of funding goes into CMOS, but that doesn't bring back revenue into the UK, as we have almost no CMOS manufacturing.

"In embedded design we are already leading the field. We need to fund research and help commercialise the technology," he pointed out.

Backing research into intellectual property, algorithm development and architecture development would give a better return for the Government's money, along with alternatives to CMOS, such as III-V semiconductors.

"We also need to make non-London research more accessible to venture capitalists, especially at the early stage."

A national centre would bring technology developers into contact with the venture capital firms and legal people needed in company development.

"There are clear opportunities here - a lot of excellent work is being carried out," said Lord Wade.

During the nine month writing of the Lords' report, the sub-committee visited places as far afield as Silicon Valley.

Lord Wade was impressed with overseas centres such as IMEC in Belgium, which started with government money, but now receives a good slice of funding from industrial investment.

He also applauded the practice of keeping R&D in the UK, while setting up headquarters in the US, where the major markets and money are centred.

The report calls for the DTI to respond to the recommendations made and to provide regular feedback.

Oxford PCBs are finer

PCBs with tracks down to 25μm wide can be mass-produced, claims a researcher at the University of Oxford.

According to university's photofabrication head Cyril Band, current manufacturing techniques cannot attain the required precision as etching rates change with track spacing leading to variable undercutting.

Widely-spaced tracks etch faster than closely spaced tracks by amounts irrelevant to conventional narrow (150μm) tracks, but crucial to tracks required for next-generation PCBs and flexible circuits.

Band's methods involves designing PCBs with uniform inter-conductor gaps, leaving redundant copper to fill open areas on the PCB (see photograph).

Isis Innovation, the technology exploitation arm of the university, is looking for companies interested in exploiting Band's work.

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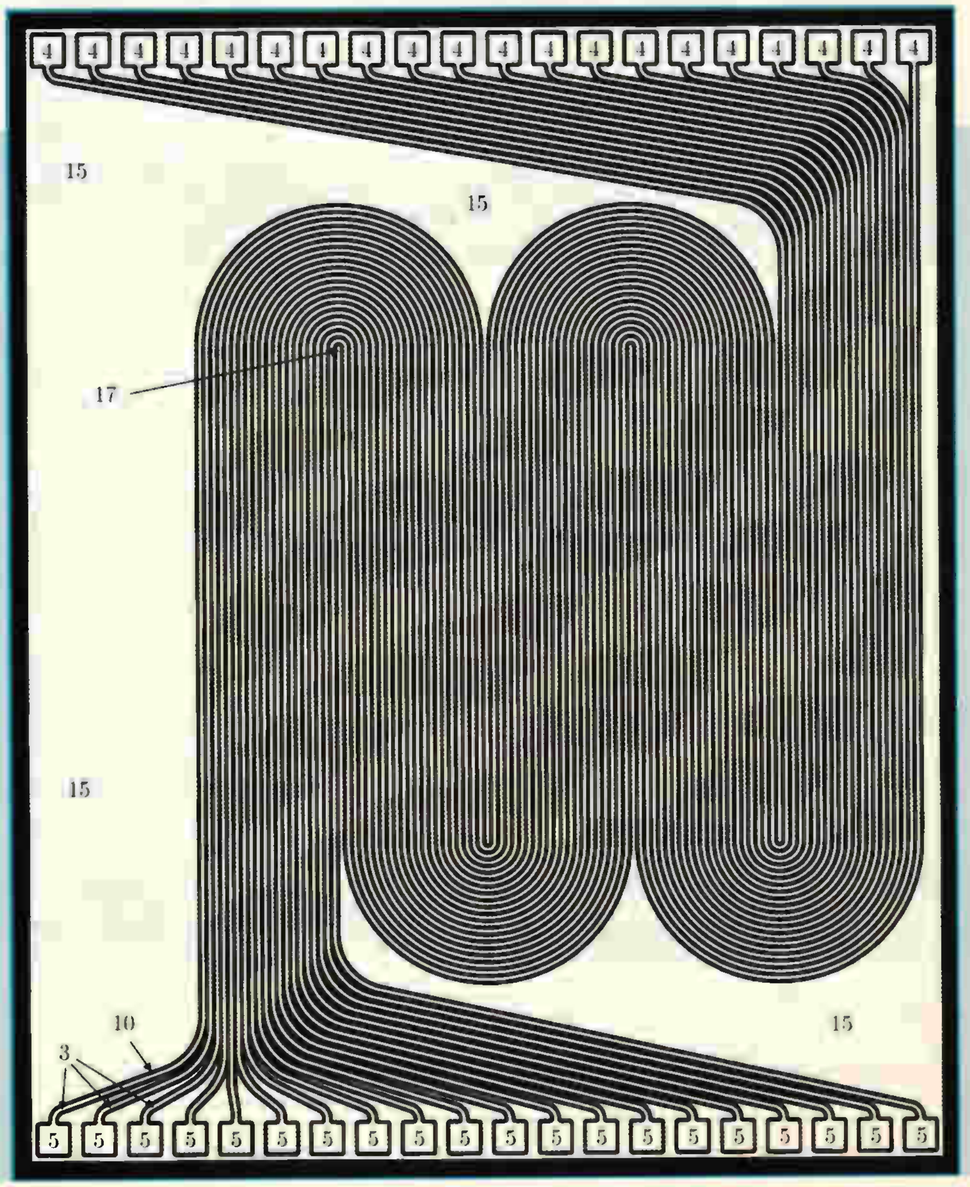


Carbon makes contact

Xerox has patented carbon-based contacts for high-reliability use in difficult environments.

CarbonConX, as the technology is called, is based on bundled carbon fibres which give the contact zone thousands. claims Xerox. of actual contact points.

The company also said carbon is non-filming. further increasing reliability.

Contacts are made by low-pressure pultrusion - pulling a bundle of fibres through a shaping die with thermoplastic or thermosetting polymer. The polymer cures in the die and holds the fibres in shape.

"Carbon fibres are less susceptible to corrosion than metal contacts. Their non-reactive nature makes them ideal for use in harsh environments, including saltwater, nuclear power. space, or medical X-ray environments," said Xerox, "Additionally, pultruded carbon fibre contacts can act as structural members, due to the high strength material characteristics of the polymer and carbon bundle."

One disadvantage is high contact resistance, although metal coating the fibres before pultrusion can reduce this.

Uncoated fibres are recommended for use with voltages of 100V or less and current levels on the order of $100mA/mm^2$. Practical contact resistances of a few hundred milliohms to a few hundred ohms are determined by contact geometry, fibre characteristics and normal force.

LeCroy has introduced 1 and 3GHz digital storage oscilloscopes in its WavePro family. All four channels in the scopes can sample at 10Gsample/s with up to 24 million points of data stored per channel. Channels can be doubled up for increased sample rate and memory depth. The colour touchscreens are 10.4inches in size. The firm is aiming the equipment at communications system design.

Mitsubishi has signed a deal with New York-based Magink Display Technologies to create the world's first large-scale, full-colour digital ink displays for the outdoor advertising industry, the companies claim.

Magink is providing its digital ink technology and Mitsubishi, its large-scale video know-how display. Magink was established in 2000 after a two-year incubation within UK-based SixEye Media Technologies.

Government to simplify patent law

Consultation has begun over the Government's plans to revamp the UK's patent laws, which have remained relatively unchanged since the 1977 Patents Act.

The major effect of the proposals is that a single application, once successful, will result in a patent that is legally valid in 24 countries.

"Changes to the law are essential if the UK is to deliver on its commitment to implement the recent changes to the European Patent Convention (EPC) with which UK law is aligned," said Melanie Johnson, the Minister for Competition, Consumers and Market.

The minister said she welcomed comments from industry: "We are seeking input on the impact of these proposals from all who have an interest in the patent system, especially from UK businesses including SMEs," she said.

Other changes could lead to the UK patent office taking over some of the preliminary work when a patent is challenged, work now done by the courts. This could reduce costs and encourage companies to maintain their intellectual property.

The new legislation will be introduced to Parliament as soon as time permits, the Government said.

Last year some 5,000 patents were applied for in the UK under the existing EPC rules, making this country the third largest user of the system.

For further information go to www.patent.gov.uk

Research yields 6nm Mosfets

IBM's research division has demonstrated transistors with gate lengths down to 6 nanometres.

The key to such as small device was using a silicon-on-insulator (SOI) substrate where the silicon below the Mosfet's channel was itself just 6nm thick. This helps reduce the so-called short channel effects which wreck the performance of these extremely small devices.

To fabricate the devices, the IBM team used bonded SOI wafers with a starting silicon thickness of 70nm. These were thinned to between 4 and 8nm to create fully depleted SOI prior to making the Mosfets.

To improve short channel effects and raise threshold voltage, the team also used halo implants which increase channel doping near the source and drain.

In the 6nm p-channel Fet, drain-source current varied between 10^{8}A/μm and 10^{4} A/μm as Vgs varied from 0.5 to –1.5V.

Another significant step taken by the IBM Research team was the making of ring oscillators with 26nm gate Mosfets. CMOS inverters had delays of 10ps, while three-input NORs and three-input NANDs had delays of 23 and 14ps respectively.

What is fully depleted SOI?

Two basic forms of SOI exist - fully or partially depleted. In fully depleted SOI the silicon layer on top of the insulator is thin - normally down to 40nm in today's processes. Thus the depletion region underneath a transistor's channel extends down to the insulating oxide layer.

Partially depleted SOI, being used by some microprocessor makers, has a layer of neutral silicon between the transistor and buried oxide layer. This suits high frequency operation.

No neutral layer means fully depleted has lower leakage currents at reduced threshold voltages, so it is better for low voltage and low power.

Hotrod heat pipe from Sandia

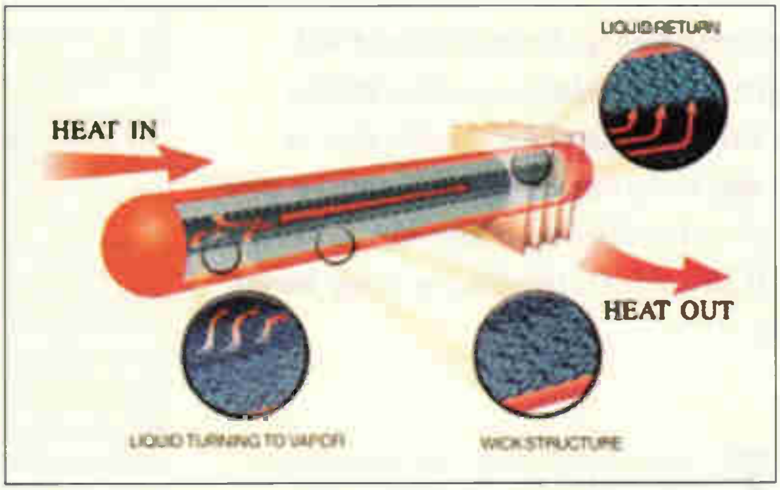
New Mexico-based Sandia National Laboratories has taken a fresh look at heat pipes to cut thermal build-up in compact equipment.

The basic technology has been used to pull heat from confined spaces for several decades. Unfortunately, existing isotropic types fail if attempts are made to extract heat from more than one place.

"An isotropic method doesn't work because it only cools the first heat source; you need anisotropic capability to cool all sources of heat directionally," said Sandia researcher Mike Rightley.

To cool several places, Sandia persuades condensed liquid to return to multiple hot spots. "We use laws of fluid mechanics to derive the optimum wick path to each heat source," said Rightley.

The wick in Sandia's heat pipe is a pattern of 60μm high curving, porous copper lines made with photolithographic techniques.



These lines can also direct the cooling liquid, in this case methanol, around fixing holes and other unavoidable obstacles.

Conventional conductive heat sinks are reaching their limits with the latest generation of microprocessors for PCs.

Surface power density in the hottest devices is around 50W/cm^2 which is likely to hit 100W/cm^2 in the near future.

Inadequate cooling is also preventing multiple high-power die being stacked inside a single package to save space.

"Space, military, and consumer applications, are all bumping up against a thermal barrier," said Rightley.

The Sandia technology is being licensed to a start-up company "that has a very interested large customer in the laptop market," said Rightley. "No internal re-design of laptops is needed. The new design exactly duplicates in external form the heat transfer mechanism already in place in laptops. Industry won't even see the difference."

Heat pipes: the principle

Heat pipes are sealed tubes with a low boiling-point liquid inside and an internal wick running from end to end.

One end of the pipe is placed in close thermal contact with a hot spot, the other is buried in a heatsink.

The working fluid boils at the hot end and its vapour travels down the tube to the cool end where it condenses, shifting heat out of the system.

Once it is a liquid again, it is wicked back to the hot end for re-use.

Bipolar process from Swindon

Zarlink Semiconductor in Swindon has developed a high voltage, high-speed analogue chip process that it is offering to foundry customers.

The HJV process is aimed at products with fast data rates and high voltage outputs, said the firm, such as drivers for lasers and modems.

"Customers want a commercial process that uses low-cost, proven silicon technology to build high-voltage, high-speed analogue devices," said Steve Phelps, silicon bipolar foundry director at Zarlink. "Our HJV technology offers significant cost and performance advantages over more exotic chip processes, and a more comprehensive suite of design components."

The process allows for both pnp and npn transistors with transition frequencies (unity gain) of 12GHz at 5V. Collector-emitter breakdown voltages are above 12V for both types of transistor, the firm claimed.

Audio power amplifier frequency compensation:

Is PLIL an Alternative to the Miller Capacitor?

A lot of audio amplifiers, from around 40 years ago right up to today, use the Miller capacitor. An inherent problem with this is that it delays the output voltage response and thus the negative feedback to the input stage. John N. Ellis, B.Sc., Ph.D. thinks he may have an alternative.

The transistor audio amplifier can be generalised as having an input stage, which may be a single transistor or differential pair, a voltage amplifying stage (VAS), a driver pair and an output pair as shown in Fig. 1. As there are more than two time constants encompassed by the feedback loop, negative feedback can cause instability that requires frequency compensation to put right. A common method to stabilise amplifiers is to use a "Miller" capacitor Ccomp. as this causes a monotonic roll-off at 6dB/octave. which is, as Nyquist, Bode and others have shown, stable.

Many audio amplifiers, ranging from the decidedly mediocre (typically from the 60's and 70's) to good ones from the 90's[1], use the Miller capacitor. An inherent problem with the Miller capacitor is that it delays the output voltage response and thus the negative feedback to the input stage. If the input signal is fast enough, this will cause transient distortion due to overloading in the input stage. until such time as the feedback "catches up" with it. The problem can be eliminated by using resistors in series with the input transistor emitters which are large enough to prevent overloading in the input stage. or using moderate resistors and increasing the current in the input stage to achieve the same voltage margin, such that the input

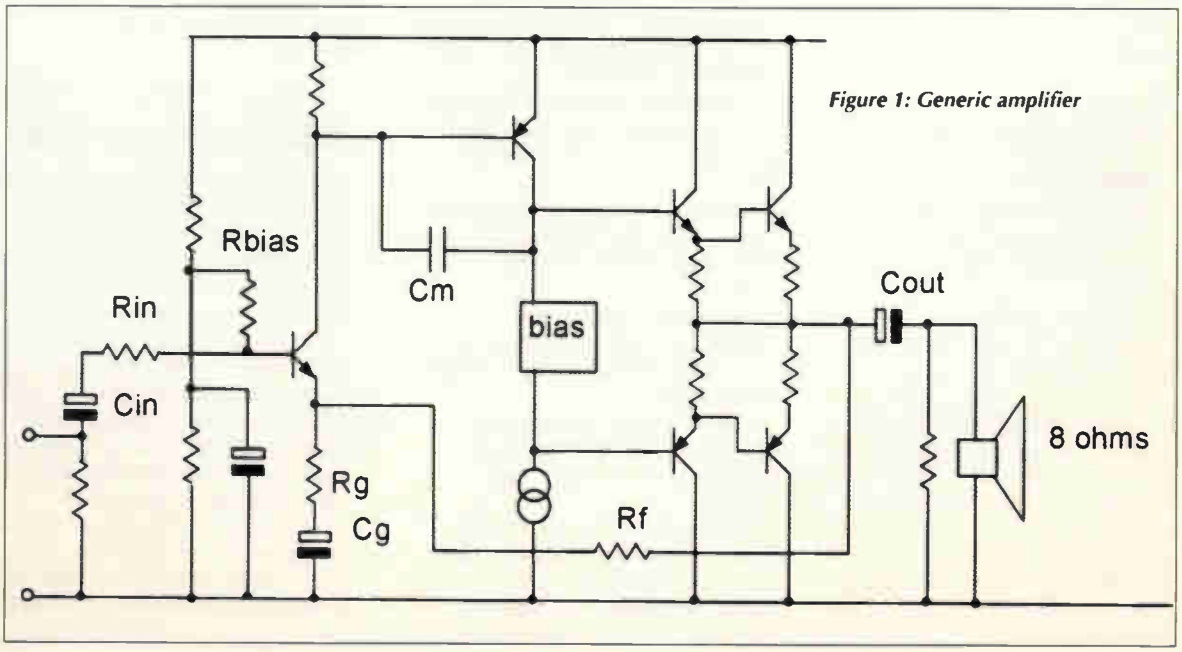


Figure 1: Generic amplifier

transistors do not cut off for any input within normal limits. This approach to "fast slew" was exploited by Stochino[2]. I hasten to add that for ref. 1, transient distortion from slewing does not arise for normal audio-band signals usually taken to be 20kHz maximum, as it has a good margin to at least to 150kHz. Nevertheless, the potential for input stage overload is not desirable, and the Miller capacitor method of compensation is not one which I would use by preference. However, the search for an alternative is not easy but phase lead compensation with input lag (PLIL) seems to be a possibility. This article reports on the investigations I have undertaken in the PLIL approach.

The use of a phase lag capacitor on the input stage of the amplifier was first suggested by Otala[3] to prevent transient intermodulation distortion. Since then, there has been much debate about whether "transient intermodulation distortion" is the right term for such distortion products (intermodulation implies continuous frequency spectra) that are transient in nature. Today it is usually accepted that control of slewing is the important point.

Several authors have compensated their amplifiers by a capacitor Ccomp connected between the collector of the VAS transistor to the feedback point FB, as shown in outline in **Fig. 2**, the so-called phase-lead method. The first author who caught my attention with this approach was Bailey[4]. Linsley-Hood also used this method[5], as did Gibbs and Shaw[6], who also included an input phase lag capacitor, and is perhaps the first example of phase-lead, input lag.

I found that when a phase-lead capacitor was used by itself, it was not reliably stable. I tested a version of Bailey's amplifier which used a small-signal PNP input transistor and NPN VAS. The original circuit used a 40361 medium-power NPN transistor in the input stage and a 40362 PNP VAS. In my circuit, using a medium power PNP input transistor (actually a 2N4036), I found that the amplifier was stable only when I increased the series input resistor to 4.7kΩ. When a small signal transistor was used, the amplifier was once more unstable.

To shed some light on the instability using phase lead compensation alone I simulated a four-stage equivalent circuit to represent the generic amplifier, **Fig. 3a**. The stages represented the input, VAS, driver and output transistors. Each transistor stage (treating the driver and output as singles) was modelled by a simple p-type equivalent circuit comprising an input impedance, base-emitter capacitance, collector-base capacitance and mutual conductance as shown in **Fig. 3b**.

To simulate Bailey's amplifier, I had to devise p-type model parameters for the 40361 and 40362, neither of which I had and are, it seems, obsolete, RCA having been taken over nearly 15 years ago now. The parameters I used were based on measured capacitance data for devices 2N2102 and 2N4036, plus estimated diffusion capacitance and gm parameters. SPICE data from some manufacturers, available on the internet, give rather better values than I suspect the original RCA transistors would have had. I also had to estimate the data for the Motorola MJ481 and MJ491 power transistors which are also past their sell-by date. The collector-base capacitance (Ccb or Cob) is in the data sheet, but other parameters were estimated from larger transistors and adjusted for the lower current handling of the MJ481/MJ491. **Table 1** gives my guesstimated data for interested readers. The rather low gm figures for the power device represents near-cut off values for a class B amplifier. Clearly there is scope for a wide range of parameters in the output stage: it is not possible to model a Class B (a large signal configuration) amplifier using small signals and expect it to be correct for all conditions. This could of course point to where the last vestige of amplifier design remains to be uncovered: the dynamic performance of transistors in a large-signal amplifier. In this case, I was seeking to reveal the basic properties of the compensation method.

Table 1: p-model data for the "Bailey" amplifier

transistor	hie (ohms)	Cbt (F)	Ccb (F)	gm (mA/V)
40361 (input)	880	260p	4p	.064
40362 (VAS)	100	510p	16p	0.4
40361 (driver)	210	340p	10p	0.2
MJ481 (output)	40	25n	250p	1.4
BC307B (alt. i/p)	4000	70p	1.5p	.064

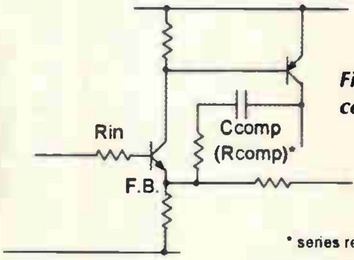


Figure 2: Phase lead compensation.

* series resistor (if used)

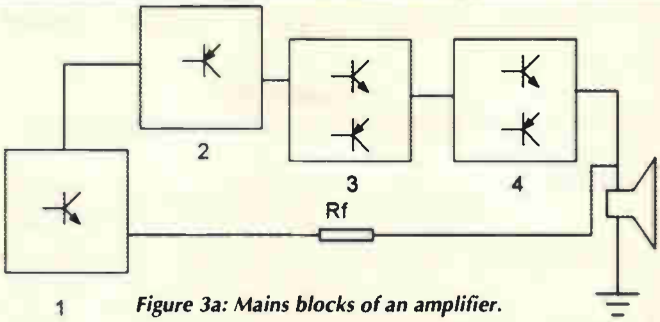


Figure 3a: Mains blocks of an amplifier.

1 - input stage; 2 - voltage amplifier; 3 - driver(s); 4 - output(s)

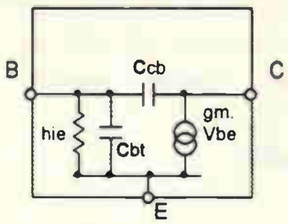


Figure 3b. π-type equivalent circuit

Fig. 3 (b)
π -type Equivalent Circuit

Cbt = total base (diffusion + depletion) capacitance
Ccb= collector-base depletion capacitance
hie = input impedance
gm = mutual conductance

In the above table, Cbt refers to the total base capacitance that is a sum of the depletion and diffusion parts.

Fig. 4(a) shows the rather awful-looking frequency response. Immediately one would conclude that this design is not stable. In the critical 1 to 10MHz region, the unity-gain frequency point has not been achieved cleanly and the phase shift is undergoing some rather alarming changes. (The straight-line jump is not real: it is an artefact of the simulation returning the phase angle between the limits of +/- p. The top arc continues the lower phase shift in practice – but at least this acts as a 180° marker). I increased the input resistance to 10kΩ, and the response is shown in **Fig. 4(b)**. This is stable, just, as the unity gain point is not quite 12dB/octave and the phase at unity gain is below 180. Substituting a small-signal transistor

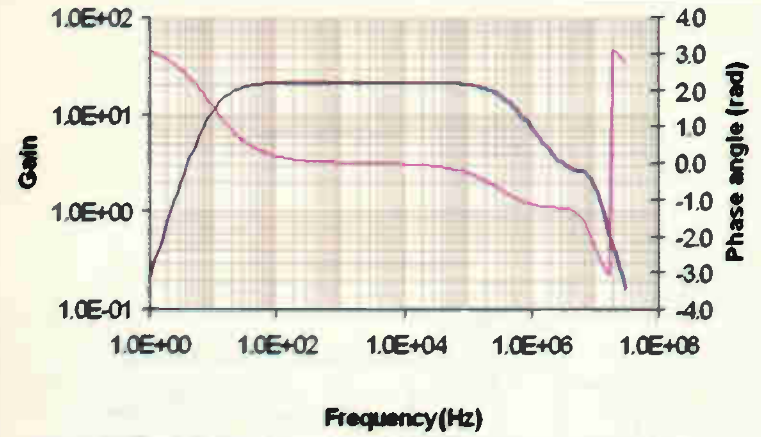


Fig 4a: "Bailey" simulated response with medium power in input stage

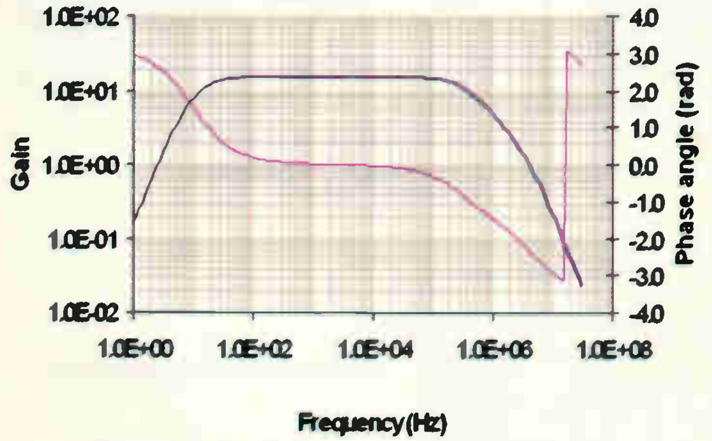


Fig 4b: With 10kΩ instead of 1.5kΩ

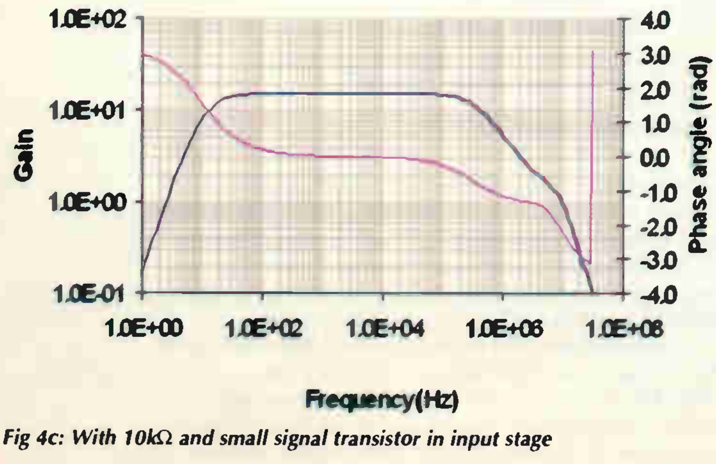


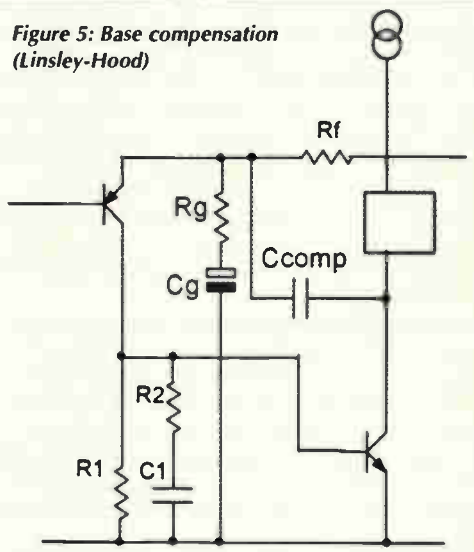
Fig 4c: With 10kΩ and small signal transistor in input stage

equivalent circuit, also listed in table 1, for Tr1, gave the response shown in **Fig. 4(c)** while retaining the 10kΩ input resistor. This is marginally unstable. While I am happy to accept that my models are somewhat simplistic, and the parameters guesstimates, the results confirm my experimental observations. In practice, Bailey's design may well have been stable with the original components but larger input resistors may have been necessary in some cases. Evidently it required the frequency response of the input transistor to have designed-in limitations. Using a 40361 may have been judicial!

Astute readers will immediately point out that the use of a resistor-capacitor network, as Bailey described (op. cit.), should in theory never give a unity-gain response. Indeed, the concept seems flawed because the gain cannot even approach unity, until such time as the amplifier open loop runs out of steam. This is where the phase-lag (Miller) method appears superior in that it has a monotonic characteristic – the gain continues to fall throughout the whole frequency spectrum.

Linsley-Hood also appears to have found that the phase-lead capacitor was insufficient by itself when higher frequency input transistors are used because in his amplifier (op. cit), he used an additional resistor-capacitor pair generating a phase-lag across the base of the VAS transistor (e.g. **Fig. 5**). Evidently, this will give rise to a

Figure 5: Base compensation (Linsley-Hood)



reduction in gain which falls monotonically (until the series resistor limits it at least) and would provide the desired improvement in stability. In my view, this is as bad as using a Miller capacitor as it does nothing for the input transistor, and would also lead to transient distortion at high frequencies. Linsley-Hood, and Gibbs and Shaw (op. cit.) both avoided using the resistor, Rcomp in Fig. 2, which Bailey had specified in series with the compensation capacitor. This at least allows the gain to be able to become closer to unity than with it. **Fig. 6** shows the response for a 470pF compensation capacitor with no series resistor. The unity gain point hovers tantalisingly around the critical frequency point, but refuses to dip below unity until the amplifier open loop limit sets in. This is just not stable enough and in practice it may be very dependent on transistor parameters.

I simulated the PLIL approach and after several variations, I found the optimum network for the single-ended input stage required: (i) a small resistor in series with the input phase-lag capacitor; (ii) a resistor in series with the input lead; and (iii), a small resistor in series with the emitter of the PNP input transistor as shown in **Fig. 7(a).** The response for a circuit with the components given is shown in **Fig. 7(b).** This time, the response is virtually ideal, with a monotonic decrease until well beyond the critical phase-shift point. This method of input lag with phase lead compensation is along the lines that Otala[3] recommended, but does not require extensive local feedback.

I checked the stability of this method firstly by considering the input phase-lag capacitor only in a simulation **(Fig. 8).** The graph shows a second-order roll-off initially, but there is a relaxation towards a single-pole slope near the unity gain point, conveniently. The circuit seems to share some similarity with a Colpitts type

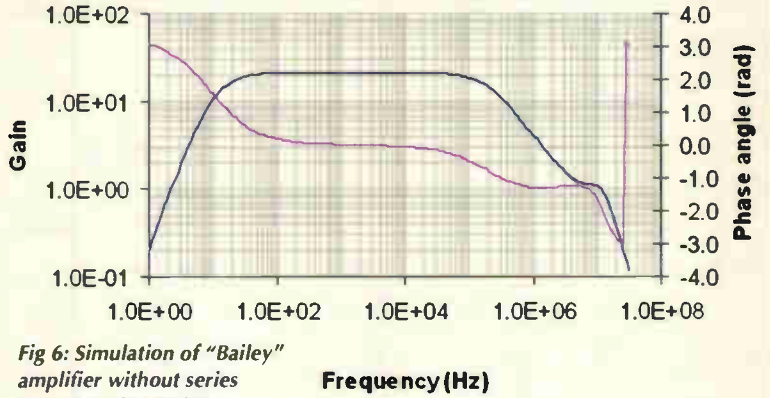
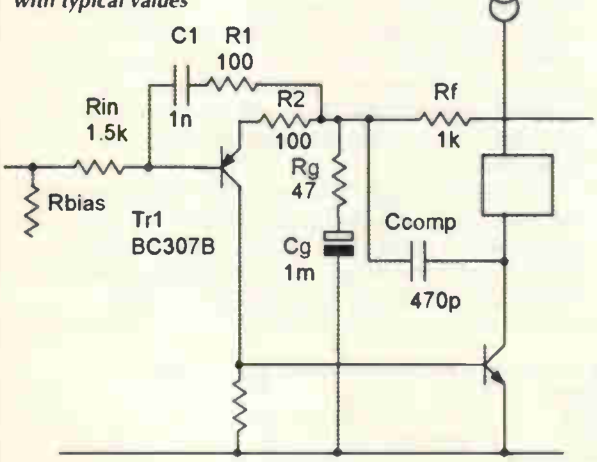


Fig 6: Simulation of "Bailey" amplifier without series compensation resistor

Figure 7a: Phase lead/input lag compensation with typical values



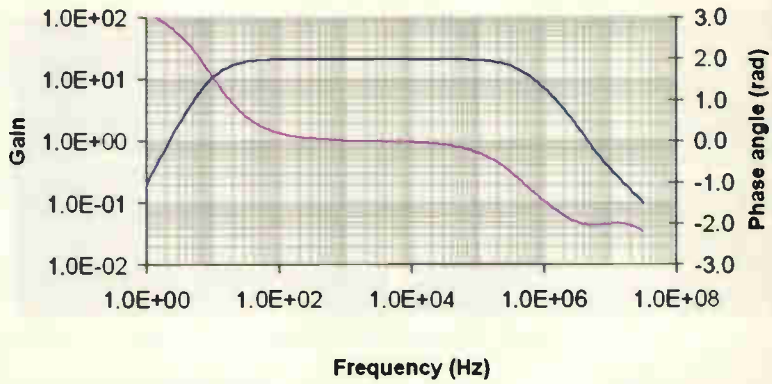


Fig 7(b): Response of "Bailey" amplifier simulation with phase lead/input lag compensation

oscillator, or a second-order filter **(Figs. 9(a) and (b).** In fact, the second-order roll-off is damped by the series resistors, and is compensated by using the phase-lead network in conjunction with this phase-lag circuit. The input capacitor-resistor network, then, is capable of providing the required monotonic control of gain at high frequencies where the phase-lead capacitor rolls to unity. But the network is definitely NOT a replacement for the phase-lead capacitor, nor for the phase-lag Miller type. The method requires both phase lead and input (phase) lag together to operate correctly.

There are two advantages of the PLIL compensation method. For one, it eliminates the Miller capacitor. Instead of burdening the input stage at higher frequencies, the phase-lead capacitor provides a signal which tries to balance the feedback side of the input stage. Measurements have confirmed the simulations in a differential version of the amplifier where the base to base voltage at 20V and 20kHz output is only about 2mV compared with the 25mV or so for the Miller compensated amplifier. This has to be kinder to the transistors than forcing them into a larger signal mode than necessary. Even a degenerated input pair will experience a reduction in non-linearity from about 0.1% to 0.02%. A fast square-wave applied to the Miller-compensated amplifier shows an alarming peak of 600mV on the base-to-base differential, **Fig. 10** while PLIL compensation eliminates this spike almost completely as in **Fig. 11(b).**

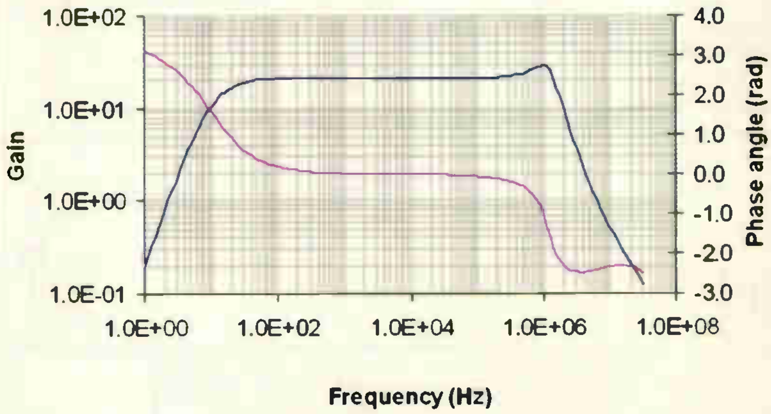


Fig 8: Simulation of input phase-lag compensation alone

The second advantage is that because the input phase-lag network has a second-order rate of climb, the loop gain is not going to be seriously impacted. This means that the distortion should be about the same as in the phase-lag compensation circuit, unlike the use of an input RC filter, **Fig. 11,** about which there has been some criticism[8], and I accept is a heavy-handed approach to avoiding transient distortion.

The time-constant of the input phase-lag network should be chosen to be around the same as or a little higher than

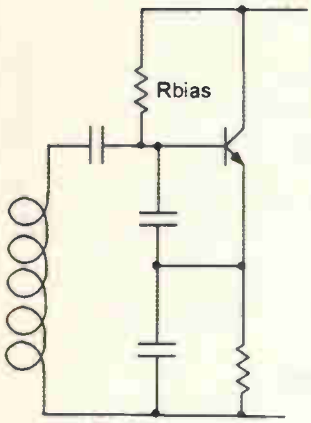


Figure 9a: Colpitts oscillator.

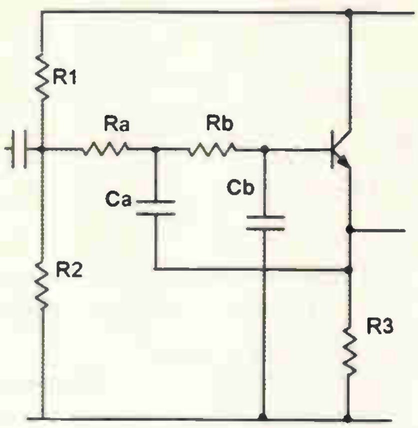


Figure 9b: Two-pole filter.

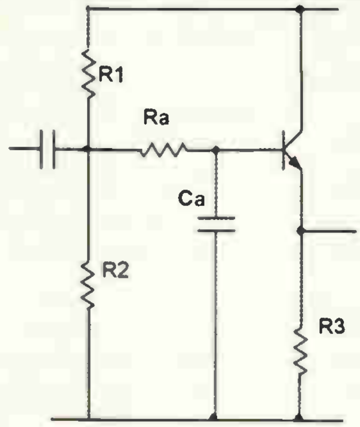
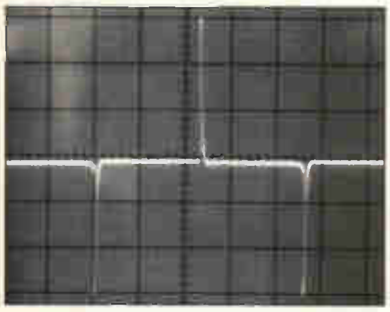


Figure 11: Simple input filter



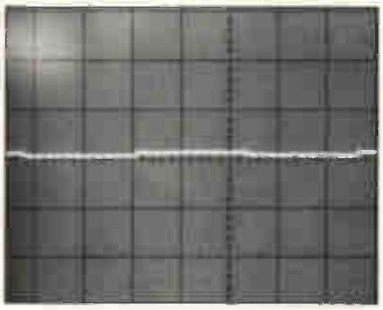


Fig 10(a): Differential signal (base to base) for Miller compensated amplifier in response to a 10kHz square wave signal
Fig 10(b): Differential signal for a PLIL compensated amplifier for same input (vert 200mV/div, hor 20µS/div)

the amplifier closed-loop roll off as set by the phase-lead capacitor and feedback resistor. In a test amplifier shown in **Fig. 12,** which is based on Self's "blameless" design (op.cit), the compensation capacitor operates with the feedback resistor to give about 150kHz closed-loop cut-off. I have chosen a slightly higher overall gain of 30 rather than 20.

As a resistor is required in series with the base lead of the input stage to ensure that the additional phase-lag capacitor does not give rise to oscillation, the noise level will be higher than without. The noise voltage I measured was under 1mV, rms, or about 100dB down from

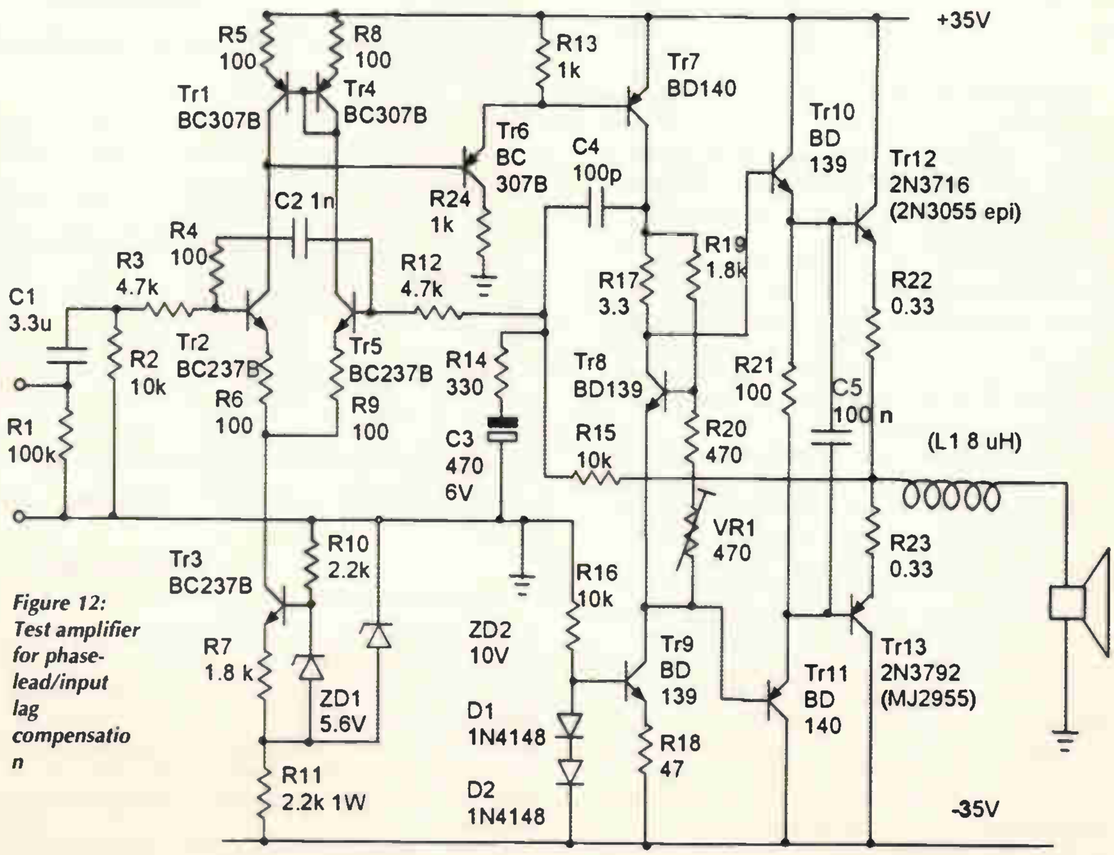


Figure 12: Test amplifier for phase-lead/input lag compensation

maximum output, and still quite acceptable.

On the question of distortion, I attempted to measure the performance but I have to say that the oscillator I used for distortion measurements was not ideal. It had more second and third harmonic distortion than the amplifier and to make any readings at all I had to subtract the reference input from the output at all frequencies, rather error-prone and troublesome.

At 1kHz and 1V RMS output, corresponding to 125mW into an 8Ω load, I could not see any additional harmonic components from the noise, setting the limit at around 0.01%, within my experimental limits. The same was true at 10kHz. At 10V RMS output, 12.5W, the distortion components were found to be largely odd harmonics, and around 1mV. Adding the fourth to ninth at 10kHz, (the odd harmonics being indicative of residual crossover distortion) the total distortion was 5mV rms giving a maximum total harmonic distortion of 0.05%. There may have been some distortion components higher than 100kHz but the analyser I used was unable to record them, and the 9th harmonic was at least smaller than the 7th. At 10V, 1kHz, the high frequency components vanished after the 6th.

Thus, it seems that, for a steady-state signal, the input-lag and phase-lead compensation method gives a distortion below 0.05% at 10kHz and 10V RMS, and considerably lower at lower frequencies, within the limitations of my experimental tests. In a short burst at 30W, before my load resistor overheated, I measured the same ratio of distortion components as at 10V. With the absence of input transient overload distortion, this approach seems to have some advantages over the Miller compensation method.

To provide a sanity check on the distortion levels, I compared the simulated open loop gains of the two methods. **Fig. 13** shows the graphs. It has to be said that the phase-lead-input lag approach does suffer a little. Curve 1 is for the Miller-compensated, modelled amplifier; curve 2 is the modelled stable PLIL amplifier and curve 3 is based on real component values required in a practical amplifier. At 1kHz the gain is down about a factor of two compared with the phase-lag (Miller) circuit, with the parameters I used. If the reference amplifier is under 0.001% at 1kHz, this leaves the phase-lead/lag design at under 0.002%. Thus, it seems that while the approach may increase noise and distortion, it is by a very small margin. There is however, some additional increase at the top end, where the components required in an actual circuit were rather greater than the model prediction. Thus, is appears that the PLIL method may need some optimisation for best performance. It may be concluded that while audible distortions are controlled, high frequency distortions may be less so.

In testing this configuration for stability during clipping, the amplifier showed a very fast recovery when coming out of clipping. Initially, it oscillated alarmingly but this was found to be due to the protection circuitry, which I removed, and the emitter resistors, which I will return to. Although the recovery from clipping was then found not to cause oscillation, I nevertheless considered that the amplifier gain should be reduced, passively, during clipping. It was easy to add the standard anti-saturation diodes, following Stochino, to the upper (VAS) stage because the additional transistor in front of the BD140 lends itself to this. The current source in the lower arm required an extra three diodes **(Fig. 14)**. The result was that the amplifier gain is killed in the pre-driver stages rather than in the driver and output stages, and the clipping signal is "soft". Recovery with this approach is well controlled, as shown in **Fig. 15**. This was measured with a reduced power supply voltage and including a pair of filter chokes to prevent mains ripple appearing on the clipped signal.

I further checked the stability by using the proverbial 2.2mF capacitor load on the output. On testing with a 10kHz square wave the amplifier showed classic ringing **(Fig. 16)**, after I had added further power supply decoupling on the amplifier rails. For continuous operation on a capacitive load, the usual small inductor or small power resistor of 0.22Ω should be inserted in the output lead.

One final point emerged from these experiments. I found that under some circumstances the amplifiers I tested sometimes oscillated at a low level, inexplicably. There was no indication from the simulations what might have

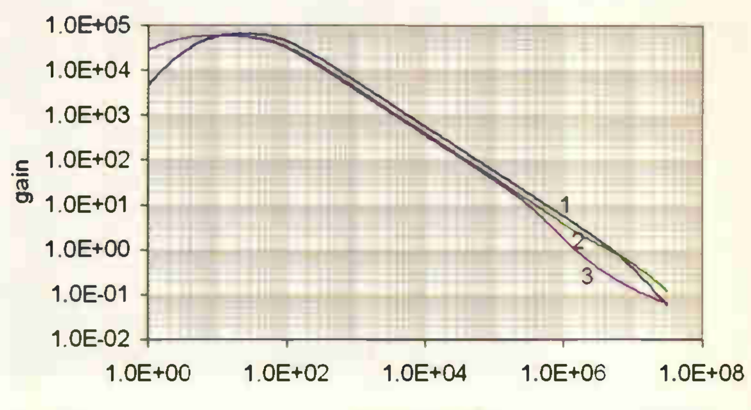


Figure 13:

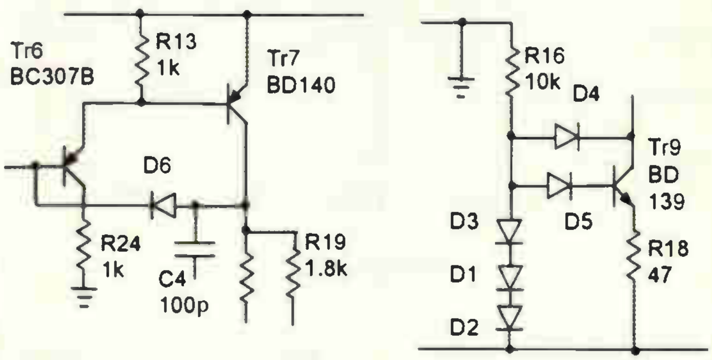


Figure 14: Adding anti-saturation diodes. All diodes are 1N4148 (but supply voltage must not exceed 75V total)

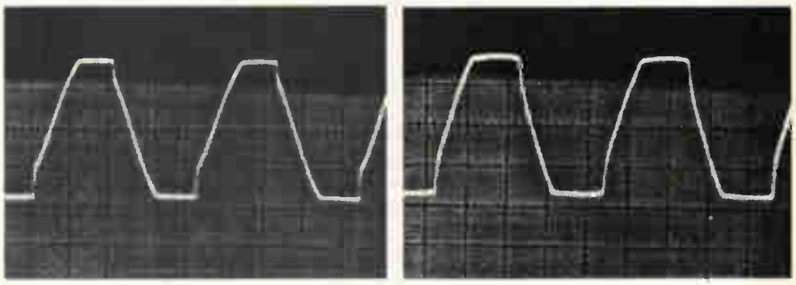


Fig 15(a): Clipping on conventional PLIL amplifier
Fig 15(b): Clipping with anti-saturation diodes added

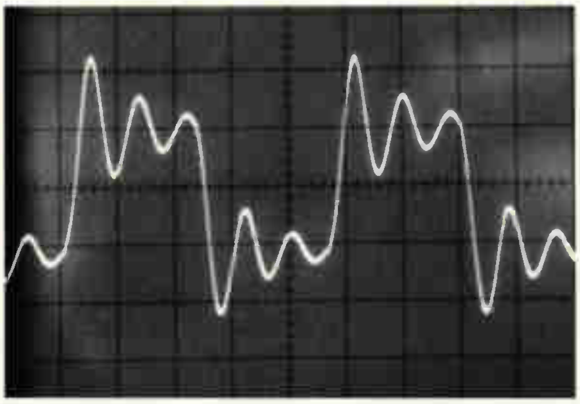


Fig 16: P.L.I.L amplifier response with 8Ω plus 2.2μF load at 10kHz. (vert 5V/div hor 20μS/div)

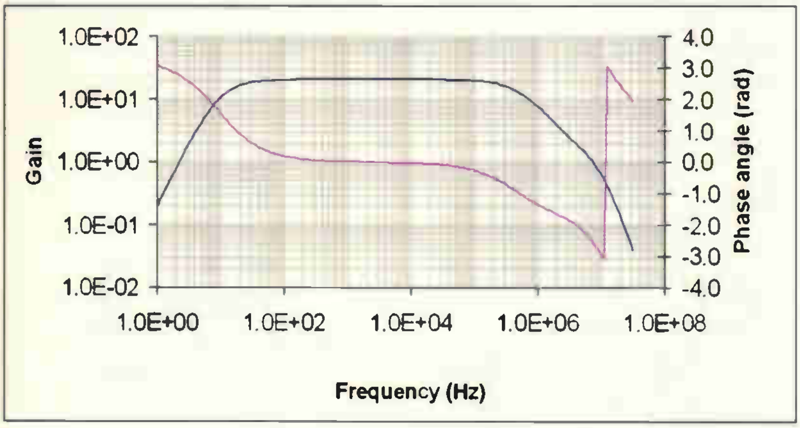


Fig. 17: Effect of 100 nH in a 0.33 ohm emitter resistor. The roll-off at the H.F. unity gain point is on an increasing slope and the phase shift is moving rapidly towards the unstable 180 degree point. The amplifier is bordering on instability. (compare with fig. 7(b)).

caused this but I suspected, from the problems with the protection circuitry, the emitter resistors. Measuring two wire-wound, 0.33Ω resistor samples I found that their impedances at 1MHz were no less than 0.6Ω for the 2.5Ω sample (corresponding to 60nH) and 0.8Ω (116nH) for the 5Ω sample. Bailey quite categorically stated that the emitter resistors should be non-inductive[9], and replacing the commercial resistors by a non-inductive helix (doubled-back) of 24 s.w.g. resistance wire eliminated the problem. I evaluated the effect of some inductance in the emitter resistor in my simulator. With just 100nH, the phase shift induced at around 5MHz, the unity gain point, is very nearly 180 degrees as indicated by the position of the step in the phase plot (**Fig. 17**). This confirms from simulation that inductive resistors can be a cause of spurious oscillations sometimes observed. I have yet to dare to test whether non-inductive resistors would allow the phase lead compensation capacitor to be connected to the output point rather than the collector of the VAS, though I suspect not. as three time-constants (two being significantly variable) are enclosed in such a feedback loop. Nevertheless, I would strongly reinforce Bailey's concern and state that the emitter resistors MUST be non-inductive. The simulations show that even small diameter helical windings. where the inductance is in the order of tens of nH, have too much inductance. Not only does this play havoc with the protection circuitry but also generates phase shifts right where they are least welcome. It may be possible to use a number of 1Ω metal film resistors in parallel, or series-parallel: measurements on the small, 1Ω type showed no significant change at 1MHz.

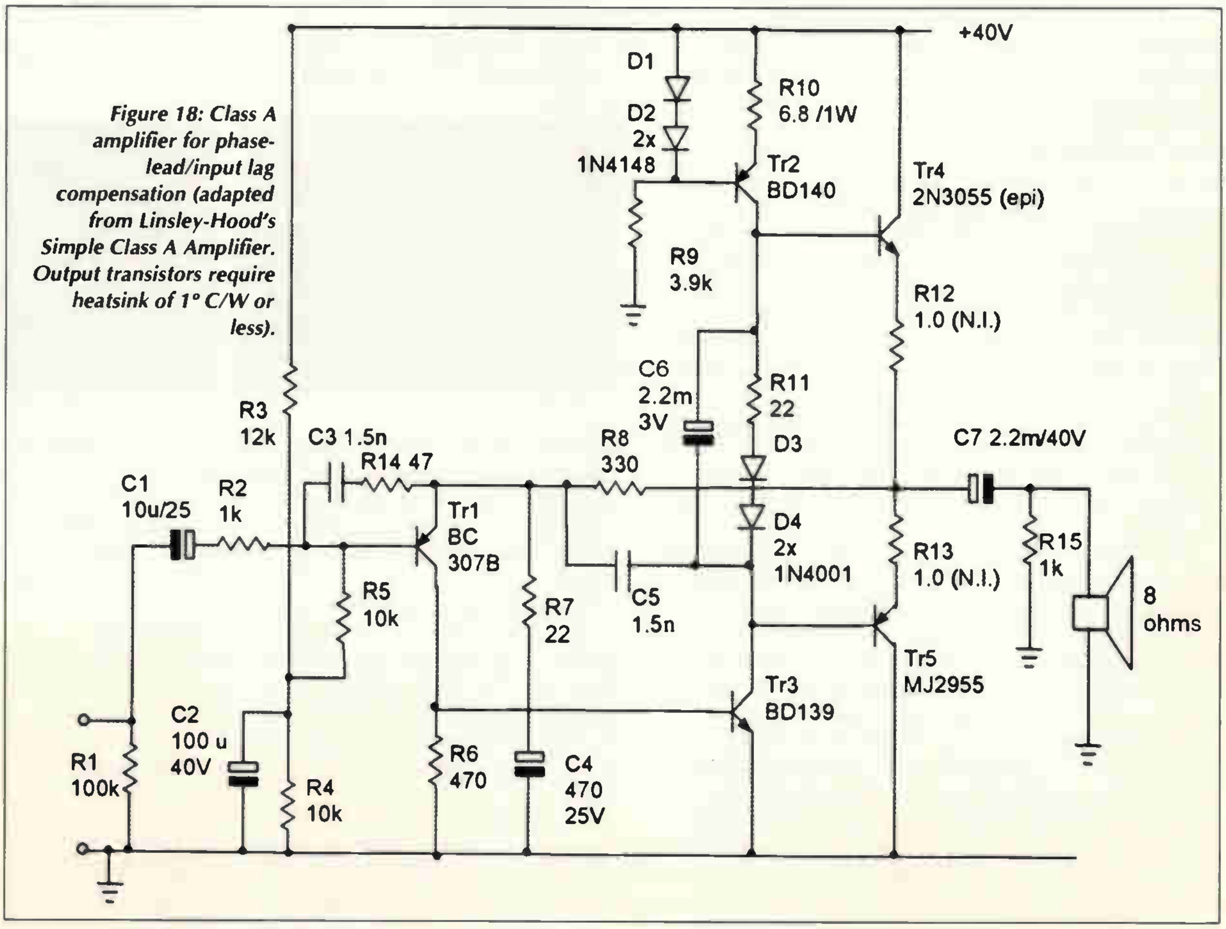
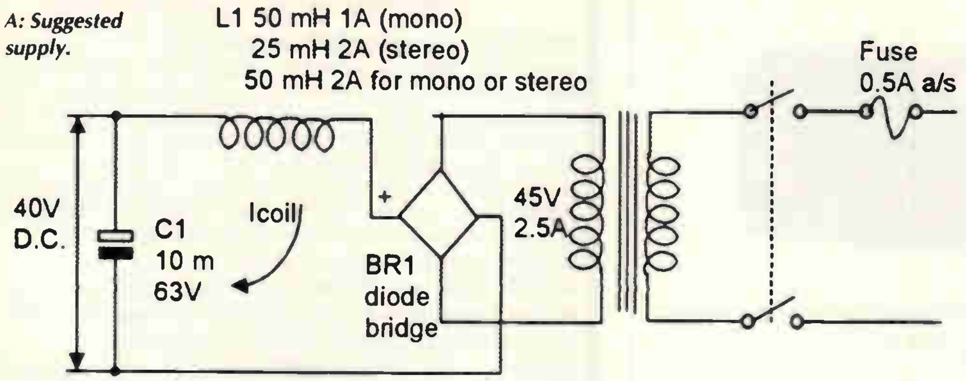


Figure 18: Class A amplifier for phase-lead/input lag compensation (adapted from Linsley-Hood's Simple Class A Amplifier. Output transistors require heatsink of 1° C/W or less).

Figure A: Suggested power supply.



In summary, a stable amplifier performance is possible with the phase-lead/input lag method when the input phase-lag is matched to the phase lead components. This has been supported through simulation. Distortion and noise may both be very slightly degraded compared with a phase-lag (Miller) amplifier, but this seems a small price to pay for a design which minimises the differential signal, and hence improves linearity, in the input transistors, particularly at high frequencies. High frequency distortion may increase slightly, so the time constants should be as high as possible. Whether the very sharp, odd harmonic distortions present at higher power levels, which are only around 1mV, cause listener fatigue is not something I can comment on.

The capacitor between the bases of the output transistors also acts to improve high frequency switching. Though I have some reservations about such a capacitor because, at high frequencies, it will pull charge from the output transistors in the same direction, despite the A.C. output signal, potentially charging unidirectionally, and reducing the driver transistor bias dynamically. However, it too helps to minimise parasitic oscillations, and on balance improves the switching speed, so is recommended.

Distortion arising from the compensation capacitor loading the VAS stage will arise to the same degree as in a Miller compensated amplifier as it increases loading at high frequencies. But the input transistors are spared the extra drive that this would have required from them since the differential signals remain low. As with all high performance amplifiers, the decoupling on the amplifier PCB needs to be good – as Self mentioned, power supply ripple should be prevented from entering the amplifier or it may appear as distortion.

I have shown through simulation, though fairly basic, how the method of using a combined phase lead and input phase lag compensation network can offer a possible alternative to the Miller capacitor. While I cannot say that all the issues with this approach have been unravelled, the phase-lag network operates as a two-pole, low-pass filter in the audio band. This achieves the objectives of an input filter and "slow" input stage at the same time, but without significantly impacting audio frequency bandwidth.

Therefore, it is capable of providing similar performance to a Miller capacitor, but without requiring extensive local feedback (unless one counts the phase-lead network as local feedback). The method works with single and differential input stages. If a single-ended input stage requires an emitter resistor, there will be some increase in distortion due to the open loop gain reduction although this is partly offset by the extra local feedback the resistor introduces. The method can be used effectively in a 15W, modified version of Linsley-Hood's class A amplifier as shown in **Fig. 18.** ■

References

1. Self, D. "Distortion in Power Amplifiers" (Series of articles) Electronics World, Aug. 1993-Mar. 1994, particularly #7, Feb. 1994.
2. Stochino, G., "Non-Slewing Audio Power Amplifier", Electronics World, March 1996.
3. Otala, M., "Circuit Design Modifications for Minimising Transient Intermodulation Distortion". Jnl. A.E.S., June 1972.
4. Bailey, A.R., "A High Fidelity 30W Audio Amplifier", Wireless World, May 1968.
5. Linsley-Hood, J.L. "Simple Class A Amplifier" (Modifications, appearing in Letters, circa June 1969 to original article in April 1969).
6. Gibbs. D.S. and Shaw, I.M., "Gemini 30W Amplifier", Practical Electronics, Nov. 1970.
7. Lohstroh, J. and Otala, M., "Audio Amplifier for Ultimate Quality Requirements", IEEE Trans. AU-21, Dec. 1973
8. Ellis, J.N. and Maynard, G., Letters, Electronics World, January and April 2001
9. Bailey, A. R., "High Performance Transistor Amplifier", Wireless World, Nov. 1966.

LETTERS to the editor

Letters to "Electronics World" Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam Road, Surrey SM3 8BZ
e-mail j.lowe@highburybiz.com using subject heading 'Letters'.

Education system to blame?

Ian Hickman's many articles amply demonstrate that having initially followed a course, which now seems outdated, is no handicap to keeping abreast of developments in ones chosen field of expertise. If there is a shortage of technically competent recruits, then I suggest we look at other changes in education in the recent past rather than being too concerned about whether courses accurately track the changing demands of industry.

Before about 1980 schools offered a more restricted range of A levels. So it was likely that an early decision about the nature of the career options to be pursued would have to be made. Anyone opting for the 'science' strand would be encouraged to study a basket of science subjects and frequently mathematics as well. One side effect was that students entering higher education had an interest in their chosen subject. They would often be expected to follow at least a year of further mathematical studies or more if their main subject had a higher mathematical content. Chemists would study a year of physics or biologists a year of chemistry.

This was perceived as too restrictive and, as post 16 education expanded, potential students were encouraged to adopt a 'pick and mix' approach to their basket of A level subjects. Such an approach may well encourage more young people to remain in post 16 education, but it may not provide any basis for entry into higher education to study a specialist subject. Choice of course on the basis of interest is replaced by choice on the basis of, 'what sort of course will I be accepted for?'

Add to this the fact that some universities have replaced a first year course of mathematical studies with 'drop in centres' for those who find even simple mathematics 'challenging', and don't require further studies in related fields if a student already has any kind of 'pass' at A level, and it is not difficult to see that a proportion of the young people leaving universities with a degree may not actually be very competent or even interested.

A second change has been the rise in educational 'navel gazing'. By this I mean that thinking about what is taught has come to be viewed as less important than thinking about how it is taught.

Twenty five years ago the journal of the Association for Science Education, School Science Review (SSR), commonly had some seventy pages contributed by classroom teachers devoted to details of how to construct useful pieces of science apparatus, many of them involving electronics. In addition there were perhaps three or four longer articles of about ten pages each, dealing with the construction or use of equipment.

When I looked at the end of 2001 there were just eleven pages devoted to making or using apparatus. Nowadays SSR is filled with 'academic' articles dealing with things like concept formation or 'student' reasoning. It seems that science is no longer something that humans do, just something they talk about. Should we be surprised if those who are being taught assimilate this attitude?

It is not just in science that the 'hands on' experience of youngsters leaving school for higher education tends to be limited. Ian Hickman commented a couple of years ago on the lack of practical experience of electronics undergraduates before starting their degree course and I've heard similar comments elsewhere.

When I left school I worked for ICI for five years and have spent the last thirty seven working in secondary, tertiary and higher education, so I have had plenty of time to watch educational fashion come and go. I keep waiting for it to swing back to day release, evening classes and part time study. It worked for me!

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Shrinking Horizons

Your correspondents all seem to have noticed the slimming down of the magazine until some of us have thought to hold our breath for the final 'pop' as it disappeared in a small puff of smoke. Certainly Alan Robinson likens EW to the other 'hobby' magazines and I initially felt slightly affronted, thinking that in its hey-day it was a professional and educational journal across the 'wireless' spectrum. Then I remembered that it was once the Radio Amateurs' newsletter or bulletin, then the high quality home constructors magazine par-excellence

A Gem

I was entertained by the December letters page, and stimulated enough to bring this little gem to your attention.

Remaindered only a year after it was published, I was fortunate at the time to pick up a book written by Ivor Catt. It was called "The Catt Concept", ISBN 0 246 10533 X and was published in UK by Rupert Hart-Davis in 1972.

Having seen some of his subsequent writings and career I realised the book was more relevant than he might have imagined when he wrote it. So I did a Google search on "Catt Concept" and Ivor is up there in the early hits.

It is almost a parable of the modern times; I now see it happening all around me, and not only in my world of technology, but in politics and new commerce as well.

I commend "The Catt Concept" to the house as a light bedtime read, should you still be able to find a copy.

See also his website for yet more gems http://www.ivorcatt.com/

Richard Stevens
Ickenham Middlesex, UK

See also Ivor's tome in this issue – ED.

(in the '20's and '30's). But then again, earlier than that it started as the Marconi Journal... Oh, I give up, but what a pedigree.

Back to hobby magazines, the rate of closing down that has gone on recently does seem ominous. Also, some of the really professional papers, at least for news and advertising such as *Electronics Times* have bitten the dust so the decline is pretty universal. As to content, yes I agree that controversial topics are most important, as although downright cranky ideas and theories ('perpetual motion machines' et. al.) are dubious as a way to increase interest and circulation, devices and systems that seem to work but which have alternative explanations, do generate great interest. I am thinking of controversies like the commercial product called the cross-field antenna. Does it operate with a 'new' interaction of the (separate) electric and magnetic fields to give a composite e-m field so that a very small antenna works as well as the large ones required by ordinary electromagnetic theory? An obvious development is the fashionable one of computing, digital devices and programming. The explosion of computing magazines of varying quality on the bookstalls shows up the present nature of this area. Whether *EW* should compete with these computer publications as regards content is a moot point. I would heartily agree that long software listings are wasteful of valuable discussion space and look stodgy even to those few who might find the programming directly useful. It's much better to have an alternative source of listings for those who need them, even for a small extra charge or postage etc. Possibly the one exception is the considerable interest that microcontrollers such as the PIC range of devices holds for a number of people, including a considerable number of analogue engineers. These simple but versatile devices do so much that the occasional practical and tutorial type article might have a fairly universal appeal. This is especially true if the quality of the material remained up to the *EW* tradition, as some other offerings elsewhere recently have left a lot to be desired in the understanding stakes.

What a shock it was to find that the original magazine title *Wireless World* is outside the present owners control. It sounds ominously like the earlier owners might resuscitate a journal called Wireless World, in other words, it appears to have currency and value for something else and is therefore being carefully bottled up...? One of the more successful popular electronics (radio) journals. namely, *Practical Wireless* (although its cover title is now simply '*PW*') has managed to thrive on the retention of 'wireless' in the title. The

Capacitor Sounds

Perhaps I should thank John Woodgate for reminding me of another oft quoted capacitor myth. It was included in my early drafts but deleted to reduce article sizes. I refer of course to the engineer's myth that at higher frequencies capacitor distortion disappears as voltage dropped across the capacitor reduces. This is not so. In practice capacitors distort both with applied voltage and through current. Circuits which cause capacitor voltage to reduce with frequency often also cause increased capacitor currents.

While not part of the present articles, I have recently performed constant current and constant voltage comparative measurements at 100Hz, 1kHz and 5kHz on the same test capacitors, which clearly prove this.

Many circuit applications also subject the capacitor to a near constant AC voltage regardless of frequency. For example the capacitor bypass across the output transistor bias control, C4 *EW* Feb. '94 p.139.

No doubt my view as to the signal path in an amplifier would differ from John's. Remember most amplifiers include negative feedback loops, any distortion introduced in these is then introduced into the signal path. In the above reference, the 220μF capacitor C2, *EW* Feb.'94 p.139 is also in the signal path.

D. Self found this component position caused distortion in his Class G amplifier, *EW* Jan.2002.The C'Dom capacitor sees significant AC and DC voltages, but being usually a small value, can use COG disc ceramic or foil with polystyrene so should contribute little.

One highly stressed and largely inadequately specified capacitor, usually 0.1μF, is used in the Zobel network. Being subject to large AC signals, this can introduce distortion. Many such capacitors fail OC due to excess stress at high frequency.

We should not forget the supply rail decoupling capacitors. Usually electrolytic, they are subject to significant DC bias and AC voltage at low frequency and currents at higher frequency.

Finally the input DC blocking/coupling capacitor, frequently a polar aluminium electrolytic, this no doubt was the application John had in mind. Any distortion here is outside any feedback loop and will be amplified in later stages. While higher frequency currents will usually be small, depending on values used, significant AC voltage can appear across this capacitor at the lowest audio frequencies. Hopefully my later articles do clarify this.

As to his other points, I did not claim measuring low distortion per se was new, simply that such capacitor measurements at usable voltages using low cost equipments were. I believe my design was the first fully worked, low cost, 1ppm measuring system, complete with PCBs. I published this so that many readers could make their own measurements.

In articles 1 & 2, I included a box 'Other measuring methods' which detailed the CTL1 test instrument originated by a major telecomms maker. A far better test than the one John describes. Developed in 1966, I personally used this equipment in around 1969/70 testing capacitors and resistors. This equipment claimed a dynamic range of 176dB.

Barrier layer ceramic capacitors were described in the text. To say these are rated at 6V or 12V is quite wrong. From the earliest days, usually called 'Transcap' these types were readily available at 3V, 12V, 18V, 25V, 50V and 100V. Maximum value at 100V being 0.22μF. The one I measured was 0.1μF rated at 50V as in reference 4. As to my hiding the Barrier Layer description that also is quite wrong. At the top right of each spectrum display I show brief details of each test and the test capacitor used.

Surprise surprise, even my old eyes can read the words 'Barrier Disc' in Figure 2 November, also the text quotes two references, 3 & 4. Reference 4 uses the supplier's description of the capacitor I used, 'Decoupling Ceramic Disc' while reference 3 says 'Barrier Layer Dielectrics - 1961'.

This leads me to my last point; Transcaps or Barrier Layer discs were in volume production at Gt. Yarmouth long before I joined the company in 1966. So I certainly do not claim any involvement in their development, at State College Pennsylvania.

Cyril Bateman,
Acle, Norfolk,
UK

paradox is that publications coming from the USA are full of the term 'Wireless', as though it was exclusively discovered over there. I for one would stoutly vote for the re-introduction of *Wireless World* as this magazine's title, what with all the 'Bluetooth this', 'r.f. solutions that', 'GSM the other' etc. The wireless world is burgeoning.

Finally, some correspondents denigrate what they call 'beginners' articles' and state that other magazines cover this area. If they do, where are they? I agree that poorly written, old hack theory is a textbook plod. Yet some of the historical and more controversial 'theory' and dare I say it, pedagogical stuff of the inspiring sort, used to attract a great number of students to *WW* and *EW*, who then tended to remain loyal to the magazine when they took up professional work. In 'the old days' (huh, I wonder if you thought, when is he going to mention them ...) a very lively correspondence always accrued when an in-depth discussion of, say 'Q', Fourier or other powerful mathematical techniques, or expositions of complex devices made them simple, were discussed. Of course, 'Cathode Ray', the late Mr. Scroggie, was for ever the task master of that approach. All in all, many of us hope the magazine will ride out the economic and possibly intellectual depression and grow back towards its former glory. Best wishes.

'Joules Watt'
Canterbury,
Kent, UK

No Conspiracy

I refer to the section headed "No Conspiracy" at the end of which you request an explanation of the apparent danger from use of mobile phones in petrol filling stations, but not from a more powerful transmitter in the same place.

Back in history (1960s), mobile radio apparatus fitted in vehicles used thermionic valves and power switching used electromagnetic relays. Sparking occurred when, typically, 250Vdc at 100mA was switched. The apparatus was frequently fitted in a car boot, near the fuel tank and I recall reading of a fire that was apparently caused due to use of such a radio system. I think, but am not sure, that it was a police car. It seemed most likely that ignition was due to sparks rather than radio transmissions. See note (*). I believe that the prohibition on radio apparatus used in petrol stations followed this event.

Current radio equipment does not use sparking relays, although base stations do use higher power than hand-held phones. It may be of interest to mention some measurements I recently made near a phone base station. They were made at a busy time, with many carriers present. The maximum total power received using a suitable half-wave dipole was about 20dB less than from the local TV transmitter about 1/2 miles distant. Given that TV has been with us for decades, it is hard to see how much weaker radio transmissions from phone base stations, still less mobiles, cause significant risk.

In our litigious world, it would require a brave official to announce that it is now "safe" to use phones in filling stations where previously they were not permitted. Alternatively, on the other side of that coin, due to the measurements mentioned in the above paragraph, all terrestrial TV transmissions must now be considered dangerous and must cease.

(*) NOTE:
It is true that strong radio signals can interact with certain metallic structures to create a spark. However, in this case, the low power of a modern phone is highly unlikely to cause a spark of sufficient intensity to ignite petrol vapour. In the mid-70s, I had an involvement with HSE concerning the Edinburgh medium wave 2kW commercial radio station. In that case possible risk was not due to petrol vapour, but due to very much more inflammable hydrogen and other gasses emitted from the nearby oil processing plant at Dalgety Bay. The station was permitted after objective assessment by HSE.

I should add that I am not connected in any way with the mobile radio industry or the regulatory authorities, and expressed views are entirely personal. The first paragraph does of course depend partly upon memory of 40 years ago.

Fred Wise,
Suffolk, UK

Identity Crisis

May I impose on you to resolve a situation, which has puzzled me for some time?

I have in my possession a drive motor from a Grundig TK20 tape recorder. As a brief description, it has a 70mm rotor – containing no windings – with a 30mm pulley attached. There are three leads, two of which are in a common sleeve, any pair giving a reading of 1100 Ohms.

Is the third lead utilised for starting in any way and could you explain the necessary operational connections (if possible without the use of relays)? Is this an induction motor?

Thanking you in anticipation,

C. Holwill
Portsmouth,
Hants, UK

From memory, these big motors (almost certainly the capstan drive) used a capacitor start system. Any reader care to elaborate? – ED.

More Catt, please

Loved the spectrum pricing article. It was something I had suspected, but I didn't realise how unfair it had been until that article. It was clear and well structured.

Would like to see more stuff like Ivor Catt (is he still about ?), he had interesting ideas and the maths articles relating to electronics as Joules Watt used to write.

What about a series on quantum mechanics and electrons? Also valves are fun - what about an article describing triodes, tetrodes and pentodes and what all the plates do, advantages/disadvantages etc. I'd like to see a description (mathematical and descriptive) of how co-ax works too, loss-less in theory.....

I guess 'difficult' maths or physics stuff does no harm, if people can't follow it they turn the page, and look at some adverts or something. But true engineers will treat it the same way a guardian reader treats his crossword. Something to exercise the mind! Feed our minds, as that's why we became engineers in the first place...

I'd like a build your own Theremin article too - I'll build it. I built the hot audio power amp too (March 1995 article).

Robin Clarke,
UK

Again, do look out for the return of Mr. Catt elsewhere in this issue. I'd also like to hear from anybody up to Robin's challenge.-ED

Air Traffic Control

Regarding the Air Traffic Control article by Nigel Cook, *EW* January 03, p12

Generally, I think air traffic control will be controlled by vested interests in each European country. This will block a technical fix.

However, the disaster on the German/Swiss border proved that national systems have to be replaced by a Europe-wide system. At this moment, the national vested interests will be in disarray, and so there is a better chance than at any other time to infiltrate a system (The Kernel Machine) whose merits are based on performance rather than on the kickbacks to the various parties involved.

Ivor Catt
St. Albans, UK

Too much audio

I have been a regular subscriber to *E&WW* for many years dating from 1979. I read your editorial in the October 2002 and appreciate your dichotomy in having to cater for the predilections of a diverse readership. Your points with regards to the 'audiophile' view of no computing based articles is manifestly borne out by some remarkable letters in the same issue. However, the content and bias of the issue in question was worse than disappointing.

I purchase *E&WW* purely to help with my professional work. An obsession with all things audio is of little use or interest to me. Many of the recent articles have offered practical introductions to subjects that are applicable to many of the companies for which I work as an electronic design consultant. For example, Dr. Eddy Insam's pieces have served to point the interested reader in the right direction on where to get started with Ethernet networking technology. Personally, I would like to see many more of these applied technology articles.

Please could you ensure that future issues are better balanced.

Huw Jones,
UK

Audio distortion

Cyril Bateman seems slightly to have missed the point of my article on distortion testing of loudspeaker cables using audio hardware and software. It seems I was not sufficiently clear in explaining my aims and intentions: I apologise.

First, the choice of speaker cable as a subject for the test was only intended to be illustrative of some of the techniques one can employ with such software (incidentally, the new version of Cool Edit Pro, admittedly more expensive at $250, has a fully zoomable spectrum display and the option of exporting the spectrum, which makes it potentially nearly as powerful as the very nice Spectra software Cyril uses and avoids some of the tedious signal-manipulation tricks I described in earlier articles).

More importantly, however, I should explain my rationale in choosing the test set-up. The entire reproduction chain (CD player and amplifiers) was exactly as I use it for subjective reviewing of speaker cables, in which situation I believe I can hear differences between cables. Typically, the distortion of the system is dominated by the power amplifier, but what I was looking for was any evidence that changing cable changed the spectrum - in which case by far the most likely explanation is that the amplifier's performance was subtly modulated by the cable's parameters, rather than that the cable itself is producing distortion. In using a CD as the signal source (with a 'perfect' dithered 16-bit digitally generated test signal of four sinusoids) and a CD recorder (16-bit, of course) as the analogue-to-digital converter, I was imposing restrictions no greater than those of the recordings with which I believe I can hear differences between cables. The test is thus fair and legitimate. Of course, real audio is typically considerably more complicated than a mere four sinusoids, but one must draw the line somewhere.

Cyril's high resolution distortion tests are impressive and may even show up effects due to cables, but having myself conducted spot-frequency THD tests that failed to show any cable-induced distortion down to about -110dB I wished to investigate other lines of attack that might perhaps show up something at a higher (more plausibly audible!) level.

In conclusion, Cyril's excellent work on capacitors is clearly much more rigorous than my own: I merely wished to present some food for thought and a few possibilities for further development on the good old engineering principle of 'what if....?'

Richard Black
London, UK

Mobile phones and radiation, etc.

A few years ago (40+), I was asked to look at the electromagnetic spectrum for any adverse effects it could have on humans. I was given; 'start at Rugby (16kHz) up to the latest radars' (2GHz), and 0.3mM to 15uμM, the then laser frequencies.

What I vaguely remember is that my findings concluded there were many frequency spots and ranges, threshold power levels and continuous power levels that appeared to have some human effect. These ranged from local burning, headaches, mood changes, etc.

In Australia someone used chickens to determine any effects by mobile phones; what a load of rubbish! Non ionising radiation can be very subtle; so I would say, "Be careful". Remember, I can get drunk on, whisky and soda, vodka and soda, ... therefore soda makes you drunk - if this makes sense to you......

John Ingram.
South Australia. ■

No bottle?

Having read Dr S.T. Hughes letter published in the December edition of *Electronics World*, please note the comments below:

The magazine has indeed very considerably reduced in page count and the range of articles. In the past there were frequent imaginative and useful designs as well as many informative of items on practical methods.

An increase in the price would be a sensible move if it meant restoring the former breadth and excellence. I fear the magazine has become a victim of the kind of corporate asset stripping and ruthless disposal that characterises so much business in the United Kingdom these days.

It is hoped that you and your colleagues will overcome the current difficulties with the publication.

L.P.

I normally throw away any communication that comes in anonymously - I have published this one only because I know that it will generate debate. I would say however, that I am extremely surprised when anyone who feels strongly enough to write in to me at EW does not then have the courage to identify themselves.

£11.99

Available from *Electronics World*

All tracks on this CD were recorded on DAT from cylinders produced in the early 1900s. Considering the age of the cylinders, and the recording techniques available at the time, these tracks are of remarkable quality, having been carefully replayed using modern electronic technology by historian Joe Pengelly.

21 tracks – 72 minutes of recordings made between 1900 and 1929. These electronically derived reproductions are no worse than – and in many cases better than – reproductions of early 78rev/min recordings – some are stunning...

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1 Washington Post March, Band, 1909
2 Good Old Summertime, The American Quartet 1904
3 Marriage Bells, Bells & xylophone duet, Burckhardt & Daab with orchestra, 1913
4 The Volunteer Organist, Peter Dawson, 1913
5 Dialogue For Three, Flute, Oboe and Clarinet, 1913
6 The Toymaker's Dream, Foxtrot, vocal, B.A. Rolfe and his orchestra, 1929
7 As I Sat Upon My Dear Old Mother's Knee, Will Oakland, 1913
B Light As A Feather, Bells solo, Charles Daab with orchestra, 1912
9 On Her Pic-Pic-Piccolo, Billy Williams, 1913
10 Polka Des English's, Artist unknown, 1900
11 Somebody's Coming To My House, Walter Van Brunt, 1913
12 Bonny Scotland Medley, Xylophone solo, Charles Daab with orchestra, 1914
13 Doin' the Raccoon, Billy Murray, 1929
14 Luce Mia! Francesco Daddi, 1913
15 The Olio Minstrel, 2nd part, 1913
16 Peg O' My Heart, Walter Van Brunt, 1913
17 Auf Dem Mississippi, Johann Strauss orchestra, 1913
1B I'm Looking For A Sweetheart And I Think You'll Do, Ada Jones & Billy Murray, 1913
19 Intermezzo, Violin solo, Stroud Haxton, 1910
20 A Juanita, Abrego and Picazo, 1913
21 All Alone, Ada Jones, 1911

NEWPRODUCTS

Please quote *Electronics World* when seeking further information

UPS that rides those brownouts

Advance Galatrek is offering a range of digital line interactive sinewave uninterruptible power systems (UPS), designed to fit on a standard 19in. rackmount cabinet tray. The LineUPS-R series comprises models from 500VA to 2000VA, and features a built in automatic voltage stabiliser that allows it to ride through sags, surges and brownouts without the need to resort to battery power. This means that loads connected to LineUPS-R are protected from potentially damaging variations in the power supply, such as spikes and electrical noise, and also allows the batteries to remain in a fully charged state in anticipation of potential mains power interruptions.

Advance Galatrek
www.aelgroup.co.uk
Tel: +44(0) 800 269394

Mosfet driver can take big transients

Linear Technology is offering the LT1910 high side N-channel Mosfet driver with an operating supply range of 8V to 48V and protection against supply transient from –15V to 60V. The LT1910 can be used as a solid-state circuit breaker or load switch to protect resistive, capacitive and inductive loads

from short circuit and over-current conditions. It is designed for harsh operating environments such as industrial, avionics and automotive applications where poor supply regulation and/or transients may be present. Applications include stepper motor control, DC motor control, robotics, heavy machinery and electronic circuit breakers. The device incorporates a charge pump to fully enhance an external n-channel Mosfet without requiring any external components. It features short-circuit and over-current protection as well as a diagnostic output signal to alert the rest of the system in the event of a fault condition. When over-current is detected. the LT1910 turns off the Mosfet then automatically turns it back on after a set time period eliminating the need for external control circuitry. The over-current value and timer are adjustable by the user. The device repeats this cycle until the fault is removed or the driver is turned off. It is offered in an 8-pin SO package.

Linear Technology
www.linear-tech.com
Tel: +44(0) 1276 677676

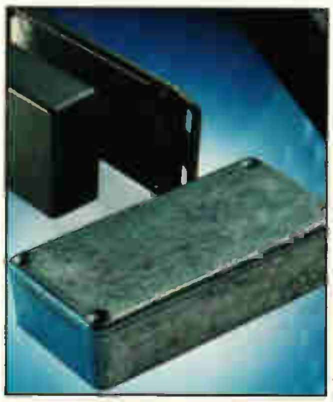
70mm fans with alarms and tach output

NMB Technologies has introduced two 70mm fans, the 2806KL and 2810KL, which offer optional tach output. and locked rotor alarm signals. Sizes of the 2806KL and 2810KL are 70 by 15mm, and 70 by 25mm respectively. The 2806KL fan delivers up to 64.6m^3/hr and the 2810KL fan delivers up to52.7m^3/hr in a free air environment. The falure rate is specified at less than 60 parts per million based on actual field test data. Both the fans meet all UL/CSA, VDE and CE requirements.

NMB Technology
www.nmbtc.com
Tel: +44(0) 01 818 341 3355

Aluminium enclosures

Hammond Electronics has introduced an extra size in its 1590 series of die-cast aluminium enclosures. Available in standard, flanged, flanged lid and waterproof versions, the G size enclosure measures 100 x 50 x 25mm. All versions have a shallow draft angle for easy PCB mounting and use countersunk screws into drilled and tapped



holes to allow repeated openings and closures. Lapped joint construction ensures continuity between lid and base. The units are available in natural or powder coated painted finish. The flanged version has factory fitted flanges assembled to the base, so the enclosure can be screwed down to a surface while the lid remains accessible for removal. In the flanged lid version, the lid extends beyond the body to let the enclosure be mounted to a surface. Waterproof versions have an extruded silicone rubber gasket around the lap joint in the lid to give IP65 sealing. Electrical continuity between the lid and base is maintained.

Hammond Electronics
www.hammondmfg.com
Tel: +44(0) 1256 812812

Chassis meets space needs for avionics

SBS Technologies has intrduced a standard 1/2 ATR short Arinc-404 chassis designed to meet the space limitations of the Arinc-404A envelope used in most avionics applications. The RCOM5-ATR-6V lightweight aluminium chassis is cooled by convection or via a base cold plate, which improves thermal performance and allows a

IGBTs help wash clothes

International Rectifier has introduced 600V non punch-through IGBTs for motor drive applications such as clothes washers and air conditioners, as well as light industrial motor drives. Dubbed Co-Packs, the devices consist of a 600V IGBT and one of its Hexfred fast recovery diodes rated at 5, 7, 12 or 20A. The single package devices are configured for half-bridge or inverter topology and have a 10µs short-circuit capability. They improve ruggedness during start-up and abnormal current and voltage spikes, said the supplier. A low current tail at turn-off reduces switching energy losses compared with previous devices, allowing modulated frequencies up to 20kHz. Higher modulated frequencies allow better torque control at lower speeds and reduced audible noise. Thinner wafers reduce electrical and thermal resistance. providing lower switching losses without any increase in conduction losses. Turn-off does not require a negative bias, eliminating the need for an auxiliary power supply, and simplifying the use of gate driver ICs.

Internationl Rectifier
www.irf.com
Tel: +44(0) 208 645 8003

Please quote *Electronics World* when seeking further information

maximum temperature range of –40 to +71°C. The chassis houses a five-slot 6U VME64X backplane accommodating up to five toploaded conduction cooled 6U VME boards, including power supply and a 300W 28VDC plug in power supply that is MIL740D and MIL461C compliant. The chassis removable surfaces are provided with environmental and EMI gaskets, which protect internal electronic assemblies from airborne contaminants.
The chassis is sealed creating a dry air environment with all boards, including the power supply, secured with wedge locks to increase resistance against shock and vibration.
SBS Technologies
Tel: +1 760 438 6900
www.sbs.com

VME graphics board

Peritek has introduced its first entry-level PCI mezzanine card (PMC) graphics board for use in VMEbus and CompactPCI embedded systems. The Tropos PMC is the first graphics controller to use Silicon Motion's SM731 graphics accelerator. The card is designed for 2D, 3D, OpenGL and DirectX-compatible displays. It supports Linux, VxWorks and Windows operating systems.
Silicon Motion's 128-bit SM731 graphics accelerator supports screen resolutions up to 1,600 x 1,200. The SM731 can be configured with 16 or 32Mbyte of high speed display SDRAM to provide local storage for image and off-screen data such as texture maps, Z-buffer and backing store.
Peritek
Tel: +1 510 531 6500
www.peritek.com

Simmer modules aid YAG laser pumping

Hitek Power has introduced a 10W simmer module for use with the flashlamps used to pump YAG lasers and in other intense pulsed-light systems. Powered from a 24V DC supply, making it suitable for medical applications, SM10 will provide up to 100mA of simmer current at 100V. The unit incorporates a trigger pulse output to drive an external trigger transformer.
Custom versions are available, either as standalone supplies or integrated into a dedicated flash lamp unit. Versions with 25 or 50W outputs will be added to the range before the end of the year.
Hitek Power
Tel: +44(0) 1243 841888
www.hitekp.com

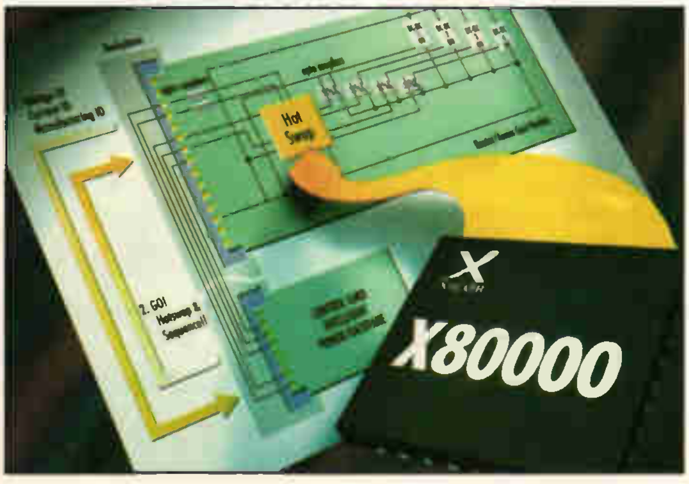
Audio IC simplifies receiver design

An audio IC from Rohm simplifies radio receiver design by integrating European RDS and American RBDS decoding functionality in one chip.
Rohm's BU1924 RDS/RBDS is a CMOS-based decoder IC with a two-stage anti-aliasing low pass filter, 57kHz eight-stage band-pass filter and digital PLL for DSB demodulation. A quality indication output for demodulated data is provided.
The BU1924 is aimed at

RDS/RBDS-compatible FM receivers including home stereo systems, car radios and FM pagers. By offering RDS and RBDS functionality, the device is suited to radio products for operation in Europe and the USA. Designed to operate with a normal 5V supply voltage, it has a maximum power dissipation of 350mW at 25°C. Available in either SOP16 surface mount packaging or as a DIP16. operating temperature is –40 to +85°C.
Rohm
Tel: +44(0) 1908 282666
www.rohm.co.uk

Power management over 48V backplanes

Xicor's latest power management devices integrate power sequencing and hot swap functions with an SMBus interface to enable power supply control in multi-card –48V backplane applications.
The devices' hot swap features allow for insertion and extraction of line cards, network interface cards and other peripherals whilst –48V of power is present on the backplane. Power supply sequencing allows for systematic on/off control of DC-to-DC converters on the line cards or other devices.
Through the use of the SMBus, interfaces allow for power distribution designs by reporting voltage, current and manufacturing identifications to a control card that can manage power distribution, timing and voltage supplies. The –30V to 110V hot swap controllers are able to sequence and control up to five independent DC-to-DC converters, offering flexible module sequencing in parallel or relay modes. Four independent built-in delay circuits are provided for DC/DC sequencing. With on-chip 2k EEPROM for storage of customer programmed features, the X80000 and X80001 devices have selectable overvoltage and undervoltage detection and protection.
Production samples are available for the X80000 and X80001 in 32-lead QFN packaging.
Xicor
Tel: +44(0) 1908 282666
www.xicor.com



Wireless system design tool models physical links

Mathworks has announced the availability of a communications Blockset, which extends its Simulink system-level design environment by providing more than 150 blocks to model the physical and link layer of communications systems.
According to the company, algorithms and wireless system models enable communications systems engineers to develop more accurate system-level simulations and specifications for wireless, broadband, broadcasting, and satellite systems and semiconductors.
The communications Blockset 2.5 can be used with other of the firm's products, including the DSP Blockset 2.5, Signal Processing Toolbox and Communications Toolboxes. Real-time Workshop, and Stateflow. to perform simulations of communications devices and links. The latest version contains an RF impairments library, which

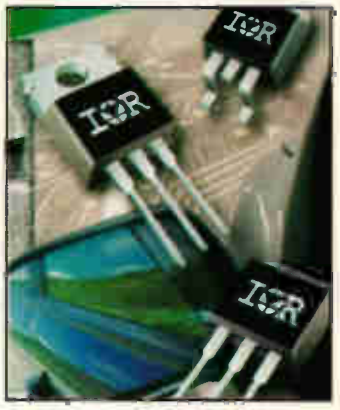
Please quote *Electronics World* when seeking further information

allows users to model the impact of nonlinearity, phase noise and other RF effects on baseband communications design. New application examples of complete end-to-end communication links, including WCDMA, Hiperlan/2, IEEE 802.11, and Bluetooth, provide a starting point for the simulation of wireless systems.
Mathworks
Tel: +44(0) 1223 423200
www.mathworks.co.uk

Eight channel UART has PCI-bus

Distributor DT Electronics is offering an eight channel UART that includes a PCI-bus interface to simplify design and save on board space. The Exar XR17C158 is an octal UART designed to meet the 32-bit PCI-bus and high bandwidth requirement in communication systems. To speed up interrupt parsing, the global interrupt source register provides a complete interrupt status indication for all eight channels. Each UART has an 16C550 compatible set of configuration registers, transmit and receive FIFOs of 64byte, fully programmable transmit and receive FIFO level triggers, transmit and receive FIFO level counters, automatic RTS-CTS or DTR-DSR hardware flow control with programmable hysteresis, automatic software (X_{on} and X_{off}) flow control, IrDA encoder-decoder, eight multi-purpose definable inputs and outputs, and a 16-bit general purpose timer-counter. The device provides data transfer in byte, word and double-word and features read-write burst operation. With PCI compliance, it operates from 5V, or 3.3V with 5V tolerant inputs.
DT Electronics
Tel: +44(0) 2476 437437
www.dtelectronics.com

Automotive trench Mosfet



International Rectifier has introduced an automotive-specific, trench Hexfet power Mosfet which the supplier claimed has a 15 per cent lower device on-resistance per unit area than alternative technology. The Mosfet technology offers an avalanche capability comparable to planar technology and up to twice that of currently available trench products, said the supplier.
International Rectifier
Tel: +44(0) 208 645 8002
www.irf.com

Please quote *Electronics World* when seeking further information

PICmicro draws 0.1µA in standby

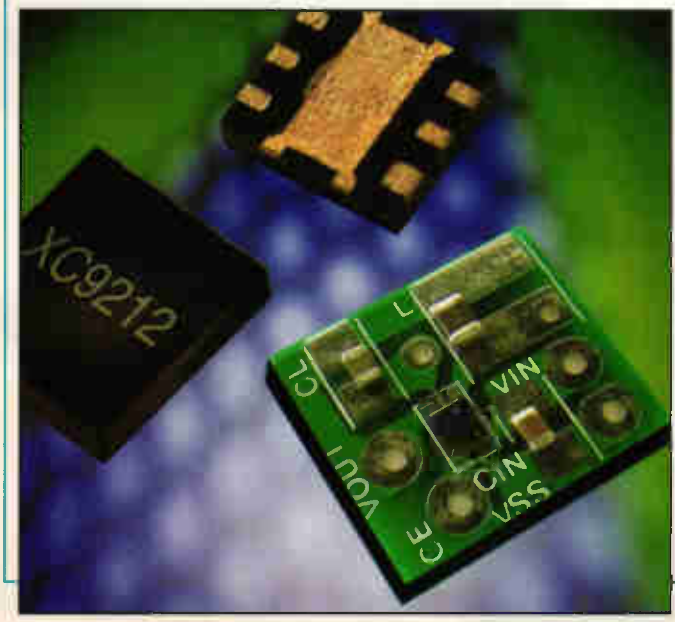
Microchip Technology's latest family of PICmicro flash microcontrollers features six power-managed modes with power consumption down to 0.1µA in standby mode and a operating voltage range from 2 to 5.5V. According to the supplier, the target power consumption will be 110µA at 1MHz, 2V and 330µA at 1MHz, 5V. The PIC18FXX20 microcontrollers are pin- and code-compatible with the firm's current 18-, 28- and 40-pin portfolio. The power management features include a flexible clock system with six software controlled power-managed modes which allow designers to execute code from a real-time clock base as well as control the speed of their code execution, thus allowing better control of the overall system power consumption. Additional features include a new low-current watchdog timer, a two-speed start-up from a reset or sleep mode and a new fail-safe clock monitor that is used to detect an external clock failure. The devices offer up to 8kbyte of flash program memory, up to 512byte of RAM memory, 256byte of EEPROM memory and an internal multi-frequency oscillator up to 8MHz. Additional features include a 10-bit analogue-to-digital converter with up to 13 channels, and an enhanced capture/compare/PWM module with one, two or four outputs.

Microchip Technology
Tel: +44(0) 118 921 5869
www.microchip.com

DC-DC Converters have drive & switch transistors

The XC9211/9212 series of synchronous-rectification type DC/DC converters from Torex Semiconductor incorporate a 0.6W P-channel drive transistor and N-channel switching transistor. According to the supplier, the intention of this is to allow for the use of ceramic capacitors. The devices are designed to be used in power supplies with an output current of 400mA, which can be configured using only a coil and two capacitors connected externally. Minimum operating voltage is 1.8V. Output voltage is internally programmable in a range from 0.9V to 4.0V in increments of 0.1V. Oscillation frequency is selectable from 300kHz, 600kHz and 900kHz. The devices can be manually switched between the PWM control mode with synchronous rectification and the automatic PWM/PFM switching control mode with non synchronous rectification, allowing fast response, low ripple and high efficiency over the full range of load (from light load to high output current conditions). The soft start and current control functions are internally optimised. During standby, all circuits are shut down to reduce current consumption to as low as 0.5mA or less. Package options are 250mW (SOT-25) and 100mW (USP-6B).

Torex Semiconductor
Tel: +44(0) 1530 510190
www.torex.co.uk



Royalty-free RTOs for x86/Pentiums

Green Hills Software has its royalty-free Integrity 4.0 real-time operating system (RTOS) for the Intel x86/Pentium architecture. Featuring a memory-protected, micro-kernel architecture that guards against

viruses, hackers and errant code, the RTOS provides resource availability for CPU and memory access in real-time applications. The RTOS includes a USB stack and NFS client.

Green Hills Software
Tel: +44(0) 1844 267950
www.ghs.com

Lead-free FPGAs

Actel is to offer environmentally-friendly lead-free packaging options for its ProASIC 500K, ProASIC Plus, eX and SX-A field-programmable gate array (FPGA) families by the end of 2002. There are also plans for lead-free packaging for its remaining antifuse- and flash-based FPGA product families by the end of 2003. The company defines an environmentally-friendly package as one free of lead, halogenated compounds and antimony oxides. According to the supplier, the majority of Japanese-based companies insist

that vendors comply with lead-free requirements. Environment-conscience initiatives in Europe and the US are gaining momentum as well, said the company.
Europe's Wastes from Electric and Electronic Equipment (WEEE) directive mandates the replacement of lead in electrical and electronic equipment by January 1, 2006, a deadline recently delayed by six months. While the US has no pending legislation to ban lead, the Computer Hazardous Waste Infrastructure program (CHIP), which promotes the recycling of electronic products, is currently under consideration.

Actel
Tel: +44(0) 1256 305600
www.actel.com

Controller connects to IP networks

Dallas Semiconductor has introduced the DS80C400, a networked microcontroller chip that integrates a high-speed 8051 core, a 10/100Mb Ethernet MAC, and silicon software TCP IPv4/v6 stack. It can be connected directly to IP networks. Operating at up to 75MHz, the DS80C400 provides ample speed to perform local control while also servicing network requests. In addition to the Ethernet MAC, the DS80C400 includes three synchronous/asynchronous serial ports that operate up to 18.75Mbit/s, a CAN2.0B controller, up to eight ports (64 I/Opins) and a 1-Wire master. Applications that require network connectivity such as MP3 audio players, web cameras, environmental controls, and industrial equipment can use the DS80C400's network interface for data collection, Visit our website www.distel.co.uk

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The **TELEBOX** is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors or AV equipment which are fitted with a composite video or SCART input. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers* (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. **TELEBOX MB** covers virtually all television frequencies VHF and UHF **including the HYPERBAND** as **used by most cable TV operators.** Ideal for **desktop computer video systems** & PIP (picture in picture) setups. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard. Brand new - fully guaranteed.

TELEBOX ST for composite video input type monitors	£36.95
TELEBOX STL as ST but fitted with integral speaker	£39.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification.
*For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

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2fi" to 3fi" conversion kit for Pc's, complete with connectors	£15.95
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8" **FUJITSU** M2392K 2 Gb SMD I/F RFE tested	£345.00

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PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with **both RGB** and **standard composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. **Integral audio power amp and speaker for all audio visual uses.** Will connect direct to **Amiga and Atari** BBC computers. Ideal for all **video monitoring / security** applications with **direct connection to most colour cameras.** High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed. Dimensions: W14" x H12fi" x 15fi" D. **Only £99.00** (D)

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INFODEC 1U, 24 port, RJ45 network patchpanels. #TH93	£49
3COM 16670 12 Port Ethernet hub - RJ45 connectors #LD97	£69
3COM 16671 24 Port Ethernet hub - RJ45 connectors	£89
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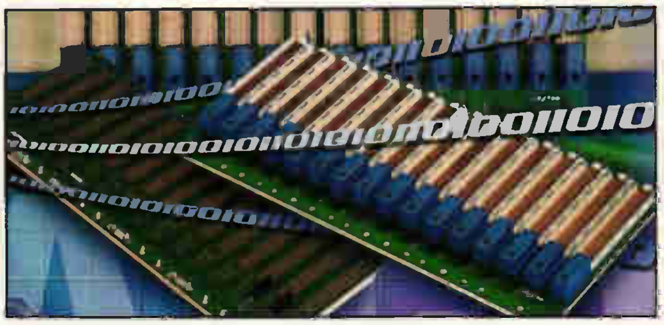
16-Slot backplanes for PICMG 3.1/2/3

APW Electronic Solutions has a prototype batch of 16-slot backplanes meeting the requirements of the latest AdvancedTCA (Telecommunications Computer Architecture) specification. ATCA 3.0 is the generic platform specification, defining the mechanics, board dimensions, power distribution and platform management requirements. It is fabric agnostic. The three fabrics for which specifications are in development are PICMG 3.1, 1Gbit/s Ethernet, 3.2, defining how Infiniband systems are built within the architecture and 3.3, defining a Starfabric implementation over the backplane providing TDM, cell, control and packet connectivity over the same fabric. In order to keep the thickness down and achieve the required electrical characteristics, they are manufactured from low dielectric (Er = 3.5) laminates and pre-preg instead of FR4; the backplanes are of 34 layer construction, 18 signal layers and 16 power/ground layers.



The initial prototypes are 5U high, 23in. wide and 6.9mm thick; production versions could be up to 8U high to include the Zone 3 rear I/O access area. A total of 3,200W can be distributed through the backplane.
APW
Tel: +44(0) 1489 774500
www.apw.com

Single chip RF transceiver

Philips is offering a single-chip RF transceiver for 2G and 2.5G mobile phones that supports up to quad-band, GSM/GPRS and full EDGE transmit/receive operations. The UAA3537 RF transceiver is designed to support dual-band and GSM to full EDGE handsets. It uses a near-zero intermediate frequency architecture for the receive channel, and a direct up-conversion architecture for the transmit channel. The intention has also been to eliminate the need for surface acoustic wave filters from the design, keeping external component count to an absolute minimum. Four integrated programmable LNAs (low noise amplifiers) in the receive channel enable designers to configure the phone for quad-band operation at 850MHz 900MHz, 1,800MHz and 1,900MHz or for dual-band or triple-band combinations of these frequencies. The UAA3537's low-noise, wide dynamic range, N-ZIF receiver has a gain control range of over 68dB, providing voice and data reception over a wide range of signal conditions. Its direct up-conversion transmitter achieves a noise performance of –163dBc/Hz at 20MHz offset, which is designed to eliminate the need for a SAW filter between the transceiver chip and the handset's RF power amplifier. The device operates over a voltage range of 2.4V to 3.0V, and is housed in a 6 x 6mm HVQFN package.
Philips
Tel: +31 40 272 2091
www.semiconductors.philips.com

Small relay switches 1.5GHz signals

Omron has introduced its smallest relay capable of switching 1.5GHz signals in mobile, wireless LAN, broadcasting and set-top box applications. With external dimensions of 20 x 9 x 8.6mm, the G6Z relay is 25 per cent smaller than the firm's current design and there are various device formats to suit applications in cable TV, broadcast studio, and set-top box applications, W-CDMA mobile basestations, ATE equipment, and wireless PABX/LAN installations alike, operating at between 1GHz and 2.6GHz. Insertion loss is only 0.2dB at 900MHz, rising to 0.5dB at 2.6GHz whilst VSWR is 1.2 and 1.5 respectively at these frequencies. Isolation is 65dB or 30dB, again at the same frequencies, whilst the relay can transmit up to 10W. It is available in both 50Ω and 75Ω variants, with E-type and Y-type PCB terminal layouts. Contact configuration can be specified in both normal and a, b reversed forms. The G6Z is available as either single-stable or 1.2 coil latching - with a very high sensitivity of only 360mW in the 2 coil latching types. The supplier has rated the relay for a mechanical life of one million operations, and an electrical life of at least 300,000 operations, under the specified operating conditions. The G6Z relay is available in both through hole and surface mounting form, and is manufactured using a lead-free process.
Omron
Tel: +44(0) 870 750 5661
www.omroncomponents.co.uk

Controller with 0.4µA LCD driver

EM Microelectronics has two microcontrollers with a built-in 4MUX LCD driver consuming 0.4µA and operating at 1.2V. These ROM mask microcontrollers are designed for controlling functions in battery-operated devices and lower cost applications, including toys, household appliances, sports timing devices, security devices and medical devices. These circuits include internal voltage regulators, so they have constant low-power consumption even in noisy environments. The devices consume 1.6µA in active mode and 0.4µA in the standby mode (LCD) off) and 0.2µA in sleep mode. They also include a melody generator that can be used for basic sound generation. The EM6625 drives 20 segments, three or four times multiplexed, while the EM6626 drives 32 segments, three or four times multiplexed. These microcontrollers have LCD frequencies of 32, 42.7 or 64Hz, allowing them to avoid interferences with harmonics in RF and communication applications.
EM Microelectronics
Tel: +44(0)041 32 755 5111
www.emmicroelectronics.com n

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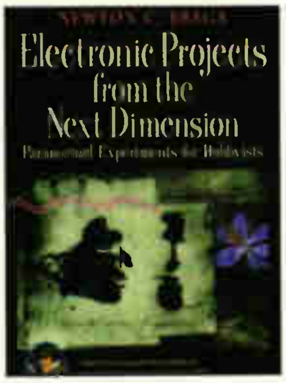

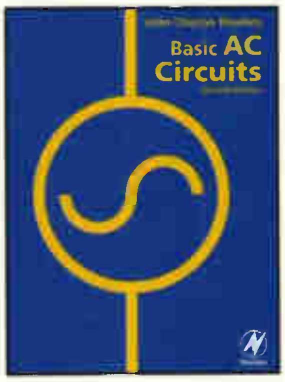

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Passive Components for Circuit Design is a unique introduction to this key area of analog electronics designed for technician engineers and anyone involved in circuit design. The coverage encompasses all component types capable of power amplification: resistors, capacitors, transformers, solenoids, motors and transducers. The behaviour of the components is explored along with the different types available and the principles of circuit design. Tolerances, stability, variation with temperature, reliability and manufacturing standards are all covered. Reading this book will improve your skills in component selection and analog circuit design. These are essential skills not only for the analog designer, but for all circuit designers, professional or amateur.

Contents: Preface; Fundamentals; Fixed resistors; Variable resistors, potentiometers and diodes; Capacitors; Inductors and inductive components; Inductive devices; Transducing components; SMT; Hardware; Index

Readership: Technician engineers, circuit designers, advanced hobbyists

Pages: 304pp

Price: UK £23.00
Europe £24.00
ROW £27.00

ELECTRONIC PROJECTS FROM THE NEXT DIMENSION

For years paranormal scientists have explored the detection and documentation of spirits, auras, ESP, hypnosis, and many more phenomena through electronics. Electronic Projects from the Next Dimension provides useful information on building practical circuits and projects, and applying the knowledge to unique experiments in the paranormal field. The author writes about dozens of inexpensive projects to help electronics hobbyists search for and document their own answers about instrumental transcommunication (ITC), the electronic voice phenomenon (EVP), and paranormal experiments involving ESP, auras, and Kirlian photography.

Although paranormal studies are considered esoteric, Electronic Projects from the Next Dimension teaches the technical skills needed to make devices that can be used in many different kinds of experiments. Each section indicates how the circuit can be used in paranormal experiments with suggestions about procedures and how to analyze the results.

Contents: White noise generators for use in instrumental transcommunication (ITC) and electronic voice phenomenon (EVP) experiments; Practical circuits for image experimentation, such as a wireless sparkling image generator, horizontal bar generator, brontophic sound, magnetic field generator, high-voltage generators (Kirlian Machine's I & II); Paranormal skills experiments with temperature change, polygraph, electro-shock, random number generation, UFO detection, and ghost-finding.

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CIRCUITIDEAS

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Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly. Where software or files are available from us, please email Jackie Lowe with the circuit idea name as the subject.

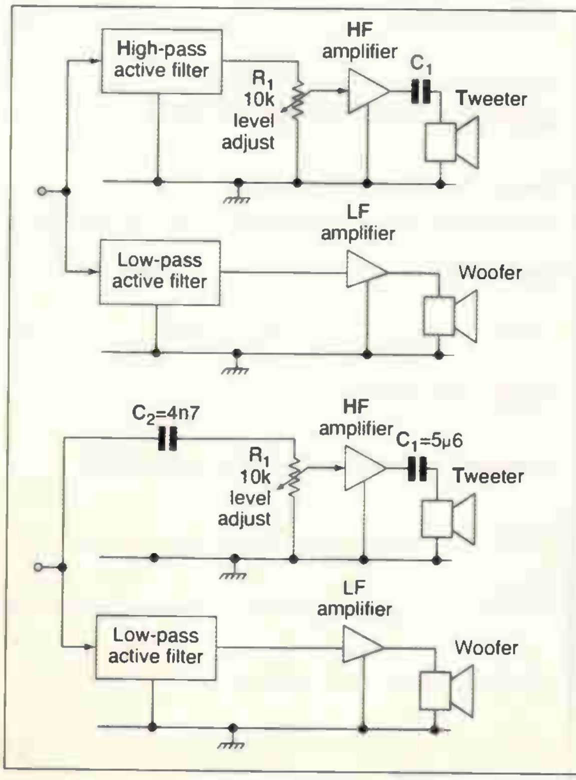
Send your ideas to: Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ *email j.lowe@highburybiz.com*

Cheaper crossover filter

I designed the filter shown for use with an electronic keyboard. The crossover design was a second-order active circuit based upon the principles of Linkwitz-Riley[1,2].

Crossover frequency is 3.5kHz. The tweeter was expensive and so the capacitor C_1 was needed to protect it in case of a fault in the tweeter amplifier. This needs to be a high quality part (polypropylene) so that sound quality is not affected.

To ensure, however, that C_1 does not contribute significant amplitude roll-off and phase shift – which would add to – those of the crossover high-pass filter) a very large value is required. I calculated that a minimum value of 30µF was needed, which is expensive.



Traditional active filter crossover, top, and a cheaper modified version with the same performance, bottom.

A better design, shown in the lower of the two diagrams, uses the capacitor C_1 to form one of the poles of the crossover high-pass filter response. The new value for C_1 is now 5.6µF so the component is much cheaper.

The other pole of the high-pass filter response was formed by a single capacitor (C_2) and R_1 on the input side of the tweeter amplifier.

The low-pass filter driving the bass unit remained as a conventional active filter using an op-amp. The capacitors in the low-pass filter and C_2 also need to be high quality types: polystyrene parts were used in the prototype.

The calculated phase and amplitude response of the crossover is unchanged. The overall component count was reduced and so construction was easier, with no loss of performance.

Peter Goodson
Bracknell
Berkshire

References

1. www.linkwitzlab.coin
2. www.rane.com/note107

Vision matrix 'return-to-n' circuit

Originally designed to be fitted to a vision matrix switch panel, this circuit will cause the matrix to return to a specific input after any other switch on the matrix is released.

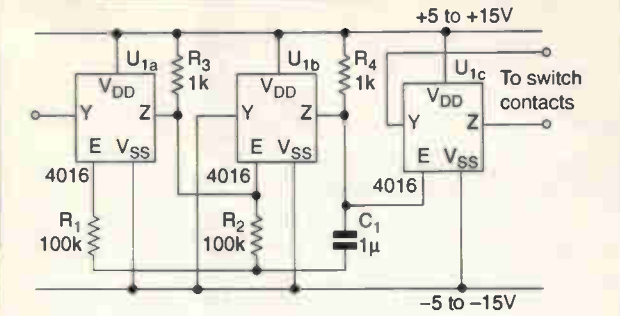
My requirement was for the circuit to be as simple as possible using the least number of extra components. The first two sections of the 4016 are configured as inverters. As such they can be made into a simple square wave generator in much the same way as two sections of a 4049.

The square wave, at about 20Hz or so, is used to control the third section of the 4016. This has its input and output pins connected across the switch contacts required to be returned to. In effect the switch is 'pushed' once every fraction of a second, enabling the particular matrix input.

Pushing any other switch will enable that input for as long as the switch is held down (provided the switch matrix has a key rollover function). When the switch is released the matrix returns to the preset input as soon as the square wave goes positive.

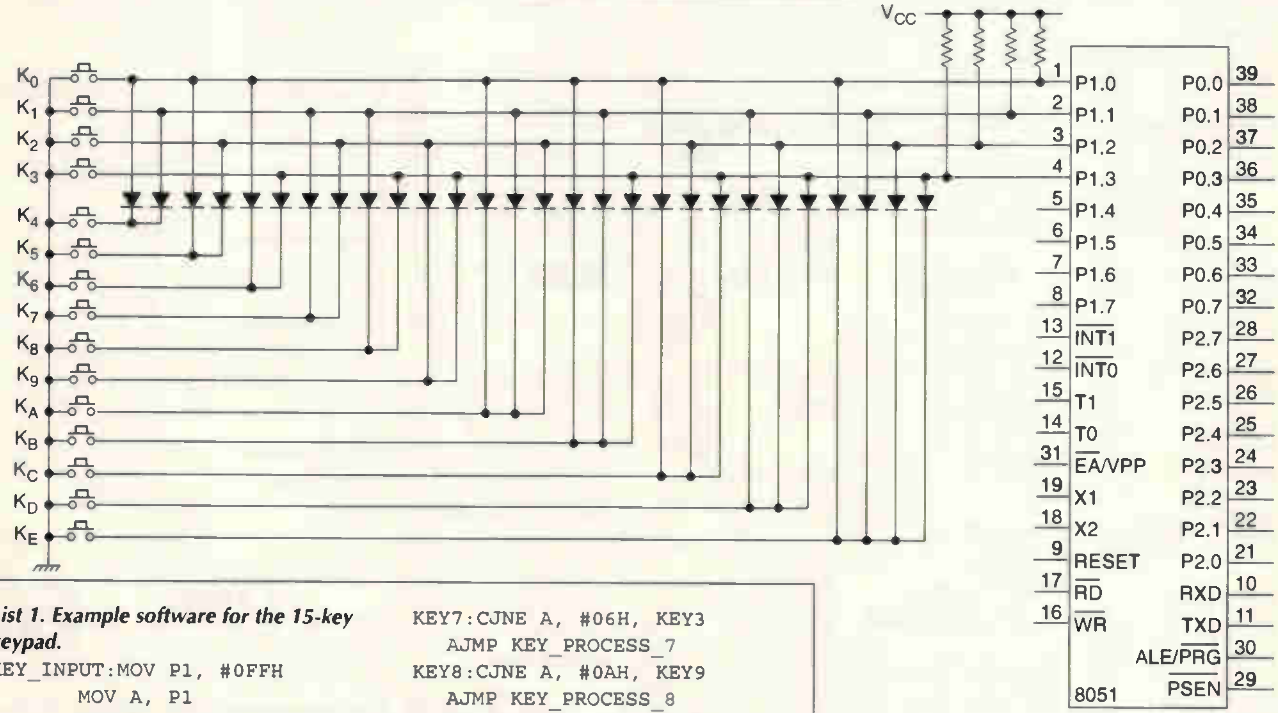
The circuit should work with either X-Y scanned keypads or with single switches to either power rails or ground but it does require a negative voltage rail to function correctly.

The square wave generator based on a 4016 can be used for other applications.



This circuit causes a vision matrix to return to a specific input after any other switch on the matrix is released.

Ian Berry
Berry Communications
Manchester



List 1. Example software for the 15-key keypad.

```
KEY_INPUT:MOV P1, #0FFH
       MOV A, P1
       CPL A
       ANL A, #0FH
   RET

   ACALL KEY_INPUT
   JNZ KEY0
   AJMP NONEKEY
KEY0:CJNE A, #01H,KEY1
   AJMP KEY_PROCESS_0
KEY1:CJNE A, #02H, KEY2
   AJMP KEY_PROCESS_1
KEY2:CJNE A, #04H, KEY3
   AJMP KEY_PROCESS_2
KEY3:CJNE A, #08H, KEY4
   AJMP KEY_PROCESS_3
KEY4:CJNE A, #03H, KEYS
   AJMP KEY_PROCESS_4
KEY5:CJNE A, #05H, KEY6
   AJMP KEY_PROCESS_5
KEY6:CJNE A, #09H, KEY7
   AJMP KEY_PROCESS_6
KEY7:CJNE A, #06H, KEY3
   AJMP KEY_PROCESS_7
KEY8:CJNE A, #0AH, KEY9
   AJMP KEY_PROCESS_8
KEY9:CJNE A, #0CH, KEYA
   AJMP KEY_PROCESS_9
KEYA:CJNE A, #07H,KEYB
   AJMP KEY_PROCESS_A
KEYB:CJNE A, #0BH, KEYC
   AJMP KEY_PROCESS_B
KEYC:CJNE A, #0DH, KEYD
   AJMP KEY_PROCESS_C
KEYD:CJNE A, #0EH, KEYE
   AJMP KEY_PROCESS_D
KEYE:CJNE A, #0FH, LP
   AJMP KEY_PROCESS_E
NONEKEY:AJMP RTUN

KEY_PROCESS_1:...
   RET
KEY_PROCESS_2:...
   RET
...
KEY_PROCESS_E:...
   RET
```

15-key keypad uses only four I/O lines

In microcontroller-based applications, it is often useful to be able to save I/O lines. This circuit allows you to implement a 15-key keypad using just four lines. Depression of the first four keys is detected directly. If key K_4 is pressed, the software detects this by checking whether the lines going to K_0 and K_1 are both low.

You can easily extend this idea for a 31 or 63-key keyboard.

Deng Yong
Shanghai Jiao Tong University
Shanghai
China

Want to win it? Simply send us the answer to the question, "across how many carriers is the signal spread in each ensemble?" on a postcard together with your name and address and your entry will go into the hat. Address the postcard to Electronics World, Highbury Business Communications, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ. Please read the competition rules first though.

This competition is sponsored by **Modular Technology Ltd.,** the makers of the DAB PCI card. More information can be found on the product in Roger Thomas' review on page 12 of this issue and also Modular's web site at www.modulartech.com.

Win DAB digital radio

Competition rules

No purchase is necessary. Strictly one entry per household. Competition closing date 12th April 2003. No entries will be accepted after that date. The draw will take place within the next working week following the 12th April and the winner will be announced as soon as possible thereafter. The prize is not negotiable. No correspondence will entered into regarding this competition. No employee of Highbury Business Communications or Modular Technology Ltd. may enter the competition.

What is DAB

Until now, analogue radio signals such as FM or MW have been subject to numerous kinds of interference on their way from the transmitter to your radio. These problems were caused by mountains, high-rise buildings and weather conditions. DAB, however, uses these effects as reflectors creating multipath reception conditions to optimise receiver sensitivity. Since DAB always selects the strongest regional transmitter automatically, you'll always be at the focal point of incoming radio signals. The DAB system was developed by the Eureka 147 Project.

How do I get it?

DAB is broadcast on terrestrial networks, and you are able to receive it using solely a tiny non-directional stub antenna. You receive CD-like quality radio programmes even in the car without any annoying interference and signal distortion.

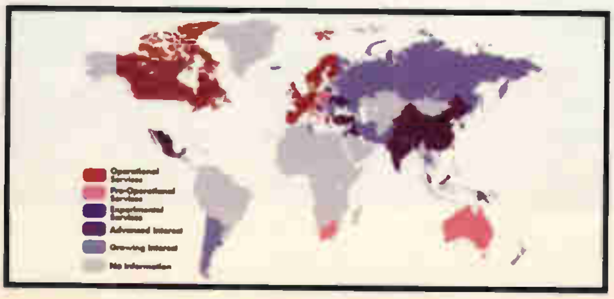
Aside from distortion-free reception and CD Quality sound, DAB offers further advantages as it has been designed for the multimedia age. DAB can carry not only audio, but also text, pictures, data and even videos - all on your radio!

You are able to listen to your favourite music programme and sing along with your idols, since the lyrics can be shown on your radio display, or you can contemplate the handsome face of the latest movie star, while a report is given on his current box-office hit.

Can I get it?

Over 285 million people around the world can now receive more than 585 different DAB services. Commercial DAB receivers have now been on the market since summer 1998. Furthermore, as well as all European countries, other non-European countries including Canada, Singapore, Taiwan and Australia have launched operational or pilot services. Countries like China and India have begun experimental services and Mexico and Paraguay among other countries have expressed their advanced interest in DAB.

DAB is available in the following countries: Australia, Austria, Belgium, Brunei, Canada, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hong Kong, Hungary, India, Ireland, Israel, Italy, Japan, Lithuania, Malaysia, Mexico, Namibia, Netherlands, Norway, Poland, Portugal, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Turkey, United Kingdom, USA.



Modular Technology DAB PCI card features

The Modular Technology DAB digital radio card fits into a PCI slot in a PC's mother board and the supplied driver works with Windows-98, Me, 2000 & XP.

The user interface provides full programme information on screen, displays text associated with programmes, allows recording at the click of a mouse, and gives users the ability to schedule recordings ahead of time from programme lists. Recordings can be stored as MPEG-2 files, or in MP3 format for high quality sound downloads to MP3 players.

Features include:

- Automatic service and programme seeking
- High quality distortion free reception
- Text displayed with programmes
- Recording at the click of a mouse

Apart from just listening to the radio, here are some other things you can do with the Modular Technology DAB PCI card...

- Look at the schedule for every station for the week ahead and select any programmes to be recorded (broadcaster's EPG permitting).
- E-mail a programme presenter at the click of a mouse.
- Download recorded programmes to most portable MP3 players for 'listening on the move'.
- Easily link to the web site of the station you're listening to.
- Show all radio stations broadcasting a particular genre e.g. Sport, News etc.
- Playback high quality recordings made on the PC.
- Set your PC's clock from the accurate signal broadcast as part of the DAB transmission.
- DAB is received through an antenna, it needs no connection to the internet.
- DAB is FREE just like AM/FM radio – there are no subscriptions or sign-ups

DAB content (music speech etc) is usually augmented by the broadcaster to include text information. This allows a receiver for example to display the current track and artists' name, or the presenter's e-mail address etc.

Minimum PC specification

Pentium-200MMX, 64Mb RAM, Spare PCI slot, antenna connection

Modular Technology Ltd designs manufactures and distributes Communications, Audio, Video and entertainment products, most of them for use with Personal Computers; selling through major retailers and OEMs in the UK and North America. Products are sold under the Modular Technology brand or in OEM livery as required. The company has extensive experience of selling Television and Radio products for PCs and their new DAB digital radio card gives users a glimpse of what they can expect from radio receivers in the future.

A Frequency Synthesizer for the VHF FM Band

The origin of this project was the desire to build a VHF FM direct conversion receiver as a follow up to the direct conversion receiver we built for the AM medium wave band (Slifkin and Dori, Synchrodyne and Homodyne Receiver, Electronics World, November 1998). Michael Slifkin and Shai Ben-Naeh take us through the practicalities.

The first stage was the construction of a keyboard controlled frequency synthesizer covering the range 88 to 108MHz with a channel spacing of 100kHz. This synthesizer should in no way be confused with the VHF DSP receiver we described more recently (Slifkin, Mayan and Globinsky, VHF receiver in DSP Electronics World, October 1999) which relies on completely different principles. We have yet to complete the whole project but feel that the synthesizer is a worthy project in its own right.

Originally, frequency synthesizers were derived from a low frequency crystal oscillator by using multipliers. These were resonant circuits tuned to a low harmonic of the input frequency. Radio amateurs found these particularly useful as the amateur radio frequencies in the past were 3.5, 7, 14, 21, and 28MHz. So, from that one crystal oscillator, they could access all the higher amateur radio bands. However, with the appearance of IC phase lock loops, these have more or less fallen into disuse. We have discussed the phase lock loop (pll) several times in our earlier articles. However for new readers we will give again a brief description. **Figure 1** shows a block diagram of the pll.

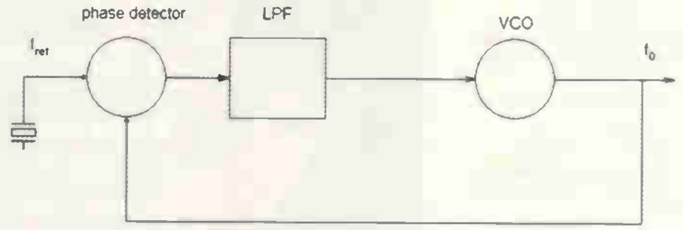


Figure 1: Phase lock loop (pll)

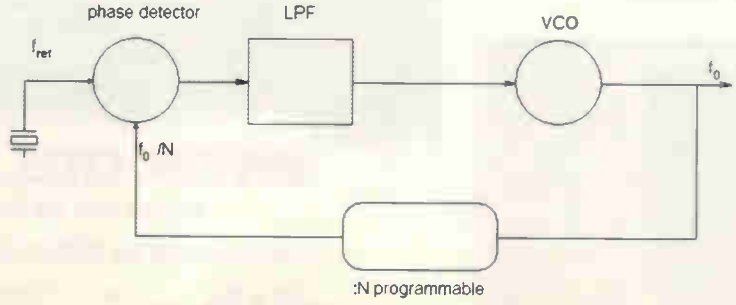


Figure 2: Simple frequency synthesizer

The reference signal is phase compared with the signal coming from the voltage-controlled oscillator. If there is any difference between the two signals, then the phase detector has an output proportional to the difference, this is sent to the VCO in such a manner as to bring the two frequencies together. After a brief interval, the two signals will be locked in frequency, albeit 90° out of phase with each other. The same device can be used as a simple frequency synthesizer as shown in **Figure 2.**

By putting an N divider, i.e. a digital device between the VCO and the phase detector, a frequency N times that of the reference signal is produced. We can get even more versatility by putting a divider after the reference signal and before the phase detector. In general this is not done as we can start from a very low reference signal. The advantages of these pll techniques are severalfold. The use of digital dividers is far simpler and far more accurate than using tuned multiplier circuits which are difficult to tune and to keep at the exact frequency. Furthermore, we can use programmable dividers operating from a microprocessor and hence use a keyboard to input the frequencies and a display to see what has been inputted

Nowadays a technique called "dual modulus prescaling" or sometimes "pulse swallowing", which allows one to use regular TTL components in spite of the high frequencies generated, is regularly employed.

First steps

Before presenting the circuit diagrams we will explain the dual modulus technique. The first step in implementing this system is the use of a high frequency prescaler. This can operate at a very high frequency and is used to divide down to a lower frequency suitable for CMOS and TTL components. The block diagram is shown in **Figure 3.** M is the programmable counter and A is the Modulus Control Counter. P is the Dual Modulus Prescaler. The prescaler can divide by n or n+1 under program control The counter A gives the number of times we need to use the n + 1 divider, whilst counter M gives the total number of divisions. This is made clearer in **Table 1.**

The total divide factor N is given by N = (P x M) + A. Different values of n for the prescaler are available in the range 5/6 to 128/129 from different manufacturers

With the proviso that $2 \leq P$, $2 \leq M$, and $0 \leq A \leq P$, $A \leq M$ and P can be n or n + 1. If one plays around with the numbers one finds that not all divisors are possible with a fixed value of n but having the ability to use n +1 in addition enables more frequencies to be accessed. This is illustrated in Table 1 where we show some of the values in the counters and the final frequencies.

The 88.0MHz frequency is obtained by simply multiplying the 100kHz reference by 20 forty-four times.

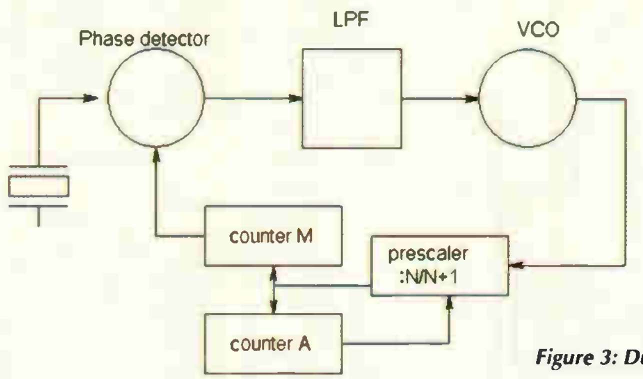


Figure 3: Dual Modulus Synthesizer

Similarly 100kHz x 45 x 20 gives the 90MHz frequency. With a fixed n in the prescaler we can only get multiples of 200kHz from our 100kHz frequency. We obtain the 88.9MHz frequency by multiplying the 100kHz reference signal by 20, 35 times and by 21, nine times.

20 x 35 + 21 x 9 = 889 giving a frequency of 88.9MHz.

Similarly the 90.6MHz frequency is obtained by multiplying (39 x 20) + (6 x 21) = 906

The counter A gives the number of times we need to use the n + 1 divider, whilst counter M gives the total number of divisions.

Commercial prescalers can be single, dual and even triple. Some also allow us to use 2n and 2n + 1 as the dividers.

Among the reasons given in the application sheet by Elanix for using this system are:

- A higher reference frequency can be used for the loop.
- Filtering of the VCO control voltage is easier.
- The lockup time is faster.
- There is less noise at the output.

The reference frequency sidebands are further away from the main output frequency. The use of the prescaler, which can operate at very high frequencies, enables us to bring down the frequencies to the range in which the counters can operate.

Synthesizer implementation

Most of the ICs used could be replaced by a much smaller number of more complex devices but we like to build up such systems from fairly simple TTL and other simple ICs to more fully understand how they operate. The complete circuit diagram is shown in **Figure 4.**

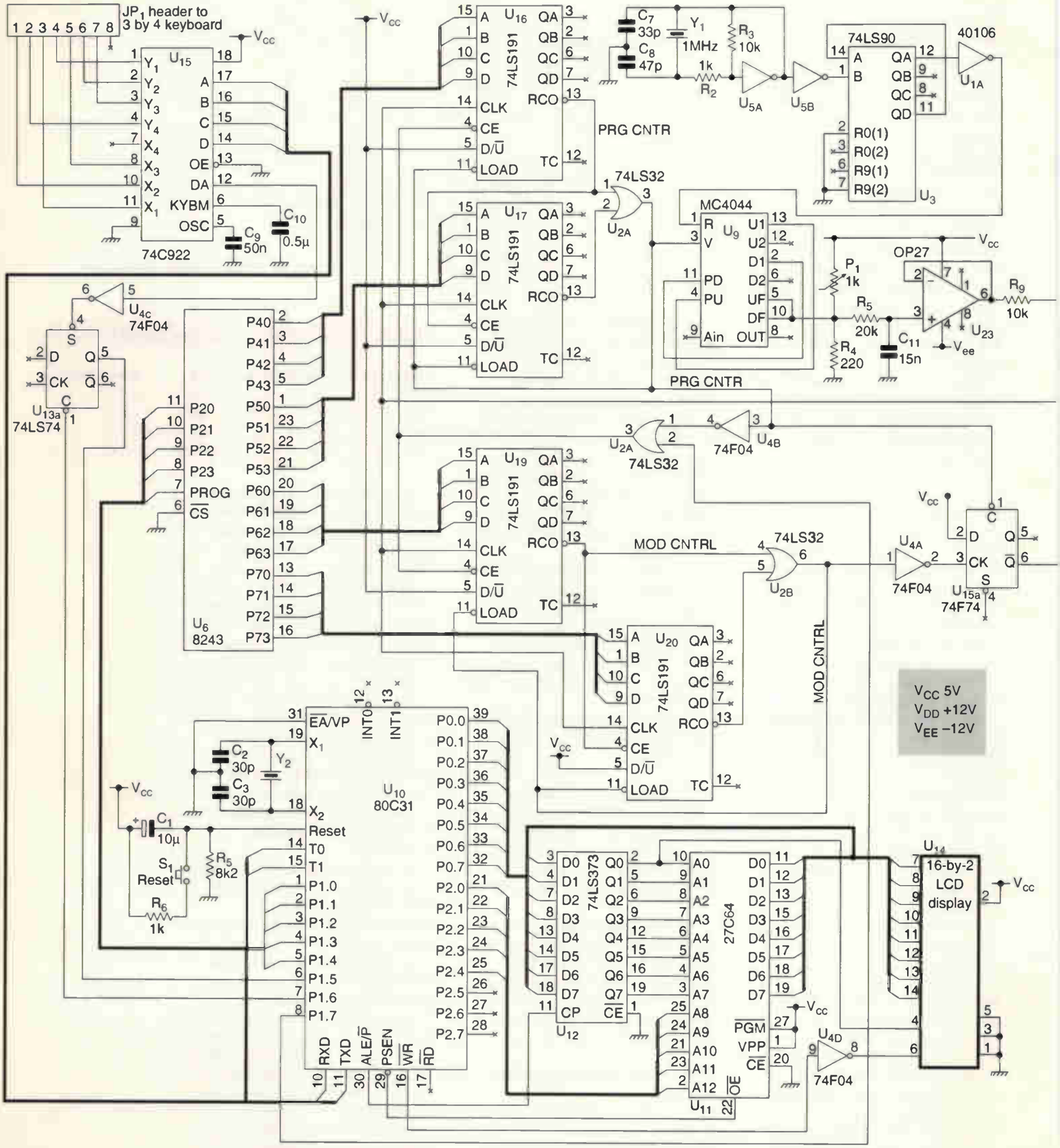
Table 1. Prescaler divides by 20/21

Counter M	Counter A	N	Freq. (MHz)
44	0	880	88.0
44	9	889	88.9
45	0	900	90.0
45	6	906	90.6

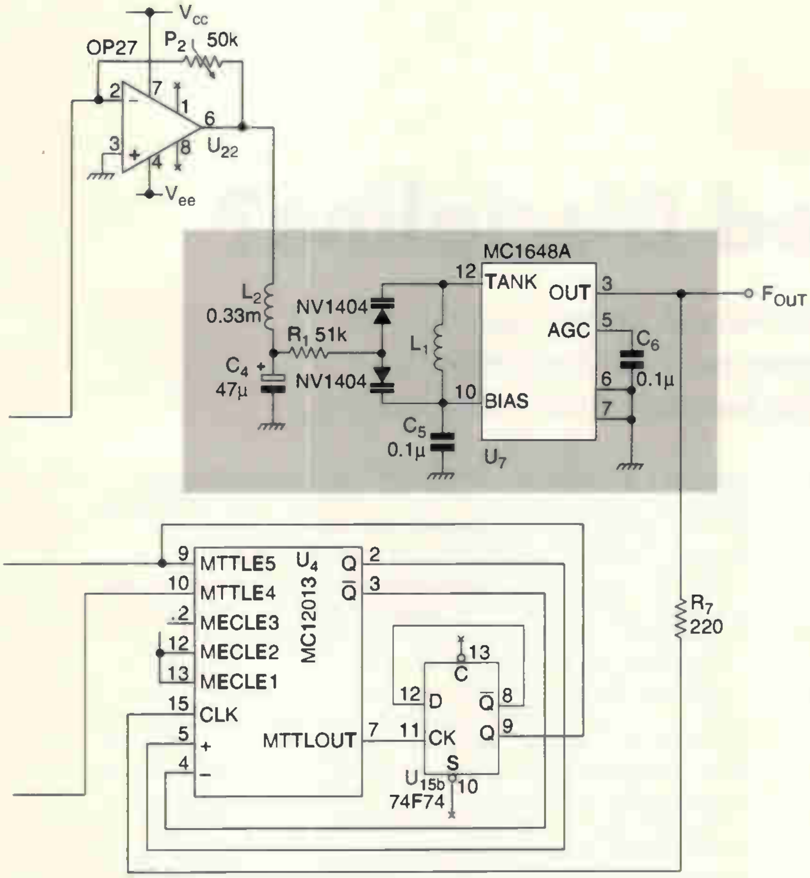
U1, 3 and 5 make up the crystal oscillator that is our standard. We actually used a 1MHz crystal and divided down by 10 to give the 100kHz standard frequency. We could say that the use of a crystal followed by a divider is to increase the versatility of the system, which of course it does. However the most compelling reason is that 1MHz crystals are very easily obtained.

The 80C31 microprocessor is an 8-bit device that has been around for quite a while and is an industry standard. It has on board 4 Kbyte ROM/EPROM and 8 x 128 bit RAM. The microprocessor has its own 12MHz crystal clock, separate from the frequency source of the synthesizer.

We had to assemble our own pll, as the commercially available single chips are not suitable for our purposes. U18 to U20 are the counter section of the pll, with U17 and 18 being the M program counter and U19 and 20 being the A modulus control. The phase detector is component U9. U15, U13 and U 4 are the keyboard section. U8 is the dual modulus prescaler giving a divide of 10/11 or 20/21. U15 is the MM54922 16-key encoder that provides all the necessary logic to encode the keyboard. U7 is the VCO. The two Varicaps (variable capacitor diodes) control the frequency. The DC error voltage coming from the phase detector controls the capacitance of these diodes and hence the frequency



JP1 header to 3 by 4 keyboard
Vcc
U15
74C922
KYBM
OSC
C9 50n
C10 0.5μ
U4C 74F04
U13a 74LS74
U6 8243
PROG
CS
U16 74LS191
U17 74LS191
U19 74LS191
U20 74LS191
CLK
CE
D/U
LOAD
RCO
TC
PRG CNTR
C7 33p
C8 47p
Y1 1MHz
R3 10k
1k R2
U5A
U5B
74LS90
R0(1)
R0(2)
R9(1)
R9(2)
U3
40106
U1A
74LS32
U2A
MC4044
U9
PD
PU
UF
DF
Ain
OUT
P1 1k
OP27
R5 20k
R4 220
C11 15n
R9 10k
U23
Vee
Vcc
PRG CNTR
U4B 74F04
U2A 74LS32
MOD CNTRL
74LS32
U2B
U4A 74F04
U15a 74F74
MOD CNTRL
VCC 5V
VDD +12V
VEE −12V
EA/VP
INT0
INT1
U10 80C31
Reset
C2 30p
Y2
C3 30p
C1 10μ
S1 Reset
R5 8k2
R6 1k
RXD
TXD
ALE/P
PSEN
WR
RD
74LS373
U12
CP
27C64
U11
PGM
VPP
CE
OE
U14 16-by-2 LCD display
U4D 74F04



of the VCO. U10 to U14 are the display section. The display U14 is the generic 16 x 2 dot matrix. Any 16 x 2 display using the Hitachi HD44780 driver or equivalent can be used.

We use the 80C31 microprocessor to control the display. Whilst this isn't strictly necessary, it is easier to implement than using TTL and the microprocessor is already available on the board. We enhance the use of the microprocessor with U5, the input/output expander 8243, that provides a cheap and useful interface between the microprocessor and the rest of the circuit. U11 is a 64 Kbyte EPROM into which the program is stored. The most important part is the program. Without it we merely have a number of dumb ICs connected together.

The source code is written in ASEM 51 8031 Assembler language and can be obtained from Electronics World. This is annotated and should be clearly understandable. The object code is given here. The program controls the LCD display, which shows the following messages at appropriate times.

- Frequency Synthesizer Press # to Start
- Frequency Range 88-108MHz.
- Enter Frequency in Four Digits
- ERROR in data entry, try again
- Now generating
- Job terminated
- or –Press * to stop

The microprocessor program also changes data to the correct binary codes. It checks validity of inputted numbers and outputs the numbers to the counters. The hardware can be used for a much wider range of frequencies simply by changing the program. This is the major advantage of digital equipment that once the hardware is built its function can be made very versatile by changing the programming. One can also convert this synthesizer to a much higher accuracy by dividing down the primary frequency to 10kHz or even 1kHz.

For those wishing to use such a device for an superheterodyne FM receiver one would need to offset the frequencies by the usual 10.7MHz (or some other unusual IF), which is very easily done in software. ■

List of Integrated Circuits

U1	40106
U2	74LS32
U3	74LS90
U4	74F04
U5	4049
U6	8243
U7	MC1648A
U8	MC12013
U9	MC4044
U10	80C31
U11	77C64
U12	74LS373
U13	74LS74
U14	DisplayMO16L*
U15	MM74C922
U16	74F74
U17,18,19,20	74LS191
U21	74LS32
U22,23	OP27

*Please note that any 16 x 2 display using the Hitachi HD44780 driver or equivalent can be used.

EMC

A Fatally Flawed Discipline?

His attendance at an IEE Open Discussion Forum on the teaching of electromagnetics in undergraduate courses on 12th December last year encouraged him to confront the EMC incubus. Ivor Catt explains.

I have been very concerned about the EMC community since 1964, when I first ran into it in Los Angeles whist designing a power supply for a torpedo-proof line printer for the US Navy in Data Products Corporation.

I became extremely concerned when in Europe it became a criminal offence to fail to take a piece of equipment through their ridiculous EMC tests. Of all the subcultures in electronic engineering, EMC is the worst.

There is a strong rumour that during the Falklands War, the British warship HMS Sheffield had to switch off its radar looking for incoming missiles in order to resume radio communication. This is why it did not see incoming Exocet missiles, and you know the rest. How was it that after decades of pouring money into the EMC community, this could happen? Do the EMC community agree that they should shoulder the blame? Of course not. This is because that community has gone into limbo, sucking in money but evading the real problems, like watching for missiles while you talk to HQ.

While visiting the EMC magicians in the Ford Motor Company, I found that it was illegal to have a car radio that inadvertently affected an overtaking car's electronically controlled brakes. However, the EMC community is totally indifferent if, whist switching on your car's starter motor, you cause a passing motorist's brakes to lock suddenly.

My experience in England started with NWS3, a British copy of US test specs. It is fatally flawed at the fundamental theoretical level. These flaws remained during further decades because of the lack of grasp of the fundamentals of electromagnetism by the whole EMC community.

Los Angeles

I first came across the EMC community as a design engineer for the Data Products Corporation based in Los Angeles, in 1964[1]. My family, our furniture and I were shipped to Los Angeles by the Ampex Corporation and I was fired seven months later and hired on the following Monday by the Ampex spinoff company Data Products Corporation down the road for 50% more salary.

At Data Products, I was put to design a power supply for a torpedo-proof line printer for use on board ship in the US Navy[2]. (As luck would have it, the evening lecturer at the 12th December meeting shipped over by the IEE from the USA came from the US Navy EMC community.) We had to meet EMC requirements, so we hired an EMC magician for six months from the company whose name I remember as Geniston. He came and sat in our offices. Immediately I went to him and asked him about the EMC criteria he relied on. He would not give me any technical information. He said that I should just carry on designing and building the prototype as before. After it was completed he would add a few grilles and things.

We did as he suggested, and on completion we sent it for EMC testing to a test company - Geniston. We were correct to choose Geniston, because this ensured that it would pass. I was mystified by all of this until I heard rumours that Navy Admirals had large holdings of stock in Geniston. Then it all made sense.

The EMC regulations prescribed that electric power drawn by the line printer must not vary at a greater rate than 3Hz. This meant that if the line printer suddenly had to print a whole row of 200 'A's:

AAAAAAAAAAAAAAAAAAAAAAAA

(requiring 720 amps) the amount of power demanded down the mains cable from somewhere else on the ship must not increase in a detectable way, at a greater rate than that indicated by the figure of 3Hz. This was because in principle the EMC test magicians would put a current probe around one of the wires, live or neutral, bringing in power. The idea was obviously that there might be a Russian spy with a current probe on the US Navy ship, and he might be able to detect whether the line printer was printing information. We all know that increased communication would indicate that the US was about to attack his brother on a nearby Russian ship. The machine sounded like a machine gun, but obviously all Russian spies were deaf, or at least all those who served in the US Navy, so the audio pandemonium was not a matter of concern for our freedom-loving democracy.

My solution to the "problem" was to take in constant power and build a shunt regulating power supply instead of the normal series regulating power supply. That is, whenever the line printer was not printing at maximum rate, I would divert all the unused power into an electric fire. This design was much admired for its novelty, and the prototype worked fine. It was appreciated most on cold mornings.

Our line printer was the most advanced and sophisticated. Each of the 120 hammers had a row of one inch square coils attached to them through which a 6 amp current would be delivered for 2msec. Thus, printing a row of 'A's meant a 6 amp sudden pulse (perhaps with a rise time of one microsecond) flowing in each of the 120 coils for 2 milliseconds. The number of turns in each coil is now unknown (although my notes do indicate 3mH), but my records tell me the rest. The DC resistance of the coil was 10 ohms, which indicates that the number of turns was large, as it would be. When EMC testing, Geniston would bring up the most sensitive antenna to two feet from the end of this gigantic electromagnet, to try to detect electromagnetic (but to ignore sonic) activity. Their resident magician would then propose blocking metal grilles and the like to blind the antenna, but on no account would he get inside our line printer and discuss our circuits and layout, with a view to causing mutual cancellation of magnetic fields. It appears that this madness continues to this day, and EMC magicians continue to stay outside each of the possibly incompatible boxes, brewing up their million pound Faraday cage test rooms and billions of nonsensical mathematical equations.

An example of some Faraday cage nonsense is when (more recently) I was an electronic engineer at GEC Chaucer House, Portsmouth, but not at the time an EMC magician. The bright young thing designated Portsmouth Tigerfish Torpedo EMC guru talked about buying a screen room (Faraday Cage). He said it should be 100dB. It was interesting that the naïve, long term defence electronics designer sitting behind me argued with him that surely 60dB would suffice. I told him that this was ridiculous. The bright young thing's future career path required that he buy the £100,000 100dB cage. What the job needed had nothing to do with it.

Back at the line printer, the 720 amps into the hammer actuators was delivered by a gigantic resident 60v electrolytic in the line printer. At that time, electrolytics exploded at –60 degrees F. Naval requirements were that on board items must survive down to –65 degrees F. Obviously, the US navy operated in very cold waters. It was frustrating to know that the USAF only required that their equipment survive down to –50 degrees F. This problem (how to print the message that the sea was frozen solid) was not solved by the time I was fired.

More costs

EMC was not the only ruse to increase costs in the defence of freedom and democracy. The printer had to survive 200g. This test involved strapping the equipment to a 4,000 pound anvil, and then

The fatal flaws

How do I get to Killarney? – I wouldn't start from here.

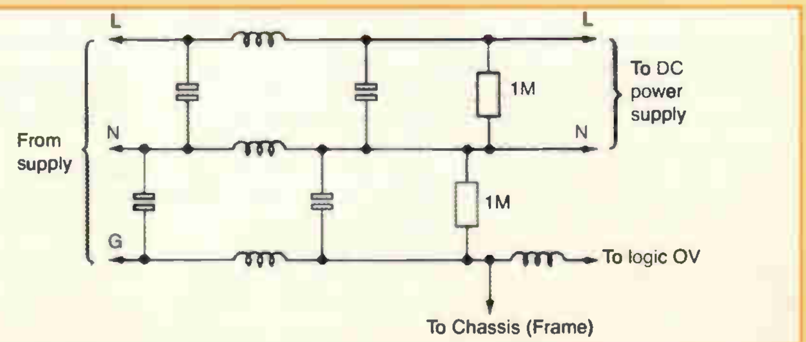
EMC will never escape from its origins – the stamping ground of ex RAF radio operators and the like. Later recruits are probably engineers who failed to cut the mustard as designers, or who were in any case in the surreal world of "defence" electronics. When a GEC or RCA product or similar failed to work properly, management would call in RFI "experts", who would do tests and write awesome reports (later on copied out from the Don White manual). Like Don White, they drew on the theory and practice in AM and then FM radio developed during the first half of the 20th century when the number of transmitters increased and they began to interfere with each other. To understand the EMC magicians of 50 years later, it is useful to see them as dinosaurs stuck in the age of radio and radio interference, decades before the arrival of digital systems.

In the IEE discussion on the teaching of electromagnetics on 12th December 2002, all the thirty attendees sounded technically naïve when they began to talk about personal computers. However, they demonstrate fatal flaws in their attitude, which would remain a problem even if digital systems did not exist.

The EMC specifications discuss conducted interference and radiated interference. Thus, the whole EMC community is committed to the idea that interference is of two types; conducted interference which travels down one wire and radiated interference which travels down no wires. This immediately confronts Kirchhoff's Laws, which insist that conducted interference travels down two wires; the signal wire and the return wire. This brings us to the second, strange weakness in the whole EMC game. They assume that two interfering units will both be electrically connected to "ground", which in their test rigs is a large plate of copper. As I moved further into high speed logic, my approach was to electrically float units in order to reduce mutual interference. Put crudely, when the length of the module is less than the wavelength of concern, grounding helps, but if it is longer, grounding hinders. (This was echoed when the discussion on the 12th dwelt on new problems arising at above 1GHz – wavelength one foot.) Thus, the very process of coming within the EMC specifications bans a potent way of minimising electromagnetic interference! In my case, I went so far as to design a revolutionary mains filter which, although safe and within British safety regulations for being DC earthed, floated at high frequency. The simple stratagem was to insert a choke in the earth line which had a DC resistance of less than half an ohm, and similar impedance at 50Hz. The mains filter was an open circuit between earth and the unit at anything much above 50Hz[4]. The filter came to market at about that time. The ideas built into that filter are crucial for limiting interference, but cannot be communicated to the EMC community or their testing standards, since both exist within a cloud of bizarre mathematics and prejudice, and would probably not understand my idea. They limit themselves to a low frequency worldview where tying something to ground reduces interference and radiation. The worst comes by attaching two already interconnected units to ground, which increases the pickup of interference, even at lower frequencies, by creating a square loop antenna.

Another fundamental flaw is the assumption that if the emission from one unit is less than the susceptibility of another unit at every frequency, taken one at a time, then there will remain immunity when a number of frequencies are emitted from one and received by the other at the same time. This assumption is implicit in the fact that EMC wallahs sweep through frequencies one at a time. This is true if a radio transmitter and a receiver tuned to another frequency are involved. However, if the susceptible unit contains digital electronics, it is not true. Here we see confirmation of the EMC community's ignorance of digital electronics, which means their ignorance of more than 95% of all of today's electronic equipment.

Another fundamental flaw in the EMC wallah's thinking and therefore testing standards is their resort to averages. In the lectures last December, I heard that their aim was to estimate the peak emission of unwanted interference on the basis of measured emission. The implicit assumption was that any system, including digital, needed minimal average interference. They just do not know that if a digital system loses just one bit, the result should be assumed to be catastrophic. They cannot get away from their world, where a bit of interference of a voice over the radio is O.K. so long as it does not happen too often. The truth is that peak emission should be calculated, not measured with test equipment. Similarly, the susceptibility to interference should be calculated, not measured. This is the fundamental flaw in the approach of the whole EMC community, to test instead of doing what they have to do in order to be relevant. To be relevant, they must get involved in the design process; or else leave the whole problem to the existing design engineers. When a customer buys some equipment, he or his advisers should consult the design details, not the test results from an EMC test.



hitting the anvil with a 3,000 pound hammer which had been raised through one foot and then left to swing at the anvil like a pendulum. Presumably nervous designers would pray for a fly, or better still a wasp, to intervene. Interestingly, all the seamen aboard would have had their legs broken, but the printer would continue to print a message ("Torpedo attack" for example). The demonstration film, where I saw a nice piece of electronic equipment turn into an array of projectiles, was taken seriously by the freedom-loving Americans watching with me. They objected to my laughter, although I was only fired much later.

We have to realise that had the resident Geniston EMC magician ventured inside our equipment, or even entered into technical discussions with me, he would probably have been betrayed as part of "rent-a-crowd", similarly to the way Weinstock would rent a crowd of milkmen and the like for a weapons project to keep his roster of "electronic engineers" up to the two thirds contractual minimum. This minimum roster saved the government funded project from cancellation. In any case, at 100% of cost plus 14%, the more milkmen he hired as engineers, the more would be the GEC profits. Professor "stinking fish" Brown played his part in this when he betrayed the IEE, who were trying to establish a way to distinguish between an EE and a milkman. In both cases, the Official Secrets Act or the like would provide ample cover. Even at this late stage, this article is probably undermining the UK's defences, which are based on bluff and scam[3], the EMC community fits well into such a scene.

The EMC requirements meant that the little three foot long line printer turned into something looking very much like a tank, as can be seen in the Data Products equipment brochures of the time. Since the antenna used by EMC magicians to detect emitted noise was brought up to a standard distance from the edge of the device under test, one obvious recourse was to make the device bigger and so push the EMC detecting antenna away from the workings inside.

Stingray

Whenever a major scandal hit GEC, Weinstock would rename it Marconi, or vice versa. MPs were too dim to realise that all the weapons scandals involved the single company. In this article, GEC stands for GEC or Marconi.

The Stingray project was special. GEC operated a number of "defence" weapon "design" scams, and Stingray was by far the most surreal[3].

Davidson, Walton and Catt had made major breakthroughs in electromagnetic theory. We needed to find out how much of our breakthroughs were known in all the electromagnetism subcultures. Two of us were employed at GEC Borehamwood (Herts, UK) at the time, so Malcolm Davidson went upstairs to the microwave design department. He came back down to report that they were only plumbers. They knew nothing, and merely played with equations and connected together tubes to pipe around only one mode.

Later, the question arose as to whether the EMC community already knew any of our advances. So I stopped teaching remedial English and got a job as the top EMC magician on the Stingray torpedo project in Stanmore, Middlesex. As a magician myself, I would be able to find out what they knew. (For instance, I would be better placed to force them to tell me what their jargon meant.) I had to avoid the EMC experts in GEC Portsmouth, GEC Rochester, etc., until I had rumbled what some of their main buzz-words (e.g. lisn) meant and found out what books they relied on. After a few days I found out that their bible was the £400 Don White manual. However, no other EMC experts would lend me their copy, or let me see it. After about ten days, however, I met a man who sold EMC devices imported from Los Angeles to our weapons industry. He volunteered to lend me the EMC bible, which was one of his products, for two or three weeks. When I asked him why, he said that he had mixed loyalty. On the one hand he was happy take a 10p capacitor manufactured in Los Angeles, renamed an EMC capacitor, sold to him for £2 for him to mark up to £5 and then sell to GEC. On the other hand, he was also a taxpayer, and was appalled by the drain on the taxpayer. (At the time, "defence" took 6% of GDP.

It took me a day or two to find out that Don White and his EMC cardinals were technically ignorant. I wrote a document blowing the gaff on Don White, which I withheld. At that stage, I knew that the EMC community knew no electromagnetic theory, much as we had found for the plumbers called "microwave engineers". However, by now I preferred to sit in GEC at £11 per hour rather than sit at home for £0 per hour. I was justified, because the same British government was funding research into my inventions at Middlesex Polytechnic, Brunel University and RSRE Malvern. I was on the research management committees. Everyone else on these committees was so jealous of the fact that my inventions, not theirs, were being funded, that they were determined that anyone else on these projects would be salaried, but not me, the inventor. This was thus a double double-cross. I would sit at my GEC Stingray desk working on the Catt Spiral projects, which paperwork looked more or less the same as Stingray paperwork. I would be paid to do nothing on Stingray, and be paid nothing to work for the same government on Catt Spiral projects. An interesting moral dilemma occurred when I skipped out of "work" on Stingray to attend (unsalaried) a management conference on one of my government-funded projects at Brunel or Middlesex. Should I claim pay for those hours away from my desk at Stanmore?

To keep my £11 per hour going, I had to keep away from other EMC magicians on Stingray. However, after two or three weeks the Portsmouth EMC magician could no longer be held off by my excuses. So two days before his proposed visit, I sent him my report rubbishing his Don White bible. Realising the danger to himself, he cancelled, and I never saw him. In the "defence" industry, reality threatens everyone.

By then I knew that EMC magicians were ex-RAF airborne radio operators or the like, good sound troopers who knew little electromagnetic theory. The £400 Don White manual gave them project plans which they could copy into their own reports for the MoD. They could also copy technical sections into their reports. All this copying was the reason why nobody except EMC magicians must ever see the Don White bible.

While Principal Lecturer in West Herts College, I found out that it was an offence to have no functioning earth leakage detector in the fuse box for power entering a room occupied by students. However, the indispensable mains filters on each machine in my room full of computers put too much electric current into the earth line. I set out to find out who generated the regulation. After some months, I homed in on an engineer hiding in the back of the IEE. I told him that that was fine; students' lives had to be protected. All it meant was that throughout England, computer training would have to be done without using computers. I would make sure that everyone knew his involvement in making it illegal to use computers when teaching computers, and so saving students' lives. He then replied that the standard was only advisory. Given minimal support, I could do the same with these ridiculous EMC standards, which at present have criminal sanctions against those who breach them. Under pressure, no technocrat will accept accountability for their enforcement.

In the past, EMC, spawned in "defence", would only boost the parasitic activity called "defence", and help to waste a fraction of the GDP. However, the recent move, where it becomes a criminal offence for commercial industry to avoid their ridiculous, expensive standards and tests, makes them a more serious threat to us all. I need assistance to winkle out the technocrats responsible for the present standards, to require them to defend the test standards, and to be accountable for them. Such people probably do not exist. If they do, we must begin to destroy the credibility of such individuals and in the end make these ridiculous standards unviable in a criminal court, because a jury will refuse to convict. ■

References:

1 See my book "The Catt Concept" pub. Hart-Davis 1972 for insight into my time in the US.
2 I discuss it in my book "Computer Worship" pub. Pitman 1973
3 See http://www.electromagnetism.demon.co.uk/gamoe.htm for more information.
4 This is discussed in my out of print book "Digital Hardware Design", pub. Macmillan 1979, p83.

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Fourier Synthesis:

defeating the Gibbs Phenomenon

Every first year electronics student knows that you can construct a square wave from the sum of an infinite series of sine and cosine waves. Text books have reproduced these Fourier coefficients for the square wave for at least 180 years. Leslie Green reaches for his calculator.

Students are told that the partial sum of the infinite series becomes a better approximation as the number of terms is increased. It is only more advanced text books that dare mention the dreaded *Gibbs phenomenon*, and even then it is often brushed aside very rapidly.

Fig 1. The Fourier partial sum up to the 11th harmonic.

Fig 2. The Fourier partial sum up to the 111th harmonic.

Any squarewave formed from Fourier coefficients has about 9% overshoot. In this article a new method is presented to simply reduce this overshoot by a factor of x30 with minimal computational expenditure.

The Fourier Series

The Fourier series for a square wave can be written as:

$$v(t) = 0.5 + \frac{2}{\pi} \cdot \sum_{n=1,\,step\,2}^{\infty} \frac{\sin[n\omega t]}{n}$$

The reconstructed waveform is a square wave of unit amplitude, which starts from zero. It is noted that only odd harmonics are used to create the waveform and that the Fourier coefficient, F_n, of the nth harmonic is simply 1/n times the amplitude of the fundamental.

Although Fourier is credited with the concept, because of his 1822 book on the analytical theory of heat, it was actually Euler who first produced a harmonic series for a square wave some 50 years earlier.

The Gibbs Phenomenon

Mathematicians knew right from its inception that the reconstructed wave never converges to any discontinuity in the waveform. This was particularly highlighted by Lagrange around 1800[1], Wilbraham in 1848 and Gibbs in 1899.

Evidently when Professor J. Willard Gibbs made the observation, the world was more ready for it. Since then, the name Gibbs has been associated with all aspects of this phenomenon[2].

With modern computer software it is a trivial matter to reconstruct a square wave from any particular partial sum of the Fourier series.

In **Figure 1**, the partial sum up to the 11th harmonic has been used. For such a small number of harmonics, the 9% preshoot and overshoot could easily be attributed to insufficient terms used in the reconstruction.

In **Figure 2**, up to the 111th harmonic has been used. Notice that the time scale has been zoomed-in by a factor of x10 as well. The rise time is seen to decrease inversely with the number of harmonics used.

You can keep increasing the number of harmonics and zooming in on the timescale, but the situation will never get any better. The series does not converge to a good square edge.

The limiting values of the preshoot and overshoot are around 8.9%, which is hardly a good starting point for a synthesised square wave. What we have here is a waveform with preshoot, overshoot and ringing; this can hardly be cited as a standard of excellence for a time domain system.

Discontinuity and Truncation

Digital signal processing is now a mature subject and it is well known that a discontinuity in the time domain becomes a source of a large number of components in the frequency domain. More specifically, in the FFT, it is well known that it is vitally necessary to 'window' a series of time-related data points before doing the FFT, in order to minimise spectral leakage.

In **Figure 3** a single sinusoidal frequency has been sampled digitally. The result of doing an FFT on this is shown as the blue waveform. This is the reference waveform when no window function is used. If the data series is processed using a raised cosine window function before doing an FFT, the resulting FFT shown in red shows considerably less spread; this is the von Hann† window.

What we wanted was a single spectral line at the input frequency, and nothing else. All of the remaining signal is spectral leakage due to the discontinuity at the ends of the waveform. The discontinuity is due to the input series to the FFT not containing an integer number of cycles of the input waveform.

This FFT example has highlighted the point that a discontinuity in a time domain waveform translates to excess terms in the frequency domain. It would therefore seem sensible to consider windowing the Fourier series of a reconstructed wave that has temporal (time related) discontinuities.

The situation is this; we have an infinite series of terms of which we are only going to use some finite number. We are effectively truncating the infinite series with a rectangular window function. If, however, we reduced the series to zero more gradually, it is to be hoped that a smoother reconstructed waveform would be produced. This is a somewhat practical matter, because any time we encounter an infinite Fourier series, we are always going to end up using a finite partial series.

Windowing the Fourier Series

Windowing a Fourier series is similar to windowing a time-related data series, with two major exceptions:

- The time-related data series has to be reduced to zero at both ends of the series.
- The FFT which results from a windowed time series is usually expressed in decibels. Therefore the visible dynamic range is vastly greater than that seen on a time domain waveform.

Given that the von Hann (raised cosine) window is so successful on the FFT, it makes sense to try a cosine window on the Fourier series. And indeed such a filter does have a good reduction effect on the ringing, but at the expense of the risetime. In fact a whole range of these filters have been tried, going back to Fejér in 1900; each has its own benefits and computational costs[3].

Indeed the paper just cited apparently gives a resolution to the Gibbs problem in terms of Gegenbauer functions. (This may mean something to the more mathematically inclined reader, but personally I couldn't understand most of the mathematical sections. Nevertheless there is still a lot of useful non-mathematical introductory and background material in the paper.)

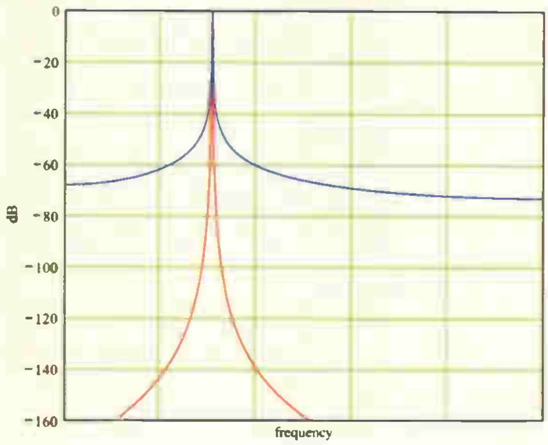

Fig 3. The FFT of a pure sinusoidal signal using a rectangular window (blue) and a von Hann window (red). Spectral leakage means that you do not get the single line that you might have expected.

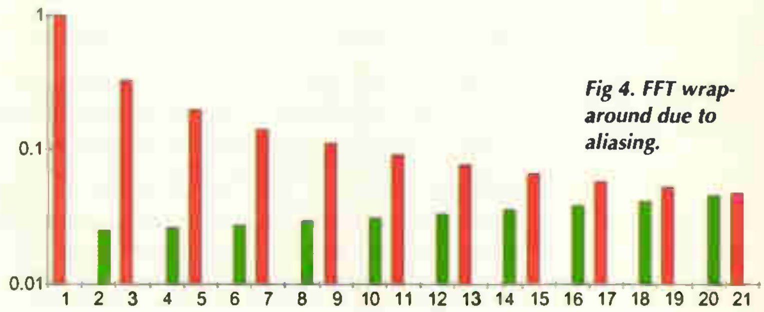

Fig 4. FFT wrap-around due to aliasing.

A Simpler Solution

What we expect is that we should be able to modify the Fourier magnitude coefficients to produce a better square wave. The phase should not need to be adjusted because of the rotational symmetry of the waveform about the t=0 point. In order to produce these new coefficients it is convenient to think about the frequency spectrum of a square wave.

When such a signal is viewed using an FFT, the slope of the envelope is from left to right until it 'hits' the right edge of the display. The spectral lines then get aliased back into the displayed range, with the slope of the envelope going in the opposite direction.

Figure 4 illustrates the situation. The red bars are reducing from left to right. The green bars are reducing from right to left; they also have a reversed phase. Note that the colour has been added only to highlight the envelopes. The data points would all be from the same FFT series.

In fact this construction forms an infinite series of slowly decaying aliases, with the phase reversing each time the harmonics reach the ends of the FFT.

Now if the square wave is synthesised, and the aliased harmonics are made to coincide with the non-aliased harmonics, then those reducing from right to left need to be subtracted, whilst those reducing right to left need to be

† This has been erroneously called a "Hanning window" for many decades, no doubt due to confusion with the Hamming window.

Table 1: The coefficients of the harmonics as they alias back into the frequency range. Notice how adjacent terms in the end columns cancel each other out.

Basic	$\frac{1}{1}$	$\frac{1}{3}$	$\frac{1}{5}$	…	$\frac{1}{n}$	…	$\frac{1}{H-2}$	$\frac{1}{H}$	$\frac{1}{H+2}$
Negative alias	$\frac{-1}{2H+3}$	$\frac{-1}{2H+1}$	$\frac{-1}{2H-1}$	…	$\frac{-1}{2H+4-n}$	…	$\frac{-1}{H+6}$	$\frac{-1}{H+4}$	$\frac{-1}{H+2}$
Positive alias	$\frac{1}{2H+3}$	$\frac{1}{2H+5}$	$\frac{1}{2H+7}$	…	$\frac{1}{2H+2+n}$	…	$\frac{1}{3H}$	$\frac{1}{3H+2}$	$\frac{1}{3H+4}$
Negative alias	$\frac{-1}{4H+5}$	$\frac{-1}{4H+3}$	$\frac{-1}{4H+1}$	…	$\frac{-1}{4H+6-n}$	…	$\frac{-1}{3H+8}$	$\frac{-1}{3H+6}$	$\frac{-1}{3H+4}$
Positive alias	$\frac{1}{4H+5}$	$\frac{1}{4H+7}$	$\frac{1}{4H+9}$	…	$\frac{1}{4H+4+n}$	…	$\frac{1}{5H+2}$	$\frac{1}{5H+4}$	$\frac{1}{5H+6}$

added. This is best evaluated by means of a table, as shown in Table 1.

Undoubtedly this table will at first seem daunting. It is actually very simple, however. Start from the top left and it is a simple progression of odd numbers underneath. Proceed to harmonic H and then 'bounce' back with a negative amplitude, due to the 180° phase shift. Notice that the last column on the right has been arranged so that the terms in adjacent row-pairs are equal but opposite. We want this last position to be zero, because we are only working up to harmonic number H; this last column represents H+2. We now head right to left on the second row, sticking to the odd numbers again. To get the first column value, we notice that for a row that starts with 1 and ends in H the difference is H-1. This enables the table to be built up slowly, but simply.

This Mathcad worksheet shows the workings with nothing hidden. Notice that there is no ringing due to the Gibbs phenomenon in this case, because the sampling rate is too low; the ringing is aliassed. Also notice that the time axis has been shifted by half a point in order to eliminate the dot in the middle of the edge.

Comparing The Overshoot Against the Fourier Coefficients

$H := 51$ $\quad t := -2, -1 .. 6$ $\quad \omega := \frac{2\cdot\pi}{H}$ $\quad n := 1, 3 .. H$ odd values only

$K := \frac{\pi^2}{11.2\cdot(H-1.06)^2}$ $\quad G_n := \frac{1}{n} - K\cdot(n-1)$ $\quad F_n := \frac{1}{n}$ $\quad K = 3.533\cdot10^{-4}$

$v(t) := 0.5 + \frac{2}{\pi}\cdot\sum_n G_n\cdot\sin(n\cdot\omega\cdot(t-0.5))$ $\quad f(t) := 0.5 + \frac{2}{\pi}\cdot\sum_n F_n\cdot\sin(n\cdot\omega\cdot(t-0.5))$

The following section of maths may look a bit complicated in terms of its quantity, but actually it is just a lot of simple manipulations; no complicated stuff at all. Adding the middle column of generalised terms from the table gives the new value. The modified coefficient for the n[th] harmonic of the Fourier expansion is:

$$G_n = \frac{1}{n} - \left[\frac{1}{2H+4-n} - \frac{1}{2H+2+n}\right] - \left[\frac{1}{4H+6-n} - \frac{1}{4H+4+n}\right] - \ldots$$

Notice that the rows have been paired to give a simplification of the series. The new coefficients are always smaller than the originals, except for at N=1. This infinite series is easily expressed in sigma notation as:

$$G_n = \frac{1}{n} - \sum^{\infty}\left(\frac{1}{2k[H+1]+2-n} - \frac{1}{2k[H+1]+n}\right)$$

This looks pretty large and untidy and I am afraid it gets worse before it gets better!

Expand using a common denominator.

$$G_n = \frac{1}{n} - \sum^{\infty}\frac{(2k[H+1]+n) - (2k[H+1]+2-n)}{(2k[H+1]+2-n)(2k[H+1]+n)}$$

Simplify the top:

$$G_n = \frac{1}{n} - \sum^{\infty}\frac{2n-2}{(2k[H+1]+2-n)(2k[H+1]+n)}$$

Multiply out the bottom:

$$G_n = \frac{1}{n} - 2\sum^{\infty}\frac{n-1}{4k^2(H+1)^2 + 4k(H+1) + 2n - n^2}$$

Take the constants out of the summation:

$$G_n = \frac{1}{n} - \frac{n-1}{2(H+1)^2}\sum^{\infty}\frac{1}{k^2 + \frac{k}{H+1} + \frac{2n-n^2}{4(H+1)^2}}$$

The whole point was to eliminate the infinite series of Fourier components; the result so far is another infinite series! However, the sigma term has a very small variation with n, so that to a reasonable approximation we can say that:

$$\sum_{k=1}^{\infty} \frac{1}{k^2+\frac{k}{H+1}+\frac{2n-n^2}{4(H+1)^2}} \approx \sum_{k=1}^{\infty}\frac{1}{k^2}=\frac{\pi^2}{6}$$

This last identity being given in formula books[4] for the Riemann zeta function. This is the justification for writing an approximation to the enhanced coefficients as:

$$G_n \approx \frac{1}{n}-\frac{\pi^2}{12}\times\frac{n-1}{(H+1)^2}$$

However, since it is an approximation, one should suspect that slightly better 'internal' coefficients could be found. Thus a better approximation is:

$$G_n = \frac{1}{n}-\frac{\pi^2}{112}\times\frac{n-1}{(H-1.06)^2}$$

This gives 0.3% overshoot, as compared to 8.9% for the original Fourier coefficients. In fact this 'approximation' is better than the original formula for G_n, due to a slight dependence on H in the original.

The calculation of this new coefficient is very inexpensive in computer time. Obviously the

$$\frac{\pi^2}{112\times(H-1.06)^2}$$

part is calculated once before the main loop. The coefficients are then calculated from the simple equation:

$$G_n = \frac{1}{n} - K(n-1)$$

References:

1. Steven W. Smith, 'Chapter 8'. in The Scientist and Engineer's Guide to Digital Signal Processing, 2nd edn (www.DSPguide.com: California Technical Publications, 1999).
2. Edwin Hewitt & Robert E. Hewitt, 'The Gibbs-Wilbraham Phenomenon: An Episode in Fourier Analysis', Archive for History of Exact Sciences, 21 (1979), pp 129-160.
3. David Gottlieb & Chi-Wang Shu, 'On the Gibbs Phenomenon and its Resolution', Society for Industrial and Applied Mathematics, SIAM REV. 39. no. 4 (Dec 1997), pp 644-669.
4. 'Mathematical Equations', in Reference Data for Engineers: Radio, Electronics, Computer & Communications, 8th edn (SAMS, 1993), p 47:8.

Modern impedance measurement techniques IV

In his fourth in-depth article covering modern methods of measuring impedance, Alan Bate* describes a hypothetical LCR Instrument based on DSP techniques.

Rounding off this final article on modern LCR instruments – which are still loosely called bridges – I look at the merits of a DSP based instrument by investigating some of the points that would need to be evaluated in the initial design phase of such an instrument.

Consider a modern DSP-based bridge such as QuadTech's 7000 series LCR measuring instrument. Its basic accuracy is 0.05% from 10Hz to 10kHz and it has seven-digit measurement resolution. It operates over a frequency range of 10Hz to 500kHz with an accuracy of 20ppm+0.02Hz using direct digital synthesis – a subject that merits another article in itself.

For non-critical applications, it can take 40 measurements a second at 0.5% accuracy. At normal speed it takes three measurements a second at 0.25% accuracy. For improved resolution, the meter can be set to take one measurement a second at full accuracy.

Now, considering the following system blocks and their associated error sources to achieve 0.05% or 500ppm total error, a possible error budget might be:

- Harmonic distortion and noise from stimulus, 100ppm.
- Three decade, range attenuator, initial ratio tolerances and temp drift, at least 100ppm +2ppm.
- Standard resistor, initial tolerance and temperature drift, 50ppm +2ppm.
- System clock frequency, initial tolerance and temperature drift, 20ppm.
- Range amplifier distortion and thermal noise, 100ppm.
- A-to-D converter accuracy, integral and differential non-linearity, quantisation and thermal noise. Effective resolution of at least 18 bits (4ppm) over the range 10% to 100% of full scale.
- Rounding errors in the dsp processing, 20ppm.
- Rounding errors from impedance calculations and display formatting, 50ppm.

Then for an even distribution of errors, each function needs to have less than 0.05%/8, or around 60ppm, total error contribution.

In practice, some functions will use more or less of the error budget. Only two, as opposed to six, AC measurements are now required. This is because the real and imaginary components of the E_u and E_s measurement and reference signals, explained in the first article in this series, are directly extracted from the FFT analysis.

Now, the in-phase and quadrature measurements are being made from a large number of samples to derive their FFTs. Typical sample size would be 1024, known as a 1024-point FFT.

In addition to the impedance calculations, which required around 22 bits of resolution with the all-analogue method to avoid rounding errors, there's a considerable increase of numerical processing – multiplications and additions – for the two FFT calculations.

Assume that each E_u and E_s measurement would consist of 2048 time samples for full accuracy. An A-to-D converter with an effective resolution more than 22 bits would seem to be desirable. This points to using the latest dual sigma-delta converters, which are 24 bit, 192kHz sampling devices. They would have to run at the lowest possible conversion rate for minimum dynamic distortion as discussed in my third article last month.

These high performance dual A-to-D converters now enable E_u and E_s to be read simultaneously, saving measurement time and settling delays by avoiding range switching. However, the range function would need to be duplicated for the E_u and E_s signals. This would throw away the great advantage of normalising out variations in gain and phase of the whole ranging circuitry by the ratio measurement as well as adding to the instrument cost.

Matching between the separate E_u and E_s signal paths would need to be made using software corrections for each range setting increasing test time and costs. For this reason, DSP would only be considered for an up-market bridge like the QuadTech 7000 series.

Required FFT window

With the old analogue method, the phase-shift detector and A-to-D combination provided narrow band detection. Remember that the A-to-D integration time was synchronised to a whole number of the drive signal periods so that the A-to-D converter integrated the PSD ripple. This also defined the PSD bandwidth which is approximately the root reciprocal of the A/D integrate period.

By increasing the integration period, the PSD noise bandwidth could be closed, reducing the noise power as the square root of integration period. For a 2:1 improvement in noise, we needed to reduce the phase-shift detect and A-to-D conversion rate by 4:1.

The same can be done in DSP by increasing the period of the FFT window length. Remember that for an efficient FFT, it is necessary to stick to a sample length that is a binary number to aid the processor calculations.

Taking our hypothetical instrument maximum frequency

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for full accuracy of 10kHz and our original analogue noise bandwidth of 50Hz, an FFT frequency resolution, or spectral line spacing (also known as bin spacing) of 25Hz would be needed. However, the FFT would respond to 50Hz and 100Hz but miss 60 and 120Hz. These are important frequencies for measuring electrolytic capacitors. A 10Hz bin spacing is therefore needed, which would cover odd and even multiples of 10 and give a theoretical noise bandwidth of 20Hz.

Now, FFT bin spacing is:

$$\frac{1}{N} \times \Delta t_{sample} = \frac{f_{sample}}{N}$$

where N is the number of samples. It is possible to have an increasingly narrow band system by increasing the size of the FFT data block or window length. In other words, the longer that the signal is viewed, the more detail that can be resolved in the frequency plane.

In order for 10kHz to be at a spectral line in the FFT output and maintain a 10Hz bin spacing, and ignoring for the moment the zero frequency or DC bin, 10kHz would need to be at spectral line;

$$\frac{\textit{spectral line frequency}}{\textit{bin spacing}} = \frac{10000}{10} = 1000$$

The next binary number is 1024, which would be at half the sample frequency. This would require an FFT of 2048 points as the useful FFT output is from zero to the half sample frequency. Hence the minimum sample rate to meet the Nyquist criteria would be an A-to-D conversion rate of 2048 multiplied by 10Hz spacing plus 10Hz for the DC component, which is 20.49kHz. This would bring each E_u and E_s sample FFT window to 100ms.

Assuming the dual converter and dual channel ranging discussed above, total measurement time becomes the sum of:

- the 100ms window
- data transfer from each A-to-D buffer to memory
- processing of the two 2048-point FFTs
- impedance calculations
- display rounding and formatting

The low-cost 100MHz Pentium processor mentioned in the previous article needed an estimated 170ms execution time for a 2048-point FFT. Assuming the impedance calculations and display algorithms processing are very short in comparison then this could give an acceptable reading rate of around;

$$\frac{1}{100\text{ms} + (170\text{ms} \times 2)}$$

or 1 to 2 readings a second at full accuracy.

On the faster settings, it would be necessary to trade a shortening of the FFT window length with a wider noise bandwidth. On the fastest setting of 40 measurements a second this could be approximately half the total measurement time, say 10ms sample time and 100Hz bin spacing using a 256-point FFT, sampling at 25.6kHz and a theoretical noise bandwidth of 2x bin spacing, or 200Hz.

The above line of thought is of course only approximate. Hardware development would be needed to arrive at an optimised design.

Lowering noise

It is also possible to increase resolution by averaging the impedance results. But increasing the FFT sample length, and hence closing the detection noise bandwidth would be a more desirable means of increasing the signal to noise. This is because of the increase in selectivity. which is very desirable at the supply frequencies 50/60Hz and harmonics thereof.

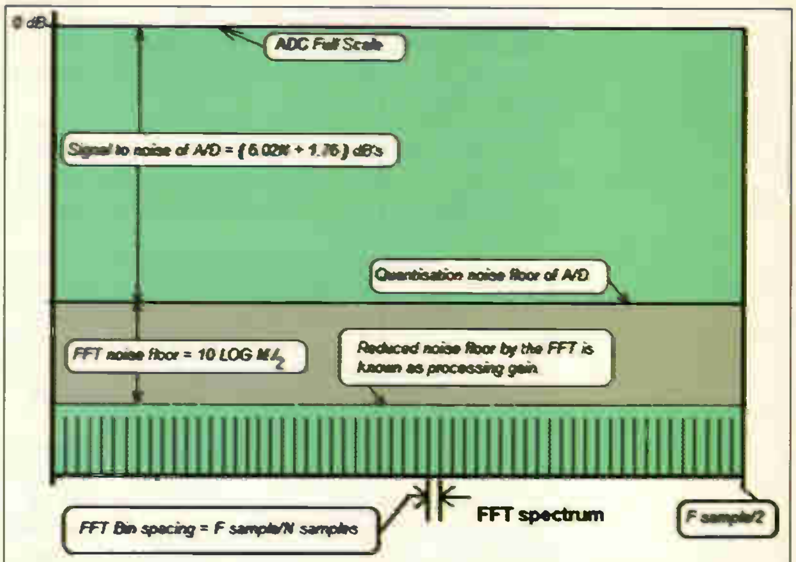


Fig. 1. The FFT noise floor is not the SNR of the A-to-D converter. This is because the FFT acts like a spectrum analyser, of bandwidth fs/M, where M is the number of sample points in the FFT, rather than fs/2. The theoretical FFT noise floor is therefore 10log10(M/2)dB below the quantisation noise floor due to the so-called processing gain of the FFT.

In fact, the FFT noise floor can be reduced well below that of the A-to-D conversion hardware noise floor by simply increasing the number of samples. In other words, the FFT noise floor is not the noise floor of the A-to-D converter. This is akin to the instrument noise floor reducing on a spectrum analyser as the resolution bandwidth setting is reduced to a bandwidth of f_{sample}/M, where M is the number of points in the FFT. It can be shown that the theoretical FFT noise floor is;

$$10\log\frac{M}{2}\text{dB}$$

below the A-to-D quantisation noise floor. In DSP talk, this is known as the processing gain of the FFT, **Fig. 1**. This would be desirable to help overcome noise limitations in even the latest available A-to-D converters.

My survey of recent 24bit/192kHz audio A-to-D converters in last month's article shows typical real noise floors of around 105dB – a short fall of 144–105, or 42dB. To make up this by processing gain would require an unacceptable 32 768 point FFT! This indicates that the latest 24 bit technology is still a little short on raw, unweighted noise performance. Our 2048 point FFT would give a 30dB noise reduction.

The A-to-D converter needs to have a noise floor of around –114dB. So what's available on the sigma-delta IC market? Until recently, most sigma-delta converters were designed for low-frequency, low-level applications such as strain gauge transducer amplifiers and medical instrumentation. The digital filtering is therefore designed for the low audio range for maximum signal-to-noise performance.

Sigma-delta A-to-D converters for audio applications do not necessarily have good unweighted noise performance. This is because the noise in digital audio includes psycho-acoustically noise shaped filtering. This masks the true A-to-D converter noise with frequency and in turn requires less stringent noise performance than the converter's resolution implies.

Table 1 in last month's article is a list of the latest 24 bit sigma-delta A-to-D converters – all developed for digital audio applications. Very recently, Analog Devices has launched a 24-bit sigma-delta A-to-D converter – the

AD7732. It is designed for instrumentation and can handle multiplexing up to 12.3kHz, which is well above our requirement of around 80Hz using a single A-to-D converter. Even multiplexing at 300Hz, the 7732 achieves 21 bits of effective resolution.

The overall A-to-D converter frequency response needs to be flat to within, say, less than 5% or 0.4dB at 10kHz to avoid too much signal loss. This is not a problem with the recent A/Ds developed for audio. They have pass-band flatness of 0.005dB.

At integer multiples of the modulator sample frequency the digital filter spectrum will repeat – i.e. it is periodic in nature – with zero attenuation around each sample rate harmonic (see Fig. 8 in last month's article). If noise exists in these pass bands, analogue filtering is needed at the A-to-D converter's input to remove it, otherwise it will alias and pass unfiltered to the converter output.

Ironically, after all the digital processing, an analogue filter is needed at the A-to-D converter input to band limit the measurement signal to keep it within the modulator Nyquist bandwidth. However, due to the wide separation between the over sample frequency and the wanted pass band of the A-to-D converter modulator, this can be a simple passive filter.

Theoretically, the filter needs to roll off to less than one LSB at the modulator half-sample rate f_n, **Fig. 2**. The number of octaves between the two frequencies is the logarithm of the frequency ratio, divided by the logarithm of 2 – the ratio of one octave.

For example, with an over-sample rate of 256×, the Nyquist frequency will be half this at 128× the A-to-D conversion rate, f_c. The required filter pass/stop-band spacing is log128/log2, or 7 octaves away.

There are seven octaves within which sufficient stop-band rejection can be achieved to reduce the alias noise below the 24 bit A-to-D converter resolution i.e. 144.5dB of rejection. This means a filter slope of 144/7 or 20.6dB/octave.

Since filter slopes come in 6dB/octave integer increments, we require a fourth-order filter – i.e. 24dB/octave. Expressed as a formula, filter order N is;

$$\frac{A_{sb} \times \log 2}{6\left(\log \frac{f_n}{f_c}\right)}$$

Here, A_{sb} is the required stop-band rejection in decibels.

In practice, the filtering can be simpler as the stimulus harmonics and thermal noise above the modulator Nyquist rate would already be at a low level. For this reason, less stringent cases like digital audio use a simple *RC* filter.

A simple RC filter however, rolls off at only 6dB/octave or 20dB/decade. This gives 42dB of attenuation at the Nyquist frequency, which may be minimal.

For a well engineered instrumentation solution a passive *LC* filter, with 12dB/octave or 40dB/decade roll-off would be more suitable, giving 84dB of attenuation at the Nyquist frequency. Choosing an *LC* passive filter would also give the lowest thermal noise in the pass band. Unlike active filters and *RC* filters, real reactances do not contribute thermal noise.

Summary of the DSP approach

Precision LCR measuring instruments based on DSP techniques have become practicable with the improvements in high-resolution A-to-D converters and cheaper, more powerful general purpose and dedicated digital signal processors.

Greatly increased processor workload would probably require the additional cost of a 32bit DSP chip to maintain acceptable measurement speeds.

Also, state of the art A/D performance would be needed in terms of conversion rate and resolution, having ideally a genuine full scale effective resolution of at least 18 to 24 bits at 25kHz.

With a practicable level of FFT processing gain, the A-to-D converter's genuine, unweighted noise floor could be –114dB. The latest ICs fall a little short of this, possibly due to manufacturers trying to get as much as possible onto one chip.

Separating the analogue and digital functions of the A-to-D converter into a chip set and running at the lower conversion rate required in an instrument like the one under discussion here should result in performance improvements. The frequency sensitive differential and integral non linearities would be smaller. In turn, noise performance would be improved (see the 'S/(D+N)' column in Table 1 of last month's article for A-to-D converter noise performance figures).

Using DSP, the improvement over the conventional analogue approach in overall accuracy appears to be marginal. Quadtech's 7000 series DSP bridges achieve no better basic accuracy than was obtainable in the eighties with the analogue PSD/AD method discussed in the first and second article.

The main improvement appears to be improved linearity and lower noise. With DSP, the multiplication required is done in software, rather than via analogue hardware, which required an ultra-linear PSD circuit using the method

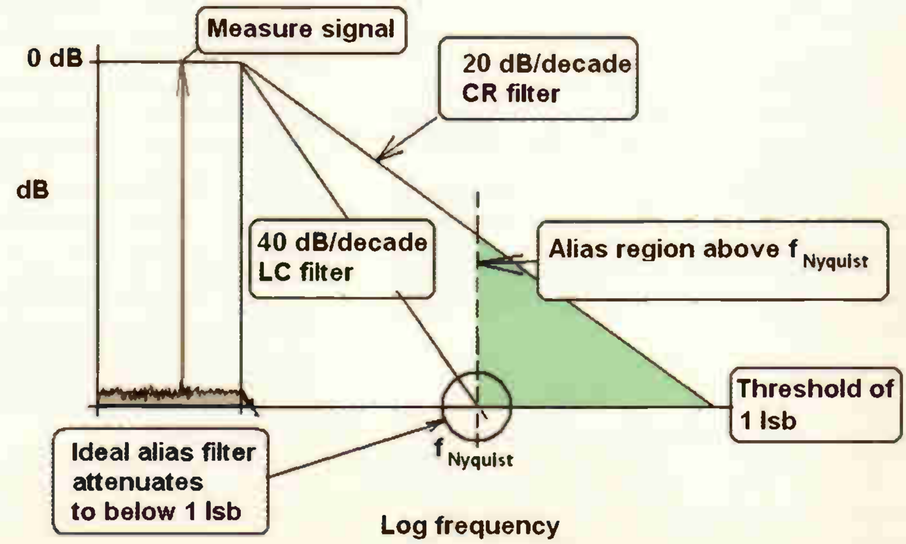


Fig. 2. With no filtering at the input of the ideal sampler, any frequency/noise components that falls outside of the Nyquist bandwidth in any Nyquist zone (see Fig. 6) will be aliased back into the first Nyquist zone or base band. For this reason, an anti aliasing filter is needed in all sampling A-to-D converter applications to remove these unwanted signals. An ideal anti alias filter will attenuate all such components below the threshold of the 'least-significant bit' of the A-to-D converter at the first half sample frequency. Over-sampling sigma-delta A-to-D converters simplify filter complexity by providing wide separation between the base bandwidth and the over sample rate.

discussed in the previous articles.

With DSP, there's also possibility of deriving the fundamental and low-order harmonic impedances in one measurement. Total rejection of noise components such as supply noise is made possible by ignoring unwanted bin data in the FFT output.

DSP opens up the possibility for achieving very narrow band detection – below 1Hz and hence very low noise, beyond what is practicable with analogue methods. However, with the ever-increasing performance/cost ratio of DSP hardware, digital signal processing, as in other areas of electronics must become the standard method for the future.

The way ahead

Impedance analysers are an exception in the instrumentation field. Most signal-processing requirements conveniently fall into high-speed, low-resolution or low-speed, high-resolution categories, where as impedance measurement demands the highest possible resolution over the widest possible frequency range.

LCR instrument technology is based on assuming that the unknown impedance is linear and can be modelled as two lumped components with all the losses expressed in one term. This is valid when the component dimensions and test fixture wiring electrical lengths are small compared to the wavelength of the measurement frequency, i.e. the circuit can be viewed as lumped parameters.

As the wavelength of the measurement frequency is approached, the unknown impedance with the test fixture becomes more of a transmission line. As we increase in frequency the range of impedance, measurement converges to around 50Ω. From around 1GHz, the network analyser becomes the only viable means of measurement.

However, the network analyser can only be used for impedance measurement near to its designed characteristic impedance, which is universally 50Ω in modern RF work. Balun transformers are used to scale from 50Ω, giving a very limited extension in impedance range.

With either the DSP or analogue PSD approach, the major problem is still guarding at the measurement interface. This is particularly so for the 'I' terminal as shunt capacitance here gives a scalar error. There's more on this in the article from the December issue. My opinion is that the bridge measurement interface is the system block that really needs reviewing!

Think surface mount

With the industry increasingly moving away from leaded to surface mount devices, or SMD, components and – thanks to the mobile phone industry – of ever decreasing size, the need for accurate measurement of chip components at measurement frequencies of up to 1GHz has grown. At present, only the PN 4294A, 40Hz to 110MHz impedance analyser and RF pod extensions even begin to address this industry trend. These are produced by Agilent, which was formerly Hewlett Packard.

As virtually all volume electronics built today uses SMD technology, the modern bridge needs to be designed primarily for this type of component. Axial-leaded components are disappearing. Radial-leaded alternatives are largely now for low frequency power applications and are easily handled by the older generation of bridges.

Apart from the physical practicalities, measurement leads really need to be eliminated for the following reasons. Firstly they make it difficult to maintain good guarding at the 'I' terminal, where the cable impedance defeats the guard amplifier performance. The phase mismatch down the four measurement cables becomes very noticeable with frequency.

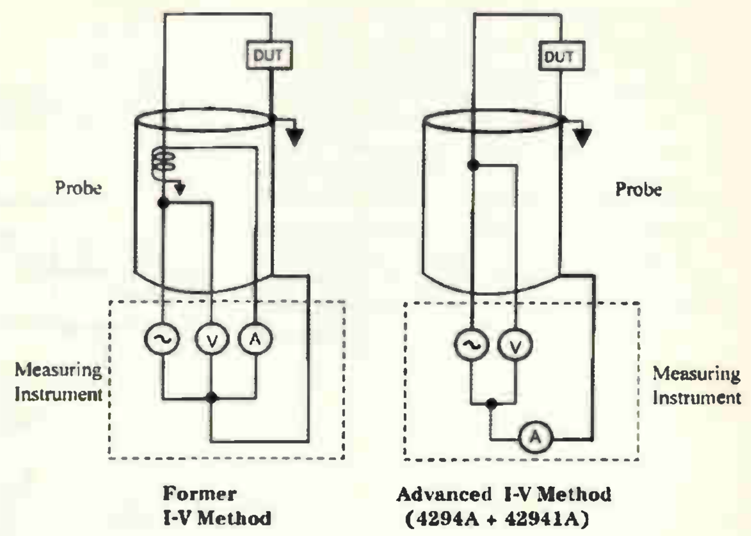


Fig. 3. In my view, the future LCR instrument will have a compact remote head for testing the unknown impedance, which is often embedded in circuitry. Agilent has developed add-on wide-band probes for the PN 4294A 110MHz bridge for this purpose. Initially, a shielded current transformer was used to monitor the unknown impedance current. By re-arranging the probe topology so that the company's wide-band guard circuit could be used in place of the transformer, the probes' impedance range has been considerably extended.

Even at 1MHz, where only 1ns delay mismatch between the 'sense' leads corresponds to a dissipation factor error of 0.001 – twice the whole dissipation factor of a typical LCR instrument.

At higher frequencies, standing waves in the drive and sense leads would make a wide band guard amplifier unstable. For this reason, the HP 4194A impedance analyser was limited to 15MHz using 1m cables. Instrument manufacturers with cable-terminated bridges have developed calibration software and portable transfer standards to partly offset this problem along with the failing guard amplifier performance.

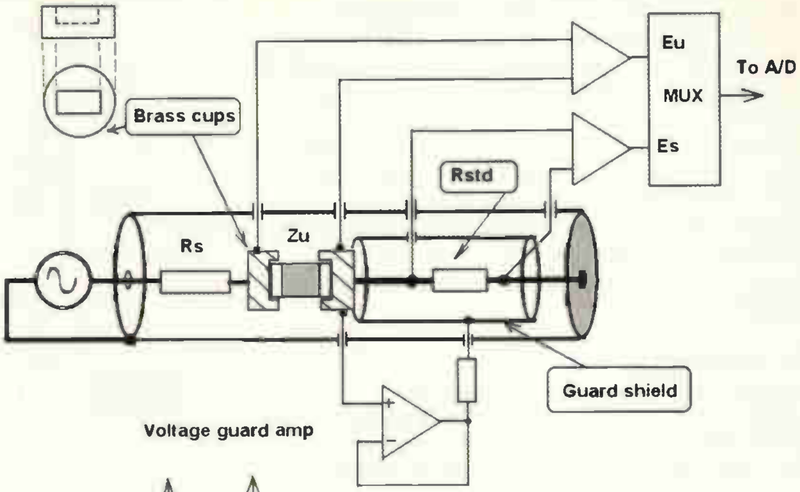
Agilent has extended the HP 4294A's performance by software correcting for the electrical lengths of the measurement cables. This is done after a calibration measurement is made with all four 50Ω measure cables terminated with their characteristic impedance at the bridge inputs.

After the cable corrections, the 50Ω termination resistors are switched out to allow normal operation. Agilent do not publish any in depth details but this interesting improvement helps in extending the instrument capability from 15 to 110MHz, way out in front of any other bridge manufacturer!

If the measurement cables are to be eliminated, this means measuring the unknown SMD component in a remote measure pod/fixture. This fixture holds the unknown impedance and shunt capacitances at the measurement terminals can be made minimal and well defined – or even eliminated – through guarding.

The unknown current and voltage sensing would be located right at the fixture measurement interface, complete with range amplifiers and A/Ds in a suitably screened housing. This would allow a fibre optic – or even a wireless – link for the digitised E_u and E_s signals to the main instrument for further processing and display. This avoids the common-mode noise, mutual coupling and HF characteristics of conventional coaxial measurement leads.

Fig. 4. My suggestion for a dedicated test fixture for the common component of today – the surface-mount service. Guarding of the current-sense resistor from the small amount of shunt capacitance is provided by the wide-band buffer and inner coaxial shield around the current sense circuit. Coaxial casing provides screening and a better-defined RF environment for Z_u, which is held by the cup jaws. The cup terminal on the generator side would be adjustable, using an insulated shaft to allow for different sized components. Access to Z_u would require a hinged lid or sleeved outer casing arrangement.



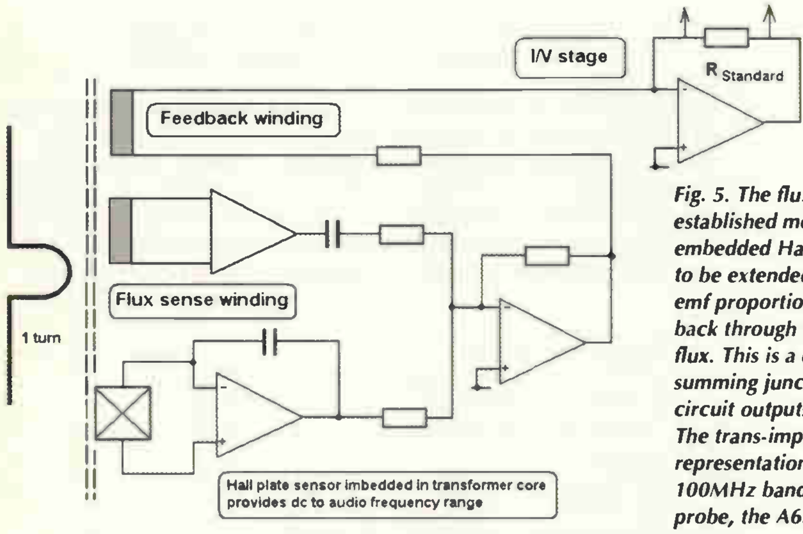


Fig. 5. The flux balancing current transformer technique is an established method of achieving a linear current transformer. The embedded Hall plate sensor enables the low-frequency response to be extended to DC. The unloaded sense winding generates an emf proportional to flux (as e=NδΦ/δt) which is amplified and fed back through the feedback winding, opposing the initial primary flux. This is a control loop where the core flux is the error-summing junction. At balance, the core has zero flux and the circuit outputs a current equal to the primary current/turns ratio. The trans-impedance stage converts the current signal to a voltage representation, E_s. Tektronix has taken this technique from DC to 100MHz bandwidth with its enhanced clip on scope current probe, the A6312.

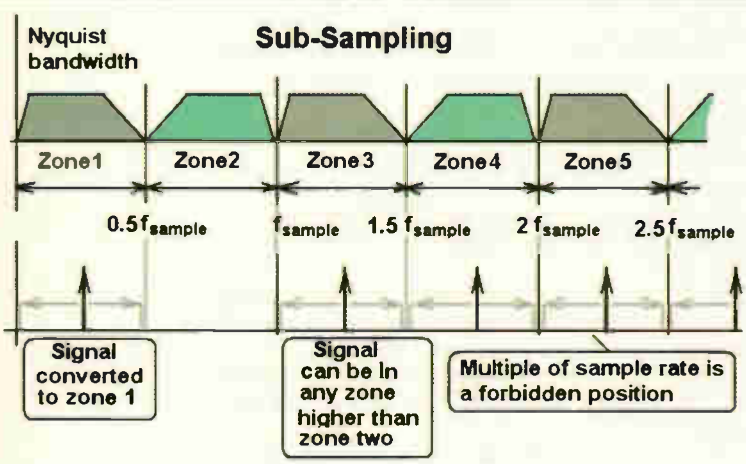


Fig. 6. With sub-sampling, aliasing is used to advantage. If the sample rate exceeds twice the Nyquist bandwidth – a zone width – the sampled signal can be down-converted into zone 1 (the base bandwidth) from any higher frequency zone, i.e. from zone 3 upwards. Even multiple zones are mirror images, but this is not a problem for the FFT process as the spectral bins in the FFT output are simply reversed in order. Two equations can be used to choose the measurement frequency to be sampled, f_m, given the sample frequency f_s and the required Nyquist f_n and bandwidth Δf; $f_s > 2f_n$. To locate the highest measurement frequency range within any Nyquist zone; $f_s = N(f_n \pm \Delta f)$ where N is even 2, 4, 6, 8... and $-\Delta f$ gives a mirrored alias.

The shunt loading scalar error is largely avoided by measuring the current right at the unknown with a very low inductive shunt resistance of, say, 100Ω at low frequencies and/or a wide-band ferrite cored current transformer for frequencies above say 10kHz. The transformer would have inherently good guarding by using a single turn or bar primary.

The snag is that at least 20dB of signal is thrown away at the front end of the system which limits our high impedance range. Agilent made such a probe as an extension to their PN 4294A, impedance analyser. The company has also recently enhanced this probe concept. More discussion on this below, **Fig. 3**.

Why not voltage guard?

Instead of current guarding using the virtual earth amplifier approach, which works very well at low frequencies, the well-defined test fixture 'I' terminal circuit could be voltage guarded using a very wide band buffer amp. This could consist of a FET follower to sense the 'I' terminal and a current feedback op-amp to provide wide gain bandwidth.

The whole 'I' terminal circuit, including the shunt, would need to be screened and the screen driven by the guard buffer amp. The voltage guard amp drives the screen at the same potential as the 'I' terminal.

Without any voltage difference between the 'I' terminal and screen, no capacitive current can flow from the terminal to the screen. Instead, the buffer amp drives the defined screen to ground, which provides shunt capacitance.

In practice, a compromise would have to be made between the capacitive load drive capability of the buffer and guard effectiveness by using a small load isolating resistor at the buffer output. The aim of the probe fixture would be to provide a minimal and well-defined shunt capacitance.

Figure 4 shows my own coaxial SMD device fixture idea with internal guard shield around the current-sense resistor. The outer coaxial tube provides electrostatic and electromagnetic shielding of the unknown impedance. This tube would need to have a sleeved lid to access the unknown impedance.

The cup-shaped brass terminals with rectangular impressions help to locate the SMD component. The 'I' terminal would be fixed while the 'E' terminal is adjusted on an insulated threaded shaft.

Another possibility for the low frequency range could be to tune, or resonate, the 'I' terminal screen-to-ground shunt capacitance with a programmable active inductor. Active filter circuits working at 10MHz are now feasible with modern wide-band op-amps, so it is safe to assume that a good simulated inductor performance to 1MHz is attainable. This would be a good point to limit the low frequency performance of the bar primary current transformer, which would take over to provide a good current guard.

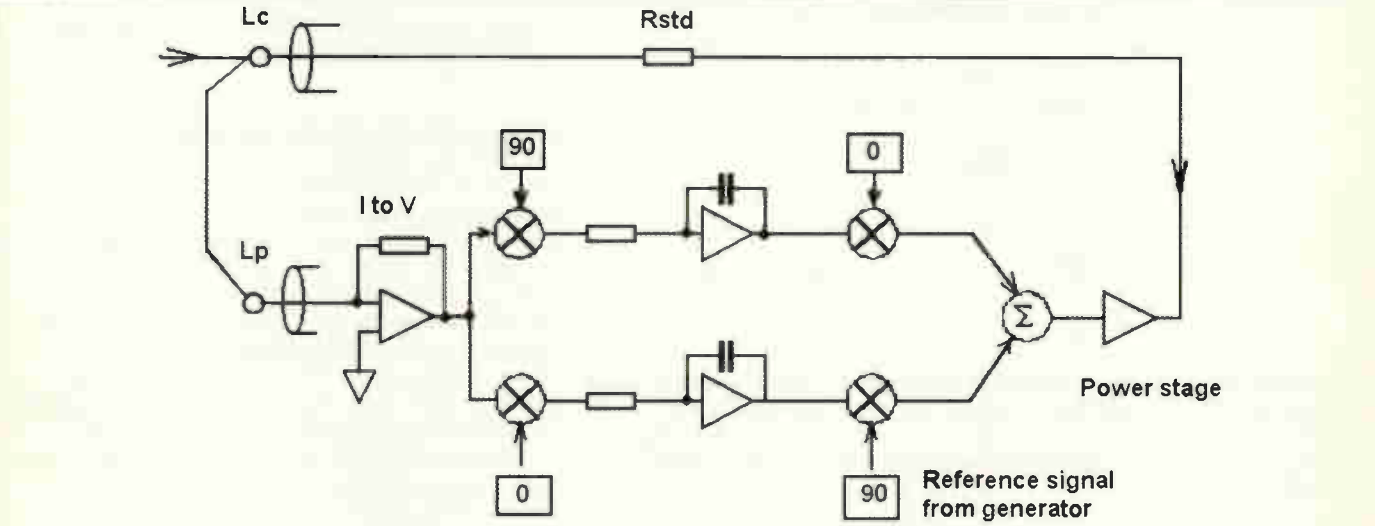
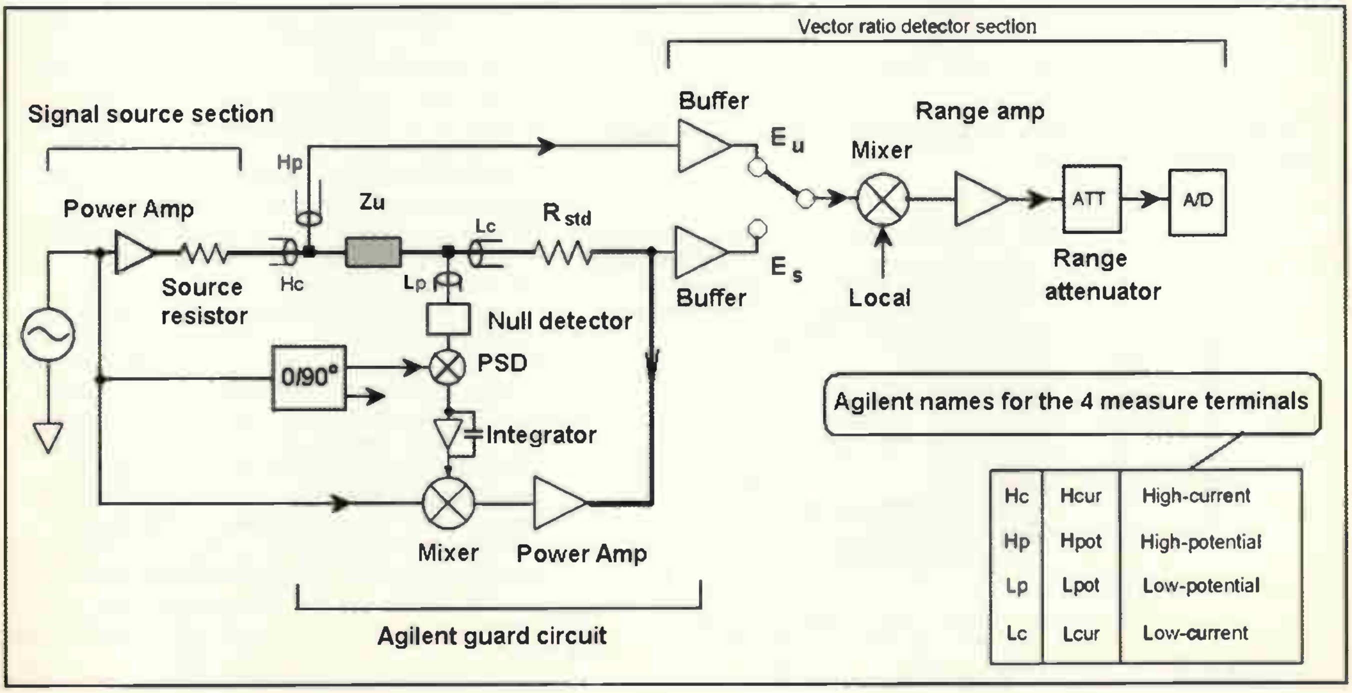


Fig. 7. In diagram a), Agilent's current-guard circuit down-converts the measurement signal at the virtual earth Lc to near zero frequency and extracts the phase and quadrature components via the PSDs. The very low-frequency signal is now noise filtered and amplified by the DC integrators to provide high loop gain before up-converting to the measurement frequency. Vector components are recombined via the phase and quadrature modulators and fed back via the wide-band buffer and standard resistor. The loop sinks signal current from Lc until a virtual earth of zero voltage is maintained. This complex approach to guarding achieves a very high gain bandwidth. Agilent has now extended this technique from 13MHz to 110MHz in the company's PN 4294A bridge. In 7b), the guard circuit of 7a) is shown in more simplified form within the measurement interface. This 110MHz instrument has the widest available bandwidth of any general-purpose LCR meter. The power of ratio measurements is maintained in the detector and ranging by multiplexing the Eu/Es measurement signals as discussed in earlier articles. Frequency down-conversion is applied, enabling low-bandwidth ranging and A-to-D circuits to be used.



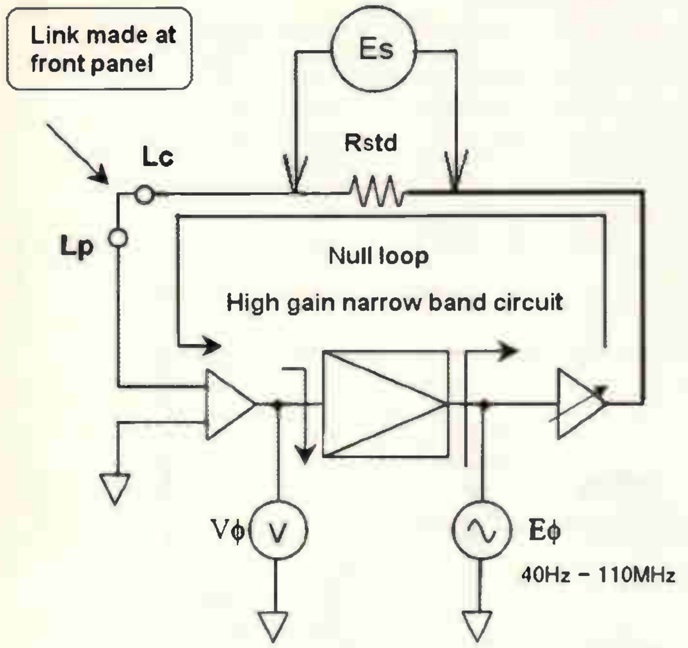


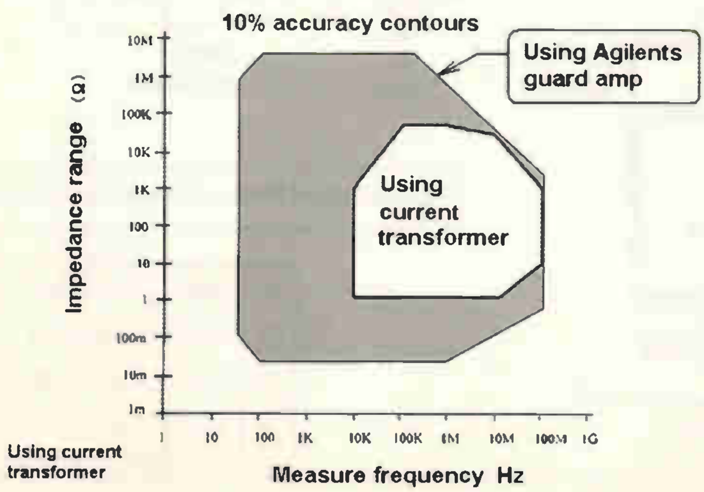
Fig. 8. Agilent has enhanced the stability of the company's guard circuit by using an internal vector voltmeter to monitor the loop gain/phase at each measure frequency as part of the self-calibrate routines. The results are stored in memory and used to compensate for the reduced stability margin at high frequencies.

An engineering rule of thumb is good transformer design can be made to work over three orders of bandwidth so with some overlap in performance we might expect the transformer to work from 0.5MHz to 500MHz.

It is possible to extend the current-transformer's low-frequency range by using a flux-balancing feedback system incorporating a Hall plate sensor. This sensor is embedded in the transformer's ferrite to sense the core flux from low audio frequencies down to DC.

Such a system achieves the highest possible linearity with a transformer since the core flux is always nulled to virtually zero by the control loop. The low-frequency Hall plate signal is combined with the high-frequency transformer signal and fed through the feedback winding to cancel the initial primary flux.

Fig. 9. Impedance maps for 10% contours for the two methods used by Agilent in the company's add on probes.



Loop gain variations from each channel are suppressed by the overall feedback, giving a flat frequency response. The output signal is a current, precisely scaled by the transformer turns-ratio, which is converted into the E_s signal by the transimpedance stage, **Fig. 5**.

This last technique has been used for many years in the Tektronix A6302 DC to 50MHz clip-on current scope probe (Every self-respecting power-supply design team should have one).

Performance of the transformer should allow 100MHz operation as the clip-on capability with the associated residual air gaps/leakage inductance would not exist. Tektronix now offers a 100MHz probe, showing it can be done anyway.

Mixing with the A-to-D converter

Above 10kHz. frequency down conversion and A-to-D conversion of the two measurement signals could be combined using a sub sampling A-to-D conversion approach – also known as under-sampling or harmonic sampling. This has become a popular communication technique to sample IF signals directly. It eliminates the need for an IF demodulator as the technique is directly equivalent to analogue demodulation.

This process is better understood by studying the frequency plane again, **Fig. 6**. We normally think in terms of only working in the first Nyquist zone, i.e. from zero to $f_s/2$ to avoid aliasing. For signals that do not extend down to DC however, the minimum sample frequency is a function of the bandwidth of the signal as well as its position in the frequency spectrum.

Under-sampling complies with an extended version of the sampling theorem. This theorem states that a sampled input can be reconstructed from the sampled data if the input frequency components lie entirely between adjacent whole multiples of one half the sample rate. In other words, the Nyquist criteria, states a signal must be sampled at twice its bandwidth in order to preserve all the signal information.

There is no constraint on the absolute location of the band of sampled signals within the frequency spectrum relative to the sampling frequency. The only constraint is that the band of sampled signals is restricted to a single Nyquist zone, i.e., the signals must not overlap any multiple of the Nyquist frequency, $f_s/2$.

Referring to Fig. 6, you will see the first image – zone 2 – will contain all the same information as zone 1 but shifted and mirrored in frequency. The order of the frequency components within the spectrum are reversed. This is easily corrected in the FFT processing by re-ordering the output bins.

The sampled signal frequency can lie in any unique Nyquist zone, and the first Nyquist zone image or base-band will remain an accurate representation. An exception to this is the frequency reversal that occurs when the signals are located in even Nyquist zones (the zones above the half sample rate are called under-sampled bands).

Quadtech states that sub sampling is used for the company's new 7000 series 500kHz and 2MHz DSP bridges which have a 80/100kHz sampling A-to-D converter. Sub-sampling requires rock-stable timing and accurate synchronisation with the stimulus signal during the measurement process. As the stimulus and A-to-D conversion clocks are all derived from a common system quartz crystal clock this is not a problem.

With sub-sampling the A-to-D converter still makes the same number of samples of the signal, but it does so over a multiple of whole stimulus cycles. For example, imagine that four samples are needed from a test sinusoid signal of 1MHz (1μs period) and the A-to-D can only sample at 100kHz (10μs period). The first sample is taken at the start of the first cycle (0) then the second is not taken until ten cycles are passed. This makes the A-to-D conversion period 10×1μs.

At this point, the wave would be sampled at 90° and the third sample 10 cycles later at 180°. The final sample is taken at 270° before starting again at 0°. Thirty cycles of the stimulus signal is therefore required to fetch all the data.

With sub-sampling, the A-to-D converter must still have good linearity at the sampled frequency. Therefore a high-performance sample-and-hold circuit prior to the A-to-D circuit would be essential to extend its HF performance while operating in the sub-sample mode.

Ultimately phase noise caused by timing jitter in the system clock and the sample and hold circuits limits performance. From published data for sample-and-hold circuits, over 80dB of spurious-free dynamic range would be feasible up to 10MHz. This is only 0.01% error contribution where the all up accuracy at the higher instrument frequencies may only be 1 to 5%.

The pathfinders

Agilent, and before it HP, has been leading the way in bridge technology for many years. The company's very effective high-frequency guard circuit together with the signal source is referred to as an 'auto-balancing bridge.' In my opinion, this term is confusing. It was originally, developed in the early eighties for the HP4192 13MHz Bridge. The company's approach to guarding the 'I' terminal was touched on in the first article but deserves reviewing here, **Figs 7a & 7b**.

The signal at the virtual earth is compared to ground by the trans-impedance or I-V error amplifier. The error signal is now down-converted in frequency to very near DC or zero frequency using the first pair of mixers. This is sometimes referred to as zero IF conversion.

By using two phase-sensitive detectors, or PSDs, the in-phase and quadrature components are resolved. There's more on this in the first and second articles in this set. The PSDs operate as synchronous demodulators and are referenced to the stimulus.

The error signal phase and quadrature components are amplified and noise filtered using analogue integrators. The amplified error signal is now re-constructed back to the stimulus frequency using the second pair of PSDs, or mixers, to up-convert the signal.

Still in orthogonal form, the signal is summed and fed back through the reference standard via the wide-band buffer amplifier. This super-heterodyne, zero-IF approach neatly overcomes the gain-bandwidth limitation of a conventional guard amplifier by down-converting each frequency to DC, where it is easy to add loop gain. This is complex but it overcomes a major problem.

Agilent has developed this technique further with its PN4294A precision impedance analyser by adding an internal vector voltmeter to monitor the gain/phase characteristics within the loop for each measurement frequency, **Fig. 8**. The results are stored in memory and used to compensate for variations in loop-phase margin. This is possibly done by adding appropriate phase lead to the local oscillators. In-depth details are not published.

It would be nice if Agilent had continued with the HP Journal! The company is not as open as the original founding company.

As mentioned above, Agilent has also been going down the pod route with add on impedance probes for the 4194A and 42941A. These probes are for impedance measurement of in circuit SMD components at RF.

The company has been able to design out the current transformer with its inherent signal loss. Instead, it has adapted the complex guard circuit described earlier to be the probe current monitor. This has meant galvanically isolating the stimulus and guard circuits from the instrument ground, Fig. **3b**.

Not surprisingly, this technique has considerably extended the low-frequency performance over the passive transformer type probe. However, this is far from a dedicated remote pod approach as there is a lot of wire and signal processing before the current signal is digitised. **Figure 9** shows Agilent's published comparison of the extended impedance plane for – wait for it – 10% accuracy contours. **Figure 10** summarises the present state of play of general-purpose impedance-measurement coverage from the market leader.

Yes the time for a re-think in LCR instrument technology is overdue! ■

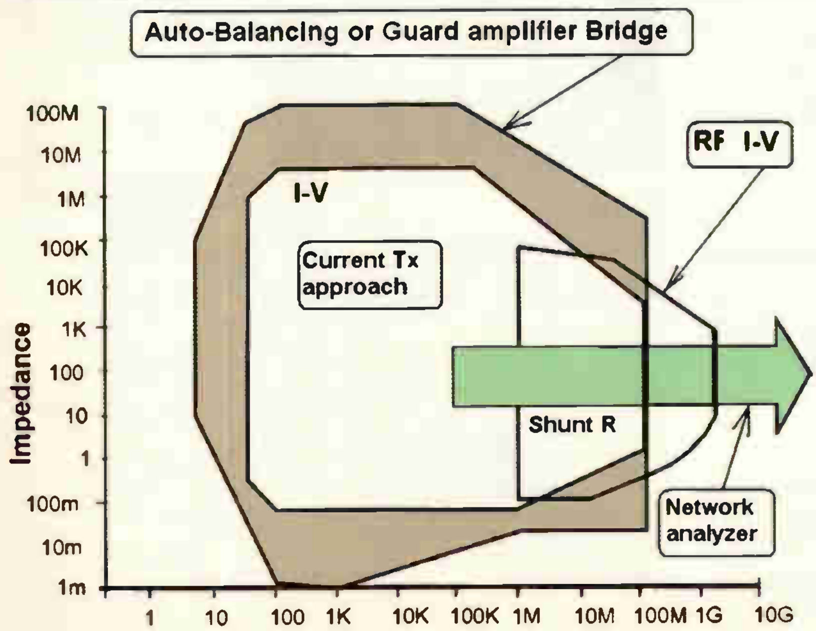


Fig. 10. Overview of the impedance coverage of the measurement methods discussed in this article. While the network analyser offers the highest frequency impedance capability, it is limited in range to near its 50Ω characteristic impedance.

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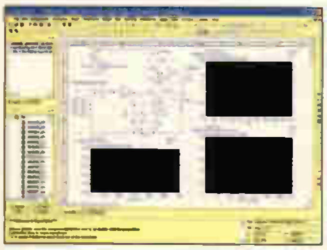

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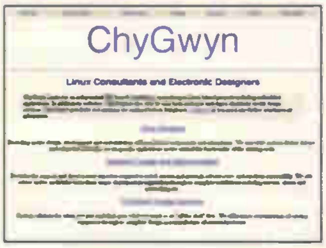

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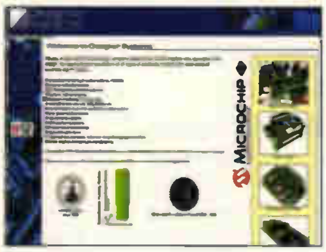

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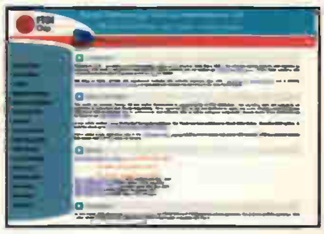

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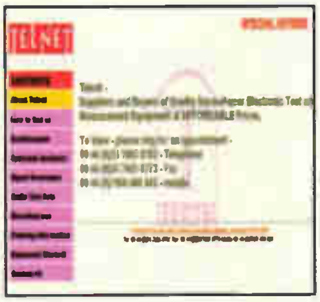

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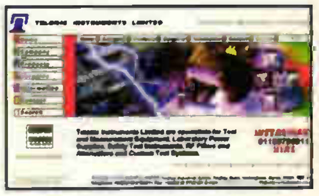

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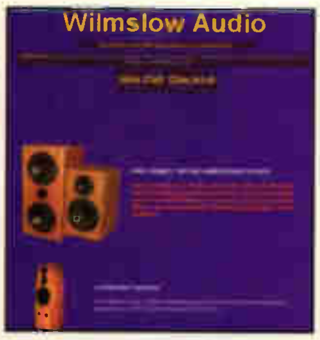

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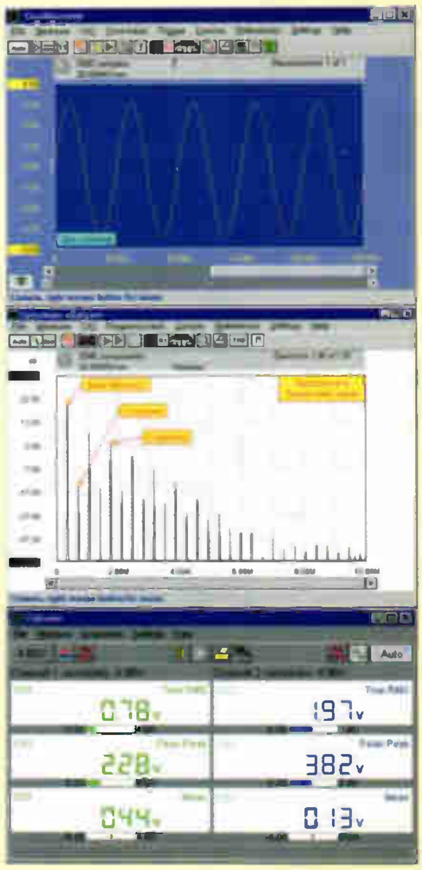

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