VI protection in power amps

DIY MFB loudspeaker

Spectrum pricing

Capacitor sound part 2

Circuit ideas:
Valve amp turn-on delay, Self-decoding indicators, Water level indicator
Quality second-user test & measurement equipment

Radio Communications Test Sets
Antenna NT 681/1C Radio Combiner Analyser: 300MHz - 3GHz (opt 1.4.7)
Hewlett Packard 9166A (1 option 1, 1,1:12)...
Tektronix 54111A...

3 COMMENT
Reader Enthusiasm

5 NEWS
• 1 Ghz on a 3cm disc
• Laser steel cutter
• New superconductor
• Alien help for disabled

24 TRANSPARENT V-H PROTECTION IN AUDIO POWER AMPLIFIERS
The desirability or lack thereof, of over-voltage and over-current protection for power transistors in audio power amplifiers remains a point of contention in the field.

56 LETTERS
• Conspiracy theory
• M.G. Scroggie
• 500 Mhz front end
• More PICs
• E. V improvements
• Electronics as an occupation
• Electrowire

60 WEB DIRECTIONS
Useful web addresses for electronics engineers.

30 CIRCUIT IDEAS
• Op-AMPs
• Economical mains LED
• Two channels — one gain path
• Valve amp turn on delay
• Self-decoding 4 of 4 indicator
• Water level indicator
• Trac drive
• Zero crossing detector

12 TACKLING INTERFERENCE PROBLEMS ON 433.92MHz
Migrating from 433MHz to 868MHz to escape interference is only a short-term fix for Short Range Devices (SRDs)

16 CAPACITOR SOUND
Cyril Bateman continues his investigations into capacitor bone distortion

24 SPECTRUM PRICING’S UNCERTAIN FUTURE
As a tool for managing radio spectrum, pricing has become the principle tool. David Rodd concludes his report.

26 TYING THE KNOT
Another exciting DIY project from the pen of Jeff Macartney, this time a motion feedback loudspeaker.
**No valid text content could be extracted from the image.**
UK firm outsuts copper with superconductors

A superconductor company has been set up in Cambridge to exploit magnesium diboride, the material unexpectedly found to have superconducting properties by Japanese scientists in 1999. Called 2G-Dxh Dioxide Conductors, the company already has £10,000 from the Cambridge Virtual Incubator Fund. In late November, it was planning to go for £300,000, which will be a mixture of angel and VC (venture capital)," said the company's founder and managing director Dr Philip Sargent.

According to Sargent, the big interest in MgB2 conductors is their low cost, cheaper than copper. He runs high-temperature superconductor HTS as an expensive £300/kA/m, non-superconducting copper at £15/kA/m.

Europe invests in nanotech

As part of its funding programme, the European Union is planning to invest €700m in nanotechnology in the coming four years. "The challenge is so big that it has to be faced by solid public-private partnerships," said EU Research Commissioner Philippe Busquin.

"With private sector contributions this amount should rise to €1bn," he said. Typical projects that could benefit include those in energy storage, processors and display technologies, bio-analysis and drug delivery, robotics and prostheses.

Funding would cover projects such as COUNT, run by six European nanotechnology centres, including NPL in the UK. It is creating a single electron current source and current meter. The equipment pictured allows the circuits to work at temperatures below 50mK. However, the EU's investment is only a fraction of the US funding for nanotech. "The US government is pouring £700m in million dollars per year into this sector," Busquin said.

Disabled man helped by Aliens

Using two motors, speech-recognition software and an exoskeleton inspired by the film Aliens, undergraduates at the US Johns Hopkins University have designed and built a device to help a disabled man grasp and lift. The project was started after the disabled man, with progressive muscle deterioration, approached Volunteers for Medical Engineering, a non-profit organisation, which got in touch with the university. The team rejected electromagnets and air pressure systems, finally settling on two stepper motors for motive power. These move flippers and elbow in small, slow, increments and hold position without power. The words "arm" and "hand" wake up the device, the elbow motor then responds to "raise", "down" or "stop", and hand motor responds to "open", "close" and "stop". A waist-carried rechargeable 12V lead acid battery powers the whole set-up. With the device a user can clap a gun firmly without crushing it. "The students did a wonderful job," said Jan Hoffberger, executive director of Volunteers for Medical Engineering.

Batteries get Guardian angel

A four-person firm from Manchester is developing a chip that monitors standby batteries, giving constant updates on their condition and potentially extending their lifetimes. Guardian Link said its technology could be used in thousands of sites across the UK, including hospitals, air-traffic control and other important sites where standby cells provide backup in case of mains outages.

"But nobody knows what condition these cells are in, because there's no fluid in them anymore," said Nigel Scott, MD of Guardian Link.

"Also, said Scott, “they are more sensitive than the old batteries used to be”.

Scott developed a technique to analyse the cell from the waveforms produced when varying frequency currents are plucked across the cell's terminals. He worked with UMIST which formulated the algorithms needed to analyse the data.

"We wanted to use spectrum analysis to break cells down into electrochemical components," said Scott.

In 1999 this resulted in a benchtop instrument, sold to AVO in the US. Now Scott is working on a single chip version where the IC is integrated into the cell. The cell’s condition is monitored constantly, with data delivered over a CAN bus. The mixed signal chip is in design at the University of Glamorgan. "It's fairly well advanced into its design. We should have it within nine to 12 months," said Scott.

Moreover, Scott said the technique is applicable to any battery chemistry. "The chip could go in a nickel metal hydride pack and tell you the condition of each cell in the pack."

Such a system could help parademics in life-threatening situations when using defibrillators, for example, or with battlefield conditions.

By controlling terminal voltage and avoiding under and over-charging, the chip can also extend battery life, Scott claimed.

This is because all standby cells have slightly differing self-impedences, so charging at constant voltage causes slightly different charging levels. Over-charging causes heat damage, while under-charging results in sulphation.

Thus a battery with a rated lifetime of ten to 12 years might only manage six. "The chip can actively do something for the cell itself," Scott pointed out.

Robot technology steps forward

This is Honda's ASIMO robot, designed essentially to assist humans.

"I think it will take another dozen years until the robots will be used at home," said Toru Takenaka, chief engineer for the ASIMO project.

"Until then there will be some use in the public areas, such as the robots working as a guide at the museums or robots working as a body guard to some persons. Or could be used in the dangerous situations instead of human beings actually being there."

It stands 1.2m tall and weighs 52kg. Currently ASIMO can walk, wave, grasp and lift things on its own, without human assistance.

Power comes from internal nickel-zinc batteries, brushless servomotors provide movement and the body is magnesium alloy. Designed essentially to assist humans, Hong's biggest contribution to robots is probably its research into balance and walking which has produced some of the best biped movement algorithms that exist. These are pulled together under Wind River's VxWorks real-time operating system.

"In the program at any given time more than ten tasks are running and if you include all of the programs, there should be something like several thousands of thousands of commands in it," said Takenaka.

"For instance, a task to take control of leg balance and task to operate arms and also the wireless communication with external systems. Also, there is communication between the motors that actually move joints."

Old idea cleans new telescopes

The huge hi-tech Gemini optical telescopes are being cleaned using surprisingly old tech materials. After much experimentation, detergents normally used to wash horses and natural sponges have proved to be the best combination.

Horse soap, apparently, is a strong detergent but non-abrasive and leaves no residue. Using it and sponges to clean the 8m mirrors was originally developed by technicians at the Gemini South telescope in Chile, but it has now been adopted at Gemini North in Hawaii.

The mirrors are 20m thick, weigh 24 tonnes, and have to be lowered to the ground for cleaning.
**Bright white LED breaks all records**

Lumileds, the Agilent-Philips joint venture, has announced what it claims is the brightest white LED in production.

Called the Luxeon 5-Watt, it emits an incredible 120 lumen, four times the previous record holder which is also a Lumileds product.

Although the LEDs are available unmounted, heat-sinking is said to be so critical that Lumileds will only be supplying most customers with 5W Luxeons pre-mounted to an aluminium-PCB sandwich. Even then, the devices must only be operated with this PCB in good contact with further heatsinking.

Several beam patterns are available, including a 'side-emitting' version which looks to be designed for use with a reflector.

Lumileds' 1W devices are available in a IO variant which has in-built beam-forming optics. Unfortunately for experimenters, this will not be the case with the 5W LEDs.

Green, cyan, blue and royal blue 5Watts are also planned, delivering outputs from 30W (blue) to 125W (green and cyan).

**Greek legend protects PC**

Software giant Microsoft is developing an operating system that adds hardware encryption to block viruses, spam and limit software piracy.

Called Palladium, the system uses its combination of hardware and software to check data from the Internet, CD-ROMs, and even inside the PC, such as from the keyboard or to the monitor.

Palladium checks all applications for author and source before installing, which should stop viruses from loading. It could also apply encryption to documents, so e-mails could only be read and not modified, copied or forwarded by the recipient.

The OS will also be liked by the music and video industries, as it might allow CDs and files to be copied once for personal use, but not more, ensuring copyright is maintained.

Processor firms AMD and Intel are supporting the development of Palladium with dedicated chips for the encryption of data.

The OS could be included in an update to Windows within two or three years.

It is named after the statue of Athena that stood at the gates of Troy, allegedly protecting the city.

---

**Women suffer in science**

Women scientists have fewer opportunities than men, drop out of the profession sooner, while their careers progress slower, claims a report from the European Commission.

The EC survey, covering 30 countries, found discrimination against women in all the European nations.

Philippe Busquin, the EU's Research Commissioner, said: "The evidence demonstrates unquestionably that women scientists are under-represented in key scientific and research positions."

This is despite the fact that women outnumber men at undergraduate level in science, especially in fields such as biological and medical.

**Antenna cuts RF radiation**

UK aerial specialist Sarantel has produced a mobile phone antenna that has a specific absorption rate (SAR) just six per cent that of competing designs.

The Wellington-based firm's PowerHelix design has an SAR of 0.07W/kg, much lower than the 1.26W/kg typical of existing mobile phone antenna.

New legislation is set to force mobile phone makers to state the SAR of their handset on packaging.

"The issue of mobile phone health is escalating rapidly," said Professor Yannis Vardaxoglou of Loughborough University's Centre for Mobile Communications Research (CMCR). The centre has worked with Sarantel to model the near field from the antenna, which uses ceramics and a double-helix moulded aerial.

"The inspiration for a radical redesign of the wireless antenna hit me while I was sending a fax through to our patent agent," said inventor Dr Oliver Leistens, technical director at Sarantel. "Our double-helix design provides lower SAR values for mobile users and reliable connections for wireless LAN and Bluetooth applications."

The firm has 12 patents filed on its designs.

---

**Magnetic RAM reaches 1Mbit**

A magnetic memory device with a density of 1Mbit has been fabricated by Motorola. The achievement is a significant step toward commercial MRAM ICs.

Several firms are pursuing MRAM as it is dense, low power and non-volatile. Motorola and IBM have the major research programmes, although Infineon Technologies and some Taiwanese firms are also interested.

"MRAM has the potential to become the prevalent memory of for Mobile Communications Research (CMCR). The centre has worked with Sarantel to model the near field from the antenna, which uses ceramics and a double-helix moulded aerial.

"The inspiration for a radical redesign of the wireless antenna hit me while I was sending a fax through to our patent agent," said inventor Dr Oliver Leistens, technical director at Sarantel. "Our double-helix design provides lower SAR values for mobile users and reliable connections for wireless LAN and Bluetooth applications."

The firm has 12 patents filed on its designs.

---

**Magnetic sensor is most sensitive**

Researchers at the State University of New York at Buffalo claim to have developed the world's most sensitive nanoscale magnetic sensor. "The magnitude of the magnetic effect created surpasses all previous records," claims the US National Science Foundation which funded the work. Sensor resistance changed "more than 3,000 per cent", said the foundation.

Made of nickel and only a few atoms in diameter, the sensor works with ultra-small magnetic field, at room temperature, said inventors Harsh Deep Chopra and Susan Hua. "The effect is spontaneous and called 'ballistic' magnetoresistance (BMR)."

Chopra predicts the sensor will be used for data storage and the ultimate capacity will be around a straight per square inch, far above today's densities.
Tachos to go digital

One of the UK's most archaic forms of technology, the tachograph, is set to be junked in favour of all-digital units logging data onto smartcards. Switching to digital tachographs on trucks and commercial vehicles across Europe will result in millions of smartcards being issued to professional drivers.

By April 2004, all new vehicles over 3.5 tons will have the digital units. The ruling follows the European Commission's adoption of technical specifications for the tachograph.

"We're replacing an instrument that been in use since the 1970s in a way that's frankly prehistoric," said a spokesperson at the Freight Transport Association.

Existing tachos scratch through a layer of wax on their paper disc to record speed.

"It's a natural progression, but like any change it costs time and money," said the FTA's spokesperson.

"I'm told it will be 25 to 25 per cent more than existing tachos, and the cost relative to the vehicle is small.

The new tachos will interface better with vehicle electronics, said Steve Wilson from manufacturer Siemens VDO: "Vehicles are advancing by using CAN-bus systems, and the tacho must link to that.

The unit itself will include a small alphanumeric LCD and thermal printer.

Pico scopes out car diagnostics

PC instrumentation firm Pico Technology has introduced an automotive diagnostics package for its oscilloscopes.

The Automotive Diagnostics Package can measure car systems such as starter current, signals from ignition, injectors and A,B,C, and RPM sensor outputs.

The system "affords automotive technicians and engineers the ability to make accurate and high-resolution measurements and compare them to... expected results," said Alan Tong, Pico's technical director.

The system uses the firm's ADC-212 oscilloscope, which uses a standard PC to display traces. The kit includes a 600A current clamp, secondary ignition pickup and test clips, leads and probes. Software includes drop-down menus of common automotive tests and expected waveforms to help identify common faults.

"The advantage is when you need to measure and record the majority of the signals, currents and voltages responsible for whether a vehicle is functioning or not," said Tong.

The complete package costs £599, or £200 without the ADC-212.
Tackling interference problems on 433.92MHz

Marc Isherwood, RF specialist at contract design and manufacturer, EMA, asserts that migrating from 433.92MHz to 868MHz to escape interference is only a short-term fix for Short Range Devices (SRDs) and that improving receiver design is a better long-term solution.

Since the days of the earliest transmitters, designers have continually migrated to higher frequencies in order to escape the interference caused by ever-increasing user numbers. Now, with the spectrum fully allocated from 9kHz to 300GHz, designers of Short Range Devices (SRDs), such as security and automotive remote entry systems, are finding that they have nowhere left to move. There are no more green field sites in the RF spectrum. The harmonisation of radio frequencies in the EEC should have made life easier for manufacturers. Instead of producing devices for 224MHz, 315MHz, 433MHz and 869MHz the single figure is now 433.92MHz. But 433.92MHz is not exclusively reserved for SRDs and the frequency is available for radio location as well as amateur and military users.

More traffic means more interference, and many designers of SRDs are abandoning 433.92MHz and have begun an exodus to the newly allocated 868MHz band. But already the cycle is repeating itself: the level of interference on 868MHz is rising and it will only be a matter of time before 868MHz is as crowded as 433.92MHz.

Of course, modulation techniques such as the various spread spectrum systems one make extraordinarily good use of the available bandwidth, but older, less efficient systems are firmly entrenched. Even now the government's desire to turn off analogue TV transmissions to free up much needed space, interference will be a constant challenge for designers. The only viable long-term solution is to make best use of the space that is available. This means better receiver design and, when required, use of the more exotic modulation systems.

At the receiving end

Efficient front-end filtering is critical to overall performance. Today, SAW-front-end filters are available with bandwidths of ±15kHz, making best use of the improved stability of the SAW manufacturing process. The major manufacturers such as RFM, Murata and Epcos make parts available in very small surface mount packages. Fig. 1 shows four centres for the input and output ports available. This does not however mean that things are simple for the designer.

To ensure there are no extraneous coupling effects between the input and output ports there must be no sharing of vias connecting to the ground plane. PCB tracks must be kept to a minimum to minimise inductive and capacitive coupling. Fortunately manufacturers are generally rather specific as to the correct layout for their parts.

To demonstrate the effects of extraneous coupling on the theoretically achievable performance of a typical SAW filter (Epcos B3555) I have performed simulations using the Eagle Gensys simulator. In Fig. 1 the Epcos B3555 is matched as suggested in the manufacturer's data sheet with no shared vias. The strange dips in the response are mostly due to internal reflections in the filter substrate, which vary considerably from manufacturer to manufacturer.

A second simulation used a common ground pin and the degradation in performance caused by introducing this shared via is clearly visible in Fig. 2. Whilst the degradation in the bandwidth characteristics might be considered minor, the ultimate rejection has suffered badly, losing some 40dB at 430MHz. This is due to the inductor now appearing as a shared ground between the input and the output ports. Even with an inductance as low as 0.1nH in the common ground pin, there is a loss of some 20dB in rejection at the same point.

A good approximation for the inductance of a PCB via is given by the following formula where h is the height and d is the diameter of the via in mm.

\[ L = \frac{\mu_0 \pi d^2}{12 h} \]

Even with 0.8mm PCB material and a diameter of 0.3mm, the via's inductance will still be around 0.4nH. In a similar manner, capacitive coupling between the input and output ports of the filter is equally bad. A capacitance of only 0.2pF will produce an equally poor result as shown in Fig. 3.

Another common problem arises with testing the system. Typically, all manufacturers test their RF filters in a 50Ω system, but in the actual application it is most unlikely that the impedances seen by the filter will be 50Ω. Impedance matching of the filter will be required. Some designers assume that the antenna will be 50Ω and only re-match the output of the filter to their systems, Fig. 4.

This will work perfectly when tested on the bench with a 50Ω signal generator or a 50Ω test antenna. Unfortunately, in the wild, antennas are often not the impedance they are supposed to be, particularly when simple whip or loop antennas are used. Even worse, some vehicle manufacturers use a length of wire embedded in the vehicle loom, take your pick for antenna impedance at this point!

Due to its small geometry, the SAW filter is sensitive to static discharge. Although manufacturers are often rather coy about ESD ratings, SAWs can typically only withstand a maximum discharge of a couple of hundred volts. If you really must connect the SAW directly to the antenna then the notes on ESD protection on the RFM website will give useful guidance.

In addition, this arrangement provides no isolation between the serial and the input of the receiver. Any local oscillator leakage present at the input is therefore directly coupled to the antenna and will contribute adversely to the EMC compliance of the product. Whilst a quite effective error in matching the filter simply results in a small loss of signal, a reactive mismatch alters the filter's bandwidth characteristics.

A 10mm error in the effective length of a wave whip can reduce the filter rejection at 433.25MHz from a typical -86dB to -16dB and add another couple of dB to the passband ripple. This can easily occur when track or connection pin lengths between the SAW and antenna are not taken into account. Similar problems occur with stray capacitance on the antenna tracks. The variation in bandwidth response with mismatch depends on the manufacturer of the SAW. Some are far more susceptible to mismatch than others.

Depending on the type of mismatch (inductive or capacitive), the filter either produces the classic triple bump in the passband, with rather sharper shoulders than normal, Fig. 5, or a substantially flat passband with rounded shoulders as shown in Fig. 6. Both forms exhibit a substantially greater in-band loss when compared with the typical -86dB that can be achieved with a properly matched part. (N.B. The mismatch has been exaggerated on both these graphs to make the effect clearer).

These figures only take into account mismatch at the input of the filter. As a SAW Filter is a symmetrical part, this mismatch will be reflected on the impedance seen at the output side of the filter, which can further degrade the response of the system.
To give the receiver software some idea of when a message is about to arrive, a consistent preamble is placed at the front of the message. In AM systems the mark space ratio of this preamble should be the same as the average mark space ratio for the data. This is because in most receivers the AM signal is detected by measuring the difference between the actual signal level and the average signal level. If the average level in the preamble differs from that in the data, then the receiver will appear less sensitive when tested with real data than with a bit error rate tester. This is due to the fact that it takes a finite time for the average level to adjust to that in the data stream, causing the first few bits of the data stream to be missed at low signal levels.

As most SRDs are not transceivers, the receiver cannot request a data packet again if it was not decoded correctly. Either an error correcting code can be used or, more commonly, the message is transmitted more than once. To ensure the best chance of successful transmission, the length of the message should be kept as short as possible.

Avoiding interference by migrating to higher, less cluttered frequencies is a short-term problem, and a front-end filter is essential for any receiver to work successfully in today's crowded spectrum. It is tempting to believe that a receiver can be made by simply connecting an aerial directly to the input of a 'complete' receiver chip. However, even 'complete' receiver chips do not include front-end filters and, in the real world, the performance of such circuits will not achieve the performance guidelines published by RAKE (Radio Activated Keyless Entry). 4

The long-term solution to tackling interference lies in careful front-end design, efficient software management and the correct choice of modulation techniques. These factors have a far greater effect on overall system performance than the operating frequency and allow designers to build circuits which operate effectively at 433.92MHz.

References
  5. American radio office.
  8. Digital modulation techniques.
  10. Power and power/data/technics
  12. Further reading:
      http://www.eagleware.com

Television Special

LIMITED TIME OFFER

Test CAT 5/5e/6 Connections

Just plug one end of your cable into the Atlas IT and the other into the Atlas Terminator and press "test". In seconds the unit will identify the cable type (straight through, crossover or token ring) and verify every connection. If there are any faults then they are clearly explained on screen.

Socket testing is possible too thanks to the special patch cables included in the outfit.

Swapped lines, missing lines, shorted lines are all uniquely identified together with the full connection pattern!

What's more, if you want to know how to make up a special network cable, the Atlas can instruct you, even down to cable colours!

The Atlas IT is supplied in a robust carry case complete with a spare terminator and spare battery.

Visit www.peakelec.co.uk to download the data sheets, user guides and copies of independent reviews.

You can pay using a cheque, postal order, credit or debit card and even pay securely online. Please contact us for overseas or volume orders - you will be pleasantly surprised.

Automatic component identification
Pinout identification
Transistor gain measurement
MOSFET gate threshold measurement
PN junction characteristics measurement
Shorted Junction identification
Just connect the part anywhere round and press the button!
Auto power on/off

Supports:
Bipolar transistors, Darlington transistors, Diode pin rectifiers, Resistor shunted transistors, Enhancement mode MOSFET, Depletion mode MOSFET, Junction FETs, Low power triacs and thyristors, Diodes and diode networks, LEDs (bicouleur). If you don't love it, we will pay your money back.

Available from Farnell, Maplin Electronic, etc.

Peek electronic design ltd
Atlas House, Kiln Lane
Harpur Ind. Est., Buxton
Derbyshire, SK17 9JL, UK
Tel: 01298 70012 Fax: 01298 70046

www.peakelec.co.uk
sales@peakelec.co.uk
COMPONENTS

Capacitor sound 2

Output Buffer and Twin-Tee Notch/Pre-amp.

Most properly designed power amplifiers measure less than 0.01%, or 100 PPM distortion when sine wave tested at 1kHz. Such small distortions are believed inaudible, yet users often claim to hear distortions from these amplifiers when listening to music.

As a result many articles can be found on internet and in specialist magazines, claiming to have identified differences in sound, between different capacitor types. Not by measurements, but by listening tests, having upgraded a capacitor. This has led to a retrofit upgrade market supplying "better" audio grade capacitors, at substantially elevated prices compared to mass market capacitors.

A common subjective claim is that oil impregnated capacitor papers sound better than film types in valve amplifiers. Others claim that a PET capacitor sounds "bright", while a Polypropylene sounds "bright" and that all ceramics sound awful. Naturally these claims have no supporting measurements.

A year ago, a particularly acrimonious letters page dispute arose regarding capacitor distortions. It seemed some of the issues raised could only be resolved by providing proof positive, that many capacitors do cause distortion. I offered to perform some comparative distortion measurements.

Commitment honoured. To measure the distortion level for most capacitors, a very low distortion generator complete with a matching low output impedance, low distortion, buffer amplifier must be used. An easily replicated, low cost, extremely low distortion test generator was described in my last article. Ref. 1

This article describes a matching very low distortion, low output impedance, buffer amplifier needed to generate a pure sine wave voltage across a test capacitor. Having a near 000% input impedance, this buffer amplifier could equally be used with many commercial generators as well as with my design. Fig. 1.

To facilitate measuring capacitor distortions using low cost instrumentation, the 1kHz test fundamental should first be attenuated some 65dB in a passive Twin Tee notch filter. Reducing the dynamic range to be measured.

Using a typical 3 volts test signal, this attenuated test fundamental plus distortion components, is reduced to a few millivolts. This small signal should be band-width filtered and pre-amplified by 40dB, to allow measurement using a 16 bit computer soundcard or the 12 bit Pico ADC-100 converter.

An easily built, low cost buffer amplifier together with a notch filter/pre-amplifier, has been designed on a second PCB. Together with my 1kHz test generator Ref. 1 these two provide a complete system able to measure distortions as small as ±130dB, 0.3 PPM or 0.00003%, below a 5 volt test signal.

To replicate common circuit drive voltages, this buffer should be able to generate up to seven volts RMS across a 1μF capacitor, fed via a 100Ω current limiting source resistor.

Test Requirement. Perhaps you already have a low output impedance test generator. The simple method I used to decide when my equipment was suitable for capacitor distortion measurements, will determine whether your existing equipment can be used.

Using a 100Ω source impedance, connect a 511Ω resistor to ground. Increase the generator output so as to measure 3 volts or more across this 511Ω using a DVM. Remove the DVM and perform a distortion measurement across the 511Ω resistor.

If one PPM or less, replace the resistor by a good, nearly perfect 1μF capacitor and without changing the generator output voltage, perform a distortion measurement across the capacitor. If less than 1 PPM, the equipment can be used to measure capacitor distortions.

The best test capacitor for this would be either a COG ceramic or an extended foil/Polypropylene. These are not distribution items so are impossible to obtain in small quantities.

Many capacitors introduce distortions onto a pure sine wave test signal. In some instances this distortion results from the unfavourable loading which the capacitor imposes onto its valve or semiconductor driver. In others, the capacitor generates the distortion within itself.

To provide a degree of notch filter tuning, a four gang variable resistor is needed, ideally it would be a well matched conductive plastic part. To fit within the screening case it cannot be larger than 18mm diameter. I could not find a suitable four gang conductive plastic potentiometer. Aljos do list a more modest four gang carbon track design, but again I did not find a supplier. Clamping through an old price list from Falcon Electronics. Ref. 2 I found a four gang 4x30KΩ Aljos potentiometer at £1.75, used in active crossover filters. I ordered five potentiometers for evaluation. Apart from being rather old stock needing re-tinning of the terminal pins, they worked well and all were ganged closer than 1dB. I used these pots in both my 1kHz and 100Hz notch filter boards.

Since then a regular and valued correspondent, Juan from Spain, has written to me suggesting I look at the Stereonic P11 four gang 100 kΩ linear control stocked by Selectronic in France. Their part number 22.5701-1 is priced at 22.71 Euros (http://www.selectronic.fr) I visited their web site several times, but the web page will not accept a UK postal code. Without a postal code, their catalogue cannot be requested. I emailed my request, but so far with no success.

The increased resistance of the P11 should not be a problem. To minimise potentiometer distorition, its tuning range is restricted by a 383C series resistor, then bridged by a 22kΩ shunt resistor. With the exception of this variable control, to minimise noise and distortion and for easy replication, all resistors used in the twin tee notch filter signal path up to the first amplifier input, used 0.5% Welwyn RC55C, seen as black in the photo. To save space the four 383C series resistors are mounted between the potentiometer and PCB, as are hidden in the photo.

Figure 1: Very low distortion, low output impedance buffer amplifier, with passive Twin Tee notch filter, bandpass filters and 40dB gain preamp printed circuit board (right). This arrangement was used with my low distortion 1kHz oscillator/develop, can measure capacitor distortions down to ±130dB.

Construcnm the notch filter boards.

Next best is an extended foil and film Polypropylene, closely followed by extended metallised film electrodes with unmetallised Polypropylene dielectric. This last, manufactured by BC Components (Philips) is stocked by Farrell as part 577-881, 0.47μF 250V. I used two of these, type 376 KJP 0.67/230V connected in parallel. Fig. 2.

If you have a generator able to provide suitable low distortion into a 50Ω resistive load, then my buffer amplifier may allow your generator to be used, however it is important to note that the series input impedance were by my buffer, some 112Ω inclusive of the 51Ω R38, is essential for its low distortion. This total value should not be changed.

Buffer amplifier design. The buffer amplifier must not itself contribute measurable distortions. Since distortion levels measured in good capacitors are ±130dB, 0.3 PPM or less, designing a suitable generator and buffer amplifier was no simple task. Designing a suitable buffer amplifier required almost as much development time as was needed for my low distortion oscillator.

To drive 7V RMS into a 100Ω/μF capacitor combination using my generator, a buffer was required with a gain of 2. Many potential buffer amplifier configurations were broad- shielded and rejected. While able to drive a resistive load, they were not able to develop a few volts across a 1μF capacitor without distorting.

An open loop buffer IC, the Burr Brown 4B483MP used with an OPA604 in the makers suggested circuit, worked...
well at low drive voltages or with smaller capacitors. Loaded with a 1000/1μF capacitor test load, it distorts at increased drive levels. By closing one link, this combination can be used on my PCB.

The most nearly suitable circuit I tried was described in the Analog Devices AD797 database. With an AD611 as the output driver, this combination claimed to be able to drive a 600Ω load to 7 volts RMS at 10kHz with less than -10dB distortion.

When breadboarded, this design produced less distortion driving into my capacitive test load than did the BUF634P circuit. For minimum distortion however, the circuit required critical matching of the impedances seen at both AD797 inputs. I was working to ensure matching in November, when my only spare AD797 was damaged. Replacements not being available until February, I was forced to try other IC options. This combination of AD797/AD111 can be used on my PCB.

A low cost NE5534A worked quite well with this AD111 output stage, but again required careful input matching to minimise distortion. An AD404A打扰ed at high drive, but the OPA134/AD111 worked best of all the combinations I tried.

Performance plots in this and my earlier article, were made using this OPA134/AD111 buffer amplifier.

With maximum drive into a 1μF load, the AD111 heats up, so should be fitted with a small heatsink, half of Maple RN69. To minimise noise pickup, the circuit was screened using a small 50mm x 50mm Perspex solder mounting well.

screening can and lid. To reduce heat build up, eight 8mm holes were drilled around the box sides with twelve 8mm holes in the lid. Capable of more than seven volts output, I found this buffer circuit sufficient to measure distortions produced by capacitors from a few hundred picoFarsads up to 1μF, at 1kHz, Fig. 3.

Notch filter/pre-amplifier design.
The minimal distortion of the test signal, a passive Twin Tee notch filter, with a nominal input impedance of 10kΩ is used. To track the notch frequency, this notch is tunable by some ±10% from its nominal 1kHz frequency. Measuring source impedances greater than 1kΩ, the loading of this passive notch filter is excessive. A high input impedance unity gain, low noise low distortion pre-amplifier can then be switched into circuit.

This notch filter is followed by four stages of low noise, low distortion, amplification and bandpass filtering. To minimise input noise, the filtered input is at 50dB down at 10kHz. To reduce high frequency input into the measuring ADC, output is at 22kHz by 22kHz. Amplified by 40dB, harmonics from the 2nd to 9kHz are maintained flat within ±0.5dB. All measurements shown in this and the previous article, were made using this pre-amplifier/pre-amplifier as the input into my ADC-100 converter.

While care was taken to minimise noise and distortion in this notch filter/pre-amplifier, its contribution is included in all my test results. Using this notch filter/pre-amplifier, the distortion of my oscillator, built using AD797 ICs and the OPA134/AD111 buffer, driving 5V into my 10μS/1μT test capacitor load, measured ±130μV or 0.3PPM, Fig. 9.

In most circuit applications, a capacitor is used either connected as a shunt in ground or in series with the signal either to tailor the frequency response or simply block DC. Our test method should permit testing capacitors in either configuration.

Capacitor jigging.
To avoid soldering the capacitor under test, some form of test jig, permitting easy exchange of various size capacitors, is required. The test jig must provide very low resistance and secure connections to the test capacitor.

I tried a number of spring contact terminal blocks. All but one required excessive capacitor lead lengths to ensure secure connections and that needed at least 5mm wires (Farnell part 268-902.) My PCB accepts this terminal block as well as the cage type below, Fig. 4.

Ultimately for my own use I choose a 5mm centres, cage type, screw terminal strip, able to secure capacitors having 4mm long wires (RS part no 425-522.) I designed to accept the wires, they easily accepts 2.5 and 7.5mm spaced tracks within its cage mount. These cage terminals grip a wire tightly but without bending or damaging the capacitor leads. The terminal strip 'jig' was used for all 1kHz measurement plots.

The buffer amplifier/BS filter jig shown can be used to test either series or shunt connected capacitor configurations. My preference is to test test, exactly as shown in the photo. The switchable current limiting resistor in series with the test signal, the capacitor being connected between signal and ground, Fig. 1.

This provides two benefits-:

1) A good capacitor acts to slightly reduce any test generator harmonics, while a bad capacitor clearly shows much increased harmonic amplitudes.

2) The capacitor test voltage can be measured directly, using a high impedance meter attached to the DVM output test point. This test point measures the voltage at the input to the passive Twin Tee notch filter.

A test capacitor connected in series with the test signal, demonstrates the lower frequencies while slightly increasing higher harmonics, relative to the shunt connection. The test voltage can only be measured by connecting a DVM directly across the capacitor. This DVM must be removed before the capacitor can be tested.

Harmonic levels between the two methods differ by only one or two dB for the same capacitor voltage. A good capacitor looks good, and bad capacitors look bad, regardless of testing in the series or shunt arrangements.

By way of comparison, using a 1kΩ source impedance, I plotted test results of a known bad, 0.1μF metallised PET capacitor, measured at the same voltage, measures substantially lower, around ±125dB. Figs 5 & 6.

Series tests.
To test in the series mode, the test capacitor and current limiting resistor are simply interchanged. The test capacitor is connected to the A.O.T resistor Vero Pins and the switch is set to the A.O.T position. The current limiting resistor is fitted to the test jig terminals, replacing the test capacitor shown in the Figure, Fig. 1.

Test Capacitor Source Impedance.
The buffer amplifier output switch provides selection of four values of current limiting, or source impedance resistors. In principle any resistance value can be used to test any capacitor characteristic. However this resistor value determines the maximum test voltage which can be developed across the capacitor and the test's sensitivity.

By way of illustration I plotted test results for a 220μF 50V 50-4 ceramic capacitor, Farnell RN69-524, using each value of current limiting resistor in turn. At 1kHz a 220μF capacitor has an impedance around 720Ω.
In the sixties, engineers at Ericsson believed that non-linearities in capacitors and resistors could be detected. They measured the level of third harmonic distortion generated in a component subject to a very pure sine wave test signal. Resistors were believed to result of badly ground resistor spirals, poor electrical contacts and non-linear materials. At that time, poor contacts, especially in capacitors, were commonplace. Fortunately today, with improved techniques, poor contacts in capacitors are now quite rare. Their original non-linearity detector design produced low distortion test signals at 10 and 50kHz. Third harmonic distortion generated by the component under test was passed through bandpass filters for measurement. Subsequently the 50kHz test frequency was dropped and a commercial instrument, the CTI component linearity tester, was produced by Radiometer of Denmark.

To accommodate the range of component impedances and test voltages needed, a low distortion output transformer was used. Having seven adjustable tapings, it was used to tightly couple the instrument to the component under test. Component impedances from 1Ω to 300kΩ could be directly measured, using source impedances of 0.05Ω to 500Ω respectively.

When testing lower impedance capacitors, the CTI1 device which I still have, claimed to be able to output 0.58 A maximum. Resulting in a maximum test voltage around 100mV at 10kHz testing a 1μF capacitor. In my view this is not sufficient to reveal the true characteristics of such an electrolyte.

Today an updated version can be obtained from Danbridge A/S, Denmark, a specialist manufacturer of capacitor test instruments. Some specialist audio suppliers quote distortion levels for Electrolytic capacitors, measured using the CTLI meter. Because of the capacitance values measured and the 10kHz test frequency, these results usually are based on extremely small test voltages. Such small test voltages will not harm the capacitor and will reveal any shortcomings in the metallic connections used in an electrolytic capacitor. However, in my experience, today these are at such low level as to be unimportant.

Most important and relevant to audio in my view, are the inherent distortions which result from the electrolytic capacitor’s diode characteristics. This diode characteristic is easily measured. Ref 5 From my test measurements at 100Hz and 1kHz, I find significant and measurable distortions when testing electrolytics, using voltages above 0.5V, but less so at very low test voltages. This is exactly the result to be expected from consideration of the constructions used to manufacture these capacitors.

Extremely tight coupling between the test capacitor and the linearity tester is implicit in the CTLI equipment design. From my early work measuring capacitors, I found it necessary to locken this coupling in order to clearly reveal anomalies, now found in many modern capacitors. By trial and error, measuring known good and bad capacitors at 1kHz, I found that 100Ω in series with a 1μF capacitor provided the best compromise between measuring current and capacitor voltage. Adjusting this resistance value according to the conditions of the capacitor impedance, at the test frequency used.

Thus I would normally use the 100kHz source impedance when measuring test capacitors of 1μF and below. Whether these measured capacitor distortions are audible or not depends on the capacitor’s location in the circuit, the subsequent gain of the circuit, capacitor voltage drive levels and whether the capacitor is inside or outside the negative feedback loop. Since I cannot determine that, my object was simply to prove absolutely, using easily repeatable methods, that many capacitors can and do distort a very pure sine wave test signal.

Intermodulations.

Is it possible that any measurable capacitor distortion using a single tone test signal, say distortion greater than 1ppm, will be made many times worse, when subject to a multiplicity of signals?, thus contributing notable intermodulation distortion. Intermodulation distortion measurements of such capacitors using just two pure tones, 100kHz and 1kHz, do show a multiplicity of distortion products, almost regardless of dielectric. Simple intermodulation distortion measurements have been measured in bad metallised film capacitors, i.e. those which show significant distortion above 120kHz, using a single tone. Testing good capacitors with the same two tones, resulted in no intermodulation products being seen.

Compared to the simple case in year 8 with the dual tone test in figure 9, we see distortion products around 20kHz and 4kHz in this dual tone test. They are not visible in the single tone test, even though both tests used the same capacitor, voltage levels and source impedance. Figures 8 & 9.

The level of distortion measured is naturally dependent on capacitor style, construction and the AC voltages present across the capacitor terminals.

Measurement equipment.

I have designed a second printed circuit board, similar to that housing my test oscillator which provides both the buffer amplifier and notch filter/amp/amplifier needed to complete a measurement system. The buffer amplifier section is designed so it can be easily separated from the notch filter/amp/amplifier discussed above.

For values above 1μF, it is common practice to change to using electrolytic types, both tantalum and aluminium. To avoid overstressing such capacitors while maintaining same distortion currents, but the measurement cannot be repeated. Similarly when testing with reduced voltage, the distortion still exist, but can be lost in the noise floor and is not seen. From many measurements of known good and bad capacitors, I found that a compromise between these impedance extremes should be used. Using a 100Ω current limiting resistor with a 1μF capacitor gave the best and most consistent results. Good capacitors looked good and bad capacitors looked very bad.

Figure 8: Distortion plot of the figure 7 capacitor, tested exactly the same except for the current limiting resistor, now 100Ω. Because the capacitor is more tightly coupled to the very low distortion test source, its distortions are partially decoupled, as you might expect.

Figure 9: A dual test frequency intermodulation distortion plot, 100Hz and 1kHz, of the capacitor shown in figure 8. Made using the same voltage and source impedance. Notice the presence of new distortion products around 20kHz and 4kHz, not present when using the single test frequency. Bad metalised film capacitors exhibit similar distortions.

To produce a low distortion notch filter it is important to use resistors having a small voltage coefficient. To ensure an easily reproducible design, I used 0.5W Welwyn IC5/2C metal film resistors, visible as black in the photograph, in the signal path. These are marked as 0.5% on the schematics. These resistors used plated steel endcaps, which I prefer for reliable long term and contact stability. Many scribes claim non-magnetic endcaps are better. I do not subscribe to that belief.

Having emerged from the notch, the fundamental signal has been reduced to a few millivolts, so my usual 1% resistors can be used. Amplified by 40kHz, the maximum output signal is still less than 0.5V.

Low distortion, low noise ICs must be used in this amplifier circuit. In my tests I found the OPA34 worked better than the OPA604 for high input levels, but found the reverse when amplifying the tiny voltages output from the notch filter. For my builds I used OPA34 for the high input impedance, high level, switchable pre-amp U9 and OPA2604 dual IC’s for the low level amplifier stages U1, U2. In each case my preferred IC choice is the first type listed on the schematic drawing. To facilitate evaluating IC’s I used Harwin through pin sockets for each position.

Similarly for capacitors, those used in the notch filter must be low distortion and for the 1kHz version, 1% COG ceramic or extended foil/Polyester types only should be used. At 100kHz which requires 100μF, such capacitors are not easily obtained. Foil Polypropylene then mini-

The widest possible choice of Twin Tee notch and bandpass filter tuning capacitors.
In this and my earlier article I used my Pico ADC-100 for all measurements, with the latest software downloaded from their site. However many readers will not have this ADC and wish to use a soundcard instead. A modern low cost PCI card with FFT software can provide improved convenience, measuring even smaller distortions using my instruments, and is possible using the ADC-100. The software I choose to use for the remainder of this series, is the "Spectra 232Plus" FFT software. It can be downloaded from: www.telemetry.vision.

Should you have only an older ISA soundcard, some software may not work. One that will, is FFT.EXE, a DOS program by Henrik Thomsen. This can be found on the Internet, also the Elektor 96-97 software CD-ROM.

Users having a modern PCI soundcard will find a very large variety of programs, often available as freeware, on the Internet. One site which links to some of the better packages is: www.pcarchtech.com/links/index.htm.

Figure 11: Photograph of the 1kHz version printed board assembly complete with BNC sockets allowed use with Hewlett Packard test jigs or four separate coax cables. The board is identical to figures 4 and 10, except for the added increase in tuning capacitor values and the higher output current buffer amplifier, designed around an Elanite EL.2230C integrat-ed amplifier.

Professional produced printed circuit boards for the 1kHz distortion signal generator, the 1kHz low output impedance buffer amplifier/mixer filter/pret-amplifier boards and the 1kHz DC bias buffer will be available.

Full details of price and availability will be provided in my next article of this series, which will also include details of my DC-biased buffer circuit and PCB.

Technical Support

Professional produced printed circuit boards for the 1kHz low distortion signal generator, the 1kHz low output impedance buffer amplifier/mixer filter/pret-amplifier boards and the 1kHz DC bias buffer will be available. Full details of price and availability will be provided in my next article of this series, which will also include details of my DC-biased buffer circuit and PCB.

References
1 Capacitor Sounds part 1 C.Bateson EW July, 2002
2 Quested Ganged 50k Linear Alps Pots. Falcon Electronics. Norfolk. 01280 578272
3 Harmonic testing points passive component filters. V. Peterton & Per-Olof Harris. Electronics July 11, 1996
4 CLTT Component Linearity Test Equipment data sheet. RE Instruments A.S. Copenhagen
5 Understanding capacitors - Aluminium and tantalum Electronics World June 1998 p.495 C.Bateson

Examples of special offers

TEK 2445A OSCILLOSCOPE - 4 CH - 150 MCS with instruction book, off the stack as come and seen untreated £190 - or tested basic working £300 - or normal Johs Radio workshop test with warranty £380. All supplied with instruction book - qty available.

TEK 2465-2465A-2465B etc available

RACAL DANA 1992 COUNTERS 1.3GHz tested from £250
RACAL DANA 1999 COUNTERS 2.6GHz tested from £400
H.P. 53131A COUNTERS 3.0GHz tested from £750
BENCH + RACK POWER SUPPLIES large range qty from £10
H.P. POWER UNITS 66311B-66312A-66309D in large qty from £250
H. P. 8922 RADIO TEST SETS TYPE G-H-M010 with HP83220 A OR E GSM CONVERTER from £500-£1,000 options available including Spectrum Anz. quantity in stock.

Most previous advertised items available in stock.

4500 CATV SET TOP CONVERTER units unused, boxed, make Texsan - make an offer for the lot within 14 days please!

For more information please contact: Tel: 01274 684007.
Since 1998 spectrum pricing has been applied successfully to many allocations to private operators, but continuing failure to understand its underlying principles has marred its future prospects.

M y article, "Spectrum pricing comes of age" in the August 1997 issue of Electronics World, discussed the principles that were being developed by the UK Department of Trade and Industry (DTI) white paper on spectrum management in 1996. That white paper professed to recognize that the prices charged for spectrum users should not be set to maximise the revenue, but should reflect the value of the spectrum and it proposed initial tariffs for the first allocated services in the private sector. But the preconditions consultations with 400 spectrum users over two years had exposed a conflict between "administrative pricing" and auctions.

The UK government preferred auctions for users in the private sector on the supposed grounds of efficient economic efficiency, transparency, predictability and certainty, but the consultations evinced a marked preference for "administrative pricing". They were the people who had experienced the technical problems of spectrum management at first hand and would not have to cope with the arcane regulations and they preferred the prices to be set "administratively", which meant by the Radiocommunications Agency (RA, the new name for the old RRD), rather than by a newly invented, unruly process. Perhaps these users preferred the devil they knew.

That white paper also announced that the defence and emergency services should have the same incentives for spectrum efficiency as the private sector and would pay charges "on a comparable basis", but it did not explain how that basis would be calculated. I reviewed that white paper for Electronics World in September and October 1996 1. It was of course gratifying to learn that my proposals for dealing with what had become a multi-billion pound national problem, which had involved me for 13 years earlier, looked like reaching the statute book at last. But there followed a general election in 1997 and the new government evidently regarded the radio spectrum as a legitimate source of revenue. It was therefore to be expected that it would probably try to maximise that revenue, as it was predicted in Chapter 8, "Technology and Telecommunications", of my book, "Prosperity from Technology", published in 1999.

Following that white paper, the Wireless Telegraphy Act 1996 gave the RA wide powers to introduce spectrum pricing and they forged ahead with administrative pricing in the ensuing four years - first for mobile networks, then point-to-point fixed links, including the whole private business radio (PBR) sector in July 2000 and extending to earth satellite stations a year later 2. They repeated the commitment to charging the armed forces and emergency services on a comparable basis, but explained that "for the purposes of clarity" the orders are under negotiation with the departments concerned.

In other words, those departments were (and are) supposed to be charged on a "comparable basis" and so increasing the costs of licences unnecessarily in the private sector.

Where angels feared to tread

In the case of administrative pricing, the RA sold five licences for third-generation (3G) mobile phones in a controversial, high-profile auction in 2000. It raised £22.5 billion for the Treasury (10 times the fee per MHz charged to the TV broadcasters and 200 times the fee per MHz for PBR). The sale was subsequently challenged by the National Audit Office (NAO). The stated objectives were optimum efficiency of spectrum utilisation, promotion of competition and realisation of the full value of the spectrum, but there are veiled words. Optimum utilisation efficiency often differs substantially from optimum economy and the meaning of "realisation of full value" is at best ambiguous.

The essence of spectrum pricing is the means of making the best practicable use of a physically scarce resource is that the users should be induced to constrain the charges for spectrum and other costs of using spectrum with their benefits of using it and consider their options. More efficient utilisation would be one way of using less spectrum but it might be better to move to a less congested band or revert to land line. Different users and potential users would come to different conclusions. Some competition would be welcome but competition is not the object and should not be artificially stimulated. Charging users more than the minimum necessary to prevent overcrowding undermines the essential principle of spectrum pricing. On the other hand "realising the full value" in an auction, if it means anything, means that the greatest possible revenue is to be realised. It did not seem to occur to the organisers of the auction, nor to the NAO, that the much higher prices per MHz obtained for the band allocated to 3G licences was an indication that bands that should be somewhat wider and the prices correspondingly lower, and the fees higher. The advantage to the 3G licensees would outweigh the disadvantage to the users in the neighbouring bands.

"Lest we forget", the RA repeatedly denied that the object had been to maximise the proceeds for the Treasury, but the organisation of the auction could hardly have been better crafted if that had been the avowed intent. The RA reserved one licence for the incumbent (now 02) and for any of the four incumbents - Vodafone, BT Cellnet (now O2), T-Mobile (now T-Mobile) in order to stimulate competition. They then employed N. M. Rothschild & Sons limited who, they said, would make a success fee of £700,000 for persuading nine new bidders to participate - at their great expense.

The bidders were required to put in simultaneous sealed bids with £400,000 as a floor price for bidding bonds in a succession of bidding rounds. The highest bidder for each licence in each round was required to secure his licence but could resume bidding in subsequent rounds. The bidding continued down to a second for seven weeks until all but four incumbent operators and one new bidder had dropped out voluntarily. In total there were nearly 500 bids of which more than half were by the eight losing bidders. They were left without licences and had to recoup their bidding costs, including those expensive bid bonds, from their other operations.

That organisation was devised explicitly to simulate auctions of other goods and services. But auctions (e.g. for pictures, houses and second-hand furniture) have evolved and been honed over centuries precisely to maximise the proceeds, but not profitability. If there had to be an auction as a matter of public policy, the RA should have set the maximum interest in advance nor to conduct it during a surge of euphoria in which the demand is likely to be exaggerated, but in the uncertain future prospects. But their inherent randomness, coinciding with no major principal objection to holding auctions at all. And it was a distortion of spectrum pricing to try to give the illusion of an auction by persuading operators to accept a new entrant against the advice of the Universal Mobile Telecommunications (UMTS) operators and the main body representing the telecommunications industry. In the end, the Treasury cleverly avoided a political intervention in the radio communication industry which may yet prove to be a poisoned chalice for the UK in the cut of the bag by reporting that "The timing of the auction was conducive to maximising revenue."

Financial Times newspaper has reported on a survey of traders who estimate that more than four in ten of the population have no interest in third-generation (3G) services which will be a bonus to mobile operators that spent billions on third-generation technology and need a rapid return on their investment. On a political basis a possible disaster has come nearer.

A persistent blind faith in deregulation

On 6th March this year the Department of Trade and Industry (DTI) published the final report of a Review of Radiocommunications in the United Kingdom after the Treasury had rejected it. It was concerned with spectrum valuation, pricing and trading as tools for allocating and assigning scarce radio spectrum across virtually the whole range of frequencies from 88 MHz to 6000 MHz. It runs to 260 A4 pages and makes 47 recommendations.

That review was preceded by a consultation which elicited 80 written responses, including one from myself, but it is impossible to say how much attention, if any, the review team paid to them individually. There are no explicit references to any of the responses in the final report.

Most of the report's 47 recommendations are sensible, but the report remains wedded to the economists' pathetic faith in deregulation and competition as the only effective way of preventing the private operators from exploiting their customers' dependence on their services for the benefit of their shareholders. It advocates extreme trading in spectrum between private operators with scant regard for the practical problems of preventing interference, less than it was feared in the DTI economists' paper in the Meritum report 20 years ago.

In reality the mere existence of four or five operators cannot ensure effective competition beyond the short term. They are an oligopoly and even before the FT survey they expected a process of consolidation in a few years time when the euphoria for high-technology industries in the general and mobile telecommunications in particular has evaporated, as even the NAO recognised. The familiar problems of oligopolistic selling would raise the regulatory costs far above the marginal costs of thecapacity stations that are springing up all over the UK. There will have to be regulation to prevent exploitation and I proposed a new approach to that subject in 1992 but, like many other sensible designs, it was discarded.

Government horizons are inevitably limited to a few years, but one might hope that the first move to the inevitable independent operators would recognise that competition is not going to end the industry's problems in the long term. They might also admit that there is little, if any, competition for the 1737-1805 MHz and 1885-1915MHz spectrum below the sky, of value and maximising the proceeds of selling or leasing it, and that beneficial trading in it depends on all the traders thoroughly understanding the technical complexities. Requiring that necessary expertise would be very expensive and experience has shown that the traders in any competitive industrial field will not go to any expense they hope they can avoid.

The disturbing thing is that the report recommends a policy of specifying bands of spectrum for such purposes and that the price should be determined "by the market users to spectrum users". But it again Folk the problem of how to calculate that value and obscure the anomaly of public and private users being charged at wildly differing rates in adjacent bands. Because the spectrum is physically continuous it follows that ideally the rate per MHz should not change substantially at any such boundary. If a boundary between such bands the rate is high on the side where the higher rate in the adjacent band must be too high. In practice such discrepancies will inevitably continue for many years, but meanwhile they should be valuable indicators of the importance of the charges in the public services and the sizes of their allocations should be gradually adjusted as and when the opportunities next become available.

The report preaches again that spectrum pricing should not be a matter of government, but it does not criticise the auction of third-generation mobile telephone licences in 2000 for becoming just such a device. Moreover it professes to be "concerned that the current regime, which in effect allocates to particular purposes, generate artificial scarcities which . . . ultimately lead to higher prices paid by consumers", without apparently realising that its recommended policy of specifying bands of spectrum for specified public services is an example of just such inflexibility.

As with the traditional theories of technology, spectrum management is not a matter of common sense, nor of applying economic theories to the specific technical or practical problems of the technology itself. There may not be many people in Britain who understand the economics of radio telephony, or the practical problems of the technology and the commercial economics of spectrum supply and demand in detail (other countries may be better placed). But there are some and they will have to be found and put in charge of the matter and given the benefit of reality and communications in the long term.

References
2. "Prospectivity from Technology - a new approach to industrial production, money and trade" in 9, 8776, 562 9, Chapter 8, "Technology and Policies". Copies can be conveniently obtained by direct correspondence to the author at the address above.
7. "Prospectivity from Technology" (see 2 above), Challenging Regulating Monopolies and Oligopolies, Copyright David Rudo 2002.
The notion of using some kind of 'servo feedback' to control speaker cone movement occurred to engineers a very long time ago. The first references that I can find date from the early 1950's and in fact Philips produced some domestic models in the 80's.

B ack in those Halcyon days ideas that we now take for granted, servo theory and negative feedback for example, were not just being widely disseminated. Hi-Fi was very much an enthusiast's activity, especially in this country. Nevertheless, several references can be found for increasing speaker 'damping' in 'The Radio Designers Handbook'. Before discussing these ideas in some detail, it would be as well to define just what motorial feedback is and how it can be employed to improve loudspeaker response.

The main problem in speaker design is that of obtaining a flat Frequency response. A typical loudspeaker has the response of a band-pass filter with a load of different resonances thrown in for good measure. Even when carefully designed, a tolerance of 2 3dB within the 'speaker's pass-band is considered good. Any power amplifier with a similar response variation would be discarded as seriously substandard! The sub of the problem is that a loudspeaker is a mechanical device and that it is passively driven. The only sensible way of linearising the response would be to actively control the cone's motion. This, however, is beset with further problems. Many forms of motorial feedback control have been proposed and tried. All of them are expensive to implement, especially in the context of an existing audio system. Still the prize of a truly flat speaker response is sufficiently alluring to make the effort worthwhile.

Measuring the position of a moving cone is surprisingly difficult and implies the use of some kind of sensor. Among the methods that have been applied include piezoelectric accelerometers, dual voice coils, photoelectric and capacitive proximity detectors and measuring the acoustic output directly with a microphone. All of these methods also require signal-processing circuitry. Furthermore, with the possible exception of using a microphone, these methods are only useful when the driver is operating as a piston. With a typical 8" speaker this region extends only up to 1kHz. At higher frequencies the phenomenon of cone break-up occurs. In this mode different parts of the cone move at different velocities and the servo's signal will become unrepresentative of the driver's output.

There is one area in which motorial feedback can be employed to advantage - namely the improvement of bass response, and this can be done without the use of expensive transducers. The basis of the idea is that a speaker system is itself a transducer and such is it a two-way device. Apply a current and the cone moves. Apply a force to deflect the cone and a back emf is generated which is proportional to the cone's velocity. All that is required is to extract the back emf, process it and apply it as a feedback signal in the power amp stage. The purpose of this article is to tie the knot between this form of motorial feedback and Thinle/Small (T/S) theory.

At first sight motorial feedback speaker systems seem to fly in the face of existing T/S theory. The usual method of designing a speaker system is to take a suitable driver and calculate the enclosure size for a flat response. Because of the interactions between the cabinet and speaker parameters this is not an easy task and the resulting system is usually a compromise between domestic acceptability and performance. However, T/S theory can tell all you need to know about any conceivable speaker/enclosure combination. The difference between a motorial feedback system and a normal system is that the open loop gain of the amplifier is used to strengthen the response at the bass end, in the same way that a negative feedback circuit uses open loop gain to reduce its non-linearity. In the design of a motorial feedback speaker system the enclosure has to be chosen so that the driver cannot self-destruct due to large bass excursions. The resulting system non-linearity is taken care of by the electronics.

If you measure the impedance curve of a driver around the bass resonant frequency you will observe that the impedance is that of a tuned circuit peaking at resonance. The rise in impedance is entirely due to the back emf generated by the driver in response to the mechanical resonance between the compliance of the surround and the cone mass. This rise in impedance can be modelled by an equivalent electronic circuit (see box). In order to suppress the rise in acoustic output around resonance, power amplifiers are designed to have zero output impedance. Unfortunately this doesn't work very well because the speaker's coil resistance is in series with the reactive components. If the output resistance of the power amp were made negative and of the same value as the voice coil resistance then the resonance could be perfectly damped by the amplifier. The result is a response that rises at 6dBye the way. This is because the driver's output would be made directly proportional to cone velocity. In practice this is difficult to do since the adjustment is critical and the voice coil impedance is very sensitive.

However by adjusting the value of the output impedance the Q of the speaker can be controlled and this relates directly to standard T/S theory. Furthermore the feedback voltage is derived directly from the driver's back emf and so qualifies for the term 'Motorial Feedback'. In order to understand the technique we must consider the three main T/S parameters that define the behaviour of a driver at resonance. These are Vas, the volume of air that has the same compliance as the speaker surround, Fs, the free air bass resonant frequency of the driver and Qts the Q of the bass resonance. Qts is essentially the factor that can be varied by the use of negative output impedance.

The definition of Qts includes the output impedance of the driver source the equation being;

\[ Qts = (Qms)^2/Qes \]

Where Qms is the electrical Q and Qes is the mechanical Q of the resonance.

Where Rs is the voice coil resistance and Rg the generator impedance. As previously discussed the output impedance of a power amp is designed to be zero and so Rg is zero. By altering the value of the output impedance Qts, Qes can be varied over a wide range. The relevance of this is that the flat response enclosure size for both sealed and vented speaker enclosures depend critically on the value of Qts. So being able to vary this parameter means that making that ideal system becomes a lot easier! Varying the Q of the driver's resonance is obviously useful, but to make a viable feedback speaker system requires that some other factors are taken into account. The rest of this article is going to concern itself with the design of sealed enclosures, the so-called...
max. baffle or IB type. The major advantage of the IB is that you only have to worry about one resonance and that the rate of bass roll-off is limited to 12dB/octave. Fig. 1 shows the effect of driving an experimental IB enclosure. The upper trace shows the response obtained when driven from a normal amplifier, zero output impedance. The lower trace shows the response obtained from the same enclosure when driven from an amplifier modified to give output impedance of 3.5Ω.

As you can see the resonant peak is far better damped. The enclosure Q has been lowered from 1.2 to 0.4. The importance of having a well damped Q is extremely important. Initially, the original Q of 1.2 response had a bouncy transient response and would overshoot when transient inputs were applied. Secondly, equalisation to a flat response would be difficult. With the Q at 0.5 or less, transients don’t overshoot and the response rolls off initially at a scale of 12dB/octave making equalisation a ‘doddle’, relatively speaking.

It’s also easy to see that, with the IB, the amount of bass that you can generate is limited to the volume of air that the driver can move. That is to say the product of the moving cone area and the peak excursion that the speaker can provide. Although you can simply pick a box size at random and fit the driver in, the results are unlikely to be as desired. The speaker results some design work needs to be done. When trying to obtain the maximum bass from an enclosure, the speaker must be paid enough attention that the driver doesn’t ‘self-destruct’! The reason is that for a flat bass response the cone excursion will increase from 0.5 to 1.2 times half the input frequency. Without correct acoustic loading, the driving force limit will be exceeded and the driver’s coil will become de-coupled or worse.

Luckily, an imp inside an enclosure acts as a mechanical load to the driver that will limit the excursion to tolerable levels providing the correct volume has been chosen. Below the driver’s resonant frequency, the response will drop off at 12dB/octave for a given electrical power input, the same, luckily, as the bass roll off of an IB enclosure. On the other hand, if the cabinet is too small, the full acoustic output will not be reached. In order to find the right enclosure volume you first need to know the electrical power rating, peak excursion and the radiating diameter, D. This can be determined by measuring the diameter of the driver plus half the surround. The last factor required is the sensitivity of the driver expressed as so many dB/W @ 1m. All the T/S parameters should be available in the driver data sheet.

With this information the enclosure can be designed from the following equations. The proof of which was given in Russel Brdeen’s ‘Roaring Subwoofer’ article.

\[ SPL = 10 \log(P) \text{db} / \text{Wm} \]

Where \( S \) is the maximum acoustic output in the driver’s hand pass band, \( P \) is the sensitivity of the driver in db/Wm and \( P \) is the power rating of the amplifier used in Watts RMS.

\[ M1 = 40 \log(D) + 20 \log(A) - 83 \text{ db/Wm} \]

Where \( M1 \) is the maximum acoustic output at 1Hz, into half space, \( D \) is the effective diameter of the driver and \( A \) the peak cone excursion computed in mm. The resonant frequency of the driver in the enclosure, \( Fc \), can be determined from:

\[ Fc = \frac{10^{Fe}}{10^{(M1-1)-(40/3)}}, \text{Qc} \text{ of the driver enclosure volume can be determined by:} \]

\[ Qc = Qc / Fc^2 / Fc \]

Finally the enclosure volume, \( Vh \), can also be determined from:

\[ Vh = Vn = \left( \frac{Qc \times Fc}{F} \right)^2 - 1 \]

Having found our optimum \( Vh \) the frequency response will be far from flat. This is where the motional feedback techniques now come in. A driver, mounted in a sealed box, will have a frequency response exactly the same as a 2nd order high pass electronic filter of the same \( Fc \) and \( Qc \). The classic 2nd order high pass can have a variety of response shapes dependent only on the Q of the filter. As previously discussed the Qc, the ‘Q’ of the speaker system response can be directly varied by manipulating the output impedance of the amplifier.

In his 1952 article\(^1\) Warner Clements outlined a simple technique to alter the output impedance of an amplifier to a negative value. To understand the technique it must be realised that even an infinite amount of negative feedback applied to a power amplifier circuit can only reduce the output impedance to zero. To get a negative output impedance, positive feedback must be used. At first sight the idea of positive feedback in audio circuit is anathema. However it has a long history. For example, many valve amp designs were improved by the judicious use of positive feedback (PF). The idea was to increase the gain of the front-end valve, which typically had little THD by using PF. This improved the open loop gain of the amplifier and thus improved the response and THD when global feedback was applied.

The modern equivalent circuit to Clements’ is shown in outline in Fig. 2. This shows a conventional power amp, \( A1 \), with a feedback loop consisting of \( R1 \) and \( R2 \). The positive feedback is applied via the shunt amplifier, \( A2 \). A small resistor, \( R3 \) is connected in series with the speaker which monitors the current flow through it. The voltage drop across this resistor is thus proportional to the current flowing through it. As the input to this amplifier will be relatively small, the voltage will decrease proportionally. Normally, feedback from this point would be negative. The inverting amplifier produces the \( 180^\circ \) phase shift required to produce positive feedback and the output operates as an earth return for \( R2 \). By inspection you should be able to see that when the system’s impedance rises the positive feedback will fall, reducing the amplifier’s gain and damping out the base resonant peak.

In order to form the circuit to work as desired, \( R3 \) should be \( 3 \times R2 \). The output impedance of the amplifier can then be calculated.

\[ V_{out} = R2 \times V_{in} \]

\[ R_{out} = R2 \]
Pin the image of the document here.
Water level indicator with audible high and low warnings

A versatile, effective and yet simple and low-cost water level indicator is described here.

This circuit represents different water levels in meaningful English characters. It has the added advantage of giving an audible warning at the lowest water level. When the water reaches the uppermost level, the electric motor that pumps the fluid is automatically stopped.

The circuit is also flexible in that it can be made to produce an audible alarm at both the lowest and highest levels.

At the heart of this circuit is programmable array logic device, which is programmable and can be programmed using PALASM assembler. Alternatively you could use a GAL16V8.

The INDICAT-PDS file is the firmware for the PAL. Here a PAL16V8 is used as PAL16L8, i.e. its output will be active low.

Connection to the PAL device can be made in two different ways, represented in Fig 1 and 2 respectively. In Fig 1, the circuit beeps continuously, while when the connections are made as in Fig 2, the device beeps in pulses whose pitch can be controlled using the potentiometer. The circuit displays five different characters on seven-segment display corresponding to five different levels. They are F for full, A for above half full, H for half, L for low and E for empty.

The electric motor is stops automatically when the water reaches the highest-level only if the motor-enable switch, labelled "MRES", is closed. The circuit connects to the motor via a normally-closed relay. The ratings of this relay will depend on the motor used.

I have tested this circuit on a Vynics PAL kit. You can request the PDS file in electronic form by e-mailing me at tejinder_marwah@hotmail.com

Tejinder Singh
New Delhi
India

£50 winner

Watch Slides on TV Make Videos of Your Slides Digitise Your Slides

"Lenging side" automatic slide viewer with built-in high quality colour TV camera. It has a camera slide output to phonograph (ELECTRA A/BG adapter and phonograph are very good conditions with low signs of use. For further details see www.deviant.com £199.00

Using a digital picture camera, such as the Canon Optura LS160, Sony DSC t/a, you can automatically digitize your pictures for fast slide production. The CANON Optura LS160 can also record video and is £99.99. You can also use any other digital picture camera to make your own "Lenging side" and your pictures can be displayed on a monitor. Using the analogue output, such as a 2:1 monitor, you can also display your slides on a TV screen.

In the above example, you can use the CANON Optura LS160 camera to make your own "Lenging side" video. You can also use any other digital picture camera to make your own "Lenging side" and your pictures can be displayed on a monitor. Using the analogue output, such as a 2:1 monitor, you can also display your slides on a TV screen.

The Headphone Amplifier Box

Balanced or unbalanced microphone or line input to headphone output

Professional portable units operating from an internal PP3 battery or external mains adaptors

\* Precision transformerless balanced inputs \* Bridged headphone output drive \* Sensitivity selectable over a wide range of input levels \* Low noise and distortion \* High common mode rejection \* Ultra high frequency \* Extremely RFI protection

The Balance Box (precision milliamp amplifier) - The Phantom Power Box - The OneStop DIN rail mounting radio frequency interference filter and voltage transient protector for voltage and current loop process signal lines

Confod Electronics
Conford Liphook Bumps GU31 2QW
Information line 01428 791469 Fax 75123
Website http://www.confodele.co.uk

ELECTRONICS WORLD September 2002

32

September ELECTRONICS WORLD

33
Triac drive features AC coupling

This circuit makes use of the AC synchronous pulses and a DC voltage to control the delay of an AC phase-control circuit. As there is no floating ground in the circuit and the ground reference is linked to the neutral line, the potential for getting an electric shock from the circuit is greatly reduced.

Typical triac triggering circuits operate at quadrants I and IV. They normally use an RC delay circuit with a bilateral triggering device such as a diac. Unfortunately, the triggering currents in quadrants I and IV are not even. The driving circuit would usually need a high margin to avoid missing the odd pulse. Triggering currents in quadrants II and III on the other hand are relatively equal. In this case, only a negative drive of similar magnitude would be needed. But there is a drawback here in that it is necessary to drive the gate negatively, that is, the flow of triggering current should be sunk out from the gate of the triac.

In order to produce a negative gate drive, most circuits tie the positive supply terminal to the ground terminal, which is shared by MT2, so that the negative current can drive the gate in quadrants II and III. Most triac control circuits in this configuration have "hot" and floating references all over the circuitry. Such a set up can be hazardous.

In the design presented here, the triac driver circuit eliminates such hazards by sharing the common ground of the circuit with the neutral power line. The hazardous locations would only be the power line input and the terminals across the load.

The driving circuit

The circuit is a typical inverter running from synchronous pulses from the zero-crossing detector circuit published on page 36. It does not need to link up to the live line for triac control as other commercial units do. With the introduction of the AC coupling capacitor, it allows additional and adequate protection for the driver circuit.

The basic principle of getting negative drive with a common ground connection is to make use of a charge and discharge circuit. A complementary output driver would be needed.

The capacitor is charged up most of the time and then discharged at 1 to 2ms after the zero-crossing point. This generates a negative pulse current passing through the gate during the discharge cycle. Note that in using the operational

£100 winner

Evaluate the full version risk free for 30 days

Free technical support

Some of the new features

- Full support and list of materials.
- Improved schematics with DIN and ANSI symbols.
- DC simulations and network analysis.
- Schematic borders and title box for professional output.
- Smith and polar plots.
- A massive 16,000 parts as standard.
- Powerful new graphing and plotting - display & switch between multiple graphs easily.
- New "workspace" window to manage your projects and files.
- "New parts" window to instantly pick and place parts.
- Combined digital and analogue graphs.
- Easy to do simulations.
- Unlimited undo/redo.
- Many new simulation models.
- Create new parts.
- Create and edit symbols.
- Create new PCB layout ports.
- New fully featured schematic editor.

Results you can rely on

B² Spice s ease of use and above all, accuracy, is why it is used by large numbers of universities and professional designers in the UK and US. B² Spice delivers simulations that accurately behave like the end result. This new version contains a plethora of additional features, from Radio Frequency simulation to PCB capabilities.

More features and simulation options than ever before

- Simulational, constant, periodic pulse, exponential, RF, single frequency, PM, AM, DC voltage, AC voltage, VCO, Vcc, piecewise linear, polynomial or arbitrary source, voltage-controlled voltage, voltage-controlled current, current-controlled voltage, current-controlled current, lossy and ideal transmission line, MESFET, uniform RC, current and voltage controlled switches are all available.

- Fully mixed mode, single / dual parameter DC sweep, AC sweep, transient analysis, small signal transfer function, Fourier analysis, AC & DC sensitivity, Smith charts, pole zero, Monte Carlo analysis, noise, distortion, operating point, temperature change, as well as generating component faults.

There are NO limits

We set no limit on the size of your design or the number of nodes or parts. It can be as large or as complex as you want. The high quality graphics ensure that your results are easy to understand and interpret. Everything can be customised to suit your needs and preferences.

30 Day no risk trial with free ongoing technical support. If it doesn't do what you want, then simply return it.

From just £159 ex VAT for the standard version.
Normal price - professional version £229 ex VAT.
Upgrades from earlier versions £179 ex VAT.
All libraries included - no hidden extra costs.
Education discounts and site licences available.

Tel: 01603 872331
Research House, Norwich Road, Eastgate
Norwich. NR10 4HA. Fax: 01603 879510
Email info@looking.co.uk www.spice-software.com
Also order on-line through GREY MATTER
www.greymatter.com/mcm/idresearch
amplifier for the driver, there are, in general, three types of output level lowering:

- 0V to Vin/2 = 1.5V, such as LM358,
- 1V to Vin/2 = 0.2V, such as TL082,
- 0V to Vcc/0.6V (rail-to-rail) output, such as TLV2462.

In this application, the output should be close to ground level during discharge so only types of the first two types can be used.

Control circuitry

The control circuit has the following novel aspects: AC coupling gate drive; power saving; independent DC supply voltage.

AC coupling gate drive: The output is virtually isolated from the gate. It provides additional protection to the circuit should someone accidentally short the control gate to MT1 or MT2 during while experimenting. This assumes that the capacitor can withstand the voltage.

Power saving: Since the triggering circuit requires a short duration of discharge current throughout the 10ms period of every half cycle, the triggering pulse may be designed to have a discharge pulse width of, say, 2ms, taking care for the capacitor to be charged up.

Assume that the charging and the discharging rates are linear and perfect. For such a 4:1 current ratio, a triac of 10mA trigger current would only need 2.5mA charging current.

Theoretically, if the triac responds in 1ms during the discharge phase, this gives a ninefold charging advantage. In other words, it is possible to change at 1.1mA for a 10mA triggering device, provided triggering occurs at the right time in the cycle. Hence, the supply current can be adjusted according to the mark space ratio of the driver.

Independent DC supply voltage: Since the triac driver is triggered negatively, it is isolated from the charging current delivered from the operational amplifier, which does not necessarily depend on the supply voltage. Thus the operational amplifier circuit may have a power supply voltage closed to its maximum limit. This would provide more charge to the capacitor for the next discharge pulse, resulting in a further saving in the charging current.

If the current consumed during the operating half cycle is limited, not only can the capacitance be reduced, but also the current consumption of the whole unit.

The complete circuit is shown in Fig. 1. The control signal is a direct voltage selected by an external variable resistor. This circuit may easily be adapted for use with microprocessor control as the input interface can be redesigned to suit various voltages.

Lamp controller

In this lamp controller, Fig. 2, control is set by varying the voltage at the input of U2. The sawtooth wave is delayed by R3/C2 for control at lower conduction angles. These parts can be ignored as they give an improvement in brightness of around 1 to 2dB.

The design is easily interfaced to digital circuitry since there is no worry of flowing ground. A mark-space ratio of 4 to 5 could be easily obtained. Higher ratios would require more precise components and further circuit optimization, such as the addition of logic gates.

The power circuit may also have room for optimization. The standby current could be further reduced by adding a pre-regulating stage of 33V zener and 10uf/25V capacitor.

Since the major current consumer is the triac trigger and the DC power circuit is a shunt regulator, which requires around 3 to 5mA to maintain the regulation, a higher voltage would shunt the charging time and increase the discharge current for triggering. In fact, regulation is not essential as the triggering pulse is generated from the short discharge pulse irrespective to the supply voltage.

A hint for optimizing the performance is to select the right triac first and then calculate the required currents and the pulse widths at different points of the circuit.

Yeuk-chi Chan
Hong Kong

Zero-crossing detector for triac control

Developed for use in lighting control circuits, this zero-crossing detector is simple and costs much less than any ASB of similar function. It also functions as a frequency doubler.

Most triac control circuits require a zero-crossing detector circuit for zero phase reference - especially when the circuit is linked to logic control units.

If the circuit is designed to drive the triac in quadrants II and III, it needs either a negative signal or an isolated triggering circuit. Using a negative supply, greater care is required in analysing the circuit since the reference ground is floated to the live terminal. With an isolated trigger, if the transformer would be expensive and may produce too bulky for small household applications.

This original idea is derived from an old trick for making full wave rectification using only one diode. The answer is to use a bridge circuit of three resistors and one diode. If the reference point is taken from the voltage divider of two identical resistors, then the voltage coming out of the diode should have a full wave rectified waveform.

Single-diode full-wave rectification

A full-wave rectifier is also a frequency doubler where the period of the power line is changed from 20ms to 10ms. The old ways of getting 10ms synchronous pulses could use Exclusive-Or gates or A transformer. These methods would have higher cost and size as compared to the circuits described here.

Figure 1 illustrates how to full-wave rectification out of a single diode. Here, the reference point is shifted up by half of the incoming voltage. This circuit fits our requirement since we don't have to consider the efficiency of the rectifying circuit. Figures 2 and 3 add details.

Zero-crossing detector

The zero-crossing detection circuit is derived from the single diode detection circuit. The load is replaced by the base-emitter connection of an n-p-n transistor.

In order to fix the voltage and allow even pulse width, a second diode is added to balance the waveform. This ensures that the transistor base would remain at a potential difference of two p-n junctions above and below ground level during turn on.

Output from the transistor is a regular 10ms negative pulse waveform. The selection of the resistors may vary the slope of the edges and the pulse widths, Fig. 4.

The circuit requires just a few components to get the full AC synchronous pulses, which in turn could be linked up to a suitable delay circuit for phase control.

The time is important to have the supply voltage common grounded to the neutral line. A simple single wave rectification is enough for Yeuk-chi Chan

Kowloon
Hong Kong

Ten year index: new update

Hard copies and floppy-disk databases both available

Whether as a PC database or as hard copy, SoftCopy can supply a complete index of Electronics World articles going back over the past nine years.

The computerized index of Electronics World magazine covers the nine years from 1988 to 1996, volumes 94 to 102 inclusive and is available now. It contains almost 2000 references to articles, circuit ideas and applications - including a synopsis for each.

The EW index data base is easy to use and very fast. It runs on any IBM or compatible PC with 512K ram and a hard disk.

The disk-based index price is still only £20 inclusive. Please specify whether you need 5.25in, 3.5in DD or 3.5in HD format. Existing users can obtain an upgrade for £15 by quoting their serial number with their order.

Photo copies of Electronics World articles from back issues are available at a flat rate of £3.50 per article, £1 per magazine, excluding postage.

Hard copy Electronics World index

Indexes on paper for volumes 100, 101, and 102 are available at £2 each, excluding postage.
High Resolution Oscilloscope

- High speed 5GS/s dual channel oscilloscope
- 50MHz, 80dB dynamic range spectrum analyser
- PicoScope & PicoLog software supplied FREE
- Plug into any desktop or laptop PC
- High resolution - 12 bits
- Large 128K memory
- 1% DC accuracy

Request your FREE Test & Measurement catalogue and Software & Reference CD, or visit our web site:
www.picotech.com

Tel: +44 (0) 1480 396395 Fax: +44 (0) 1480 396296 E-mail: post@picotech.com

NEW PRODUCTS

Please quote Electronics World when seeking further information

Optical connectors and assemblies
Radiosonic have added the Fujikura range of optical connectors to their product line. The firm’s products are primarily used in fibre optic networks. The standard range of over 45 types includes multimode, field-installable versions, backplane connectors, adapters, mechanical splices and fibre optic cord assemblies. Where applicable the connectors are fully compliant with international specifications including JIS and IEC standards. Cable assemblies are all produced in Fujikura’s ISO9002 accredited facility. Radiosonic Tel: 01784 439093 www.radiosonic.com

Infrared daughter boards open doors
The IRTI and IRDI infrared pulse transmitter and detector from RF Solutions are designed for applications such as automatic door opening and building security systems. Both transmitter and detector boards have 5I/0L pin to enable vertical mounting into customer PCBs. The transmitted infrared beam has a typical frequency of 40kHz and can be detected by the IRDI module at a distance of up to 20m. If the beam is broken, then both high and low output signals are generated on IRDI pins nine and seven respectively. The thick film hybrid technology used on both modules results in stable electrical characteristics and high IRI immunity. Supply voltages required are 9VDC for the transmitter, and either 12 or 24VDC for the detector.
RF Solutions Tel: 01273 480681 www.rfsolutions.co.uk

Low power SRAMs run at 1W
Apta group has introduced a range of monolithic SRAMs designed to minimise power in handheld appliances. Featuring maximum operating and standby power dissipation limits of 1W and 82mW respectively, the MS50ST/256 devices, from the company’s JIMP range, are 512 x 8SRAMs with access times of 15ns and 20ns. The devices are packaged in a 48-ball (1mm pitch) 'chip size' bga ball

Fast probes for 5GHz scope
Tektronix has announced two oscilloscope probes and accessories for the acquisition and analysis of high-speed signals in computer, communications and advanced electronics. It is the firm’s first oscilloscope probe to implement IBM’s silicon germanium (SiGe) technology. Called the P7260, the active probe has a 6GHz bandwidth and better than 75ps rise time capability. It features a toggle switch that offers the choice of using the probe with a dynamic range of 6V peak-to-peak with ±25 attenuation or at 1.5V peak-to-peak with ±5 attenuation with increased sensitivity. An input capacitance of less than 0.5pF. The PPM100 Probe Positioner employs 3-axis control that holds a probe in position, the tool is available with either a high-mass base camp or a clamp. The TCA-1MEG high-impedance buffer amplifier provides selectable input coupling, selectable bandwidth limits, and a 1MHz input.
Tektronix Tel: 01344 390000 www.tektronix.com

September 2002 ELECTRONICS WORLD 38
Motor drive gets intelligent power module
International Rectifier (IR) has launched its first programmable isolated intelligent power module (IP-IPM) in the INTERO range. The device integrates the power stage with the embedded drive board containing a programmable DSP on board. It is designed for three-phase, AC induction and brushless DC industrial and servo motor drive up to 15kW. The IRPMB1050-1200 is rated at 1000V and 50A and includes all power semiconductor for three-phase inverter power stage, including no-punch-through IGBTs, as well as a programmable 40MIPS DSP, current sensing, isolation, protection and power stage protection for direct interface with the motor drive host and the input stage. The module includes an ascertainable 25mMHz serial port compatible with the scalable controller interface (SCIF) IEEE 1588-1992 (SCIF), service provider interface (SPI), and controller area network (CAN). A joint Action Test Group (JTAG) IEEE 1149.1 standard port for DSP interfacing and an isolated serial port input with strobe signal for quadrant encoders or SPI communication are also included. The device is housed in the BMP package that has the mechanical outline of the industry-standard Encapsulated Pin 2 package. International Rectifier Tel: 020 8465 8000 www.if.com

Power buffer IC gets in a tri-state
Torex Semiconductor has a pair of tri-state output power buffer IC with built-in lead-frame and divider circuits. Designed for voltage-controlled optical oscillator circuits, the XC2300I are CMOS buffers with maximum operating frequencies of 70 and 160MHz respectively. Torex Semiconductor Tel: 1509 899992 www.torex.co.jp

Packet processor for 3G basestation
Broadcom Technology is offering an access packet processor from WinPath designed to handle data and control path packet processing functions required in 2.5G and 3G basestations and subscriber loop access multiplexers. The design incorporates a MIPS440 Risc processor core, which can be removed and used with an external PowerPC compatible processor. With 18 instruction-parallel cores available in the WinPath771 which includes both control path and data path functionality and the WIN770 for data path only (no MIPS core). Each product is offered in both 166MHz and 200MHz versions. Broadcom Technology Tel: 01727 791000 www.broadcom.co.uk

Microwave or optical test get custom switch system
Philips Electronics has launched an automotive software semiconductor design tool, the SAPT350 is a dual IF car radio and audio Digital Signal Processor (DSP). According to the supplier, user specific functions can be configured to match the software platform required for the car radio manufacturer's system. The chipset includes audio features including adaptive ultrasound 11 kHz and hearing loss, combined with a high sound quality. The software radio also includes an IDE interface, enabling digital radio. Philips Electronics Tel: 0021 40 272 0291 www.semiconductors.philips.com

Trimmers for tight corners
A small trimmer chip capacitor measuring 1x1.7 x 0.85mm is available from Murata. According to the supplier, the TZR1 series requires one third of the board mounting area of a 2mm device. The trimmer is available in two capacitance value ranges: 1.5 to 4.0pF and 3.0 to 8.0pF. Both are available at 25°C, operating temperature range from -25°C to 85°C. Primarily designed for high frequency applications, these miniature trimmers are suitable for RF and wireless equipment applications. Murata Tel: 01250 81666 www.murata.co.jp

Light low VCO for wireless Internet systems
Semicoretronics is offering a VCO specifically for wireless Internet systems, which generates frequencies between 2535-2675MHz within 0.4-2.9% DC of control voltage. According to the supplier, this low VCO VCO exhibits a clean spectral signal of ~86dBc/Hz, typically. The SMV250A/0 provides the end user with an output power range of 55dBc/Hz to a 50ohm load and supports the

Controller with built-in TCP/IP
Epson's latest network controller incorporates the protocol stack functions and other elements needed to connect household and industrial appliances to a network. As protocols required for TCP/IP connectivity are processed internally, only simple command and data need to be sent from the host MPU. The S500000 network controller that use 8-16 bit MIPS to change into network- connectable devices without any advanced operating system or commercial protocol stack. The company also intends to provide IPv6 support for faster connections and intends to develop an interface module that incorporates the S500000 network controller. While the protocol stack includes ARP, ICMP, IP, TCP, UDP, HTTP, DHCP, TFTP, SMTP, SNMP, with IPv6 under planning. Applications are expected to include home electronics products, home security, home gateways, electric power and gas control terminals.

150W switching PSU in 1U enclosure
Ultimate Renaissance is offering EU-Com factor switchers packing 150W and available in output voltages from 1.8V to 48V. The CoreTech is available in quad, triple, dual and single output versions. Each output voltage is selectable from 3.3V to 48V from output 1 and 2, at 150W maximum from output 1 and 100W maximum from output 2. Choices for outputs 3 and 4 allow any values from 3.3V to 24V, at 45W. Outputs 3 and 4 can also be combined for a maximum 60W continuous delivery. Features include remote sensing, single wire current sharing on outputs 1 and 2, OVP, over current protection and thermal shutdown. Active power factor correction is also included and all units are packed in 4.2 x 8 x 1.5m. u-channel suitable for 19" enclosures. Ultimate Renaissance Tel: 01795 439310 www.ur-home.co.uk

100W quarter-brick DC/DC converters deliver 1.2V
The Lambda PAQ series of DC/DC converters, available from Powerline, is a range of industry-standard quarter-brick profile devices with ratings from 50 to 100W designed for use in distributed power systems where the voltage is converted at board level, the units feature up to 90 per cent efficiency and do not require heatsinks. Nominal input voltage is 48V DC and output voltages of 1.2V, 1.8V, 2.5V, 3.3V and 5V are available at current ratings from 10A to 25A depending on the model. Line and load regulation are 10mV. Overcurrent and overvoltage protection are fisted as standard. Remote sensing, remote on/off control and series operation are available as options. Powerline Tel: 01094 753800 www.powerline.co.uk

Alphanumeric LCD with CMOS drivers
The 3C series of alphanumeric dot-matrix LCD modules from Wibledon-based CTI Components have been designed with built-in CMOS driver devices to reduce component count and simplify the interface circuitry. Available in formats ranging from 2 lines of 8 characters to 4 lines of 40 characters.
NEWPRODUCTS

Please quote Electronics World when seeking further information.

High reliability memory wins size upgrade

Apa, formerly HMP Europe, has upgraded its range of high reliability memory modules making use of its printed uncommitted memory array (Puma) design, which allows for the addition of higher order address lines. The 4 x 512k x 8 Puma2 SRAMs feature the same footprint as the first generation 4 x 8k x 8 devices. The hermetically sealed, ceramic part is housed in a 66-pin PGA package. The range can now offer: 8, 16 and 32-bit wide memory devices. They are user-configurable, and upgradeable and can feature a combination of memory types, such as EEPROM, flash and SRAM in a single footprint. For example, a 512k x 16 flash and 128k x 8 SRAM die can be supplied in one device. There is also a surface mount equivalent constructed as two stack layers each with two memory die.

Apa
Tel: 0151 2903500

Low power microcontroller

Hitachi has introduced the first member of its HI950X low power series of flash microcontrollers. The HI9502024F is also the first member of the series to offer an on-chip debug interface, which allows users to debug applications in circuit using the firm's own EDF debugger. The microcontroller incorporates 32kbytes of flash memory that can be programmed and erased with a single power supply. The device operates at maximum frequency of 10MHz using a 3V power supply, and offers on-chip peripherals including a 32kbit sub-clock, timers, a special asynchronous timer, watchdog timer, asynchronous/synchronous serial interface, 10-bit analog-to-digital converter, 32 x 4 LCD controller/driving and high-current pins. The device is supported by the E6000 real-time in-circuit emulator with 4Mbyte of emulation RAM, 256 PC break points and 12 cascadeable and complex hardware break points (events). An evaluation board is available. The HI930204F is available in two 80-pin Quad Flat Packages, the 14 x 14mm QFP-80A and the 14 x 20mm QFP-80B, as well as a 2 x 12mm 80-pin Thin Quad Package, the TQPQ-80C. Hitachi
Tel: 01628 581563
www.hitachi-eu.com

Controller with built-in TCP/IP

Toshiba Electronics has launched a range of miniature chip scale power Mosfet packages that it claims are over 60 per cent thinner than conventional TO-220M (D2PAK) devices and require 30 per cent less PCB mounting area. Called the Slim TFP package, it has a board mounting area of 10.7 x 9.2mm and a profile of 1.7mm. The devices have high DC current handling capabilities and are rated for power dissipation of up to 125W. A four-pin structure (gate, drive source, main current source and drain) is intended to minimise the effects of parasitic inductances while offering electrical noise immunity. The first Mosfet in the new package will be a 500V, 8A device with an on-resistance of 750mΩ. Future devices will include 200 and 250V Mosfets.

Toshiba
Tel: 01276 694730
www.toshiba-europe.com

FRUSTATED!

Looking for ICs TRANSISTORS!

A phone call to us could get a result. We offer an extensive range and with a World-wide database at our fingertips, we are able to source even more. We specialise in devices with the following prefix (to name but a few):

SJ SAA 5SA 5SB 5SC 5SD 5SE 5SF 5SG 5SH 5SI 5SK 5SL 5SM 5SN 5SO 5SP 5SQ SSS 5SSU 5ST 5SU 5SV 5SW 5SX 5SY 5SZ

We can also offer equivalents (at customers' risk).

We also stock a full range of other electronic components.

Tel, phone, Fax, Credit Card orders & calls welcome.

Cricklewood Electronics Ltd

Professional PCB Layout & Mixed Mode Simulation at Computer Store Prices!!

£97

NEW Easy-PC V6.0

Easy-PC for Windows V6.0 is released with now even more time saving features:

• On-line design rules checking
• Single 'shot' post processing for all your output files
• PCB Footprint & Schematic Wizards for fast creation
• Import DXF files from your mechanical drawings
• and many more new features!

Spice Based Simulator

Easy-Spice is a powerful A/O mixed mode simulator with superior convergence and functionality.

• Easy-Spice is integrated with Easy-PC Schematics
• Supplied ready to use with SPICE libraries and models
• Easy to learn and use and supplied with a full manual

For more information or for a demo copy call us on +44 (0)1684 773662 fax +44 (0)1684 773664 or E-mail info@numberone.com or download a demo copy from www.numberone.com

September 2002 ELECTRONICS WORLD
NEWPRODUCTS

Please quote Electronics World when seeking further information

controllers. The TPS400x PWM step-down DC-DC controllers feature a patented predictive gate drive technology and are designed to achieve overall converter efficiencies greater than 95 per cent, said the supplier. PUD technology is designed to provide the highest efficiency in step-down control by driving Mosfet power transistors at two to four per cent greater efficiency than conventional adaptive gate drive technology. Two internally fixed operating frequencies are available, at 300 and 600 kHz, as well as source and sink options. A programmable closed-loop soft start, short circuit disable and thermal shutdown provide protection for system circuitry. Texas Instruments Tel: 01242 290000 www.ti.com

200W power module baseplate cooling

Lambda's latest halfbrick DC-DC power module has a nominal input voltage of 48V. The single output 200W PAH200484 series offers a range of output voltage of 1.8, 2.5 or 3.3V. The DC-DC converter has a power density of 72.4 W/in² and power efficiency of 90 per cent at an output of 3.3V. According to the supplier, there is no need for baseplate cooling under normal temperature conditions. Module footprint is 58 x 61mm and profile is 40mm. The open modules can be convection or forced air cooled. Operating temperature range is –40 to 85°C. Lambda Tel: 01271 856666 www.lambda-gb.com

CMOS monochrome and colour CMOS image sensors

National Semiconductor has expanded its range of CMOS image sensors which are expected to find applications in wireless access devices, entry-level digital cameras and industrial products, including security cameras and scanners. The monochrome LM9618 and colour LM9628 VGA CMOS image sensors feature the wide linear and non-linear dynamic ranges and operate over industrial temperature ranges, so are suitable for outdoor applications. The sub-QCIF (quadrature common interface format) LM9630 supports frame rates exceeding 60fps. The 1.3Mpixel monochrome LM96338 and colour LM9648 sensors offer an optical format of one half inch. National Semiconductor Tel: 0870 2421771 www.national.com

Multimeter has reference accuracy

Fluke's 8050A reference multimeter is an 8.5-digit resolution instrument designed as a precision measurement tool for calibration laboratories. In addition to measuring voltage and current for both AC and DC, and frequency, the meter also includes other features. A ratio feature, with front and rear connectors supporting all 8050A functions and GPIB control, allows for automated measurement transfers. There is also current measurement up to 20A. One year accuracy is specified as ±1ppm and 20-minute transfer uncertainty is 0.12ppm. Fluke Tel: 01604 256689 www.fluke.co.uk

1GHz SAW filter for networking

Epson’s quartz-based precision SAW (surface acoustic wave) resonator for networking applications is claimed to improve on the temperature characteristics compared to conventional SAW resonators by 50 per cent. The firm also offers prototype-free custom device development. The SAW resonator has an improved temperature coefficient of –1.7 ± 10⁻⁶. Fundamental oscillation up to 1GHz is supported. Epson www.epson-electronics.de

Processor board has PCI bridge to 133MHz

Radstone Technology’s latest G4DSP signal processor board based on the 7410 PowerPC is some processors with AVX-Vec between 400MHz and 550MHz includes a processor and memory upgrade. The design means that the board provides each 7410 PowerPC™compatible node with 32MB of 72bit 400MHz PRAM, to a peak of 133MHz. As with the hardware architecture, software support is also open standard to protect software investment and ease development. The G4DSP supports VxWorks, VxMP and VSPWorks DSP OS from Wind River Systems and also MPI message passing libraries and VSPIL signal processing libraries from MPI Software Technology. It is available in five ruggedisation build levels for industrial or extended temperature, shock and vibration environments in either air-blown or conduction-cooled formats. Radstone Tel: 01327 259444 www.radstone.co.uk

CROSSFIRE

SUPERCONTROLLERS

ALSO LOW COST

DEVELOPMENT

Target easily & quickly.

It CAN™ 'C' compiler, assembler & linker all Windows® based.

Support all languages.

Slew Rate Debug.

Full Driver Support with Libraries.

Real Time Multitasking OS with free run time license.

Free Unlimited email support.

www.cms.co.uk

see our web site for full details

E A SOWTER LTD

PO Box 36 IPSWICH IP1 2EL ENGLAND

Tel: +44(0)1473 252794

Fax: +44(0)1473 252188

E Mail: sales@sowter.co.uk

Web: http://www.sowter.co.uk

Design and Manufacture of all types of Audio Transformer using Nickel and Grain Oriented cores

Free catalogue

Free technical support service

Popular types from stock

ELECTRONICS WORLD September 2002

www.cms.co.uk

see our web site for full details

CAMBRIDGE MICROPROCESSOR SYSTEMS LTD

Unit 17-18 Zone ‘D’ Chelmford Rd Ind Est. Great Dunmow, Essex CM6 1XG

Telephone: 01371 875644 email: sales@cms.co.uk

Telford Electronics

Old Offices Mess, Hoo Farm, Hurners Lane, Harton, Telford, Shropshire TF6 6DJ, UK

Tel: (0044) 01952 665451 / 670178

Fax: (0044) 01952 677978

E-mail: telfordelectronics@btinternet.com / marc.007@btinternet.com

Web: http://www.telford-electronics.com

Shop opening to the public on Saturday 7 September 2002 9am – 2pm

Second User – Electronic Test and Measuring Instruments – DC to 100 GHz

FANTASTIC BARGAINS TO BE HAD

Please visit our regularly updated web site for all your equipment needs.

We have a clearance/graveyard site with goods from as little as £15.00!!
Transparent V-I protection in Audio Power Amplifiers

Part I

The desirability or lack thereof, of over-voltage and over-current protection for power semiconductors in audio power amplifiers remains a point of contention in the field. Michael Kiwanuka explains.

For example, Nelson Paulo suggests recommending multiple transistor complementary output stages, as mandated by class-A operation, to circumvent the need for V-I protection of bipolar devices, while Rod Elliot suggests that V-I limiters can be dispensed with altogether by adopting e-MOSFETs.

These views appear to be rather more widely accepted than they should, and constitute a charter for near heroic unwavishness in amplifiers so configured. The error diode-clamping of gate-source voltage for e-MOSFETs is thought by some to be all that is required with regard to protection. While the over-diode method (identical with 10V>V_{gs}<20V to prevent premature clamping), they only serve to protect the e-MOSFET gate oxide from over-voltage destruction, and do nothing whatsoever to protect the device from accidental short circuits and forbidden voltage-current combinations that may occur when the amplifier is called upon to drive reactive loads.

The positive temperature coefficient of on-resistance and therefore negative temperature coefficient of drain current, enjoyed by e-MOSFETs eliminates the secondary breakdown phenomenon which is the bane of bipolar transistors, but does not constitute a licence for willful violation of power dissipation limits in linear audio-frequency applications. This is in contrast to ultrasonic switching usage, where e-MOSFET dissipation bounds can be blissfully ignored, and adherence to drain current and drain-source voltage limits will suffice.

All output stage semiconductors used in complementary, or quasi-complementary, (Bell or half bridge), linear audio power amplifiers, without exception, require V-I protection for reliable operation. However, such circuitry must be carefully designed to prevent premature activation during normal amplifier operation.

**Single-slope, linear-foldback limiting**

Musty to medium-power, (sub-100W), commercial audio amplifiers incorporate a single-slope, linear foldback, voltage-current protection circuitry (Figure 1), attributed to S.O. Finch. In practice, the complementary output transistors, T1 and T2, may exist as a compound arrangement of at least two transistors in series. The collector-emitter voltage, Vce, across T2 is sensed by R1 and R2, while the output current, in the guise of a voltage developed across emitter resistor R1, is simultaneously monitored by R1 and R2. The voltages are thus summed algebraically at the base of the protection transistor, T2, which is driven into conduction, shunting the current to T2, in the event of an over-voltage, over-current or simultaneous occurrence of both conditions in the output device.

The series resistor, R1, (typically 100k), expedites this process by limiting the current required by T2, to shunt voltage drive to T2. The forward-biasing diode, Dp, protects the output device from excessive base-emitter reverse bias due to over-rail voltage spikes generated by inductive loads, while Dp performs the same function for the small-signal protection transistor, by preventing its base-collector junction from being forward biased.

If the output approaches the negative supply rail while driving a sufficiently low impedance, the current sunk by T2 generates an appreciable voltage drop across its emitter resistor. The output is therefore at a significantly higher potential than the common input to the complementary output stage. Transistor T1 is reverse biased, and T2 is base-collector junction, in the absence of Dp, would be forward biased, resulting in current flow from emitter to collector.

Diode Dp prevents this form of spurious, inverse- active mode limiter activation by decoupling T2's collector as T2's base-emitter is reverse biased. The potential at T2's emitter is then equal to the output voltage since, contrary to Duncan's non-conducting and non-zero current, except negligible leakage, flows through its emitter resistor. By

### Figure 1: Single slope, linear-foldback protection circuit applied to a complementary emitter follower.

### Figure 3: Output conditions at point A on the protection locus in figure 2.

### Figure 4: Output conditions at point B on the protection locus in figure 2.

**symmetry**, the explanation above also applies to the negative half of the circuit. A small-value capacitor is sometimes connected across the base-collector junction of each protection transistor, with a view to eliminating any parasitic oscillation that may occur sporadically in the network during the limiting process. These capacitors appear in parallel at A, C and are entirely unnecessary, as they create an ill-defined and therefore undesirable feed-forward path around the output stage, shunting it out of the global feedback loop at high audio frequencies, precisely where the amplifier is most vulnerable with respect to non-linearity. Such vulnerability is due to a necessarily diminished feedback factor at high audio frequencies in the interest of Nyquist stability. Connecting the capacitor, (of the order of 100pF), across the base-emitter junction of each protection transistor is the preferred solution.

The resistor values for the arrangement in Figure 1 are obtained by drawing the desired protection locus onto a linear scale graph of the output transistor's safe operating area, (S.O.A). One of the three resistors (usually R1), is assigned an arbitrary value (typically 100kΩ), and the remaining resistors calculated from simultaneous equations developed from two convergence points on the protection locus.

This arrangement requires that the linear protection locus intersects the S.O.A's Vce axis at a value greater than the sum of the module of the amplifiers supply voltages, otherwise T2, turns on under normal loading when the output swings negative, even with the open-circuit output. Similarly T1 must be activated under normal output loading when the output swings positive. This effectively short-circuits the small signal circuit preceding the output stage directly to the output, causing gross and very audible distortion. Failure to adhere to the above condition appears to have caused some designers to erroneously abandon electronic S.O.A protection of any form altogether.

This requirement however, constitutes a significant limitation with regard to efficient utilisation of the comparatively large S.O.A in the low-Vce region of the graph, especially at high supply-rail voltages when, in the case of bipolar transistors, secondary breakdown severely curtails flexibility in optimal placement of the protection locus. This is graphically illustrated in figure 2, for an amplifier with ±40V supply rails, using Motorola's excellent 14000W, MJL3281A-MJL1302A complementary power transistors.

Only the positive half, Fig. 3, of the circuit in figure 1 needs to be calculated to the required component values. Ideal devices are assumed, with infinite input impedance, zero saturation voltage, and zero ohmic resistance, the error thus accrued is negligible. Let V_{C}±0V5, R_{L}=220R, R_{L}=22R. Taking two arbitrary points, A and B on the locus, such that,

\[ 0.6 \leq \left| V_{C} \right| \leq 80V \]

where for point A, I_{C}=6.85A, V_{C}=0V, and for point B,
PROJECTS

\[ I_{c} = 4A, \ V_{CC}=36V, \ \text{it follows from figure 3:} \]

\[ R_{e} + R \cong 220/(R + 220) \]

With reference to figure 4:

\[ I_{c} = I_{T} + I_{T} \]

\[ I_{c} = 0.6/0.6 - 3.72)/R + (4 - 3.72)/R \]

\[ 0.6 + R_{e}(36.28/R + 0.28/220) \]

(3)

Solving (1) and (3) simultaneously gives \( R_{e} = 2K4 \) and \( R_{e} = 1430R \). To afford an acceptable degree of precision, it is recommended where necessary, that these values be made up from series, or parallel combinations of 1% resistors.

When the output swings to +40V, then 80V appears across \( R_{e} \) in series with \( R_{e}/2R_{e} \), to a good first approximation. Therefore the voltage present at the base of the protection transistor, \( T_{P} \), is given by:

\[ V_{C} = \frac{80(R_{e}/R_{e})}{(R_{e}/R_{e}) + R} \]

It follows therefore that subject to instantaneous collector current, \( I_{c} \), being less than the maximum permissible collector current, \( I_{CMAX} \), at \( V_{CC}=20V \), spontaneous activation of \( T_{P} \) cannot occur. A general expression which shows the rapid verification of the compliance of any amplifier using single slope, linear foldback limiting may developed:

\[ 2V_{C}(R_{e}/R_{e}) + R \]

\[ V_{C} = 0.6/6 \]

(4)

Equation 4 is valid subject to the following condition:

\[ I_{c} = \frac{I_{CMAX}}{\sum R} \]

(5)

This condition is invariably fulfilled during normal operation, as no practical loudspeaker system would demand that the output transistor sustain \( V_{CC}=20V \), while providing any appreciable current.

Figure 5: Compromised single slope, linear foldback scheme resulting in grossly inefficient S.O.A utilisation.

Figure 6: Linear protection locus clearly shows infeasibility of scheme in figure 5.

Figure 7: Output conditions at point B on the protection locus in figure 6.

Figure 8: Ideal emitter follower used to determine instantaneous collector current, \( I_{C} \), collector-emitter voltage, \( V_{CE} \), and device dissipation, \( P_{D} \).

Figure 9: Instantaneous Vce, \( I_{C} \), and \( P_{D} \) in sourcing output transistor, driving 100W into \( (80/60) \).

Driving reactive loads.

A clear appreciation of the nature of the amplifier's load is required to establish the bounds within which the V-I limiter must remain reactive. Figure 8 shows an ideal complementary emitter follower, (in Electronics Workbench's excellent Multisim professional simulation), used to drive a standard \((80/60) \) test load to +40V supply rails.

The plots obtained in Fig. 9, show that the voltage \( V_{CC} \), across \( T_{P} \) is precisely 180° out of phase with the current, \( I_{c} \), is required to source, the voltage across the device is at a minimum when its collector current is at a maximum, and vice versa. Instantaneous power dissipation is merely the product of instantaneous device voltage and current. Peak transistor dissipation, \( P_{D\text{peak}}=50W \), occurs twice in \( T_{P} \) 's conducting half-cycle, at half the peak load voltage, \( V_{CC}=20V \), and half the peak load current, \( I_{CC}=25A \). As the \((80/60) \) load line lies well below the linear protection locus in figure 10, (reproduced from figure 2), it is clear that a single pair of MJE3281A/MJE330A power transistors, operating from ±40V rails will comfortably drive an 80Ω dummy load to clipping without V-I limiting. This however, will certainly not be the case with loudspeaker loads, which are invariably reactive 17/8. An amplifier with 'high-fidelity' aspirations, intended to drive full-range, multiple-transistor loudspeaker systems, including electrostats, should at least be capable of driving a \((46/60) \) impedance without V-I limiting.

An \((46/60) \) impedance was devised by driving a 20Ω resistor in series with a 45Ω 9441 capacitor at 1KHz with the ideal complementary emitter follower in figure 8. The tracs thus obtained, Fig. 11, were used to plot the \((46/60) \) load line in figure 10. Peak transistor dissipation, \( P_{D\text{peak}}=352.9W \), occurs at \( V_{CC}=65.97V \), and \( I_{CC}=56A \). In other words Fig. 12, because current leads voltage in a capacitive impedance, the NPN transistor, \( T_{P} \) in figure 8, is required to source \( 7.68A \) when the output swings.
Figure 10: Reactive load gives rise to an elliptical line, resulting in more than seven times greater peak device dissipation than for the (10,46°) case.

away from the negative supply rail to \(-5.97\) V. Similarly, the PNP device, \(T_D\), must sink \(7.68\) A when the output swings to \(-5.97\) V from \(V_{CC}\). Note that the crossover discontinuity in the output voltage characteristic (Figure 12), now precedes zero crossing by \(60^\circ\), at \(V_{CC} = 35\) V. For a \((42,1.0^\circ)\) inductive impedance, in which current lags voltage, the output conditions are reversed, with the load demanding \(7.68\) A from \(T_D\) when the output swings from the positive supply to \(-5.97\) V. Regardless of the nature of the load however, device voltage, \(V_{DS}\), and load voltage, \(V_{DL}\), are always

\[ 180^\circ \text{ out of phase, and being a voltage follower, the} \]
\[ \text{input voltage is always in phase with} \ V_{CC}. \]

The linear foldback protection locus of Figure 10 only permits \(3.1\) A at \(V_{CC} = 45\) V, therefore a minimum of three, (ideally four), output pairs are required to drive a nominal \((42,1.0^\circ)\) loudspeaker system from \(60\) V supply rails without intensive limiter activation. On this basis and using other established techniques\(^3\),\(^5\),\(^6\) including D.C. offset, and thermal overload protection, a reliable, low distortion, \(100\) W into \((42,1.0^\circ)\) class-B amplifier may be constructed.

As the cost of power transistors is significant, there is a compelling financial incentive to minimise the number of devices used by utilising the S.O.A. as efficiently as possible. To this end it has been suggested\(^6\) that ideally the protection locus should closely match the bounds of the S.O.A. This is unnecessary, as reactive load drive primarily requires that current delivery in the \(V_{DS} = V_S + V_T\) region be maximised without violating D.C. safe operating limits. In general an optimally located, non-linear protection locus with no more than one breakpoint should suffice.

Single slope, single breakpoint non-linear foldback limiting.

Introducing a zero-gradient segment Fig. 13, at some optimal point in the protection locus permits the enhancement of current delivery at the low-Vcc end of the S.O.A., without significantly compromising available current at higher device voltages. The single slope, linear foldback 'protocol', (equation 4), is made redundant, as the protection locus does not cross the Vcc-axis at any point. This scheme is briefly mentioned in reference \(20\), where it is dismissed in favour of the comparatively

Figure 11: Instantaneous Vcc, IC, and PD in sourcing output transistor, driving 150W into 40.1.60°.

Figure 12: Transistor \(T_D\) delivers 7.68A to the (40,1.60°) load when output swings away from \(-Vcc\) to \(-5.97\) V. Note that the crossover discontinuity marked \(X\) precedes zero voltage crossing by \(60^\circ\).

Figure 13: Single slope, single breakpoint non-linear foldback protection locus.

The zero-slope segment, B-C, is realised by splitting \(R_2\) in figure 1 into voltage divider, \(R_{2A}\) and \(R_{2B}\) Fig 14, and shunting \(R_3\) with a fast recovery diode, \(D_I\). The diode applies a constant voltage, \(V_{D0}\) (to a first-order approximation), across \(R_3\) for,

\[ 0.64V + V_{D0} < (2V_{cc} + 80V) \]

Therefore, for,

\[ 0.64V + V_{D0} < (2V_{cc} + 80V) \]

subject to \(I_C = 1A\), the diode effectively clamps the voltage across \(R_{3A}\) and \(R_{3B}\), preventing the development of sufficient voltage across \(R_3\) to turn on the protection transistor. However, for,

\[ 0.64V < V_{D0} + (40V) \]

and \(I_C = 1A\), the increased potential drop across \(R_3\) with \(I_C\) results in a net increase in voltage across \(R_{3A}\) and \(R_{3B}\), inducing a large enough voltage drop across \(R_3\) to trigger the protection transistor.

For \((DV < 0.64V)\) the diode is off (open-circuit to a first-order approximation) and the circuit reverts to a linear foldback, single slope regime. Resistance values are calculated by developing simultaneous equations for segments B-C, and A-B, at points B and A respectively Figs. 15, and 16. Resistor, \(R_1\) is selected with a view to minimising diode power dissipation when \(R_1\) and the diode are exposed to the magnitude sum of the supply rails.

With reference to figure 15, let \(R_3 \times 8k\), and \(I_C = 1A\). Assuming \(V_{D0} = 120V\), then,

\[ I_C = I_{3B} + I_{D0} \]

And,

\[ R_{3B} = \frac{0.64V}{I_{3B}} \]

From equation 6,

\[ \frac{40 + 0.33I_{3B}}{8k} = \frac{V_{D0}}{I_{3B}} + \frac{R_{3B}}{R_1} \]

With reference to figure 16, and invoking equation 7:

\[ I_{3B} = \frac{V_{D0}}{103} \]
In figure 16, output conditions at point A on the protection locus in figure 13.

20. A minimum of three output pairs is required to drive a (461.6 mV) load, since available current at Vce=41V97 remains uncharged at 3n3A1. However, with the protection locus in figure 13, available current per output pair at Vce=41V is increased from 6A4 to 7A1, and the current at Vce=62V, increases from 0A5 to just under 1A5 per output pair.

Since the locus is not linear, caution must be exercised to ensure that, while pursuing the secondary objective of enhancing current delivery in the low-Vce region of the S.O.A, available current in the critical higher device voltage region, (i.e., Vce=5V-Vce=20V), is not simultaneously compromised by the location of the breakpoint.

The circuits in fig. 17, and 18 are frequently used to realise single slope, single breakpoint non-linear foldback protection. The zener diode in figure 17 is used to establish the flat portion of the locus. This is a rather unsatisfactory solution as in practice the zener breakdown voltage can vary about its nominal value with current by as much as 25%, so that the diode is driven in and out of breakdown, as is the case here. The breakpoint in the protection locus would therefore be ill defined in practice, significantly enhancing the potential for S.O.A violation.

The more dependable p-n diode is used (figure 18), to effect a single slope, single breakpoint regime by means of a simple, voltage polarity-dependent divider. However, this scheme (beloved of American manufacturers) is sub-optimal with respect to flexibility in breakpoint placement as diode commutation can only occur at Vout=0V, i.e., Vce=Vce, so that the nominally zero-slope portion of the locus is solely defined by the voltage drop across R2 being equal to the protection transistors base-emitter voltage, Vbe.

The locus in fig. 20, requires a nominal Rce=0R647, more than doubling gain step distortion generated by a class-AB amplifier, relative to the circuit in figure 14 for which Rce=0R622. A smaller value for Rce cannot be employed as this would result in a commensurate and necessarily unsafe vertical displacement of segment B-C. Thus segment B-C is fixed for Vce=9V, and results in an even more inefficient S.O.A stage in the crucial Vce=62V=25Vce region than the compromised single slope, linear foldback arrangement in figure 5.

Further, using a fixed reference voltage (zero volts in this case) independent of the floating collector-emitter voltage, Vce, as the basis for Vce protection is rather optimistic, as it presumes equally invariant supply rails that do not sag under load. A nominal 40V supply rail which sags by 5V under load would effect a 5V horizontal displacement (figure 20) of segment A-B to D-E. Conversely, a primary supply surge could cause a potentially disastrous horizontal translation along B-C of segment A-B into and perhaps well beyond the transistor’s S.O.A limits.

Since the diodes in figure 18 are in theory never forward biased simultaneously, the modification in figure 19 is often adopted in what may at first appear to be an elegant
carrier storage causing the diodes to conduct briefly when reverse biased. This often results in minute, intermittent zero-crossing oscillations at the output, particularly with a reactive load, which may easily be misdiagnosed as crossover distortion.

Since segment B-C is established by merely selecting $R_{DQ}$ on loci A-B-C (Figure 20) it is required to obtain a solution. With reference to Fig 21, and letting $R_{1}=220\Omega$, and $V_{CC}=40V$,

$$I_{S} = \frac{V_{CC}}{R_{1}}$$

**Where,**

$$I_{S} = \left(\frac{40 - 34.02}{220}\right) = 0.22\text{mA}$$

**With** $V_{CC}=40V$ and $V_{CC}=220\Omega$,

$$I_{S} = I_{T}$$

The circuit in Figure 18 is capable of modest improvement, however and therefore merits closer scrutiny.

This scheme can be made more efficient, (Figure 22), by changing the voltage dividers fixed reference voltage from zero to two arbitrary voltages, $V_{BE}$ and $V_{CE}$ of equal magnitude but opposite polarity, such that,

$$V_{O} = \frac{\left|V_{BE}\right| + \left|V_{CE}\right|}{2}$$

Nominal 40V rails are assumed. This enhances the flexibility of the circuits, as the breakpoint can now be freely located along C-F, Fig. 23, giving rise to a more efficient locus, B-E-F.

The reference voltage is generated by a zener diode, which in contrast with figure 17, is acceptable, as the current established by the diode's current limiting resistor, $R_{Z}$, is reasonably constant, which makes for a substantially invariant voltage drop across the diode. A depletion mode MOSFET configured as a current regulator could be used instead of $R_{Z}$ to firmly establish quiescent conditions. This is expensive, and therefore probably unjustifiable in a commercial unit.

The reference voltage is equal in magnitude to the output voltage, $V_{O_{T}}$, at the breakpoint in locus B-E-F, Fig. 24, i.e.,

$$V_{O_{T}} = \frac{V_{BE}}{2}$$

with $V_{BE}$=1.2V, the voltage drop across the zener diodes in series, $V_{O_{T}}$, is approximately 20V.

Therefore, is recommended however that the voltage drop be realised with multiple low-voltage devices, $V_{BE}$=4.5V, as these possess a significantly lower series impedance. Therefore $Z_{1}$ and $Z_{2}$ may in fact consist of six Motorola 1N5240B 10V zeners, in series with a forward biased 1N4148 diode, the whole quiescing at a nominal 10mA established by $R_{Z}$.

Crucially in Figure 22, the cathode of the zener $Z_{2}$ is connected directly to $V_{CC}$, effectively bootstrapping $V_{BE}$ to the supply rail, so that any anomalies on the supply are directly impressed on the reference voltage. This substantially eliminates the potentially fatal tendency of segment B-E to migrate back and forth along C-F with no ideal supply rail variation. Similarly $V_{O_{T}}$ is bootstrapped to the supply rail by connecting the anode of $Z_{1}$ to $V_{CC}$.

With reference to Fig. 25, and taking $R_{1}=220\Omega$, and $V_{CC}=40V$,

$$I_{S} = I_{T}$$

**Where,**

$$I_{S} = \left(\frac{40 - 35.9}{220}\right) = 0.18\text{mA}$$

**With** $V=40V$ at 20mA,

$R_{1}=V/V_{CC}$

$R_{1}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$

$R_{F}=V_{BE}/0.7=220\Omega$

$R_{Z}=V_{CE}/0.7=220\Omega$
Conspiracy theory
The town of Valley Stream, Germany, has petitioned the Federal District Court in Washington to remove the source of Radioactive Ribbons, which has had the less than satisfactory result of the German government receding to re-crow its lease which expires in 2005. This has happened because almost half the citizens of the town now have cancer and they have nothing else to blame it on but the powerful transmitters of Radio Ribbons, aimed to reach Eastern Europe and Central Asia. It has taken place for some decades, but it is too late to do much if there is even the slightest necessity for it by these days.

You notice that citizens come second to this ruling, but the station would be closed immediately. The same phenomenon comes up in this country with other stations from rubbush tips and incinerators. And although GM plants, we have to drum in, presumably, the chemical town of Cubatao in Brazil, where there are no winds and internal mortality is variously quoted at 27% and 43%, to suggest that just as Tony Blair's latest sentence as our benefactor, it is turning into something else.

500Mhz sampling front end - June 2002 issue
You have probably a fair number of comments from other readers concerning Mr. Hickman's interesting and touching article. Nevertheless, I thought I would write to you with an observation of my own.

With regard to producing shorter gate sampling pulses, I suspect that the avalanche pulse generator employed has already reached the limit of its capability in this direction. Some improvement may be indeed be achieved by using a slower gate delay line, L.I., and a transistor having a higher transition frequency than the current 250 Mhz. As a matter of fact, we have a 350 Mhz PIN diode, in my lab, which should be better suited for this purpose.

PS. Noting the current on the super-regen in EW April 2002, Hickman wrote about 3W and in his book on their operation and shows how well they perform in this manner.

Howard Miles
Medlock Mountonic
Leicester, UK.

Any takers? - Ed.

More PCB ideas
The May issue of your excellent publication has just been received here in the Antipodes. The article by Cyril Batten on PCB-making was, like all of CY's articles, excellent. Cyril suggests some simple ways of producing boards but there is another, apparently little known or utilized, technique for producing one-off PCBs.

For several years, I have been producing boards by direct-printing to the copper-clad stock, then etching etc. as usual. Boards of all shapes and sizes, in the complexity of the examples shown in CY's article and, of course, PCBs of greater complexity are easily and quickly produced. I have also used Easytrack for design (antiquated, I know, but adequate for most application), for far more simulating the Windows-based programs which I also have) and plotted out a HP7550A plotter. I also use a HP7550A on occasions, but other types of plotter (e.g. Roland) should be usable. A plot on paper is first made, then a suitably sized piece of copper-clad stock is taped down by its edges so as to cover the plot. The pen is charged to an etch-resistant type and the plot done again onto the copper. The board is then etched.

Some tips for those who wish to try this technique; Suedder Leumocure 313 500mhz is a very fine copper base material, a good tool to make, etc. The finishing etch resist pen, make sure it's not (and cheap) etch resist pen, I think the black ink on the plotter, although I have used the red ones successfully. The pen can be mounted with tape in a drawing jig so that you can charge a plotter pen so that the machine car can pick it up. The machine may pick it up with a 'polishing' motion, using very fine 'wet & dry' paper and a deep of deterrent under the enzyme. I do not know what looks best as it gives the surface a pattern of tiny 'scratches' which help the pen make a connection. Be careful not to get anything placed inside the polyurethane cartridge. Occasionally a task or two will require etching with etch resistant pens, but I think that this is due to carelessness on my part in cleaning the copper. In this application the necessity for preparing the copper surface is vital and at least one level of importance above the usual. Watch the orientation of the printout as it may be necessary to 'flip' the artwork to avoid a mirror-image product, depending upon whether your board is SMD or through-hole. Of course I have never felt a need for making a mirror reverse board and then trying to assemble it! The sequence below for Easytrack is worthwhile, both for the support given for this 'obsolete' program and for the delightfully helpful Bob Barnes makes me believe that better computerized arrangements are to be had for the asking, try your local drafting supplies shop or building plan draughtmen.

With regard to CY's notes re: drills, I have found it wise to use cartridge drills in a hand-held machine as they work very easily. A drill stand is to be preferred, I use a Dremel but I think it a little crude and am saving up for a 'proper' unit!

Kerry Power
Coffs Harbour
Australia.

References;
Easytrack;
www.eia.com/australian Drills;
Toolshop (Joseph Moran) on eBay has a good range of drills

Exposure
In my experience exposing either side separately invariably ends in tears, or at least misalignment. So here is my double-sided method.

A pair of 500W halogen flood lights, with glass removed, are good U.V. sources for less than five pounds each, at 26" (670mm), defined by the height of the shelves in my kitchen, results in a 15 min. exposure time. One lamp is placed above and one below a pair of shelf brackets on which a polyurethane carrier simply rests on. The polyurethane carpet is simply two pieces of non-U.V stable polyurethane hinged at one edge with 'gaffer' tape and clipped shut with 'I'm building' clips. Simply take top foil and trim appropriately. 1" (25mm) of 3M edges, then align it against the bottom foil on a light box and secure with masking tape, leaving the three trimmed edges, forming an envelope that the PCB is placed inside, that is in turn masked. Finally I add erasing, the whole assembly then rests on the shelf brackets and is exposed.

Jo Atkin
(by email)

Another UV source
I would like to add the following information to the recent articles from Cyril Batten about printed circuit making that appeared in EW.

A powerful UV source for photoresist exposure is also available for EPOX-ERAM erasing. It is perfectly made from medium-pressure mercury arc lamps, such as the Philips 100W, although almost any. It can be made using a Labco tube inside a glass bulb, coated on the inside with fluorescent material and have metal rods, which do not disturb the exposure. The space between the discharge tube and the bulb is filled

with an inert gas, probably nitrogen. By carefully breaking the neck of the bulb around the metal pipe, the glass can be removed and the exposed discharge tube used by itself, in the same socket and with the same current limiting inductor as the whole lamp. This tube emits strongly in the 363 and 365nm mercury lines and also in the visible 546nm line. Two safety considerations apply: first, the discharge tube is made of fused quartz and gets hot when running. So, it must be handled with the same care as a halogen lamp bulb, that is, no separate glass cover, but locates in the same socket as above, or any other that will allow it. Secondly, the tube should be made to one length and as main potential, so they must not be touched by hand or conductive objects when electrical. The lamps are being replaced in outdoor lighting by metal arc lamps, but are

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 i.low@highburybiz.com using subject heading 'Letters'

September 2002 ELECTRONICS WORLD

LETTERS

EW improvement ideas
I think the magazine might well benefit from a change of direction (larger page count, lower cover price, rename to Wireless World, OK only joking) although I suspect there are no lobbies for it any more like is the case of "popular science". Personally, I feel the readers' letters are the best part, especially the constructive (but well argued) comments and I also feel there should be a historical feature every (or nearly every) issue, as this broadens the approach of the magazine and, of course, the magazin efrom so many others. You don't want to become just a close or look alike of other electronic magazines, as this is a highly useful area and would be dropping the old values in any case.

Andy Emerson
UK

A quick comment on EW content recently....
One thing that's rather annoying, is when several pages of a mag are taken up with software listings. I think that these days it's highly improbable that anyone thinking of building a project won't have internet access - if not themselves then via someone they know. Stuff like this belongs on a website so it can be downloaded, error-free by those who want it. There's no need for an all-singing flashy corporate site - just a URL in the article to get the file. Obviously there may be instances where parts of a software listing may be useful or informative, but the inclusion of whole chunks is a long and unnecessary. The inclusion of two pages of HEX listing on June 2002 was particularly ridiculous. I have no idea why this was put in there but if that's all you could find it to put then things must be getting pretty desperate!

Mike Harrison
UK

Suffer to say that in future code will be available by email in the short term and I'm hoping to get a readable format published in the not too distant future. There won't be anymore HEX listings.....unless they are VERY short!

Ed.
Electronics as an occupation

People who are self-employed, e.g. doctors, electricians, plumbers, are usually able to earn more than electronic professionals who mostly work for a salary. It is difficult for a design engineer to work for himself (as an electronics profession) could start, manage and own a more electronic manufacturing companies themselves. Those who are self-employed could learn from medical doctors. For example, if you have a repair shop, let your customers make sure you always have work. Charge them for fault finding, regardless of whether you can identify the problem or fix it. If your repair operation turns out to be failure, still charge for it. In a free market economy, salaries should be determined by demand and supply. If electronic professionals are not happy with their pay or status, they should seek other occupations. Students tend to take courses that interest them, without considering the future demand for it. The future requirements are also determined by the qualifications and requirements. Electronics is an interesting subject, and unfortunately too many people think it is a hobby. Many occupations increase the income beyond the free market level by having a union recommend fees and by reserving work. For example, even all those who are not even interested in the prescribed medicine you need, you cannot get it without paying a doctor for a consultation (the patient usually has to discover the side-effects for himself). Nor can you get the results of some medical tests without paying. Only a certified electrician may work on the electrical wiring of your home (at least in some countries). It is impossible to register a trained electrician. Engineering associations should recommend salary levels. If all else fails, consumers could be obliged to obtain a "prescription" from a qualified electronic engineer or technician to buy electronic equipment. After all, we need to make sure that the equipment is right and to be aware of the equipment that could also be dangerous in the wrong hands, e.g. a microwave oven used incorrectly.

Electronics is successful. If opportunities to design products that fail more often and go obsolete. Microsoft has demonstrated how you can force the public to continuously buy new hardware and software. Just make the operating system ever larger, requiring a bigger, better computer, and convince the peripheral electronic manufacturers to only supply drivers for the latest Microsoft products, we've got it made. For those who are in doubt, this letter can be taken entirely seriously. Dewald de Lange South Africa

PS. Through the decades that I have read Electronics World, you have had some very unique and well illustrated articles. With electronics becoming more integrated, and designed by large companies, the demand for electronic magazines is likely to shrink. Let's hope Electronics World survives.

More with readers like you, I don't think we'll have a problem. Ed.
ANASOFIT LTD
http://www.anasofit.co.uk
Superior, the affordable, mixed-mode vectorial circuit simulator. Wrote by an analog design engineer for those Tutorials who like keeping things simple.

BEDFORD OPTO TECHNOLOGY LTD
http://www.bedopto.co.uk
Optoelectronic products & design development. Product development, electronic design, circuit design, computer controlled, developing electronic systems.

CRICKLEWOOD ELECTRONICS
http://www.cricklewoodelectronics.co.uk
Cricklewood Electronics stock one of the widest ranges of components, especially semiconductors including ICs, transistors, capacitors, all at competitive prices.

COMPONENT KITS
http://www.componentkits.com
"Component kits LLC manufactures and distributes electronics Component Key, used for professional engineering design, prototyping, university, lab, and hobbyist BOM.

CREATIVE INTERNATIONAL
http://www.creative-int.com
Electronic product design company with over a decade of experience protecting it's own product range and designing and manufacturing innovative products for client companies/individuals.

EAGLE PCB DESIGN SOFTWARE
http://www.puresoft.co.uk
Professional PCB design made easy! Fully functional free-version download.

CROWNHILL ASSOCIATES LTD
http://www.crownhill.co.uk
Crownhill supply top class development tools for use with Micro-Controllers and SmartCards. Products include Smart Card development tools, Smart Cards, Micro-Development tools and Bespoke Service Design.

CRICKLEWOOD ELECTRONICS
http://www.cricklewoodelectronics.co.uk
Cricklewood Electronics stock one of the widest ranges of components, especially semiconductors including ICs, transistors, capacitors, all at competitive prices.

DB TECHNOLOGY
http://www.dbtechnology.co.uk
EMC Testing and Consultancy. EMI shielded and open area test site. • Compliance Tests. • Rapid, accurate on-site compliance tests. • Tests included. FCC Listed. • Pads, high-foamy testing available.

DESIGNER SYSTEMS CO.
http://www.designersystems.co.uk
Equinox Technologies UK Ltd, specialise in development tools for the embedded microcontroller market.

FELLER UK
http://www.feller-at.com
Feller (UK) Ltd. manufacture Felly approved converters (Isolated radii plugs and connectors) and Power Supply Cables for all Helexotronics Controllers to National and International Standards.

FIELD ELECTRIC LTD
http://www.fieldelectric.co.uk
First Electric Ltd has been successfully trading since 1958 in the re-sale of used test & measurement equipment & computer hardware. We buy and sell in small or bulk quantities and can source equipment to particular requirements. Visit our web site or call 41 01938 85736.

FUTURE TECHNOLOGY DEVICES INTL. LTD.
http://www.ftech.com
FTD designs and sells USB-2200 and USB-2210 verified to USB 2.0. Connects to your PC via drivers these devices simply the task of designing or upgading USB peripheral.

J W HARDY COMMUNICATIONS
http://www.jwhardy.co.uk
The only UK based online selection of magnifiers and low-vision aids, including handheld, hand-free, illuminated, magnifying stands, loupe sheets and inspection loupes.

MAPLIN ELECTRONICS
http://www.maplin.co.uk

MAGNIFICO
(The Magnifier Company)
http://www.magnifyingglasses.co.uk
Micrel. Applications for telemetry, defence and remote control.

MINIFICO
(The Magnifier Company)
http://www.magnifyingglasses.co.uk

PHEONIX LTD
http://www.phoenixltd.co.uk
Manufacturer and supplier of low cost general purpose and serial I/O digital modules and accessories. PCB based software for data logging and control applications.

RADIONETRIX
http://www.radionetrix.co.uk
A fully secure and Innovative Internet ordering system from Maplin Electronics. The specialists excels in retail and mail order company to business and retail consumers alike, 15,000 products available online.

MATRIX MULTIMEDIA LTD
http://www.matromultimedia.co.uk

LABCENTER
http://www.labcenter.co.uk
Download evaluation versions of our unique Protessa VSIV manual mode SPICE and CPU simulator, and see the full range of Protessa PCB Design products. Register the Protessa and your evaluation versions online for use as free as 60 days.

LORCALL LTD
http://www.lorcall.co.uk
e-mail lorcall@london.com
Suppliers programmes and repairs of new and refurbished two-way radio equipment. Reconditioning and repackaging service available. All types of batteries chargers and antennas supplied.

QUASAR ELECTRONICS
http://www.quasarelectronics.co.uk
Over 250 electronic kits, projects and ready built units for hobby, educational & Industrial applications.

EAGLE PCB DESIGN SOFTWARE
http://www.puresoft.co.uk
Professional PCB design made easy! Fully functional free-version download.

RAFSEL ELECTRONICS
Professional test & measurement equipment.

www.rafsel-electronics.co.uk

RIMO-AK-PP
http://www.art-decade.com
We provide the following services: System design, test & analysis, Software design & coding, Hardware design, Document technical review, Authoring & proof reading, R&D design, Hardware design.

RF DESIGN
http://www.spike-software.com
RF Design offers powerful simulation software for professional engineers and educational institutions. All the software is available on a 30 day trial basis. Comes with free technical support.

SOFTEC
http://www.softec.co.uk
As a PC based test and copy software, SoFtec can copy a complete index of Electronic printed circuit design over the past ten years. Photo copies of articles from both issues are also available.

TEMWELL CORPORATION
http://www.temwell.cor.ru
Manufacturer & Exporter of Metalic EMI Filters, 30 Watts RF Power Filter and handheld BASE Station DUPLEXERS

TELNET
http://www.telnet.uk.com
Too quality tested second User and Measurement Equipment rental services UK.

TELCOM
http://www.telecom.co.uk
Take your e-mail to the E-mail shot screen to are acknowledge Electronics in IBM required. take your of vat MUM web information plus this offer issue. www.componentkits.com Ranging optocouplers custom, TECHNOLOGY pannel http://www.cricklewoodelectronic.com Teletubbies simple. http://www.anasoft.co.uk http://www.maplin.co.uk http://www.magnifyingglasses.co.uk (Moulded M2) LTD. Enabling‚ tools, Micro-Controllers Professional Cards, Micro-Design Cards, Rapid, Compliance Card Design, Card Design, R.F. network Spectrum. Shop online for R.F. network components. We supply a full range of TV, radio reception equipment to receive terrestrial/digital signal from terrestrial and satellite sources. We provide a free planning service for your R.F. networks, MATTY and SMARTY etc.

Microbalances. Telonic, CELESCO ET RALFE ELECTRONICS. The specialists excels in retail and mail order company to business and retail consumers alike, 15,000 products available online. Consultancy, Radio-frequency and digital communication systems. Harmonised European harmonised standards EN300 220-3 and EN61046-3 and are CE certified by an independent notified Body. Radio module, modems, telemetry, audio transmitters, cameras, antennas, remote controls and much more. All UK designed and manufactured.
WEB DIRECTIONS

Put your web address in front of 20,000 Electronics fanatics.

Electronics World acknowledges your companies need to promote your web site, which is why we are now dedicating page 9 in every issue to WEB ADDRESSES.

This gives our readers the opportunity to look up your company name, to find your web address and to browse the magazine page to find new sites.

We also understand that cost is an important factor, as web sites are an added strain on budgets, I am sure you will agree these rates make all the difference.

FOR 12 ISSUES:

Lineage only will cost £150 for a full year just £12.50 per month. This includes your companies name, web address and a 25 word description.

Lineage with colour screen shot will cost £250 for a full year just £21.75 per month. This will include the above plus a 3cm screen shot of your site, which we can produce if required.

To take up this offer or for more information ring on 0208 726 6228.

E-mail: Lordickshanks@highbury.com

Company Name

Web address


Test Equipment for rental or second user looks at the industry’s lowest prices. All types of equipment from all leading manufacturers including general purpose, communications and industrial test items fully refurbished with 1 year warranty. Rental rebates given on purchase.

TECHNICAL AND SCIENTIFIC SUPPLIES

http://www.testequip.com

Suppliers of pre-1995 equipment and components.

- Test/Measurement equipment
- Valves and semiconductors
- Transducers and pressure gauges
- Scientific books and catalogues
- Manuals and data sheets

TOTAL ROBOTS

http://www.totalrobots.co.uk

Robot Kits and Control Technology products, including 50% off the first Obstacle-Oriented Programmable Integrated Circuit. Secure on-line ordering and fast delivery.

ULTRACOM

http://www.ultra.com

Ultracom specialises in the design and manufacture of data radio products including Radio Modems, Radio Modems, Filters and Antennas for real-time data communication. In addition to our standard RF products we provide tailored solutions for customers' wireless communications requirements. Our wireless data radio's are used in the most varied applications: transforming environmental data in tropical conditions, locating moving targets, remote control of cameras, controlling pump stations in waterworks, monitoring real estates, transforming data in public transportation information systems.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ULTRALINKS

http://www.ultralinks.com

Ultrapulse are a leading supplier and manufacturer of communications and accessories, including patch panels, transmitters, and filters. Ultrapulse are a leading supplier of high quality, custom-made, RF and microwave modules, and also offer RF, microwave, and digital circuit design services.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

UTRAX PCB DESIGN SOFTWARE

http://www.utrax.co.uk

UTRAX's PCB designer is fully integrated with PCB generation software, allowing you to generate high-quality PCB designs.

VUTRAX

http://www.vutrax.com

Vutrax electronics is an electronic design and prototyping company.

UTRAX is a leading supplier of high-quality, custom-made, RF and microwave modules, and also offer RF, microwave, and digital circuit design services.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Solutions

http://www.TestEquipmentHQ.com

Solutions are a leading provider of test and measurement equipment, offering a wide range of products to meet your needs.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VUTRAX - the UK's largest supplier of high-quality loudspeaker kits and drive units.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

UTRAX PCB DESIGN SOFTWARE

http://www.utrax.co.uk

UTRAX's PCB designer is fully integrated with PCB generation software, allowing you to generate high-quality PCB designs.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WILMSLOW AUDIO

http://www.wilmslow-audio.co.uk

Wilmslow Audio offers a wide range of high-quality audio products, including speakers and amplifiers.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WEB WIZARD 1.6 Real-Time Digital Filter

WEB WIZARD 1.6 (formerly RTDF) is a unique real-time audio-bandwidth digital filter system with infinitely adjustable characteristics - all available at the click of a button. It uses a DSP unit that runs the filter and a friendly Windows-based interface that allows you to design and download any kind of filter you like, all within seconds. You don't need to know about filter maths, DSP or analogue filter design - all you need to know is what kind of filter you want. With Signal Wizard you can do more than specify the gain of the frequency response - you can also specify the phase of any frequency, with a resolution of one hundred thousandth of a degree! If you don't want to bother with phase, Signal Wizard will design with total phase-free distortion, no matter how complex or sharp the filter is. You are not limited to the design tool interface either - you can also import frequency responses as text files, specifying just magnitude or magnitude and phase. Once you are happy with the design, just download the filter and run it in real-time. Low-pass, High-pass, multiple-band or arbitrary are all possible.

Use this coupon to order Signal Wizard

Please send me filters at £199.00 excluding shipping and UK special delivery and VAT (£359.55 fully inclusive)

Name

Address

Phone/fax

Total amount £

I enclose a cheque

Please charge to my credit/debit card

Card type

Card No

Expiry Date

Please mail this coupon to Electronics World with payment. Alternatively fax credit card details with order on 020 8722 6098.

Address orders and all correspondence relating to this order to Signal Wizard Offer, Electronics World, Anne Boyen House, 9-13 Ewell Road, Cheam, Surrey, SM3 9SZ email j.low@journalmedia.co.uk

Make cheques payable to Electronics World

Visit the website at:

www.umist.ac.uk/dias/pais/signalwizard.htm

September 2002 ELECTRONICS WORLD
As an advertiser you can be certain that your sales message is going to be read by decision-making electronics professionals with the power to purchase your products.

The pre-paid rate for semi-display setting is £17 per single column centimetre (maximum 4cm). Box number E22 extra. All prices plus 17.5% VAT. Cheques, postal orders etc to be made payable to Highbury Business Communications Ltd. Advertisements together with instruction should be sent to Electronics World Classified, Highbury Business Communications Ltd, Anne Boyle House, 9-13 Ewell Road, Cheam, Surrey SM3 0DZ. Tel: 020 8722 6028. Fax: 020 8772 6096.

ARTICLES WANTED

WE BUY: ICs, Memory, Relays, Caps, PSU, Semiconductors, Polulated Boards, Computers + Test Equipment

ANYTHING CONSIDERED

For our wide range of Semiconductor + Passives List, please ring, fax or email

MAIL ELECTRONICS

TEL: 0181-761 4520 / FAX: 0161-763 6953
EMAIL: andrew@mailelectronics.co.uk
www.mailelectronics.com

BEST CASH PRICES PAID

For all valves K168 PX4 and other audio types

Wide range of valves and CRT stocked

Tel: 01403 784961

Billington Exp Ltd
Fax: 01403 730019
Email: sales@billingtonexp.co.uk
Visits by appointment

WATERBECHE ELECTRONICS

www.wasser.dial.pipex.com

TEL: 01223 662550
FAX: 01223 440853

RF DESIGN SERVICES

All aspects of RF hardware development considered from concept to production.

TRADE ENCLOSED

15% cash return

Prices from £45 + vat

M&G Radio
66 Waterplace Street, Letchworth 0 208
Tel: 01438 270114 Fax: 01438 242681

FOR SALE

Need a Remote Control manufactured?

You can get it from Wallis!

We are a manufacturer and distributor of replacement remote controls and associated software in both Fast and Low-Cost solutions for OEMs and end users.

For further information please contact us.

Wallis Remotes, AT9 Riverside Business Centre, London, SW18 4QG
(Tel) 020 8870 3388 (Fax) 020 8870 9988
(Email) sales@wallis-universall.co.uk

TOP PRICES PAID

For all your valves, tubes, semi conductors and ICs.

Langreux Supplies Limited
1 Main Road, Crayke, York YO1 2DG
TEL: 0345 898 1156 FAX: 0345 898 1156

TOP PRICES PAID

For all your valves, tubes, semi conductors and ICs.

Langreux Supplies Limited
1 Main Road, Crayke, York YO1 2DG
TEL: 0345 898 1156 FAX: 0345 898 1156

POWER SUPPLY DESIGN

Switch mode PSU

Power Factor Corrector

designed to your specification

Tel/Fax: 01422 424221
Email: sales@kitchenbath.co.uk

FOR RACK TO M&B audio Sussex

19 optima

Panel and power ICs.

Leeds 0113 9EZ

Tel: 0113 0113 9EZ

Fax: 0113 0113 9EZ

SUSPENSION

MANUFACTURED

Easr

All considered

SERVICES

Technical support is provided online via our web based forum, www.picbasic.org, or to tutors via telephone direct from the Author. Additional support can be provided to tutors using our development system for educational purposes.

Development system

Prototype PCB system

Programmers

Supplied with source code and documentation for 20 Educational projects. Supports LCD displays from 2x16 Chrs to 128x64 dot matrix Graphics panel

All supporting components stocked at competitive prices

e.g. PIC 16F84 4/2 - £1.80 each, PIC 16F877 4/2 - £3.95 each

LCD 2x16 Chrs, £7.50 each

LDC 128x64 dot matrix £15.95 each

Many more items stocked, email sales@crownhill.co.uk for prices

PIC BASIC COMPILERS

PIC Basic Plus & PIC Basic Pro Compilers

PIC BASIC Plus, supports the popular 14 bit Microchip PIC-Microcontrollers, allowing the user to write professional programs in BASIC. The compilers produce fast, tight machine code to load directly into the PIC-Microcontroller.

The Compiler produces code that is guaranteed 100% compatible with Microchips MPASM assembler. The compiler allows direct comparison between the BASIC program and the assembly listing. Two compilers are available, the PIC Basic Pro, entry level compiler and PIC BASIC Plus, professional compiler. Both produce fast assembly code from BASIC. The Compilers run under Windows 95,98,NT,ME and XP and are supplied with a comprehensive, Windows based editor with Syntax highlighting and just two key clicks to compile and program and detailed manuals with worked examples. The Compilers support a range of programmers including the Microchip PICSTART-plus and our own development programmers. For a free demo of the Pro compiler visit our web site www.lcetbasic.com, or join our web based forum to hear what other users think of our compilers and supporting products... (PIC BASIC Pro is supplied with the book "Experimenating with the LET Basic Pro compiler" by Les Johnson, an invaluable guide for the beginner.) See the web site for an example chapter.

Technical support is provided online via our web based forum, www.picbasic.org, or to tutors via telephone direct from the Author. Additional support can be provided to tutors using our development system for educational purposes.

Development system

Prototype PCB system

Programmers

Supplied with source code and documentation for 20 Educational projects. Supports LCD displays from 2x16 Chrs to 128x64 dot matrix Graphics panel

All supporting components stocked at competitive prices

e.g. PIC 16F84 4/2 - £1.80 each, PIC 16F877 4/2 - £3.95 each

LCD 2x16 Chrs, £7.50 each

LDC 128x64 dot matrix £15.95 each

Many more items stocked, email sales@crownhill.co.uk for prices

32, Broad Street, Ely Cambridge, CB7 4AH

Tel: +44 (0) 1353 666708
Fax: +44 (0) 1353 666710
sales@crownhill.co.uk

All prices exclude VAT, postage and packing.

www.picbasic.org

Visit our web sites at www.picbasic.org
The HS801: the first 100 Mega samples per second measuring instrument that consists of a MOST (Multimeter, Oscilloscope, Spectrum analyzer and Transient recorder) and an AWG (Arbitrary Waveform Generator). This new MOST portable and compact measuring instrument can solve almost every measurement problem. With the integrated AWG you can generate every signal you want.

- The versatile software has a user-defined toolbar with which over 50 instrument settings quick and easy can be accessed. An intelligent auto setup allows the inexperienced user to perform measurements immediately. Through the use of a setting file, the user has the possibility to save an instrument setup and recall it at a later moment. The setup time of the instrument is hereby reduced to a minimum.

- When a quick indication of the input signal is required, a simple click on the auto setup button will immediately give a good overview of the signal. The auto setup function ensures a proper setup of the time base, the trigger levels and the input sensitivities.

- The sophisticated cursor read outs have 21 possible read outs. Besides the usual read outs, like voltage and time, also quantities like rise time and frequency are displayed.

- Measured signals and instrument settings can be saved on disk. This enables the creation of a library of measured signals. Text balloons can be added to a signal, for special comments.

- The (colour) print outs can be supplied with three common text lines (e.g. company info) and three lines with measurement specific information.

- The HS801 has an 8 bit resolution and a maximum sampling speed of 100 MHz. The input range is 0.1 volt full scale to 80 volt full scale. The record length is 32K/64K samples. The AWG has a 10 bit resolution and a sample speed of 25 MHz. The HS801 is connected to the parallel printer port of a computer.

- The minimum system requirement is a PC with a 486 processor and 8 Mbyte RAM available. The software runs in Windows 3.xx / 95 / 98 or Windows NT / 2000 / XP and DOS 3.3 or higher.

- TiePie engineering (UK), 28 Stephenson Road, Industrial Estate, St. Ives, Cambridgeshire, PE17 3WJ, UK Tel: 01480-460028; Fax: 01480-460340
  TiePie engineering (NL), Koperslagersstraat 37, 8601 WL SNEEK The Netherlands Tel: +31 515 415 416; Fax: +31 515 418 819
  Web: http://www.tiepie.nl