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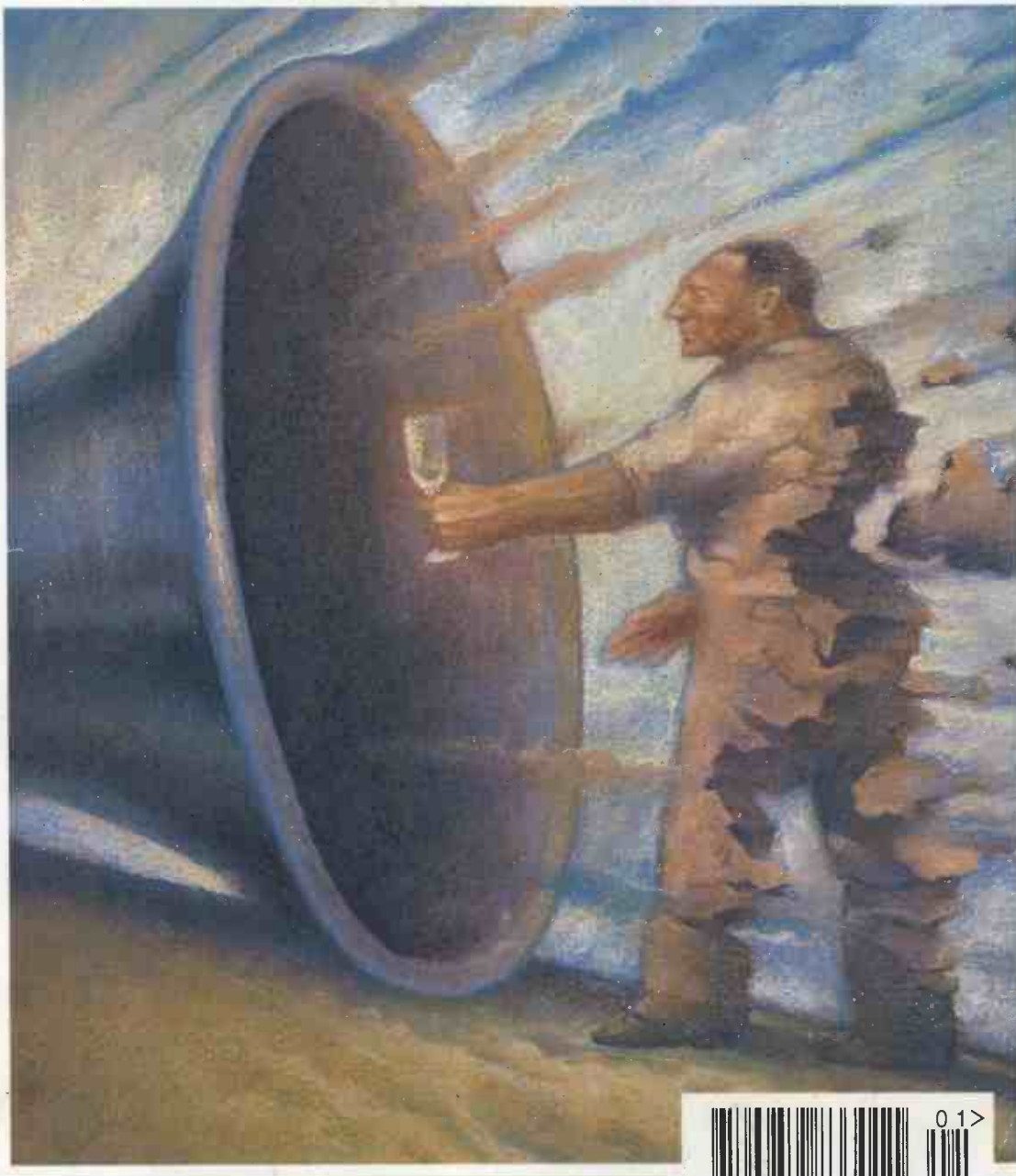

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Cover – Hashim Akib

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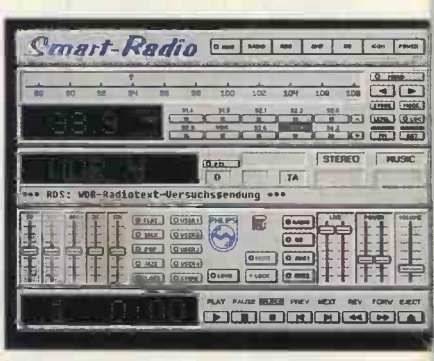

Its now possible to view broadcast Radio Data on the PC – page 4.

Chasing the dragon

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REED BUSINESS PUBLISHING

Asia is an obsession of this Government. If only we could emulate Asian growth rates and success in the new high-tech industries, think ministers, the UK would be a 'Tiger' economy – a kind of Taiwan or South Korea.

What is it about the Asian Tigers that our Government feels has created their success? Low tax, low interest rate, *laissez-faire*, deregulated capitalism red in tooth and claw, seems to be the Government's answer.

To anyone who follows the success of Asian high-tech industries this is a laughable misapprehension. The most successful Asian high-tech economies have had governments which, very carefully and consistently over many years, followed a policy of acquiring – then disseminating as widely as possible – the key technologies for success in high-tech.

Take the most successful Asian economy – Japan. Back in the fifties, the Japanese government put import restrictions on US microelectronics products; forced US companies selling microelectronics in Japan to license their technology to Japanese companies; and forced Japanese holders of such licences to sub-license the technology to spread it to as many companies as possible.

Take Taiwan. In 1976 the government bought seven micron microelectronics technology from RCA and has subsequently refined it – in the same laboratory – through every subsequent technology generation down to a modern 0.25 micron process. From time to time the Taiwan government has spun-off its pre-production r&d process lines into the private sector forming such companies as UMC, TSMC, Winbond and Vanguard.

In Korea much the same thinking produced the microelectronics r&d organisation KIET (Korean Institute for Electronics Technology) and the 1982 Semiconductor Industry Promotion Plan which directly led to the moves of Samsung, Hyundai and Lucky Goldstar into the memory chip market with huge success – today microelectronics accounts for one tenth of Korea's total exports.

So much for *laissez-fair* capitalism! The UK Government thinks that people can compete in high-tech without access to the latest technologies; in Asia governments are thrusting these technologies upon companies.

The wooden-headedness of the Government was matched by that of UK industry. While Asian high-tech industry blossomed on the back of growing capabilities in microelectronics what were the bosses of the UK electronics industry saying? Were they saying that they needed state-of-the-art microelectronics technology to stay alive?

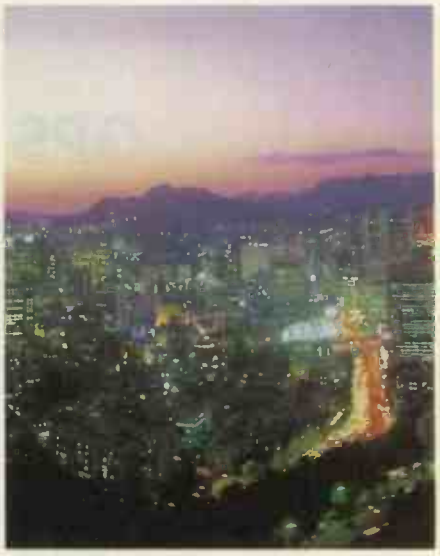
With the noble exception of John Clark of Plessey, they were not. Ferranti allowed its world lead in ASIC technology to dribble away. After 1971, GEC-Marconi never made the investments required to be a world leader in microelectronics manufacturing.

So the best possible recent news is that the new head of one of the UK's largest electronics concerns – BT – is to be a microelectronics man. Peter Bonfield, is ex ICL and, more importantly, ex of microelectronics giant Texas Instruments.

The two strengths of microelectronics men are: a belief in the learning curve and open minds. The first means they actually expect technology to double its capability every couple of years for the same cost; the second means that they have a sponge-like capacity for new ideas.

In many of the world's great electronics companies, the semiconductor divisions are doing so well that the heads of them are becoming, for the first time, credible contenders for the top corporate job. This is when we can expect a massive increase in the efficiency with which microelectronics is applied.

Take for instance a UK national scandal: whereas the technology to increase the data carrying capacity of domestic phone lines from today's 28.8kilobits per second to the 144kilobits per second of ISDN has been around for many years, it is only now being offered to homes by BT and at a scandalous price of hundreds of pounds for a couple of chip-sets – one at the user end and another at the exchange end costing less than a tenner each.



The most successful Asian high-tech economies have had governments which, very carefully and consistently over many years, followed a policy of acquiring – then disseminating as widely as possible – the key technologies for success in high-tech.

Oftel's refusal to allow open competition to supply upgraded capabilities to the local loop seems disgraceful to the citizen wanting better services, or to anyone who wants the UK to be an efficient industrial economy. But it makes perfect sense to a BT executive seeking maximisation of the profit earning potential of every technological change – which usually means delaying change.

To a microelectronics man, such a wilful disregard to promote and implement available technology goes against the grain. If Bonfield can get the learning curve mentality of Microelectronics Man to replace the dead-head mentality of Telecoms Man and Government Man he will do the UK a massive favour. ■

David Manners

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GPS attacked over GPS chip claims

GEC Plessey Semiconductors, GPS, has clashed with Rockwell Semiconductor and Motorola of the US in claims over chip-sets for the global positioning system market.

"We are the only people offering a complete integrated chipset," said Brian Hick at GPS. "All the others are built around dsp cores or use discreet front ends."

"Absolute rubbish!", said Nigel Williams, chairman of Manhattan Skyline, Rockwell's UK distributor. "We took the first large European order for Rockwell's integrated gps chipset.

"We've had three to four design wins already and one production order. In the accounts we've been in we haven't seen any competition."

Motorola also disputes GPS's claim. The company has been competing in the gps market at board level but is about to move to chipsets.

"We've not announced a product yet but we're talking to selected customers about an integrated chipset," one of the Motorola gps team commented.

However, Brian Hick said that GPS had sold 150 of its development systems for its chipset, which consists of a bipolar silicon front end, a 35MHz surface-acoustic-wave filter and a 12-channel correlator. An *ARM 60* processor is used with the chipset.

"We want to see if customers want further integration", said Hick. "The obvious move is to integrate the *ARM* core and the correlator." Rockwell's latest two-chip set is called Zodiac. Encapsulated together in a PQFP are a gallium arsenide front end and an analogue c-mos die.

The second chip contains a single die incorporating a 12-channel dsp, a microprocessor and co-processor in a TQFP. The set costs $70.

Others targeting the gps chipset market are Philips and SGS-Thomson.

David Manners, *Electronics weekly*

Pictures from radio to enhance your PC

In an intriguing move, Philips Semiconductors has developed a module and a set of components that let pcs receive and decode RDS (radio data system) broadcasts, displaying the information on the screen.

Dubbed the *Smart-Radio* module, Philips claims it provides the first high-quality radio reception for pcs, superseding previous solutions that relied on chips developed primarily for car receivers.

"Now radio can be seen as well as heard," said David Canha, sales manager for Philips Semiconductors. "*Smart-Radio* expands the listening experience to computer users as well as providing on-screen text."

Kaveh Kianush, project leader of Philips' radio IC design team, adds that just as tv tuners have been added to the pc so some users have been demanding stereo-quality radio reception as well.

"In a multimedia pc it might be nice to have some background music playing while you perform another task," said Kianush. "The RDS facility then adds the ability to receive data, which might be market information or advertisements."

RDS broadcasts are widely used throughout Europe to transmit the station's identification, traffic bulletins, weather and other information alongside the normal fm signal. In the US the Electronics Industries Association (EIA) is supporting the RDS standard and has launched this year a $1m campaign to install hardware encoders in the top 25 radio markets across the US. The EIA's plan is to equip several radio stations with the encoders, allowing RDS signals to reach 85% of the US radio audience.

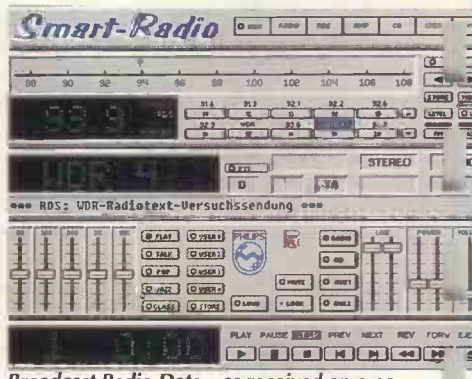
The heart of Philips' strategy is the *OM5604* module, which is the fm radio tuner and preamplifier. The module is carefully shielded to isolate it from the noisy pc electrical environment and prealigned.

It uses the *TEA5757H* tuner IC designed by Kianush's team for this application. The tuner IC uses twin frequency locked loops to provide speedy scan tuning and tuning to up to 99 frequency presets. The module is completed with a preamplifier providing 900mV line audio outputs and an I^2C bus controller chip. The module is programmed and controlled via this bus.

PC and pc-card makers can then augment this module with the *SAA6579* RDS demodulator and the *CCR921* RDS decoder chips. Philips engineers have developed a prototype pc plug-in card based on the *OM5604* module and written a *Windows* software utility to control the radio from the screen.

Kianush says the card and the software are for demonstration purposes and it is unlikely Philips will sell either on the pc user market. "The idea is to support pc and card makers with the architecture," he said.

Simon Parry, *EW*



Broadcast Radio Data – as received on a pc.

Quantum pc card order. *UK-based telecom products specialist, Quantum Electronics, has received an order of £500,000 for its Type II PCMCIA fax modems that can be used with GSM lines as well as land lines.*

Equivalent to over 50,000 cards over a period of three years, the order will help Quantum Electronics reach its goal of attaining a £20m turnover employing 200 within the next five years. The company currently has around 100 employees and its latest financial results show a £4m turnover.

4kV/µs V-mode op-amp is claimed as world's fastest

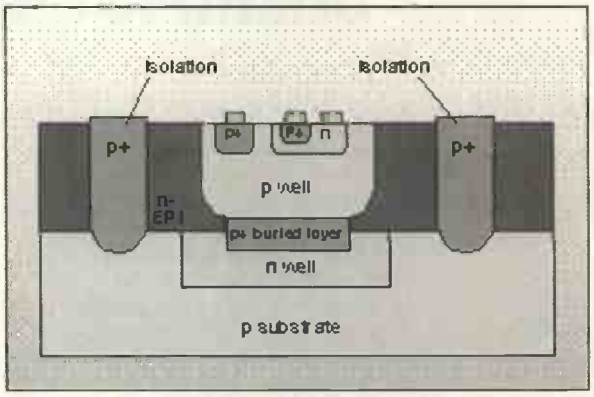
National Semiconductor has introduced an op-amp that has a slew rate of 4100V/µs which it claims is the world's fastest voltage-feedback operational amplifier.

The *LM7171* is indicative of trend in which innovative amplifier front-ends and high-performance processes allow voltage-feedback op-amps to encroach on current-feedback territory. This tempts engineers who are ignorant of current-feedback techniques to design high speed circuits.

However, National Semiconductor engineer Mark Holdaway thinks current-feedback op-amps will continue to reign at the top. "Current feedback amplifiers have a flat open-loop gain response, whereas the gain of voltage feedback amplifiers decreases at 20dB/decade from dc," said Holdaway. "Therefore current amplifiers have an inherent gain advantage in high speed applications."

The *LM7171* has a 4100V/µs slew rate and a bandwidth of 220MHz (Av=2) at a supply voltage of ±15V. With a ±5V supply the figures are 950V/µs and 140MHz.

Maximum output current of the amplifier is 100mA and it has been designed with stability in mind. This allows the device to drive heavy, capacitive loads like video cables with claimed low distortion, resulting in high-quality images. Supply current is typically 6.5mA and offset voltages down to 200µV are available.



National's new 4100V/µs voltage-mode op-amp uses proprietary VIPIII bipolar process. This allows vertically integrated pnp transistors to be made with performance similar to nearby npn transistors. The third generation of the VIP process produces npn and pnp transistors with f_ts of 3GHz and 2GHz respectively.

EMC awareness receives a boost

The DTI launched on 1 December 1995 its £100,000 extension to the EMC awareness campaign. The money will pay for five technical consultancy hotlines around the country.

The extension is to be managed by Salford University Technical Services which says the current 16 emc clubs, established as part of the original £450,000 awareness campaign, will be grouped into five consortia. These will each run a hotline providing full-time technical support for six months until May next year.

David Southerland of the DTI said the intention of the extension was to "deal with the immediate panic" before EC regulations are enforced on 1 January. "A lot of people still have questions but the emc clubs haven't got any spare capacity," said Southerland. "The extension will help."

Southerland added that the extra money would be found within the DTI and said the Microelectronics in Business programme would not be affected.

NiMH batteries could see doubling in capacity

A nickel-metal-hydride battery with a claimed energy capacity twice that of typical NiMH cells is being developed by Matsushita. The battery stores 300Whr/l compared to conventional NiMH cells which offer around 170Whr/l.

Nickel-metal-hydride cells offer higher energy densities than Nickel cadmiums and have a lower environmental impact. They are appearing in portable products like mobile phones and laptops, but there is some debate whether they will be overtaken by lithium technology secondary cells.

Lithium ion cells have higher energy densities, around 280Whr/l with 360Whr/l predicted. The Matsushita battery, if it proves to be mass-producible, brings NiMH strongly back into the fray.

- AER Energy Resources of Columbus, Georgia, is claiming a 50% increase in the capacity with a 78% hike in output power for its rechargeable zinc-air batteries. AER makes batteries that fit under popular laptops increasing their run time to over 12 hours between charges.

UK X-ray litho work to continue

Oxford Instruments is continuing development of its Helios II X-ray synchrotron for IC lithography despite uncertainty over the viability of the technology. X-ray lithography is considered slow and too expensive for production purposes by some semiconductor manufacturers.

However, Oxford Instruments believes the synchrotron, due next year, is not an expensive machine considering its capabilities and is in discussion with a number of IC makers.

"I don't think the synchrotron is expensive. Considering the investment needed, our machine doesn't cost much. Optical steppers are slightly less expensive, but still comparable," said Alistair Smith, head of the semiconductor processing division at Oxford Instruments.

Helios II is a twenty-stepper machine that can provide continuous operation from a high intensity X-ray source. Oxford Instruments expects X-ray lithography to become the norm before the end of the decade.

Apple pushes PowerPC against Intel

Apple Computer, worried about the progress of *PowerPC* microprocessor development, has pressured its partners IBM and Motorola to boost the microprocessor's performance sooner to keep pace with Intel.

Although Apple says that *PowerPC* is still a better platform than *Pentium Pro*, it acknowledges that the *PowerPC*'s performance advantage has been eroded by Intel's *Pentium Pro* family.

David Nagel, vice-president of Apple Research and Development, said: "We have been concerned about *PowerPC* development and we have communicated that concern to IBM and Motorola. They have promised to address the issue and we are confident they can get the *PowerPC* back on track."

When the *PowerPC* was first unveiled, its supporters promised a 200% increase in performance compared to Intel microprocessors. The performance advantage has been reduced to between 10 and 50%. "Fifty per cent is still an important advantage for a lot of computational tasks," says Nagel. "I wish it wasn't the case, but Intel has done a good job in narrowing the gap."

Cabling makers dispute unshielded twisted pair emi

Claims that unshielded twisted pair cabling may not meet emissions rules under the EMC Directive have been attacked by three leading cable network suppliers.

Nortel, AMP and AT&T have demonstrated that category 5 UTP should not push installed networking equipment outside the limits of the EN55022 emissions specification, provided the terminal equipment is fully EMC compliant.

"There is a great deal of misinformed rumour generated by the shielded cable manufacturers," said Arthur Green, marketing manager for Nortel Cable Networks. "It simply isn't true that shielded cabling is the only way to meet the EMC Directive and we have demonstrated it at 155Mbit/s."

Nortel tested a 155Mbit/s ATM broadband communications link running over 100m of UTP category 5 cable including patch panels. Measured emissions were at least 8dB better than the EN55022 Class B (domestic) limit from 30MHz to 1GHz.

Current legislation requires that all active LAN equipment should be certified to EMC Class A in commercial environments from the beginning of January 1996.

According to Green, as long as the cable terminations are suitably balanced category 5 UTP will support data rates up to 155Mbit/s and meet the EMC regulations.

Balancing the current flow in each arm of the twisted pair cable is necessary to ensure that noise currents are cancelled out at the receiver input. Nortel also suggests that inductive chokes are connected in series with the input transformer to keep the common-mode rejection ratio to the necessary 40dB.

Part of any common-mode noise signal is converted into a differential-mode noise signal which passes directly into the input of the receiver. The level of balance in the UTP link was measured by Nortel to be better than the necessary 40dB from 20 to 100MHz and better than 50dB from 1 to 20MHz.

According to Paul Cave, manager of AMP's networking group, manufacturers with only shielded products are using the EMC argument to boost sales. "There is confusion in the market caused by people with a vested interest in streaming the market down the shielded route," said Cave.

Richard Wilson, *Electronics weekly*

Surround sound for the pc embryo

Aimed at multimedia pcs, Dolby Laboratories has introduced Dolby Surround Multimedia – a cut-down version of the Dolby Surround Pro-Logic system used in home cinema.

The intention is to promote Dolby Surround-sound encoding among games companies who can use it to increase the sense of participation in their games.

The signals that Surround Multimedia decodes are the same as those in the Pro-Logic system, but the different listening requirements of a pc, allow the playback system to be simplified.

A pc user sits in a well defined position in front of the computer.

The home cinema audience, on the other hand, is spread around a room. The '3D' sound field of a PC does not need to be so big, and the Multimedia Surround system exploits this.

Windows 95 sales misjudged

Despite being the most highly marketed product in history, Microsoft's *Windows 95* is not reaching its sales targets and most home pc users say that they have no immediate plans to install the system.

Market research firm Dataquest says that it misjudged earlier forecasts of demand for the operating system and has reduced its forecast for 1995 shipments by 3.6m. It now says that 26.4m units will ship this year instead of 30m, and expects 10m units will remain unsold at the end of the year, gathering dust on shop shelves.

"The lower forecast is due to two factors: It is an artifact of forecasting a product at a time when it was not yet in the market, when there was no final shipment date and Dataquest is taking a more conservative view of the holiday season," said Dataquest analyst Paul Cubbage.

Also a survey of home pc users by market research firm Odyssey, found that just 6% of respondents had installed Windows 95. About 53% said that they would not install it and 30% said they didn't need it.

A survey of home pc users by market research firm Odyssey, found that just 6% of respondents had installed Windows 95.

Quarter micron geometries for GPS

GEC Plessey Semiconductors (GPS) has unveiled its technology roadmap coinciding with potential fab capacity down to 0.25µm. Next year it anticipates having its first silicon germanium chips on 0.35µm technology.

By 1997, the company will prototype 0.35µm c-mos production, with a 3.3V 0.35µm process scheduled for 1998. A further 2.5V 0.25µm c-mos process is expected by the end of the decade.

GPS is to pursue a more aggressive track in bipolar with 0.5µm, 5V and 3.3V, triple metal layer processes in production next year.

The company will sample a 0.35µm SiGe process next year with production scheduled for 1998. By the end of the decade GPS could have 0.25µm SiGe process.

GPS's first SiGe products will be 2.4GHz rf front-ends, low-noise amplifiers and mixers. ■

Monitoring heartbeat

It has been brought to our attention that Baki Koyuncu's "Monitoring Heartbeat" feature published in our July 1995 issue is based on John Becker's "Biomet Pulse Monitor" design published in the February 1993 issue of Everyday with Practical Electronics. We recognise that Copyright belongs to Everyday with Practical Electronics and apologise to them and to their Technical Editor John Becker for this unintentional infringement.

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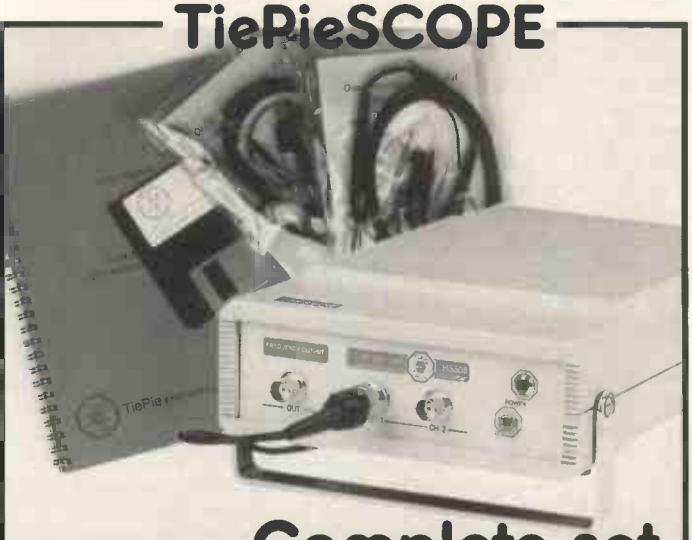

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RESEARCH NOTES

Jonathan Campbell

Gravity reveals military vehicle secrets

Experiments to measure different aspects of gravity are unremarkable in the modern laboratory. But if three scientists at Mitre Corporation in the US are correct in their assumptions, we could one day see portable gravity gradiometers scanning dusty lorries as part of arms limitation monitoring. Or even being used by Police on the M25, checking if vehicles are overloaded.

According to the researchers, Steven Gray, John Parmentola and Richard LeShack, the basic principles which make gravity gradient measurements possible are relatively easy to understand – it is the hardware and software engineering principles that are really involved .

Suffice it to say that the team proposes to use gravity gradients to monitor the weight of military vehicles, to help assess what type of arms, if any, they are carrying. Other studies have suggested that gravity profiles could be used to distinguish between conventionally-armed and nuclear cruise missiles. Or used to count the number of warheads on board an intercontinental ballistic missile or submarine-launched ballistic missile.

The approach would have certain advantages not shared by other techniques. It is non-contact, there can be no argument that design secrets are being revealed – as is the case with x-rays – and background readings can cause problems with γ-ray detectors. Scale equipment can also suffer when being used for in-motion measurements.

The researchers point out that the idea that the mass of an object can be estimated directly from gravity gradiometer measurements is easy to understand. At sufficiently large distances, all objects can be approximated to point masses and various expressions exist to relate gravity to mass.

Of course things get a little trickier when measurements are taken closer in, since the objects are no longer point sources.

Most of a recent paper (Estimating the weight of very heavy objects with a gravity gradiometer," *J. Phys. D: Appl Phys*, Vol 28 (1995) pp. 2378-2388) is taken up with explaining how to correct for the non-spherical nature of real world objects.

Obviously, much work has to be done to arrive at a reliable device giving reproducible results in a real situation. But in a world where scientists routinely talk in terms of the gravity exerted by a single grain of sand, such problems will surely not detain researchers for long.

***Steven Gray**, The Mitre Corporation, 202 Burlington Road, Bedford, MA 01 730, USA.*

Chemistry cracks open memory limits

Innovative but relatively minor changes in silicon-processing techniques could open up a three-fold reduction in the area required for capacitive components in microelectronic devices. Electronics experts are welcoming the advance as allowing further miniaturisation of memory devices which would otherwise soon hit capacitance limits using conventional methods.

Basis of the breakthrough, announced by R F Cava and colleagues at AT&T Bell Laboratories, is an increase in the dielectric constant of Ta2O5, tantalum oxide, by addition of 8% TiO2 titanium oxide ("Enhancement of the dielectric constant of Ta2O5 through substitution with TiO2", *Nature*, Vol 377, pp. 215-217).

Ta2O5 is known to form high-quality thin films, though its dielectric constant is low at around 35. Addition of TiO2 boosts that figure to 126.

Ta2O5 and TiO2 are already well used and understood in electronics, unlike many of the more exotic compounds that have been suggested in the past to increase the dielectric constant. This allows the area of capacitors to be reduced.

The exact reason why the TiO2 boosts the dielectric constant of Ta2O5 is not yet wholly clear. So far TiO2 it seems to be unique in its effect.

However the researchers say that at around the 8% TiO2 level, the new material is likely to be processable with very similar conditions to those currently employed to make pure Ta2O5 films.

As well as the area reduction, the workers say that the material could eliminate the need for complex three-dimensional capacitor geometries often resorted to, to yield acceptable capacitance in small-area components.

***R F Cava**, AT&T Bell Laboratories, 600 Mountain Avenue, PO Box 636, Murray Hill, New Jersey, 07974-0636, USA.*

Putting electric cars under the microscope

Calls for ever-smaller electric vehicles have led to a breakthrough by Japanese workers at one of the largest suppliers of technology to the automotive industry worldwide. In shape it looks like an estate. It is light-weight, has a record breaking speed capability in its class, and you can even have it finished in pure gold. Only one drawback – the vehicle is only 7mm long.

In fact the microcar developed by researchers at Nippondenso Research Laboratories in Japan is currently the smallest wheel-driven mechanism in the world. Overall weight is 65mg and the car is reported to have recorded a top speed of 100mm/s.

Power for the car is through a miniaturised step motor built around an isotropic barium-ferrite magnet rotor that has been machined into a tube shape by a cylindrical grinder ("Performance of a 7mm microfabricated car, Akihiko Teshigara et al, *Journal of Micromechanical systems*, Vol 4, No 2, pp. 76-80). The rotor's core is made into a four-pole magnet by placing it between four contact probes whose coils can generate a four-pole magnetic field. It is then joined directly to a zirconia front wheel shaft.

Chassis and wheels are made of stainless steel, and for the shell body, the main material used is a 30µm nickel film produced by plating onto an aluminium mould, etching away the aluminium, then protecting the nickel with gold. Microparts are so small that researchers had to resort to a mechanical manipulator usually found in bioresearch cell handling.

During testing, three running conditions were identified. In the low frequency range, alternation of the magnetic pole of the stator core is slow and the alternation interval long. So the rotor rotates step by step with each step being 90°. But at certain angles of rotation, motor torque increases too quickly and the wheels lose their grip, resulting in a stop-go movement. In the medium frequency range, movement is much smoother, with maximum speed being attained at 100Hz. But local variations in surface friction can cause some erratic movement – even backwards travel.

In the high frequency range, the rotor could not keep up with the changing field and simply rotated back and forth. However, surprisingly the effect produced the smoothest and most consistent forward movement. Researchers believe movement was due to a vibration of the stator caused by its asymmetry. Clearance between the wheel shaft and the chassis allowed this vibration to move the wheel into and out of contact with the surface, enabling a smooth and net movement in one direction.

A speed of 100mm/s might not seem sports performance, but it could be too fast for a 1/1000th scale car. Wear of the rotating parts is quite severe. Unfortunately, in tests, lubrication caused adhesion due to molecular force or surface tension.

Plainly there is still work to do before a millimetre scale machine becomes useful in industrial and medical applications. And of course, the design does not really have any practical implications for real electric cars. Where on Earth are you going to be able to find atomic-scale furry dice?

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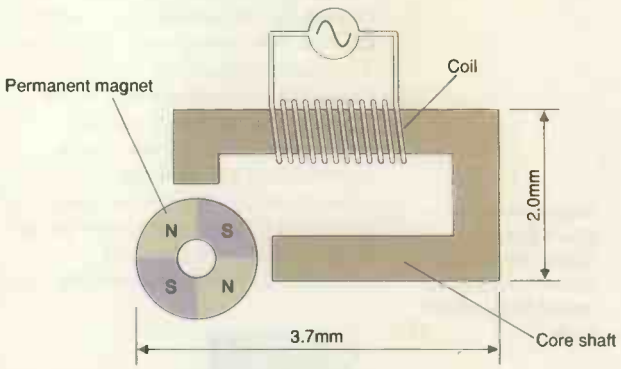
Email: atesiga@rlab.denso.co.ip.

Watching the microcar go through its paces...

...about the same size as a grain of rice



Micro step motor at the heart of Nippondenso's 7mm car

Plastic lasers breakthrough performance boundaries

Sealing laser modules in plastic can provide several operational advantages. But such modules have rarely demonstrated good operating characteristics and so far reliability has been uncertain. However, three researchers from NTT Opto-electronics Laboratories in Japan are claiming to have built a device that could make plastic moulding practicable, heralding the next stage in laser module fabrication technology for optical fibre transmission.

The lasers ("Pigtail type Laser Modules Entirely Moulded in Plastic," M Fukuda, *Electronics Letters*, Vol 31, No 20, pp. 1745-1747) are Fabry-Pérot type 1.3µm-band bulk or strained MQW BH devices. They have no facet coatings, are mounted on silicon heat sinks with a fibre guide. The heat sinks are then bonded on a TO18 stem usually

used for compact disc lasers.

In the fabrication process, the laser is manually mounted so that the light emitting region can be set at the centre of the fibre guide. In this way, the Japanese team reports, optical coupling can be obtained without alignment, by inserting the fibre along the guide. Distance between the laser facet and the fibre end (optical input port) is a few tens of micrometres.

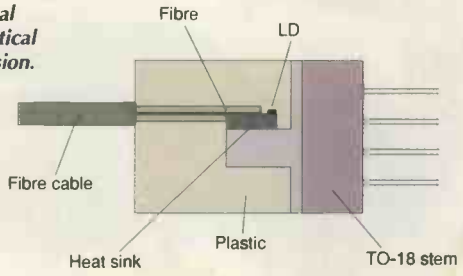
The entire laser-mounted stem and fibre can then be covered with epoxy resin and cured. Refractive index of the resin is set at around the value of the fibre core.

Results show that good modulation characteristics can be produced, and the 3dB band-width under sinusoidal wave modulation is more than 3GHz at a current of 30mA.

Following tests, life is estimated at over 105h – even at 70°C and a constant output power of 5mW.

Fukuda and colleagues say that the work proves the feasibility of plastic pigtail lasers and demonstrates a practical low cost method for optical transmitter production.

Plastic lasers offer practical and low-cost optical sources for optical fibre transmission.



M Fukuda, NTT Opto-electronics Laboratories, 3-1 Morinosato Wakamiya, Atsugi-shi, Kanagawa, 243-01 Japan.

Using infrared to see through the traffic jam

We can't – or don't want to – halt the unwavering progress of the automobile. But we can make a better job of keeping all that metal moving along the roads, if a simple system being tested in New York finds favour in the UK.

Good traffic control involves counting the number of vehicles, analysing their movements in real time and taking control measures, such as switching on green lights. Unfortunately magnetic-loop detectors are relatively inflexible and any modifications are going to mean digging up the carriage-way – never the best way to improve traffic flow. They are also limited in their capabilities and can not be used to record speed and length data of individual vehicles, or for vehicle identification and tracking.

But infrared systems now being developed look as though they can do all that – and more. The first commercial system, produced by Eltec Instruments, has just been launched, and in an unrelated study recently, researcher Tarik Hussain and colleagues revealed the full potential of such systems to improve traffic flow ("Infrared pyroelectric sensor for detection of vehicular traffic using digital signal processing techniques", T M Hussain et al, *IEEE Transactions on Vehicular Technology*, Vol 44, No 3, pp. 683-689).

Pyroelectric systems rely on sensors mounted above a roadway to monitor traffic passing on individual lanes below. The detectors convert incident thermal infrared optical power into an electrical output signal.

Pyroelectric crystal sensors develop an electrical charge on their surfaces when incident radiation is absorbed by a coating on the crystal surface and converted to heat. The heat alters the lattice spacing of the crystal and causes a charge differential, measurable as an output voltage to sense the passing vehicles.

The signal, typically in the millivolt range, is then passed through a comparator block that uses mirror op amps to compare the received signal from the detector when a vehicle passes, to the steady-state condition. High cmrr op-amps – of the order of 60dB – allow the system to respond only to the difference signal.

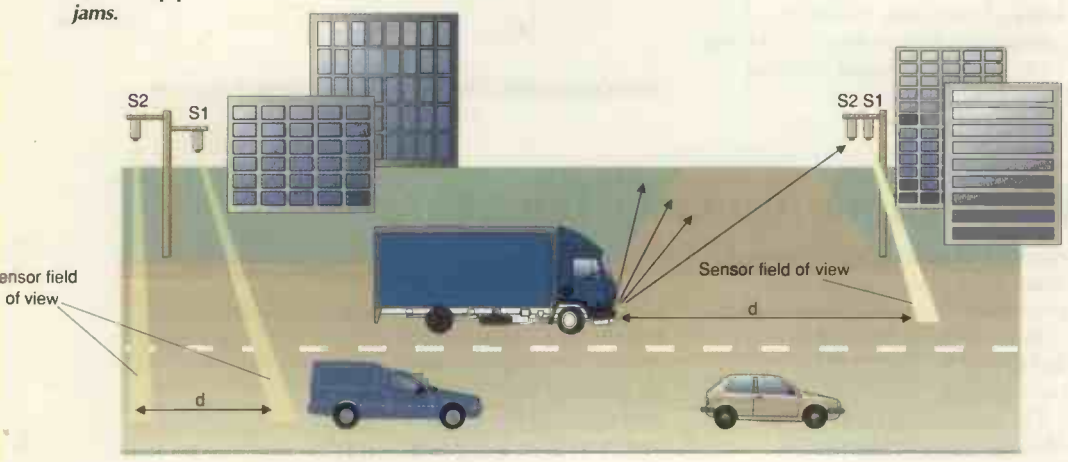
For the 50-60m detection distances typically required, a gain of 40dB on the op-amp gives acceptable signal-to-noise ratios. The difference signal is fed to an *LMC555* to generate a series of pulses which feed a counter.

In use, the pyroelectric detectors can be mounted on lamp standards or anywhere where they can have a line of sight to the vehicles. Counting output pulses is then a simple matter. But using a second sensor along the road allows much more information to be obtained. The system can sense the duration of each signal in each sensor, and also the time between signals. So speed, acceleration and length of vehicle can all be calculated.

Different signal widths result from cars, vans and lorries in terms of signal widths and the field tests showed that weather conditions had little effect. The researchers say that the system could survive several hundred fold reduction in visibility to a level at which traffic probably couldn't circulate anyway.

Counting error was found to be less than one in 200 vehicles and was more accurate than magnetic loop sensors which overcount by detecting additional axles in the case of lorries. ■

Infrared sensors could form the backbone of traffic control system that would help prevent jams.



T M Hussain is with Farradyne Systems Inc, New York, NY 10119, USA.

Designing a horn loudspeaker

Ketil Parow details how to design a no-compromise, full-range tractrix horn loudspeaker featuring the combined benefits of high efficiency and crossover-free operation.

Why a horn? Much has been written about horn speakers over the years, and I am not going to repeat all of it here. I will however point out the obvious advantages, and my points of view. First, I will kill some of the myths about horn loudspeakers.

- Bass reproduction from a horn is not tinny. Some poorly-designed systems may have a tendency to produce 'empty' bass. In these cases, chances are that the designer compromised too much, foreshortened the horn in order to reduce the physical size. Poor wood quality may also have contributed to the poor quality.

- You do not need a vinyl record player and valve amplifiers to make a horn sound good. Advantages of a horn system are noticeable – regardless of equipment technology.

- Treble is not poor from a one-way horn system. There is a number of 'full-range' drivers available that are not truly range. This is not so with the Lowther drivers I used.

There is wide agreement on the following pros of horn loudspeakers.

- A horn system is far more efficient than an infinite baffle of bass reflex system. This offers not only more sound per input watt. For a given signal peak level, spl, the driver's excursion is accordingly smaller. As a result, the driver operates with more linear excursions so distortion is lower.

- Sound from a horn is more dynamic and more life-like than that from closed or vented boxes.

- In my experience, multi-way systems in vented or sealed enclosures can be seriously compromised by sloppy construction. A horn is less sensitive to enclosure materials and wood-working accuracy.

- Crossover networks are difficult to design, expensive, and the end results are unpredictable. A one-way horn removes these problems and produces a single sound source.

Design goals

Does the world need a new horn design? There is a number of well-designed horn systems in existence. However, on reviewing some of the existing designs, they did not appeal to me for various reasons.

The modern designs seem to compromise too much in order to limit their physical dimensions. Older designs are no doubt good, but they *look* old fashioned. I want my speakers to look modern.

When I set out on this project, the only goal that was well-defined was that I wanted a back-loaded horn. Bass reproduction was to go well below 40Hz. Physical size was not an absolute restraint.

Horn theory overview

This section merely scratches the surface of horn theory. Those of you wanting to design your own horn are referred to the literature list. I will however provide all the theory relevant to the horn that I designed in enough detail to allow you to duplicate my work.

A horn is an acoustic transformer coupling the speaker cone movement to the air. It transforms a small volume of air moving with high energy into a low-energy, large movement of air. This is where the efficiency comes from.

The horn forms a funnel starting at the throat, closest to the driver and ending at the mouth. Cross-sectional area of the funnel expands along the length of the horn at a rate depending the formula used. This is known as the contour.

Any given horn is only effective down to its cut-off frequency, f_c. To calculate the horn, you need to know the mouth and throat area, the cut-off frequency, and the chosen contour.

Mouth dimensioning

Mouth area is calculated from f_c. Circumference of a circular mouth should be

List. Pseudo code for calculating the horn's tractrix contour.

```
;Sample code
Def var r       as decimal . ;See the above formula
Def var x       as decimal . ;See the above formula
Def var a       as decimal . ;See the above formula
Def var  r_throat       as decimal . ;Radius at throat
Def var  r_ fe_mouth    as decimal . ;Radius for a Fully
                        ;Expanded mouth (free space loading)
Def var  hl_ feas decimal . ;Horn Length when Full Expansion
                        ;(free space loading)
Def var  Size_factor    as integer .          ;See below
Def var  step           as integer initial 1 . ;See below
Def var oldx            as decimal initial -1 .
Def var  xfromthroat    as decimal .
Def var  prec           as decimal initial 0.001 .
               ;simulate radius growth with prec(ision) of…
Input r_throat          ;Get the radius of the throat
Input Size_factor       ;Get the size factor
                        ;(1 for free loading,
                        ;2 for the middle of a floor,
                        ;4 for wall placement, 8 for corner placement)
Input r_fe_mouth        ;radius for free loaded mouth
Input step              ;Get the desired step value
                        ;(output for every <step> length units)

r = r_throat * sqrt(Size_factor).
               ;Start at the size-factor adjusted r.
a = r_fe_mouth.                    ;End at the fully expanded mouth.
hl_fe = a * log((a + sqrt(a * a - r * r)) / r) - sqrt(a * a - r * r).
                        ;Calculate the length of the horn
do while r <= r_fe_mouth: ;Leave the loop when we're at the mouth.
  x = a * log((a + sqrt(a * a - r * r)) / r) - sqrt(a * a - r * r).
               ;Calculate the x (dist from mouth)
  xfromthroat = hl_fe - x.          ;Find dist from throat
  If trunc(xfromthroat / step, 0) > oldx then do:
                        ;Did we just step over to a new value of x?
    display             ;Yes, print the line out...
      xfromthroat at 1                  column-label "Dist. throat"
      sqrt(r * r * M_PI / Size_factor)  column-label "Square"
      r / sqrt(Size_factor)             column-label "Radius"
      (r * r * M_PI / Size_factor)      column-label "Area".
    oldx = xfromthroat / step.        ;And keep current step value
  End. ;New step value
  r = r + Prec.                       ;Increase radius by Prec
end.
;End Sample code
```

Performance

I don't have the tools to measure frequency response, but bass response seems reasonably flat in the deep end. I suspect, however, that there's a small dip in the response in the high bass region. It may be possible to reduce this with experimentation on cavity-damping/room-placement.

One of the most amazing things about these speakers is the sound output they are capable of. Out of interest, I tried powering them up using a Walkman, and they actually filled my basement – which is a big room. According to my measurements, 2-3W driving these speakers should suffice. At 1W, they are loud enough for most people to start holding their ears.

Horn speakers require tweaking to perform at their best. Seemingly insignificant adjustments in room placement can shift the sound from beautiful to dreadful. At this point, I am still not 100% sure that my speakers are optimally placed, and some of the above noted problems may still go away.

Lowther drivers are often criticised for having peaks in the high mids/low treble regions. I think the critics are, to some extent, right on this. There is a pronounced peak somewhere in that region, making some vocals/guitars sound a little harsh. There are some common tweaks to remedy this. Loosely stuffing some clean, long-hair wool between the whizzer-cone and the main cone is one of them.

equal to one wavelength of f_c, which gives,

$$r_m = \frac{c}{2\pi f_c}$$

where, c is the speed of sound, at 34290cm/s or 1125ft/s.

If you try inserting a sample value in the formula of, say, 30Hz, you will get an outrageous mouth radius of 182cm. This, however, is a mouth size calculated for free space loading. That means that the dimensions are good if the horn is hanging from the roof, radiating into all eight quadrants of the space. For wall placement, the horn will be radiating into only two quadrants, so you can safely reduce the size by a factor of $^8/_2$, or four.

For corner placement, the situation is even better. The horn will be radiating into one quadrant only, and you can reduce the size by a factor of eight. In this example, that will bring the mouth down to $r_m/\sqrt{8}$, which is 64cm. In a square horn, this corresponds to a square side of 114cm – which is still large.

It is possible to reduce the mouth size still further, even without compromising the overall design, as explained later.

This horn's f_c was set at 32Hz, and calculated for corner placement.

Throat dimensioning

Theory here is somewhat more obscure. However, there are some valid thumb rules in calculating the throat area. In his 1974 article (see recommended reading) Dinsdale said, "For maximum bandwidth of a horn, one uses throat-to-driver ratios of 0.50 to 0.30; for maximum efficiency one uses ratios of 0.50 to 0.70."

Personally, I chose the throat area of my horn empirically. I browsed through 10-20 comparable horn designs, and decided on the basis of the designs most resembling mine. The driver I chose has an effective area of 211cm^2. This indicates that the throat area should be somewhere between 63cm^2 and 148cm^2. I decided on a throat area of 100cm^2. That gives a throat radius, t_r of 5,65cm.

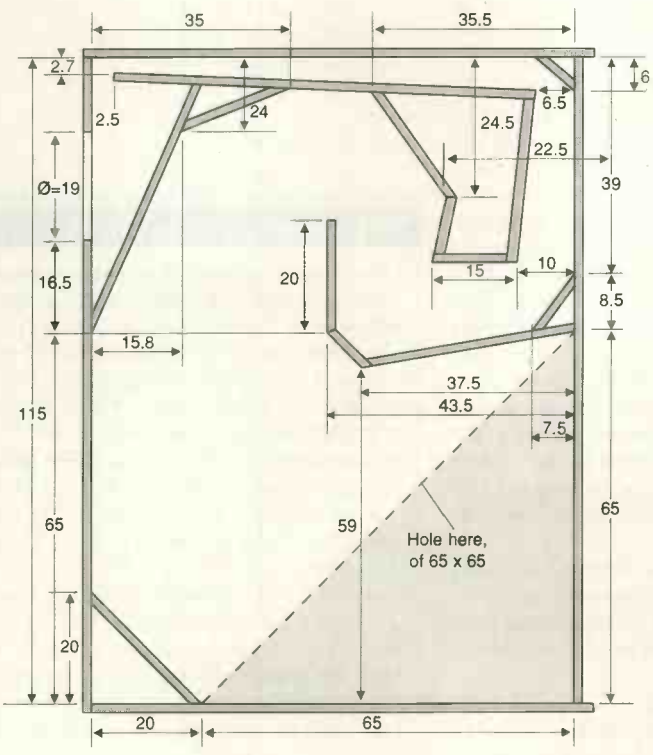
Horn contouring

Common contours for horn loudspeakers include conical, exponential, hyperbolic, and the tractrix. Of these, the conical is the easiest one to calculate and convert into a physical unit, but it is also the least efficient. Conical contours are never used for bass horns, because of the poor response and the impossibly long horns that result.

The exponential is the most common, and is easy to calculate. The hyperbolic contour is a variety of the exponential, and is the most efficient type. The trade-off is more distortion in the deep bass region. Hyperbolic horns are

Tractrix horn expansion from the throat

Distance	Radius	Square	Area	Const. width	L. straight	Dist, inch	Const. w, inch	L. straight inch
				37.00			14.6	
0	5.64	10.00	100.00	2.70		0.00	1.06	
10	5.99	10.61	112.53	3.04	9.93	3.94	1.20	3.91
20	6.35	11.25	126.64	3.42	9.93	7.89	1.35	3.91
30	6.73	11.94	142.48	3.85	9.88	11.82	1.52	3.89
40	7.14	12.66	160.36	4.33	9.89	15.76	1.71	3.90
50	7.58	13.43	180.48	4.88	9.87	19.70	1.92	3.88
60	8.04	14.25	203.03	5.49	9.80	23.62	2.16	3.86
70	8.53	15.12	228.61	6.18	9.85	27.57	2.43	3.88
80	9.05	16.04	257.31	6.95	9.78	31.50	2.74	3.85
90	9.61	17.03	289.85	7.83	9.81	35.45	3.08	3.86
100	10.19	18.07	326.35	8.82	9.73	39.37	3.47	3.83
110	10.82	19.17	367.65	9.94	9.72	43.31	3.91	3.83
120	11.48	20.35	414.22	11.20	9.67	47.25	4.41	3.81
130	12.19	21.61	466.81	12.62	9.63	51.18	4.97	3.79
140	12.94	22.94	526.27	14.22	9.59	55.12	5.60	3.78
150	13.75	24.36	593.56	16.04	9.54	59.06	6.32	3.76
160	14.60	25.88	669.75	18.10	9.48	63.00	7.13	3.73
170	15.51	27.50	756.05	20.43	9.41	66.94	8.04	3.70
180	16.49	29.22	853.78	23.08	9.32	70.88	9.08	3.67
190	17.53	31.06	964.84	26.08	9.23	74.81	10.27	3.64
200	18.64	33.03	1090.96	29.49	9.11	78.75	11.61	3.59
210	19.82	35.14	1234.48	33.36	8.99	82.68	13.14	3.54
220	21.10	37.40	1398.57	37.80	8.86	86.62	14.88	3.49
230	22.47	39.82	1585.84	42.86	8.68	90.56	16.87	3.42
240	23.94	42.44	1800.80	48.67	8.50	94.50	19.16	3.35
250	25.53	45.25	2047.51	55.34	8.25	98.43	21.79	3.25
260	27.25	48.30	2333.01	63.05	8.01	102.37	24.82	3.15
270	29.12	51.61	2663.60	71.99	7.68	106.30	28.34	3.03
280	31.16	55.23	3049.89	82.43	7.33	110.24	32.45	2.89
290	33.40	59.20	3504.50	94.72	6.91	114.18	37.29	2.72
300	35.88	63.59	4043.91	109.29	6.40	118.11	43.03	2.52
310	38.66	68.52	4694.61	126.88	5.83	122.05	49.95	2.30
320	41.82	74.13	5494.64	148.50	5.15	125.98	58.47	2.03
330	45.54	80.71	6514.42	176.07	4.37	129.92	69.32	1.72
340	50.14	88.87	7898.07	213.46	3.43	133.86	84.04	1.35
350	57.04	101.10	10221.90	276.27	2.17	137.80	108.77	0.86



Prototype enclosure design, cross section. Front and back panels are 37cm wide. Note these dimensions apply for 22mm mdf.

Table 1. Inside dimensions of the horn. Note that the mnemonics are referred to in Table 2.

Dimension	Mnemonic	cm
Width	IW	37cm
Depth	ID	85cm
Height	IH	115cm

also somewhat longer than exponential horns. Combinations of all these types can also be found.

The tractrix is a curve well-known in the world of mechanics. In a stroke of genius, the late Paul Voigt applied the tractrix to horn speaker acoustics in 1926. The tractrix contour has characteristics similar to the exponential, but has the advantage of being shorter since the curve expands faster. The disadvantage is that it is somewhat awkward to calculate. This is because you cannot directly calculate the area $A(x)$ at a distance x from the throat.

In this design, I decided to employ the tractrix contour to save space and wood.

Calculating the tractrix

The formula for calculating a tractrix contour is as follows,

$$x = \frac{a\log(a+\sqrt{a^2-r^2})}{r} - \sqrt{(a^2-r^2)}$$

Where x is the distance from the mouth of the horn, a is the radius at the mouth and r is the radius at distance x from the mouth.

The tractrix curve can also be constructed using two straight rulers.

However, if you have access to a computer and some form of compiler, the most convenient method is to write a small program to calculate the curve. Pseudo code outlining how this is done is presented in the **List.**

Coupling horn and driver

Before designing the enclosure, some attention needs to be directed to the volume of air – the cavity – between the driver's back side and the horn throat. It is best to keep higher frequencies out of the horn.

A good thumb rule is to let the horn handle 3-4 octaves or fewer. You should therefore dimension the cavity in such a way that it will act as a low-pass filter with an upper cut-off 3-4 times the horn's cut-off frequency. Also, the upper cut-off should be set at a point where the horn's length equals an odd multiple of the wavelength. This is because the horn is loaded from the back of the driver, 180° out of phase. In this way, cancelling of the frequencies around the upper cut-off is avoided.

Calculate the volume of the cavity V_c using,

$$V_c = \frac{C \times \text{throat area}}{(2\pi \times \text{upper } f_c)^3}$$

In my design, this was not considered. This is because I wanted to leave plenty of space available for experimenting with different upper cut-off frequencies and damping of the cavity. However, I advise would-be constructors to take advantage of this equation.

Folding a bass horn

This is by far the most difficult part of constructing a bass horn. Horn length should be measured along the middle of the duct. Through a bend, the length should be measured along the middle of the duct, all the way around the bend. That makes it a little difficult to construct the bend correctly, but by employing a pair of callipers and a ruler, it is possible.

At first glance, the most convenient method appears to be to keep one wall of the horn straight, while expanding the horn with the other wall. This provides for a convenient way of making the cross-sectional areas match the distance. However, it also makes it harder to measure the distance, since the distance will be on an angled line.

The formula gives you values for x measured along a straight centre line in the middle of the duct, while the radius – and calculated squares/rectangle heights – will expand in both directions from the centre line.

I solved this trigonometrical problem with a spreadsheet. I inserted output from the tractrix contour program into the spreadsheet, and added a number of columns. One of the columns contains the length along the straight wall of the horn, corresponding to the length along the centre line, x. This makes it a lot easier to draw the horn.

In this spreadsheet, the first four columns are created by the tractrix calculation program. These are, distance, radius, square and area. Height of the duct with a width of 37 is shown in the next column, entitled Const. width. In the L. straight column, length of the straight duct wall over the corresponding distance is shown. This has been found by applying simple trigonometric functions to the angles given by the increase in height *versus* the length increase shown in the Distance column.

In the spreadsheet that I used, I also calculated the minimum space requirements for each row of the table. This gave a good indication of the final overall size, given the horn length.

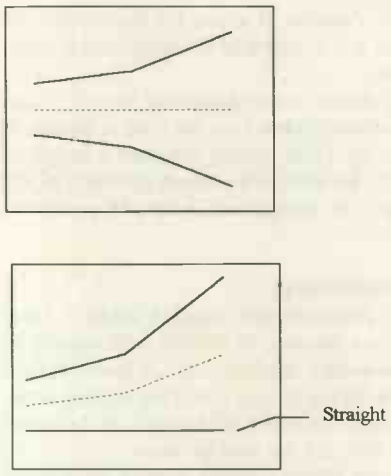
And a time to compromise...

Comparing the spreadsheet to the drawing reveals that the mouth area of horn appears small. It has been foreshortened, i.e. terminated at a mouth smaller than the actually calculated mouth area.

An accepted method of foreshortening the horn, is to base the mouth opening on a higher frequency than the fc used to determine the flare rate. Normally, a horn's 'true cut-off' will be at a frequency of around $1.25f_c$. This allows the horn to be terminated at an area of 7314cm^2. This corresponds to a duct height of 198cm in our 37cm constant-width horn.

Purists will tell you not to foreshorten the horn any more than this, and they are right. However, reviewing a large number of bass horns, I've found that even some of the most acclaimed designs are foreshortened more than this – and in some cases a lot more. The resulting design theoretically yields an uneven response versus frequency curve in the 1-2 octaves above the f_c. However, so will any speaker located in any room. Depending on the acoustical damping characteristics of the speaker's surroundings, this natural reflection phenomenon may, or may not, be in excess of the irregularities of the horn.

After having done some thorough research on the subject, I have found a number of thumb rules for foreshortening horns. One of them is that the mouth area should be at least five times the area of the throat. This rule is probably best-employed for front-loaded



Folding the horn. In order to transfer the horn from paper to woodwork, it can help to draw one side flat and double the curve on the opposite side. But this also has the disadvantage of making the distance more difficult to measure since the horn axis is no longer a straight line.

Mounting the drivers – caution

Take great care when handling the Lowther drive units. The magnetic gap is open, and small metal objects, swarf and dust can easily be drawn in to the gap. If that happens, the unit will need to be serviced. A useful tip is to cover the whole unit with thin tights as soon as you remove the plastic bag it is shipped in, and then mount the driver with the tights in place.

Table 2. Dimensions of panels required for the horn. In the interests of flexibility, the choice of wood thickness has not been fixed.

Qty	Board	Width	Depth	Height
2	Top	IW	ID + front panel thickness + back panel thickness + 1	
2	Bottom	IW	ID + rear panel thickness + 1	
2	Front	IW		IH + bottom panel thickness
2	Rear	IW		IH
4	Sides		ID + front + back thicknesses	IH + top + btm thicknesses

horns. Another is to cut the horn when the length is at a quarter of the theoretical f_c wavelength.

My design's foreshortening is well within these thumb rules. I cut the horn at an area of 91cm by 37cm, giving the horn a length of 288cm. Because of the mouth geometry of this design, the mouth will in fact be somewhat larger.

Dimensioning

Inner dimensions are listed in **Table 1**. Since there's a number of options with regards to wood quality, thickness, etc., I have left final dimensioning to you. Using the original drawing, the outer board dimensions can be calculated like this, for two speakers.

I used 22mm medium-density fibre-board for the top/front and side panels, and 16mm MDF for the back/bottom and inner boards. My advice however is to use marine plywood, as thick as you can afford. Also, if I were to build these speakers again – which I am sure I will, incidentally – I would cut some boards for bracing the cabinet, between the top panel and the topmost inner board, between the front board and the middle (vertical) inner board, and between the side panels toward the mouth opening. ■

Recommended reading

Dinsdale, J., Horn Loudspeaker design, *Wireless World*, Mar-June 1974. Note, there are errors in the tables of tractrix horn lengths.

Edgar, BC, The Show Horn, *Speaker Builder*, 2/90.

Edgar, BC, The Monolith Horn, *Speaker Builder*, 6/93.

Edgar, BC, The Edgar midrange horn, *Speaker Builder*, 1/86.

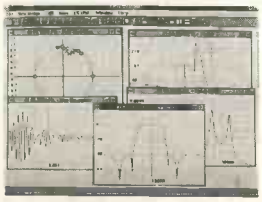
Edgar, BC, Solving the Klipschorn throat riddle, *Speaker Builder* 4/90.

Edgar, BC, The Klipschorn throat revisited: Or, Oooops, *Speaker Builder*, 6/90.

Hanna CR and Slepian, J, The Function and Design of Horns For Loudspeakers, *JAES*, Sep 1977 Vol. 25, No. 9, pp. 573-585. (Reprint of 1924 article).

Discussion: The Function and Design of Horns For Loudspeakers, *JAES*, Mar 1978, Vol. 26, No. 3, pp. 131-138. (Reprint of 1924 article).

Ketil Parow is a 30 year old programmer / software analyst at RADAR Software AS in Norway. His hobbies include loudspeaker design and building, wood-working and scuba diving. Ketil is also a part-time musician.



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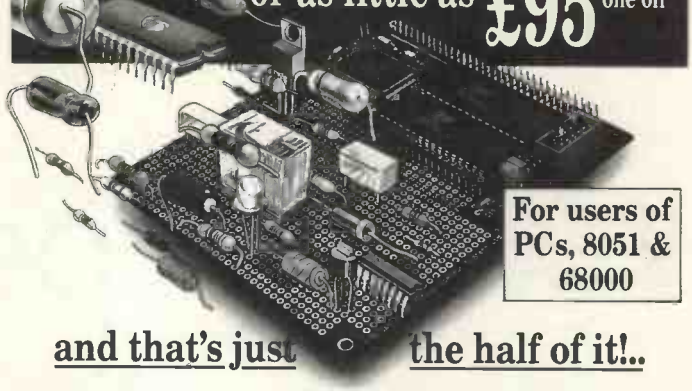

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High performance direct conversion

Rod Green and Richard Hosking discuss how extending the polyphase direct conversion receiver concept produces a system with high performance, impressive selectivity and variable bandwidth.

There have been many direct conversion receiver designs published, many with acceptable performance despite their simplicity. Problems with simple designs are the 'audio image', and difficulty receiving modes other than cw and ssb.

The audio image – ie receiving signals on both sides of the local oscillator frequency – can be eliminated using phasing techniques. It is possible to achieve opposite side-band suppression with these circuits of 55-60dB. This level of suppression approaches that achievable with a crystal filter.

A block diagram of a polyphase dc receiver, **Fig. 1**, published in *EW+WW* March 1994, is shown in with a plot of the receiver selectivity in **Fig. 2**. You can see that as the receiver is tuned across the the signal carrier frequency from one side-band to the other, the response drops very rapidly from 0 to –60dB.

'High-side' selectivity, illustrated in Fig. 2, depends on the low-pass filter following the audio phase network. In the case of the previous polyphase design a five-pole low-pass filter was used to give attenuation of approximately 30dB per octave above 3kHz. As a result the –60dB point occurs at about 12kHz from the carrier.

Obviously, better results could be obtained using higher order switched capacitor or digital filters, with response determined by the design of the filter and the number of poles. Alternatively, if the 'crossover' effect that occurs as the receiver is tuned across the carrier frequency could be utilised on the high side of the audio pass-band, the result would be a receiver of excellent selectivity.

By extending the polyphase direct conversion receiver concept it is possible to produce such a design – **Fig. 3**.

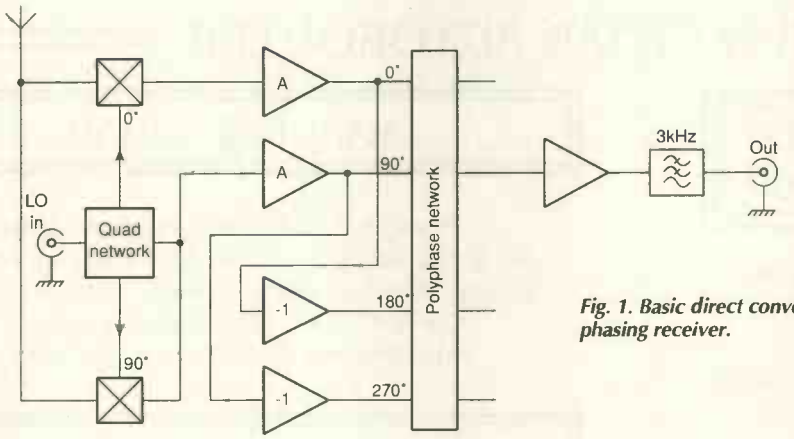


Fig. 1. Basic direct conversion phasing receiver.

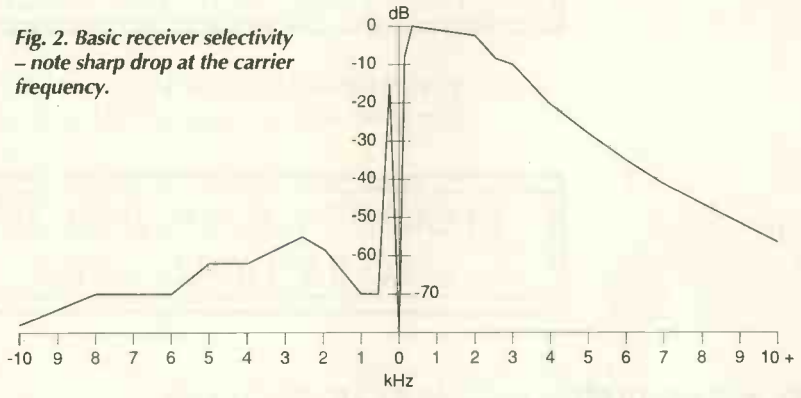


Fig. 2. Basic receiver selectivity – note sharp drop at the carrier frequency.

A different rf phasing network

The front end of the receiver, **Fig. 4**, is a direct conversion phasing design similar to the one described in *EW+WW* March 1994. The major difference in this part of the circuit is the rf phasing network. Instead of the bistable circuit, a two-pole rf polyphase network is used, see panel.

The first set of mixers translate from signal frequency down to an 'audio IF' at 0Hz and a wide-band polyphase network provides suppression of the opposite side-band, **Fig. 5**. Instead of combining the outputs of the polyphase network they are used as inputs to a second set of mixers at a second intermediate frequency of 461kHz, **Fig. 6**. The intermediate frequency is not critical and any convenient choice could be used.

As the second mixer local oscillators are in quadrature, this section is in effect an ssb generator at 461kHz. The 461kHz ssb signal is

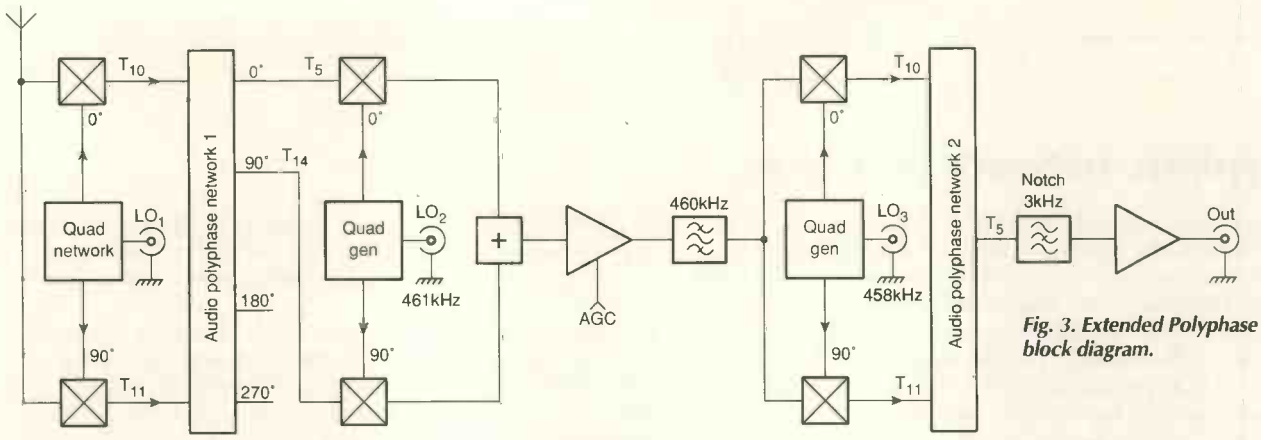


Fig. 3. Extended Polyphase receiver block diagram.

amplified and passed through a band-pass filter before being applied to a third set of quadrature mixers, **Fig. 7**. The filter is not critical, but it is required to attenuate responses at harmonics of the intermediate frequency local oscillators.

For the third mixers, the local oscillator is offset from the second local oscillator by 1 to 10kHz. Third mixer outputs are applied to a second audio polyphase network identical to the first, Fig. 5, to make this section in effect a second polyphase ssb receiver.

Phase relationships of all the signals are arranged so that the first section provides the selectivity on one side of the receiver passband while the third section provides the selectivity on the other side.

Variable offset between the second and third local oscillators allows a variable receiver bandwidth, ie frequency difference between the two oscillators. The *AN4061* dual mixer is used for the second and third mixer pairs. This device is designed for use in colour tv cameras and is highly balanced and matched. In addition, it requires a minimum of external components.

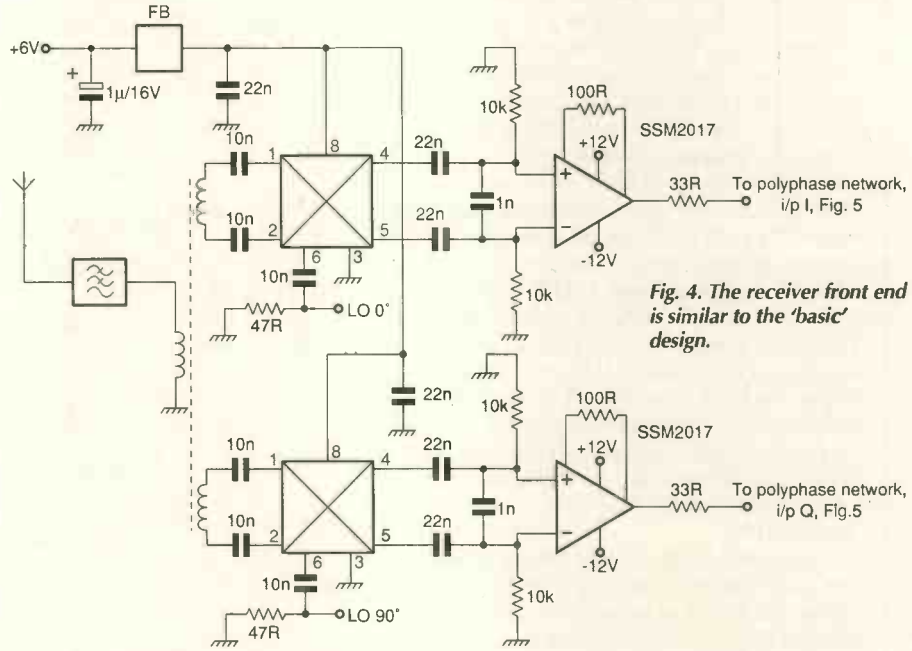
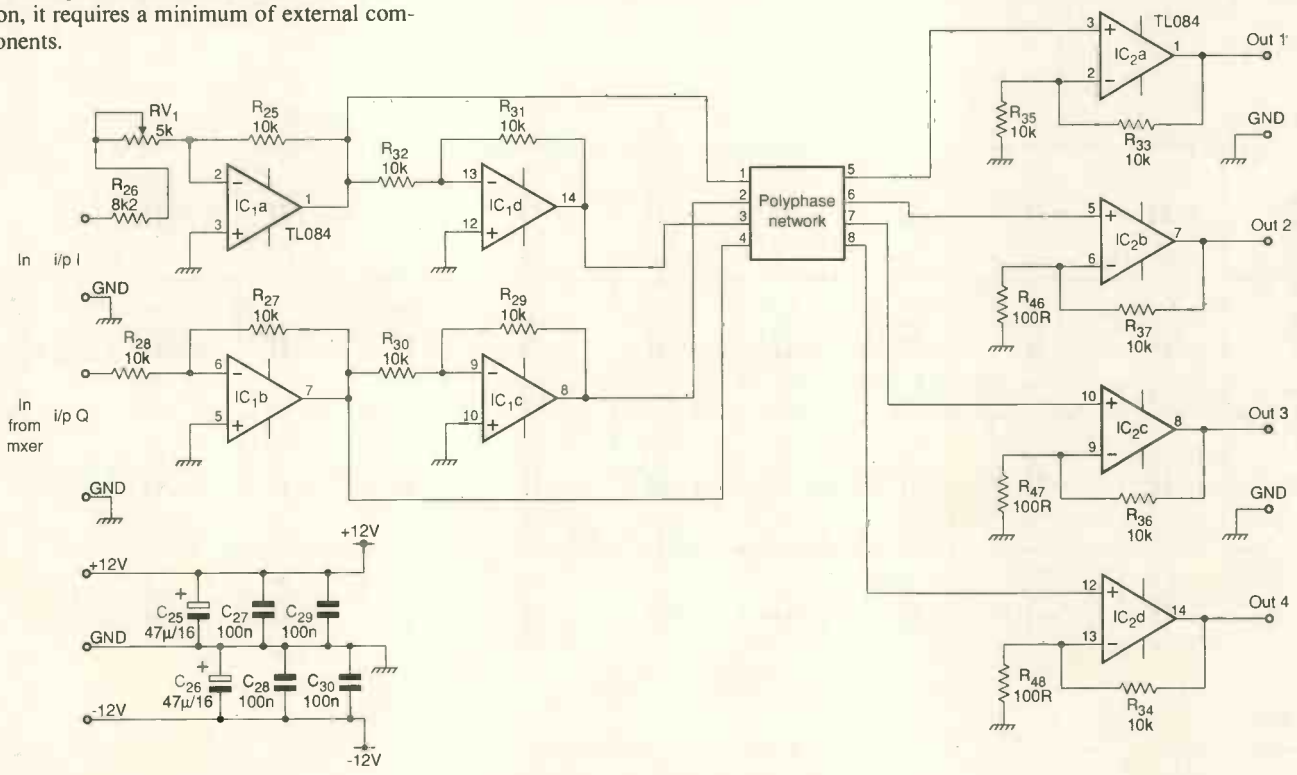


Fig. 4. The receiver front end is similar to the 'basic' design.



Polyphase network principles

The principle of the polyphase network has been previously described. Briefly, if the network is fed with four signals in quadrature, they are cancelled in one direction – for example 0°, 90°, 180° and 270° – and passed in the other – 180°, 90°, 0° and 270°. More importantly, in this design, the signals are cancelled in the network. The outputs do not need to be combined to achieve cancellation and are available as quadrature pairs to feed into the second set of mixers. We used 9 pole audio networks to give an accurate quadrature response up to about 10kHz, Fig. 5 and the diagram below.

Network response was measured with a phase meter to be accurate to within 0.2° over the relevant pass-band. This accuracy is consistent with the measured system selectivity of approximately 55dB.

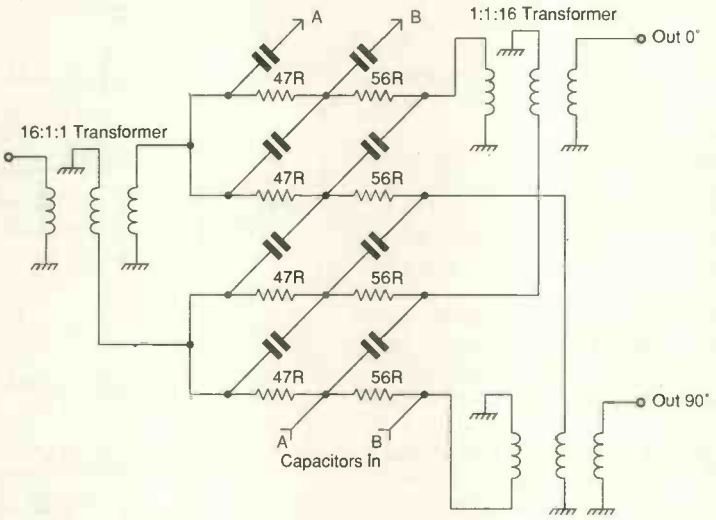
Note that networks have maximum attenuation within their quadrature pass-band. Above and below the quadrature pass-band, amplitude of the output products rises. A low pass RC section at about 15kHz was necessary after the first audio network to prevent overloading and cross-modulation in the second set of mixers from high frequency audio products. The network is relatively immune to component variation but it is still useful to choose matched capacitors and 1% resistors to achieve best performance.

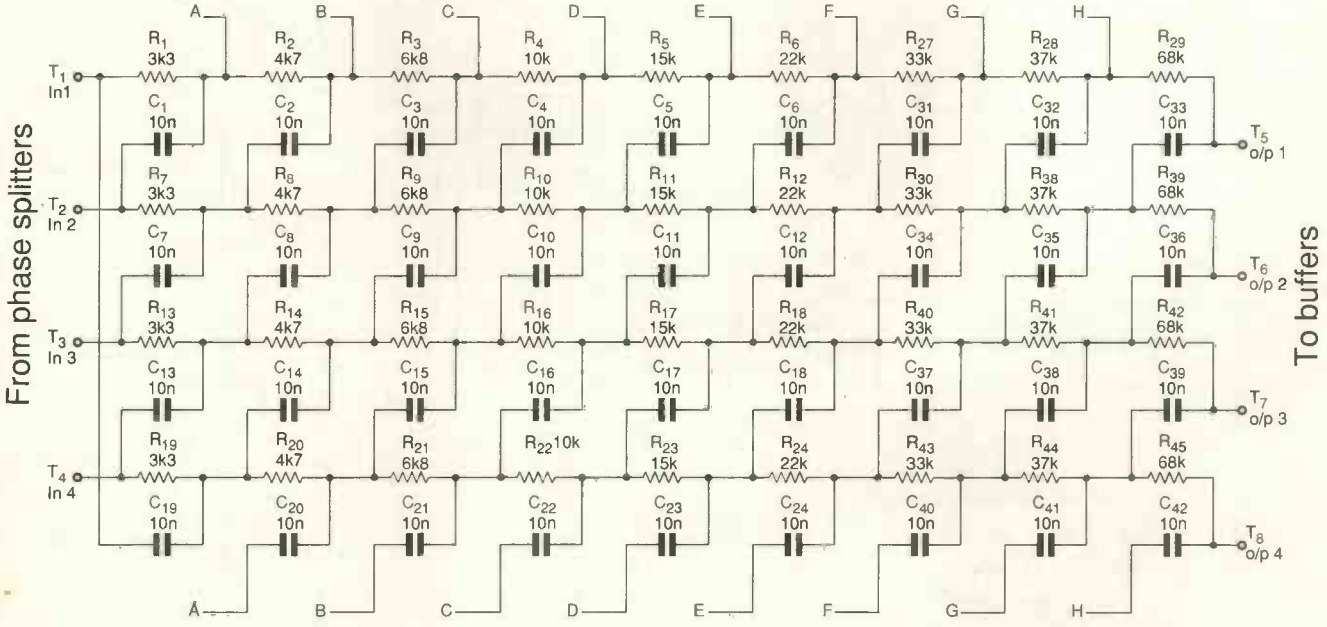
And at rf?

The polyphase network can be made to work at rf up to about 30MHz. Above this, stray capacitance and phase errors in other parts of the circuit cause unacceptable phase error.

In the front end of this receiver, we used a two pole network to give good results over the 3.5 to 4MHz band, diagram right. A transformer is necessary to provide balanced input drive to the network and to provide impedance matching. In this receiver transformers were wound on ferrite beads.

Loss in the network is not great if only two poles are used. It is possible to construct a broadband network with six or more poles to cover a decade or more, but network loss becomes significant. An alternative approach is to use several networks with a smaller number of poles and switch between them for different bands.





(Top) RF polyphase network which is accurate over the 3.5 to 4MHz range. (below) Audio polyphase network detail.

Local oscillator quadrature signals for second and third mixers are generated using dual bistable devices in a ring configuration. Front end quadrature rf signals are generated using a broad-band rf polyphase network with values for the band of interest.

To minimise board space, surface-mount components can be used for polyphase networks. A notch filter is necessary in the audio output to eliminate a tone due to carrier feed-through in the second set of mixers. In this case we used a switched capacitor filter.

System blocks

Figure 8 gives a visual representation of the signals as they pass through various stages of the receiver.

Assume selectivity is set at 3kHz and that the incoming signal spectrum includes a dsb signal on 10MHz. Carriers C1-3, are on 9.990, 10.007 and 10.018 MHz, Fig. 8a). The first local oscillator, LO1, is set at 10.003MHz and the first set of mixers and phasing networks are arranged to receive the lower side-band.

Signals above 10.003MHz are attenuated by the phasing network. Note that this attenuation extends only to the limit of the phasing network response. In this case we used a polyphase network with poles extending to about 10kHz. As a result products from sig-

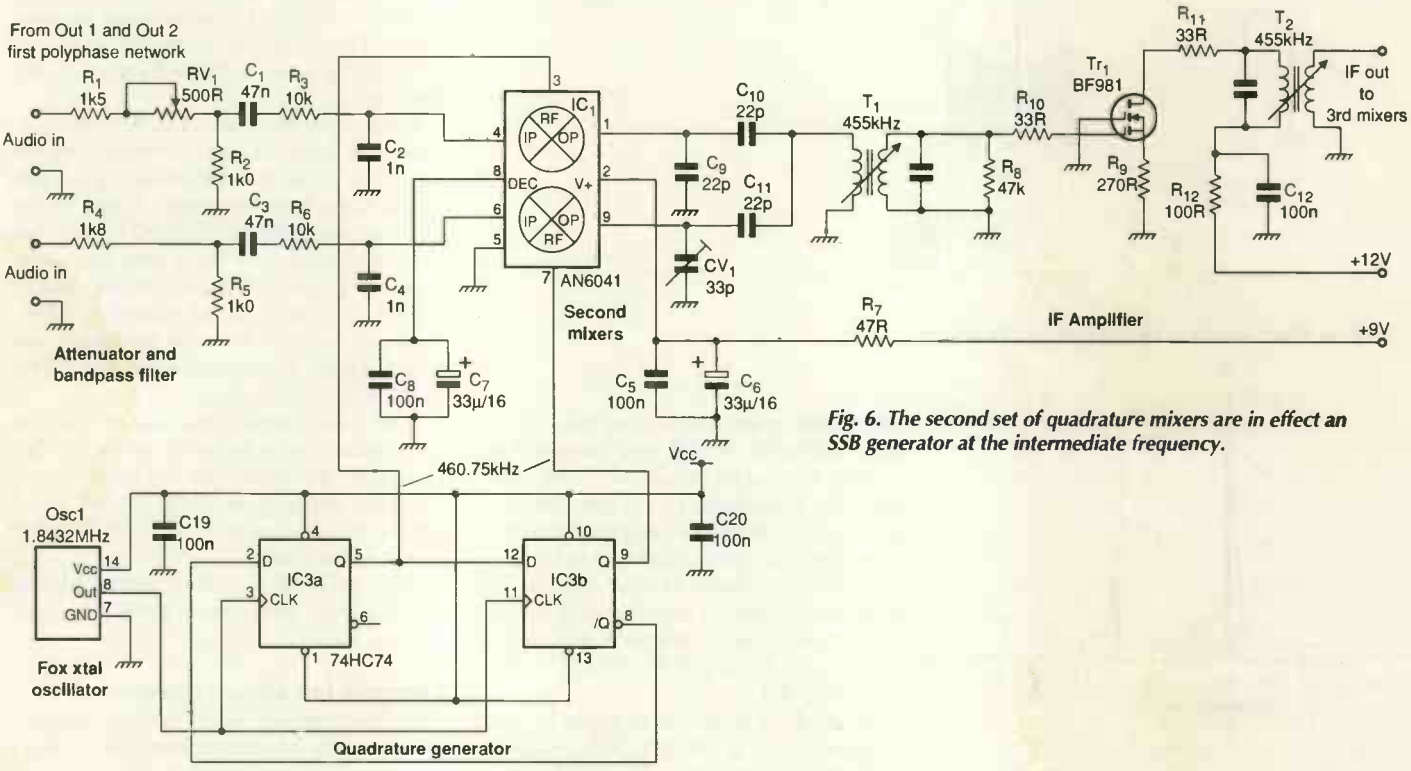


Fig. 6. The second set of quadrature mixers are in effect an SSB generator at the intermediate frequency.

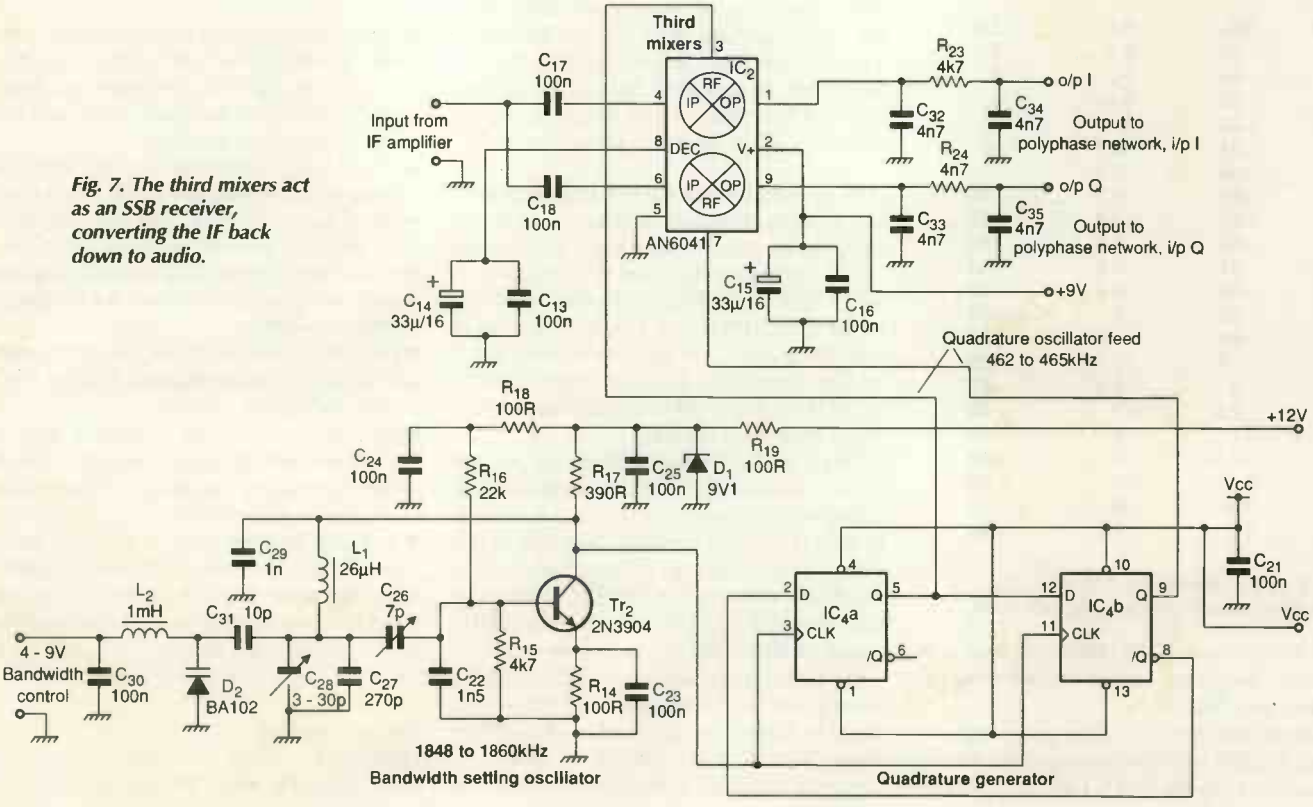


Fig. 7. The third mixers act as an SSB receiver, converting the IF back down to audio.

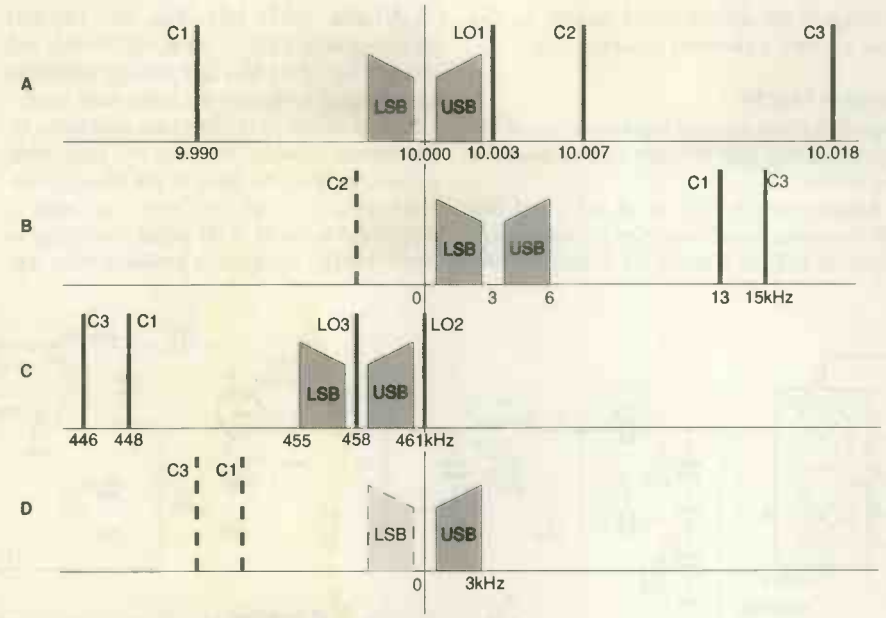
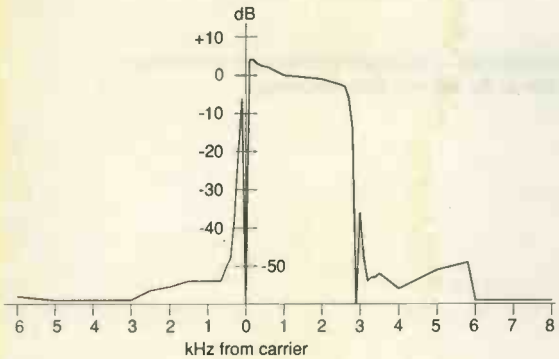


Fig. 8. Signal spectra at various points in the reciver.



F (kHz)	dB	0.4	2.5
10	–59	0.3	3
8	–59	0.2	4
6	–59	0.1	4
5.8	–49	0	60
5	–51	–0.1	–6
4	–56	–0.2	–21
3.5	–52	–0.3	–38
3.4	–53	–0.4	–48
3.3	–53	–0.5	–50
3.2	–54	–0.6	–54
3.1	–48	–0.8	–54
3.0	–36	–1	–54
2.9	–60	–1.5	–54
2.8	–14	–2.0	–56
2.7	–6	–2.5	–57
2.5	–2.5	–3	–59
2.0	–1	–4	–59
1.5	–0.5	–5	–59
1.0	0	–6	–58
0.8	0.5	–8	–58
0.6	1	–10	–58

Fig. 9. The receiver shows 'brickwall' selectivity on both sides of the passband.

nals above about 10.013MHz will appear in the first polyphase output as audio signals greater than 10kHz.

Output from the first audio polyphase network, Fig. **8b**), contains products from the dsb signal and products from C1 and C3 at 13kHz and 15kHz respectively. Note that C2 has been eliminated. Recall that the polyphase network has output phases of 0°, 90°, 180° and 270°. A quadrature pair of these outputs is applied to the second set of mixers with phases arranged to produce lower side-band ssb with a local oscillator, LO2, at 461kHz. The IF spectrum includes the original dsb signal from 461 to 455kHz – inverted – and products from C1 and C3 at 448 and 446kHz respectively, Fig. **8c**).

The third set of mixers is driven by local oscillator LO3, at 458kHz. This section is arranged to receive upper side-bands. Resultant output is demodulated audio from the upper side-band of the original dsb signal, Fig. **8d**). The lower side-band and all the carriers have disappeared. Selectivity on both sides of the pass-band is sharp due to the crossover effect described above.

AM reception via direct conversion?

It is possible to receive amplitude modulation using the receiver. Assume that a 10MHz AM signal is being received and that selectivity is set to 10kHz. The first local oscillator would be set to 10.010MHz to give an audio output with the original AM upper side-band inverted from 0 to 10kHz. The AM carrier would be at 10kHz and the AM lower side-band would range from 10 to 20kHz.

Single side-band output from the second section would in effect be a reconstituted AM signal with the carrier at 451kHz. It is possible to detect this using envelope detection. In this case it is necessary to provide intermediate frequency selectivity at 451kHz as only signals between 10.010MHz and 10.020MHz would be attenuated by the first section.

In practice, heterodynes from other signals are a problem. Alternatively the AM signal could be limited and the third local oscillator phase locked to the carrier to give synchronous detection with good selectivity. In this case, audio output would represent the original amplitude modulation upper side-band from 0 to 10kHz.

The receiver's performance

Front-end performance depends on the quality of the first local oscillator and first mixers. In this case, we used *NE602* active mixers which have only average strong signal handling due to their rf gain and low power design. Maximum input level before limiting is about –25dBm. Dynamic range is about 90dB. This could be improved as in all receivers by using high-level mixers in the front end.

Selectivity is impressive, **Fig. 9**. These measurements were taken at 3.6MHz with the selectivity set at 3kHz. Reference point was 0dB at 1kHz from the carrier. 'Lobes' in the response within 300Hz of cutoff at each side of the pass-band were due to poor quadrature accuracy in the polyphase networks below 300Hz. This effect could be reduced by 300Hz high pass sections after the polyphase networks or poles at frequencies less than 300Hz in the polyphase networks.

There was a spurious response at –49dB at twice the selectivity frequency setting – in this case 6kHz. We assume that this is due to poor side-band suppression in the second set of mixers. It could almost certainly be improved with a second design.

Subjectively the filter improved intelligibility of signals over the original polyphase receiver alone.

Complex but advantageous

Though the receiver is somewhat complex, it offers several advantages over conventional superhets and dc receivers,

- Apart from responses within the audio pass-band – ie within about 10kHz of the signal frequency – any spurious responses are determined by first local oscillator quality and first mixer strong signal handling.
- 'Brickwall' selectivity can be achieved without crystal or mechanical filters and bandwidth is easily variable. This order of selectivity could be achieved using dsp techniques. However digital processing generally requires higher current drain which may not be ideal in portable equipment.
- Potentially, amplitude and frequency modulated signals can be received, making this a multimode design.
- Automatic gain control is easier to apply to the intermediate-frequency amplifier than at audio, as would be the case in a conventional direct conversion receiver.
- It would be interesting to measure group delay characteristics of the system though we have not done this. In theory the system should show a relatively linear characteristic over the whole pass-band. ■

Further reading

Hosking R. 'Polyphase direct conversion SSB', *EW+WW* Mar 1994, pp. 202-206.

In this extract from his book *Valve Amplifiers* Morgan Jones takes you through the steps of designing a valve power amplifier, and presents a prototype with a unique feature.

A fresh look at valve power

When designing your first valve amplfier, you need to be realsitic. You are not going to design a world beating amplifier overnight, and by restricting your ambitions you stand a much better chance of making something that actually works.

The design example presented here is a 10W Class AB1 push-pull 'ultra-linear' amplifier using *EL84* output valves. There are a number of reasons for this choice,

- It is cheap. If you have a 340V HT supply, this can be smoothed by 385V capacitors intended for switch-mode power supplies. In addition, the HT could be provided by a 240V isolating transformer with a silicon bridge rectifier. If any mistakes are going to be made, then it is best to make them with reasonably inexpensive components rather than expensive ones.

- There are many reasonably cheap second-hand amplifiers such as the Leak Stereo 20 or Leak TL12+, that can be cannibalised for their transformers.

- Powerful amplifiers require considerably more skill in layout and construction, and generate bigger bangs, so it is advisable for designers to start small.

Bevois Valley amplifier

This design acquired its name because the prototype was built from a pair of mono amplifiers bought for £15 – including pre-amplifier – in Bevois Valley. Once the output valves have been chosen, transformer configuration is limited, and therefore the entire output stage is fixed.

Transformer primary impedance needs to be around 8kΩ anode to anode, and with 43% taps for minimum distortion. This component might have been scavenged from a Leak, or it might even have been bought new. Either way, you will need an HT of 320V, and each valve will require $8V_{RMS}$ for full output. Our task is to design superior driving circuitry using the following specification.

Low noise. With the low noise obtainable from cd or a good vinyl recording, noise in the power amplifier needs to be undetectable. A signal-to-noise ratio of 100dB, relative to full output power, is not an unreasonable figure to aim for. This rules out pentodes and high sensitivity.

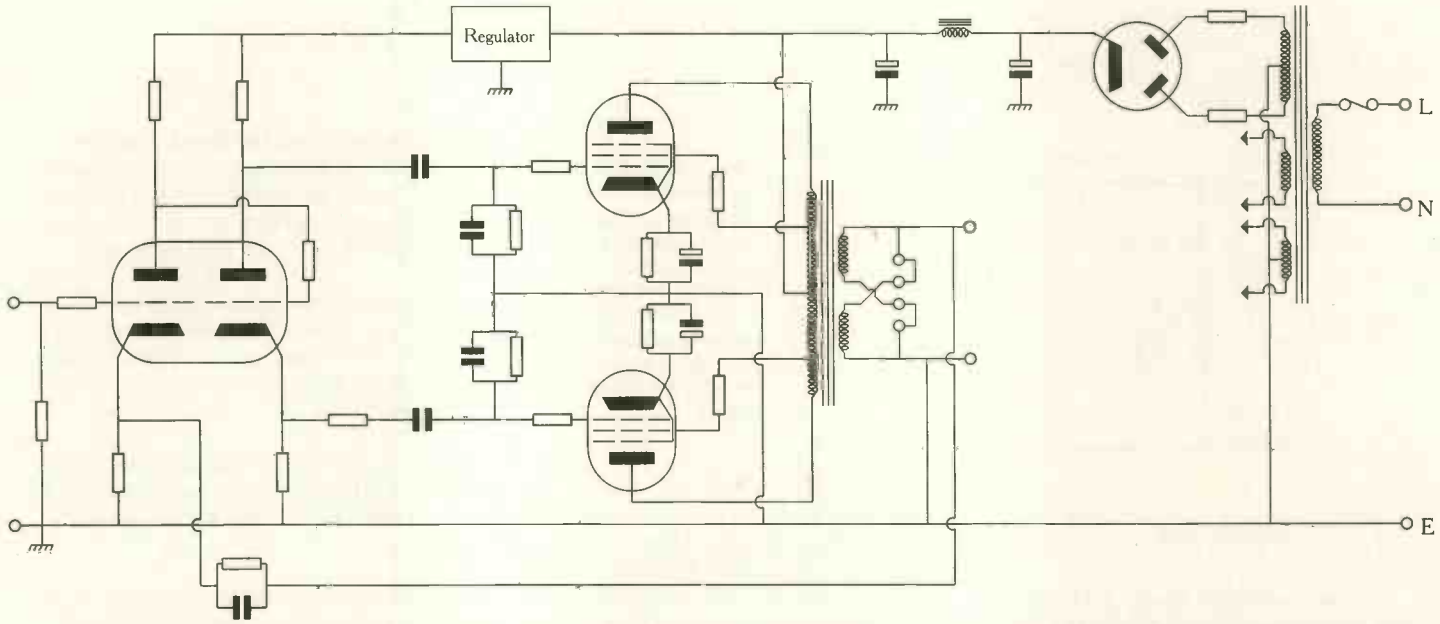


Fig. 1. Power amplifier using concertina phase splitter and featuring – possibly for the first time – cathode build-out resistor in the driver stage.

No hum. This implies superb standards of construction, and/or dc heaters for the input stage.

Stability. To achieve good stability an absolute minimum of stages is needed.

Distortion. This is a tricky topic. If you want distortion measured in parts per million, then you had better buy a decent transistor amplifier. If you think that hearing is everything and measurement is nothing, then sell the house and buy a single-ended triode amplifier. We have to be honest about this. Valve amplifiers do not measure well, but they do sound good. Presumably, we listen to music to enjoy it, so this quality is important. However, I see no reason why we should tolerate obvious engineering faults. As a result, these will be removed – although this will not imply perfection.

Simplicity. Valve designs should be simple. Simple systems tend to have simple shortcomings. Additionally, they are repairable. Complex systems are built on silicon, have lots of legs, and are repeatable and disposable.

Together, these criteria demand that we use a concertina phase splitter direct coupled from the input stage without a driver stage, and we can instantly draw a circuit diagram. That this circuit is quite similar to the GEC912-Plus demonstrates that there is little new under the sun. The design rationale however is new, and to my knowledge, the cathode build-out resistor in the phase splitter is unique, **Fig. 1**.

Since the output valves are being driven directly from the phase splitter, linearity of the phase splitter is paramount. The chosen phase splitter only has a gain of 1, so the input stage will also need excellent-linearity.

Only three valves are really suitable for a concertina stage – the *6SN7*, *ECC82* and *E88CC*. We will use the E88CC.

Optimisation of dc conditions

Because the two stages are dc coupled, the design of the two stages will be interactive. As before, the way to deal with an awkward problem like this is to garner as many facts as possible, label the drawing, and see if anything useful appears.

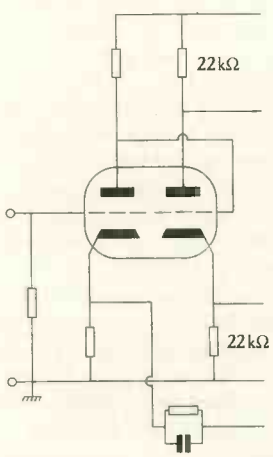


Fig. 2. Determining the operating conditions of the driver/input stage. The value 22kΩ is used because Z_{out} is approximately equal to R_L. A significantly lower value would result in excessive power dissipation.

Having chosen a concertina stage, we can start by labelling the anode and cathode loads as 22kΩ. This traditional value is used because Z_{out} is approximately equal to R_L and while output resistance needs to be minimised, a significantly lower value would result in excessive power dissipation, **Fig. 2**.

Generally, with an anode voltage of 80 to 90V, linearity of the *E88CC* is best when the grid is at –2.5V. Although the concertina operates under heavy feedback, it would be preferable if it were linear *before* feedback. As a result, it is necessary to juggle conditions such that both valves are biased with V_{gk}=–2.5V.

Since the concertina has a gain of around unity, it might be possible to arrange component values such that the signal current drawn by the concertina is equal and opposite to the signal current drawn by the input stage. This would result in zero modulation of the HT supply, and would make the HT requirements less stringent.

After much drawing of loadlines, I found that all three requirements could be met simultaneously. Additionally, they met the previously unstated requirement of being achievable with the HT available.

Balancing signal currents is the easiest requirement to satisfy. If the concertina had an A_V of unity, then for equal and opposite currents we would use an anode load in the input stage equal to the sum of the anode and cathode loads of the concertina. Since the concertina has A_V of less than one, proportionately less signal current is swung into the input stage, which means a higher value of anode load:

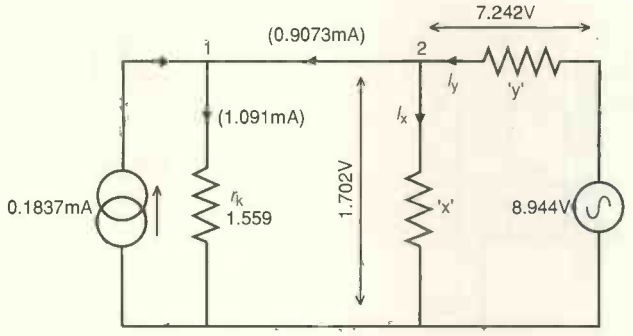


Fig. 3. Equivalent circuit of ac conditions at the valve amplifier input stage. Labelling currents and other relevant information makes calculating the cathode bias and feedback resistors easier.

$$R_{L(input)} = \frac{R_{anode} + R_{cathode}}{A_{V(concertina)}}$$

For the concertina, R_k=R_a=22kΩ obtains, and optimum biasing is needed. Since the HT voltage is not known, gain has to be guessed. Fortunately, because the *E88CC* has such a low anode resistance, and the concertina has heavy feedback, it is possible to make a good guess at gain.

Since the *E88CC* has a low anode resistance, gain for a given value of anode load does not change greatly with HT.

As a result, an HT of 300V can be guessed at, and a loadline can be plotted to determine the gain of an *E88CC* with a 44kΩ anode load and –2.5V grid voltage. This results in an A_V of 28.75. The feedback equation can now be used to determine the gain when used as a concertina,

$$A_{V(concertina)} = \frac{28.75}{1+28.75} = 0.966$$

Even if had the approximation been based on μ, the error would only have been 0.3%, indicating that the guess should be quite accurate. From this result, the value of anode load for the input stage can be calculated from,

$$R_{L(input\ stage)} = \frac{44}{0.966} = 45.53k\Omega$$

Alternatively, R_L for the input stage can be set at 47kΩ, and the concertina resistors reset to 22.7kΩ. This is a more convenient choice since the 47kΩ resistor will dissipate almost 1W, and so a 2W component is needed. This could be provided by 4×47kΩ 0.6W devices in series/parallel, or by a single 2W component.

It is inconvenient to provide non-standard values in higher ratings, whereas the concertina resistors are only dissipating around 0.33W. This can be more easily met by standard resistors.

The closest approach to 22.7kΩ is provided by 24kΩ in parallel with 430kΩ, but this means that the 24kΩ resistor is dissipating almost all the heat, and a 0.6W component is marginal. You could use a 2W 24kΩ resistor, but the tolerance of 2W resistors is usually 2%. A better solution is to use 36kΩ in parallel with 62kΩ, which is not such an accurate approach to 22.7kΩ, but the resistors are closer tolerance. Also, the power is more evenly distributed between the components so that they are operated well within their ratings.

These choices of loads for the input/phase splitter stage will ensure equal and opposite signal currents, so we now need to arrange the correct biasing. The only way of doing this is by an iterative process.

Both stages will have an HT of less than or equal to 300V due to the voltage drop from the output stage. It is also known that each stage will have an anode voltage of 80 to 90V, for a –2.5V grid.

First draw the loadline for the concertina and find V_a for V_{gk}=–2.5V. This value is then subtracted from the HT voltage to give the voltage across R_k and R_a, and divided by 2 to give the voltage across R_k. Voltage on the grid will be 2.5V lower than this, and will equal the anode voltage of V_1.

The next job is to draw a loadline for V_1 to see if the optimum anode voltage corresponds with the voltage just derived. If it doesn't, the only variable is HT voltage. Fortunately, a few iterations – by hand, not computer – found that a 285V HT voltage met all requirements, and this will be provided by a regulator.

I must say that the last determination was an incredibly tedious process. It was only carried out because in adjusting the biasing, it became obvious that it was also possible to fiddle both valves' bias voltage into balance as well. A nice computer model using real valve characteristics would solve this problem in considerably less time.

Now that the HT voltage for the two stages is known, all the ac parameters can be calculated, and the value of the build-out resistor for the concertina determined.

Cathode bias and feedback resistance

This is easily the most complex calculation in the design of a power amplifier with negative feedback applied to the cathode of the input stage. These four factors are significant:

- Cathode bias voltage needs to be set correctly. This would normally be a trivial application of Ohm's law, but in this case the bias current flows through the cathode resistor and the feedback resistor.

- The input valve generates a feedback current through the cathode resistor, in addition to any current sourced from the output of the amplifier.

- Ratio of the two resistors needs to be set so as to obtain the desired negative feedback.

- As far as ac is concerned, the cathode resistor is shunted by r_k of the valve.

Now, with the restrictions specified, it should be possible to label a diagram and derive some equations. Since 2.5V bias on the cathode is needed, and anode current is 190V/47kΩ, the total resistance to ground from the cathode must be 618.4Ω.

Anode signal swing for full output is 8.636V rms. This means that the anode signal current must be 8.636V/47kΩ=0.1837mA rms. This current also flows in the cathode circuit and will develop a feedback voltage across any unbypassed cathode resistor.

If input sensitivity of the amplifier is to equal 2V rms, and we know that the unmodified sensitivity is 298mV rms, the feedback voltage required at the cathode will be 2–0.298V, which is 1.702V rms.

For full output of 10W, the signal at the output of the amplifier will be 8.944V rms. This means that there will be 7.242V rms across the feedback resistor. Since r_k will shunt the cathode resistor at ac, it is necessary to find r_k:

$$r_k = \frac{R_f + r_a}{\mu + 1}$$

Using this equation, you will find that r_k=1.559kΩ.

Assume that the output of the amplifier is a true Thévenin source driving the network through the feedback resistor 'y'. The valve's own feedback current is represented as a Norton current source, and the cathode resistor 'x' is shunted with r_k. Note that **Fig. 3** is an ac diagram.

Our first observation is that there is a resistor of known value r_k with a known voltage of 1.702V across it, so current through it is 1.091mA.

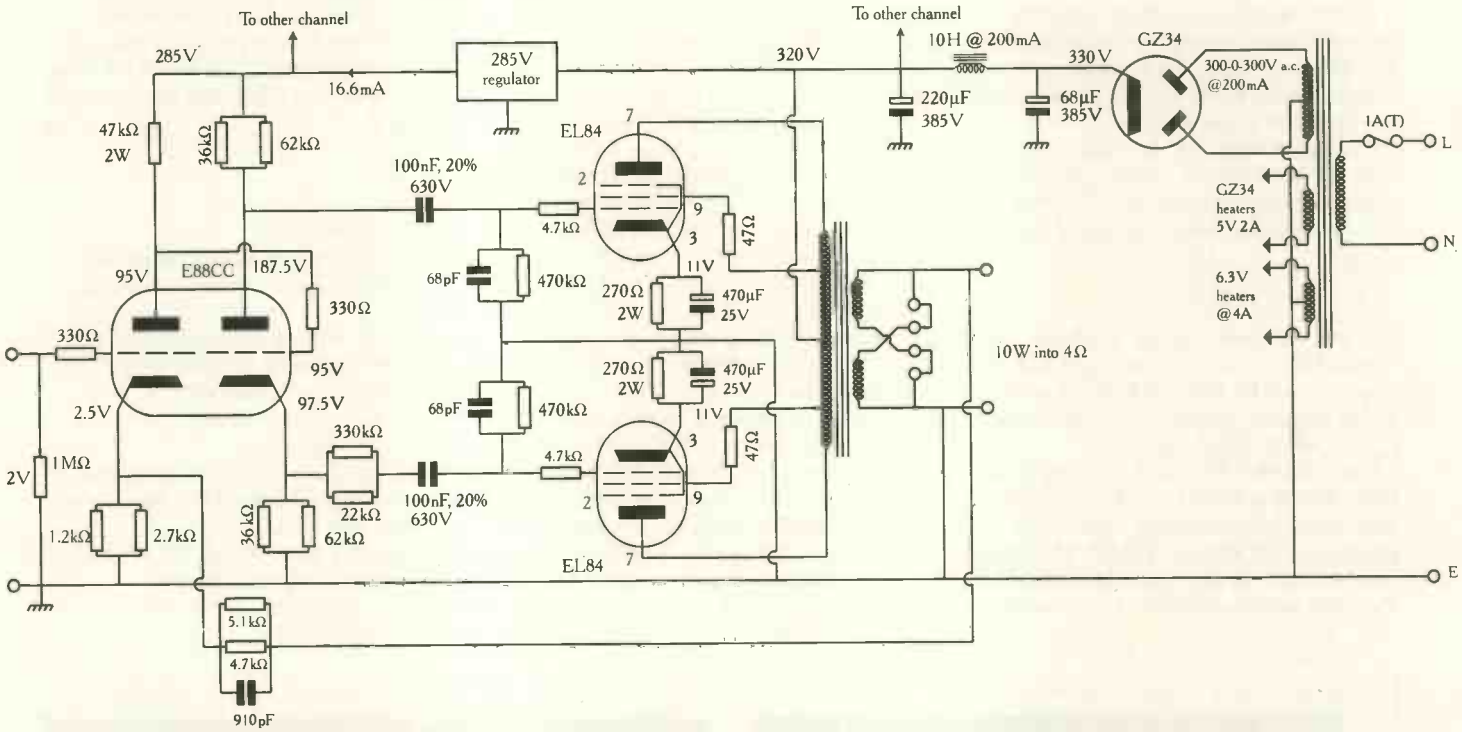


Fig. 4. Practical 10W Class AB1 push-pull amplifier using EL84 output valves and featuring the 'ultra linear' output stage.

We can now see that node 1 has two known currents flowing through it, so we can find the third, using Kirchhoff. If there is 0.1837mA flowing into the node, but 1.091mA leaving it, then 0.9073mA must be supplied by the other node. Moving to node 2, you can see that any current coming into the node must be supplied by I_y and that this splits through the resistor 'x', and to node 1. Formalising this;

$$I_x + 0.9073 = I_y \quad \text{(Eq. 1)}$$

You can use Ohm's law to make statements about the currents in resistors 'x' and 'y':

$$I_x = \frac{1.702}{x} \quad \text{(Eq. 2)} \qquad I_y = \frac{7.242}{y} \quad \text{(Eq. 3)}$$

The final restriction is the dc restriction, which says that x and y in parallel must give 0.6184kΩ.

$$0.6184 = \frac{xy}{x+y} \quad \text{(Eq. 4)}$$

The way to solve the equations is to substitute the second and third equations into the first:

$$\frac{1.702}{x} + 0.9073 = \frac{7.242}{y}$$

Rearranging, and simplifying:

$$7.982x - 1.876y = xy.$$

It is now possible to substitute this into the fourth equation, and solve it to give the ratio $y=2.953x$. Substituting this ratio back into the equation yields $x=828\Omega$. Using the ratio you therefore need 1.2kΩ in parallel with 2.7kΩ for the cathode resistor, and 4.7kΩ in parallel with 5.1kΩ for the feedback resistor.

Distortion consideration

Some of V_1's cathode current is now flowing through the output transformer, and it might be thought that this would cause distortion. Assuming that dc resistance of the transformer secondary winding is negligible, the current flow will be,

2.5V/2.44kΩ≈1mA.

Now the current turns ratio of the transformer is 31.6:1 – secondary-to-primary – so 1mA of dc flowing in the secondary is equivalent to 31µA out-of-balance dc flowing in the primary. Compared to 40mA each side, this is negligible, since output valve balance is highly unlikely to be as good as this.

All component values for the driving circuitry are now known, so the values for the output stage can be determined. The *EL84* is allowed a maximum grid leak resistor of 300kΩ with grid bias. As cathode bias is being used however, this can be increased to 470kΩ. A 0.1µF coupling capacitor is necessary, which should be polycarbonate, or preferably polypropylene, with a rating of 400Vdc or more.

A value of 4.7kΩ is traditional for grid stopper resistors on the *EL84*. They may not be needed, but it seems sensible to fit them just in case. A resistance of 47Ω in series with g_2 is alleged to reduce distortion while reducing peak power. I have not tested this, so fitting them is a matter of personal choice. The Mullard circuits included them, but the Leaks didn't.

From the data sheet, the cathode bias resistor should be 270Ω and dissipate 0.45W. Resistors rated at 2W are commonly used here, but a 15W chassis mounting metal clad type with tabs is a much better choice. This is because an electrolytic capacitor is going to be placed very close to this resistor, so it needs to be kept cool. The resistor also provides convenient tags for anchoring the capacitor.

The cathode bypass capacitor should be 2200µF for a 1Hz cut-off. But as discussed earlier, this value would cause additional problems; a good compromise is 470µF 63V. A rating of 63V may seem excessive, since it will only see around 11V, but the higher voltage component will have a lower effective

series resistance. This becomes significant when you are trying to bypass the 90Ω cathode resistance of the valve.

Because there is only one *RC* network plus the output transformer in the entire amplifier, low-frequency stability will not be a problem. High frequency stability is not assured, and so this should be investigated.

The input stage has its basic sensitivity reduced from 298mV to 2V, which corresponds to a gain reduction of 6.71. From this, you can calculate the new r_a for the stage:

$$\frac{\mu R_L}{R_L + r_a} = 6.71 \frac{\mu R_L}{R_L + r_a'}$$

Solving this, and using r_a=5kΩ, gives r'_a=302kΩ, in parallel with R_L=47kΩ; this gives r_{out}=41kΩ. You will find that applying global negative feedback invariably causes $r_{out} \approx R_L$ for the input stage.

The concertina has 3.2pF of Miller capacitance. Allowing for strays, 5pF is a reasonable total value. In combination with 41kΩ, this gives a cut-off around 780kHz. The output stage will have an input capacitance that loads the 22kΩ output resistance of the concertina, so should be determined. Although the *EL84* is a pentode, it will still have Miller capacitance, albeit greatly reduced, so this should be included in the calculation.

You can find anode gain of the output stage by calculating voltage across the 8kΩ transformer primary for 11W. It is known that $16V_{RMS}$ from grid to grid is needed to drive the stage. This gives a gain to the anode of 18.54. Since C_{ag}=0.5pF, this would result in a Miller capacitance of 9.8pF. Unfortunately, this value of C_{ag} is for the pure pentode connection. On the other hand, we will be using the 'ultra-linear' connection, where g_2 does not stay at a constant potential. This means that allowance must be made for the Miller effect from C_{g_2}. Unfortunately, the Mullard data sheet does not give a value for this, so it is probably wise to allow another 10pF.

Adding these to C_{in}=10.8pF produces a total input capacitance of around 35pF, including strays. Driven by the concertina, this gives a cut-off of 200kHz, and is the dominant pole. To achieve high-frequency stability, slug the input capacitance of the output valves, and not the concertina, as is usually done. This will have the advantage that additional capacitance will swamp variations in the capacitance between valves, improving high-frequency balance. Shunt capacitors of 68pF across the *EL84* grid leak resistors will slug this pole to 72kHz. It is now possible to draw a full circuit diagram of the amplifier, with component values, **Fig. 4**. ■

Further reading

Colloms, M, 'High performance loudspeakers', 3rd edn. Pentech Press, London, pp. 188-206, 1985.

Futterman, J, 'A practical commercial output transformerless amplifier', *Journal of the Audio Engineering Society* October 1956.

Hedge, L B, 'Cascade AF amplifier', *Wireless World*, 283-87, June 1956.

Mullard, 'Tube Circuits for Audio Amplifiers', reprinted by Audio Amateur Press, Peterborough, New Hampshire, 1993.

Williamson, D T N and Walker, P J, 'Amplifiers and superlatives', *Journal of the Audio Engineering Society*, 2(2), 75-80, 1954.

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CIRCLE NO. 122 ON REPLY CARD

DIY circuit analysis

Using brief Basic routines, John Hopkins demonstrates how you can analyse simple circuit networks on the PC – and in doing so, provides an insight into how Spice functions.

If you have used an analogue simulator, such as Spice, you may have wondered how all those intricate calculations are carried out.

If you have a version of Basic – such as the one included with MS-DOS – you can gain an insight into Spice by trying out the routines described here. What follows is not intended to be a replacement for a proper simulator, but rather an exercise in trying to understand how network analysis is carried out.

Consider solving a linear network consisting of resistors, capacitors, inductors and active devices driven from an appropriate signal source. Transistors – and other active devices – are non linear, but by considering small signal operation at a suitable dc working point, you can linearise the problem.

Figure 1 shows a network involving only resistors and a dc source. The usual way of solving this without computer aid is to use Kirchhoff's laws and set up a system of equations. For our purposes, it is best to use the nodal analysis method.

You begin by numbering the nodes, making the earth node zero and then allocating the numbers 1,2,3... as far as necessary, as in Fig. 1. Analysis is then conducted in terms of voltages at each node, by writing a statement of Kirchhoff's current law at each node.

The sum of the currents flowing through the resistors, worked out from the node voltages and Ohm's law, is equal to the current from the independent source connected to that node.

At node 1: V(1)/1+(V(1)–V(2))/10+(V(1)V(3))/100=1
At node 2: (V(2)–V(1))/10+(V(2)–V(3))/10+V(3)/100=0
At node 3: (V(3)–V(1))/100+(V(3)–V(2))/10+V(3)/1=0

Equations can be tidied up so that terms involving a given node voltage are grouped together.

Node 1:(1+1/10+1/100).V(1)–V(2)/10–V(3)/100=1
Node 2:–V(1)/10+(1/10+1/10+1/100).V(2)–V(3)/10=0
Node 3:–V(1)/100-V(2)/10+(1+1/10+1/100).V(3)=0

There are some simple rules for constructing these equations.

- At each node, a term is formed by summing the reciprocals of the resistances attached to the node, multiplied by the voltage at the node.
- Remaining terms on the left-hand side of an equation are formed by considering the resistances connected to each of the other nodes in the circuit.

These terms are all negative and consist of the other node voltages divided by the connecting resistances.

- The right-hand side is the independent current source value.

The equations can be written again with the numerical values worked out,

$$1.11V(1)–0.1V(2)–0.01V(3)=1 \quad [1]$$
$$–0.1V(1)+0.21V(2)–0.1V(3)=0 \quad [2]$$
$$–0.01V(1)–0.1V(2)+1.11V(3)=0 \quad [3]$$

An elegant way to solve the equations is by the use of Gaussian elimination.

If you take equation [1] and multiply each term by 0.1/1.11 and then add it to [2], the term involving V(1) in the new version of [2]

vanishes. Similarly, if you multiply through [1] by 0.01/1.11 and add it to [3], then the term in V(1) will vanish there too. The result of these operations is,

1.11V(1)–0.1V(2)–0.01V(3)=1 [1]
0.201V(2)–0.101V(3)=9.01E–2 [2]
–0.101V(1)+1.11V(3)=9.01E–3 [3]

Of course you can repeat the trick to get rid of the term in V(2) in [3]. Multiplying [2] by 0.101/0.201 and adding to [3],

1.11V(1)–0.1V(2)–0.01V(3)=1 [1]
0.201V(2)–0.101V(3)=9.01E–2 [2]
1.059V(3)=5.43E–2 [3]

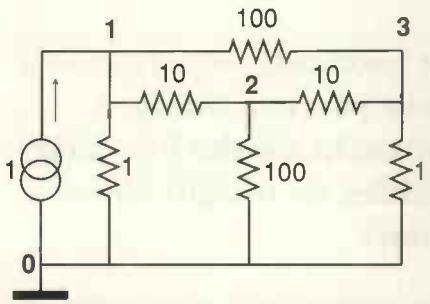

Fig. 1. Simple dc circuit illustrates computer-aided network analysis. Current source is in amps, resistance in ohms.

Each node voltage can be calculated using back substitution. From [3]:

V(3)=5.43E–2/1.059=5.12E–2

Putting this value into [2], V(2) is found to be,

V(2)=(9.01E–2+0.101×5.12E–2)/0.201=0.474

And using these values in [1],

V(1)=(1+0.1×0.474+0.01×5.12E–2)/1.11=0.944

This is the solution to the problem. Of course, this method can be employed in more complicated situations. Although Gaussian elimination is not the preferred method for solving the equations, it is simple and serves as an introduction to more advanced techniques.

Gaussian elimination.

When written in Qbasic with operations applied to the coefficients of each term in the equations, the algorithm is reasonably compact. You can therefore draw up an array (a matrix) of these coefficients, and then work out the procedure from that. A set of three equations, written with symbols for the coefficients, would look like,

a(1,1) V(1)+a(1,2).V(2)+a(1,3).V(3)=a(1,4) [1]
a(2,1).V(1)+a(2,2).V(2)+a(2,3).V(3)=a(2,4) [2]
a(3,1).V(1)+a(3,2).V(2)+a(3,3).V(3)=a(3,4) [3]

So the array we are using is:

a(1,1)	a(1,2)	a(1,3)	:	a(1,4)
a(2,1)	a(2,2)	a(2,3)	:	a(2,4)
a(3,1)	a(3,2)	a(3,3)	:	a(3,4)
left-hand side of eqns				right-hand side

All coefficients are taken as positive at this stage, although for a real problem some numbers would be negative, as we have seen. To eliminate V(1) from [2] multiply [1] by a(2,1)/a(1,1) and then subtract the new first equation from [2].

To eliminate V(1) from [3] multiply [1] by a(3,1)/a(1,1) and then subtract the new first equation from [3]. At the second stage, to eliminate V(2) from [3], multiply the new second equation by the new a(3,2)/a(2,2) and then subtract it from the new equation [3].

Difficulties caused by differences between the old and new equations can be neatly avoided by simply storing new coefficient values in the array which held the old values. This is easy to do and has the advantage that it is economical on memory space. As a result, you do not need to discriminate between old and new values of coefficients, and the reduced array or matrix now looks like,

a(1,1)	a(1,2)	a(1,3)	:	a(1,4)
	a(2,2)	a(2,3)	:	a(2,4)
		a(3,3)	:	a(3,4).

Referring to **Fig. 2**, you will see that it falls into four parts. Firstly, there is a straightforward section which defines a number of integer variables and dimensions arrays a(N,N+1) and V(N). The program then asks for values of the coefficients to be used in the calculation. Secondly, sections two and three headed 'reduction of matrix' and 'back substitution' do the calculations. These have been developed from a flow chart by Dorn and McCraken.[1]

If, like me, you need more explanation of computer programs, then the following comments may help. Think in definite terms about the procedure.

To start with, assume that the number of equations N=3. Integer K refers to the number of the equation which is to be multiplied and then subtracted from the others, so it will start at 1 and go to 2 to complete the procedure.

The general array element is a(I,J), with the first integer (I) being thought of as the row number and the second (J) as the column number.

Element a(K,K) is the one which divides the Kth equation, and is called the pivot. So the I loop runs from the next equation (starting at number 2). This is used to work out the multiplier M and set elements which are going to be eliminated equal to zero (there is no need to work them out). It is also used to multiply

Fig. 2. Qbasic program for solving network analysis equations. If your PC has an older version of Dos, you can easily modify the programs to cope with the Basic it uses.

```
CLS
PRINT "Solution of linear eqns by Gaussian elimination."
DEFINT I-K, N
INPUT "What is number of eqns"; N
DIM a(N, N + 1), V(N)
PRINT "Enter values of elements:"
FOR I = 1 TO N
FOR J = 1 TO N + 1
PRINT "Element"; J; "of row";I
INPUT a(I, J)
NEXT J: NEXT I

REM Reduction of matrix.
FOR K = 1 TO N - 1                  'Eqn used to eliminate V(K), omit last eqn.
FOR I = K + 1 TO N                  'Start at next eqn.(I is row number)
M = a(I, K) / a(K, K)               'Work out multiplier, a(K,K) is pivot.
a(I, K) = 0                         'Entries up to pivot are zero.
FOR J = K + 1 TO N + 1              'J is column number.
a(I, J) = a(I, J) - M * a(K, J)     'Calculate new elements and store in original array
NEXT J
NEXT I
NEXT K

REM Back substitution
V(N) = a(N, N + 1) / a(N, N)        'Last variable.
FOR I = N - 1 TO 1 STEP -1          'Work back towards first eqn.
S = 0
FOR J = I + 1 TO N                  'Sum of terms to right of variable
S = S + a(I, J) * V(J)              'being evaluated.
NEXT J
V(I) = (a(I, N + 1) - S) / a(I, I)  'Variable value.
NEXT I

REM Print results.
PRINT : PRINT "Solution:"
FOR I = 1 TO N
PRINT "V("; I; ")="; V(I)
NEXT I
END
```

Fig. 3a) Qbasic program to solve a dc network.

```
DECLARE SUB Equations ()

    'Type a list of DATA statements
    'at the.beginning, as follows:

REM DC network of Fig.1
    DATA 7,3
    DATA CS,1,0,1
    DATA R,1,0,1
    DATA R,1,2,10
    DATA R,2,0,100
    DATA R,2,3,10
    DATA R,3,0,1
    DATA R,1,3,100

DEFINT I-K, N
READ Numele, N          'No. elements, nodes.
DIM a(N, N+1), V(N)
DIM G(N, N), CS(N)

FOR I = 1 TO Numele
READ Type$
SELECT CASE Type$       'Decide element type
    CASE IS = "R"
       READ J, K, R
       G(J, J)=G(J, J)+1/R: G(K, K)=G(K, K)+1/R
       G(J, K)=G(J, K)-1/R: G(K, J)=G(K, J)-1/R
    CASE IS = "CS"
       READ J, K, Csource
       CS(J)=Csource: CS(K)=-Csource
END SELECT
NEXT I

REM Set up matrix
FOR I=1 TO N: FOR J=1 TO N
       a(I, J)=G(I, J)  'Array filled with
NEXT J: NEXT I          'conductances.
FOR I=1 TO N
       a(I, N+1)=CS(I)  'RHS, current sources.
NEXT I

CALL Equations          'Solve eqns.

CLS
PRINT "Solution"
Format$="&              &"
PRINT USING Format$; "Node"; "Voltage"
PRINT
form$="##               ##.####"
FOR I=1 TO N
PRINT USING form$; I; V(I)
NEXT I
END
```

remaining elements in the selected equation – number 1 to begin with – by M, subtracting each from the value in the other equations and storing the result in the same location.

The process above needs a further (innermost) loop (J). It deals with the columns in an equation, or more precisely only the columns starting at K+1. This is because the other elements are going to be zero anyway.

Back substitution

Now the job is finished by back substitution. This is done in the third section of the program, the fourth prints the result.

First, there is a simple evaluation of the last variable, ie V(N)=V(3). Then, working backwards through the equations, you evaluate V(N–1), then V(N–2) and so on. This is done by summing the terms on the left-hand side which lie to the right of the variable being evaluated. Finally, the sum is subtracted from

Fig. 3b) Sub program for solving equations.

```
DEFINT I-K, N
SUB Equations
SHARED a(), V(), N
    'REM Reduction of matrix, using
    'Gaussian elimination.
FOR K=1 TO N-1
FOR I=K+1 TO N
M=a(I, K)/a(K, K)
a(I, K)=0
FOR J=K+1 TO N+1
a(I, J)=a(I, J)-M*a(K, J)
NEXT J
NEXT I
NEXT K
    REM Back substitution.
V(N)=a(N, N+1)/a(N, N)
FOR I=N-1 TO 1 STEP-1
S=0
FOR J=I+1 TO N
S=S+a(I, J)*V(J)
NEXT J
V(I)=(a(I, N+1)-S)/a(I, I)
NEXT I
END SUB
```

Fig. 4. This subroutine can be used for printing the matrix to provide a more readable format.

```
FOR I=1 TO N: FOR J=1 TO N+1
PRINT USING "##.####"; a(I, J);
IF J=N+1 THEN PRINT
NEXT J: NEXT I
```

the right-hand side and divided by the coefficient of the variable we need.

General comments

You should find that the program will work for any reasonable number of equations N. One of the problems that you can encounter if you simply invent equations without reference to a network is that some of the pivot values can be zero, in other words a(K,K)=0. This will not happen if you use a network as the source of the problem, provided that you always allocate an earth node and label it zero and number the other nodes in sequence 1,2,3... None of the values should be left out.

Creating a netlist

The usual way of getting circuit configurations into a package such as Spice is by means of a list of components and their node numbers. To deal with the problem in hand it is necessary to specify resistors and current sources. These methods are described fully in Vlach and Singhal[2].

Resistors require their conductance values to be stored in an array called G(J,K), the J,K values being the node numbers to which each resistor is connected. Since the problem is going to involve N equations, the highest node number will be N, so the greatest values of J and K will be N. You therefore dimension the array: DIM G(N,N).

Assuming that J,K and the resistor value R have been read into the program, you can now create an entry into G as follows,

$$G(J,J)=G(J,J)+1/R : G(K,K)=G(K,K)+1/R$$
$$G(J,K)=G(J,K)-1/R : G(K,J)=G(K,J)-1/R$$

To understand this, consider the 100Ω resistor connected between the nodes 1 and 3 of Fig. 1. According to the assignments above, provided that all elements of G are zero at the outset, then the effect is to make,

$$G(1,1)=.01 : G(3,3)=.01$$
$$G(1,3)=-.01 : G(3,1)=-.01.$$

If these are interpreted as the elements of the matrix, ie a(1,1)=G(1,1) etc, then you have the appropriate values for the coefficients on the left-hand side of the equations. When these instructions are used repeatedly, the effect of the G(J,K) terms on the right-hand side is to add the conductances of any resistors which terminate on the given pair of nodes.

If a resistor is connected with one end to earth, say K=0, then all but G(J,J) will have no effect. This is because the corresponding matrix elements are not used in the Gaussian elimination.

Now for the current sources. Here we create an array CS(N), and assign values to it as follows,

$$CS(J)=Csource : CS(K)=-Csource$$

where J is the node connected to the positive end of the source, and K is the negative end. We enter these values into column N+1 of the matrix. **Figure 3** reads in a netlist and then solves the resulting equations.

As you see, the program has a main section and a sub program to solve the linear equations. The only other thing you might need to do to convince yourself that the program is operating correctly is to add a short program segment to print the matrix, **Fig. 4**.

References

1. Dorn, W, S. and McCracken, D, D, 'Numerical methods with FORTRAN IV case studies', John Wiley, 1972.
2. Vlach J and Singhal K, 'Computer methods for circuit analysis and design', Van Nostrand Reinhold, 1994.

Further reading

Feldman P and Rugg T, 'Using QBASIC', Que Corporation, 1991.

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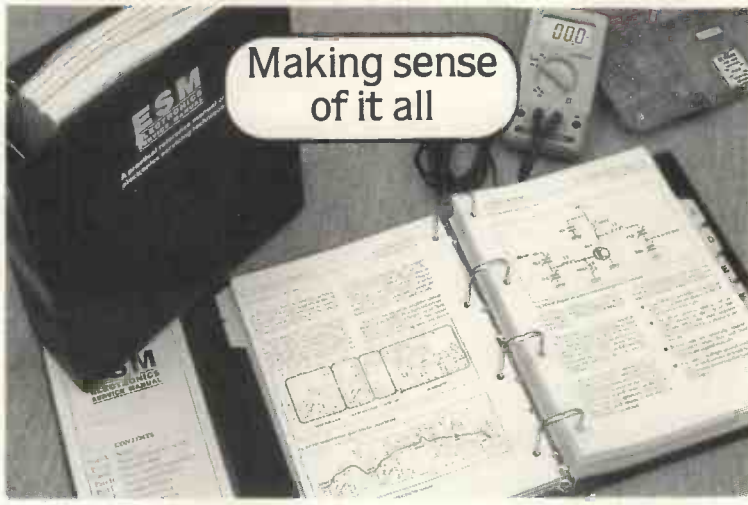

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LETTERS

Letters to *"Electronics World"* Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

S&K distortion culprit?

A.D. Ryder, in his letter 'Sallen & Key Distortion', November 1995 issue, discusses a distortion mechanism often seen when op-amps are used with divergent inverting and non-inverting input source impedances and applied common-mode voltages.

A Sallen & Key filter represents an extreme case of this, with medium-high impedance at the non-inverting input and – usually – zero impedance at the inverting input, as in his example. However, the distortion can also be seen in other non-inverting amplifier topologies when working from medium to high impedance sources, if the source/feedback impedances are not balanced.

The basic distortion culprit is a non-linear capacitance-voltage characteristic at the amplifier input(s), i.e., a varactor-like behaviour. This produces the distortion when appreciable common-mode voltage is applied. For a given signal input, the distortion generated is proportional to the source impedance, that is higher impedances will produce more distortion from a given amplifier.

As Mr. Ryder notes, operating the op-amp in the alternate inverting mode avoids this distortion. This is because the non-linear C-V mechanism is not exercised for this condition.

Several means can be used to control this distortion in Sallen & Key filters. One is to simply scale the filter impedances to the lowest level possible. This reduces distortion by simple brute force means. Use, for example, two 11kΩ resistors and 4.7/47nF capacitors, etc.

A more complete approach is to provide direct compensation for the distortion, by taking advantage of the intrinsic amplifier input characteristics. Op-amps are inherently differential-mode input devices; as such they produce this distortion at both inputs. It then follows that matching the impedances at the two inputs will provide a compensating delta-V/delta-C distortion at the feedback input. This conveniently causes the distortion at the output to be minimised by virtue of the amplifier's natural common-mode rejection.

A simple first-order *RC* pair in the feedback path provides some compensation, but full distortion reduction is seen when the input *RC* components seen at the non-inverting input are duplicated one for one in the feedback path. For Mr. Ryder's example, this would be accomplished by synthesising an equivalent two-terminal impedance network, composed of, at the top, a 470pF capacitor in parallel with two series 110kΩ resistors. The lower of these is shunted by a 4.7nF capacitor.

The bottom of this network is returned to the amplifier output, completing the filter. In this setup, the amplifier sees identical impedances at the two inputs for all frequencies, the desired condition for lowest distortion due to common-mode inputs.

This topic has been discussed previously in (1) and (2) for filter applications, and in (3) and (4) for straightforward amplifiers. Data contained in (2) shows an order of magnitude or more reduction in thd with the use of the compensating network in a Sallen & Key filter.

Reference (4) also illustrates another method of beating the problem, by bootstrapping the input stage of a susceptible amplifier.

Walt Jung
Analog Devices Inc.
(Office), 410 692-6702
(fax) 410 692-2158.
Email: Walter.Jung@analog.com

References
1. Scott Wurcer, 'An Input-Impedance Compensated Sallen-Key Filter', Analog Devices AD743 data sheet.
2. Walt Jung, 'Active Filter Circuit Subtleties', Analog Devices OP176 data sheet.
3. Walt Jung, 'Op-Amp Device/Topology Related Distortions' of 'Audio Line Drivers and Buffers', part of Chapter 8 of 'System Applications Guide', Analog Devices, 1993.
4. Walt Jung, 'Bootstrapped IC Substrate Lowers Distortion in JFET Op-Amps', Analog Devices AN-232, July 1992.

Anyone remember this?

In 1914 the Marconi Wireless Telegraphy Company, acting for the Admiralty, built a 100kW spark transmitting station on Ascension Island. This, by any standards, was a remarkable task. Apart from being one of the most remote in the world, this island had virtually no infrastructure, and the sole population comprised a garrison of Naval staff and their servants.

Every item required in the project had to be brought in. In addition to the transmitter/receiver site, with its six, 305ft tubular steel masts supporting a massive 'T' antenna, the project also required the construction of complete power station, delivering 500V dc for the transmitter and a separate 220V dc supply for lighting and staff accommodations.

Incredibly, the entire job was completed within three months. My society, thanks to the help and generosity of the Marconi Company, has a good deal of information concerning the description and specification of this installation. Sadly we have very little information concerning its operational life. May I appeal to any readers who may have any such information, or even photographs, to contact me at the following at,
Ascension Heritage Society,
c/o BBC Atlantic Relay Station,
Ascension Island,
South Atlantic Ocean.

Phil Brooks
Secretary, AHS
Ascension Island.

EMC clarified

Mr Bore's argument, expressed in last December's Letters, is valid to some extent, but his description of the situation is inaccurate. He can be forgiven for being confused, because there is a positively scandalous amount of wrong information – even disinformation – rife in the industry. The authorities seem powerless to control matters.

Radiated emissions are by no means the only disturbances which are controlled by limits in standards. The EMC Directive does not require any testing at all to be undertaken: all it requires is that 'apparatus' does not cause interference, and is not unduly sensitive to legitimate or permissible electromagnetic disturbances that can be expected to occur in the environment(s) in which the manufacturer intends or expects the apparatus to be used.

In most cases, the manufacturer is required to make a legally-binding declaration to this effect. This declaration can, for most types of apparatus, be supported in either of two ways: conformity to the appropriate standards which have been notified as acceptable to the Commission by publication in the EU Official Journal, or by the 'Technical File' route, known as TCF. With the TCF route, standards may be used in part, but essentially, it requires a technical report prepared or endorsed by a 'Competent Body'. This body may be an officially recognised test laboratory.

In spite of a concerted campaign to cajole equipment manufacturers into the TCF route (to support the high proportion of Competent Bodies in the UK – far higher than in other countries) the standards route is, for most products, simpler, cheaper and more certain.

It is essential however, that the appropriate standard(s) are applied, and this is a particular source of confusion. For products that have no particular appropriate standards ('product standards' or 'product-family standards'), there are Generic Standards EN50081-1 and -2 and EN50082-1 and -2.

These standards make provision for exemptions from testing where there is clearly no call for it – see for example, Clause 8 of EN50081-1. Some product standards are rather elderly, and do not contain such a provision explicitly. However, provided the decision not to test is recorded with reasons, and preserved as required by the Directive, a statutory defence of 'due diligence' is provided in, for example, the UK Regulations implementing the Directive.

Mr. Bore's example figures, however, are not realistic. For most types of product, radiated emissions are controlled above 30MHz. Below this frequency, the efficiency of most products as antennas is low because their dimensions are small compared with the wavelength. But at 30MHz and higher frequencies, quite a small amount of antenna power is required to produce, for example, the limit field strength of 30dB(μV/m) (31.6μV/m) at 10m specified in EN50081-1. If the equipment were as efficient a radiator as a half-wave dipole, the requisite input power to the dipole would be given approximately by: $(31.6\times10^{-6}\times10)^2/118.4=0.84\text{nW}$

KRS John Woodgate
(Chairman, British Standards Technical Committee EPL/100)

Improved hot audio

Having analysed Jeff Macaulay's valve power amplifier featured in the October 1995 issue of Electronics World, I have found an imbalance in the circuit that the following equations highlight.
In the equations,

u is V_{in}
i is change in Tr_1 emitter current from its quiescent value
I is change in Tr_2 emitter current from its quiescent value
m is the value of R_3
M is the value of R_4
p is potential at Tr_1 emitter
P is potential at Tr_1 emitter
$-E$ is potential of the negative rail
f is the value of R_2
F is the value of R_5
b is the value of R_{12}
B is the value of R_{13}
h is the value of R_{11}

Emitter current of Tr_1 is,

$$\frac{p-0}{m}+\frac{p-u}{f}$$

which in the quiescent state is,

$$E\frac{f}{b}\left(\frac{1}{m}+\frac{1}{f}\right)$$

and similarly the quiescent emitter current of Tr_2 is,

$$E\frac{F}{B}\left(\frac{1}{M}+\frac{1}{F}\right)$$

When V_{in} is instantaneously at some value u the emitter current of Tr_1 is,

$$\left(f\left(\frac{u}{f}+\frac{u}{b}+\frac{E}{b}+\frac{u}{h}\right)-0\right)\frac{1}{m}+\left(f\left(\frac{u}{f}+\frac{u}{b}+\frac{E}{b}+\frac{u}{h}\right)-u\right)\frac{1}{f}$$

which simplifies to,

$$\frac{Ef}{bm}+u\frac{f}{m}\left(\frac{1}{f}+\frac{1}{b}+\frac{1}{h}\right)+\frac{E}{b}+u\left(\frac{1}{b}+\frac{1}{h}\right)$$

and so the change of Tr_1 emitter current from its quiescent value is,

$$u\frac{f}{m}\left(\frac{1}{f}+\frac{1}{b}+\frac{1}{h}\right)+u\left(\frac{1}{b}+\frac{1}{h}\right)$$

and so we have,

$$i=u\left(\frac{1}{m}+\frac{f}{mb}+\frac{f}{mh}+\frac{1}{b}+\frac{1}{h}\right)$$

Similarly the instantaneous emitter current of Tr_2 is,

$$\left(F\left(\frac{E}{B}-\frac{u}{h}\right)-0\right)\frac{1}{M}+\left(F\left(\frac{E}{B}-\frac{u}{h}\right)-0\right)\frac{1}{F}$$

which simplifies to,

$$\frac{EF}{BM}-\frac{uF}{Mh}+\frac{E}{B}-\frac{u}{h}$$

and so the change of Tr_2 emitter current from its quiescent value is,

$$I=-u\left(\frac{F}{Mh}+\frac{1}{h}\right)$$

Applying the resistor values specified in the circuit (working in mA, V and kΩ),

$$i=u\left(\frac{1}{1.8}+\frac{10}{1.8\times68}+\frac{10}{1.8\times0.68}+\frac{1}{68}+\frac{1}{0.68}\right)=10.3u$$

and,

$$I=-u\left(\frac{10}{1.8\times0.68}+\frac{1}{0.68}\right)=-9.6u$$

The ratio between these is 1.07 so the imbalance is higher than it need be. It could be improved with the circuit on the right. Components with functions similar to the original circuit have the same labels as the original circuit.

In the quiescent state the emitters of Tr_1 and Tr_2 are at ground or 0V. To allow quiescent current to flow the emitter resistors $R_{3,4}$ are not returned to ground but to an appropriate negative potential. With perfect balance the sum of the currents in $R_{3,4}$ will be constant, so this appropriate voltage is determined by R_{18} across which there will be a constant potential difference.

The value of R_{18} has been chosen to give the same quiescent current as the original circuit.

There are two ways of looking at the operation of the phase splitting arrangement.

The potential at the junction of the equal-valued resistors R_5 and R_{17} will be the average of the potentials at the transistor emitters so if phase splitting is perfectly balanced this potential will remain at 0V. By connecting this point to the inverting input of A_2, A_2 will control the potential at the emitter of Tr_2 so that the potential at the junction of R_5 and R_{17} is as close to 0V as its raw gain will permit. Hence the phase splitting is as well-balanced as possible.

The other way of looking at the circuit is to consider R_{17}, R_5, A_2 and Tr_2 to be a conventional amplifier with feedback which takes its input from the emitter of Tr_1. The gain of the amplifier is –1 so it straightforwardly inverts the potential at its input and so provides the opposite phase.

A_1 has 100% negative feedback applied so the potential of the emitter of Tr_1 will equal V_{in}, and that of Tr_2 will be $-V_{in}$.

In this circuit, let t = the value of R_3, R_4, r = value of R_5, R_{17} and s = the value of R_{18}.Quiescent emitter current of both Tr_1 and Tr_2 will be half that flowing through R_{18}, ie.

$$\frac{1}{2}\cdot\frac{E}{\left(s+\frac{t}{2}\right)}$$

or

$$\frac{E}{(2s+t)}$$

Potential at the junction of R_3, R_4 and R_8 will be

$$-\frac{E.t}{(2s+t)}$$

Hence when $V_{in}=u$ and the emitter of Tr_1 is at potential u the emitter current of Tr_1 will be,

$$\frac{\left(u+\frac{E.t}{(2s+t)}\right)}{t}+\frac{u-0}{r}$$

which is,

$$\frac{u}{t}+\frac{E}{(2s+t)}+\frac{u}{r}$$

and so the change in current from the quiescent value is,

$$u\left(\frac{1}{t}+\frac{1}{r}\right)$$

Applying the resistor values specified (working in mA, volts and kΩ) the change in Tr_1 emitter current is

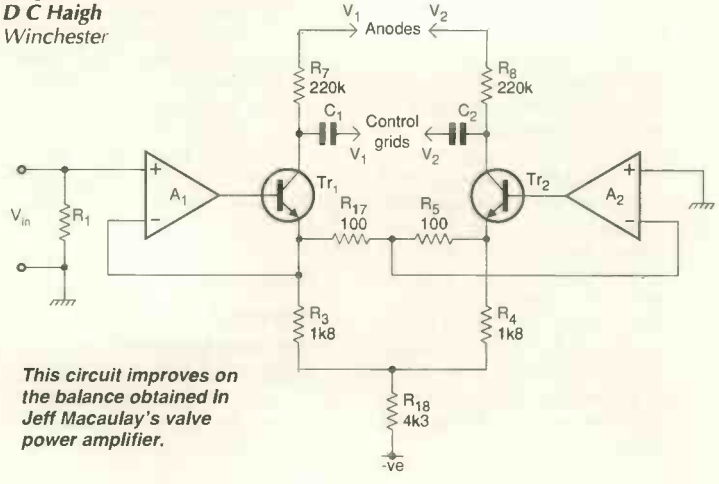
$$u\left(\frac{1}{1.8}+\frac{1}{0.1}\right)=10.6u$$

Similarly it can be shown that the change in Tr_2 emitter current is –10.6u.

I have not yet built this circuit but I would expect it to perform better than the original. Also its component count is lower.

Finally, I am a little worried about the voltage rating of C_5 and C_6. Allowing a 2V drop across the bridge rectifier, the peak on these capacitors will be 394V. This is perilously close to the specified voltage rating of 400. If the mains input voltage were to rise to 244V there might be an expensive bang.

D C Haigh
Winchester



This circuit improves on the balance obtained in Jeff Macaulay's valve power amplifier.

Linearity confusion

Looking back at past debates of fet/bjt linearity, I noticed that the word linearity is being referred differently by some correspondents.

A lot of the fet supporter comment on the linearity between g_m and V_{gs}. Fair enough. Suppose g_m does increase linearly with V_{gs}. Then we can write $g_m=kV_{gs}$, where k is a constant.

Knowing that $g_m=Id/V_{gs}$ and substituting $g_m=V_{gs}$ gives $Id=kV_{gs}^2$. What is important in audio signal amplification is linearity between I_d and V_{gs}, not between g_m and V_{gs}.

The fet's square law does have an advantage though. Distortions produced by square law devices are mainly even order. Using such a device in push-pull results in cancelling of even-order distortion. If precise matching can be done for output devices – which I doubt – fets may have less distortion in the end.

Bipolar devices are probably more linear on their own, but due to the doubling of odd-order distortion under push-pull operation, they may have higher distortion compared to a perfectly aligned fet stage.

Using fets with reasonable g_m also results in lower open-loop output impedance. This is due to the source follower output impedance of $1/g_m$. Output impedance below 1Ω would be enough to control most speakers.

There is another point. Given low open-loop output impedance, any back emf and radio-frequency disturbance coming from the speaker will be earthed at the output terminals. Amplifiers relying on global negative feedback to lower output impedance behave differently. Any unwanted rf/emf coming in from the output terminals will be injected into the second base of the long tailed pair. As a result, the amplifier is forced to perform disturbance rejection on top of the amplification it has to do. This is not ideal.

Mr Self rejected the idea of

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Waveform characteristics

Sinewave distortion	<1% at ≤200kHz
Triangle non-linearity	<1% at ≤200kHz
Square rise and fall	<20ns

Output

50Ω o/p impedance	50Ω ±5%
0dB amplitude	2Vpp to 20Vpp no load
–20dB amplitude	200mV to 2V pk-pk, no load
–40dB amplitude	20mV to 200mV pk-pk, no load
Logic	Capable of driving 20 ttl loads
Offset	±10V no load, ±5V 50Ω load
Duty cycle	10% to 90%

General

Operating temp.	+5°C to +40°C
Weight	1100g
Size, overall	203mm x 195mm x 75mm
Power requirements	110/120V or 220/240V 50/60Hz externally set
Power consumption	typically 10VA
Specification	BS EN 61010-1/1993

External frequency control

VCO frequency modulation/sweep

Impedance	10kΩ ±2%
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resistively loading the V_{as} transistor due to distortion. However, it has its merits when bipolar devices are used at the output. Choosing R_1 at 5kΩ, and assuming an output Darlington h_{fe} of 10000, the open-loop impedance will be 0.5Ω. As a result, there is no need to resort to feedback to lower open-loop output impedance.

Varying the value of R_1 results in a trade off between distortion and open-loop output impedance. Subjectivists may find it interesting to replace R_1 with a 100kΩ potentiometer.

Lastly, why doesn't anybody use the Siliconix Vmos device which claim superior linearity over ordinary mosfets? I hardly ever see the Toshiba IGBT's used either.

Koji Kiyoleawa,
Allestree
Derby

Excellent grounds for more debate

I beg to disagree with sentiments expressed by John Watkinson in your letters column of *EW*, Nov '95. Contrary to John's point of view, I do feel that the debate on audio amplifiers has been healthy and should be encouraged.

Whether for Aerospace, Marine, Defence or Industrial applications, amplifiers are fundamentally the same. As a result, whatever is learned by investigating audio amplifiers is certainly applicable to the other areas just mentioned.

The fact that audio-frequency amplifiers have been hotly debated over these many months, is a clear indication that a lot has been taken for granted over the years. Of course thanks to our new tools of trade, analyses are made so much easier. This however, is not to take anything away from those who have burnt the midnight oil to bring it all to us.

For most of us in the 'Third World' where we are more at home with wild life than wires, the closest we get to Spice is in our cup of morning tea. Hence we are very grateful to the Selfs, Olssons, Hoods, and Duncans for the privilege of having the chance to share their simulation and test results, and also their unquestionable technical expertise.

Clyve J. Caines
Technical Services Manager
Nairobi, Kenya, East Africa.

Duncan disputes

Prof. Cherry in Letters, Nov '95, has not read my words. On p. 393, May '95, the number of electrolytic capacitors is unspecified. Instead I clearly refer to a ratio of three, as unequivocally shown between his Figs. 11a) and b) on p. 20, Jan '95. I am glad that Prof. Cherry recognises that music signals are usually asymmetrical.

As a world-renowned advocate – along with top recordists – of a minimum record/replay path built from all-dc electronics, ideally free from unnatural high-pass capacitors, the discharge error he mentions does not much concern me; his caution should be directed as those like Self, whose power amplifier alone contains as many electrolytic capacitors as my entire, ideal dc audio chain.

Much as I love his approach to electronics, it appears that Prof. Cherry cannot see nor share the joke over the futility (on his own objectivist terms) of his scheme, viz: "there are no sharp edges nor sub-sonic signals surviving in multitrack recordings because of all the high-pass filters; So making the last and hundredth device in the chain have an ideal square wave response is a waste."

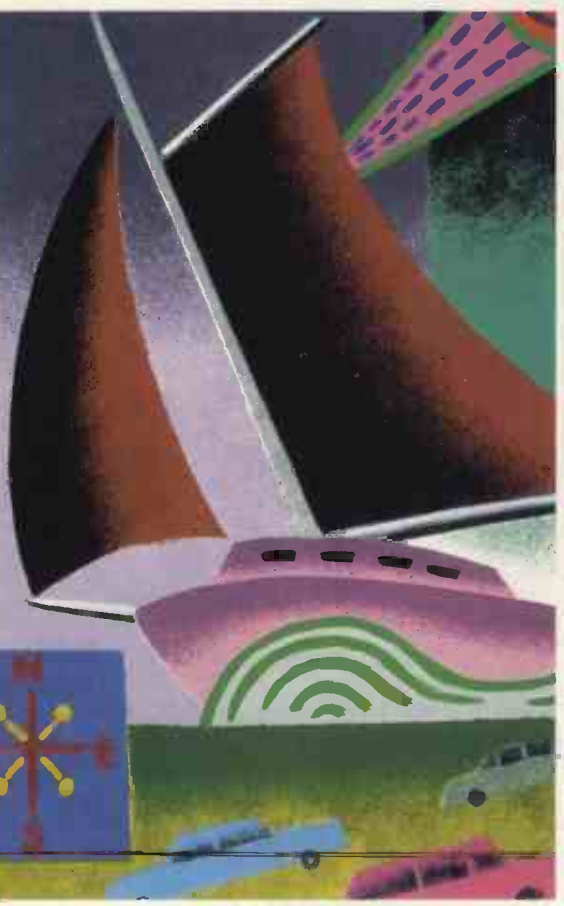
If Prof. Cherry chooses to ignore the role of capacitor constructions, impedances and microphony on sonics, and denies real electrolytic capacitor tolerances and temperature coefficients, that is not my problem. There are in-depth works on audio capacitor reality by Marsh and Jung and someone called Duncan. The five minutes of tweaking he suggests is ok by me but grossly unacceptable to most manufacturers, as rightly indicated by Self, and it ignores drift and temperature coefficient.

Since my colleagues and I design and produce audio systems that have helped enthrall many thousands of discerning customers, I have enough substantion, thank you. At least we'll be open minded enough to give Prof. Cherry's low-frequency compensation scheme a listen some day, even if we think it is as deranged as his chassis earthing recommendations.

Ben Duncan
Lincoln ■

A new direction in **orientation**

Sensitive down to to 10nT, the *FGM* three terminal magnetic detector is suitable for a host of two and three-axis orientation applications. Richard Noble explains.



Richard is Technical Director of Speake & Co Ltd.

The most well known orientation detector is the common compass, the simplest form of which is a single axis device known as a steer-on-heading compass or 'poor man's autopilot'. It comprises a single magnetic sensor mounted on a rotatable disk, marked in degrees around the periphery and fitted with a stationary indicating pointer, **Fig. 1**.

Output of the sensor is connected to a frequency-to-voltage converter circuit feeding a centre-zero meter display as described in the November issue of *EW*.

In Fig. 1, if the boat veers to the left, the meter needle swings to the right, indicating the need to steer in that direction to correct the course. If the rotating disc is turned to a new heading the needle shows the best direction to steer in until the new heading is reached. At this point it returns to the centre position.

Magnitude of the deflection gives an indication of the amount of correction needed at any time. This type of steering system is said to be easier on the helmsman than having to remember and follow a degree bearing.

For this simple system to be useful, the sensor must be gimballed and weighted so as to keep its axis level at all times. Since it is only a single axis device it only needs a single gimbal, provided that the gimbal rotates with the heading disc.

The next level of complexity is a two-axis compass. For this, it is best to replace the frequency-to-voltage converter with a microcontroller of some sort as a number of more complex operations need to be carried out – especially if a readout display is wanted.

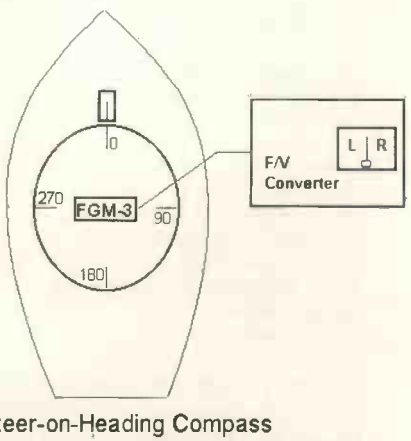
Many varieties exist, all capable of dealing with the requirements of a compass. But because the sensors have their own analogue-to-digital feature, microcontrollers which have frequency or period determining features built in are the obvious choice in this instance.

Angular sensitivity

It is useful to look first at the angular response of an individual sensor. Because of its structure it 'sees' the full magnitude of a field, which is aligned along its long axis. For any field at right angles to this axis, it gives zero output in the sense that its period corresponds to that of a zero field condition.

For a field aligned at an angle between these two extremes the response is proportional to the projection of the field on to the long axis of the sensor, therefore to the cosine of the angle between field and sensor. This gives rise to the classic figure-of-eight polar diagram, comprising two contacting circles or, in the three dimensional case, two contacting spheres, **Fig. 2**.

If sensors are aligned along the axes of any two or three axis coordinate system the



Steer-on-Heading Compass

Fig. 1. Simple steer-on-heading compass comprising a sensor mounted on a rotatable disc, marked in degrees around its periphery, and fitted with a stationary indicating pointer.

sensor outputs represent the direction cosines of the field vector with respect to that coordinate system. For convenience the chosen system is usually cartesian but this is not essential.

As described under the calibration and linearising techniques, it is convenient to normalise the sensor readings by dividing through by the zero-field period. In orientation type devices it is also convenient to then subtract one from these normalised values to yield equal positive and negative ranges about zero. These adjusted values are then proportional, but not yet equal, to the direction cosines of the field vector.

The reason is that no two sensors are exactly alike in absolute sensitivity, and must now be calibrated so as to achieve a standard sensitivity. This can be done by the calibration coil method described earlier, after which proportionality constants can be assigned as multipliers to equalise the sensitivities. Alternatively it can be done by aligning the individual sensors in turn along the local earth field vector in the two possible directions, 180° apart and determining the corresponding maxima and minima for each sensor. Proportionality constants are again assigned to equalise the sensitivities.

Two-axis orientation sensing

The two axis compass uses twin sensors superimposed at right angles to one another in the same location and both constrained to lie in the horizontal plane. The sensitivity equalising process in this case can be semi automated by rotating the sensors through a full 360° and allowing the software to determine the maxima and minima for both axes.

Assume that the two now standardised values are x and y components of the local field vector, h, having a modulus equal to $\sqrt{(x^2+y^2)}$. Now, the final normalisation can be realised by dividing each component by this modulus. This gives the true direction cosines of the field vector which together define the unit vector i, having the same direction as the field vector, h.

This process eliminates the effect of any variation of the absolute magnitude of the measured field, since the sum of the squares of the direction cosines always equals one. Earth field variations are insignificant in this context, but supply or ambient temperature changes are neutralised provided all sensors are equally affected.

The direction cosines can be readily converted to a more customary representation such as angular heading as follows.

Assume that the compass heading indication is aligned with the y-axis and label the components of the unit vector, i_x and i_y. Then it can be seen from **Fig. 3** that if θ is the conventional heading angle,

$$\tan\theta = -i_x/i_y$$

and

$$\theta = \tan^{-1}(-i_x/i_y)$$

and the compass heading is simply the arctangent of the ratio of the x and y components of the unit vector in the Earth's field direction.

For a three-dimensional coordinate axis system with the z-axis at right angles to the other two there is no conflict with anything that has been said so far, provided that the z-axis remains vertical. In fact this becomes the necessary condition for the successful operation of this type of compass, which needs to be gimballed in two directions and appropriately weighted.

It will be evident that some attention to signs and the possible divisions by zero will be required in considering the full circle of 360°. While this arctangent solution may be possible for a computer with trigonometric functions in a high-level language, it is not appropriate for a lower level of implementation such as a microcontroller. However, the underlying principle remains the same in alternative approaches.

The full circle in which the heading vector lies may be segmented into eight 45° octants and the octant occupied by the field vector can be identified by simple non trigonometric tests, easily applied in software.

The rules which do this involve the signs of the i_x and i_y components and the comparative magnitudes of these components taken as an ordered set. For example if $i_x<0$ and $i_y>0$ the heading must lie in the first quadrant. If, in addition, $|i_x|<|i_y|$ it must lie in the first octant between 0° and 45° as in the previous diagram. Other combinations uniquely identify the remaining octants, **Table 1**.

Table 1. These combinations uniquely identify octants in a two-axis heading system.

Sign of i_x	Sign of i_y	$\|i_x\|>\|i_y\|$ or $\|i_x\|<\|i_y\|$	Octant No
negative	positive	less	1
negative	positive	greater	2
negative	negative	greater	3
negative	negative	less	4
positive	negative	less	5
positive	negative	greater	6
positive	positive	greater	7
positive	positive	less	8

Implementation of these rules on their own provide an eight point compass with a ±22.5° accuracy, which while not very precise may be adequate for some undemanding applications. There are other benefits in more sophisticated versions. The first advantage of this technique is the Gray-code like way in which the octant rules work.

At each octant boundary only one of the rule parameters changes. For example at 45° no sign changes occur but the inequality between i_x and i_y changes direction. At 90° no inequality changes occur and the sign of only iy changes. This property prevents large scale jitter and confusion which might otherwise occur at the octant transitions if the changes were not totally synchronous.

A second advantage is that in each of the octants, a linear function of either i_x or i_y can be identified which is virtually equal to the desired heading angle, to within a small error.

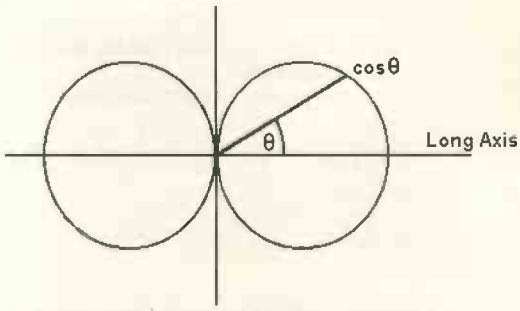


Fig. 2. Polar response of the sensor. Because of its structure, the sensor sees the full magnitude of a field aligned along its axis.

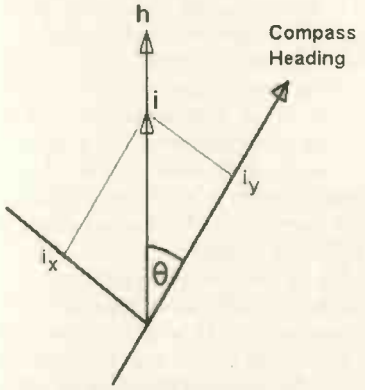


Fig. 3. In a twin-axis heading system, the direction cosines are readily converted to a more customary representation such as angular heading.

In the 0° to 45° range if ki_x is interpreted as a radian angle it is in fact very little different from the appropriate arctangent for that octant.

If k=1.08 the error in doing this is nowhere greater than about 1.25°. If k is ignored and the unit vector x component alone is interpreted as radians the error is never worse than 4.5°, permitting the implementation of a 5° precision compass very easily. Note that for this purpose the modulus of the x component is used, eliminating the need to consider signs. Note also that $|i_x|$ is less than $|i_y|$.

In the next octant, between 45° and 90°, ki_y interpreted as an angle and subtracted from 90° is very close to the correct heading. This pattern repeats around the full circle and leads to the following rule.

Whichever of the direction cosines is the smaller is interpreted as an angle and in odd octants is added to the nearest quadrant boundary. However in even octants it is subtracted from the nearest quadrant boundary to obtain the heading.

If as is likely in a software implementation the octants are numbered 0 to 7 rather than 1 to 8, the odd and even should be reversed in the previous statement of the rule. In conjunction with using k=1.08 this rule will provide almost ±1° precision in a software implementation requiring no trigonometric functions.

Alternatively, since the error is small, a very short lookup table of adjustments to be added to the heading obtained with k=1 will improve the precision to a level of around ±0.5°.

Table 2. Correction factors for the two-axis heading system.

Measured angle	Added correction
0°-20°	0°
20°-29°	0.9°
29°-33°	1.8°
33°-37°	2.7°
37°-39°	3.7°
39°-41°	4.3°

This technique will not produce a compass of this accuracy. Rather, the contribution to the total error budget from this source will be minimised to the extent indicated. Other sources may contribute larger errors in a final design if they are not suitably addressed.

One important potential error is lack of orthogonality in the axes of the two sensors. This can cause a smoothly varying error around the whole compass circle which can be much larger than those discussed above. Fortunately there is a relatively simple correction technique for this as can be seen from the following analysis.

In **Fig. 4**, i is the unit vector in the field direction, θ is the heading angle and ϕ is the small angular error by which the x-axis sensor departs from the correct right angled position. Also i_x is the true x component of the unit vector, i_y is the true y component and i_x' is the apparent measured x component of the sensor in error.

You can see from the geometry of the figure that,

$$i_y = i\cos\theta$$
$$i_x = i\sin\theta$$
$$i_x' = i\sin(\theta-\phi)$$

Expanding the last relation,

$$i_x' = i\sin\theta\cos\phi - i\cos\theta\sin\phi$$

Since ϕ is small $\cos\phi$ may be taken as one and $\sin\phi$ as just equal to ϕ giving

$$i_x' = i\sin\theta - \phi i\cos\theta = i_x - \phi i_y$$

Hence,

$$i_x = i_x' + \phi i_y$$

It can be seen from this that the desired x component of the unit vector can be obtained from the apparent measured component, for all angles, by adding a small fixed portion of the y component. The proportion to be added is equal to the orthogonality error in radians.

The value of ϕ can be found, for a standardised and normalised sensor set by rotating the configuration in the Earth's field and measuring the angle between the zero-field positions of each sensor.

Alternatively the algorithm can be added retrospectively to an otherwise completed compass by checking the error during a full 360° rotation. The value of ϕ can be taken to be the average of the errors at 90° and 270° shown by the digital display. Such a determination needs only to be made once.

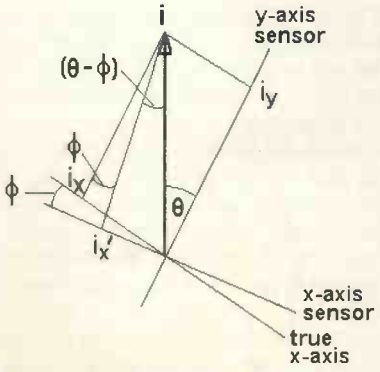


Fig. 4 . Errors in orthogonality depend on direction of tilt and heading.

If the microcontroller has no convenient way of memorising the correction it could alternatively be read from a trimmer value on power-up using *RC* timing or some other relatively crude analogue input method. The orthogonality then becomes one of the possible adjustments available to the user during the compass 'boxing' exercise.

Detecting errors

Probably the largest of the final observed errors will arise from failure to constrain the axes of the sensors to the horizontal plane. The errors depend on the direction of tilt and the heading, and on some headings small angular tilts will multiply up to much larger heading errors.

For example on a north heading a 1° north-south tilt will produce no error, but a 1° east-west tilt will give rise to almost 2.5° of heading error. There is no simple cure for this other than effective double gimballing, suitably weighted, though short term averaging of multiple readings can improve the stability of the displayed output.

Another more complex alternative is to use a gravity sensor to determine the direction of the gravity vector and use trigonometric calculation to correct for the effects of tilt.

A final aspect of overall accuracy concerns the required precision of sensor readings. Interestingly, this is surprisingly lower than might be thought. Using the type of algorithm described earlier, a full 360° of 1° precision requires only that the measured components be slotted into one of forty-five almost evenly spaced bands. A relatively low six-bit binary measure will cover this. For a 5° precision a miserly four bits is adequate.

In conclusion, for those who may design, build and use a compass, in anger, the illusion of precision created by a 360° digital display may hide a lack of precision which is real. The cautious navigator rarely places total faith in compass accuracy and never trusts it as his sole instrument of navigation.

Triple sensor systems

Using three orthogonal sensors permits a three-dimensional determination of both magnitude and direction of the local field vector. This determination is only made with respect to the axis system of the sensor configuration and not in any absolute space. Nevertheless it can provide the basis of many interesting applications other than the compass.

The compass is not the only device which requires absolute referencing. The extension to three dimensions permits – in principle – the exploitation of the Earth's field in 'virtual reality' simulations, with the possible advantage of a 'free roving' capability.

The potential to free rove in a large space is a consequence of the fact that the field behaves as a fixed orientation vector everywhere in the space. It can be converted to the forward looking vector of a virtual reality helmet, provided that it can be referenced to some absolute space.

The sensor configuration alone is not adequate for the following reason. For each angle the field can take with reference to the sensor axis system it is possible to rotate the axis system a full 360° around the field vector without any change in the sensor outputs. This ambiguity must be resolved to obtain the desired absolute reference and requires one more fixed orientation vector. The obvious one is Earth's gravity vector which will always provide a local vertical.

While a compass design can make use of a slow response device such as a mercury pool on resistive quadrants or a dielectric bubble on capacitive quandrants, these are useless for virtual reality applications. They usually don't have the angular range and they certainly don't have the speed required to follow rapid head movements.

The minimum requirement would be a speed compatible with a flicker free video image refreshing system, say 70Hz, though some systems specify a response rate of 250Hz. To satisfy this kind of requirement calls for something like an accelerometer configuration with a flat bandwidth of this order, which also extends down to dc.

Such devices have been recently developed, spurred on by the automobile air-bag market, but low-g versions are still very expensive in small quantities. They also have relatively poor signal-to-noise ratios at wide bandwidths. This is not too severe a problem, however, since like the compass algorithms already described, high angular accuracy can be obtained with low binary spans.

Pseudo three axis systems

There is a class of systems which use a three axis sensor sytem, but eliminate the need for the gravity vector by an additional constraint on one axis. They have the superficial appearance of three-dimensional systems but do not exploit all the possible degrees of freedom.

The searchlight is a classic example. It rotates in azimuth around 360° and could rotate in elevation through 180°, but does not have any mechanism for rolling around the remaining axis, since it would be entirely pointless.

If only the human head was satisfied by the same mechanism. Virtual reality would be

much easier to implement.

The reason that this works is that as soon as the roll axis is constrained to remain horizontal, the rotational ambiguity around the field vector, mentioned previously, disappears. The trigonometry of the unit vector components is soluble and yields not only the azimuth angles, like a compass, but also the elevation angles.

Gun platforms fall into this category, as do steerable satellite type aerials, some robot mechanisms and any device which needs to point to a direction in space from a horizontal platform. Complex devices of this nature are probably well served by the expensive mechanisms they already employ, but there may be many simpler applications which could benefit from a low cost magnetic sensor configuration and a microchip solution, previously not economic.

One interesting idea may be exploitable in the economy end of the flying sport. Aircraft magnetic compasses are notoriously impossible objects, since even the addition of a gravity vector sensor solves nothing when it indiscriminately combines gravity with the accelerations of manoeuvering.

In level flight, a gimballed flux-gate compass works well but is useless in turns. Nevertheless it remains a reasonable tool to a power pilot in transit. Since a glider pilot spends a great deal of time in spiral turns, chasing thermals, it is not very appropriate most of the time.

If one axis could be reasonably constrained most of the time, a usable compromise might be achievable. Since the full horizontal rotation of 360° is required and roll angle can be large, the only restriction possible is in the pitch axis. Aircraft do not generally spend very long periods in pitching manoeuvers – except during aerobatic activity. They may, however, alter pitch modestly during climbing, descending or turning. During any steady state version of these activities acceleration or deceleration along the line of the fuselage is small or nil.

If a three dimensional sensor configuration were gimballed transversely and suitably weighted, it could perhaps maintain the pitch axis of the sensor set sufficiently horizontal to allow the strategy under discussion to generate a heading and additionally a bank angle of acceptable precision.

Whatever the precision, it would represent a vast improvement on the conventional fully gimballed compass and add half of an artificial horizon into the bargain. It would also weigh and cost less than any gyroscopic equivalent.

Three and two dimensional ferrous detectors

It is possible to elaborate the design of fixed single sensor vehicle detectors described earlier, with advantage, by using a two sensor version. Even when restricted to the horizontal plane, an orthogonal sensor set can provide more information, in the sense that it can provide both angular and magnitude signals for the anomaly caused by the vehicle passage.

An object with a magnetic moment possesses an external pattern of lines of force similar to that of a permanent magnet. This line of force pattern combines additively with the earth's field lines of force which consist locally of straight parallel lines.

If the disturbing magnetic moment passes very close to the sensors it produces not only a variation in field magnitude but also large swings in the angular orientation of the detected field. If the passage is more remote from the sensors, not only is the magnitude of the signal reduced, but also total angular swing.

While the time variation of these parameters gives some indication of the speed of the passage, if the magnitude of the signal is plotted against the angle in a polar diagram, what results is a time invariant 'signature' of the object. In some sense this signature contains information about the range, since for a close passage it will have a large angle polar diagram and for a remote passage a small angle diagram. This range is not absolute as it will also depend on the equivalent magnetic length of the magnetic moment being observed, which is roughly correlated with the size of the vehicle most of the time.

The fall off in field strength is proportional to the inverse cube of the ratio of the range to the magnetic length. As a result, the field from large objects falls off more slowly than that from small ones.

Actual magnitude and angle variations will be quite small but can be increased to usable size by the digital heterodyne method or, in

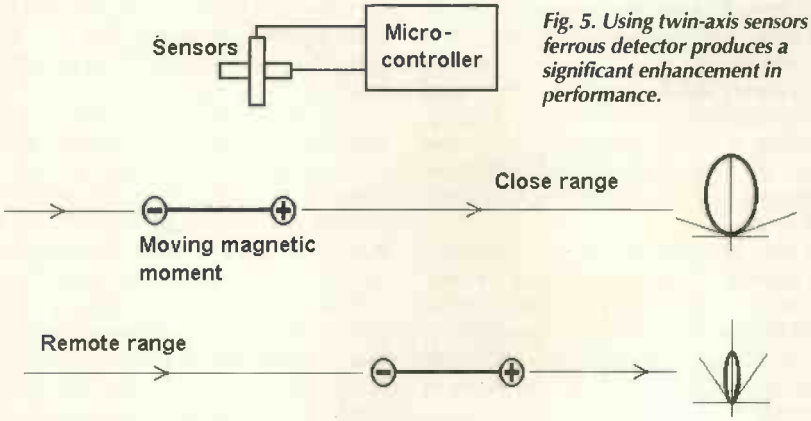


Fig. 5. Using twin-axis sensors in ferrous detector produces a significant enhancement in performance.

this case its software equivalent. The polar diagrams shown are simplified and guesswork, not based on any tests, **Fig. 5**.

It seems that this is an area worthy of more serious research on practical real life situations, since it may resolve the problems of lane separation and vehicle classification in multiple vehicle studies.

Orientation sensitivity elimination

The ferrous detection systems discussed so far have been static ones and the fixed large signals produced by the earth's field can be relatively easily eliminated from the desired indications.

In situations where the sensor configurations will inevitably be subject to unpredictable movement, the high orientation sensitivity becomes a serious disadvantage in the search for very small signals.

However, consider a perfectly standardised and normalised, perfectly linearised and perfectly orthogonal sensor set. The problem is easy to deal with since the sum of the squares of the three outputs must always be equal to the field vector modulus squared – a scalar quantity without any orientation. Success of any real implementation will clearly be only a function of how close to perfection the above requirements come.

The mathematics are simple and readily implemented on computer or microcontroller. Basic sensitivity of the sensors is adequate, matching of the calibrations is more constructive than absolute accuracy, orthogonality correction can be carried out to a fairly high degree, but non-linearity may be a troublesome source of error.

A technique helpful in these circumstances is to use some sort of negative feedback to improve both linearity and stability. The method consists of overwinding the sensor with a solenoidal coil in which a controlled field can be produced. This field is automatically adjusted to cancel out to zero, the local field which the sensor would otherwise experience.

Solenoid current giving rise to this cancelling field must be proportional to the local field being cancelled. Since the sensor only ever sees a zero field, its own non-linearity is no longer of consequence and the cancelling current is a direct and linear measure of the local field magnitude.

This approach obviously calls for a d-to-a converter to control the current in the cancellation coil. With a microcontroller, this could be a pulse-width modulated, single-bit, output and low-pass filter arrangement, as used so successfully in many current low-cost digital audio devices. Software complexity increases but the hardware cost is still held low, probably calling only for a linear current generator of modest current capability.

In any case, total 360° orientation de-sensitising is not always needed. Reductions in the angular variation achieved by other means will often considerably improve performance. Examples are a detector carried in a normally level vehicle, or a neutral buoyancy weighted float, trailed just submerged. An error may exist in the output but it remains passably constant.

This type of system, **Fig. 6**, could find uses as a detector of seabed wrecks in modest depths or as a search tool in archaeological studies. Constructed with sufficient care, it provides a low cost and compact alternative to nuclear magnetic resonance devices in some applications. ■

Magnetic unit conversions

Magnetic flux density

	gauss	tesla	gamma
1 gauss	1	10^{-4}	10^{5}
1 tesla	10^{4}	1	10^{9}
1 gamma	10^{-5}	10^{-9}	1

Magnetic field strength

	amp/m	oersted
1amp/m	1	0.01257
1oersted	79.58	1

Note: technically, the FGM-3 sensor measures flux density in gauss, but since in a vacuum – and virtually in air – the units of flux density are the same magnitude as those of field strength. Since the sensor can only really be used in air, oersted have been used in the text and diagrams as equivalent to gauss.

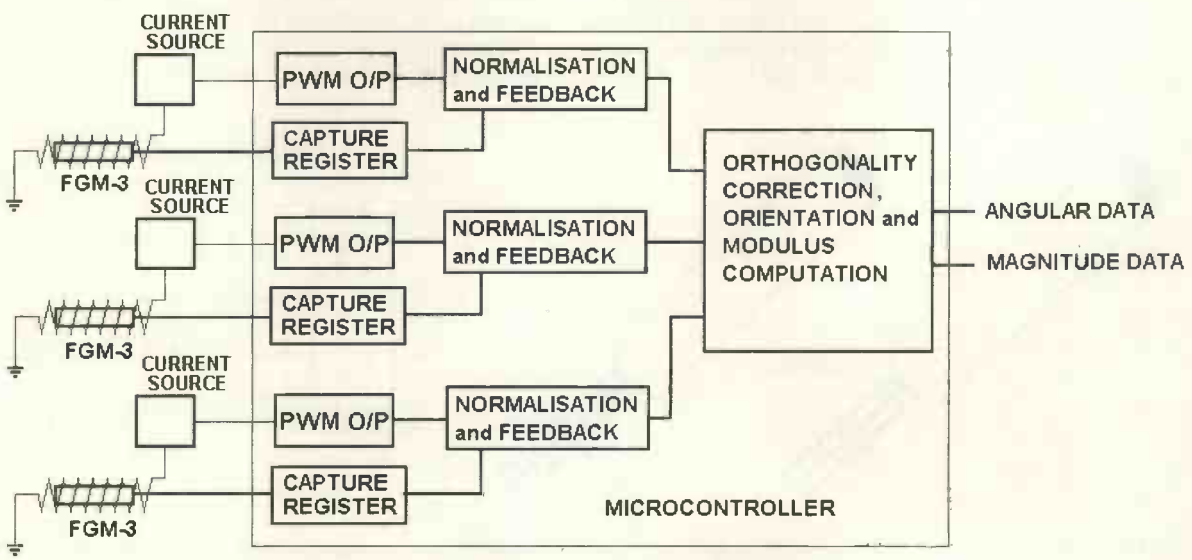


Fig. 6. In a three-dimensional sensor system, a microcontroller with pwm facilities can be used to supply the cancellation coils.

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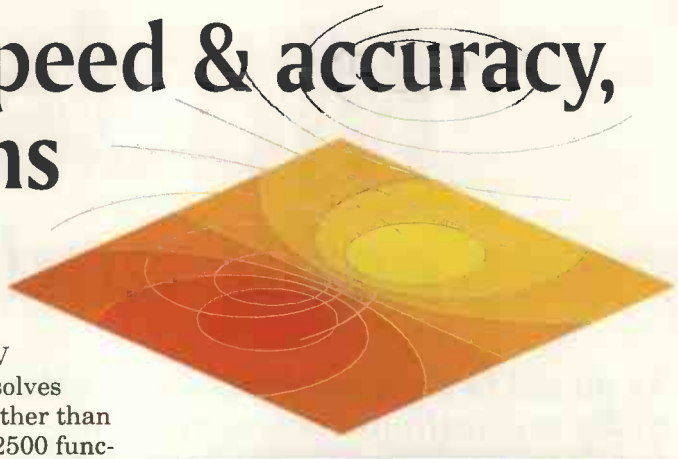

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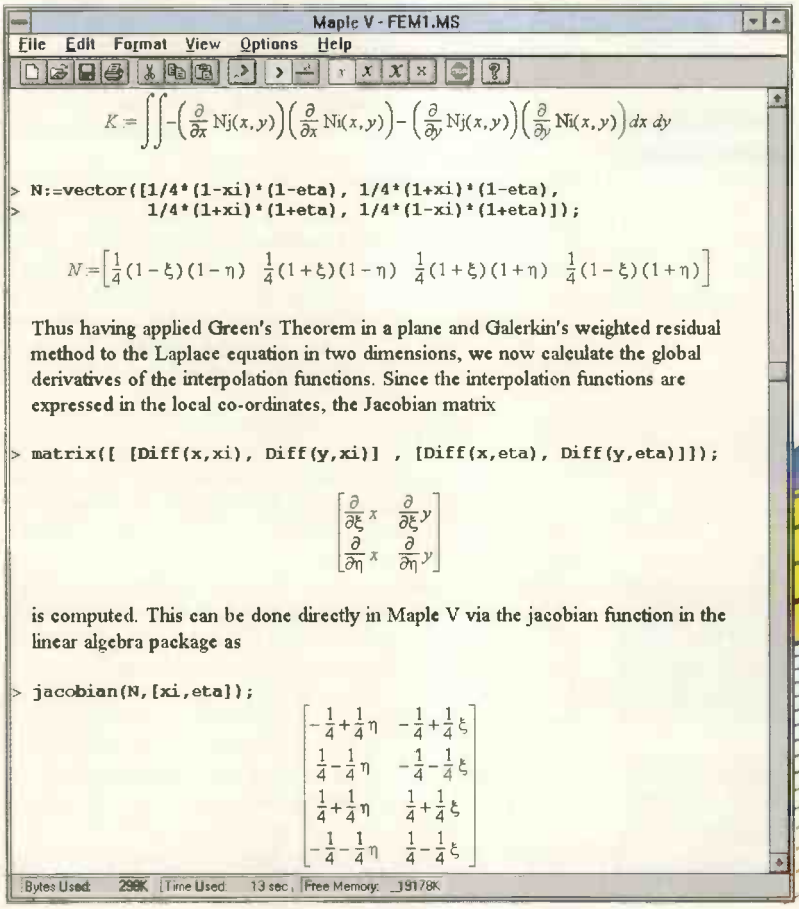

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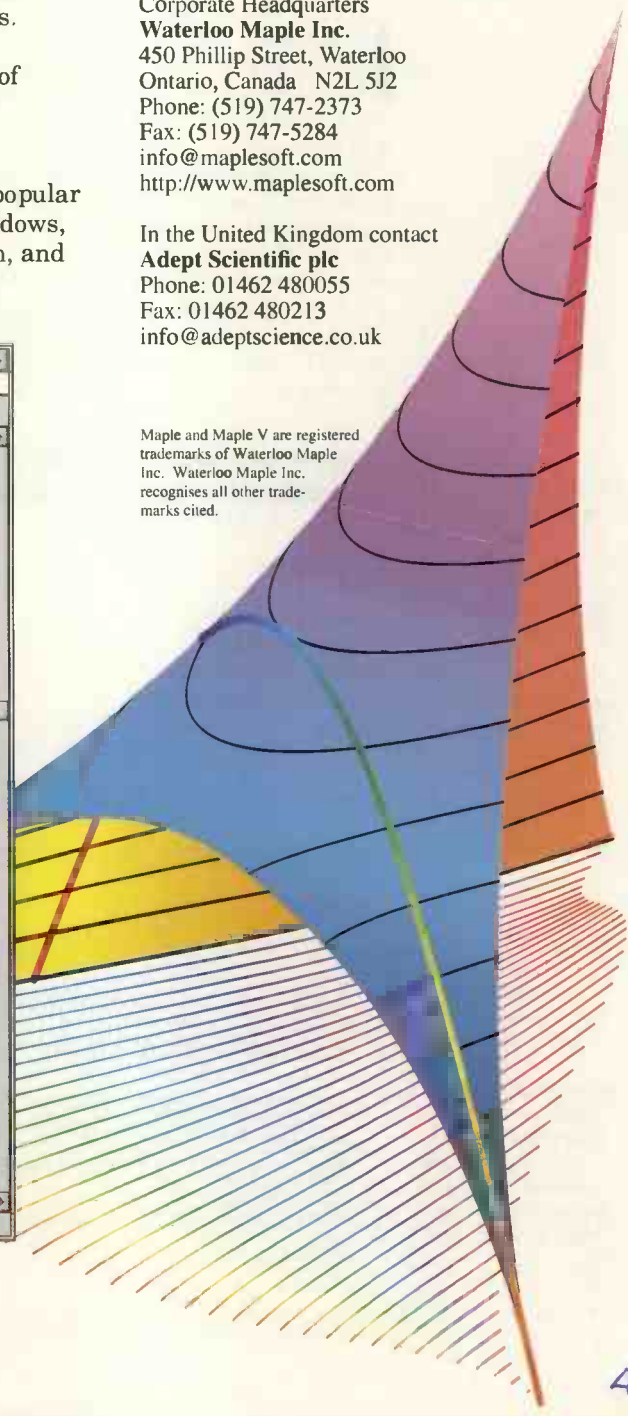


Modelling
cable and cmr

As an aid to designers optimising balanced audio and instrumentation systems, Ben Duncan demonstrates how to model common-mode rejection and simulate cmr testing. In the process, he exposes some of the the subtleties of connecting shielded cables.

In an earlier article[1], a number of IC makers' Spice 'macro' models were tested for common-mode rejection. Some subsequent wider testing reinforces the impression that makers' models have some way to go to simulate reality in this area.

For example, the Spice model of the *SSM 2017* – a true differential receiver converting balanced lines to unbalanced – yields about –35dB common-mode rejection when tested,. While the data sheet omits to graph cmr, real units sampled over five years have consistently measured around –65dB to –70dB. The comparison is across the audio band.

Rather than allow these failings to damn the use of today's powerful circuit analysis tools, progress can be made by other means.

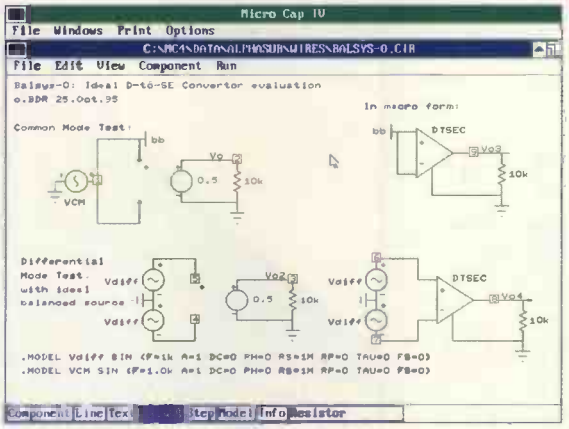


Fig. 1. Four sub-circuits simultaneously demonstrate the cmr of a perfect dual-to-single-ended converter, and the macro'd form; and the differential gain of the same DTSEC, and again, the macro'd form. For cmr testing a single V_{cm} test source is shared whereas for the differential gain testing, MicroCAP handles four independent sources.

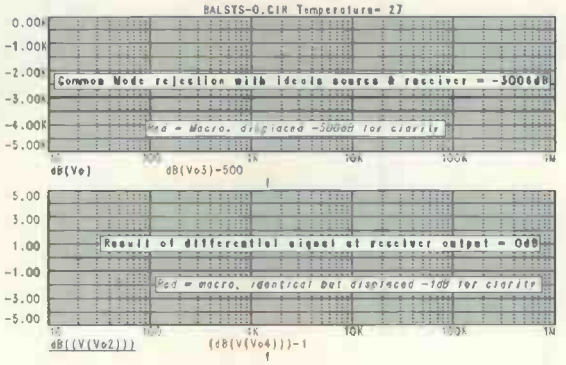


Fig. 2. Upper plot shows dual-to-single-ended converter based on linear V-of-V has more than adequate 'perfect' common-mode rejection of –3000dB. Lower confirms 0dB differential gain from lower pair of test circuits. To achieve this, the V-of-V's ratio must be set at –6dB.

Ideal balanced receiver

For most investigations, a perfectly balanced differential receiver or differential-to-single-ended converter with near infinite common-mode rejection is an ideal that will help designers isolate other causes of common-mode rejection degradation.

A linear 'V-of-V' source that provides the ideal differential-to-single-ended conversion is available in *MicroCAP-IV* and *-V*. For other simulators based on Spice 2G, voltage-controlled voltage source 'E' is a similar element.

A major advantage of using an ideal source rather than an op-amp or other active device model, is that the device performance is completely free from physical limits. Slew limits, maximum voltage swing and dc offset are all initially irrelevant to cmr investigations. The linear 'V-of-V' in *MicroCAP* has just one parameter – a setting for numeric V_{in}/V_{out} ratio, for example 1.0 for 0dB.

Looking at the top left circuit in **Fig. 1**, the raw part appears as a circle – the output side – associated with two round input terminals – the isolated inputs – on the left. Here, we are interested in checking the cmr of the device, so the balanced input terminals are linked and driven by an ac common mode test voltage, V_{cm}.

In ac mode, the test level defaults to a nominal 1V and frequency is swept – irrespective of the generators' amplitude and frequency defined in the .MODEL statement text beneath.

Macro capabilities

MicroCAP's macro capability is easy to use and is a little more than just a means of grouping key strokes. In Fig. 1, the circuit on the right repeats the identical V-of-V after being macro'd into a four-pin op-amp shape. This is called DTSEC, which represents a differential-to-single-ended converter. The tie 'bb' connects the V_{cm} test source. In analysis, the single ended output voltages are read between the named nodes V_o, V_{o2}, etc, and ground.

In Fig. 1, the lower pair of circuits comprise a wholly independent differential gain test of the same V-of-V, and again, the macro'd version of it, DTSEC, is on the right. This demonstrates *MicroCAP*'s ability to simultaneously test independent circuits, thereby greatly speeding up investigation and control investigative file branching.

Figure 2 is a plot of results. The recovered differential signal is 0dB. For this to be the case, the V-of-V's gain parameter needs changing from the default 1.0 to 0.5, ie. –6dB. This is because the two voltage sources V_{diff} needed to model a perfect balanced source are both set at 1V and summed in ac analysis mode. This is an intrinsic feature which cannot be changed.

The DTSEC's cmr is not quite infinite, but at –3000dB, the ratio comfortably exceeds physical limits assuming there are about 1×10^{80} (1.6kdB) atoms in the local universe. Of course, the macros on the right-hand side of Fig. 1 perform exactly the same. To enable this to be seen, their expressions in Fig. 2 include '–1V' and '–500dB' in the upper and lower plots respectively, as an offset for clarity.

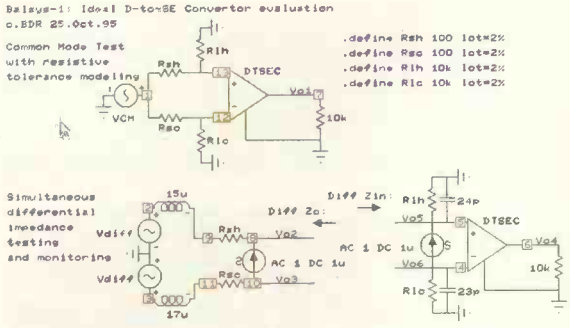


Fig. 3. Receiver cmr workshop screen packs in another 3 simultaneous tests. In the upper circuit, the isolated effect of different resistor absolute values and tolerances (lot=X%, and optionally even %Dev tolerances) can be rapidly explored. In the lower circuit, the differential test generator from Fig. 1 and its output resistors, is split from the DTSEC, and its input resistors. The Z_{diff} of both halves is then read using individual 'I' sources, set up to force a frequency-swept ac current of 1A differentially up each. The current converts the ac Y axis from volts to an ohms scale.

Virtual cmr workshop

In **Fig. 3**, the DTSEC is being tested in a circuit where the resistive connections and their errors are real enough, but where reactive effects are being ignored. This would be a reasonable comparison for an on-board interface, where transmitter and receiver connections are very short.

Resistors are defined in the statements on the right of the schematic. Values of R_{sh} or $R_{source,hot}$ and its twin, R_{sc} or $R_{source,cold}$ are typical output stand-off resistors. Hot load resistor R_{lh} and its cold twin R_{lc} are typical of a conventional audio bridging audio input, to the IEC.268 convention. These provide a bias and discharge path, as well as defining input impedances R_{diff} and R_{cm}.

The DTSEC drives a 10kΩ resistor but this is in no way essential in *MicroCAP*. It just makes the single ended output visually stand out.

In the lower half of Fig. 3, a completely different pair of tests is going on. Here, the circuit above has been split and independent current sources inserted. These sources are 'I' in *MicroCAP*s menu but labelled 'S' on page. Inserting the current sources forces current up the test source's output, and raises the DTSEC inputs. You will see that each source's label reads 'ac 1 dc 1u'. Noting the spaces, it means the ac current is 1A, but only 1μA of dc. Spice syntax is similar.

The wanted ac part is then swept by the ac analysis, and the output – in linear volts instead of decibels – is read as ohms. Since the connection is differential, the outcome is a plot of the differential impedance, Z_{diff}, of the source and load. The two differential generators V_{diff} are unused but need not be removed. To make the impedance plots more realistic, plausible parasitic reactances have been added. These comprise transmitter series source inductance and receiver shunt capacitance.

Figure 4 shows how these apparently disparate measurements tie together. In the top plot, 250 linear Monte Carlo runs show how common-mode rejection might vary over a population with the cited rather sloppy 2% tolerance parts. The middle plot confirms the Z_{diff} of the DTSEC is varying about 20kΩ, bowing down at rf on the right. This plot provides an instant visual check of the span of the resistors' range stepping.

Likewise, the lower plot confirms that the $Z_{o\text{-}diff}$ of the balanced generator is about 200Ω, with the source inductances just having effect at 200kHz. This kind of measurement gets more interesting at this frequency and above, when cable reactances are added.

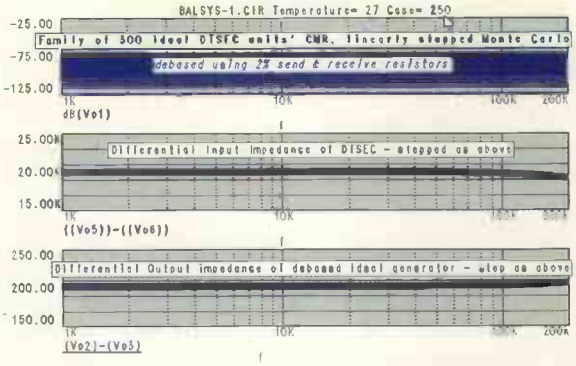


Fig. 4. Using a DTSEC macro instead of a macro-model speeds investigation; with a 100MHz 16bit pc, it takes just 25 seconds for the effects of the toleranced parts to be evaluated in two hundred and fifty linear Monte Carlo runs – while simultaneously monitoring the stepped resistor values by plotting differential send and receive impedances.

In **Fig. 5**, the effects of shunt capacitative reactance are added and part isolated for study. This time the circuit source and load resistors are untoleranced, but offset with realistic high specification mismatches of 0.025% for 20Ω and 0.001% for 100kΩ.

Shunt capacitance is also untoleranced, and perfectly balanced. As in Fig. 3, capacitors connect to ground. By practical inference, this is the local zero volt reference, seen underneath the DTSEC.

Common-mode test source V_{cm} shares the same ground by definition; don't be deceived by its leftside geographic location. In the upper circuit, the introduced shunt capacitance is just 22pF – believable if the interface is proximate on a groundplane pcb. In the lower figure, capacitance is far higher, being typical of tens of yards or so of shielded cable, the total value possibly including shunt rf filter capacitors.

When looking at the outcome in **Fig. 6**, it is important to note that the added capacitors are not in any way unbalancing the line. Yet the higher capacitance, while not as a load, begins to significantly degrade the common-mode rejection at low rf of around 1MHz, and above. Of course, the model neglects other effects becoming significant at 1MHz but the trend is clear enough.

Introducing cable effects

Accurate balancing of analogue and audio signal feeds has a major role to play in emi immunity for emc. But attaining high cmrs in balanced transmitters and receivers alone is not good enough. Real cmr may depend as much, or more, on the

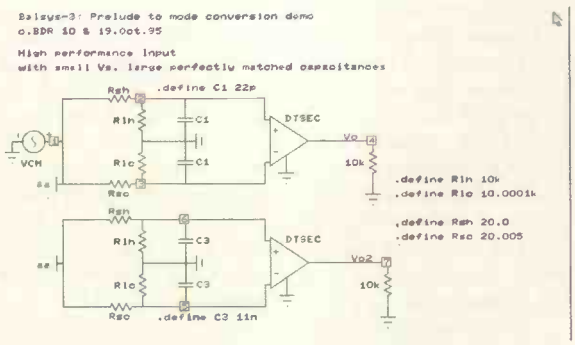


Fig. 5. In these two test circuits, the effects of perfectly balanced shunt cable and rf filter capacitances are examined in a high cmr performance environment.

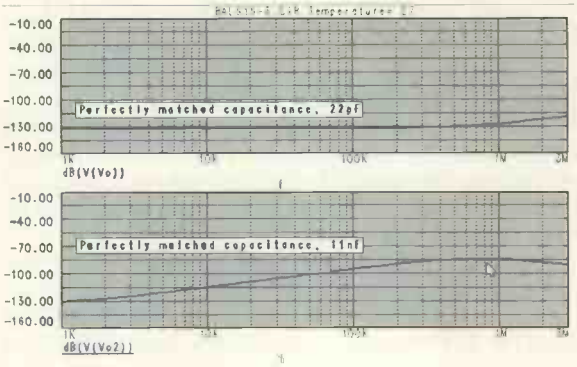


Fig. 6. These plots show how absolute capacitance matters, at least when referred to the DTSEC ground. Lower curve shows how hyper-matching alone is not enough to preserve hf cmr.

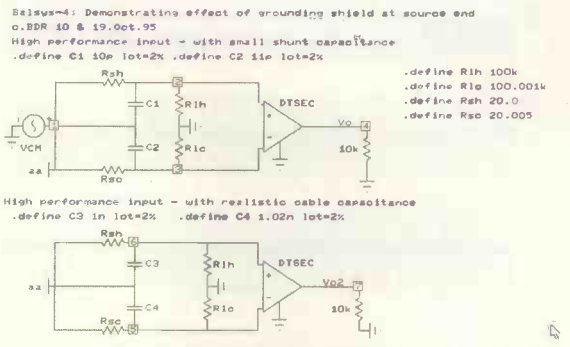


Fig. 7. Shunt capacitance definitions have been appended with core-to-shield capacitance tolerances that are typical of real shielded pair cables.

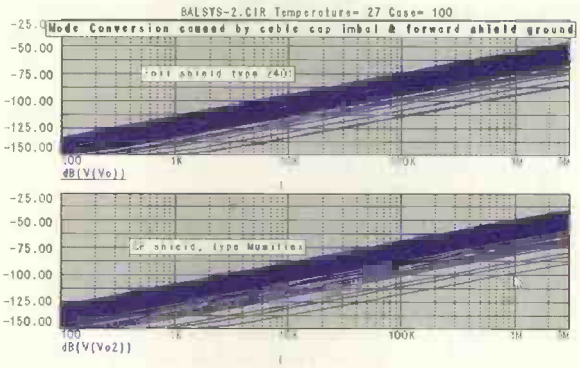


Fig. 8. Stepping through 100 linear Monte Carlo'd core-to-shield cable capacitances. In reality, as cable capacitance imbalances are more fixed and skewed, some better cmr results may be discounted, while worst cases remain plausible.

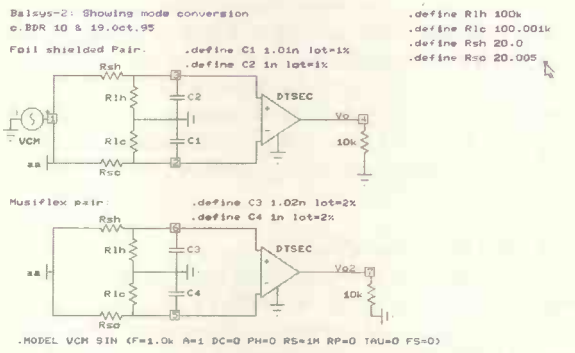


Fig. 9. Cable shield is strapped at the balanced transmitter's ground end, alias V_{cm}'s hot side. This scheme is 'more' correct in theory, than terminating at the receiver end.

quality of cable used, and moreover, on the way that cable shielding is connected.

A recent *AES* paper[2] has drawn attention to cmr degradation caused by core-to-shield capacitance imbalance in twisted pair shielded cables. It specifically highlights the effects of the pairs having naturally separate colours of insulation, for example red and black. Owing to the different additives used for colouring, each type has a different permittivity. This, and differences in the extruded insulation thickness, lead to a different capacitance between the circuit legs. Typically this is of the order of 1-5%. This may not seem much, but it has increasingly serious repercussions at rf in any system requiring high emi immunity.

After comparing the spot foil-shield capacitances of some balanced cable offcuts lying around the lab, **Fig.** 7 mimics the reality. In the upper circuit, the 1% typical imbalance between two cores of a foil-shielded pair, for example Alpha type *2401*, is modelled by defining the core/shield capacitances $C_{1,2}$ with independent 1% tolerances.

Musiflex stage cable has a soft conductive plastic shield of higher resistivity. Typical imbalance was higher at 2%, conservatively approximated with $C_{1,2}$ independently set at 'Lot=2%'. Again, '%Dev' tolerances could also be appended if statistical data is to hand.

As in Fig. 5, note that realistically imbalanced resistive values set a maximum cmr baseline, and that cable capacitances are tied to ground. This is the receiver output reference, alias local 0V. This means the shield is connected to earth only at the receiver end. While disputable[2], this method often works in practice and is considered essential when a shielded multicore is unplugged from 90kW of front-of-house power amplification.

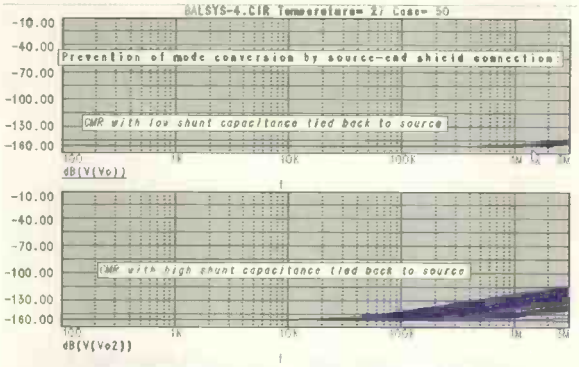


Fig. 10. Common-mode rejection plots back up the theory – as the effects of the shunt cable capacitance on cmr is greatly diminished – compare with Fig. 8. Still, a more advanced model is needed to account for many documented instances where consistently wired systems have actually buzzed less with the Fig. 5 and 7 type connection.

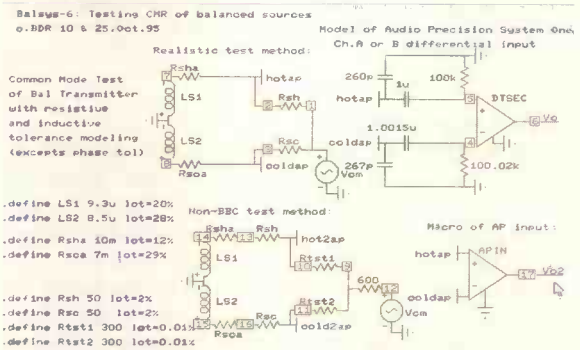


Fig. 11. To test the cmr of a balanced transmitter, a common-mode signal may be forced equally up both legs, and a the resulting error voltage is read with a well balanced, bridging receiver. Here, two slightly different methods are compared, using a model of the test set that would be used in realspace. The transmitter, represented passively by R_{sha} and L_{S1} and the other half, could also be a full circuit, a macro-model or any other representation, subject to implicit modeling limitations.

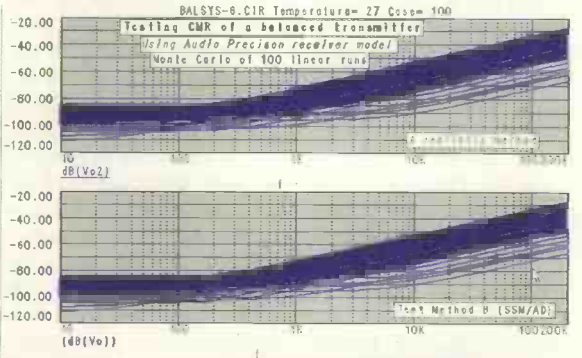


Fig. 12. In 100 linear runs, there is not much in the two cmr test methods. The hf degradation (above 1kHz) could be tackled by controlling the differences and tolerances in the leg inductances. Variables used are simulating careless layout, for example different track lengths and varying cable dress in production. The cmr seen on the left (at 10Hz) is governed by resistor mismatch alone. Even with 2% series output resistors, output cmr is better than –80dB. But earlier figures show why this is no excuse for complacency, since receiver and cable imbalances add their toll.

But what are the hazards?

Figure 8 shows the effect of stepping the cables' capacitative imbalances over the given tolerances. Clearly the random mismatching caused by tolerancing is wrecking hf balance with cmr affected most. Using a cable with twice as much core/shield capacitance tolerance than the foil type is not helping – by 6dB as you might expect.

In **Fig. 9**, the circuit has changed subtly. The cable capacitances' drain ends have been 'back-referred' effectively to the source ground. This ground is notionally the 'hot' side of the V_{cm} source. In effect, connection of the cable shield has been changed from receiver to transmitter ground. Now, as shown in **Fig. 10**, high-frequency cmr degradation is far lower, and the effect of inter-pair capacitance mismatch is also diminished.

The fact remains, however, that in giant, touring multimedia audio systems, the most inobtrusive system noise quality has required a flexible approach as to which end of the shield should be grounded. Others have noted as much[3]. This means the Fig. 7 model, while a firm basis, and useful for predicting performance of specific systems, naturally requires some more parasitic elements to be added to be useful in many real applications.

Output cmr test station

In **Fig. 11**, output cmr is measured by two external methods, where the source can be modelled as just an impedance. A third method, specified by the BBC, is outside the scope of this setup, as it requires the source to be active and driven.

In the upper figure, R_{sha} and L_{S1} represent the active source's impedance with high negative feedback, and the inductance modelling the effect of diminishing negative feedback at hf. Resistors R_{sh} and R_{sc} are the usual output resistors. Again, all parts have arbitrary but realistic fixed imbalances and tolerances.

The test involves shorting the balanced output terminals and applying V_{cm}, the test signal, to this point. A balanced receiver is then connected *before*, and across the output resistors. Common-mode rejection, i.e. balance, is proportional to the voltage here.

The ability of circuit modelling to mimic even the industry standard test gear you might use to verify computations, has not been widely published hitherto. To change this, on the right, the cmr of the analyser input of my Audio Precision *System One* test set has been modelled, by measuring self-cmr, then adjusting the values of the shunt and series R_s and C_s to closely match the curve.

In the lower circuitry of Fig. 11, output cmr is measured by another method, cited by SSM in their *SSM-2142* data sheet. Here, V_{cm} is connected driven up the source via a pair of quite tightly matched ±0.01% resistors, R_{tst}, in series with a third resistor.

This method requires a fiddly fixture, but avoids any need to delve inside the box. On the bottom right, the AP input (above) has now been macro'd into the same shape as the dual-to-single-end converter.

Results, shown in **Fig. 12**, demonstrate there is not a lot between the two test methods – at least over 100 linearly stepped Monte Carlo runs shown. A few minutes spent running such tests can evaporate myths, thereby reducing the noise floor at audio conventions! ■

References

1. Duncan B., 'CMR under Test', *EW&WW*, July '94.
2. Whitlock B., 'Balanced lines in audio systems', *JAES* June '95.
3. Muncy N., 'Noise susceptibility in analog and digital signal processing systems', *JAES* Jun '95.

High-performance thd meter

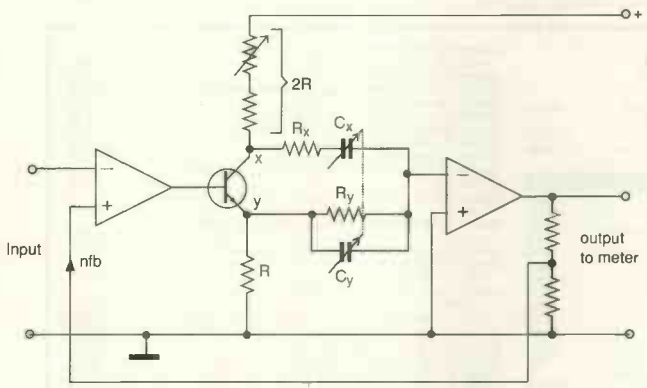
Taking advantage of modern components, Ian Hickman has developed a new distortion meter combining a measuring resolution of 0.001% with design simplicity.

I designed this thd meter for testing hi-fi amplifiers, in conjunction with a low distortion sinewave oscillator.

Figure 1a) is a schematic for a thd meter design dating from the early seventies[1]. Figure 1b) shows its full circuit, which is interesting in that it highlights some of the problems in thd meter design.

The complete instrument includes a low-pass filter with a choice of switchable cut-off frequencies. This extends the lower limit of the measuring range by limiting the noise bandwidth. Provision for selecting a high-pass filter to reject hum is also included but not shown.

Designed as a distortion monitor, the circuit was intended for use with a separate external audio-frequency voltmeter – preferably one with true rms response.



Notch circuitry

Using a Wien bridge arrangement, the circuit provides a notch or transmission zero at the fundamental of the sinewave test signal. However, the notch produced by this type of circuit is cusp-shaped. Not only is it very narrow at the null, but its return to full output at very low and very high frequencies is leisurely.

Some quick sums show it to be still 7.5dB down at the second harmonic of the notch frequency. This is because of the low Q of the Wien network caused by the two capacitors and two resistors, not the complete bridge. It is well below unity – in fact just a third. Consequently, it is necessary to include the notch circuit in an overall negative feedback loop. This brings the response at the second harmonic to ideally much less than 1dB down.

The effective absence of negative feedback at the frequency of the test signal when the notch is correctly tuned to it, however, means that the fundamental is considerably accentuated in the stages within the loop. As a result it is necessary to keep the input amplitude well below the overload level of these stages. This helps prevent the distortion meter introducing distortion of its own.

A consequence is that the noise floor can limit attempts to measure very low thd levels. A further consequence of negative feedback is to narrow the notch, making tuning critical. The original article[1] recommended a slow motion drive with at least a 100:1 reduction ratio. These and other considerations limited the measurement range of the instrument of reference 1 to the order of 0.01% at 1kHz.

Some years ago, I designed and built a thd meter with ranges down to 0.01% full scale, permitting readings down to around 0.002% or lower. It used a state-variable filter, svf, based circuit which, having a higher Q, does not

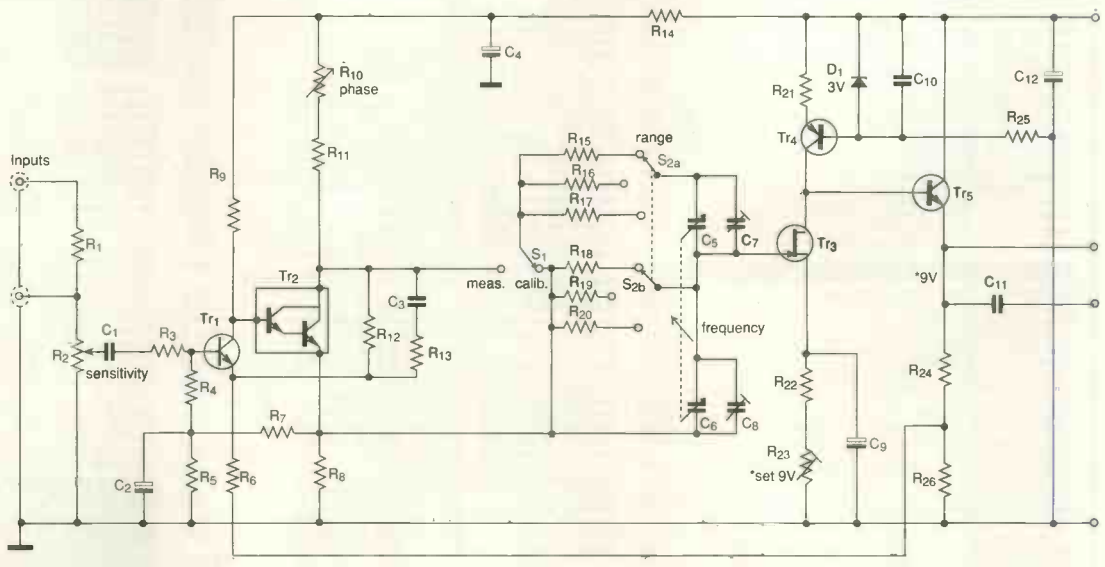


Fig. 1a) Above, schematic of a notch circuit with negative feedback to provide a (nearly) flat response by one octave either side of the notch.
b) On the right, part circuit of the distortion monitor described in reference 1.

need so much overall negative feedback to obtain a reasonably flat response at the second harmonic.

Measurements at the limit of the circuit's sensitivity were very tricky due to the narrowness of the notch, as detailed in the panel. Consequently, when making thd measurements on a low-distortion oscillator[2], the thd meter was preceded by an auxiliary test circuit. This consisted of a fixed-frequency twin-tee network followed by a two pole Chebychev high-pass filter. Tuning and peaking of the latter were adjusted to give a sensibly flat response, in conjunction with the notch, from the second harmonic upwards. Three such circuits permitted spot frequency testing at 20Hz, 600Hz and 10kHz.

While this arrangement provided thd measurements which are reliably accurate – due to suppression of the fundamental in a passive network before it meets any active circuitry – the restriction to spot frequency testing is in practice a serious drawback.

A new approach

For many years, I have been planning to replace my original distortion meter with an improved design offering continuous tuning and a wider notch. The wider notch is needed for measurements down towards the 0.001% level since adequate suppression of the fundamental is not possible with a single two-pole notch circuit.

As indicated in the panel, to measure even 0.01% thd, requiring suppression of the fundamental to at least 0.003%, implies an accuracy of tuning of 15ppm – the equivalent of 0.015Hz at 1kHz. This required accuracy is not an absolute figure. It is relative to the frequency of the sinewave oscillator providing the test signal. Even if stability of the notch tuning were perfect, the oscillator may not exhibit the necessary long term stability to allow readings to be taken. Even if it did, the short term stability of an *RC* oscillator is likely to be inadequate.

The inevitable close-in noise sidebands will be inadequately suppressed by the notch. If you prefer to think in the time domain, frequency of the oscillator will shuffle about by a minuscule amount. This results in the fundamental peeping out randomly on either side of the notch, preventing a steady reading representing the harmonics only.

Notches in tandem

The solution presented here is to use two notches in tandem, greatly reducing the suppression required of each. This four pole arrangement also permits a design that avoids the accentuation of the fundamental within the loop. This is necessary with a two-pole notch circuit to achieve a response at the second harmonic which is no more than, say, 1dB down on the 'flat', ie on the response far from the notch.

The scheme is outlined in **Fig. 2**, where the first stage is an svf notch circuit with a Q of unity. As a result there is no accentuation of the fundamental, high pass, band-pass and

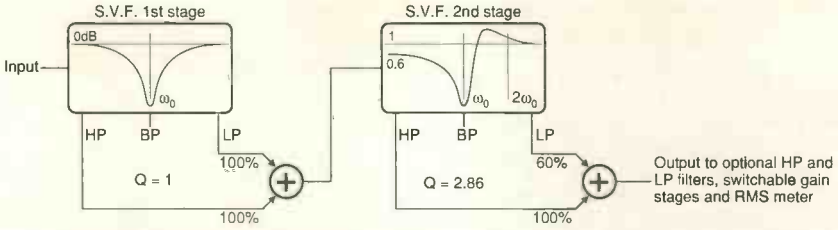
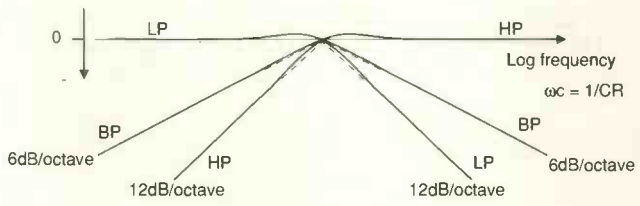


Fig. 2. Schematic arrangement of an improved front-end of a thd meter. This provides reduced internal distortion and less critical tuning of the notch.



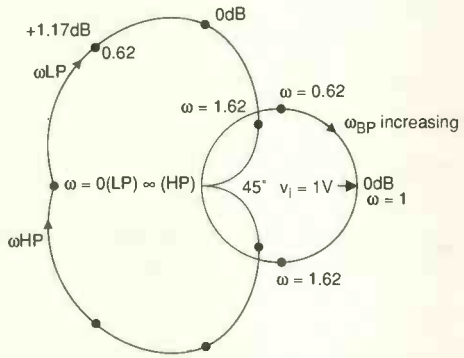


Fig. 3a) Frequency response of the low, band and high-pass outputs of a state variable filter with a Q of unity (Bode plot). b) As a) but shown as an Argand or vector diagram.

low-pass responses. All are unity at the tuned notch frequency, **Fig. 3**. With the chosen Q of unity, there is a slight peak in the low-pass response of just over 1dB at 62% of the tuned frequency – and at 1.6 times the tuned frequency in the case of the high pass response. But in thd testing there is no signal present at this frequency. As low and high pass outputs are in antiphase, summing them produces a notch at the tuned frequency.

The first stage sums equal contributions from the low and high pass outputs, resulting in a symmetrical notch. With the chosen Q of unity, this is just 1.6dB down at twice the notch frequency.

High pass output is summed with just 60% of the low-pass output by the second stage. This results in the notch occurring below the tuned frequency, with low-frequency response only 60% that of the high-frequency response, Fig. 2. Furthermore, the notch now occurs at a frequency below the svf stage resonant frequency. Resonant frequency is that at which low, high and band-pass responses are all equal, and is given by,

$f=1/(2\pi CR)$.

Flat response

By choosing a smaller value of *CR* for the second stage – in conjunction with the chosen ratio of low to high-pass contribution – its notch can be arranged to coincide with that of the first.

By choosing a suitable value of Q for the second stage, a peak occurs at its resonant frequency, ie somewhere above the notch. Its amplitude can be made +1.6dB at twice the notch frequency. This compensates for the –1.6dB response of the first stage. In fact, by judicious adjustment of the second-stage resonant frequency, ratio of low to high-pass contribution and Q, overall response can be made flat at the second and all higher harmonics.

The arrangement has certain similarities to a four-pole elliptic high-pass filter, but there is a significant difference. Instead of spacing the two frequencies of zero response apart so as to maintain a designed stop-band attenuation, A_s, all the way down to 0Hz, they are made coincident. This is because there is only one signal in the stop-band – namely the fundamental of a sinewave test frequency. The harmonics all lie in the pass-band, which in this design is flat to within less than 0.1dB.

Performance of the thd meter

The two stages were made up in temporary form, as per **Fig. 4a)** and **4b)** and tested. Note the tuning arrangement using a potentiometer to drive each integrator's input resistor *R*. This scheme using a fixed *R* provides linear tuning. As a result, poor resolution is avoided at the high-frequency end of the range which occurs if tuning is effected by varying *R*.

Figure 5a) shows the notch output of the Fig. 4a) circuit, set to 1kHz, at 10dB/vertical division, the span being 0-5kHz. Over 60dB of rejection was observed, the residual due to the low and high pass outputs being not quite in antiphase: 60dB down corresponds to a depar-

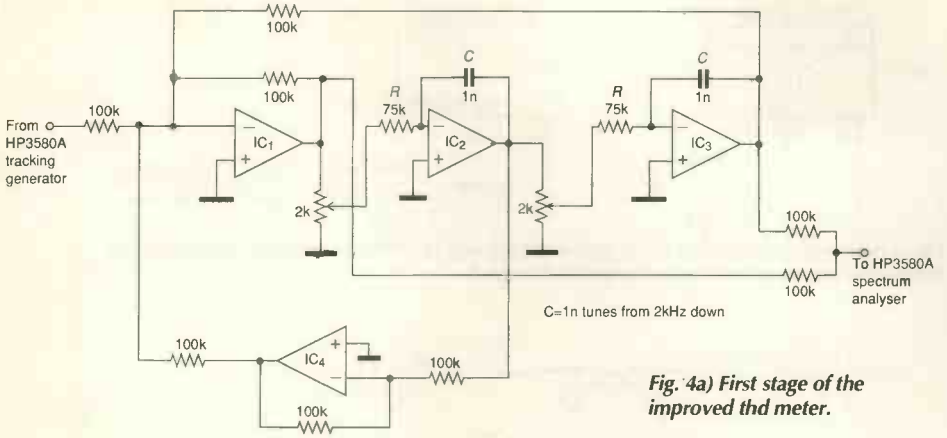
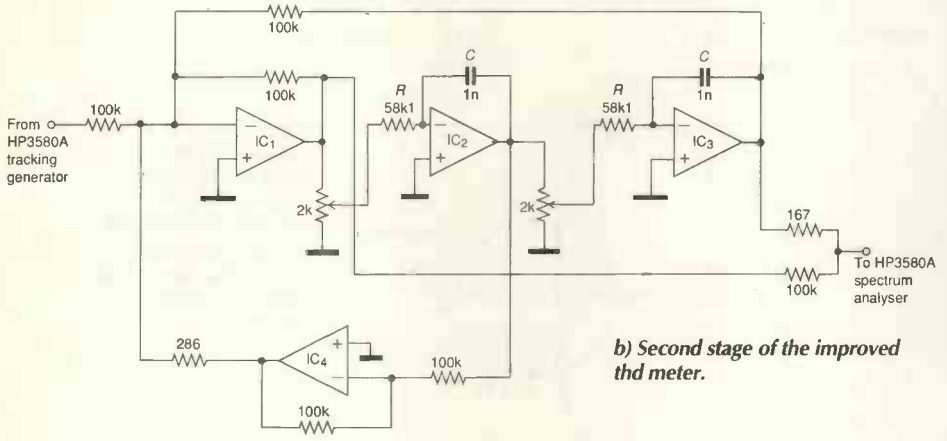


Fig. 4a) First stage of the improved thd meter.



b) Second stage of the improved thd meter.

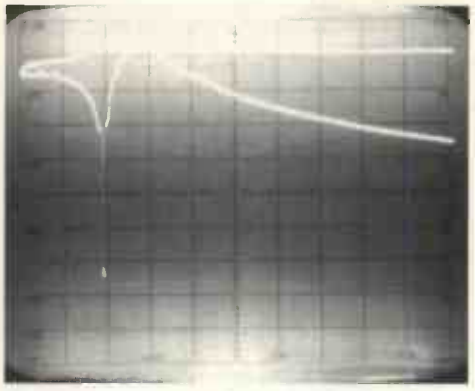


Fig. 6a) Second stage response, notch trace and low-pass trace 10dB/div.

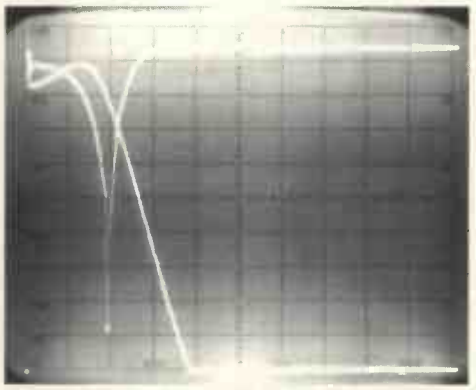


Fig. 6b) Combined four-pole notch response 10dB/div. at output of second stage, with first stage low-pass response at 1dB/div.

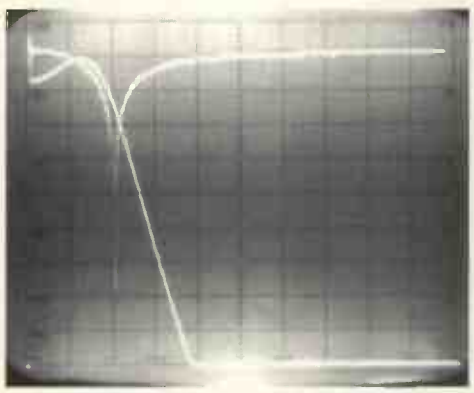
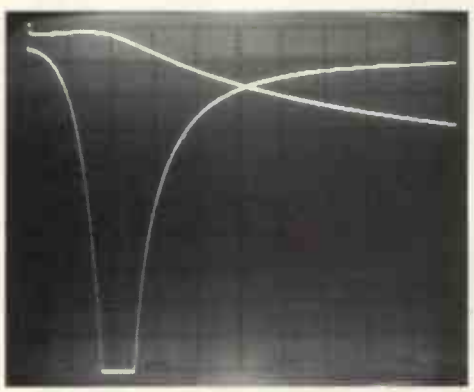


Fig.5a) First stage response; span 0 to 5kHz, notch trace 10dB/div, low-pass trace 1dB/div.



b) As a), but notch trace 1dB/div and low-pass trace 10dB/div.

ture from 180° of just 0.053°.

Also shown is the low-pass output at 1dB/div, showing the expected peaking of about +1dB. Note that the traces are offset so the 0Hz levels of the two traces do not correspond. Figure **5b)** shows the same results, this time with the notch trace at 1dB/div and the low-pass at 10dB/div. Compared to the response at 5kHz and higher, it can be seen that the response at 2kHz is indeed 1.6dB down as predicted by theory.

Figure 6a) shows the response of the second svf stage, with its tuning set so that the notch again occurs at 1kHz. The stage's resonant frequency is actually 1.29kHz, with around 10dB of peaking at the low pass output. This results in a smaller peak in the notch output, the response still being +1.6dB at 2kHz relative to the far-out high frequency response. When this is combined with the first stage response of Fig. 5, the result is a response which is level at 2kHz and upwards, Fig. **6b)**.

The notch should be 120dB or more deep, but as displayed it is limited to the spectrum analyser's noise floor at –90dBref. To reliably achieve 60dB or more suppression in each stage, putting the fundamental of the test sinewave below noise, a phase trim should be provided for each stage, similar to **Fig.** 7.

To complete the picture

A complete thd meter front-end must include facilities to accept inputs of various amplitudes, so some kind of input attenuator is required as indicated in Fig. 7. The potentiometer used should be a wirewound type, to avoid introducing noise. The twin gang tuning potentiometers should also be wirewound, for the same reason. Also shown is a 'set level' switch which permits meter deflection to be set to full scale on the incoming signal, before notching out the fundamental.

Figure 7 shows a fine tuning trim on the second svf stage. This optional trimmer assists in obtaining the maximum possible fundamental rejection. It becomes necessary if the twin gang tuning potentiometers for the two stages are ganged together. In this case, an 'initial tune' position is needed which permits tuning of the first stage for maximum rejection.

The second stage is now also approximately tuned due to the ganging. Final adjustment of the second stage frequency and phase trims completes the tuning. Dual gang 2kΩ wirewound pots are available to special order‡ with the shaft extended at the rear, permitting the tuning of the two svf stages to be ganged.

Due to the 20dB gain stage between the first and second svf stages, the lower limit of the measurement range is set only by first stage noise. Should thd measurements exceeding 10% be required, provision must be made to switch the 20dB gain stage to 0dB.

Results shown in Figs 5 and 6 were taken using *TL084* quad op-amps in circuits prototyped on bread boards. In the final design, these op-amps would be unsuitable, due to

‡Available from Spectrol Reliance Ltd. Tel, 01793 521351, fax, 01793 539255.

Classic state-variable filter

This circuit diagram is the classic four op-amp state variable filter. There is a three op-amp variant, but this involves taking the damping term from the band-pass output back to the non-inverting input of IC_1, resulting in a common mode component at the filter input.

The tuned frequency or maximum gain frequency at the band-pass output is given by $f=1/(2\pi CR)$. At this frequency the high, band and low-pass outputs are all equal in amplitude, with the band and low-pass outputs lagging the high-pass output by 90° and 180° respectively.

With resistor values shown, low-frequency gain at the low-pass output and high-frequency gain at the high pass output are both unity. Gain at the tuned frequency is numerically equal to the circuit Q, where $Q=RQ/100k$. The transfer function is given by

$$numerator/(s^2+Ds+1),$$

where the numerator equals 1 for the low-pass output, s for the band pass and s^2 for the high-pass output, and $D=1/Q$.

Now s is the complex frequency variable $\sigma+j\omega$, but for the purposes of determining the steady state response of the circuit to sinewaves, s can be ignored. This leaves just $j\omega$ as the variable, where $\omega=2\pi f$ radians per second.

Things can be simplified even further by normalising the frequency, that is, simply assuming that whatever tuned frequency you are interested in is unity. Thus gain at the low-pass output is given by $1/(-\omega^2+Dj\omega+1)$. At the tuned frequency, where ω is 1, this amounts to $1/jD=-j(1/D)$ where $-j$ indicates a phase lagging 90° on the input. At the tuned frequency, if D is $^1/_2$, ie Q is 2, the gain is ×2 or +6dB at –90° relative to the input.

Notch output of Fig. 4a) is obtained by summing the high and low-pass outputs. As a result, gain is given by

$$(-\omega^2+1)/(-\omega^2+Dj\omega+1).$$

Clearly, the numerator is zero when ω is 1. On substituting $D=1$ and $\omega=2$, the gain turns out to be ×0.83, or –1.6dB. This is the response of the circuit at the second harmonic of a sinewave test signal, when the notch is tuned to the fundamental. In Fig. 4b), D is set to 0.35 (Q=2.86) and the contribution from the low-pass output is reduced to 60%. Now, gain is given by

$$(-\omega^2+0.6)/(-\omega^2+0.35j\omega+1),$$

resulting in the response illustrated in Fig. 6a). Note that in this case, though, $\omega=1$ corresponds to 1.29 times the $\omega=1$ of the first svf section. In other words, this is 1.29kHz for a 1kHz test signal, making the notches of the two stages coincident.

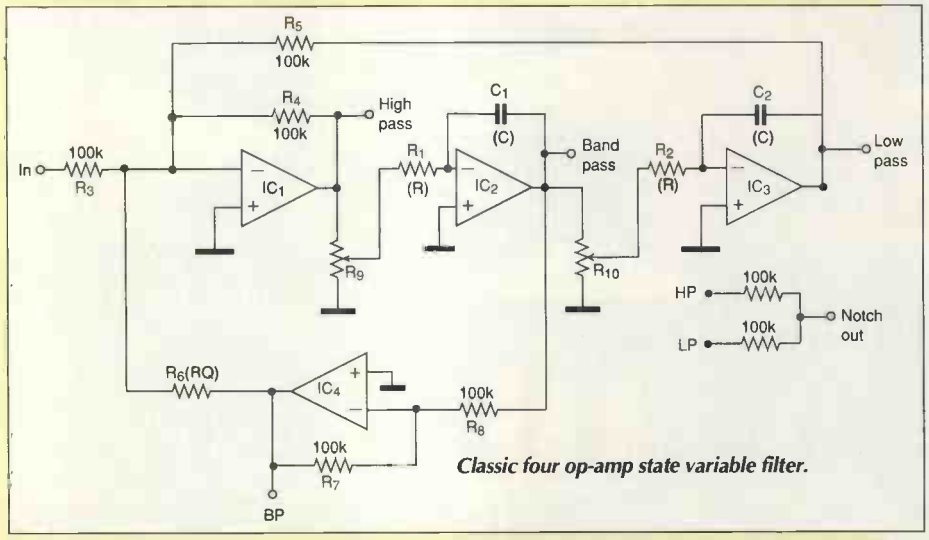
Sharpness of the notch in the circuit of 4a) can be found by a little judicious approximation of the expression

$$(-\omega^2+1)/(-\omega^2+j\omega+1).$$

Remember that D is 1 for this circuit. At $\omega=1$, the numerator is zero and the denominator is $j\omega$, or just unity – amplitude-wise.

If frequency is changed by 0.1%, the denominator is virtually unaffected. However, with ω now equal to 0.999, the numerator becomes 0.002, or only 54dB down on the response at $\omega=0$ or infinity. Thus for a fractional detuning from the notch of δ, the output rises from zero to 2δ.

For reasonably accurate thd measurements even down to a modest 0.01%, the fundamental must be suppressed to 0.003%. As a result, the accuracy of tuning must be at least 0.0015%, or 0.015Hz at 1kHz.



Classic four op-amp state variable filter.

their thd of around 0.003% typical. A better choice is the Burr Brown *OPA2604* dual fet-input audio op-amp, with its 0.0003% typical thd figure.

Clearly, careful construction and screening between stages is necessary to achieve 120dB or more of fundamental suppression. Given this, the limiting factor on readings is likely to be noise and hum. The former can be reduced by a low-pass filter immediately preceding the measuring circuit. It should have switchable cut-off frequencies of say 200, 80 and 20kHz, and include a switchable high-pass filter with heavy attenuation at 50Hz for the 20kHz selection. ■

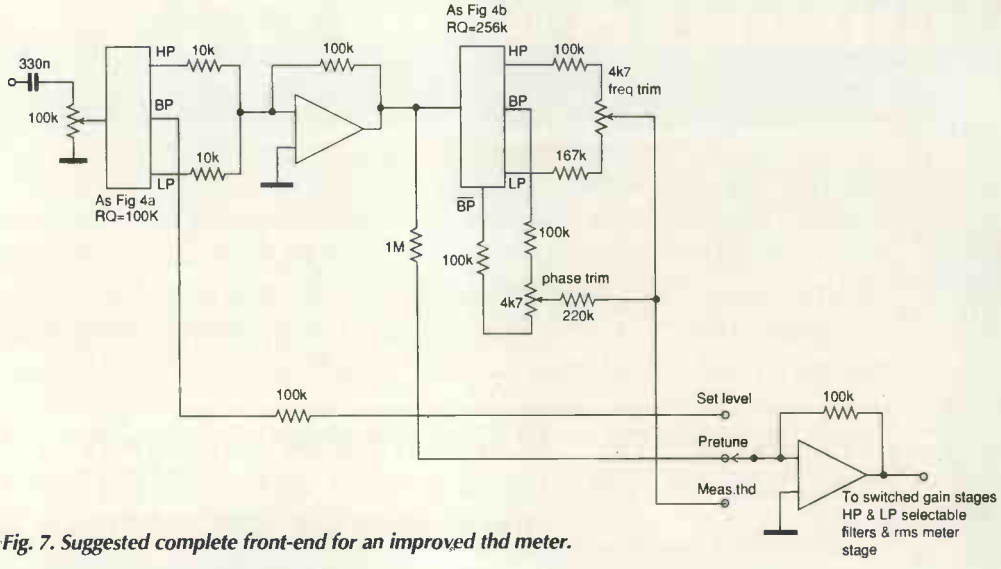


Fig. 7. Suggested complete front-end for an improved thd meter.

References

1. Hood, JL, 'Portable distortion monitor' *WW*, July 1972, pp. 306-8.
2. Hickman, I, 'Low distortion audio oscillator', *EW+WW*, May 1994, pp. 370-6.

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PC software control

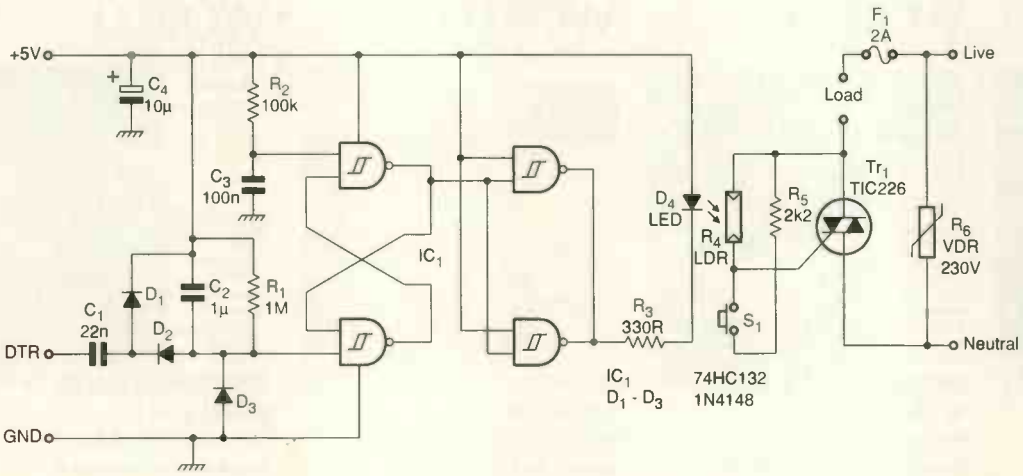
Using only the Request to Send (RTS) line from a serial port, this circuit allows a pc to be switched off under software control, while the serial port is still usable for other purposes. No power is used by the switch when the pc is off.

Briefly actuating the 'on' switch fires the triac, whereupon the pc supplies 5V to the control circuit. The flip-flop is reset by R_2C_3, led D_4 is on, the light-sensitive resistor R_4 conducts to complete the feedback loop and the triac stays on. Voltage-dependent resistor R_6 eliminates accidental triggering of the triac by excessive dV/dt.

Now applying a train of pulses, for example 10kHz for a second, to the Data Terminal Ready, DTR, line charges C_2, sets the flip-flop and extinguishes D_4, so that power is removed from the pc.

Mount D_4 and R_4 close together in a light-tight enclosure, D_4 being a high-efficiency diode.

Torsten Martinsen
Aalborg
Denmark



Using this software controlled pc switching circuit, the serial port is available for other purposes.

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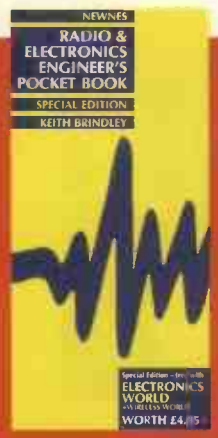

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Missing-phase shut-down for three-phase motors

Three-phase motors are only switched on when all phases are present, but there is always the chance that one phase might fail during operation. This circuit shuts the motor down to avoid burning out the other two phases and indicates the missing one, efficiently and less expensively than is usual.

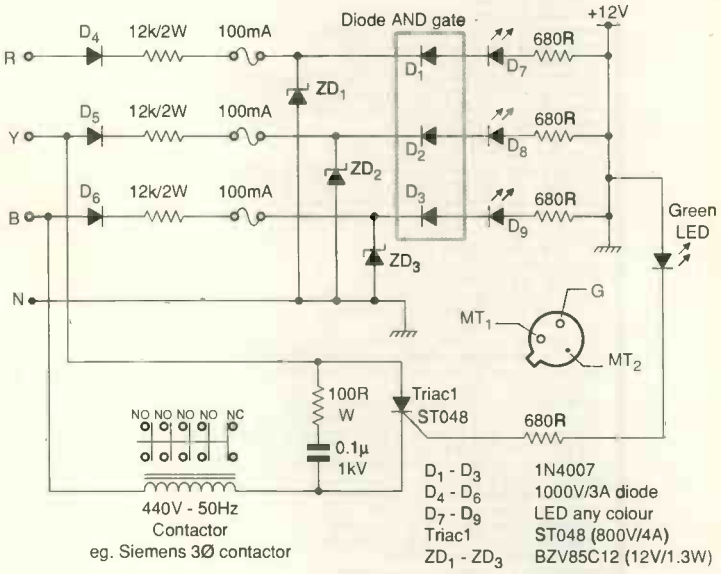
Power for the motor comes via the contactor through the triac driver circuit, the green led indicating the fact. The three-phase supply is converted to 12Vdc by the diodes $D_{4,5,6}$ and the *BZV85C12* zeners, the three lines being presented as inputs to the diode And gate formed by $D_{1,2,3}$, the output of which drives the triac gate only in the presence of all three phases.

If a phase fails, the triac does not fire and the control circuit is inoperative, the relevant led in the And gate indicating which phase is missing.

In the original circuit, the contactor is a 440V, 50Hz type; for a 220V coil, connect between yellow phase and neutral.

Porus M Mehta
Bombay
India

Less expensive than usual, but still efficient, this simple circuit automatically shuts down a three-phase motor if a phase fails.

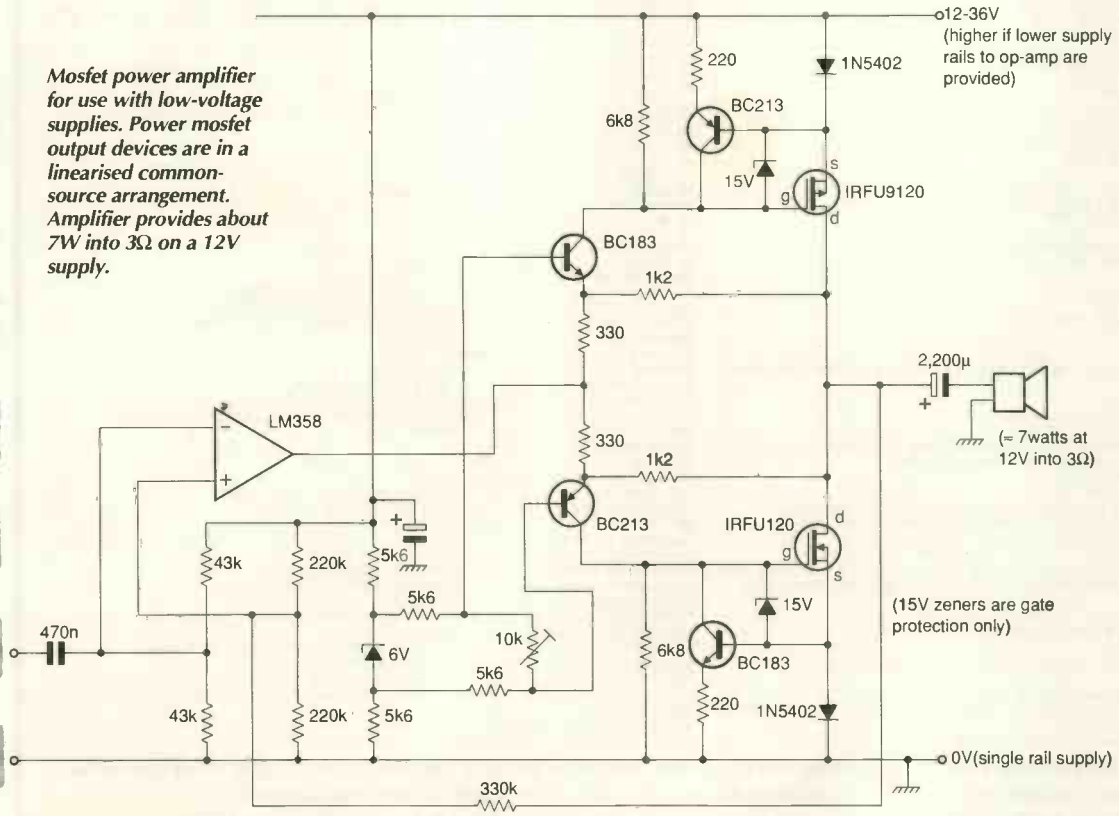


Low-voltage audio power amplifier

Power amplifiers are, perhaps, more vulnerable than other circuitry; in particular, those working on low voltages using bipolar transistors seem to suffer the most. This design has power mosfets in a circuit adapted to reduce non-linearity in a common-source configuration, in which low supply voltage is feasible. Gate drive in the usual source-follower circuit must exceed the supply to obtain a rail-to-rail output In this circuit, the common-source output stage is bootstrapped, very simply, so that the common-source square-law transfer characteristic is greatly linearised. In this case, the two transistors appear not to be purely feedback devices, but behave as variable attenuators and make gate impedance roughly inversely proportional to transconductance. A high-impedance driver produces a linear output at the expense of two diode drops, matching the performance of the bipolar devices used in emitter-follower output stages.

A Ziemacki
Rotherham
West Yorkshire

Mosfet power amplifier for use with low-voltage supplies. Power mosfet output devices are in a linearised common-source arrangement. Amplifier provides about 7W into 3Ω on a 12V supply.



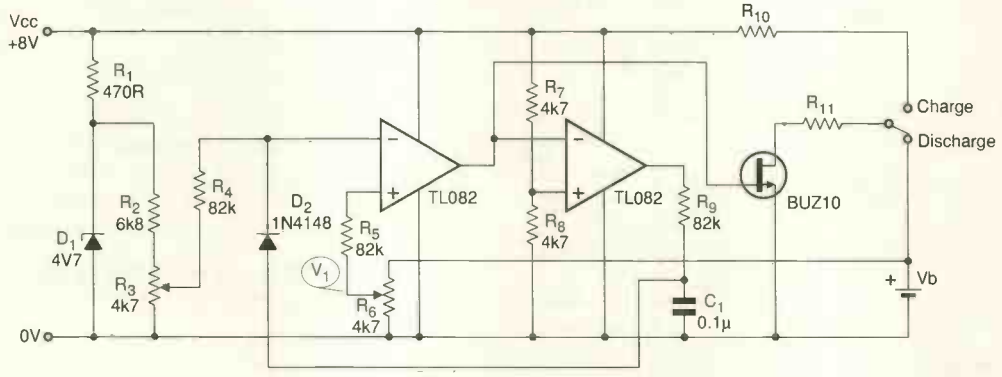
NiCd battery discharger/charger

NiCd cells should be discharged to 1V: this circuit does that and subsequently charges the cells at the 100mA rate.

Reference for the first *TL082* comes from R_3 and is set to 0.7V, V_1 being adjusted to V_{batt}/n, where n is the number of cells. While V_1 is above 1V, the *BUZ10* is on and the cells are discharging, but when V_1 decreases to below 1V, the circuit is latched off via $D_2R_9C_1$ and discharge is complete. Switching in R_{10} begins the 100mA charge, the value of this resistor being $(8–1.45n)/0.1$. Adjustment of R_6 allows the discharge of up to 30 cells, assuming R_6 is man enough for the job and can be adjusted with sufficient accuracy. Discharge resistor R_{11} is $5\times n(\Omega)$.

The circuit will work with up to 20 lead-acid cells by setting V_{ref} to 1.75V, R_6 as needed and selecting R_{11} appropriately.

Ken Hughes
Wokingham
Berkshire.



Circuit for discharging and charging up to 30 NiCd cells or 20 lead-acid types.

Fast, precise pulse generator

Newport Components's *31A5500* tapped, active delay line (from RS), together with advanced c-mos logic (ACL), eases the design of a pulse generator to produce 3ns transients and pulse-width accuracy within 2ns.

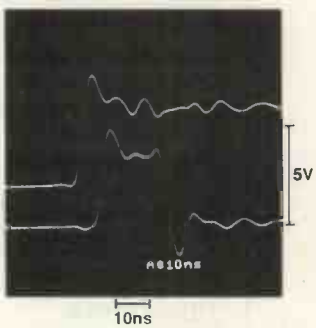
An input pulse longer than the required output, rising at better than 10ns/V, goes to one input of an XOR and to the other by way of the selected delay in the *31A5500*, so that the gate output is high during the delay; the AND prevents anything further happening during the delay, after the input pulse has gone low.

Propagation delay from the leading edge of the input is accounted for by two ACL delays, amounting to 8ns, and the transient times are determined by the AND gate – around 3ns for ACL. A possible problem is that the output of the line is not much more than the specified high for ACL.

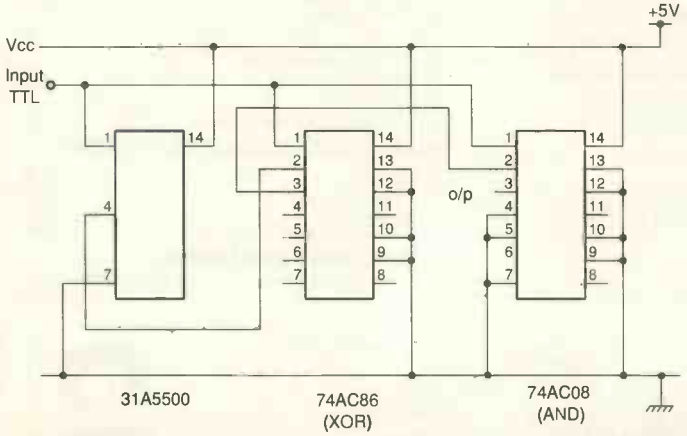
Instead of the delay line, the unused gates could be used to make up the delay, the six available contributing about 3.8ns per gate at 25°C, although the delay will not be as precise as with the line.

The result shown in the oscillogram was obtained by the circuit built on Veroboard with the ics in sockets.

Nick Wheeler
Sutton
Surrey.



Upper trace, pulse leading edge at the output of a function generator operating at 2MHz. Lower trace, delayed by about 8ns, is the output of the AND gate.



Notes:
1 0.02µF capacitor on each device socket
2 Pinout of 31A5500 (and other 31A delay lines) as follows:

1	Input
2, 3	NC
4	Tap 2 (2 delays)
5	NC
6	Tap 4 (4 delays)
7	GND
8	Out (5 delays)
9	NC
10	Tap 3 (3 delays)
11,13	NC
12	Tap 1 (1 delay)
14	Vcc

Delay line pulse generator gives 3ns rise and fall times and pulse-accuracy to within 2ns. Narrowest pulse available is 5ns.

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Narrow-band, voltage-controlled oscillator

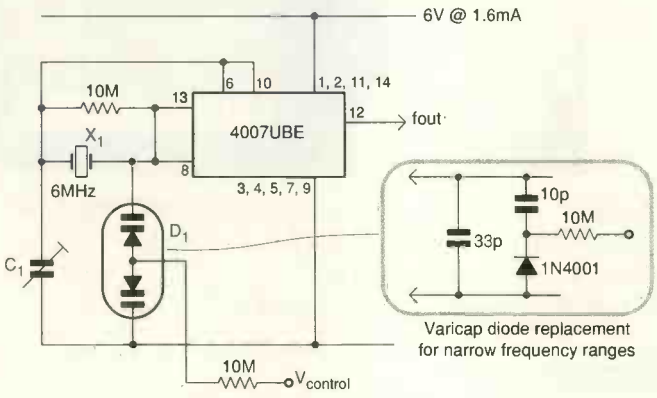
As a tone decoder to detect a single frequency in the presence of interference, a narrow-band vco in a phase-locked loop works well. Unfortunately, combining a narrow band and a well defined centre frequency is not easy, particularly if initial tuning is to be avoided. A crystal oscillator is one method, its frequency being "pulled" by a Varicap, but the frequency sweep is only a few hundred hertz at frequencies in the 1-10MHz range and at maximum deviation stability is poor.

Ceramic resonators offer the advantage of wider frequency adjustment. The main diagram on the left shows a low-power 6MHz oscillator using a cmos *4007UBE* IC with an *RS type 656-215* ceramic resonator. The *BB102* varicap provides adjustment capacitance C, the centre frequency being set by C_1 (about 33pF).

Sweep range is around 50kHz for a change of 33-220pF, the characteristic being logarithmic to give a falling frequency with increasing capacitance. Sensitivity therefore depends on capacitance: –4kHz/pF at 10pF and –80Hz/pF at 470pF.

A cheaper alternative is to replace the Varicap with a rectifier diode, having some junction capacitance. A 1N4001 – as shown in the diagram contained in the block – provides a 4kHz sweep at 6V.

R G Harrison
Charvill
Reading.



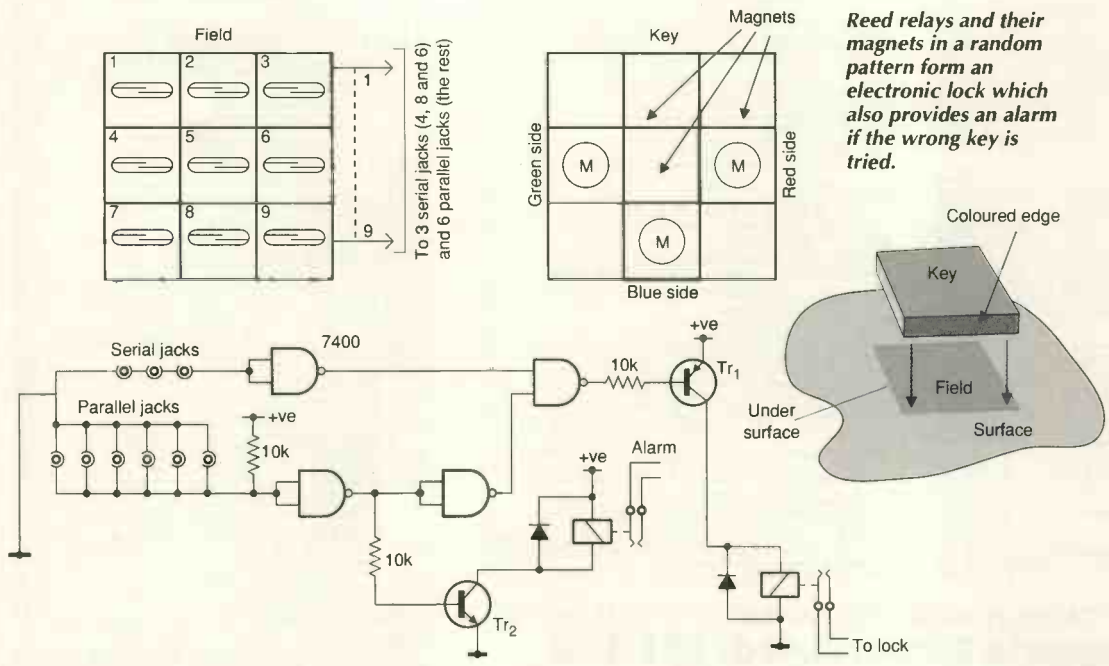
As a narrow-band vco, a ceramic resonator can give better results than a crystal can provide, and the circuit is simpler to design. A diode is even cheaper.

Electronic lock relies on magnetic poles

Giving an unauthorised user no indication of how to use it, this lock uses a magnetic key inserted into a field of reed relays.

Out of nine (or more) possible positions, only three contain the magnets to operate the relays, the three operated being effectively connected as an And gate. Inserting the key energises the output transistor and, therefore, the lock, but only if the remaining relays are not operated; if any of the others operate, being connected as an Or gate, the lock stays locked and the alarm sounds.

Ronny Tegel
Arlov, Sweden



Reed relays and their magnets in a random pattern form an electronic lock which also provides an alarm if the wrong key is tried.

Evaluate DSP for £90

Allen Brown has been looking at an evaluation kit with a price tag designed to bring DSP development within the reach of every engineer.

Digital signal processing, dsp, techniques have become very popular for solving a range of problems in electronics. Whether it is filtering, spectral analysis, noise reduction or information coding, there is a very good chance that dsp can offer a solution.

Having decided that dsp is an appropriate direction to find a solution, the next question centres on what hardware should be used. There's a number of processor manufactures to choose from, and to make the choice easier, a number of companies now provide low cost evaluation modules hosting a signal processor.

One such product is the *DSP56002EVM* from Motorola which sells for £90, exclusive, and provides a very low cost gateway into practical dsp. Shown in **Fig. 1**, the *DSP56002EVM* comprises a 40MHz *DSP56L002*, which is a low-power version of the *DSP56002*, and 128kbyte of sram. It also has a Crystal Semiconductor *CS4215* – which is a 16-bit multimedia audio codec – and is fitted with three 2.1mm jack sockets for analogue i/o.

The board can be controlled directly from a pc via a serial link. It is provided with *Debug-EVM* software, allowing the user to monitor the internal registers and memory of the *56002* processor. Facilities for emending assembly code at the processor level are also provided, as are technical data sheets on both the *DSP56002* and the Codec.

DSP56002 architecture

The processor is a fixed point device with two 56bit accumulators, designated A and B. It has a dual data architecture – X and Y memory with individual buses – feeding general purpose registers X and Y. There are also eight address registers r_{0-7}, each with auxiliary registers, m_{0-7} and n_{0-7}, for implementing address modifications.

Instructions are fetched on the program bus and with its hard-wired multiplier and arithmetic and logic unit the DSP56002 is able to perform multiply, add and dual channel data move operations in a single clock cycle.

Harvard architecture on-board memory comprises 512-by-24 bit program ram and 256 by 24bit ram for both X-data and Y-data. There is also a boot rom in the program memory area for allowing external code to be downloaded from a slow eprom during the boot-up phase. Both X and Y data spaces have rom areas dedicated to A-law/μ-law and sine coefficients respectively.

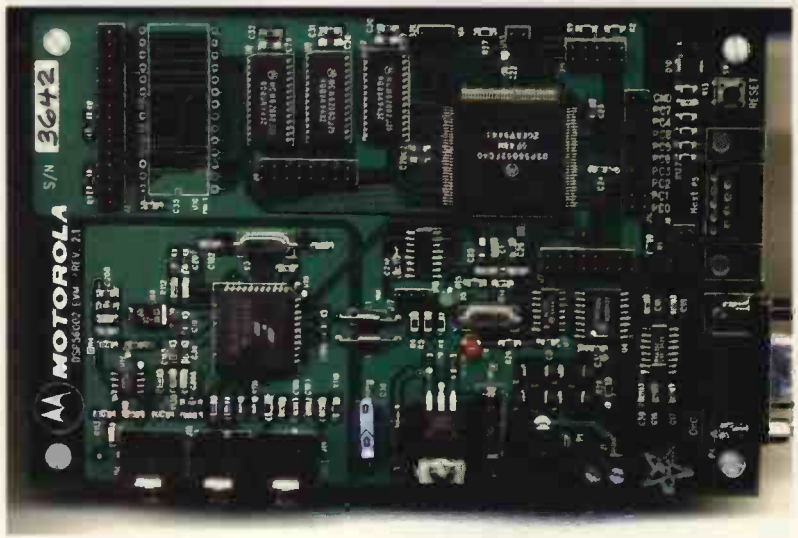


Fig. 1. DSP56002EVM featuring a DSP56L002 and a CS4215 multimedia audio codec from Crystal Semiconductor. Using the evaluation module serves as an ideal method to become acquainted with the signal processor.

The *DSP56002* has an interesting array of on-board peripherals. A 24bit timer/event counter, a synchronous serial i/o port, a serial comms i/o port, a host interface port and a *OnCE* port for on chip emulation. This provides an easy way of observing what is going on inside the processor. To complement its architecture the *DSP56002* has a generous instruction set and each line of assembly language code can have four sub-instructions, each relating to a different functional unit on the processor.

Evaluation kit hardware

Analogue i/o operations are performed on the cmos *CS4215* 16bit stereo codec. It supports cd, fm radio quality music, telephone quality speech and modems. The device's a-to-d converters are 64-times oversampling delta-sigma types with on-chip filters which adapt to the sample frequency. The *CS4215* allows integration of microphone, line-level inputs and i/o gain settings, along with headphone and monitor speaker drivers, resulting in a very small footprint.

Codec sampling is between 4kHz to 50kHz and the device can perform 16bit or 8bit audio data coding compression in either A or μ-law. This makes more efficient use of the 16bit dynamic range by applying a gain that is dependent upon the instantaneous signal amplitude.

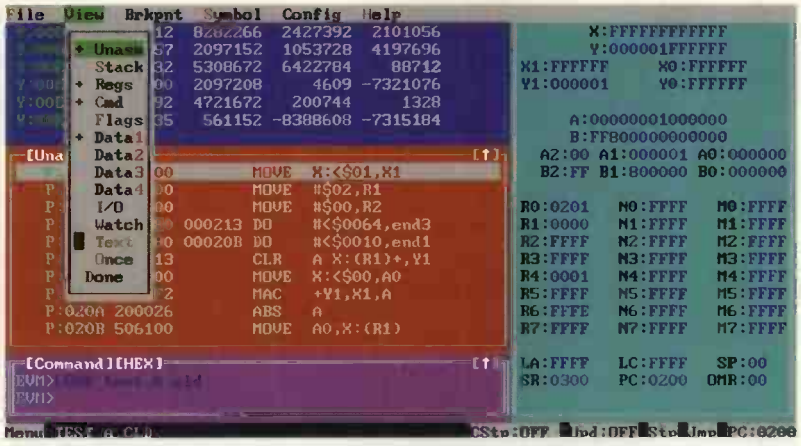


Fig. 2. Typical screen display of the Debug-EVM software showing the register contents, a fragment of disassembled code and the contents of part of the data memory.

The limitation of the codec lies in its output sample rate of less than 50kHz. Although adequate for stereo audio needs, the evaluation kit would not be suitable for investigating higher frequency applications. Its appeal would probably be limited to first time users of dsp technology.

In addition to the 128kbyte of sram, the *DSP56002EVM* also has a space for an *AT29C256PC* flash eprom which can serve as program memory or as X-data memory for read only purposes. Motorola only provides holes for the eprom – not even a proper dil socket. It would have been far more useful if an eprom in a dil had been supplied.

Without the eprom, once the power to the module is switched off, the memory loses its contents – thus limiting its usefulness. Also, Motorola leaves room for a second nine-pin D-connector to enable a dumb terminal to be interfaced to the *DSP56002EVM*. Again the company could have been a little more generous and supplied the D connector as standard, together with some software routines for running an external led display or dumb terminal.

Software for dsp evaluation

Communication with the *DSP56002EVM* is effected via an RS-232 serial link which accesses the *OnCE* facility on the main processor. The *OnCE* permits all the register contents to be interrogated and dumped via the serial link to the pc.

Registers can also be modified, and as a result allow the user to emend software errors. The accompanying software – *Debug-EVM* – is a development system package which greatly facilitates software testing. It only runs under dos, but it can be called from within windows.

The other attractive feature of using the *OnCE* is that it negates the need for a monitor program to be resident on the evaluation module. This feature is common on evaluation systems hosting conventional microprocessors and occupies valuable memory address space.

A typical screen display of *Debug-EVM* is shown in **Fig. 2**. The display can show several fields, for example register contents, disassembled code, graphical i/o and memory contents. However, these do not operate as smoothly as windows equivalent using the graphics user interface (gui) standard.

Provided with the package is a *DSP56002* assembler. Once a sources code is run through the assembler an executable file is generated which can be downloaded into the evaluation module's memory. The whole operation is quite painless.

When the *Debug-EVM* software is running the user has the option of executing a host of features normally found within microprocessor monitor systems, for example implanting break points and single stepping the code. Although acceptable if you are only running one evaluation kit, if you wanted to run a second, the limitations of the dos version of the *Debug-EVM* would soon become apparent.

Worked dsp examples

To run a number of the worked examples, the user is asked to provide a stereo music source – such as a Walkman – and a set of headphones. The worked examples given in the *Quick Start* document – comprising 16 pages of A4 – include a program for removing a 60Hz signal using a notch filter and implementing the codec process on audio signals.

There is also a program implementing a low-pass digital filter. These are quite useful as demonstrations and serve as good introductions to the *DSP56002*. Routines are also provided for driving the codec. There should be more examples available and this deficiency is not helped by the absence of a credible user manual containing information on the kit's hardware features. Although there is some information on a disk readme file – by no stretch of the imagination would this pass as a user manual.

There is however a printed manual for the *Debug-EVM* software. Probably a great deal could be done with the kit but without the relevant hardware details the scope for development will be somewhat limited. The general impression is that it is very much intended for the engineer who already has a reasonable knowledge of microprocessors.

Summary

The *DSP56002EVM* gives instant access to the possibilities of the *DSP56002*. Its stereo channel analogue i/o is a very attractive feature which allows the processor to used in audio signal processing applications or for any processing requirements under 50kHz.

However, in view of the fact that many potential users probably would not have a knowledge in dsp, I feel that the product would be better served if provided with a comprehensive user manual. Having performed the exercises laid out in the *Quick Start* document you could be left wondering 'what do I do with it now?'

On the whole, I feel that a stand-alone module for a dsp chip is a good idea. But unless more is provided for the non specialist interested in investigating the possibilities of the *DSP56002*, I feel its appeal will soon run out. ■

Availability

DSP56002EVM costs £90, excluding VAT and postage, and is available from Arrow Jermyn, St Martin's Business Centre, Cambridge Road, Bedford MK42 0LF, tel 01234 270027,fax 01234 214674.

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AC107	40p	BD267	45p	BLY48	85p	MJ2955	55p	2N2218A	24p	7818	25p	12A/400V		AN316	350p	BA6304	120p	LA4120	270p
AC125	30p	BD269	45p	BR100	14p	MJ3000	100p	2N2219	24p	7824	25p	TIC246D	105p	AN360	100p	BA6305	140p	LA4140	60p
AC126	30p	BD278	50p	BR103	37p	MJ3001	100p	2N2221	23p	7905	25p	16A/400V		AN362	140p	BA6410	220p	LA4160	100p
AC127	30p	BD311	100p	BR303	85p	MJE29A	30p	2N2222	23p	7906	30p	TIC253D	190p	AN366	150p	BA6411	250p	LA4182	180p
AC128K	40p	BD314	100p	BSS74	33p	MJE30A	30p	2N2369	15p	7908	30p	20A/400V		AN610	160p	BA6993	150p	LA4190	300p
AC141K	45p	BD315	150p	BSX20	15p	MJE340	25p	2N2484	15p	7912	30p	TIC263D	205p	AN3312	350p	BA7001	150p	LA4192	140p
AC176	22p	BD317	150p	BT100A	70p	MJE350	80p	2N2646	40p	7915	30p	25A/400V		AN3821K	600p	BA7004	200p	LA4200	130p
ACY18	48p	BD331	40p	BT106	180p	MJE520	30p	2N2904	20p	7918	30p			AN3822K	600p	BA7007	200p	LA4201	120p
ACY19	48p	BD332	40p	BT109	90p	MP8112	45p	2N2905	20p	7924	30p	*THYRISTORS*		AN3990K	300p	BA7021	180p	LA4260	230p
AD149	60p	BD361	60p	BT119	100p	MPSA05	15p	2N2906	18p	78L05	24p			AN3991K	400p	BA7022	350p	LA4261	300p
AF125	50p	BD362	60p	BT146	99p	MPSA06	15p	2N2907	18p	78L08	24p	2N5061	20p	AN5025	250p	BA7751LS	150p	LA4270	300p
AF139	30p	BD370	30p	BTY79	140p	MPSA13	15p	2N3019	28p	78L12	24p	0.8A/60V		AN5033	400p	BA7752	250p	LA4420	140p
AF239	30p	BD371	30p	BU105	80p	MPSA20	15p	2N3053	18p	78L15	24p	TIC116C	59p	AN5132	250p	BA7755	150p	LA4422	130p
BB105B	18p	BD410	50p	BU108	100p	MPSA42	15p	2N3054	40p	78L18	24p	8A/300V		AN5150	400p	BA7767AS	155p	LA4430	130p
BB205B	24p	BD433	28p	BU109	80p	MPSA43	15p	2N3055	38p	78L24	24p	TIC116D	70p	AN5151	600p	CA3011	110p	LA4440	150p
BC107	8p	BD434	30p	BU110	90p	MPSA70	15p	2N3055H	50p	79L05	35p	8A/400V		AN5215	100p	CA3048	190p	LA4445	150p
BC108	8p	BD435	31p	BU111	100p	MPSA92	20p	2N3442	85p	79L08	35p	TIC126D	75p	AN5256	150p	CA3052	190p	LA4460	120p
BC109	8p	BD436	30p	BU124	60p	MPSA93	20p	2N3702	9p	79L12	35p	12A/400V		AN5262	175p	CA3054	95p	LA4461	120p
BC109C	10p	BD437	28p	BU126	65p	MR510	35p	2N3703	9p	79L15	35p	TIC126M	90p	AN5265	80p	CA3085	135p	LA4500	200p
BC140	20p	BD438	36p	BU180	100p	MR856	36p	2N3704	9p	LM309K	100p	12A/600V		AN5352	600p	CA3088E	200p	LA4505	220p
BC142	20p	BD439	40p	BU184	100p	OC28	350p	2N3705	9p	LM317T	100p	C106D	28p	AN5411	450p	CA3089E	150p	LA4508	200p
BC143	20p	BD440	40p	BU204	65p	OC29	250p	2N3706	9p	LM323K	350p	4A/400V		AN5421	150p	CA3090Q	250p	LA4510	100p
BC147	8p	BD441	40p	BU205	70p	OC35	350p	2N3707	9p	78H08KC	800p	BR103	37p	AN5429	420p	CA3130S	100p	LA4520	170p
BC149	8p	BD533	50p	BU206	100p	OC36	250p	2N3710	12p	79H12KC	700p	BR303	85p	AN5512	100p	CA3134E	280p	LA4550	200p
BC159	8p	BD534	38p	BU208	70p	OC45	50p	2N3711	12p	79HGKC	800p	BT106	180p	AN5515	160p	CA3140E	38p	LA4555	120p
BC160	30p	BD535	38p	BU208A	75p	OC200	180p	2N3771	85p			BT119	100p	AN5520	550p	CA3160	85p	LA4570	130p
BC171	10p	BD536	38p	BU208AT	200p	R2008B	100p	2N3772	90p	*LEDs*		17088	200p	AN5521	100p	CA3189E	230p	LA5112	200p
BC172	10p	BD537	40p	BU208D	130p	R2010B	100p	2N3773	100p	3mm		17089	200p	AN5612	200p	CA3193E	230p	LA5523	150p
BC177	14p	BD538	40p	BU209	90p	S2000A3	175p	2N3799	18p	RED	5p	17127	200p	AN5613	200p	CA3260E	170p	LA5527	150p
BC178	14p	BD643	50p	BU225	120p	S2000AF	175p	2N3819	29p	YELLOW	8p	15/80H	230p	AN5615	300p	CA3290E	150p	LA5700	300p
BC179	14p	BD645	50p	BU226	120p	S2055A	175p	2N3903	11p	GREEN	8p	15/85R	230p	AN5620	250p	CX108	950p	LA7011	220p
BC182	7p	BD647	50p	BU312	90p	S2055AF	200p	2N3906	11p	5mm		SG264	800p	AN5622	275p	CX136	600p	LA7033	400p
BC182L	7p	BD649	50p	BU325	55p	S2530A	100p	2N4031	25p	RED	5p	SG613	1500p	AN5625	400p	CX139A	750p	LA7042	280p
BC183	7p	BD675	40p	BU326A	75p	S2800M	72p	2N4401	12p	YELLOW	8p			AN5712	180p	CX141	750p	LA7046	300p
BC183L	7p	BD676	40p	BU406	60p	TIP29	15p	2N4403	12p	GREEN	8p	*COMPUTER ICs*		AN5722	140p	CX145	725p	LA7224	150p
BC184	7p	BD677	38p	BU406D	85p	TIP29A	22p	2N5061	20p					AN5730	160p	CX150B	325p	LA7505	250p
BC184L	7p	BD678	40p	BU407	55p	TIP29C	25p	2N5088	20p	*RECTANGULAR LEDs*		Z80ACPU	100p	AN5732	120p	CX175	325p	LA7507	250p
BC212	7p	BD679	40p	BU407D	75p	TIP29E	40p	2N5192	50p	5mm × 2.5mm		Z80ADMA	200p	AN5753	130p	CX187	825p	LA7520	200p
BC212L	7p	BD680	40p	BU408	60p	TIP30	25p	2N5241	500p	RED	5p	Z80ACTC	140p	AN5763	450p	CX804A	775p	LA7620	500p
BC213	7p	BD681	45p	BU408D	75p	TIP30C	25p	2N5245	45p	YELLOW	8p	Z80ASIO-1	210p	AN5790	240p	CX867	575p	LA7800	90p
BC213L	7p	BD682	45p	BU409	85p	TIP31A	22p	2N5294	30p	GREEN	8p	Z80ASIO-2	210p	AN5791	225p	CX868	525p	LA7801	100p
BC214	7p	BD705	50p	BU426A	70p	TIP31C	27p	2N5296	30p			75107	65p	AN5836	450p	CX877	300p	LA7802	300p
BC214L	7p	BD707	50p	BU500	100p	TIP32	24p	2N5448	12p	*OPTO COUPLERS*		75110	75p	AN5900	130p	HA1125	120p	LA7806	260p
BC237	7p	BD709	50p	BU505	90p	TIP32A	21p	2N6107	40p			75113	100p	AN6135	120p	HA1197	130p	LA7808	250p
BC238	7p	BD711	50p	BU505D	90p	TIP32C	28p	2N6292	40p	4N37	58p	75122	110p	AN6247	200p	HA1199	130p	LA7820	100p
BC239	7p	BD736	50p	BU505DF	90p	TIP33	50p	2N6385	120p	4N38	68p	75154	100p	AN6270	400p	HA1319	200p	LA7823	200p
BC300	20p	BD826	50p	BU506	100p	TIP33C	60p	2N6403	160p			75162	700p	AN6300	600p	HA1338	300p	LA7910	150p
BC301	20p	BD828	50p	BU506D	70p	TIP34	50p					75182	95p	AN6306	380p	HA1339A	350p	LA7940	200p
BC302	20p	BD839	55p	BU506DF	120p	TIP34C	60p	*RECTIFIER DIODES*		*BRIDGE RECTIFIERS*		75183	95p	AN6320	180p	HA1377	120p	LC7131	260p
BC303	20p	BD897	50p	BU508A	70p	TIP35C	65p					75195	185p	AN6332	320p	HA1388	320p	LC7132	400p
BC304	25p	BD899	50p	BU508AF	95p	TIP36C	65p	BY127	8p	W005	16p	2114	150p	AN6341	200p	HA1389	210p	LC7137	450p
BC327	7p	BD977	50p	BU508D	75p	TIP41A	20p	BY133	8p	1A/50V		2532	200p	AN6344	440p	HA1392	120p	LF347	110p
BC328	7p	BDX33	60p	BU508DF	115p	TIP41C	22p	BY164	40p	W01	18p	2716	100p	AN6350	610p	HA1394	170p	LF353	48p
BC337	7p	BDX65	80p	BU508V	110p	TIP42A	20p	BY179	35p	1A/100V		2732	200p	AN6359	500p	HA1397	200p	LF355	60p
BC338	7p	BDW24	55p	BU508VF	100p	TIP42C	22p	BY184	32p	W02	19p	2732A	220p	AN6360	320p	HA1398	240p	LF357	70p
BC441	28p	BDW93	50p	BU526	75p	TIP47	40p	BY206	11p	1A/200V		2764	150p	AN6362	400p	HA11219	280p	LF398	300p
BC446	8p	BDW94	50p	BU536	100p	TIP48	40p	BY207	9p	W04	21p	27C64	200p	AN6371	350p	HA11221	180p	LM301	26p
BC477	18p	BDY92	100p	BU546	125p	TIP50	60p	BY227	19p	1A/400V		27128	150p	AN6387	480p	HA11225	130p	LM311	35p
BC516	22p	BF137	35p	BU608	120p	TIP51	80p	BY228	28p	W06	23p	27256-25	150p	AN6884	200p	HA11235	120p	LM319	165p
BC537	25p	BF167	30p	BU626	120p	TIP52	80p	BY298	15p	1A/600V		27512	300p	AN7105	170p	HA11251	190p	LM324	30p
BC546	8p	BF181	18p	BU705	130p	TIP54	85p	BY299	18p	W08	28p	4116	40p	AN7110	75p	HA11423	140p	LM335Z	120p
BC547	8p	BF183	20p	BU706DF	175p	TIP105	65p	BY448	20p	1A/800V		4164-15	80p	AN7114	120p	HA11724	650p	LM339	35p
BC548	8p	BF195	7p	BU706F	150p	TIP106	65p	BYX10	15p	BR81D	33p	4164-12	90p	AN7115	110p	HA12002	220p	LM348	50p
BC549	8p	BF199	8p	BU801	70p	TIP107	65p	BYX55/600	25p	2A/100V		41256-15	80p	AN7116	90p	HA12003	250p	LM358	45p
BC550	8p	BF200	16p	BU806	70p	TIP110	40p	BYX70/500		BR82D	33p	41256-12	100p	AN7120	100p	HA12005	180p	LM380	80p
BC556	8p	BF225	30p	BU807	60p	TIP111	40p	OA47	10p	2A/200V		41256-10	110p	AN7130	75p	HA12017	100p	LM381	150p
BC557	7p	BF240	16p	BU902	110p	TIP112	35p	OA91	10p	BR82D	33p	41464-12	150p	AN7140	170p	HA13001	110p	LM382	130p
BC558	8p	BF245	25p	BU903	110p	TIP112H	50p	OA202	10p	2A/400V		6116	80p	AN7145	195p	HA13002	200p	LM386	60p
BC559	8p	BF254	15p	BU920	100p	TIP115	30p	IN4001	3p	BR86D	43p	6264-10	210p	AN7146	210p	HA13006	400p	LM387	100p
BC560	8p	BF255	12p	BU922	110p	TIP116	30p	IN4002	3p	2A/600V		62256-12	300p	AN7154	180p	HA13007	400p	LM393	45p
BC637	20p	BF256	18p	BU930	130p	TIP117	30p	IN4003	3p	BR88D	43p	6502A	360p	AN7156	240p	HA13108	350p	LM431	50p
BC639	20p	BF257	18p	BU2508A	130p	TIP120	37p	IN4004	3p	2A/800V		65C02	930p	AN7168	200p	HA13412	600p	LM710	45p
BC640	20p	BF259	18p	BU2508AF	130p	TIP121	35p	IN4005	3p	BR810	43p	6522	280p	AN7178	180p	HA13432	400p	LM723	40p
BCY33	200p	BF262	25p	BU2508D	130p	TIP122	30p	IN4006	3p	2A/1000V		6800	210p	AN7222	75p	HA17524	250p	LM741DIL	18p
BCY34	200p	BF270	18p	BU2508DF	150p	TIP125	30p	IN4007	4p	BR810	43p	6802	220p	AN7254	150p	ICL7106	650p	LM741MET	45p
BCY70	16p	BF273	15p	BU2520AF	225p	TIP126	40p	IN4148	2p	2A/1200V		680	500p	AN7256	250p	ICL7660	240p	LM747	55p
BCY71	16p	BF311	21p	BU2520DF	225p	TIP127	35p	IN5400	9p	BR83	43p	36808	500p	AN7310	60p	KA2102	150p	LM1889	300p
BCY72	16p	BF336	20p	BU2525AF	325p	TIP130	30p	IN5401	8p	2A/200V		6809	500p	AN7311	90p	KA2130	150p	LM1894N	200p
BD115	30p	BF337	20p	BUH515	200p	TIP131	30p	IN5402	8p	BR84	43p	6810	150p	AN7410	150p	KA2206	150p	LM3900	40p
BD124P	50p	BF338	20p	BUT11AF	55p	TIP132	30p	IN5403	8p	2A/400V		6818	380p	AY3-1015	290p	KA2209	125p	LM3909	100p
BD131	25p	BF362	30p	BUT12	80p	TIP141	65p	IN5404	8p	BR86	44p	6821	130p	AY3-1270	800p	KA2210	230p	LM3914	160p
BD132	25p	BF367	13p	BUT56A	75p	TIP142	75p	IN5405	11p	2A/600V		6840	290p	AY3-1350	450p	KA2212	80p	LM3915	160p
BD133	50p	BF371	17p	BU18	80p	TIP145	50p	IN5406	12p	BR62	80p	6845	200p	AY3-8910	360p	KA2213	130p	LM3916	270p
BD135	20p	BF421	18p	BU18AF	80p	TIP146	70p	IN5407	12p	6A/200V		6850	90p	AY3-8912	400p	KA2214	150p	L200	200p
BD136	20p	BF422	21p	BUX10	150p	TIP147	80p	IN5408	12p	BR64	72p	8085A	300p	BA301	55p	KA2261	100p	M491BB1	500p
BD137	20p	BF423	25p	BUX11	200p	TIP150	90p	RGP15	25p	6A/400V		8086	500p	BA311	80p	KA2263	100p	M494B1	700p
BD138	20p	BF455	12p	BUX12	150p	TIP151	60p	RGP30	16p	BR251	150p	8088	480p	BA313	60p	KA2264	100p	M50115P	320p
BD139	20p	BF458	19p	BUX20	350p	TIP2955	42p	SKE4F2/06	60p	25A/100V		8156	300p	BA333	80p	KA2284	100p	M50117P	500p
BD140	20p	BF462	50p	BUX21	450p	TIP3055	42p	SKE4F2/08	80p	BR252	165p	8224	240p	BA401	60p	KA2401	150p	M50119P	525p
BD144	90p	BF471	28p	BUX22	450p	TIPL760	100p	SKE4F2/10	100p	25A/200V		8226	240p	BA402	50p	KA2412	350p	M50784	300p
BD157	38p	BF472	28p	BUX37	220p	TIPL763A	200p	SR2M	60p	BR254	185p	8250	750p	BA511	145p	KA2912	125p	M50786	500p
BD166	30p	BF479	30p	BUX40	210p	TIPL791A	80p			25A/400V		8251	200p	BA514	160p	KA2914A	300p	M50790	600p
BD175	30p	BF494	16p	BUX41	200p	TIS61	15p	*I.C. SOCKETS*		BR256	200p	8253	160p	BA516	150p	LA1130	240p	M51161	300p
BD177	30p	BF495	16p	BUX42	200p	TIS90	15p			25A/600V		8257	220p	BA521	100p	LA1150	150p	M51381P	200p
BD179	32p	BF595	16p	BUX47A	220p	TIS93	20p	8 PIN	5p	BR258	240p	8271	3400p	BA524	240p	LA1185	150p	M51387P	800p
BD181	45p	BF596	16p	BUX48A	150p	ZTX107	11p	14PIN	6p	25A/800V		8279	270p	BA526	180p	LA1201	75p	M51544	150p
BD182	60p	BF615	30p	BUX80	180p	ZTX108	11p	16PIN	7p	BR351	185p	8283	400p	BA527	95p	LA1210	140p	M51848	150p
BD184	60p	BF617	30p	BUX84	50p	ZTX109	12p	18PIN	10p	35V/100V		8284	440p	BA532	100p	LA1222	80p	M54523P	200p
BD187	30p	BF760	40p	BUX85	50p	ZTX212	20p	20PIN	12p	BR352	200p	8287	260p	BA534	220p	LA1230	130p	M54563P	200p
BD201	33p	BF763	40p	BUX86	30p	ZTX300	10p	22PIN	13p	35V/200V		8288	650p	BA536	150p	LA1364	200p	M58484	500p
BD202	38p	BF870	22p	BUX87	50p	ZTX301	16p	24PIN	14p	BR354	220p	8748	700p	BA546	160p	LA1365	120p	M51516	260p
BD203	42p	BF871	22p	BUX98A	350p	ZTX302	10p	28PIN	16p	35V/400V		8755	800p	BA612	120p	LA1368	220p	M51518	200p
BD204	42p	BF960	38p	BUY69A	200p	ZTX303	20p	40PIN	18p	BR356	230p	8T26	95p	BA656	110p	LA1385	170p	MB3712	140p
BD222	31p	BF961	35p	BUY71	250p	ZTX304	10p			35V/600V		8T28	110p	BA658	350p	LA2000	150p	MB3713	130p
BD225	31p	BF964	38p	BUZ11	200p	ZTX320	20p	*ZENERS*		BR358	260p			BA684	400p	LA2101	270p	MB3714	270p
BD232	31p	BFR90	85p	BUZ71	75p	ZTX501	13p			35V/800V		*LINEAR ICs*		BA685	400p	LA2200	190p	MB3715	250p
BD233	30p	BFR91	99p	BUZ80	200p	ZTX502	10p	400 mWatts		BY164				BA1310	160p	LA3160	120p	MB3722	280p
BD234	32p	BFT43	30p	BY448	20p	ZTX503	18p	2V7 to 39V	5p	1,5A/100V	40p	AN203	210p	BA1320	75p	LA3210	65p	MB3730	160p
BD235	28p	BFX29	20p	BYT11	25p	ZTX504	25p	1.3 Watts		BY176		AN210	165p	BA1330	120p	LA3300	140p	MB3731	220p
BD236	30p	BFX84	20p	C106D	28p	2N696	26p	2V7 to 39V	9p	1.5A/800V	40p	AN214Q	170p	BA1360	160p	LA3301	110p	MB3756	160p
BD237	21p	BFX85	20p	IRF630	150p	2N697	22p					AN228	280p	BA4403	220p	LA3361	100p	MB3759	200p
BD238	24p	BFX87	15p	J174	38p	2N698	40p	*VOLTAGE REGULATORS*		*TRIACS*		AN252	150p	BA5101	350p	LA3375	300p	MB8719	360p
BD239	30p	BFX88	15p	J300	50p	2N78	22p					AN259	250p	BA5102	140p	LA4030	180p	MC1455	45p
BD240	40p	BFX89	60p	MJ900	200p	2N914	28p			TIC206D	60p	AN262	140p	BA5204	200p	LA4031	140p	MC1496	65p
BD241A	40p	BFY50	14p	MJ1000	200p	2N930	18p	7805	25p	4A/400V		AN271	230p	BA5402	180p	LA4032	140p	MC3401	45p
BD243A	50p	BFY51	14p	MJ1001	200p	2N1131	28p	7806	25p	TIC225D	69p	AN274	250p	BA5406	180p	LA4051	160p	NE555	20p
BD244	50p	BFY52	14p	MJ10012	300p	2N1132	28p	7808	25p	6A/400V		AN301	330p	BA5408	180p	LA4100	85p	NE556	40p
BD245	50p	BFY56	25p	MJ15003	250p	2N1613	24p	7812	25p	TIC226D	68p	AN303	250p	BA6104	250p	LA4101	80p	NE558	80p
BD246A	50p	BFY64	25p	MJ15004	300p	2N1711	24p			8A/400V		AN304	360p	BA6208	175p	LA4102	100p	NE565	110p
						2N1893	30p												

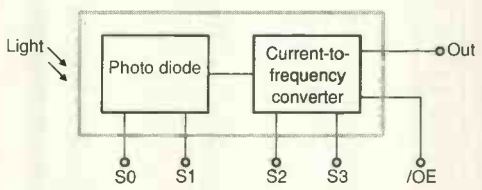
Bits of light

Claus Kühnel describes how combining the Basic Stamp microcontroller and a TSL230 forms an extremely simple light-to-RS232 interface.

For silicon photo diodes, the detectable spectrum of light extends from about 300nm to 1100nm.

Short circuit current of the silicon photo diode is proportional to incident irradiation and almost independent of temperature. The down side is that photo diodes generally produce only a very small signal current. As a result, the analogue circuits for processing the diode output can become expensive.

Design costs reduce however when the photo diode and its amplifier are integrated into the same chip or module. In the case of the photo diode used here, not only are the diode and its amplifier mounted in the same module, but there is also digital circuitry, allowing the device to communicate directly with a microcontroller. In addition, the chip can operate from supply rails down to 2.7V



The TSL230 light-to-frequency converter comprises a photodiode and current-to-frequency converter integrated into an eight-pin dil package.

Light sensing with the *TSL230*

The *TSL230*, from Texas instruments, is a programmable light-to-frequency converter. Both silicon photo diode and current-to-frequency converter are housed in a clear plastic dual-in-line package with eight-pins.

When the device is set for maximum sensitivity, an irradiation of 450µW/cm^2 (λp of 660nm) produces an output frequency of typically 1MHz. The light sensitive area of this photo diode is typically 1mm^2.

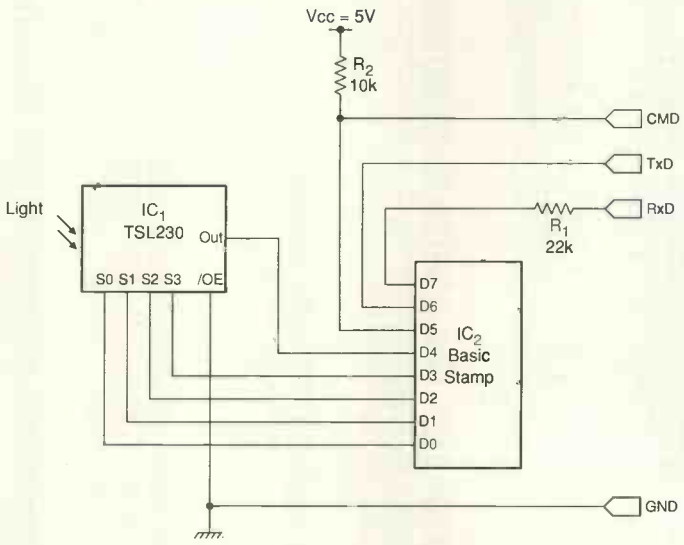
This photo diode is configurable. Its sensitivity can be increased by a factor of 10 or 100. Further adjustments can be made via programmable on-chip frequency dividers allowing divide by 2, 10 or 100 of the output.

In addition to control inputs S3 to S0 there is an output-enable input. When active-low, this pin switches the output of the device into a tri-state condition, allowing outputs of several devices to be connected to a common line.

Programming conditions are listed in the table. The first line in the table is hatched since these conditions invoke a special mode.

Frequency division causes a symmetrical output, i.e. one with a 1:1 duty cycle. While S3 and S2 are low, duration of the output pulse extends from 125ns to 500ns and symmetry is not defined.

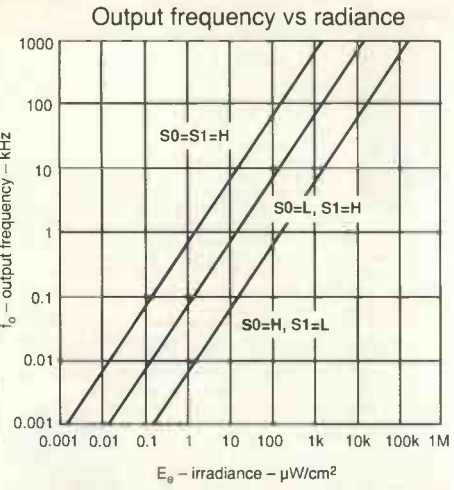
The TLS230 programmable light-to-frequency is linked to a host controller by a simple RS232 interface and one command line. After this command line is pulled low, the Stamp asks for a command. This command sets inputs S3 to S0 of the TLS230. Following setup, the Stamp sends the measured value to the host periodically.

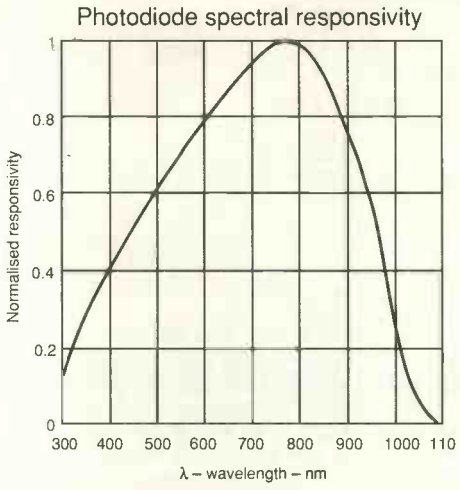


Basic Stamp is designed for ease of use. It has eight i/o lines and is programmed using a high-level Basic dialect. As a result, forming an interface to read data from the light-to-frequency converter and translating the reading to RS232 for use on o pc is very simple.

Listing – PBASIC-source

```
'[Constants]
'
    symbol RxD    = 7
    Symbol TxD    = 6
    symbol TSL230 = 4
    symbol baud   = N2400

'[Variables]
'
    symbol key    = pin5
    symbol ss     = b0
    symbol period = w1

'[Initialisation]
'
    dirs = %01001111
    pins = %00000101

'[Main Code]
'

    start: if key = 0 then enter
           loop: pulsin TSL230,0,period
           serout TxD, baud, (#period,10,13)
           debug period
           pause 1000
           period = 0
           goto start

    enter: serout TxD, baud, ("SS?",10,13)
           serin RxD, baud, #ss
           ss = ss - $30 & $0f
           debug %ss
           pins = ss
           goto loop
```





Typical performance of the TSL230 light-to-frequency converter. Both are for 25°C. Conditions for frequency versus irradiance were 5V supply, λ_p of 670nm and S3=S2=L.

When S1 and S0 are low, the device switches to the power-down mode. This reducesmaximum supply current from to 2mA to 10μA.

Basic stamp as an RS232 interface

In order to determine light level, the *TSL230's* output frequency must be measured. Interfacing the *TSL230* to a pc or controller allows the conversion and display to be carried out in software.

The simplest solution results from building this interface using a microcontroller best suited for this kind of application. On the *Basic Stamp*, there are eight free configurable i/o lines and the device is programmable in a Basic dialect known as Pbasic, which is an abreviation of Parallax Basic. This language was developed especially for microcontroller applications.

Interfacing to the host computer is carried out via a simple three-wire connection according to RS-232 standards and an additional command line.

Light detection software

At the label 'start' in the program, the command line CMD marked 'key' is queried. If the i/o line is pulled low by the host controller a jump to the label 'enter' results.

The *Basic Stamp* sends the characters 'SS?' to the host and waits to receive a value to setup the control lines S3 to S0. After masking for all evetualities, and a possible display in the debug window of the development system, the control inputs are set up. A jump to the label 'loop' leads to the endless loop, where the program runs normally.

The TSL230 light to frequency converter is programmable for both sensitivity and output frequency scaling via four programming inputs.

S3	S2	Frequency scaling	S1	S0	Sensitivity
L	L	*f*	L	L	Power down
L	H	*f*/2	L	H	1×
H	L	*f*/10	H	L	10×
H	H	*f*/100	H	H	100×

The low period of *TSL230* output pulses is measured using the command 'pulsin'. To calculate output frequency from this low time the pulse sequence must be symmetrical. As a result, the hatched condition in the table is unusable.

Results from the command 'pulsin' are saved in the 16 bit variable 'period'. Resolution is 10μs. After getting the half period duration, the result can be transferred to the host. The *Basic Stamp* sends an ascii sequence closed by a carriage return and line feed. After a pause of one second, chosen arbitrarily, the whole process is repeated.

In applications allowing some of the programming inpuits to be hard wired, the spare i/o lines on the stamp could be connected to, say, a led or beeper and used for signalling light level limits. ■

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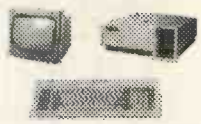

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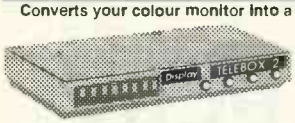

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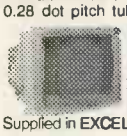

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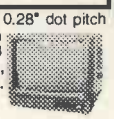

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Cermet trimmers. The *Spectrol Reliance model 76* is a 0.25in square, single-turn cermet trimmer, available in three pin styles for top or side adjustment and covering the 10Ω to 2MΩ range at ±10% tolerance. Contact resistance variation is 1% or 3Ω (there is a multi-finger wiper), voltage and resistance adjustability ±0.05% and ±0.15%. The trimmers can be cleaned by immersion. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Chip inductors. Panasonic has two new series of chip inductors having high *Q*s and in package sizes approaching the ridiculous – down to 1.6 by 0.8 by 0.8mm. *ELJRE* and *ELJND* series provide inductances from 2.2nH to 1μH, have high self resonance and *Q* between 4 and 18 at 100MHz. Panasonic Industrial (Europe) Ltd. Tel., 01344 853827; fax, 01344 853313.

Connectors and cabling

Adaptable cigarette-lighter plugs. Since there appears to be no standard for the diameter of car cigarette-lighter plugs, all those bits of gear that "simply plug into the lighter socket" probably won't. Accordingly, Pedoka has made all-purpose plugs with a sliding mechanism so that they will fit into any socket. Pedoka Ltd. Tel., 01462 422433; fax, 01462 422233.

Triaxial camera cables. Nokia's range of triaxial camera cables is extended to include 8mm and 11mm *Triflex* cables, which have a stranded inner conductor and special sheath to increase flexibility. The existing 8mm, 11mm and 14mm cables continue in production and, as with the new types, can be supplied cut to length or terminated and tested. Transradio Ltd. Tel., 0181 997 8880; fax, 0181 997 0116.

25-way connector. Bulgin's *Buccaneer* range of connectors for use in hostile surroundings now includes a 25-way version, which is produced in five mounting styles: in-line flex, chassis, bulkhead surface and low-profile flange. Gold-flashed contacts are rated at 1A, 50Vac/dc and may be inserted into the contact carrier in any combination up to the maximum 25 ways without tools. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Power inlets. A new range of power inlets in the Schurter *Multifit* range are the *Combifit* pcb-mounted types that need no wiring. They snap fit to the board or can be screwed, being soldered at the same time as other components. Versions now available are combined inlet/outlet, inlet/switch and inlet/fuse models; types with surge protectors and filters will be introduced soon. Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

Coaxial idc. *Erni* has an insulation-displacement connector for 75Ω cable-to-pcb connections, in which assembly simply entails tightening a screw to pull down a cover, providing a gas-tight seal. It allows precise cable alignment and is claimed to be extremely reliable. The metallised housing gives emc shielding. Maximum current is 1.5A; crosstalk attenuation 45dB to 500MHz, shielding attenuation 60dB to 500MHz and reflectance factor under 0.1. Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

Crystals

Express crystals. IQD now includes *UM1* crystals in its express manufacturing service, allowing the production of custom-specified crystals to be made in three days. Due to its construction, the *UM1* copes with shock and vibration and is therefore suitable for the avionics industry and other rugged surroundings. Frequency range is 950kHz-250MHz to within ±5ppm. IQD Ltd. Tel., 01460 74433; fax, 01460 72578.

Saw resonator. Seiko Epson's *FS-555* is a surface-mounted, quartz-based, surface acoustic-wave

ACTIVE

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3V, 16-bit a-to-d. Analog Devices' *AD7715* is a 16-bit analogue-to-digital converter for 3V working. It has a programmable-gain input. A three-wire serial interface reduces the number of interconnection lines and couplers for isolated systems, the input taking differential inputs. Gain, signal polarity and update rate are all controlled by software. Polar Electronics. Tel., 01525 377093; fax, 01525 378367.

Discrete active devices

Reliable s-m discretes. Transistors and diodes in the *Rohm SC-59* series allow more reliable automated manufacture than the SOT-23 devices. The range contains switching transistors and diodes, digital p-n-p and n-p-n types with built-in resistors and both transistor and diode arrays. Although the devices are direct physical replacements for SOT-23, they have improves structures to reduce thermal stress to the bond wires and reduced vulnerability to humidity, with better power dissipation and improved alignment on the board. Also in stock is 1.6mm square EM3 series. Polar Electronics. Tel., 01525 377093; fax, 01525 378367.

Logic

3.3V, low-emi clock drivers. *S3LV306/308/318/368* comprise AMCC's family of 3.3V clock drivers to meet the requirements of logic running at up to 100MHz. 306 provides 10 outputs at half f_{in} and 10 at f_{in}, 308 and 318 give 20 and 30 outputs respectively at f_{in}, while 368 gives six at f_{in} and eight at $f_{in}/2$ synchronously; all outputs at f_{in} asynchronously. Output drivers provide 24mA, dropping to 4mA when the output reaches 0.8V, followed by a slower transition to 0.4V. This "virtually eliminates" ground bounce and any resulting emi. AMCC Inc. Tel., 001 619 450-9333; fax, 001 619 450-9885.

Microprocessors and controllers

Stepper drivers. Sanyo Denki offers the *PMM8723/14* for driving two-phase and five-phase stepper motors. They are cmos ics and each, with a pulse oscillator and power switching transistors, forms a complete drive. Both have excitation mode changeover terminals for different phase excitation. Power supply is 5V for the PMM8723 and 4-18V for the 8714. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Cameras

High-resolution still camera. Sony's *XC-7500* monochrome camera module uses a progressive-scan ccd imager to give 659 by 494-pixel, full-frame still images of rapidly moving objects, shuttering the whole frame at one instant to provide the full vertical resolution at 60dB s:n ratio. Pixels are square, so that the processor does not need to make compensating adjustments. The E-Donpisha asynchronous reset shutter mode allows immediate exposure of 10^{-5}s with long-term integration from 1/60s to infinity. Outputs are twin, two-channel interlaced or non-interlaced and a single non-interlaced output. The camera is compatible with the EIA standard and a CCIR model is to be produced shortly. Sony United Kingdom Ltd. Tel., 01932 816000; fax, 01932 817000.

resonator for the 300-360MHz range of comms systems, ecl oscillators and rf modulators. Frequency tolerance is ±100ppm and series resistance 30Ω. The device measures 1.5 by 4.8 by 5.2mm and is suitable for automatic assembly. Advanced Crystal Technology. Tel., 01635 528520; fax, 01635 528443.

Displays

Super tft. Hitachi announces a new 'super-tft' lcd technique that produces a 70° angle with no colour shift or change and is forecast to compete with crts when several viewers are present. The technique used is in-plane switching (IPS), in which the liquid-crystal molecules switch the light transmittance while keeping their longitudinal axis parallel to the substrate. First product to use this method will be a 262k colour, 13.3in 1024 by 768 pixel display. Hitachi Europe Ltd. Tel., 01628 585163; fax, 01628 585160.

SVGA colour lcds. A new screen size of 11.3in is introduced by Sharp, with tft and stn SVGA-compatible colour displays. Power consumption and weight are both less than in the current 10.4in types used in notebooks and they are more compact designs. Hero Electronics Ltd. Tel., 01525 405015; fax, 01525 402383.

Filters

Motor filters. Roxburgh offers the *MIF* range of motor inverter filters with the aim of reducing noise from inverters using long runs of cable. Single-phase types handle 3-32A, the three-phase versions coping with 4-180A. They meet EN55022B requirements, with over 80dB of common-mode and 40dB of differential-mode noise reduction at 150kHz. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

Hardware

Cooler Pentia. Sanyo Denki introduces the *San Ace MC* fan cooler to dampen the ardour of *Pentium P6* chips. The fan and its integral heatsink take up a volume of 66 by 62 by 30mm the heat transfer rate allowing up to 30W for a 25°C temperature rise; thermal resistance is 0.79°C/W. Voltage range is 7-13Vdc, speed 3600rev/min at 12V and noise rating 29dBA. Locked-rotor protection is standard and an alarm output is fitted. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Test and measurement

Photometers. Tek's *J18* range of hand-held digital photometers is now available. A range of pre-calibrated heads, automatic units selection, scaling and zeroing allow the measurement of chromaticity, luminance, illuminance, radiance, irradiance and led output. When used with the *J1810* chromaticity head, the instrument measures, in real time, colour for matching and balancing in television studios and monitor manufacture. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

Spectrum analysis. Marconi Instruments has a new range of general-purpose and microwave spectrum analysers. The *2390 Series* consists of the 2393 for 9kHz-2.9GHz, the 2390 covering 9kHz-22GHz and the 2392 for 9kHz-26.5GHz. All three have built-in am/fm receivers and a 1Hz resolution frequency counter to allow the identification of interfering signal, and resolution bandwidth of 3Hz-30MHz enable signals from a large range of equipment to be examined. There is a 2.9GHz tracking generator for response measurements and an optional quasi-peak detector and filters are provided for emc testing. Marconi Instruments Ltd. Tel., 01438 742200; fax,01438 727601

Oscilloscope calibration. For both analogue and digital oscilloscopes, Fluke's *5500A-SC* represents a new facility for use with the *5500A* Multi-product calibrator, which itself handles thermometers, power meters, power harmonic analysers and other instruments. *5500A-SC* is a levelled sine generator at up to 250MHz for bandwidth verification, a square wave for calibrating voltage gain, a low rise-time pulse generator for pulse response and a time-marker for time-base calibration. This is a single board that plugs into an internal slot in the *5500A*. Fluke UK Ltd. Tel., 01923 240511; fax, 01923 225067.

Screened rooms. For emc testing, Seaward has modular screened rooms to provide fully rf shielded and controlled environments for pre-compliance testing. The rooms can be stand-alone or linked to existing buildings. Features include minimal cavity resonance, supply filtering, the ability to take heavy equipment and a removable panel for rfi penetration. As options, there are radio absorbent material to give a uniform field for radiated immunity test, are conditioning with waveguide protection, a revolving test table and cctv monitoring from a separate room. A larger version has a separate instrument lobby. Seaward Electronic Ltd. Tel., 0191 586 3511; fax, 0191 586 0227.

Otdr plug-ins for *FiberMaster*. Tektronix's *FG Series* plug-in modules for the *TFP2A FiberMaster* optical time-domain reflectometer are meant for use in cabling, cable head-end facilities and lans. *FG1300* works at 1310nm and the *FG1315* at both 1315 and 1550nm, both being single-mode and having temperature characteristics for indoors or temperate outdoor weather. Dynamic range at 1310nm is 31dB. Tektronix UK Ltd. Tel., 01628 403300; fax, 01628 403301.

Ethernet adaptor. The *Interphase 4221* VME Ethernet adaptor is a networking card to provide up to four Ethernet ports per VME slot. It provides a single-port version or a dual-channel type with two ports and a daughter card on the baseboard. An optional Ethernet daughter card gives two further ports. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Literature

MPS. The MPS (Maplin) components catalogue now has over 1000 pages and the latest edition includes more than 1500 new products. Two of the new sections are Navigation, which includes GPS systems, and Education, including lasers, meteorology and solar power. Equipment from resistors to computer hardware is to be found in these pages. MPS Electronics. Tel., 01702 554171; fax, 01702 553935.

Keyswitches. Low-profile keyswitches are described in a new brochure by Cherry. The *ML* switch is designed to give the full 3mm travel preferred by touch typists on standard keyboards. Cherry Electrical Products Ltd. Tel., 01582 763100; fax, 01582 768883.

Relays. Matsushita has a catalogue of relays, including power, signal, *PhotoMOS*, time delay, safety, automotive and surface-mounted types, with some ic modules. Highlights include the *AQV212 SOP*, said to be the world's smallest semiconductor type at 2.1mm high, and the *TX2*, which is rated at 60W and 220V_{max} and 2A_{max} and which withstands a 2500V rms surge. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Optical encoders. In 24 colour pages, Grayhill's new brochure describes the *Series 61* family of rotary optical encoders, including a 128 cycle/rev range. The publication contains advice on applications, describes the quadrature decoding

Interfaces

PCMCIA buffer. Elan has the *B158 Buffer Card*, which provides a simple interface between external circuits and the PCMCIA slot. It allows high-speed data transfer without signal conditioning or control, providing an interface for portable application, with eight bidirectional data lines, 15 address lines, memory read/write, i/o read/write signals and a single interrupt line. In-line resistive terminations reduce cross talk and reflection, with a view to reducing emc. A screened mini-i/o connector is used. Elan Digital Systems Ltd. Tel., 01489 579799; fax, 01489 577516.

Switchable filter. Kemo's *VBF18* is an adjustable band-pass/band-stop filter frame which can take one or two channels, each of which is mode-selectable. Frequency is adjustable by front-panel rotary switches from 0.01Hz to 99.9kHz to a resolution of three digits. In band-stop mode, it gives a notch filter response with theoretical ripple of ±0.1dB in upper and lower pass-bands, response being 1dB down at $^1/_6$ octave points and –50dB at 2% from centre frequency. Kemo Ltd. Tel., 0181 658 3838; fax, 0181 658 4084.

technique and provides a section on interfacing to controllers. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Materials

Solders and adhesives. *Multicore* has a new range of low-residue solder pastes needing no cleaning and high-performance epoxy adhesives for surface-mounted components. *Multicore NC63* paste leaves little clear residue and provides a good print definition to 16mil pitch at printing speeds up to 100mm/s in air or nitrogen. *Multicore SA-35* adhesive has a rapid cure for high-speed dispensing at over 16,000 dots/hour; it has high insulation resistance and low dielectric constant to make it electrically invisible after curing for 45-60s at 130°C. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

Production equipment

Fluid dispensers. For the accurate application of flux, masking agents, solvents and water-based materials, Intertronics supplies pens and refillable bottles in the *Fisnar Flow-Seal* range which are provided with spring-loaded nibs and a valve to control the amount of material and prevent evaporation. Nibs are available in chisel, bullet and pointed shapes in acrylic and in a polyester chisel shape. Intertronics Ltd. Tel., 01865 842842; fax, 01865 842172.

Power supplies

2V dc-to-dc. Ericsson's *PKG 4310 PI* is a new member of the *PKG* series of dc converter modules. This one offers up to 75% efficiency at 30W output, causing only 30°C case temperature rise at 1m/s air velocity, which reduces the need for heat sinking, although there is thermal protection built in. Case size is about 3in by 2in by 0.43in and the dual in-line pin layout allows mounting on 1in centres. Output is adjustable, there is a remote on/off function and a shutdown function to avoid discharging batteries during mains failure. Ericsson Components AB. Tel., 01793 488300; fax, 01793 488301.

Crt supply. Cathode-ray tube supply *M153/02* by Farnell Hivolt has been redesigned as the *CRM183* to give better performance and efficiency. Output voltage is now 18kV at 300µA, varying by less than 50V for 100µA load change at 18kV. The 600V auxiliary output is now standard and tracks the 18kV supply. The unit is controllable by a signal from a d-to-a converter or op-amp, by an internal or external reference and potentiometer or by fixed resistors. Custom versions can be supplied. Farnell Hivolt Ltd. Tel., 01234 841888; fax, 01234 824698.

720W in a 3U rack. Melcher has the *PSK* family of switching regulators, from which is available up to 720W of output at 5V-36V, with inputs up to 144Vdc and with no additional heat sink or air cooling. Features include continuous short and open-circuit protection, sense lines, true current sharing for parallel operation, inhibit and continuous output adjustment to 42.5V. The devices come in both chassis and 19in rack form. Melcher Ltd. Tel., 01425 474752; fax, 01425 474768.

Radio communications products

Tunnel-diode detectors. A family of tunnel-diode detectors in the *ACT15000* range from Anglia Microwaves exhibits output voltage stability of, typically, ±0.15dB over the –65°C to 100°C temperature range. The family operates in bands between 100MHz and 18GHz and versions are made for use in applications from broad or narrow-band ecm receivers to low-noise video amplifier inputs. Output impedances are between 75Ω and 125Ω and the square-law range is 34dBm, extended to 38dBm with load selection. No bias is needed. Anglia Microwaves Ltd. Tel., 01277 630000; fax, 01277 631111.

Antennas for mobiles. The Swedish company Carant Antenn AB offers a range of easily installed antennas for cellular phones. *GIGAtop* corrosion-proof antennas cope with all systems to 2.5GHz and complies with the European factory assembly standard, so that they can be mounted by car manufacturers, particularly since they need only 6.5mm between car body and roof lining. Also available are magnetically mounted temporary types that will withstand a speed of 120mile/h. Carant Antenn AB. Tel., 0046 8 768 03 65; fax, 0046 8 792 06 77.

Radio time. Galleon Systems has a range of modules and ics to form radio-controlled clocks, synchronised to MSF Rugby. Modules need only a ferrite antenna to receive; with an additional level-shifter, the modules drive a decoder directly. The ics receive and demodulate the MSF signal and there are three microcontroller modules to complete the clock with functions such as led drive or RS-232 interface. Also available are clock kits on a small pcb. Drivers for Windows, MS-DOS, Novell, Windows NT, DEC, Unix and Windows 95 are available. Galleon Systems Ltd. Tel., 01564 777166; fax, 01564 777169.

Switches and relays

Sil relays. From Astralux, the *Series 160 SIL* relays come in a transfer-moulded package occupying 5 by 19.5mm of board space and 4-pin solder or socket mounting. Normally open and nc contacts are available, energised by 5V, 12V and 24V, handling 100Vdc, 0.5A and 10W switching capability. Astralux Dynamics Ltd. Tel., 01403 240055; fax, 01403 255657.

Microswitches. The *D2F* range of pcb-mounted microswitches for computer mice is now extended for other uses. Measuring 12.7 by 5.8 by 6.5mm, the switches handle up to 125Vac or 30Vdc at 3A and actuators are of pin plunger, lever or roller form as standard, other types being available. A quick reverse-action mechanism gives high speed. Omron Electronics Ltd. Tel., 0181 450 4646; fax, 0181 450 8087.

Navigation systems

Piezo gyro. *Gyrostar* is a rotational angular-velocity sensor by Murata, intended for use in navigation, location systems and satellite antenna positioning. A triangular vibrating prism uses the Coriolis effect to provide output from two piezoelectric sensors mounted on the prism and driving a differential amplifier. In this way, output is much higher than that normally obtained from piezo vibratory instruments. The unit copes with seven direction changes per second at a maximum angular velocity of ±90°/s at 25°C, producing a ±2Vdc swing. Supply is 5V at 15mA. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Sil changeover. A miniature, single in-line changeover switch for pcb mounting, the *SECME 1K2* measures 10 by 2.5mm, standing 6.4mm off the board and can be mounted on a 2.54mm matrix. Contacts are gold-plated, the base is sealed and feet allow it to withstand wave soldering. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Transducers and sensors

Optical encoder. Grayhill's *61D Series* panel-mounted industrial optical encoder has a life span of over 10^6 cycles, 2.5µs and 4.5µs turn-on and turn-off times, position and direction of rotation outputs. Multiple, concentric versions, a type with one code change per detented position, extended temperature working, military specification, and various sealing and switching options are offered. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

Photosensors. Matsushita introduces the *UZC Series* of cylindrical photoelectric sensors that have a detection range of up to 12m. The sensors operate from 10-30V dc or 24-240V ac supplies and provide output from either n-p-n or p-n-p transistors, which have short-circuit protection. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Universal load cell. Control Transducers's S-Beam range of load cells copes with force measurement in compression or in tension and with weighing and is provided with a range of mounting accessories and matched output to ease corner adjustment. *PS Series* cells are in nickel-plated tool steel, encapsulated to IP67, and cover the range 20kg to 10,000kg, inaccuracy due to all causes being less than ±0.027%. Excitation required is 5-12Vac/dc and output 2mV/V from 350Ω. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

COMPUTER

Board-level products

Virtual laboratory. *Multiple Instrument Station* by ABI is a software/hardware package to emulate six measuring instruments on a pc: counters, a digital storage oscilloscope, direct-voltage probes, function generators, programmable analogue outputs and a power supply. It fits the 5.25in drive bay, so that connections are to the front panel; one expansion slot is needed. The software works under *Windows* and provides familiar-looking instrument panels and controls. ABI Electronics Ltd. Tel., 01226 350145; fax, 01226 350483.

Please quote *"Electronics World"* when seeking further information

Computers

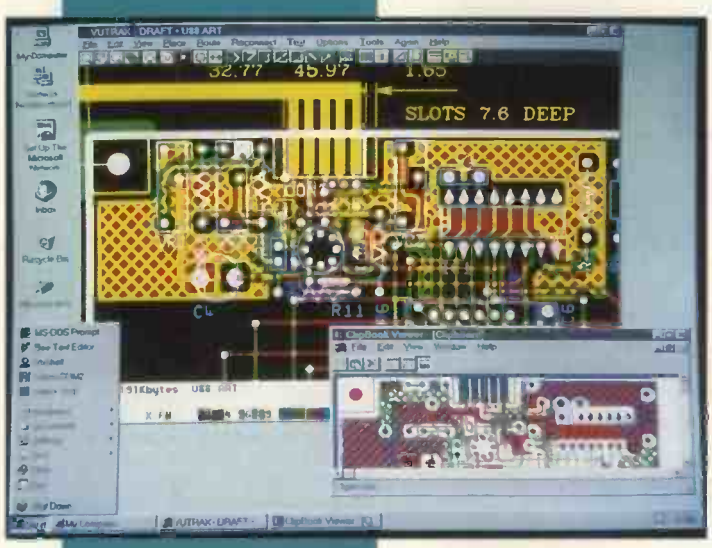
Pentium card. IMS introduces a new plug-in Pentium cpu card, the *PCA-6157*, and ISA/PCIbus unit to be used in a passive backplane or as an embedded controller. The board has temperature sensing and overheating alarm outputs. It is based on the Triton chipset, taking cpus working at frequencies from 75MHz to 150MHz. Features include both ISA and PCI local bus, PCI SCSI-II interface, two PCI Enhanced IDE hard disk interfaces, two floppy interfaces, two RS-232 Interfaces with high-speed buffers and a bidirectional parallel port. There is also 256/512Kb of extra cache and the board can accommodate up to 128MB of memory. Integrated Measurement Systems Ltd. Tel., 01703 771143; fax, 01703 704301.

Pentium motherboard. From the Apricot subsidiary of Mitsubishi comes the *Diamond PCI/ISA* motherboard, based on the Triton chipset. It is intended for "cost-sensitive" pc systems, but can be configured as a fully featured multi-media computer with audio, IRDA remote control and support for modems and live video. Optional software gives remote control of television, radio, audio, cd and telephone. The mother board supports all Pentia up to 150MHz. Apricot Computers Ltd. Tel., 0121 717 7171; fax, 0121 717 3692.

Embedded pc with display. *AXIS* from Blue Chip is an embedded pc and display which, combined with either a keyboard or touch screen, forms a complete pc for use in industrial surroundings. It comes in ac or dc versions and is contained in a nickel-plated steel enclosure, has a mono or colour display, up to 540Mbyte of hard disk storage and two 16C550 serial ports. It is intended for mounting behind a clear panel in an enclosure, but may be used as a stand-alone computer or mounted on a wall. Blue Chip Technology. Tel., 01244 520222; fax, 01244 531043.

Single-board 486. From AMC, the PC/AT-compatible *AMC-490* is an all-in-one single-board 486 (up to DX4/100) computer with an on-board svga controller, PCI-bus and ISA-bus support. Display-intensive work is eased by the use of a Trident *TGUI9440* chipset with 1 or 2Mb of video memory, allowing 32-bit graphics at up to 33MHz, and by the standard *Feature Connector*. There is also a high-speed local-bus IDE controller supporting modes 3 and 4 hard disks to enable data transfer at up to 11Mb/s. Four IDE devices, including large hard disks, cd-rom drives, tape and other types may be connected. Features include two RS-232 serial ports and a bi-directional parallel port and a floppy controller. Simm sockets can take up to 256Mb of dram. Advanced Modular Computers Ltd. Tel., 01753 580660; fax, 01753 580653.

Faster pcb design. Computamation's *Vutrax* pcb design package is now in version 11.4, in which double the previous speed and many extra features are offered for the same cost as earlier versions. Features include the provision of software in 32-bit or 16-bit form, as appropriate for the work in hand; improved Windows presentation; more checking facilities; and extra graphics config. files to include support for controllers in the 800-by-600 modes for best trade-off between speed and resolution for dos users. Computamation Systems Ltd. Tel., 01525 378939; fax, 01525 850459.



Data acquisition

Transducer control panel. Amplicon Liveline's *EX206* transducer excitation and signal-conditioning panel provides current or voltage for up to 16 channels and is intended to work with the *PC226* expandable a-to-d board. This newest 200 series board offers a wider range of excitation and software programmable analogue threshold trigger. Each input is configurable for 2, 3 or 4-wire rtds, lvdts, solid-state temperature sensors, voltage-excited 2-wire sensors and strain gauge transducers. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

PCMCIA data/fax modems. Contained in stainless steel cases, 14.4kb/s data/fax modems by *DIP Systems* use V.42bis data compression to handle data rates of up to 57.6kb/s and fax to 14.4kb/s. Three versions are the basic type, a Hayes AutoSync model and a voice-enabled unit which discriminates between voice, data and fax, reacting in the relevant manner. In this mode, the modem can behave as a digital answering machine. All models come with installation and diagnostic software, Pipex access and Tel-me software. DIP Systems. Tel., 01483 202070; fax, 01483 202023.

Data communications

PC serial interface. IMS offers the *PCL-740*, a high-speed serial port interface card, which can be switched between RS-232,422,485 or current loop. It has a *16C550* uart with an on-chip fifo buffer to reduce processing load, particularly in *Windows* applications. In RS-485 mode, a network of serial devices can be built over distances of 1200m with only two wires, the card sensing direction of in-coming data and switching transmission to suit. The card comes with a suite of software for programming and debugging, together with high-level language drivers for most of the popular development languages. Integrated Measurement Systems Ltd. Tel., 01703 771143; fax, 01703 704301.

Software

Heart education. Guildsoft has two packages on cd-rom designed to teach the basics of the heart. *SmartHeart Teacher*, in addition to the rom, with its animation and sound, contains a heart monitor to allow the user to see on the pc screen the working of his own heart; the output from the monitor is an ecg record acceptable for medical purposes and savable on a disk. *SmartHeart Plus* builds on this by allowing true single-lead arrhythmia monitoring. Output can be faxed or sent by modem to a physician. Guildsoft Ltd. Tel., 01752 895100; fax, 01752 894833.

New catalogue

This last minute entry is SSI's 1996 catalogue featuring new additions including wide range of computer cables, connectors and assemblies, loudspeakers, PA/disco equipment, instruments and hundreds of component-level products. SSI, Tel., 0181 6431126, fax 0181 6433937.

HART AUDIO KITS – YOUR VALUE FOR MONEY ROUTE TO ULTIMATE HI-FI

Hart Audio Kits and factory assembled units use the unique combination of circuit designs by the renowned John Linsley Hood, the very best audiophile components, and our own engineering expertise, to give you unbeatable performance and unbelievable value for money. We have always led the field for easy home construction to professional standards, even in the sixties we were using easily assembled printed circuits when Heathkit in America were still using tagboards!. Many years of experience and innovation, going back to the early Dinsdale and Bailey classics gives us incomparable design background in the needs of the home constructor. This simply means that building a Hart kit is a real pleasure, resulting in a piece of equipment that not only saves you money but you will be proud to own.
Why not buy the reprints and construction manual for the kit you are interested in to see how easy it is to build your own equipment the HART way. The FULL cost can be credited against your subsequent kit purchase.

K1100 AUDIO DESIGN 80 WATT POWER AMPLIFIER.

This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hifi system. This kit is your way to get úK performance at bargain basement prices. Unique design features such as fully FET stabilised power supplies give this amplifier World Class performance with startling clarity and transparency of sound, allied to the famous HART quality of components and ease of construction.
Useful options are a stereo LED power meter and a versatile passive front end giving switched inputs, with ALPS precision Blue Velvet low-noise volume and balance controls. Construction is very simple and enjoyable with all the difficult work done for you, even the wiring is preterminated, ready for instant use!. All versions are available with Standard components or specially selected Super Audiophile components at £29.60 extra per channel, plus ú2.40 if you want to include Gold Plated speaker terminals.

K1100B Complete STANDARD Amplifier Kit,.....£395.21
A1100B Factory Assembled.....£499.21
K1100SC Complete SLAVE Amplifier Kit,.....£333.62
A1100SC Factory Assembled.....£422.62
K1100M Complete MONOBLOC Amplifier Kit,.....£261.20
A1100M Factory Assembled.....£329.20
RLH11 Reprints of latest Amplifier articles.....£1.80
K1100CM Construction Manual with full parts lists.....£5.50

"CHIARA" SINGLE ENDED CLASS "A" HEADPHONE AMPLIFIER.

This unit provides a high quality headphone output for 'stand alone' use or to supplement those many power amplifiers that do not have a headphone facility. Easily installed with special link-through feature the unit draws its power from our new Andante Ultra High Quality linear toroidal supply. Housed in the neat, black finished, Hart minibox it features the wide frequency response, low-distortion and 'musicality' that one associates with designs from the renowned John Linsley Hood. Pre-terminated interconnecting leads and PCB mounted sockets prevent supply polarity reversal and on-board diagnostics provide visual indication of supply line integrity. Volume and balance controls are Alps "Blue Velvet" components. Very easily built, even by beginners, since all components fit directly on the single printed circuit board. The kit has very detailed instructions, and even comes with a complementary roll of Hart audiograde silver solder. It can also be supplied factory assembled and tested. Selling for less than the total cost of all the components, if they were bought separately, this unit represents incredible value for money and makes an attractive and harmonious addition to any hifi system.

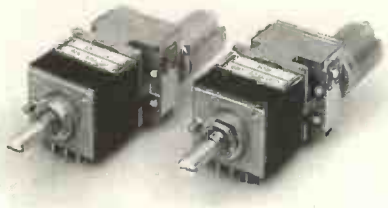
K2100 Complete Kit.....£109.50
K2100SA Series Audiophile version with selected audiophile components.....£112.46
A2100SA Series Audiophile version, factory Assembled.....£149.46
K3565 "Andante" Power Supply Kit to suit "Chiara".....£85.42
A3565 Power Supply, Factory Assembled.....£128.42
CM2100 Construction Manual.....£2.50
SPECIAL OFFER. Both units together, Kit Form.....£184.92
Factory Assembled and Tested.....£267.88

"Andante" SERIES 20VA AUDIOPHILE POWER SUPPLIES

Specially designed for exacting audio use requiring absolute minimum noise, low hum field and total freedom from mechanical noise this unit is a logical development from our highly successful 1550 series.
Utilising linear technology throughout for smoothness and musicality makes it the perfect partner for any module requiring fully stabilised ±15v supplies.
Two versions are available. K3550 has 2 ±15v supplies and a single 15v for relays etc. and can be used with our K1400 preamp and our K1450 RIAA pickup preamp, as well as other useful modules soon to be introduced. The K3565 is identical in appearance but only has the ±15v lighter current supply for use with the K1450 RIAA pickup pre amplifier or "Chiara" headphone amplifier.

K3550 Full Supply with all outputs.....£93.75
K3565 Power Supply for K1450 & K2100.....£85.42

ALPS *"Blue Velvet"* PRECISION AUDIO CONTROLS.



Now you can throw out those noisy ill-matched carbon pots and replace with the famous Hart exclusive ALPS 'Blue Velvet' range components only used selectively in the very top flight of World class amplifiers. The improvement in track accuracy and matching really is incredible giving better tonal balance between channels and rock solid image stability. Motorised versions have 5v DC motor.

MANUAL POTENTIOMETERS
2-Gang 100K Lin.....£15.67
2-Gang 10K, 50K or 100K Log.....£16.40
2-Gang 10K Special Balance, zero crosstalk and zero centre loss.....£17.48
MOTORISED POTENTIOMETERS
2-Gang 20K Log Volume Control.....£26.20
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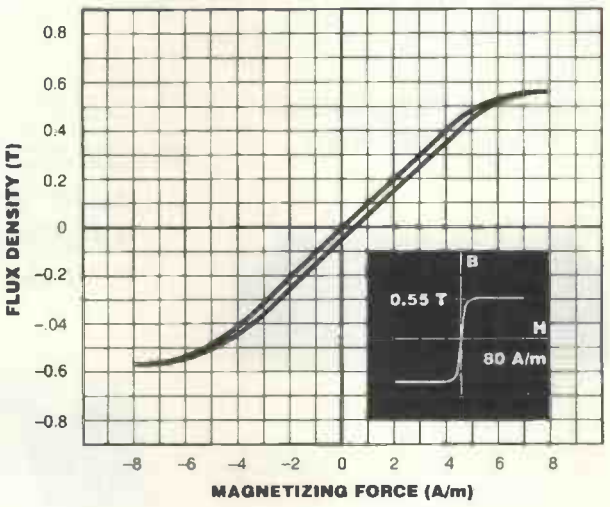
APPLICATIONS

High permeability cores for emi filtering

Detailed in a technical bulletin from Allied Signal is a highly permeable core designed with a highly flat or 'sheared over' dc hysteresis loop.

High permeability, typically greater than 90,000 at 1kHz, 2mA/cm, makes these cores particularly effective for noise suppression applications, such as electromagnetic interference filtering. Major benefits include high attenuation for excellent suppression of electromagnetic noise and low profile. Weight and volume reductions of up to 50% are possible and core loss is low.

Other applications include high accuracy current and pulse transformers as well as ground fault protection devices.



Curve results from cores designed to exhibit a flat or 'sheared over' dc hysteresis loop. Resulting benefits include high initial permeability over a wide range of operating frequencies, high accuracy and low core loss.

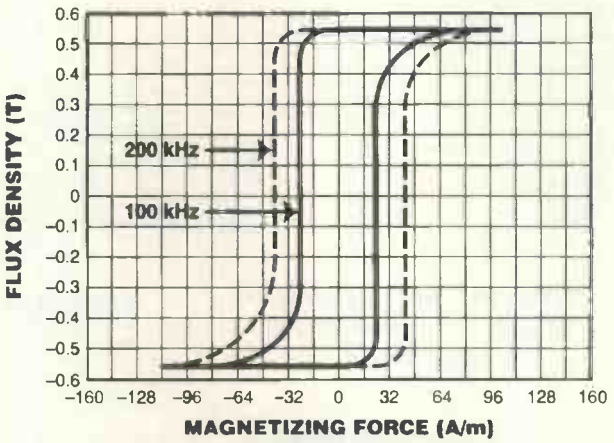
Square-loop cores for magnetic amplifiers

Square loop cores detailed in a further Technical bulletin from Allied Signal claim to be able to operate at higher frequencies than previously possible. In addition, they are said to enable magnetic amplifiers to be made with unparalleled precision and output regulation efficiency.

Magnetic amplifiers can be used for outputs with currents of 1A to several tens of amps but they are also used at lower currents, where tight regulation and efficiency are important.

Conventional regulated outputs are limited at higher frequencies and output currents, and linear regulators are inefficient. Independent switch-mode sub-regulators avoid the inefficiency, but they also require more complex and expensive circuitry relative to a magnetic amplifier.

***AlliedSignal Inc**, Amorphous Metals, 6 Eastmans Road, Parsippany NJ07054, USA, tel (201) 581 7653, fax (201) 581 7717.*



Square loop magnetic cores are designed to exhibit an extremely square dc hysteresis loop and high B_{SAT}.

Power controller designed with emc in mind

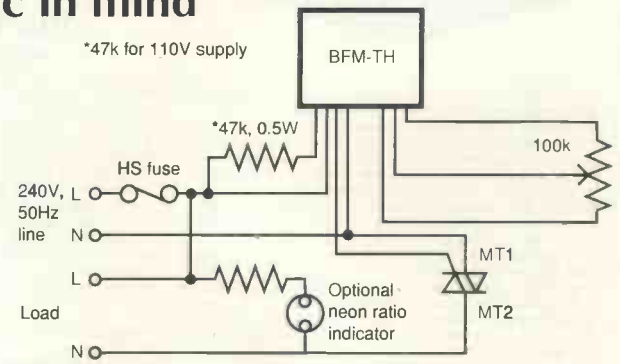
A power controller designed specifically to comply with the soon to be introduced emc regulations is described in an editorial feature form Sutronics.

The *BFM-TH* burst firing trigger circuit requires only the inclusion of a 100kΩ potentiometer and suitable triac to give a compact versatile power supply.

Unlike phase-angle controllers and electromechanical contactors, the device generates virtually no radio-frequency interference. This is a result of switching occurring when the supply waveform is within ±5V of the zero-crossing point. Also, because the switching element is a triac, there are no moving contacts and as a result no arcing.

Due to the controller operating on a burst-fire principle manual control of resistive loads such as hot plates, ovens etc can be achieved.

***Sutronics,** 62 Park Road, Swanage, Dorset BH19 2AE, tel/fax 01929 426400, email: sutronics@tcp.co.uk.*



Powered either by 220/240V or 110/120V this circuit offers current drain of less than 2.5mA, which is said to be significantly lower than for other burst-fire controllers. With pulse duration of 0.1ms and an amplitude of 2.5V at 100mA the circuit is capable of driving any triac with a gate current up to 100mA.

90% smps efficiency using flyback topology

Data sheet *PWR-TOP200-4/14* from Power Integrations details the operation, device characteristics and application issues of the company's three-terminal off-line pulse-width modulation switch family.

TOPSwitch is a self biased and protected current-to-duty cycle converter with linear control and an open drain output. High efficiency is achieved through the use of cmos combined with high integration. Integration eliminates the external power resistors normally needed for current sensing and/or supplying initial start-up bias current.

This three pin device implements buck, boost, flyback or forward topology and will easily interface with both opto and primary feedback. Supporting continuous or discontinuous operating modes, it is intended for 100, 110 or 230V ac off-line power supply applications in the 0-100W range. The device can also be used for 230/277V ac off-line power factor correction up to 150W.

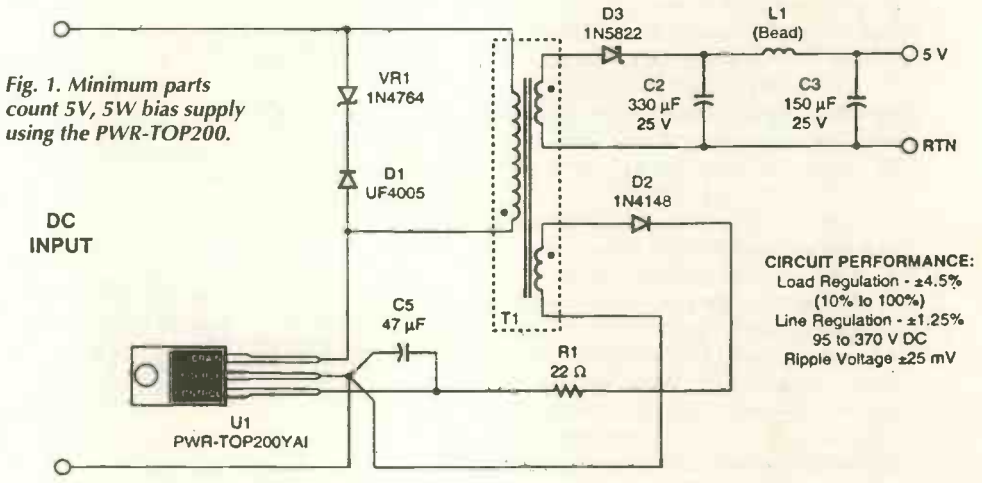


Fig. 1. Minimum parts count 5V, 5W bias supply using the PWR-TOP200.

Primary feedback regulation

Figure 1 is a simple 5V, 5W bias supply based on the *PWR-TOP200*. This universal-input flyback power supply employs primary-side regulation from a transformer bias winding. Line and load regulation of ±5% or better can be achieved from 10 to 100% of rated load.

Voltage feedback is obtained from T_1's bias winding, eliminating the need for an opto-coupler and secondary-referenced error amplifier. High-voltage dc is applied to T_1's primary winding. The other side of the transformer primary is driven by the integrated high-voltage mosfet transistor within the *PWR-TOP200*.

The clamp circuit implemented by VR_1 and D_1 limits leading-edge voltage spikes caused by transformer leakage inductance to a safe value. The 5V power secondary winding is rectified and filtered by D_3, $C_{2,3}$ and L_1 to create a 5V output voltage.

Output of the T_1 bias winding is rectified and filtered by D_2, R_1 and C_5. Voltage across C_5 is regulated by U_1, and is determined by the 5.7V internal shunt regulator at the control pin of U_1.

When rectified bias voltage on C_5 begins to exceed the shunt regulator voltage, current flows into the control pin. Increasing control pin current decreases the duty cycle until a stable operating point is reached.

Output voltage is proportional to bias voltage by the turns ratio of the output to bias windings. Capacitor C_5 is used to bypass the control pin. It also provides loop compensation for the power supply by shunting ac currents around the 'control' pin dynamic impedance. In addition, it determines the auto-restart conditions.

Boost PFC pre-regulator

As a fixed frequency, discontinuous mode boost pre-regulator, the *TOPswitch* can be used to improve power factor and thd in applications such as power supplies and electronic ballasts. **Figure** 2 operates from 230V ac, delivering 70W at 430V dc with typical power factor of over 0.98 and a thd figure of 7%.

Bridge rectifier BR_1 full wave rectifies ac input voltage. A boost power stage comprises L_1, D_1, C_4 and the *TOPswitch*. Diode D_2 prevents reverse current through the device's body diode due to ringing voltages generated by the boost inductance and parasitic capacitance.

Resistor R_1 generates a pre-compensation current proportional to the instantaneous rectified ac input voltage which directly varies the duty cycle. Capacitor C_2 filters high frequency switching currents while having no filtering effect on the line frequency pre-compensation current.

Resistor R_2 decouples pre-compensation current from the large filter, C_3. This prevents an averaging effect which would increase thd. Capacitor C_1 filters high frequency noise currents to prevent errors in the pre-compensation current.

When power is first applied, C_3 charges to typically 5.7V before the *TOPSwitch* starts. It the provides bias current until the output voltage becomes regulated. When this occurs, series connected zener diodes $VR_{1,2}$ begin to conduct. They drive current into the control pin, and directly control the duty cycle.

Capacitor C_3 together with R_3 performs low-pass filtering on the feedback signal to prevent output line frequency ripple voltage from varying the duty cycle.

***Power Integrations Inc**, 411 Clyde Avenue, Mountain view, California, 94043. Applications Hotline, (800) 552-3155, fax, 468-0809*

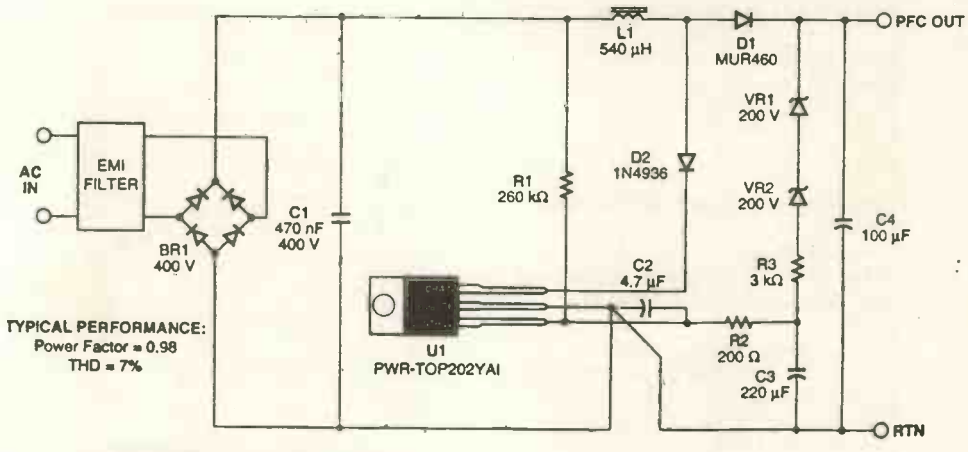


Fig. 2. 70W, 230V ac input boost power factor correction circuit using the PWR-TOP202.

20mA vco operates to over 1GHz

Described in Motorola's *ECLinPS LITE* technical data book is a low-power voltage controlled oscillator designated the *MC12148*. This *LC*-tank-based device operates at up to 1100MHz. Housed in 8-pin SOIC packaging, it needs just 20mA from a 5V supply, and it features a phase noise of typically –90dBc/Hz at 25kHz.

The *MC12148* requires an external parallel tank circuit comprising an inductor and capacitor. A varactor diode may be incorporated into the tank circuit to provide a voltage-variable input for the oscillator. Alternatively, the *12148* is suitable for many fixed-frequency applications, but it will not operate in conjunction with a quartz crystal.

Based on the vco circuit topology of the *MC1648*, the device uses advanced bipolar process technology which results in a design capable of operating at a much higher frequency, but needing only half the current.

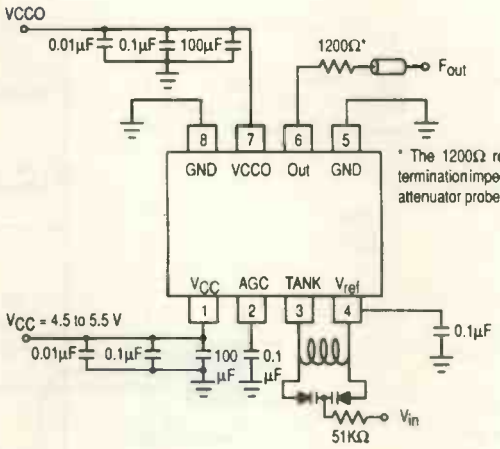
Typical frequency stability of the *12148* is 3.6kHz/mV with supply fluctuations, but only 0.1kHz/°C with temperature change. Second harmonic from the carrier is –25dBc, while signal-to noise ratio is 40dB.

Emitter-coupled logic output circuitry of the *12148* is not a traditional open emitter output structure. Instead it has on-chip termination with a nominal value of 500Ω. This facilitates direct ac-coupling of the output signal into a transmission line.

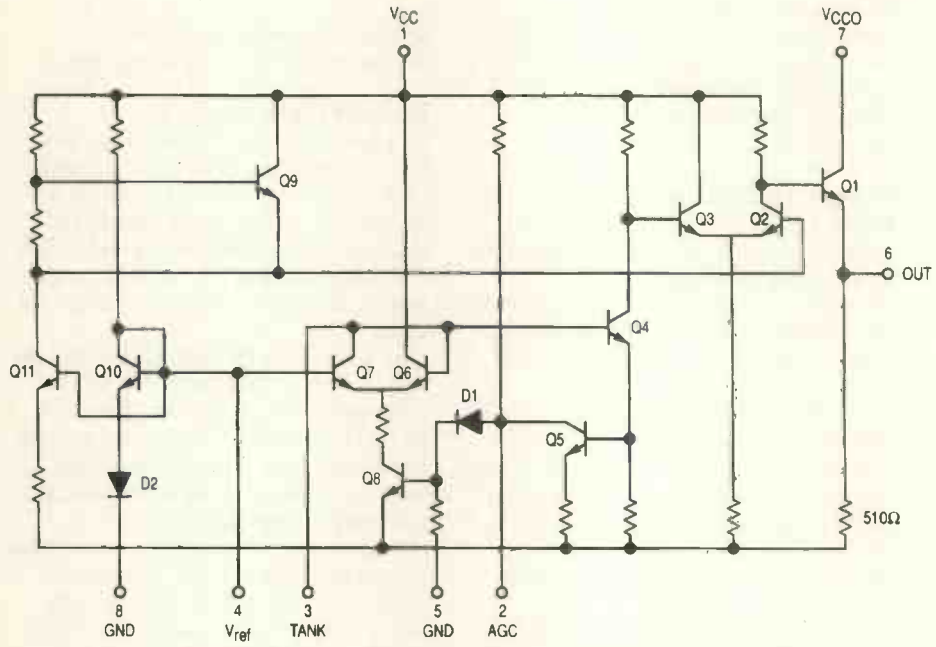
Because of this output configuration, an external pull-down resistor is not required to provide the output with a dc current path.

Output is intended to drive one ecl load. If you need to fan the signal out, an ecl buffer such as the *MC10EL16* line receiver/driver is useful.

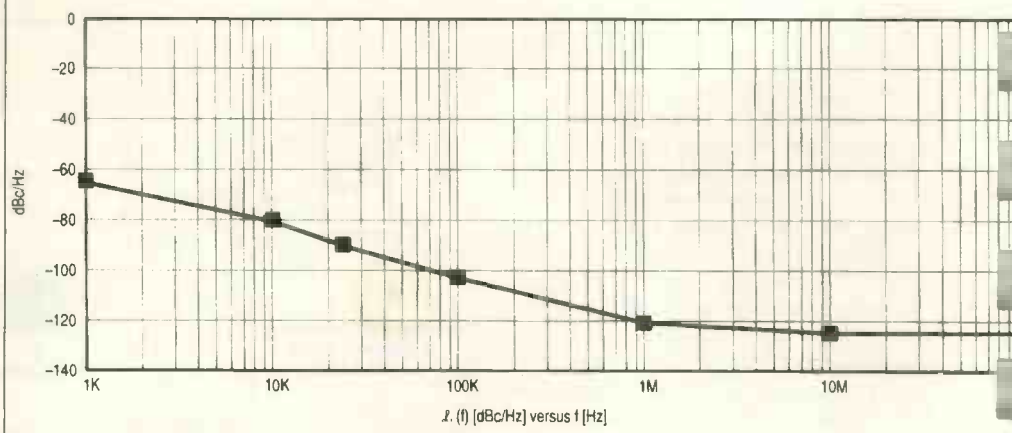
Motorola Semiconductor Products Sector, *Buckingham Street, Aylesbury, AY1 1XX, tel 01296 395252, fax 01296 21999.*



Typical test circuit for the gigahertz low-power vco. Operating from a nominal supply of 5V, the device is also useful in applications requiring a fixed frequency.



Internals of the MC1248 vco. The device exhibits a phase noise of –90dBc at 25kHz.



Typical evaluation results with the low power oscillator, 930MHz cw.

Tank component suppliers

Below are suppliers who manufacture tuning varactors and inductors which can be used to build an external tank circuit

Coilcraft Inductors A01T thru A05T
Coilcraft-Coilcraft, Inc
1102 Silver Lake Rd
Gary, Illinois 60013
tel, 708-639-6400

Loral Tuning Varactors GC1500 Series
Loral
16 Maple Road
Chelmsford, Massachusetts 01824
tel, 508-256-8101 or 508-256-4113

Alpha Tuning Diodes DVH6730
Alpha Semiconductor Devices Division
20 Sylvan Road
Woburn, MA 01801
tel, 617-935-5150

Distortion BY design

Building on his previous articles discussing ac analysis with Spice, Owen Bishop details how distortion can be assessed on a pc.

More advanced versions of Spice include the command .DISTO for analysing distortion. Here, I use the routine included in *IsSpice*. This does not adhere exactly to Spice syntax, but it does cover much the same aspects of circuit behaviour.

Before looking at the routine in operation, it is instructive to examine the test circuit using the standard ac frequency sweep. The circuit is a wide-band amplifier based on a single rf transistor, **Fig. 1**. Its frequency range is extended by including an inductor in the collector circuit. Assuming that other component values are suitable, it is necessary to settle on a suitable value for the inductor which will give an extended but reasonably flat-topped frequency response.

Draw the schematic and enter component values, including the voltage source, V2 1 0 AC 1. Use the Edit control box to add the .AC command statements to the netlist. The lines required here are, .AC DEC 10 1K 100MEG, and .PRINT AC V(2). These call for the voltage at node 2 to be displayed for a frequency sweep from 1kHz to 100MHz, with ten steps per decade.

Overall response

Select Simulate from the Actions menu. When the analysis is complete, the Simulation Status screen displays a small graph of V(2) in decibels against frequency. These plots are intended only to give an overall picture of the response, not for reading off values. In fact, there are no values displayed on the x-axis and only the lowest and highest level marked on the y-axis.

Often the plot does not completely fill the frame in the vertical direction. As a result, its shape is somewhat obscured and the curve is flatter than it would be with a better choice of scale on the y-axis.

This can be remedied. Click twice on the plot; when the Rescale Plots dialogue box appears, click on the Auto button, then on the OK button. The plot is re-displayed with a more sensible scale. Of course, the associated *Intuscope* program provides much clearer plots with fully graduated axes, but the small plot is good enough for the moment and allows the overall effects of sweeping component values to be observed.

Sweeping inductances

Sweeping the inductor value is most easily done by using the Simulation Control dialogue box. I normally keep this minimised as an icon, because it obscures the plots when there are more than two on the screen. Clicking on the icon restores the box, **Fig. 2**.

Now click on the Persistence panel and enter '10'. This allows up to ten curves to be displayed before the plot is cleared and renewed. Click on the Stimulus button to bring up the Stimulus Picker dialogue box. Click on l1 to list the sweepable parameters associated with the inductor. Double-click on Inductance.

At this point, a small control panel headed 'l1:inductance' appears and displays the present value of the inductance, 10µH. Frequency response that is already displayed shows a sharp peak which indicates that this inductance is too large. Clicking on one of the buttons in the row below increases or decreases inductance, the buttons further to the left or right effecting the biggest change.

Check the Always option, then place the mouse on the next-to-leftmost button and hold down the mouse button. Inductance is decreased in steps of 1µH and at each step the simulation is re-run and its output curve displayed. In Fig. 2, the top curve with the prominent peak is for 10µH and the bottom one for 1µH.

The shape of the lower curve shows that 2µF is too small a value, insufficiently extending the amplifier's bandwidth.

The best response, with no appreciable

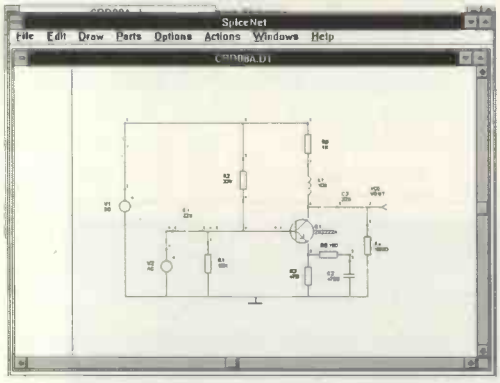


Fig. 1. This wide-band amplifier includes an inductor to extend the response curve into the higher frequencies. A search for a value of inductor L1 to give widest frequency response with minimum distortion is the subject of most of this article's analyses.

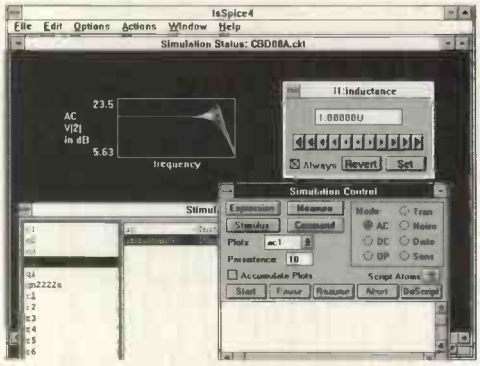


Fig. 2. The first step in the investigation is to sweep the value of inductor L1 of Fig. 1 and plot the frequency response at the output node 2. This screen illustrates a quick and easy way of doing it.

Defining distortion

When a pure sinewave passes through a circuit, its shape is almost always altered. The distorted non-sinusoidal shape of the output signal can be described as the sum of the original fundamental sine wave, frequency *f*, plus sine waves of frequencies 2*f*, 3*f*, 4*f*..., *nf*, the harmonics. Amplitudes of the harmonics usually differ from each other and from the fundamental. Some harmonics may have zero amplitude. The fundamental and harmonics may also differ in phase.

Usually, the fundamental has the greatest amplitude. Amplitudes of the harmonics decrease with increasing order. For this reason the biggest contributor to harmonic distortion is the second-order harmonic, followed closely by the third-order. In a distortion analysis, Spice calculates the amplitudes of both second and third-order harmonics.

This can be done for a single value of the fundamental or, more often, input frequency is swept over a given frequency range and distortion is calculated at a number of points within this range. In Spice2 distortion is expressed with reference to the fundamental's amplitude. Second-order harmonic distortion, HD2, at any given frequency of the fundamental is calculated as the amplitude of the second-order harmonic, divided by the fundamental's amplitude. Third-order distortion, HD3, is calculated similarly.

Harmonics of the fourth and higher orders can usually be ignored and are not calculated. Note that values of the distortion terms are ratios, so they have no units.

Another type of distortion is produced if the input signal consists of at least two simultaneous sine waves. If two signals have frequencies f_1 and f_2, the output signal contains 'sum and difference' signals, with frequencies (f_1+f_2) and (f_1-f_2). This is known as intermodulation distortion. Amplitudes of these signals (relative to the fundamental) are calculated by Spice as SIM2 and DIM2. Not only is there intermodulation between the fundamentals but it also occurs between the fundamental and the harmonics.

An enormous number of intermodulation signals is obtained, even with relatively few harmonics, but usually most of these are insignificant. Spice calculates only one of these signals, $(2f_1-f_2)$. The command line refers to this as DIM3. The two harmonic distortion values and the three intermodulation values constitute complete distortion analysis.

The range of a Spice distortion analysis is specified in the accompanying .AC command, for example,

```
.AC DEC 10 100 10MEG
```

This specifies 100Hz to 10MHz, with ten steps per decade. Distortion is calculated for a load resistor, described by,

```
.DISTO ROUT 5 0.9 1M 0.25
```

ROUT is the netlist name of the output resistor. Distortion is to be calculated for every fifth step, that is twice per decade. Analysis is for two frequencies, with $f_2/f_1=0.9$ – the ratio must always be between 0 and 1. Power developed by the fundamental in the output resistor is set at a reference level of 1mW – this is the default, so this parameter can be omitted. Amplitude of f_2 is 0.25 times that of f_1. Output is specified by a line of the form,

```
.PRINT DISTO HD2 HD3 SIM2 DIM2 DIM3
```

This calls for values of all five distortion terms, based by default on the magnitudes of the amplitudes. Output can also be calculated in terms of real (R) or imaginary (I) components, or for phase (P), by keying these letters after the appropriate terms. Values on a decibel scale are obtained by including DB, for example,

```
.PRINT DISTO HD2 (R) HD2 (I) HD3 (DB).
```

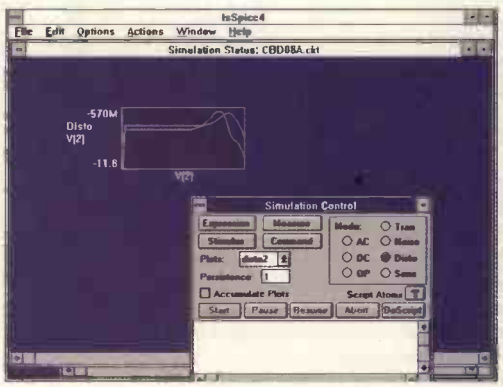


Fig. 3. A plot of the distortion analysis shows how second and third order distortion vary with frequency.

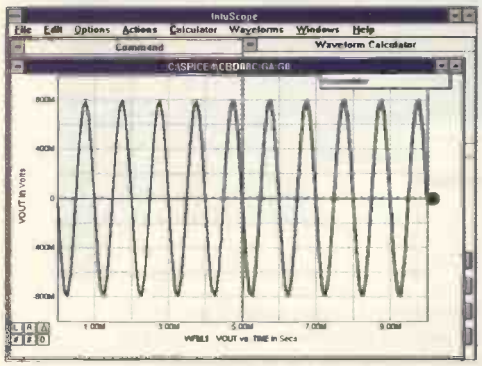


Fig. 4. Transient output of the amplifier (L1=4μH) when the input is a 1kHz sine wave with an amplitude of 0.1V.

peak and with maximum bandwidth, occurs when inductance is 4μH. Working in this way makes selection of component values easy, and is one of the more novel and useful facilities of this simulator.

Circuit analysis

Having found a value which provides the widest bandwidth and a level response, analyse the circuit for distortion. *IsSpice* syntax differs slightly from Spice2 – see panel 1. Command lines are,

```
.DISTO DEC 10 1K 100MEG
.PRINT DISTO V(2)
```

The .DISTO line has the same format and syntax as the usual .AC line. The .PRINT line specifies the output node. There is no need to state which distortion term is required, since amplitudes of both second and third-order harmonics are calculated automatically. Also make additions to the voltage source statement,

```
V2 1 0 AC 1 DISTOF1 DISTOF2 0.1
```

The DISTOF additions specify magnitudes of the signals f1 and f2 during the frequency sweep. Only DISTOF1 is used for calculating harmonic distortion. DISTOF2 is used if intermodulation distortion is being calculated.

By default, as with DISTOF1 above, magnitude of the f1 signal is 1 and 0.1 for the f2 signal. A second value after each of the two

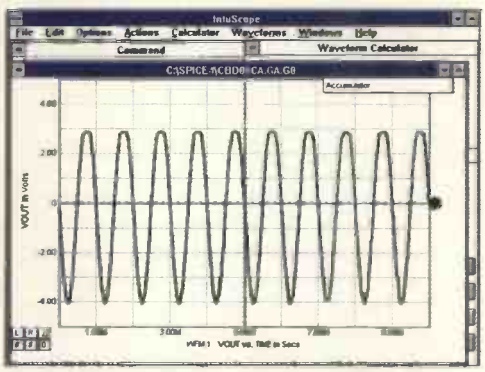


Fig. 5. Increasing input amplitude to 0.5V shows the beginnings of clipping and general asymmetry of the curve. Although the curve looks like a sine wave, thd is nearly 10%.

keywords can be used to specify their phases, the default of which is 0°. DISTOF may be used with more than one independent voltage source in the same circuit.

Note that *IsSpice* calculates amplitudes (in volts), not the ratio between the harmonic and fundamental amplitudes, as in Spice2. HD2 and HD3, if required, are obtained by using a calculator.

Figure 3 shows initial results of the analysis with a 4μH inductance. To begin with, the screen shows only second-order distortion. This is indicated by the legend DISTO1 in the Plots panel of the Simulation Control box. To

plot both terms on the same grid, click on the Start button. This plots both second and third-order amplitudes as shown in the figure. The curve with the pronounced peak is the third-order curve.

Distortion curves can not be plotted in *Intuscope*. For precise details, look in the Output file – Exit the simulation, select Edit Text Files, then click on the OUT button. This displays the output file which lists amplitudes of both of the frequencies as they are swept over the prescribed range. Both curves have a similar shape.

Over a wide range at the lower frequencies, amplitude is almost constant, increasing by no more than 1% of its 1kHz value. It then rises fairly sharply to a peak at the high-frequency end, falling steeply beyond the peak. **Table 1** summarises these features for this and subsequent analyses. Comparison with the ordinary ac analysis-results shown in **Table 2** shows that at, 1kHz, second-order distortion is 0.42/8.05, i.e. 0.05 of the fundamental, ie HD2 is 0.05. It rises to about 0.15 where the curves peak, between 12 and 15MHz.

Intermodulation values are obtained by re-running the same simulation after adding the f2/f1 value to the .DISTO line. These too are summarised in Table 1, which shows that they are relatively unimportant. For example, the sum and difference distortions when L1=4μH are only 0.01 of the fundamental at 1kHz.

Repeating analyses with L1=10μH presents a different picture. Behaviour of the amplifier is unaffected at low frequencies, starting at 1kHz, but the frequency at which distortion begins to exceed 1% is much lower than when L1 is 4μH. The distortion peaks to higher values and the intermodulation distortions also peak at lower frequencies. These results confirm that 4μH is a preferable value for L1.

Further investigation of distortion in more detail can be undertaken using a full print-out of the output files and a calculator, but this short discussion illustrates some of the ways in which distortion may be examined.

THD analysis – a different angle

Transient analyses include a routine that is also of value in examining distortion. If a pure sine wave of given frequency is fed into a circuit, the composition of the set of harmonics emerging at the output indicates the degree of distortion.

Ideally, only the fundamental should appear at the output, but circuits are nearly always far from ideal. The Fourier analysis, .FOUR, examines the output signal and computes amplitudes of the fundamental and its harmonics.

It sounds as if .FOUR does the same things as .DISTO. There are some points of similarity, but the way in which they are carried out is totally different. A .DISTO analysis is preceded by an .AC analysis, which applies small-signal inputs to the circuit when at its dc operating point.

Non-linear components are linearised during the analysis. A .FOUR analysis, by contrast, simulates the action of the circuit in the time domain. All voltage and current sources are fully operational, and with intrinsically non-linear devices behaving in their non-linear ways.

Results are saved in a file that lists one or more output values at each instant in time.

Table 1. Key values of distortion in the amplifier circuit of Fig 1.

Inductance of L1	Distortion term	Initial amplitude (V)	up to (MHz)	Peak amplitude (V)	at (MHz)
4μH	2nd-order	0.42	0.63	1.26	15.8
	3rd-order	0.35	0.32	1.08	7.9
	f_1+f_2	0.08	1.26	0.18	25.1
	f_1-f_2	0.08	1.26	0.18	25.1
	$2\times f_1-f_2$	0.11	0.5	0.31	12.6
10μH	2nd-order	0.42	0.40	4.03	15.8
	3rd-order	0.35	0.32	2.24	7.9
	f_1+f_2	0.08	0.79	0.47	15.9
	f_1-f_2	0.08	0.79	0.47	15.9
	$2\times f_1-f_2$	0.11	0.39	0.66	10.0

Table 2. Amplitude of the fundamental at the amplifier output (Node 2).

Inductance of L1	Initial amplitude (V)	up to (MHz)	Peak amplitude (V)	at (MHz)
4μH	8.05	6.3	8.25	12.6
10μH	8.05	1.6	13.57	15.8

Fourier and transient analysis

Next follows the .FOUR analysis. This takes the results of the Transient analysis and mathematically analyses them to characterise the set of sine waves that constitutes the waveform. Spice2, and consequently *IsSpice*, determines amplitudes and phase angles for the fundamental and the first nine harmonics *f* to 9*f*. This takes harmonic analysis further than the .DISTO routines.

For comparison with the .DISTO analysis, take the netlist for Fig 1 and edit it for transient analysis followed by .FOUR. Delete lines containing AC and .DISTO, including the statement defining V2. Then add these lines,

```
.TRAN 10U 10M
.FOUR 1K V(2)
V2 1 0 SIN (0 0.1 1K)
.PRINT TRAN V(2)
```

Since Fourier analysis depends on data produced by a transient analysis, it is essential to include the .TRAN line, even if the precise shape of the transient curve is of no particular interest. The line quoted above specifies time steps of 10μs lasting for a total of 10ms – M is 'milli' in Spice. The .FOUR line sets the fundamental frequency to 1kHz, and the value to be analysed is the voltage at node 2.

The voltage generator is set up between nodes 1 and 0, excited by a sine wave, delay zero, amplitude 0.1V, and frequency 1kHz. Total time of the analysis allows for ten complete cycles of the waveform, although only the final cycle is analysed by .FOUR. This gives time for the circuit to get into a steady operating state.

In a transient analysis capacitors begin uncharged, unless initial values are set. Similarly, inductors begin with zero current through them and with zero induced emf. In a simple circuit such as this, values reach steady levels after fewer than ten cycles, but it is a safe habit always to run for at least ten cycles.

Select Simulate from the Actions menu; the Simulation Status screen displays a plot of ten sinusoidal cycles, or rather, ten inverted sinusoidal cycles, since this is an inverting amplifier. Select Scope, then select VOUT=V(2) on the Waveform menu.

Transient analysis is displayed as in **Fig. 4**, and is a typical inverted sine wave with no visible distortion. Exit *Intuscope*, then Exit Simulation Status, select Edit Text Files and click on the Out button. The output file has the usual netlist, followed by a table of the Initial Transient Solution (dc operating point values), Fourier analysis, and data generated by the Transient analysis. Running the analysis for ten more-or-less repetitive cycles creates a lot of data – 20 pages of it, if printed out.

Fourier analysis table **Table 3** begins with a statement of the thd. Harmonic zero is the dc component of the waveform. This is listed separately in some other implementations of Spice. Harmonic one is the fundamental, which has an amplitude of 0.785732V, and lags 179.85° behind the input signal. This verifies the statement above that this is an inverting amplifier. The table lists Magnitude and phase angle – relative to the input signal – for the nine harmonics.

Amplitudes tend to fall off with increasing order, though harmonics five and six are slightly larger than harmonic four. Phase

Total harmonic distortion

This is calculated from,

$$THD = \frac{\sqrt{(a_2^2 + a_3^2 + \ldots a_9^2)}}{a_1} \times 100$$

where a_1 is the amplitude of the fundamental, and a_n is the amplitude of the n^{th} harmonic. It is a useful single-value measure of the overall distortion.

Table 3. Fourier analysis – values rounded to three significant from six.

THD: 0.518%

Harmonic	Frequency	Magnitude	Phase	Norm. Magnitude	Norm. Phase
0	0	–0.00181	0	0	0
1	1000	0.786	–180	1	0
2	2000	0.00405	90.9	0.00515	271
3	3000	0.000359	161	0.000457	341
4	4000	0.000109	125	0.000136	304
5	5000	0.000119	138	0.000152	318
6	6000	0.000111	143	0.000142	322
7	7000	0.000106	156	0.000134	336
8	8000	0.000102	155	0.000130	335
9	9000	7.37e–005	172	9.37e–005	352

angles for harmonics three to nine lead the input by between 125° and 172° respectively. Absolute values are sometimes of interest, but it makes possible comparisons between tests under different sets of conditions if the values are normalised.

The last two columns of the table show magnitude and phase angle normalised so that the fundamental has amplitude 1, and phase angle 0°.

Looking for distortion

Table 3 shows what happens to a small signal at a frequency that is comfortably within the bandwidth of the amplifier. As expected, distortion is minimal.

Repeat the analysis after editing the netlist to make L1=10µH. Figures obtained show differences only in the last or next-to-last of the six significant figures. Overall there is a slight increase in amplitudes but they are negligible.

Whether inductor L1 is 4µH or 10µH is immaterial when frequency is low. Fourier analysis operates at only one frequency; it does not sweep the frequencies as does .DISTO. As a consequence, edit these lines of the netlist to,

```
.TRAN 800P 800N
 .FOUR 12MEG V(2)
 V2 1 0 SIN (0 0.1 12MEG)
```

Edit L1 to a value 4µH. Run the analysis as before. The waveform appears undistorted but the analysis shows a thd of 1.36% – more than at 1kHz, though not excessive.

Normalised amplitude of harmonic two is 0.0136 and that of harmonic 3 is 0.0073, both are appreciably larger than before. But the fourth and subsequent harmonics are very small – there is a change of pattern. Alter L1 to 10µH and repeat. Thd increases to 2.8247% and harmonics increase roughly in proportion.

Clipping

One important application of .FOUR is to investigate clipping and similar forms of distortion. This is quite outside the scope of .DISTO.

Using the same circuit as above, re-edit to the lowest distortion settings – with a frequency of 1kHz and L1 at 4µH – but increase amplitude of V2 to 0.5V. The simulation shows a waveform that is clipped but only just, **Fig. 5**. Fourier reveals a generally unacceptable thd of 9.67%. Second and third harmonics contribute most to this (normalised amplitudes 0.0874 and 0.0375) but the fourth and subsequent harmonics are lower than before. ■

Using frequency spectra

Many simulators lack .DISTO but Fourier analysis can be used for assessing harmonic distortion. In SpiceAge, enter a netlist to describe the circuit of Fig. 1, with L1 equal to 4µH, and with V2 amplitude 100mV, sine excitation at 1kHz. Set probes to measure the input signal (node 2) and the output signal (node 7).

The procedure is to run a transient analysis and use the Fourier option to analyse and display the result. SpiceAge performs a Fast Fourier Transform on the whole wave train not just the last cycle. For most accurate results, sample several cycles and make the sampling period cover an integral number of cycles. In the Sweep Times dialogue box, set start time to zero, stop time to 5ms and step time to 10µs. This gives time for 5 cycles of the waveform. Run a Transient analysis which shows a sine wave, amplitude 0.725V, **Fig. 6**.

Follow with a Fourier analysis but first use the Probe Control box to de-select the input probe, as we do not need to analyse the pure sinewave input. Also in the Graph Scaling box, set the x-axis maximum to be held at 10k. Frequencies higher than this have such a low amplitude that they may be ignored.

Under Y-display mode, select Lines to Origin – to give a spectrum – and Phase Plot. Only the fundamental (1kHz) and the first two harmonics appear, **Fig. 7** – the rest are too small to show on this scale. One way to bring more into view is to select dB scale under Y-display mode. This will also bring into view lines for many other frequencies, some of which may be cross modulations but many of which will be 'mathematical noise'. To cut these out, set the y-axis minimum to be held at –85dB. Frequencies at amplitudes less than this may certainly be ignored.

It is clear from these results, **Fig. 8**, that the distortion products of this circuit are all so small that they can be ignored.

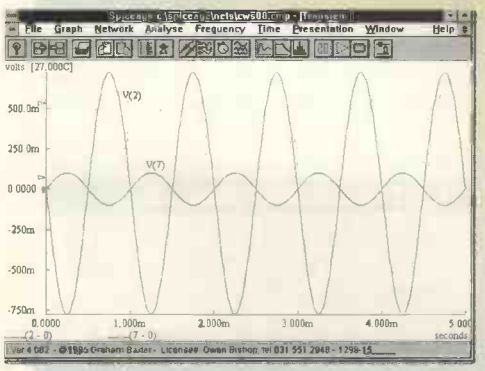


Fig. 6. Amplifier input and output contrasted. SpiceAge allows several graphs to be plotted on one set of axes, with suitable scale factors and offsets on the Y-axis, so as to display all curves in the most intelligible fashion.

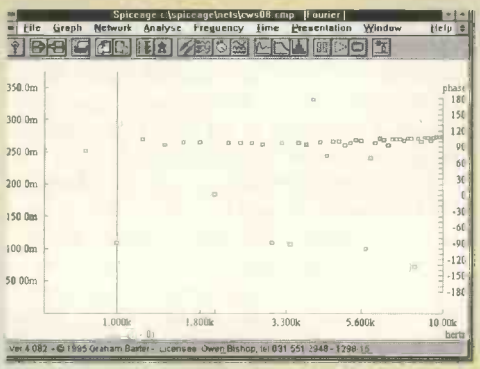


Fig. 7. Fourier analysis by SpiceAge shows the fundamental plus a miniscule 2nd-order harmonic. Phase plots are relative to an input with phase angle +90°; add 90° to displayed values.

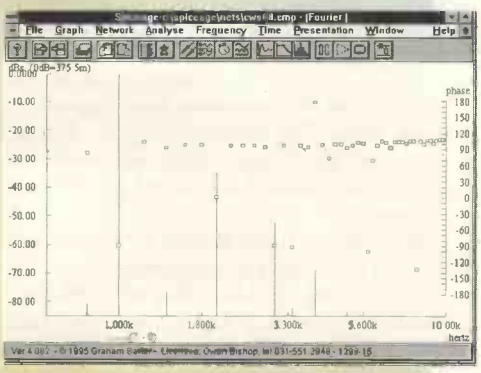


Fig. 8. A plot on the dB scale shows more harmonics, most of which are too small in amplitude to contribute significant distortion.

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***FM TRANSMITTER KIT** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £15 REF: EF62 (kit) Transmits to any FM radio.

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER COMPLETE WITH COINSLOT MECHANISMS originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? SALE PRICE JUST £2.50 REF SA23

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- An external power line for use with the experiment section.
- Various connection lines and block jumpers.
- The comprehensive PAL TRAINER User's Manual. This has been written in precise, easy-to-understand English, and takes the student right from unpacking and setting up the system, through a short demonstration program which runs without the need to do into PALASM and then, in a gentle step-by-step sequence, through 23 separate experiments.
- The complete PALASM software package, whose separate manual also contains a number of example programs.

SIMPLE, FAST, FRIENDLY

The design parameters of THE PAL TRAINER were that it should:

- run on IBM XT, AT or compatibles - with no need for ANY other hardware.
- provide a complete training course, from initial logic design, to PC simulation, device programming & testing.
- be enjoyable, readily-understandable, but fully applicable to 'real-world' situations.
- include a top programming language - in this case AMD's PALASM Version 4, widely regarded as the PLD standard. Version 4, incidentally, can be linked to other schematic packages such as OrCad.

USING THE SYSTEM

The two main parts of the PAL TRAINER are the programmer and the applications sections.
Using the programmer section, up to 3 GAL devices are placed in ZIF sockets, and programmed from the PC using the supplied software. This lets you choose a particular PAL to emulate, loads a JEDEC file into memory (either generated from the PAL TRAINER's own software or any other appropriate software package), downloads the JEDEC file to the GAL, and even lets you 'view' the GAL once it has been programmed.

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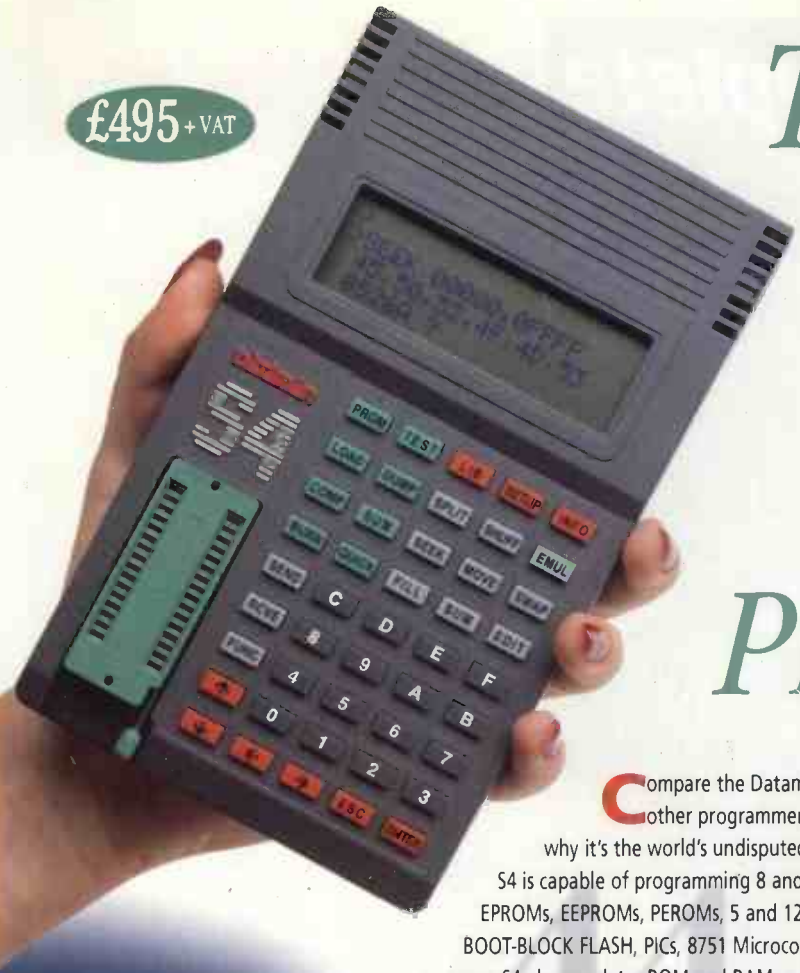

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