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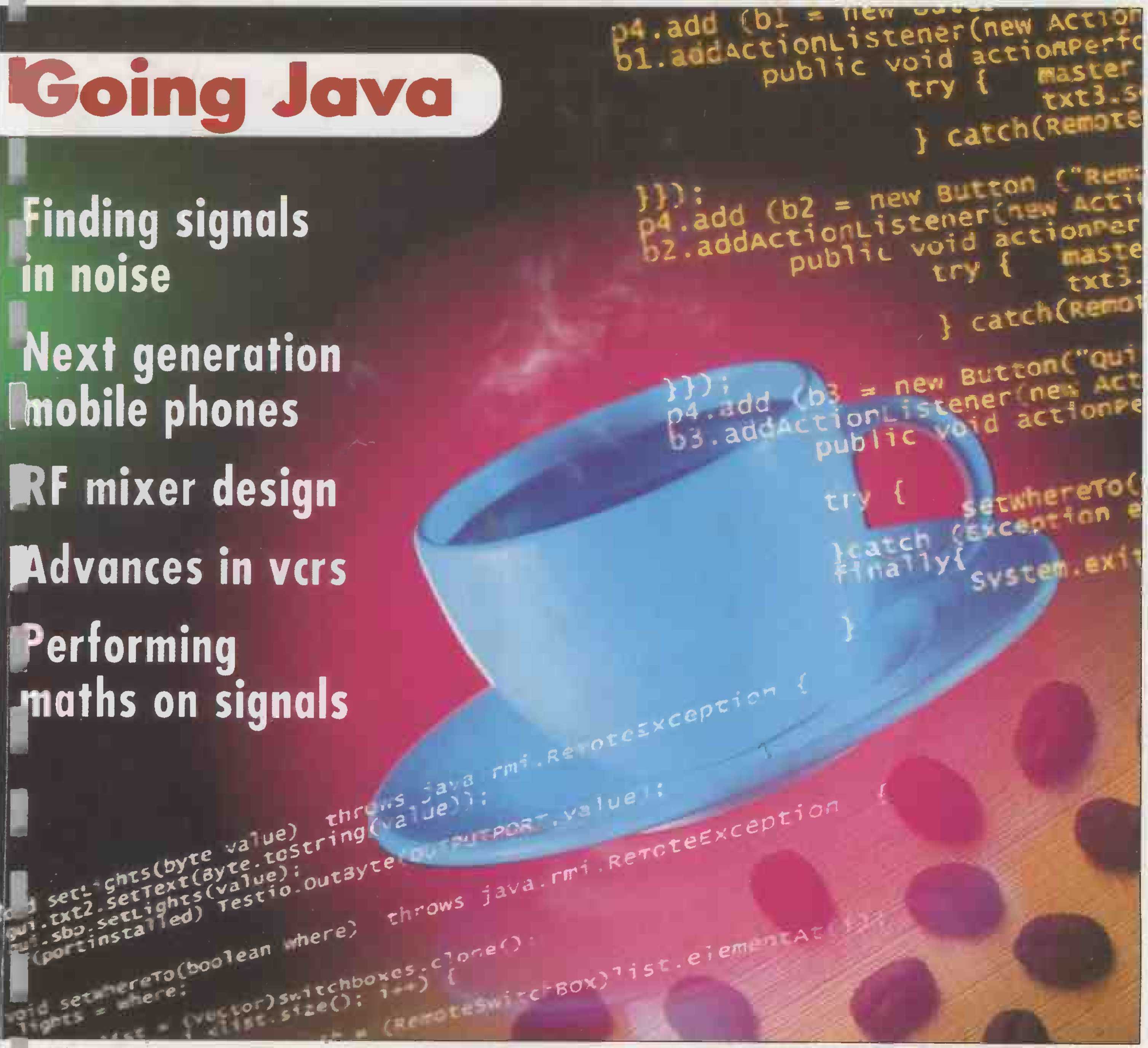

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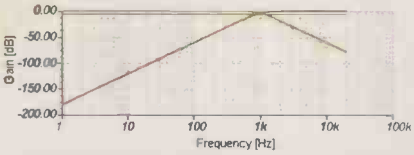

An active crossover network with no dip and requiring only the simplest of maths to work out? See page 288.

Cover photograph by Mark Swallow

Have you ever set your video recorder to record a program that was subsequently rescheduled? A technique that gets round this problem is just one of the recent advances in VCR technology discussed on page 296.

Cover CD – technical data on relays and timers from the largest manufacturer of European-made general-purpose relays, Finder. Turn to page 333.*
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REED BUSINESS INFORMATION

The pc's final boot?

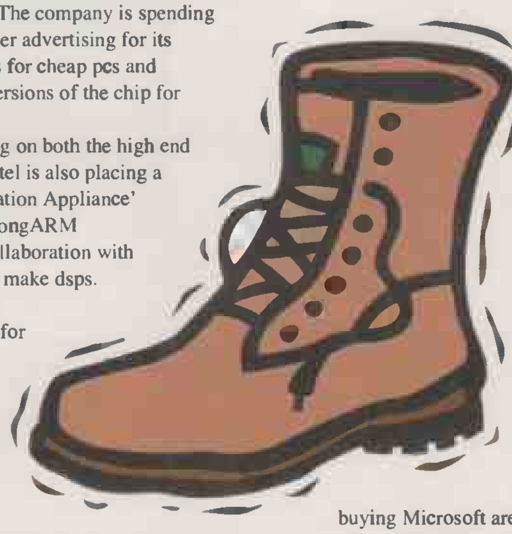
Later this year we could see pc architectures going off in two different directions – the first time there has been such a split since it was launched eighteen years ago. This could flag the start of the post-pc age.

On the one hand is the Intel vision of 600/800MHz Rambus pcs coming out in the second half of the year. On the other hand, there's a move to machines with a 133MHz pc system bus using double data rate dynamic ram.

The Rambus side will take the upper end – $1500-$2,000 end of the pc market while the PC133 is expected to take the $500-$1,000 end.

Betting on both ends, Intel has invested $600m in Micron Technology and Samsung to stick with Rambus DRAMs. The company is spending heavily on consumer advertising for its Celeron processors for cheap pcs and introducing new versions of the chip for under £100.

As well as betting on both the high end and low-end pc, Intel is also placing a bet on the 'Information Appliance' market with its StrongARM programme and collaboration with Analog Devices to make dsps. These are aimed at consumer markets for the boxes that will hang onto the television or the telephone to make them capable of Internet browsing and e-mail.



Some time soon, Joe Soap may be making his mind up on the future of the pc. If he just wants e-mail, word processing and web browsing, then these functions can be made on a single chip and sold either as information appliances or incorporated into televisions, set-top boxes – or even telephones.

In this scenario the television remains the central IT appliance in the home with, maybe, a host of peripheral devices bouncing signals back and forward to it via infra-red.

However, if Joe Soap decides he wants to keep his pc but have something robust, easy to use and which doesn't obsolete every couple of years, then he may go for the £500-£800 pc. He can tuck that away in a study or spare bedroom and use it for work away from the living room. For him the pc industry's annual trek up the hertz and bytes trail will be irrelevant.

However, if pcs are to handle large amounts of graphics – as in games playing, digital photo manipulation or video-conferencing – if they are going to be efficient at multi-tasking and if they are going to be good for speech recognition, voice processing and translation, then the pc's technological evolution is not yet ended. Gigahertz processors accessing a gigabyte of Rambus DRAM will be for him – probably by Christmas.

To an extent, it depends on what Joe Soap wants to buy, but his choice will be spurred by many wanting to overturn the Wintel hegemony.

"It's good business to be The Anti-Gates," said Scott McNealy, Sun's chairman, president and ceo, at a recent analysts meeting in Rome.

With his own microprocessor architecture SPARC, his own Internet programming language Java, and his own interconnection system for IT appliances Jini, McNealy feels he, and only he, has the tools to destroy the Wintel's supremacy.

Other contenders have, he said, failed: "How much longer is the MIPS chip going to be out there? Or the PowerPC? There just aren't other platforms out there.

Compaq can't get Gates to port Windows to Alpha or persuade Grove to have Merced run Unix."

He argues that the reasons for buying Microsoft are already eroding: "Why pay a penny for Windows when you can download Linux legally for free, when you can download Netscape Navigator legally for free, when you can download Java, legally for free?"

But a bigger revolution is underway pushing Wintel into the sunset. "We're heading into the post-pc era", said McNealy, hopefully, "NCs (network computers) are like Freddy – they're coming back".

"Over time, companies are going to stop buying computers. How many companies buy telephone switches? Or nuclear power plants? Or dig their own wells? It's silly."

"The concept of you taking care of your own data is as silly as looking after your own money. You don't keep all your money in your back pocket – you give it to a stranger in a bank. It's their job to keep it safe. The concept of storing your data remotely to be managed by professionals is the right answer."

It could be an interesting year. ■

David Manners, *Electronics Weekly*

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Prospects good for UK electronics industry

Industry observers are upbeat about the prospects for the UK electronics sector this year, despite warnings from the Confederation of British Industry (CBI).

According to Anthony Parish, director general of the Federation of Electronics Industry (FEI), the FEI is "quite bullish" about the industry's prospects. "That's not to say that profits will be huge but we are better prepared than some industries," said Parish.

The Printed Circuit Interconnected Federation (PCIF) executive director, Brian Haken, is "definitely upbeat" about the industry's prospects. He points to the PCIF book-to-bill which last November finally exceeded one, and it is expected to do the same in December. "This is a clear indicator of where the market is going," said Haken.

He also points to the heightened product design activity which the PCIF has monitored. "We feel the market is on an upward sloped. By the fourth quarter of this year we will be well on the road to recovery," said Haken.

The latest CBI quarterly survey which indicates that electrical electronics manufacturers are more pessimistic about business than other UK manufacturing sectors.

PCs still booming

Strong demand in Europe and the US created a good year for the worldwide PC industry in 1998, says US market research firm Dataquest.

The PC industry reported growth of 15 per cent last year with US and European PC markets representing 65 per cent of PC shipments.

"Affordability and growing relevance of Internet content is sustaining double-digit PC growth in the US," said Dataquest analyst Bill Schaub.

"Dataquest's latest survey suggests that as many as 37 per cent of US households are now connected to the Internet."

Compaq Computer again held the top vendor spot with almost 14 per cent market share followed by IBM, Dell Computer and Hewlett-Packard.

Electronic eye... A laser radar capable of warning helicopter pilots of obstacles such as overhead cables has been developed by Dornier. Objects as small as five millimetres thick can be detected from a range of several hundred metres, giving pilots plenty of time to avoid the obstacle.

Will European telecomms companies be forced into xDSL?

Europe's telecomms operators will be forced to adopt xDSL technology for local loop connections to the home, reckons Aido Romano, managing director of STMicroelectronics.

"The pressure in this direction means it is only a matter of time. There's no way they can resist the strength of the demand," says Romano.

The EU is expected to start legislative moves in the second half of this year. It will move to redefine the term 'universal service' which telecomms operators are obliged to provide, and could include xDSL services in the definition.

If adopted, it would force telecomms operators to provide xDSL at a reasonable price.

The operators already use xDSL technology to provide E1 business leased lines costing upwards of £20 000 a year. However, chip sets costing $50 are making cheap xDSL modems available to the home, and Compaq is already bundling them with pcs.

Businesses would dump leased lines if they could get xDSL services at consumer prices, which makes some operators reluctant to adopt the technology.

UK regulator Oftel's paper *Access to bandwidth: Bringing higher bandwidth services to the consumer* concludes that xDSL is the best way of providing faster home-links for UK Internet users, who number two million and are doubling every year.

Oftel says BT's 85 per cent ownership of local loop lines could hinder adoption.

The US 1996 Telecommunications Act forced US telecomms operators to give up a line to any local carrier which had a customer wanting xDSL service.

David Manners, *Electronics Weekly*

Pentium embedded ID is to be "turned off"

Intel has run into serious problems with its plans to embed an electronic serial identification number (ID) in its Pentium III microprocessor.

After disclosing that its Pentium III will have a unique embedded ID number to improve e-commerce and security features, Intel received a storm of protests from US organisations concerned about the 'Big Brother' implications of tracking PC users.

Organisations such as Electronics Privacy Information Center and the Electronics Freedom Foundation called for Intel to remove the ID feature and began organising a boycott of Pentium III chips.

"We have been meeting with two of the privacy groups to explain the technology and assure them the feature will be turned off but users will have the option to turn it back on," said an Intel spokesman.

New architecture promises smaller, faster ICs

A US start-up has come up with a novel design for embedded microprocessors that promises smaller, faster ICs.

TeraGen has invented an architecture it calls thread processor technology. Several simple processing units called microthread engines (see diagram) are placed on a chip. In parallel, these can replicate the functions of existing processor architectures.

"What we're developing is a technology that's a flexible way of creating processors," says George Alexy, president and CEO of TeraGen.

On-chip software or microcode, held in a read-only memory, converts conventional processor instructions into primitive operations for the microthread engine.

"We describe the architecture we're implementing in the underlying microcode," said Alexy.

This means that it is conceivable that any existing processor instruction set could be emulated by the microthread engines. This could cover eight to 32-bit processors.

And because each engine and its set of primitive operations are very simple, they will run very fast – easily over 200MHz in a 0.5μm process, Alexy said.

"The first platform that we are targeting is an eight bit microprocessor," adds Alexy. More specifically it is the 8051, still used in vast numbers today. At the speeds needed by 8051 designs, the chip will draw little current.

The devices are also small, Alexy claims." Because of the characteristics of the design, it's heavily ROM, datapath and RAM oriented. These are very dense which leads to small, high performance die," he pointed out.

As the microthread engines can emulate pretty much anything, they will also be used to emulate peripherals.

The only thing that changes the engine from emulating a processor or a peripheral is the microcode in the ROM. This allows for a simple chip layout.

Development times, cost and chip size could all be reduced by up to 40 per cent, the company claims.

TeraGen chips could replace older processors in existing designs and re-use the existing code without changes.

Applications such as mobile phones, where the chip includes a CPU, DSP and peripherals could also be targeted.

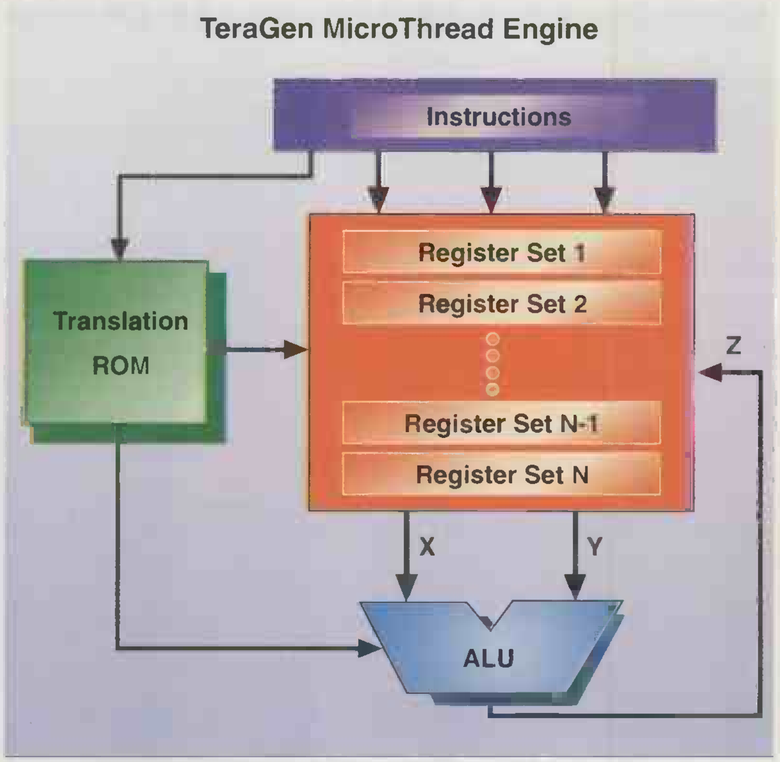
In the future, Alexy said microcode could also be implemented in RAM, making the engines reconfigurable.

TeraGen will be licensing the technology to semiconductor companies as well as designing its own chips.

"We have two licences at this time with semiconductor companies," said Alexy.

The first 8051-compatible product is due sometime this year.

Richard Ball *Electronics Weekly*



Thread bare... The thread processor gets its name because it takes processor instructions and breaks them down into multiple threads. Each thread is executed by an engine. The multiple engines are under the control of a real time operating system.

MediaPC imminent

National Semiconductor says it is on schedule to deliver samples of its *MediaPC* system-on-a-chip product in June

"We are dead on schedule with *MediaPC*. We expect tapeout in March and we already have a lot of interest from potential customers," says National's CEO Brian Halla. "We will also be offering *MediaPC* versions that are customised for different applications, for example in cellular phone applications."

The company is rapidly shifting production to a 0.18μm process at its Portland fab, beating a similar move by Intel.

National has staked its future on developing cheap PC devices embedded in a range of applications. The first *MediaPC* chip combines several intellectual property (IP) cores. It is designed for applications such as fast DVD decoding for use in digital set-top TV boxes.

"It would take Intel a long time to catch up with what we've done. They don't realise how long it has taken to acquire all the IP you need and there are major challenges in testing such an integrated chip," claimed Halla.

National's Israeli-based subsidiary has been instrumental in developing much of the *MediaPC* design, especially integrating the reusable components required when producing variants of the chip.

One concept National has been touting for its *MedicaPC* is the *WebPad*, a wireless display using *MediaPC* and offering Web surfing and Internet access through a 2.4GHz wireless connection.

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HP 8410-A-B-C Network Analyser 110Mc/s to 12 GHz or 18 GHz - plus most other units and displays used in this set-up - 8411a-8412-8413-8414-8418-8740-8741-8742-8743-8746-8650. From £1000.
Racal/Dana 9301A-9302 RF millivoltmeter - 1.5-2GHz - qty in stock £250-£400.
Racal/Dana Modulation Meter Type 9009-9008 - 8Mc/s - 1.5GHz - £150/£250.
Marconi RCL Bridge type TF2700 - £150.
Marconi/Saunders Signal Sources type - 605B-6070A-6055A-6059A-6057A-6056- £250-£350. 400Mc/s to 18GHz.
Marconi Microwave 6600A 1 sweep osc., mainframe with 6650PI - 18-26.5 GHz or 6651 PI - 26.5-40GHz-£750 or PI only £600. MF only £250.
Tektronix Plug-ins 7A13-7A14-7A18-7A24-7A26-7A11-7M11-7S11-7D10-7S12-S1-S2-S6-S52-PG506-SC504-SG502-SG503-SG504-DC503-DC508-DD501-WR501-DM501A-FG501A-TG501-PG502-DC505A-FG504-7B80 + 85 - 7B92A.
Gould J3B test oscillator + manual - £150.
Tektronix Mainframes - 7603-7623A-7613-7704A-7844-7904-TM501-TM503-TM506-7904A-7834-7623-7633-7844-7854-7104.
Marconi 6155A Signal Source-1 to 2GHz - LED - £400.
Barr & Stroud Variable filter EF3 0.1Hz-100Kc/s + high pass + low pass - £150.

Racal/Dana 9300 RMS voltmeter - £250.
HP 8750A storage normalizer - £400 with lead + S.A. or N, A Interface. Board fitted.
TEKTRONIX - 7S14-7T11-7S11-7S12-S1-S2-S39-S47-S51-S52-S53-7M11.
Marconi mod meters type TF2304 - £250.
Systron Donner counter type 6054B - 20Mc/s - 24GHz - LED readout - £1k.
Racal/Dana counters-99904-9905-9906-9915-9916-9917-9921-50Mc/s-3GHz - £100 - £450 - all fitted with FX standards.
HP180TR. HP181T, HP182T mainframes £300 - £500.
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HP8683D S/G microwave 2.3-13GHz-opt 001 - 003 - £1k.
HP8640B S/G AM-FM 512Mc/s or 1024Mc/s. Opt 001 or 002 or 003 - £800-£1250.
HP86222A+B Sweep PI -01-2.4GHz + ATT £1000-£1250.
HP86290A+B Sweep PI-2 - 18GHz - £1000 - £1250.
HP86 Series PIs in stock - splitban from 10Mc/s - 18.6GHz - £250 - £1k.
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HP8615A Programmable signal source - 1MHZ - 50Mc/s - opt 002-£1k.
HP8601A Sweep generator .1-110Mc/s £250.
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HP5335A Universal counter - 200Mc/s-£1000.
HP5328A Universal counter - 500Mc/s - £250.
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HP3552A Transmission test set - £350.
HP3763A Error detector - £500.
HP3764A Digital transmission analyser - £600.
HP3770A Amp delay distortion analyser - £400.
HP3770B - £450.
HP3780A Pattern generator detector - £400.
HP3781A Pattern generator - £400.
HP3782A Error detector - £400.
TEKTRONIX 577 Curve tracer + adaptors - £900.
TEKTRONIX 1502/1503 TDR cable test set - £400.
Racal 1991-1992-1998 - 1300Mc/s counters - £400-£900.
Fluke 80K-40 high voltage probe In case - BN - £50-£75.
EIP545 micorwave 18GHz counter - £1200.
Fluke 510A AC ref standard - 400Hz-£200.
Fluke 355A DC voltage standard - £300.
Wiltron 610D Sweep Gen + 6124C PI-4-8GHz-£400.
Wiltron 610D Sweep Generator +61084D PI - 1Mc/s - 1500Mc/s £500 - 10 Mc/s - 18GHz - £1000.
HP8699B Sweep PI YIG oscillator .01 - 4GHz - £300. 8690B MF-£250. Both £500.
Dummy Loads & Power att up to 2.5 kilowatts FX up to 18GHz - microwave parts new and ex equipt - relays - attenuators - switches - waveguides - Yigs - SMA - APC7 plugs - adaptors etc. qty. in stock.
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Marconi TF2019 S/G 80Kc/s-1040Mc/s. AM/FM - £500.
Marconi TF2019A S/G 80Kc/s-1040Mc/s. AM/FM - £650.
Marconi TF2022E S/G 10Kc/s-1.01GHzs. AM/FM - £1260.
Marconi TF6311 Microwave Sweep S/G 10Mc/s - 20GHz c/w TF6501 amplitude Anz. plus heads 10Kc/s-20GHz. Heads available to 40GHz - £4000.
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Marconi TK2373 Extender to 1.25GHz - £300 - £400.
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HP3325B Synthesized function generator - £2500.
HP8405A Vector voltmeter - late colour - £400.
HP8508A Vector voltmeter - £2500.
HP8505A Network Anz 500KHz-1.3GHz - £1000.
HP8505A + 8502A or 8503A test sets- £1200 - £1500.
HP8505A + 8502A or 8503A + 8501A normalizer - £1750-£2000.

HP8557A .01Mc/s-350Mc/s - 8558B 0.1-1500Mc/s - 8559A .01-21GHz 180T or 180C-D-T £500 - £2000.
TEK492 Spectrum Anz-OPT 2-50Kc/s-21GHz - £2.5k.
TEK492P S.A. opt 1-2-3-50 Kc/s - 21GHz £4k.
TEK495 S.A. 100Hz - 1.8GHz - £3k.
TEKTRONIX - HP Oscilloscopes - 100Mc/s-465-465B-1740-1741 etc - £300 - qty in stock.
Phillips 3217 50Mc/s oscilloscopes - £150-£250.
Phillips 3296 350Mc/s IR remote oscilloscope - £500.
Hitachi VC6041 Dig storage oscilloscope - 40Mc/s - £500.
TEKTRONIX 2445 + DMM - 250Mc/s - £800.
R&S APN 62 LF S/G 0.1Hz - 260KHz with book - £500.
Wavetek-Schlumberger 4031 Radio communication test set - £POA

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Anritsu MN95B Variable Att. 1300.
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W&G PS19 Level Gen – £1k.
W&G DA20+DA1 Data ANZ.
W&G PMG3 Transmission Measuring Set.
W&G PSS16 Generator.
W&G PS14 Level Generator.
W&G EPM-1 Plus Head Milliwatt Power Meter – £450.
W&G DLM3 Phase Jitter & Noise – £500
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W&G PS10 & PM10 Level Gen.
HP5352B Microwave counter Opt 010--005. 46 GHz brand new £5000.
HP8342A+5344A Microwave counter +Syn 18GHz - £1600.
HP8112A Pulse Gen 50MC/S - £1400.
HP8660 C&D S/G AM/FM - Phase • 01-110MC/s - 1300MC/s - 2600 MC/s £1-£3k.
HP4274A LCR Meter + Adaptor.
HP8754A Network ANZ 4-1300MC/S + 8502A + cables.
HP8754A Network ANZ H26 - 2600MC/S + 8502A + cables.
HP8116A Pulse function Gen £2200.
HP3588A S.A. 10Hz - 150MC/s opt 001-003.
HP54100A DIG Oscilloscope 1GHz - P.O.R.
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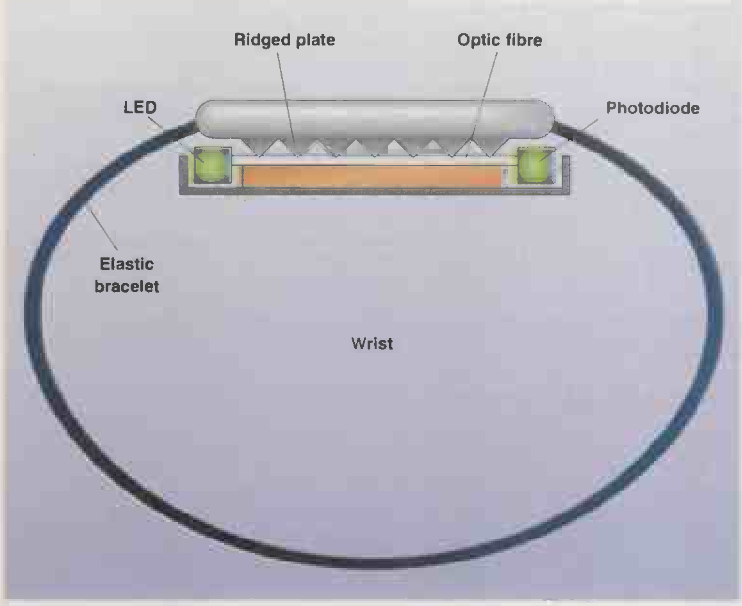
CIRCLE NO. 106 ON REPLY CARD

Fibre sensors detect fatigue

Optical fibres are affected by their environment. This can be a problem if you are shipping data long distances, but exceedingly useful if you are a sensor maker. Temperature, force and pressure can all now be measured by their effect on fibres.



By making use of force sensitivity, reports the IEE's *Electronic Letters* (vol 34, no 21, page 1991), fibres are now being used to measure physiological parameters.

The sensor concerned is the size and shape of a wrist watch and has been developed by a multi-discipline academic team from Lorient in France to indicate the phases of human sleep.

It measures the heartbeat, blood pressure variations, breathing frequency and breathing amplitude.

In the sensor, a fibre is trapped between two metal plates, one of which is ridged. Forcing the plates together causes the ridges to deform the fibre which changes its attenuation through variations in refractive index at the contact points.

A 1mW laser diode and a photodiode allow the attenuation to be sensed.

An ordinary elastic wrist watch strap holds the assembly against the inner wrist and, being attached to the outer plate, sets a bias force on the fibre.

The signal from the photodiode is processed using a Texas Instruments *MPS 430*, transmitted over an RF link, then further processed to extract the required parameters.

Although the first application will be in sleep analysis, the developers see it finding use in other medical areas and industry. For instance, it could be the basis of a fatigue detector for workers operating dangerous machinery.

Steve Bush *Electronics Weekly*

GPS gets more precise

The US Government plans to spend $400m to improve the accuracy of the global positioning system (GPS) with two additional signals for civilian use.

The signals will improve accuracy by allowing (GPS) receivers to compare reception of signals and correct for atmospheric distortions.

"This initiative represents a major milestone in the evolution of GPS as a global information utility, and will help us realise the full benefits of this technology in the next Millennium," said US Vice President Al Gore.

He added that signals will be available to civilian users worldwide and will help private industry develop and improve GPS applications.

Shared cars experiment

A public shared car pool based on smartcards is being trialed in the Unite States.

American Honda Motor has teamed with the University of California to make available twelve natural-gas-powered Honda Civic cars for public use.

The CarLink programme provides members with the ability to drive to local light railway stations to get to work. During the day, other programme members use the cars locally, returning them at the end of the day for commuters to get home.

Special smartcards give members access to the CarLink fleet, while on-board electronics systems allow a central command centre to keep track of the vehicles' locations.

The year-long programme is designed to study transportation systems that have be introduced on a commercial basis, and to help reduce pollution levels.

Honda has been involved in a similar project in Japan called the intelligent community vehicle system which began operations in October last year.

Disk density breakthrough

Seagate Technology has claimed a breakthrough in hard-disk-drive technology that dramatically increases data density. The company says it has managed to record 16 billion bits per square inch – three times the capacity of current hard drives.

Seagate has developed disk drive read heads made of giant magneto-resistive (GMR) heads combined with a new type of ultra smooth cobalt alloy for the disk platter. The heads fly just 15 nanometres above the magnetic media.

The achievement caps IBM's competitive efforts to increase recorded bits per square inch which stand at 11.6 billion bits per square inch.

Seagate hard disk drives using the advanced GMR heads are expected to start shipping later this year.

Laser helps heal burns

Victims of serious burns could get help from an unusual source – a high-power laser.

One step on the way to healing deep burns is called debriding, the removal of dead skin to expose the live tissue below for treatment. This is normally done only by a skilled surgeon.

A research programme at Oak Ridge National Laboratories in the US aims to automate this process using a pair of lasers, one to three-dimensionally map the burn and the other to burn away the dead tissue – all in one pass.

Although using a laser to remove tissue in this manner is not new, the mapping is. "It can map the dead tissue to within 5μm," said ORNL spokesman Ron Walli.

The project is a technology demonstrator. The eventual aim is to produce a self-contained unit that will fit on a trolley.

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CIRCLE NO.107 ON REPLY CARD

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	12th	Advanced	Gatwick
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	14th	Advanced	Bristol
June	7th	Introductory	Daventry
	8th	Advanced	Daventry
	9th	Advanced	Manchester
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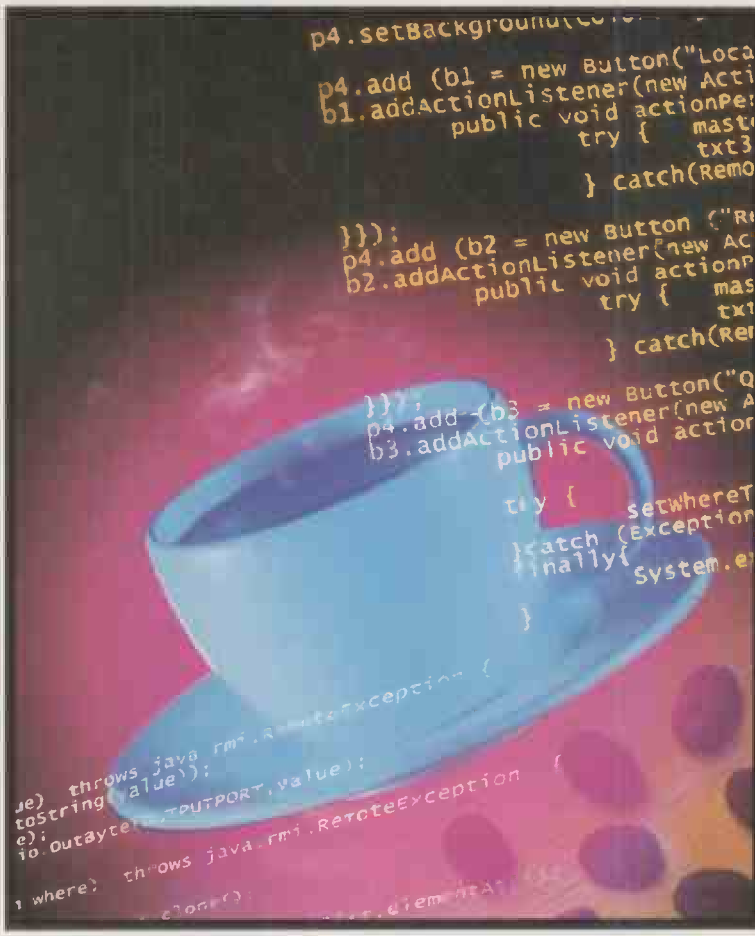
CIRCLE NO.108 ON REPLY CARD



Is Java a panacea, or an insidious force that will bring the end of civilisation as we know it? Much hype surrounds the Java programming language but what's it really all about? Les Hughes explains.

Exploring Java

Java is more than a new programming language. It represents a whole technology capable of powering systems from the smallest to the largest. Java smartcards could be used to decode your satellite television or to carry your new E-Cash euros. Add more computing power and basic Java becomes Personal Java.

Moving into the more familiar pc and Unix area, Java allows you to have your favourite applications available, regardless of the operating system. Increase computing power still further and Java can run your Internet server, undertaking E-Commerce securely using Java enabled jewellery for identification, **Fig. 1**.

This is not hype. Most of these systems are available off-the-shelf today. But as with any modern technology, gaining an insight to what 'it' really is can be difficult.

What is Java?

Simply speaking, Java is a programming language and a 'run-time' execution system, **Fig. 2**. While it has some nice touches, Java is not perfect – or indeed revolutionary. Those with

Fig. 1. Java on a button. Dallas Semiconductor's iButton is a computer chip housed in stainless steel. It can be worn by a person or attached to an object for up-to-date information at the point of use.
Each button holds a guaranteed-unique registration number engraved in the silicon. Some buttons have memory to store typed text or digitised photos; information can be updated as often as needed with a simple, momentary contact. Some buttons even have a real-time clock, temperature sensor or transaction counter.
Shown here is the latest product in the family, the Cryptographic iButton. It contains a microprocessor and high-speed arithmetic accelerator to generate the large numbers needed to encrypt and decrypt information. Messages sent over the Internet and scrambled using the button can only be unscrambled at the other end by someone with another authorised iButton. The Crypto iButton runs Java, giving you the ability to update the services the button provides. Data is transferred at around 140kbit/s. See www.ibutton.com.

insight draw attention to the various aspects of C (syntax), C++ (objects), Smalltalk (virtual machine) etc., that can be found within Java.

However, perhaps the way in which these elements are combined and packaged is what gives Java its uniqueness. Most modern languages have, more or less, most of the features available to Java programmers, albeit often as a 'bolt-on' or addition to the core language.

For example, the concept of threads or 'doing many things at once' is available to Unix and Windows programmers using C/C++. However, writing a multi-threaded program for Unix is drastically different from writing one for Windows.

Many of these problems derive from the fact that these traditional languages have evolved over time. C++ was created as an extension to C; C++ is nearly 20 years old and C is even older. Computing has moved on enormously over this period and many languages have become cluttered with historical baggage.

Java on the other hand was designed from the ground up, taking the best features from current languages and addressing the needs of modern systems.

Creating programs with Java

The Java language is based around the idea of objects, as are most modern languages. If you've never used an object-oriented approach – hands up all you C or Pascal programmers – things can seem entirely alien.

Programs no longer 'flow' from start to finish. Instead, many software 'things' are created and told to get on with their individual tasks **Fig. 3**.

Most of us can think in terms of real-world 'things that do things'. For example, a phone is a thing that establishes a connection with your friends when you press those numbered buttons. It's a thing that generates tones for an exchange and then passes our voices across the phone system.

Objects everywhere

Object-oriented techniques allow developers to model these real world 'things' in software; to translate real things into software things. There's more on this in the 'Object-oriented principles' panel. They also allow these software things to get on with their job without interference from others.

Going back to the telephone analogy, do you really care how the call is connected? It's not your job to whistle tones at the exchange; it's the phone's job. Object orientation lets us specify our 'things', how they talk to each other and the actions that occur after these messages have been passed.

The software engineer or architect has to map out these communities of things, Fig. 3, and make sure that they are all compatible. Of course, an object can refuse to accept an instruction from another; your friend's phone won't be connected to yours if she's already talking to someone.

When writing a Java program though, you don't write objects. In the same way that a manufacturing plant makes phones from a CAD drawing, objects are created from a blueprint called a class.

As a programmer, you design the class and the Java run-time manufactures objects from it. When you execute a Java program your classes are pulled together by the Java run-time and a whole host of chattering objects are born. Your program springs into life in an instant.

Writing Java

So how do you write a Java program? Well, you write it in exactly the same way that you write any other program. You enter some code after having planned your design. You compile this code and then execute on a suitable machine.

The process may seem the same as any other language but the results are completely different. Traditionally, a program written in a language such as C is first compiled into an intermediate file, which is then linked with standard code from a library file to form a platform specific executable, i.e. a file with a '.exe' extension. Windows extends this idea by using dynamic link libraries, or 'DLLs'.

The system loads pre-compiled code from these library files into your application as it runs; some of the compile-time work is now undertaken at run-time .

Java takes this concept further by piecing together the whole application at run-time. All publicly available things – i.e. things that you can grab hold of and use – are written in their own source file and compiled into their own class file.

You don't produce a single .exe file. Instead you produce a collection of '.class' files – tens, hundreds, or maybe even thousands of them. These class files are the building blocks of your application. They are loaded on demand and unloaded when no longer needed by the run-time execution system.

In this sense, Java is a dynamic language, delaying much of the work done usually done at compile time until run-time .

When, at some point during execution, your program calls for the use of your 'phone' class, the Run-time will

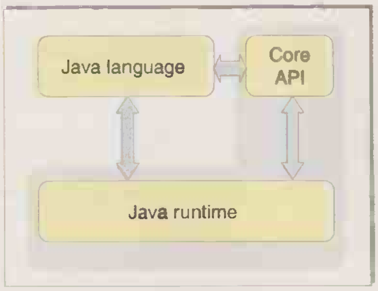


Fig. 2. Java technology key components are the programming language and the 'run-time' section, which is essentially code that executes the program.

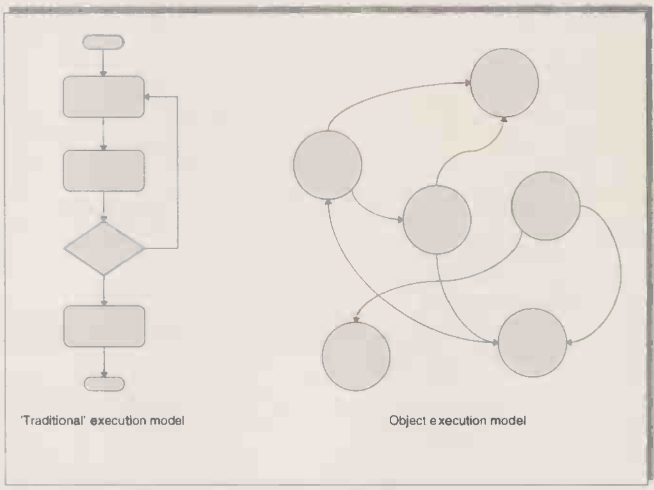


Fig. 3. Traditional one step at a time program flow versus object-oriented execution.

Need more information?

Excellent books concerning the Java Language do exist as well as some terrible ones. At the time of writing, JDK 1.2 had just been released and most books still concentrate on JDK1.1.x. By now, you should really ignore anything to do with JDK 1.0.2.

My personal favourites are:

- Java in a Nutshell (2nd ed.), Flanagan, O'Reilly, 1997 1-56592-262-X A good desktop reference.
- Thinking in Java, Eckel, Prentice Hall, 1998 0-13-65723-8. Full text is available from www.bruceeckel.com along with source code, errata, etc.
- Java Virtual Machine, Meyer & Downing, O'Reilly 1997 1-56592-194-1 : for more information on the JVM – including a Java Assembler.
- Beginning Object-Oriented Analysis and Design, Liberty, Wrox Press 1998 1-861001-33-9: an excellent guide to things OO, although based on C++.

All of these books should be available from

`http://www.amazon.co.uk/`

Javaworld is a good source of information at
`http://www.javaworld.com/`

The Brighton University Resource Kit comprises two cds of computing related material – including JDK 1.1.6 – and is available for £5.00 from The BURKS Project, Faculty of IT, Watts Building, University of Brighton, Lewes Road, Brighton BN2 4GJ. Alternatively see
`http://burks.bton.ac.uk/`

JDK for Linux is available from
`http://www.blackdown.org/`

And of course, for all things Java – JDK for Windows, documentation, etc. – the Java home page is
`http://java.sun.com/`

load your class file and get to work calling whoever. If you replace your phone class later, you can get the running application to automatically use your new phone after unloading the old one with some quite simple programming. Software is now a plugable component that can be varied at will.

Java takes this idea further with its 'Beans' component model. Beans are somewhat like Visual Basic controls that are brought together inside what is called an integrated development environment, or IDE. Examples of these are JBuilder or Café.

The developer has the task of dropping Beans into the application framework provided by the IDE and then joining them up graphically. This is almost programming without writing code.

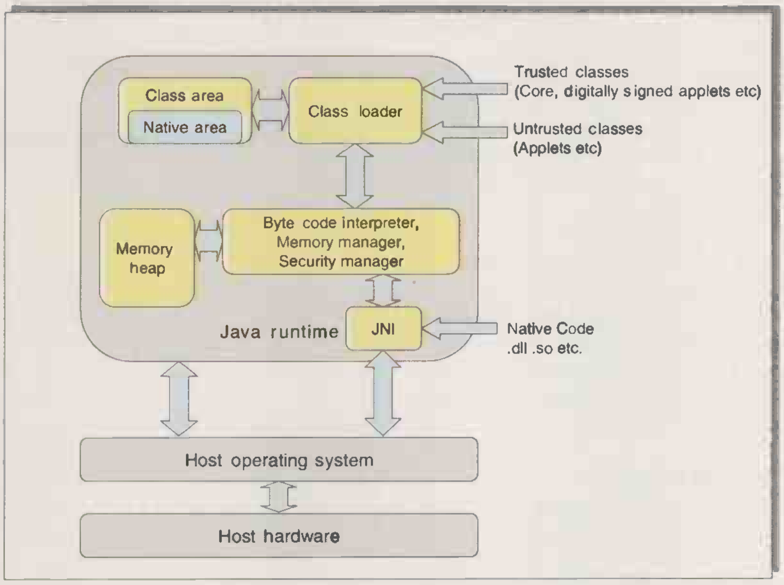


Fig. 4. Java runtime. As a programmer, you design the class and the Java runtime manufactures objects from it.

The Java virtual machine

One of Java's much publicised claims is 'Write Once, Run Anywhere,' or WORA. Java programs are intended to be completely portable – without recompilation, porting or any of the other headaches of maintaining code across multiple platforms.

Indeed, the `javac` compiler provided by Sun as part of the JDK is a Java program. It's in the sun.tools.javac package inside classes.zip if you're interested.

So how can a non-platform-specific program – i.e. one that knows nothing

OO principles

Object-oriented technology is radically different from the principles used with a structured language such as C or Pascal. The three cornerstones to object orientation are Inheritance, Polymorphism and Encapsulation.

Inheritance: In the same way that you inherit characteristics from your parents, software things can inherit attributes from other things. Inheritance allows you to specialise or generalise your classes.

For example, consider the phone example mentioned in the main article. A normal 'landline' phone is somewhat different from a cell phone. But they are both phones; they inherit the ability to contact people from a general idea of 'what a phone's all about' – a generic phone, **Fig. 5**.

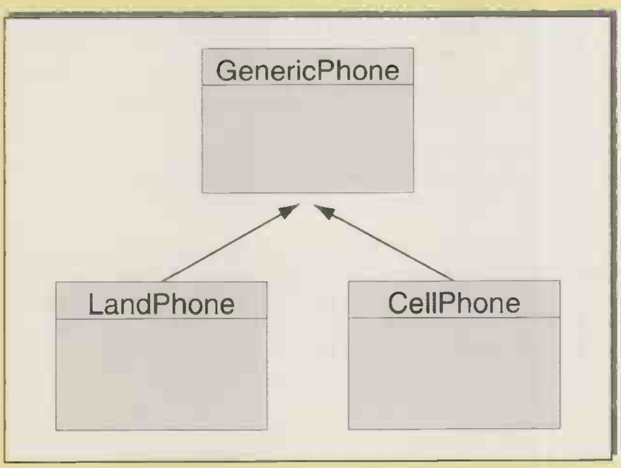


Fig. 5. Inheritance hierarchy. Java incorporates the concept of passing attributes from one module to the next.

Cell phones specialise the general 'ring' behaviour of the generic parent phone to play annoying tunes instead of ringing like a land phone. In fact, the generic phone doesn't exist in the real world and so we call it an abstract class – you can't make objects from an abstract class, they exist just for the purpose of modelling.

The real cell and land phones are then termed concrete classes and we can create objects from them.

Encapsulation: Encapsulation allows you to keep yourself to yourself, only exposing certain attributes through a well defined interface. Coming back to the phone example, the manufacturer encapsulates all of the electronics inside the phone case, only exposing the keypad.

We use the phone through this interface. We have no knowledge of the actual circuitry used to implement the various functions of the phone – a custom IC, discrete logic or even transistors; the internal workings are of no concern to us, we just want to make calls. This leads to the ideas of Interface and Implementation.

The interface defines how others access us and the implementation defines how we do what we do internally. A well defined interface allows us to unplug software components and to plug in new versions – the interface remains the same, only the implementation changes.

Polymorphism: The final pillar of object orientation is polymorphism. Polymorphism is perhaps the most alien concept for the C/Pascal programmer to grasp. Inheritance allows you to move all of the common functionality into a parent class. Child classes can then specialise that behaviour to meet their own needs.

Polymorphism lets you access these behaviours in a uniform manner. Assume that you have a voice activated phone in a box, **Fig. 6**. You don't know whether it's a cell phone or a land about your computer, be it a MAC, a Windows PC, a Linux PC or even a Unix Workstation – produce executable code for your specific processor, regardless of what type it is? And what about WORA? Compiled code can't be transferred from one type of machine to another and still be executed, can it?

Java solves these problems and attempts to deliver WORA by introducing its own machine code format called 'bytecode' and its own 'virtual' computer to execute bytecode. Along with some handy libraries of code, this virtual machine forms the second part of the Java technology – the Java runtime platform, Fig. 4.

The virtual machine gives Java its security, its dynamic nature and its platform independence. Java source code is compiled into bytecode, which is then loaded, verified and finally executed by the Java Virtual Machine. This virtual machine has an instruction set similar to many other real microprocessors.

For example, those of you familiar with the X86 assembly language would recognise `add` as the instruction that adds two registers together. A similar instruction for the JVM would be `iadd` – integer add – and the corresponding bytecode is $0x60_{16}$. These bytecodes are stored in the class file by the compiler, along with some other information.

When objects created from your class come to execute, the JVM steps through each entry in the class file executing real instructions on your computer that give the desired action. The JVM can be thought of as an emulation program, emulating a piece of hardware that has never existed.

It is this virtual machine approach that allows Java to screen downloaded class files and to protect your computer from the nasties lurking on the Internet. No code ever has access to your hardware without a nod from the JVM and the JVM can reject suspect class files before they have a chance to execute.

Taking this to extremes, when the JVM is itself embedded inside Internet Explorer or Netscape Communicator, the web browser tells the JVM what it should and shouldn't allow, selectively disabling features that could expose you to harm.

The technical term for the environment provided by a web browser is the Sandbox and, like a sandbox in your garden, it allows potentially naughty children to dig around to their hearts content without pulling up your shrubbery!

Of course, the most determined child can always find a way to dig up your roses and Java programs are no different – any system administrator will tell you there's no such thing as a totally secure system. Java's security model is reasonably useful though, offering good protection for the average Internet user.

Talking to the Natives

One nice thing about the Java system is the ability to easily extend the JVM using Native Method calls. Native Methods can be thought of as calls to a piece of C or C++ code that has been compiled for a specific platform – Windows, Unix, etc.

While these calls are used extensively by the JVM itself – for networking, file access, etc. – they can be used to access non-supported hardware.

Utilising the Java Native Interface (JNI) is a simple affair from the Java end of things but can get somewhat hairy from the C point of view. A further article is planned in which I will explore the interesting area of interfacing using Java/JNI in some depth.

Other interesting corners

There is a number of other interesting features built-in to the Java technology. Systems are becoming increasingly distributed and Java allows us to run code remotely as if it were on our machine.

The Java way uses the Remote Method Interface; a set of calls that automatically transport our requests across the network almost invisibly to the programmer. Java also has support for the CORBA industry standard.

Internationalisation is an important area for application developers – wouldn't it be nice to be able to translate menus, dialogue boxes, etc., into the local language on the fly without having to maintain a number of versions? Date format can give rise to problems too – 01/04/99 is either Jan 4th or April Fools' day depending on which side of the Atlantic you are.

Why should everyone have to learn American English to be able to use a computer? Java's internationalisation

phone but you do know that if you say 'Call Home' it will call your house.

So you say 'Call Home' and have a quick chat. It's only when the bill turns up that you realise that it's your cell phone in the box and not your cheaper land phone. Polymorphism – *many + forms* – allows you to make that call regardless of the actual type of phone that you are talking to. It's a phone isn't it?

In other words, you use the generic phone interface and the run-time system works out exactly what type of phone you are really talking to. It is the inheritance hierarchy, coupled with the interface defined by using encapsulation that allows polymorphism to work.

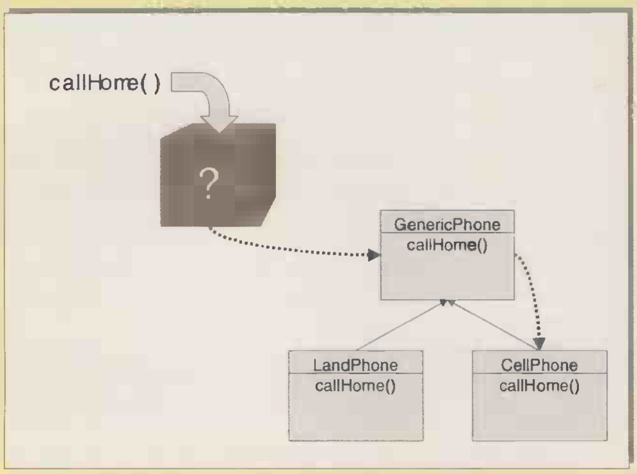


Fig. 6. Polymorphism. Inheritance allows you to move all of the common functions into a parent class. Child classes can then specialise that behaviour to meet their own needs. Polymorphism lets you access these behaviours in a uniform manner.

allows the program to automatically reconfigure itself for the locale of the machine – changing text, error messages, menus, dates, currency format – \$, £, FF, etc. – without intervention by either the user or the programmer.

There are many aspects of Java such as database connectivity (JDBC), directory services (JNDI), telephony (JTAPI), 2D and 3D graphics, serial and parallel port communications and an extensive set of GUI foundation classes (Swing/JFC).

Each of these areas could fill an entire issue. If you are interested in them, you can get further information from the various web sites mentioned separately.

And it's free

One great thing about Java for the professional and hobbyist alike is that the reference implementation – which is as near to a standard as there is – is freely available from Sun Microsystems (`java.sun.com`). It is packaged as the Java Development Kit (JDK) and includes a compiler, debugger, JVM and documentation – all for free.

Unfortunately, the JDK is command line driven but this is a small price to pay. If you can't bring yourself to download the tools from the website, the latest release of the BURKS cd rom includes JDK 1.1.6

`http://burks.bton.ac.uk/`

You will also need a decent editor; the Programmers File Editor,

`http://www.lancs.ac.uk/people/cpaap/pfe`

is a reasonable choice. This is also on the BURKS cd.

Beyond the free JDK, others such as Borland, or Inprise as they are now known, and Symantec ship Java development environments that have a nice GUI interface and additional tools. Microsoft's *J++* – alleged to depart from the Java standard – is another Java development tool, primarily aimed at Java development for win32.

In summary

This article has given an overview of object-oriented technology and Java in particular. Java is a vast technology that tries to provide support for everything from embedded microprocessors to enterprise-wide transaction systems. Answering the question, "What's it all about then?" is near impossible within a few thousand words but hopefully, you now have an idea of what all the noise is about. ■

Les is a Senior Lecturer in Software Engineering with the School of Engineering, University of Greenwich and a Sun Certified Java programmer. He currently teaches first and second year Software Engineering and third year Internet Technologies using Java, Patterns and UML. Unfortunately, he still has to revert back to C/C++ occasionally.

MyFirstJavaApp.java – a taste of things to come

To give you a taste of the Java language, a small sample application is shown below. This program, when run, displays a window with a button and a text box. Clicking the button changes the message displayed in the text box.

```
import java.awt.*;
import java.awt.event.*;
public class MyFirstJavaApp extends Frame {
      Button clickMe;
      TextField someText;
      int clickCount;
      public MyFirstJavaApp() {
            clickCount = 0;
            setTitle("MyFirstJavaApp");
            setBackground(Color.lightGray);
            setLayout(new FlowLayout());
            clickMe = new Button("Click Me!");
            someText = new TextField("Java's
Great!",20);
            add(someText);
            add(clickMe);
            setSize(300,75);
            setVisible(true);
            clickMe.addActionListener(new
ActionListener() {
                        public void
actionPerformed(ActionEvent a) {
                              clickCount++;

someText.setText("You've clicked me "+
clickCount + " times!");
                        }});
            addWindowListener(new
WindowAdapter() {
                        public void
windowClosing(WindowEvent w) {

System.exit(0);
                        }});
      }
public static void main(String args[]) {
      MyFirstJavaApp myApp = new
MyFirstJavaApp();
}
}
```

Line by line, here is how the program works.

Lines 1 and 2 import various classes from the standard Java library – similar to a #include C statement or 'uses' in Pascal. The AWT is a windowing toolkit that enables us to build a simple graphical user interface.

Line 5 declares our class. Our class is called 'MyFirstJavaApp' and we use Inheritance to extend a basic window class (called a Frame in Java speak).

Lines 7-9 define a few variables for us to use later. The first is a clickable button, the second a text box and the final variable represents an integer.

Objects are created at run-time from class descriptions. This construction process requires some initialisation code – we call this a constructor method and this is shown in lines 12-42.

The constructor first initialises our clickCount integer, then performs some required housekeeping – setting the title of the application, its background colour and installs a helper object that manages the layout of our components.

Lines 20 and 21 create our button and text box while lines 24-25 actually add then into the window. Lines 27-28 perform more housekeeping, setting an initial size for the window and then displaying it.

The remainder of the constructor is dedicated to wiring up our components. Of importance are lines 33 and 39. Line 33 is run every time you click on the button; it updates our clickCount and then messages out textfield asking it to change the displayed text.

Line 39 lets us exit our application in the normal 'Windows' way. If lines 37-40 were removed, then the application would need to be given the 'three fingered salute' – CTRL-ALT-DEL – on a Windows box or through some other means on other platforms.

Last but by no means least comes the misleadingly simple main method. This is similar to a main function in C in that this is the point where the program actually starts. However, all we really need to do is to create an instance of ourselves – to manufacture an object from our class pattern. Line 47 does this.

A new object is created using our class as its pattern. This causes the constructor to be executed, which in turn creates our window, adds the various GUI components – springing into life in an instant.

That's all there is to it. The details of compilation and execution vary, depending on the version of Java (1.1, 1.2) and the tools – JDK, JBuilder, J++ – that you are using.

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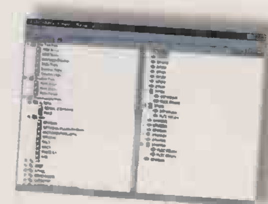

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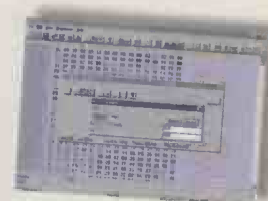

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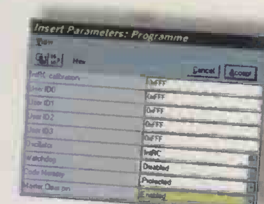

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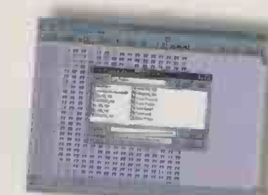

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Mobile phones: the next generation

With a new generation of mobile phones on the horizon, Tim Forrester presents an overview of the standards issues yet to be resolved, and details the new technology involved.

Over the past two decades, mobile telephone technology has advanced almost beyond recognition. Until the late seventies a 'mobile' telephone often consisted of a boot mounted radio the size of a small brief case, offering half duplex operation – i.e. push to talk – on a limited number of crystal controlled channels.

Due to technology limitations, the equipment and calls were expensive. Further, the coverage and system capacity were severely limited by the lack of infrastructure – such as relay base stations and automated call routeing.

To make or receive a call involving an early 'radio-phone', it was necessary to call the radio-phone operator to establish a connection. There was no direct dialling in either direction. But with the advent of the micro-processor it became possible to design an automated system without the need to use an operator to connect calls.

Since the arrival of early cellular telephones, the technology has advanced at an astonishing pace – driven by the need to provide ever greater capacity, coverage and services, all at an ever decreasing cost to the consumer.

This pressure has resulted in the development of some very advanced communication technologies, the power and sophistication of which is often little known or understood by the average user.

The third generation debate

At present there is an on-going technical debate to determine the communication standards for the third-generation of mobile telephony.

The main purpose of third-generation technology is to provide greater system capacity in terms of users and perhaps more importantly an increase in available bandwidth to support data intensive communication – such as Internet access and e-mail directly to and from a mobile phone.

This technical debate centres on the competing proposed standards of W-CDMA and Qualcomm's cdma2000, both of which use code division multiple access technology, usually referred to as CDMA. This pair of articles is here to help you understand the principles of spread-spectrum CDMA as applied to a mobile phone system.

For comparison purposes I briefly outline the major operating principles of GSM – an existing mobile phone technology – then concentrate on CDMA in greater depth in the second article.

Due to space constraints it is not possible to detail the call set up mechanism of either the CDMA or GSM systems or some of the more esoteric aspects of CDMA. But after reading the articles, you should be able to appreciate the basics of a cdmaOne system and follow the debate as the regulatory authorities finally determine the specification for third-generation mobile phones.

At the time of writing there is considerable debate about the detail of the third-generation specification. But it is widely expected to employ CDMA technology in preference to more established TDMA, i.e. time-division multiple access, and the even older frequency-division multiple access, or FDMA, systems.

Points of contention

Presently, the main points of contention for a third-generation system using CDMA are the frequency plan and data

A mobile phone system's objectives

There are many objectives for a mobile phone system. The following is an outline of the more important ones.

The system operator wants to optimise a number of conflicting requirements – a major goal being to maximise profit or return on capital investment. This leads to the requirement of maximising system capacity – effectively fitting the maximum number of users into a finite bandwidth.

Furthermore the operator wants minimal infrastructure costs – again to maximise profit. The system needs to be robust. If it isn't, calls will be dropped, causing lost revenue and customer frustration.

The phone manufacturer wants a product that is attractive to the end user, inexpensive to produce and easy to manufacture.

The end user essentially wants the reliability, audio quality and low cost of a wired domestic phone combined with the freedom to communicate with anyone from anywhere at any time. More sophisticated users of mobile phones may also want voice mail, e-mail, Internet browsing and other digital services.

However, for the vast majority of users a wireless equivalent of a domestic phone is more than adequate.

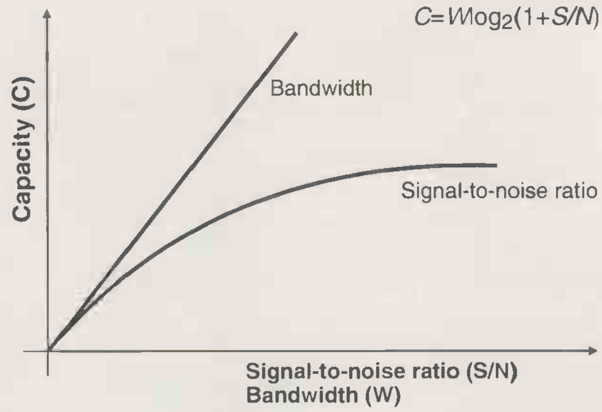

Fig. 1. Shannon's theory predicts the maximum amount of information that can be passed though a given bandwidth with a given signal-to-noise ratio.

rates. There are other protocol issues that also need to be agreed.

The situation is further complicated by the position of Qualcomm. This American company holds over 200 patents – many of which are considered essential to the development of a 3G CDMA system. Some of these patents are being contested by European competitors.

Qualcomm, and many other allied companies, have invested heavily in cdmaOne technology. They would like the third generation to be an evolutionary step forward while still maintaining 'backwards compatibility' with existing cdmaOne systems. This would result in minimising the infrastructure costs and technical pain associated with the introduction of a completely new system.

Specifically, Qualcomm is promoting its cdma2000 as the next evolution for the 3G standard. Whereas other companies are promoting W-CDMA, which currently uses a slightly different clock rate and other system differences.

Companies opposing Qualcomm would prefer a new frequency plan and data rate that would not be backward compatible, but may offer other benefits. It is suspected by some that opposing companies prefer a new data rate and frequency plan only to 'level the playing field' and deny Qualcomm and its associates a competitive advantage.

Despite the above conflict, it is largely agreed the 3G system will use some flavour of CDMA. This is because it is now accepted that CDMA offers greater system capacity and the potential for supporting higher data rates.

However, it has been well documented in the technical press that Qualcomm will only agree to licence its CDMA patents to competitors who want to use frequency plans and data rates different from those of cdma2000 if there is a clear unambiguous technical advantage over the proposed cdma2000 standard.

To date this issue is still unresolved. At this point I will leave the 'political' issues and concentrate on the technology.

See the panel 'A mobile phone system's objectives' for more background.

System capacity

Shannon's theory predicts the maximum amount of information that can be passed through a given bandwidth with a given signal-to-noise ratio.

Figure 1 details Shannon's equation for those of you who are not familiar with it. The graph shows that acceptable capacity can be achieved with even a low signal-to-noise ratio – providing adequate bandwidth is allocated.

The essence of Shannon's equation and supporting information theory is to prove that optimum usage of a given bandwidth is obtained when the signals are 'noise like' and a minimal signal-to-noise ratio is maintained at the receiver.

These principles are at the heart of a spread-spectrum communication system.

Until the advent of GSM, most domestic wireless phones were largely analogue in their operation. That is, they used simple frequency modulation and occupied a certain bandwidth for the duration of the call. There was no attempt to encode speech in a spectrally efficient and secure manner.

Older analogue cellular phones also required 'guard bands' between channels and were subject to various types of interference – much of it self generated. This effectively reduced available bandwidth; degrading the overall efficiency in terms of users versus available bandwidth.

Endurance

For the end user, endurance of a mobile phone is a major concern. Mobile phone designers go to great lengths to maximise talk and standby times.

Inevitably, for a given battery capacity, the endurance of a phone is determined by the power it consumes during standby operation – i.e. waiting for an incoming call – and the radio frequency power it is required to transmit during a call.

Ideally, the power consumed during standby operation should be zero – obviously not practical unless the phone is turned off. During a call the dc power consumed should equal the rf power output – which is again not possible due to circuit overheads and other inefficiencies.

By careful design it is possible to offer standby times of over 100 hours and talk times of over 8 hours from physically small 3.6V, 1.2Ah lithium-ion batteries.

Obviously, the system architecture and other factors affect these times, but system operators have developed a number of tests to determine standby and talk times. This enables them to compare the relative performance of phones supplied for use on their systems.

The exact techniques they use to determine talk and standby times are beyond the scope of this article.

The digital revolution

GSM was a giant leap forward in terms of capacity and call security. The use of advanced low power digital technology permitted the invention of efficient voice encoders, i.e. vocoders, and powerful data encoding techniques.

These factors combined to provide a system with much improved capacity and security. They also allowed talk and standby times to increase by as much as a factor of ten.

Many older analogue cellular phones had at best standby/talk times of 20 and 1 hour respectively. GSM phones on the other hand can typically achieve 200 and 10 hours depending on battery technology and capacity.

However, even though GSM is now well established in the UK and many other countries around the world, its history goes back to the early eighties – and maybe even further. As such its infrastructure is unable to support the increased data rates now required by certain applications, although some work is being done to improve data rate speeds.

Inside GSM

GSM employs the principles of time-division multiple access, shortened to TDMA, and frequency-division multiple access, or FDMA. The use of TDMA in many ways relaxes certain criteria of radio performance.

Specifically as the mobile only has to transmit or receive – but not both simultaneously – the problem of the transmitter blocking the receiver is greatly reduced.

Furthermore, as the mobile is only operating in either transmit or receive

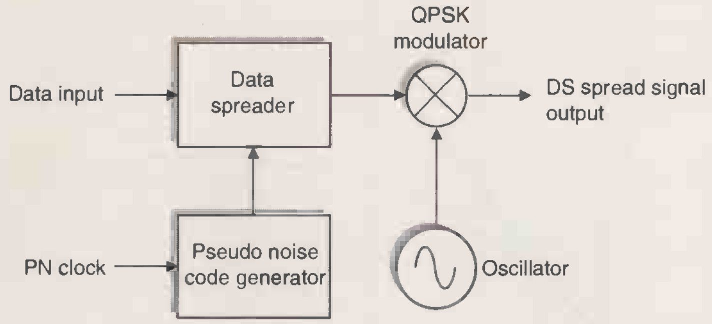

Fig. 2. Generating a 'direct sequence' spread-spectrum signal.

on typically an eighth duty cycle, power consumption is reduced.

GSM900 uses mobile transmit channels on a 200kHz spacing from 880MHz to 915MHz and receive channels from 925MHz to 960MHz. This results in a 'duplexing frequency' of 45MHz. In other words, Tx and Rx frequency pairs are always 45MHz apart, simplifying the frequency generation schemes.

There are also DCS1800 and PCS1900 systems that use GSM technology but they operate on 1800MHz and 1900MHz respectively. Duplexing frequencies are 95MHz for DCS1800 and 80MHz for PCS1900.

All of the above systems involve a modulation data rate of 270.833kbit/s, a frame rate of 4.615ms, a time-slot period of 576.9μs and a Gaussian minimum shift keying modulation scheme, i.e. GMSK, superimposed on the rf carrier.

There are eight time slots per frame with a Tx/Rx split of three time slots, to give enough time for the rf sections to change from Tx to Rx and *vice versa*.

Each 200kHz channel can support a maximum of eight users – by virtue of the eight time slots per frame.

In operation, each base station transceiver, or BTS, produces a broadcast channel identified as a BCH. The function of the BCH is to alert any mobiles within range that service is available.

The BCH also contains embedded information telling the mobile the identity of the network, paging messages and various other information.

Looking for the best transmitter

At switch on, the mobile searches many channels for a BCH signal and will select the strongest to provide service.

Eventually, as the mobile moves out of the selected service area, the system hands the mobile off to another BTS that can offer a better service. This is known as a 'hard hand-off'.

The correct operation of hard hand-off as used in GSM is critical to system performance and to avoiding of 'dropped calls'. In contrast, CDMA uses a technique of 'soft hand-off'. This is effectively a 'make before break', the operation of which will be explained later.

With regard to the GSM system, the BCH signal is only transmitted from a BTS on a specific frequency and the corresponding receive frequency is left clear and is used by mobiles to announce their presence to the BTS.

In return when a call is to be made, the BTS will allocate a traffic channel, or TCH, specifying a frequency and time slot to the mobile.

In essence this is the operation of GSM in the simplest possible terms.

Working in cells

Normal terrestrial mobile phone systems use a cellular method to allow frequency re-use. In other words, the total available bandwidth is divided up into frequency sub-bands and each cell is allocated a number of channels within this sub-band. Adjacent cells use different sub-bands, thus co-channel interference from adjacent cells is largely avoided.

When a mobile is at the limits of service from a particular cell, it would normally be handed over to another cell that can offer a better service, and so on as the mobile continues on its journey.

GSM as described above works on a cellular basis.

The CDMA revolution

Prior to CDMA, most advanced digital mobile phone systems used a system of time and frequency multiplexing, with GSM as outlined above being one of the major standards.

Unfortunately, as elegant as GSM is, it suffers from a number of compromises.

- Each radio channel needs a frequency guard band.
- Complex frequency planning to avoid interference from adjacent cell sites.
- Certain radio channels will be unavailable due to mutual interference
- Each time slot needs a time guard band.
- A time slot is occupied even if there are pauses in speech.

It has long been known and proven in practice that spread spectrum – essentially another name for CDMA – is the technology of choice for maximising information traffic through a communications satellite.

CDMA takes this spread spectrum technology and adapts it for terrestrial use. In doing so, it largely overcomes many of the problems associated with a traditional TDMA or FDMA system.

Spread-spectrum issues

As I mentioned earlier, CDMA is based on spread-spectrum technology. Spread spectrum was originally developed for military use as long ago as WW II. At the time, its attractions to military users were its low probability of interception and resistance to jamming – commonly referred to as processing gain.

Due to technology limitations though, the implementation of commercially viable spread spectrum systems was not possible until the advent of low power digital signal processors and other digital technologies with the power to decode the complex rf signal in real time.

Qualcomm was the first company to demonstrate a commercially viable spread-spectrum mobile phone system. Until this time, users and operators had become familiar with the concepts of frequency and time multiplexing. As a result, the idea of a spread-spectrum system with all users transmitting at the same time on the same frequency must have seemed illogical.

However, to approach Shannon's ideal capacity, signals need to occupy all of the available bandwidth and appear noise like – which CDMA does. And spread spectrum offers other benefits, as I will describe later.

There are two main types of spread spectrum, frequency hopping, shortened to FH, and direct sequence, or DS. As the name implies, frequency hopping results in the frequency rapidly hopping between channels in a pseudo random manner at a rate much greater than the information being conveyed. Hence the information signal is spread across a much wider bandwidth, making it more difficult to detect and jam

Direct sequence also spreads the information content, but in a different way. Each bit of signal information is multiplied by a much higher data pseudo random 'chip'; thus the effective signal bandwidth is also much wider.

Both DS and FS offer 'processing gain', which is determined by the ratio of, signal bandwidth to information bandwidth.

For illustration purposes only, the block diagram in **Fig. 2** details how a typical DS spread spectrum signal might be generated. Typically, the incoming data source is multiplied, i.e.

exclusive-ored, with a much faster pseudo noise-like digital stream (chip stream). The resulting spread data stream is used to modulate a coherent carrier signal.

In this way, the direct-sequence spread spectrum signal output is centred on the oscillator frequency and has a bandwidth approximately twice that of the spread data stream. Essentially, the processing gain is the ratio of information data rate to spreading rate.

Note that, referring again to Fig. 2, other types of modulator are also feasible, such as BPSK. Further, the information could be imposed on the coherent carrier directly and the carrier directly spread by the high-speed chip code.

Direct sequence versus hopping

The main reason CDMA uses direct-sequence spread spectrum as opposed to frequency hopping is that it allows for a shared pilot signal, which is vital to system operation. This pilot signal – similar to GSM's BCH signal – is generated by transmitting on a known frequency with an easily identified code.

In addition, hopping does not generally make for easy resolution of multipath signals, whereas with direct sequencing, multipath signals are spread out in time. This makes them more easy to correlate by means of a so-called 'Rake' receiver.

What resource does CDMA share?

Probably the most important aspect to understand about CDMA is the 'resource' it shares amongst users.

In previous mobile phone technology, such as GSM, the shared resource was a combination of frequency bandwidth and time slot. This resulted in a mobile transmitting at a given time for a set period on a pre-determined frequency.

With CDMA it is essential to realise from the outset that the shared resource is radio-frequency power. Specifically, the system controls the rf power output of mobiles such that the received signal strength at the base station of any mobile is effectively the same as any other mobile. This is achieved by *closed-loop power control*, which ensures that a nearby mobile transmits at an appropriately low power while a distant mobile transmits at an appropriately high power.

Thus, the closed-loop power control attempts to maintain a signal-to-noise ratio for each mobile at the base station which is just adequate. Any excess power received from any mobile effectively reduces system capacity and may cause interference to other base station and mobile units – reducing capacity as per Shannon's equation.

It is for these reasons that mobile radio-frequency power control is at the heart of a successful CDMA system.

People in a room?

The above concept can perhaps be better understood by thinking of mobiles within a cell as people in a room, with each person speaking a different language.

The base station could likewise be thought of as a centrally placed listener. Provided that this listener knows the language of a particular person he or she could decode just that one person and ignore the rest.

The listener could also instruct all or one of the persons in the room to speak louder or quieter.

In this way the listener would endeavour to ensure that all persons are heard at the same volume – thus the processing power of the brain would then be able to select the desired person. ■

In a second article, Tim plans to explain CDMA technology in more detail.

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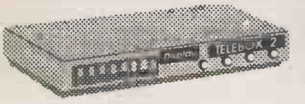

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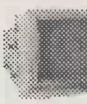

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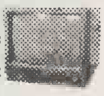

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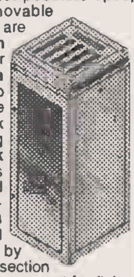

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LETTERS

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Rewriting history

I enjoy reading the articles you publish on early developments in electronics and often find valuable information relevant to my own historical researches into electricity and music. Two recent articles however, contain dubious statements; I am surprised that nobody else has responded at least to the first.

Andrew Emmerson's myth-debunking exercise *Rewriting History* November 1999 misses the point about the German Magnetophon tape recorders.

Of course these machines were no secret before 1939; but in America and Britain they would not have been considered to be any improvement over existing steel wire machines.

The crucial difference between the pre-1989 Magnetophons and those "captured" at the end of the war was the incorporation of frequency AC bias In the recording circuitry, developed by Hans Joachirn von Braunmuhl and W. Weber in 1940. Their 1943 US patent was not the first for AC bias; but in combination with higher quality magnetically coated tape their work significantly; improved the fidelity of German sound recordings

The result was that listeners could no longer distinguish between live and recorded broadcasts, giving the Allies the mistaken impression that Hitler's speeches were live transmissions, and that he was travelling all over Germany to make these broadcasts.

This qualitative difference explains why steel wire machines virtually disappeared after 1945 and the captured Magnetophons were rapidly developed into commercial machines by Ampex and other companies

Hugh Davies
London

Andrew replies:
Your correspondent suggests that "I missed the point" in my article; I rather think he introduces a different and indeed valid point.

However dramatic the improvement to sound recording brought about by hf bias may be, it does not invalidate my statement that many commentators repeat the myth that the Allies had no knowledge of the magnetic tape recorder until American troops discovered German Magnetophon machines playing out propaganda tapes. This, I'm pleased to note, Mr Davies does not dispute and nor do I dispute his additional observations.

A little discord

Richard Brice's survey *Electronics in Music* from the Dec 1998 issue contains a couple of questionable assumptions. The earliest amplified guitars, in the late 1920s, did not use contact microphones as we know them today (based on piezoelectric crystals; the first crystal microphones were not invented until 1931) but such devices as record player cartridges; electromagnetic pickups for guitars were also developed around 1931 following crude attempts in the early 1920s.

The tape-based Chamberlin from the late 1940s was by no means the "world [sic] first sampler": several instruments in the 1930s used sounds recorded on optical film sound tracks or rotating glass discs (as in the mechanisms for most telephone 'speaking clocks' from the same period), including the Hardy-Goldthwaite organ, the Welte Lichtton Organ and the Singing Keyboard.

Indeed from 1906 up to at least the early 1950s patents were granted in several countries for 'samplers' based on every sound recording medium, beginning with shellac discs, some of which were based on working models

Finally, on the musical side, Brice's example of a work featuring The Ondes Martenot soloistically (Marcel Landowski's 'Jean de la Peur') is unfortunate. since this work – the subtitle of the composer's First Symphony does not even appear in a list (printed in the only book devoted to Martenot and his invention[1]) of six works by him that include the instrument; a better choice would have been one of several concertos, including one by Landowski himself.

...not so fast

Andrej Chomyn, Letters March 1999, was a little too hasty when devising his solution to the circuit puzzle of Jean-Marc Brassart, Letters February. If he needed only five minutes to find his circuit, it took me less than ten seconds to see that it is woefully erroneous.

Indeed pressing S_1 will leave the LDR unconnected making low level measurements impossible. Pressing S_1 and S_2 together will i no way permit to adjust for full scale. Strong light measurement only seems possible by pressing S_2.

I am not at all a circuit designer and I confess to have needed more than half an hour – as predicted by J M Brassart – to find the following working circuit.

This little exercise raises at least two interesting questions: first, is there any design method that will lead automatically to a correct circuit and, second, is there only one correct solution?

Jean-Pierre van Dormael
Wezembeek-Oppem
Belgium

During many years in industry, devising modifications to accommodate changes in components, I find the best approach to problems like Jean-Marc Brassart's brain teaser in the February issue is first, sketch that part of the circuit which remains unchanged irrespective of function, shown as a). Points where further connections will be made are identified as 1,2, 3 and 4.

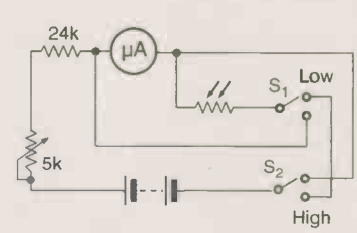
Next, add the switches, linking as necessary ti the previously identified points, diagram b). As required, each switch selects a range, both switches are off. Using this approach, the transition from a) to b) took me six minutes.

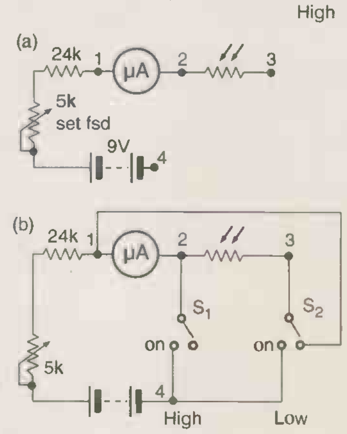
Keith Cummins
Address not supplied

With reference to Jean-Marc Brassart's circuit in the February issue and Andrej Chomyn's reply in the following one.

If both switches are operated to adjust the full scale reading the meter will be shorted out and adjustment will be impossible. The solution took more than five minutes but less than 30.

Carl Heinlein
Willingham
Cambridge





Jean Pierre and Carl worked out the upper light-meter solution and Keith the lower.

The third part of Brice's series, "*Electronic Effects in Music*" March 1999, contains a further inaccuracy. Wah wah effects do not use a band pass filter but a low-pass filter, thus the adjustable 'centre' frequency control is actually for the cutoff frequency.
Hugh Davies
London

Richard replies:
I'm sorry that Hugh Davies assumed I was talking about 1990s piezoelectric contact microphones when I wrote about the world's first electric guitars; but such an assumption does seem a little bizarre!

What is true is that the first attempts to amplify guitars involved using contact microphone assemblies as stated.

His second point is more valid. Although I actually describe the Mellotron as an "primitive analogue sampler" I did – perhaps somewhat sloppily – refer to the invention as "the world first sampler" in view of its ability to provide sampled drum loops.

Modern samplers are more often used nowadays to provide 'chunks' of music – most often drum loops – rather than simply samples of waveforms and it was in this respect that I made the connection.

Mr Davies' last point is simply wrong. In view of the large number of wah-wah designs, it's possible he may have a pedal which is a low-pass filter but there are many others – the majority – which are substantially band-pass; listening to the effect is enough to tell you that!

Ionisation chamber and filament surges

Dr Imarisio seems to describe the personal radiation monitor which I once used regularly about forty years ago while calibrating fast neutron detectors.

The attached picture – taken with a cheap and cheerful Casio QV-100 digital camera – shows one of two which I 'rescued' when the work ceased, with a ball pen alongside.

The monitor is set to zero by plugging it on to a power unit, squinting into a magnified image of the tiny Röntgen scale and adjusting the voltage – about 800V I believe – until the quartz fibre indicates zero.

Radiation detector.

Leakage is indistinguishable from radiation – 'fail safe' I suppose – so a rather clever sprung pin makes contact with the chamber during charging and releases to isolate it again afterwards.

I hope that the end of the cold war has made them redundant.

Filament surges. The recent correspondence on filament surges reminds me of my experiments about 50 years ago with supplying 0.15A series valve heaters from 2.0μF, 400V capacitors instead of the normal resistive droppers. As well as being lossless, capacitors form a semi-constant current source and would presumably reduce surges.
John Norman
Via e-mail

Roaring subwoofer

I am building the subwoofer as described in the February 1997 issue and have performed a significant amount of testing on it. I have come to the following conclusion.

Transistor Tr_1 – a BC327 — is not fit for the job. I have blown up three transistors doing test on full power. The maximum V_{ce} it can resist is only 60V, which is not sufficient. I replaced it successfully by BC640, which has a V_{ce} of 80V.

I modified the output stage to a full complementary stage using a *BD317-BD318* complementary pair. It simplifies the design since Tr_3 is eliminated.

I detected some minor oscillation of around 2.5MHz at high power. The only way to eliminate it was by shunting R_{16} with a 4.7nF capacitor.

Referring to Fig. 3, Measuring the response of the pick-up coil below the 73Hz resonance frequency of the box, the result was a perfect velocity curve

Regeneration

Ian Hickman's article on super-regenerative detectors unearthed some ancient recollections, dating back to my youth also. As I remember, the Holy Grail of amateur radio set builders then was the 'One Tube Loudspeaker Set' and the super-regenerative design came the closest to this ideal. I mention this because the first publication I know of, that describes this principal goes on at length about impressive loudspeaker operation from a small number of tubes.

The publication I reference is titled 'Some Recent Developments of Regenerative Circuits,' V.10, June, 1922, Proceedings of the Institute of Radio Engineers, by Edwin H. Armstrong. The first paragraph reads:

It is the purpose of this paper to describe a method of amplification which is based fundamentally on regeneration, but which involves the application of a principal and the attainment of a result which is it is believed is new. This new result is obtained by the extension of regeneration into a field, which lies beyond that hitherto considered its theoretical limit, and the process of amplification is therefore termed 'super-regeneration'.

Armstrong goes on to describe several configurations of receivers with an extremely detailed, almost cycle-by-cycle, analysis of operation. Here is where he goes into a most enthusiastic description of loudspeaker performance providing audibility 500 yards away! Sensitivity definitions had yet to be established.

All these receivers were externally quenched. Later designs used self-quenching where the grid circuit time constant was large enough to periodically cut off oscillation at a super audible rate. It was called 'squegging', and while useful in this case, it could be undesirable in other applications. Armstrong almost invented self-quenching many years earlier.

In possibly the first description of the regenerative receiver, Proceedings of the IRE, V3. 1915, he mentions that these receivers have a problem with self-blocking of oscillation if an excessively large grid circuit time constant is used. In the 1922 paper, he references British patents by Turner and Bolitho for grid-triggered relay circuits that go into free oscillation when the grid voltage falls below cut off.

Super-regenerative receivers were extensively used at vhf and uhf before and during WWII. German submarines used a radar counter measure receiver of this type until it was discovered that the radiation from the oscillating detector made it a wonderful radar target.

In the USA, in the early fifties, an fm receiver called the 'Freemodyne' used a Super-regenerative slope detector. These were not popular with neighbours attempting to listen to the same station.

Just for general interest, Edwin H. Armstrong established himself as a powerful, original and influential developer of American radio communication technology. In addition to the regenerative and super-regenerative systems, he is usually credited with the first practical super-heterodyne receiver design and almost single-handedly pioneered fm radio broadcasting in the USA.

But Armstrong could be contentious. The second referenced article has a testy, back and forth diatribe with Lee DeForest about the merits of hard versus gassy Audions, which the editor finally cut off. (Armstrong won).

During his lifetime, the fm system he envisioned was thwarted by opposing interests, leading ultimately to his suicide.
Bill Woodworth
Ridgecrest, CA. USA

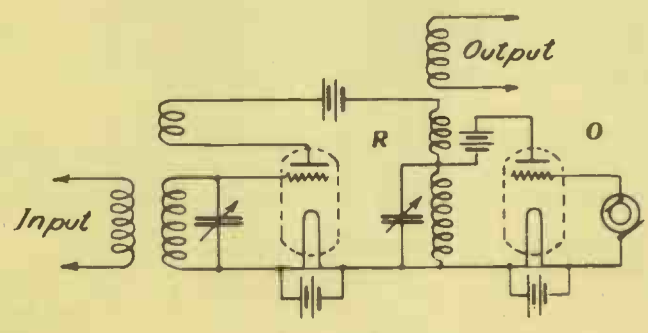


FIGURE 1

Diagram from the 1922 IRE article by Armstrong. It shows an externally quenched design with output to a separate detector. Here, 'R' is the receiving valve and 'O' is the quenching signal source.

falling at 6dB/oct. I could not find any sign of a breakpoint around 40Hz as shown in Fig. 3. For that reason, I had to modify the correction network around A_8. I replaced the two resistors of 560k by 330k in order to shift the cut off frequency of that filter to around 85Hz.

The maximum effective power the box can handle is only 30W or 15W per speaker. Trying to put more power into it makes the box sound as a rattlesnake. The speakers are clearly at their excursion limit.

Testing the speakers in free air below their resonant frequency gave the same power. I cannot understand why a speaker in a closed box and in free air shows the same power limit. Maybe you understand.

Conclusion: I tested the box with organ music containing 29Hz and the sound was really impressive!

Johan Stockman
Adegem
Belgium

Missing charge

Brian Close raises an apparent paradox on the sharing of charge between a charged 100μF capacitor and a similar uncharged one in the December 1998 issue 'Letters'. The paradox may be resolved by considering the practical aspects of the sharing.

If the circuit is completely lossless there will be no sharing, and the charge will simply oscillate in perpetuity from one capacitor to the other when they are connected. The current and frequency are determined by standard text book analysis from the capacitances, start voltage and circuit inductance only.

If however there is any loss in the circuit, resistive, dielectric or radiative, as obviously there will be, the circuit will be damped. If this equivalent resistance is low, the circuit will perform a damped oscillation until both capacitors end up at the same steady voltage.

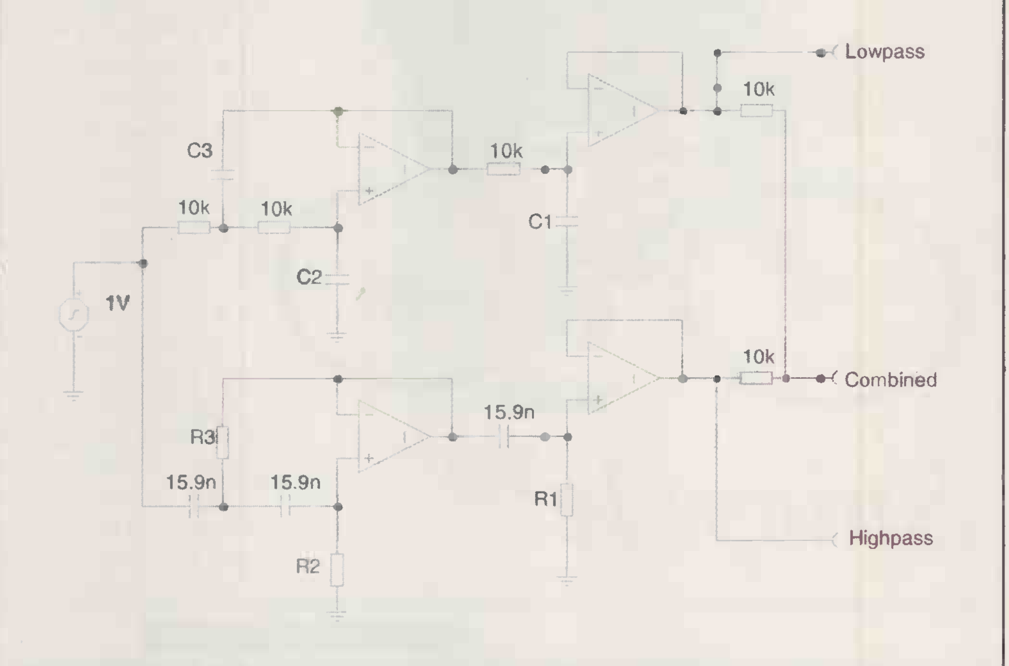
If the resistance is high the charged capacitor will perform an overdamped discharge until both capacitors also are at the same steady voltage. I will ask you to check by standard text book analysis that in both cases the total energy dissipated in the equivalent resistance is exactly half that of the original stored energy in the first capacitor.

The final state is as Brian Close shows in his second figure, the original charge of 5mC is conserved and equally shared, 2.5mC in each capacitor, and each capacitor ends at 25V, half the original voltage and 31.25mJ energy, and one quarter of the original 125mJ energy as shown. The remaining half of the original energy, 62.5mJ has been dissipated in the equivalent resistance. Moral – don't put resistors in switched mode power supplies.

This is a nice demonstration example for Physics/Electronics undergraduates, or possibly sixth formers, using a recording oscilloscope monitoring voltage and current, an example in single shot pulse technology, and even of switched mode basics. The next question to ask however is whether half of the energy is dissipated if the two capacitors are not equal.

Should anyone wish to experiment it is worth noting that the 125mJ stored energy is approaching hazardous levels, and the cracks from low-loss discharges may reach ear damage levels. Finally to cause some real trouble, what happens if the charged capacitor is connected to the other through a diode?

E Thornton
Wotton-under-Edge
Gloucestershire



Too simple to be useful?

Can someone explain please, in simple terms if possible, why this third-order two-way active filter is not perfect as a loudspeaker crossover network?

When the low and high pass signals are added, the combined signal has *no* dip or peak at the crossover frequency. If the two loudspeakers are mounted as close together as possible and with their voice coils in the same plane, surely the overall response must be as flat as the drivers will allow?

Whatever the problem is with this design, its got to offer much higher fidelity than is possible with any passive crossover network. As a bonus, an active crossover allows you to connect each speaker directly to its amplifier, increasing efficiency and damping factor.

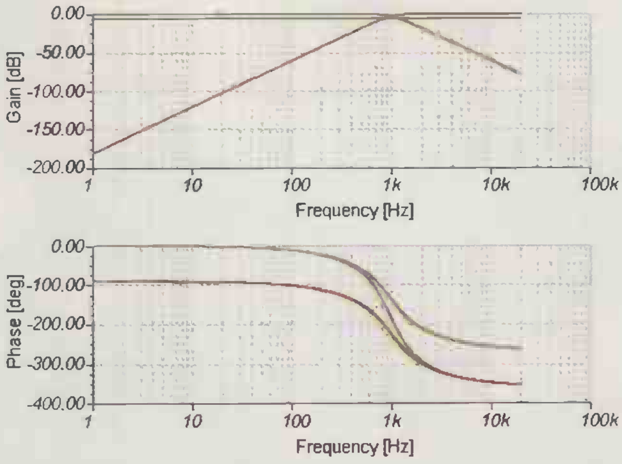
But this network is so easy to implement that it has got to have a serious drawback. Otherwise, why would such complex solutions have been proposed over the years?

The two output resistors are only there so that my CAD simulator - Tina - could produce an output curve representing the sum of the low and high-pass sections.

For the low-pass filter, you work C_1 out to have an impedance, X_C, of 10kΩ at the crossover frequency. Capacitor C_2 is simply $0.5C_1$ and C_3 is $2C_1$.

In the high-pass section, R_1 is 10kΩ. The capacitor values are all equal, and worked out so that their X_C is 10k at the crossover frequency. Resistor R_2 is $2R_1$ and R_3 is $0.5R_1$.

My first implementation was a four-way design using video speed discrete op-amps in the hope of getting best performance. But I had no CAD package at the time and I forgot to take into account the input impedance of the discrete op-amp when I worked out the components. Nevertheless, I found the results amazing.



With modern cmos op-amps designed for hi-fi, input impedance and distortion will be insignificant. If you are not too bothered about distortion, or you just want to prototype the filter, any op-amp can be used from the 709 up.

Jim Cahner
Via e-mail

Telephone lamp switch

If the telephone rings at night, a lamp comes on for a period long enough for you to lift the handset and gather your wits together. The period may be extended by pushing a switch. The circuit is optically isolated from the telephone line.

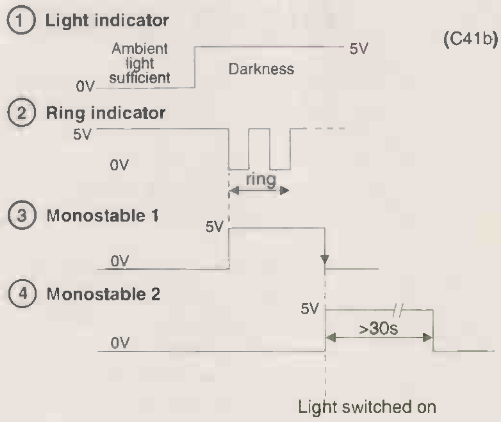
When the handset is on hook, there is 48V dc across the Tip and Ring lines, the coupler led is off and draws little current; the coupler transistor is also off and there is 5V on the Ring Indicator line.

When the telephone rings, there is 100V ac superimposed on the direct voltage and the voltage on the transistor collector falls to zero during each ring period.

The other coupler, associated with the light-dependent resistor, assesses the ambient lighting condition, the ldr having a resistance of 15kΩ when illuminated and at least 100kΩ when unlit, the transistor being switched on and off respectively, between 0V and 5V.

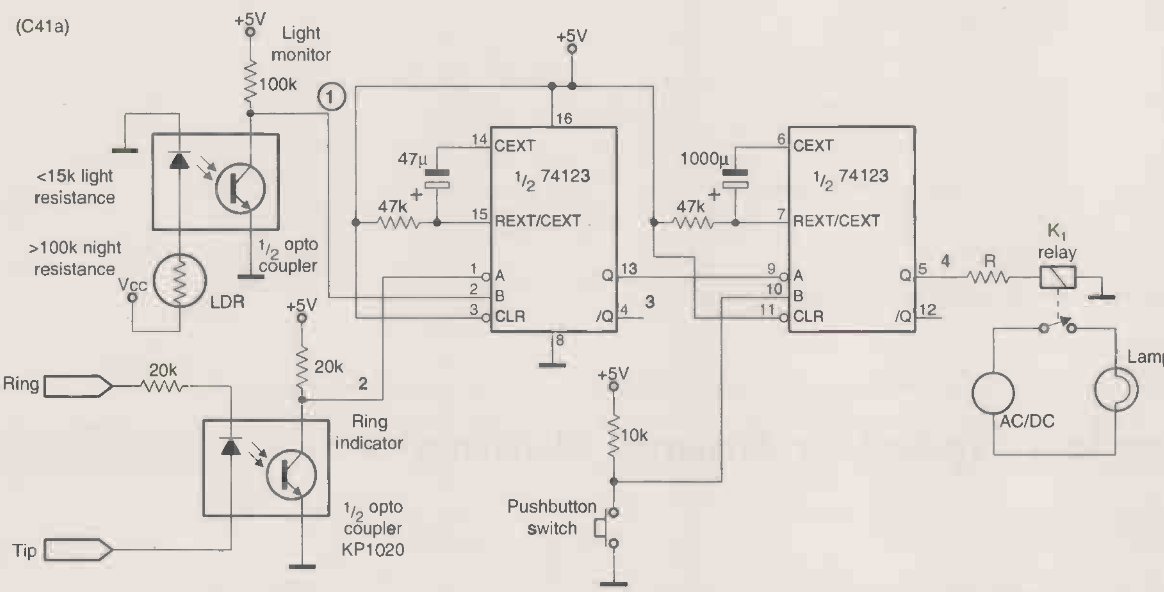
The first *74123* retriggerable monostable generates a pulse with a programmable width, its trailing edge of high to low triggering the second monostable, which controls a relay and switches the lamp on and off. This period is extendable by retriggering the second monostable by means of the push-button switch.

The light then goes off after the required time, which is set by varying the value of the second timing capacitor from the 1000μF shown. Sensitivity to light may be varied by means of the light detector transistor's collector resistor.



A R Jayan
Electronics Research and Development Centre
Kerala
India
C41

This automatic telephone lamp is completely isolated and needs no attention whatever.



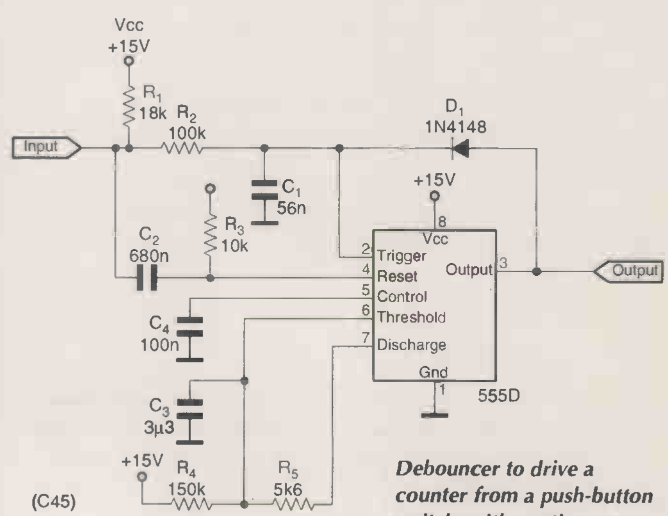
Push-button debouncer

I needed to drive a decade counter with a push-button switch with a view to frequency selection in a signal generator, and developed this debounce circuit to interface the switch to the counter.

The function of the *555* is to provide a single pulse at the output each time the input goes low; if the input remains low after the output pulse ends, then the 555 retriggers, since C_1 discharges via R_2. Pulses therefore appear at the output while the button remains pressed, allowing the subsequent frequency selector to step without further activation of the push-button.

Releasing the switch charges C_1 through $R_{1,2}$. To distinguish between a single pulse and repeated ones, the first one is timed at 500ms, while further pulses are 200ms long. This is done by inserting a resistor between the capacitor and pin 7 of the 555 to prevent C_1 discharging before the 555 is reset. The timer is reset each time the input goes low to make sure the output pulse appears each time the button is pressed; the 555 cannot then be retriggered before C_3 discharges.

Van den Abeele Bernard
Evergem
Belgium
C45



Debouncer to drive a counter from a push-button switch, with continuous pulses if required.

Digital circuit 'organiser'

Designed to organise the timing of digital circuitry for various functions, this simple circuit uses only a *4017* decade counter with its decoded outputs and a spare Nand.

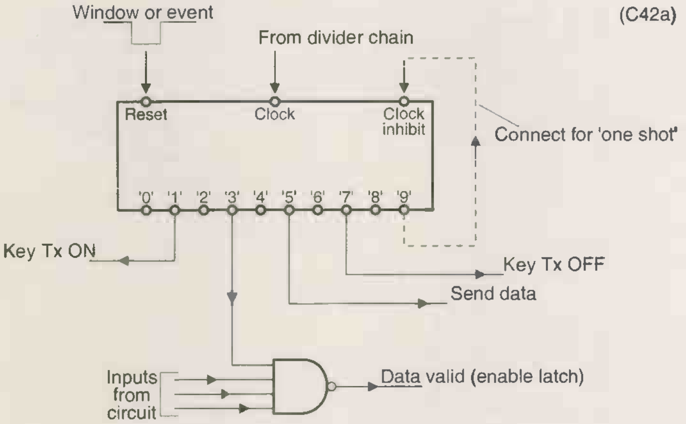
The *4017* receives clock signal from a suitable point in a divider chain fed by an oscillator, in the usual way. Outputs from the counter are used as follows:

a: count 1 is a trigger for external circuits;
b: output 3 is Nanded with points in the external circuit that need to be monitored;
c: outputs 2 and 4 are unused, to provide time isolation between adjacent counts to allow signal on input 3 to settle after propagation delays and rings;
d: and outputs 5 and 7 are triggers.

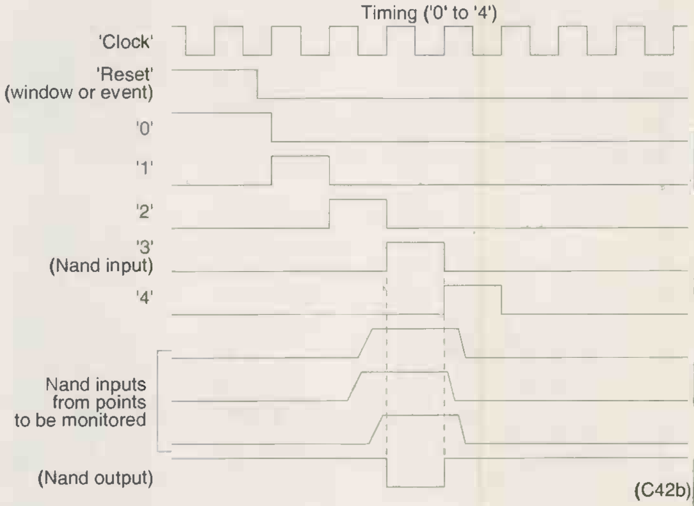
If the external circuit needs the timing to coincide with certain events, the 9 output can be connected to the clock enable pin. In this case, the start of the event sets the counter, which progresses from 0 to 9 and then stops until it receives a reset.

More counters may be connected in series to obtain more functions.

M F Trowbridge
Sturminster Newton
Dorset
C42



Simple counter circuit to monitor and trigger events in a digital circuit.



Simpler loudspeaker thump eliminator

£50 Winner

In contrast to one or two such circuits recently seen in the audio press, this thump suppressor verges on the minimal.

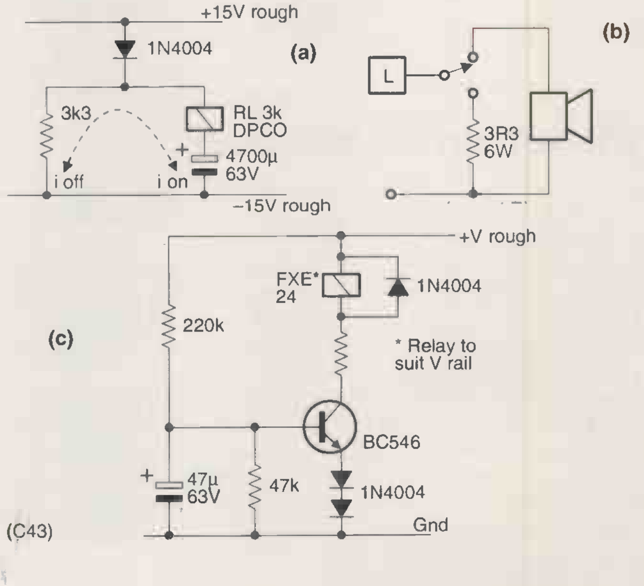
At switch-on, *C* slowly charges and reduces current through the relay coil until, after a few seconds, it ceases and the relay drops out.

The reverse occurs at switch-off: after a second or two the discharge current is insufficient to keep the relay on, the diode preventing other paths.

A 3.3Ω, 6W resistor bypasses the speaker. A pcb-mounted double-pole changeover relay, an *FXE-24* serves in this application.

The variation shown at (c) has been in use for eight years in many sub-bass amplifiers with no trouble.

Paul Nelson
Congleton
Cheshire
C43



Very simple, but effective 'thump' suppressor for speakers (a). At (b), the relay contact and speaker connection for one stereo channel only, and at (c) the variation now in use for sub-bass amplifiers.

Two-op-amp sine generator

Sinewave oscillators using three op-amps of the type described by Hickman[1] are now fairly well known, but since one of the op-amps is simply an inverter it is possible to manage with two, by making one of them, A_1 in the diagram, a non-inverting integrator.

This is a differential circuit, in which R_1C_1 at the non-inverting input balances R_2C_2 at the other. Op-amp A_2, with R_3C_3, is a conventional inverting integrator. For oscillation, each integrator must contribute 90° phase lag to cancel the 180° of the inversion and the loop gain should be just over unity.

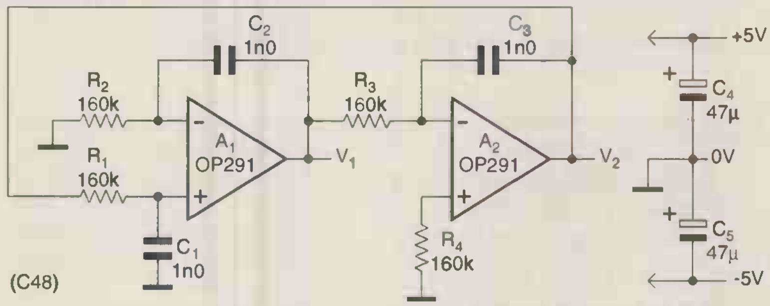
An op-amp of the *OP 291* type is ideal because of its rail-to-rail output to within 10mV, since the amplitude is set with V_1 just clipping, while V_2 is present at minimum distortion and still virtually ±5V of output. Best results are obtained by adjusting one or other rail for symmetrical clipping at V_1. Frequency is 1kHz with the values shown, R_4 being optional.

Initial setup is critical, since there are no thermistors or diodes for regulation, this fact also having a bearing on a likely vulnerability to temperature changes.

The most reliable method is to match $R_1R_2R_3$ to within ±0.1% with a 3.5-digit meter and to select $C_1C_2C_3$ if possible to within ±0.5%. Next, increase the gain by 3% by adding 5MΩ across R_2 or 33pF across C_1 or, possibly, making R_2 a 150kΩ with a series 20kΩ trimmer at the zero-volts end.

If C_3 is made slightly high in value, lowering the frequency by half that percentage, the setting of R_2 is less critical and the gain may be set high to allow more tolerance to temperature changes. ■

C J D Catto
Cambridge
C48



Sinewave generator using two op-amps, which usually come in twos or fours, not threes.

SPEAKERS' CORNER

The moving coil is the most common form of transduction used in loudspeakers, but being partly electrical and partly mechanical, it is equally misunderstood by specialists in both fields. Here John Watkinson explains what happens.

The linear moving coil motor used in most loudspeakers is in many ways simply a linear version of the ubiquitous rotary electric motor – and it shares many characteristics.

Figure 1a) shows that a motor is intended to convert electricity to mechanical power, whereas a generator, b), is intended to convert mechanical power to electricity.

The use of the word intended is deliberate because there is actually no difference between a motor and a generator except the direction of energy flow.

A motor-generator shown at **c)** may produce an output at a different voltage to the input and so it is an impedance converter having the attributes of a transformer. A generator-motor **d)** can produce an output at a different rotational speed to the input and has the attributes of a mechanical gearbox.

Gear boxes

Transformers and gearboxes are impedance converters. The impedance connected to the output is reflected into the input by a ratio which is the square of the turns or gear ratio.

Figure 2 shows that a transformer and a gearbox both having a 2:1 ratio have an impedance ratio of 4:1. A motor, a generator and the moving coil motor of a loudspeaker are all impedance convertors. Mechanical impedance on one side is reflected to the other side as electrical impedance and *vice versa*. This means that an electromechanical system can be modelled by converting all of the mechanical parts to their electrical equivalent.

Figure 3 shows that the impedance conversion of a moving coil motor can be simulated by treating it as a transformer. On the left side the quantities are electrical, on the right side, mechanical quantities are simulated electrically, such that the velocity is equal to the voltage and the force is equal to the current. This is called a mobility analogy.

The connection between the two sides is that the equations of force-creation and back-emf creation must hold. The force on the coil in newtons is given by the product of the flux density in the gap, B in teslas, the length of coil wire actually in the gap in metres and the current in amps.

The back-emf, V, is the product of B, l and the velocity in metres per second. In both cases it is only the product of B and l which is of any consequence. This is known as the Bl product and its units are expressed – interchangeably – in tesla-metres or newtons per ampere.

Figure 3 also shows how the electrical impedance can be calculated as a function of the mechanical impedance. Note how the impedance ratio is the square of the Bl product, hence the use of Bl:1 to describe the turns ratio of the pretend transformer.

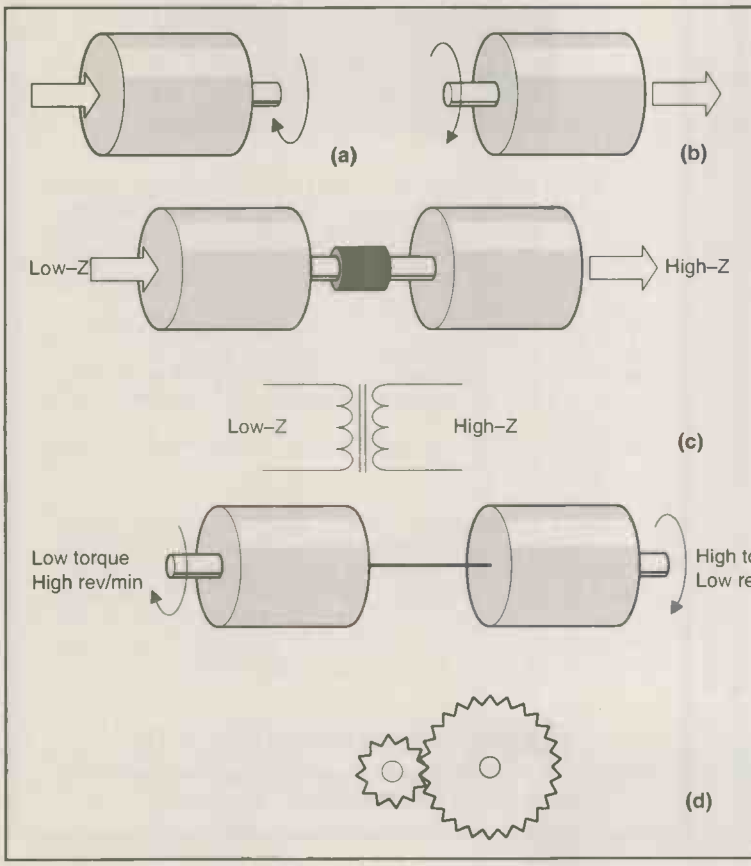


Fig. 1. Motor/generator basics. a) and b) emphasise that there's no difference between a generator and a motor. Illustration c) shows a motor-generator combination that is analogous to an impedance converter and d) outlines a mechanical impedance converter.

Impedance inversion

It is also of considerable significance that the mechanical impedance is inverted. In other words the electrical impedance seen by the amplifier is the reciprocal of the mechanical impedance seen by the coil. This is initially sur-

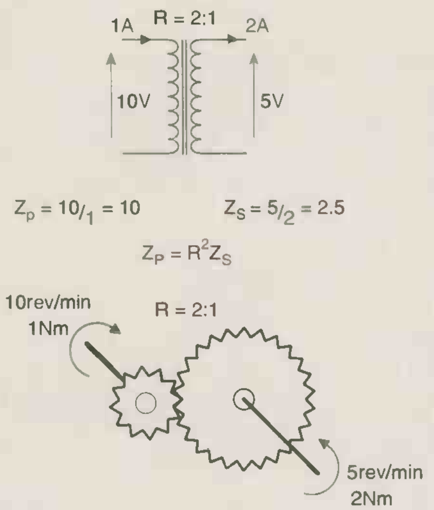


Fig. 2. A transformer and a gearbox with a 2:1 ratio both have an impedance ratio of 4:1. The impedance ratio is the square of the turns or gear ratio.

prising, but in fact it does explain why the current taken by an electric motor rises when its load increases.

Figure 4a) shows the essential parts of a moving coil speaker. On the left is the coil having a *Bl* product and a dc resistance R_e. The force from the coil excites a mass-spring-damper system. The force is distributed between the mechanical impedances due to moving mass, the compliance and the resistance seen by the mass.

As was shown in an earlier 'Speakers' corner', a mass-controlled system has a velocity response that falls with frequency at 6dB per octave and a compliance controlled system has a velocity response which rises at 6dB per octave. This corresponds to the electrical behaviour of a reactive device.

Figure 3 shows that current is analogous to force and voltage is analogous to velocity. An inductor in series with the current/force would produce a voltage/velocity proportional to frequency. This is the behaviour of a compliance.

As a result, a compliance driven by a moving coil motor can be replaced by an inductor. By a similar argument, a mass can be replaced by a capacitor.

It is easy to prove that this works in practice. A small motor gearbox from the local model shop can be connected to a resistor, an inductor or a capacitor in turn to see the result of trying to turn the shaft. With the resistor, the motor is harder to turn. With a capacitor, of several thousand microfarads, the motor is initially harder to turn, but continues running for some time in the same direction when the shaft is released. This is because the system is acting like a flywheel.

With a suitable inductor – and one of sufficient inductance is hard to find – the motor will reverse direction when the shaft is released, because the system is acting like a spring.

Figure **4b)** shows that the loudspeaker can be modelled by direct replacement of the mechanical parameters with electrical ones. However, as the moving coil simply acts like a transformer, the parameters can be brought to the primary side simply by impedance converting them using the square of the *Bl* product as in c).

The result is that – at low frequencies at least – the entire moving coil speaker can be modelled as just four components. This is a tremendous advantage because a few simple calculations can eliminate a lot of tedious experiment. ■

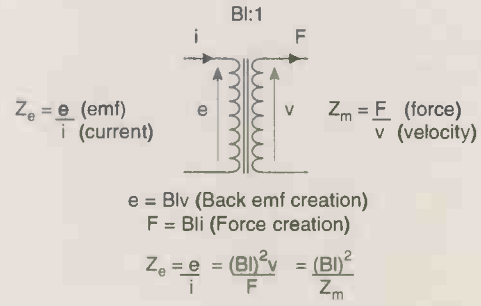


Fig. 3. Impedance is inverted through the motor. The conversion ratio is Bl, the impedance ratio is (Bl)2.

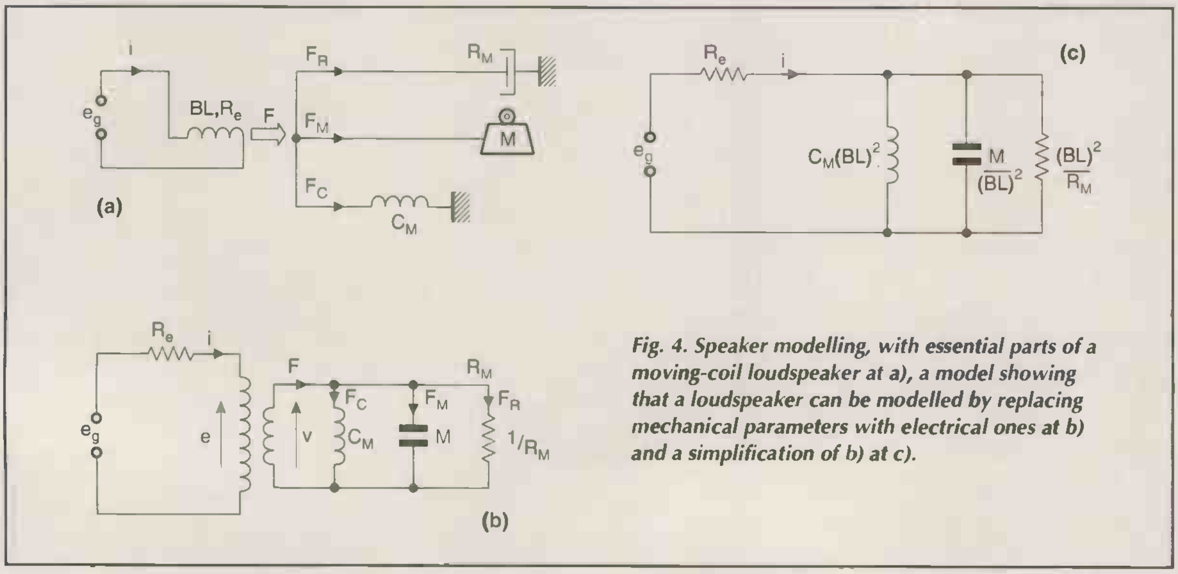


Fig. 4. Speaker modelling, with essential parts of a moving-coil loudspeaker at a), a model showing that a loudspeaker can be modelled by replacing mechanical parameters with electrical ones at b) and a simplification of b) at c).

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Address http://www.tiepie.nl

PLUG IN AND MEASURE

TiePie introduces the HANDYSCOPE 2
A powerful 12 bit virtual measuring instrument for the PC

The HANDYSCOPE 2, connected to the parallel printer port of the PC and controlled by very user friendly software under Windows or DOS, gives everybody the possibility to measure within a few minutes. The philosophy of the HANDYSCOPE 2 is:

"PLUG IN AND MEASURE".

Because of the good hardware specs (two channels, 12 bit, 200 kHz sampling on both channels simultaneously, 32 KWord memory, 0.1 to 80 volt full scale, 0.2% absolute accuracy, software controlled AC/DC switch) and the very complete software (oscilloscope, voltmeter, transient recorder and spectrum analyzer) the HANDYSCOPE 2 is the best PC controlled measuring instrument in its category.

The four integrated virtual instruments give lots of possibilities for performing good measurements and making clear documentation. The software for the HANDYSCOPE 2 is suitable for Windows 3.1 and Windows 95. There is also software available for DOS 3.1 and higher.

A key point of the Windows software is the quick and easy control of the instruments. This is done by using:
- the speed button bar. Gives direct access to most settings.
- the mouse. Place the cursor on an object and press the right mouse button for the corresponding settings menu.
- menus. All settings can be changed using the menus.

Some quick examples:
The voltage axis can be set using a drag and drop principle. Both the gain and the position can be changed in an easy way. The time axis is controlled using a scalable scroll bar. With this scroll bar the measured signal (10 to 32K samples) can be zoomed live in and out.

The pre and post trigger moment is displayed graphically and can be adjusted by means of the mouse. For triggering a graphical WYSIWYG trigger symbol is available. This symbol indicates the trigger mode, slope and level. These can be adjusted with the mouse.

The oscilloscope has an AUTO DISK function with which unexpected disturbances can be captured. When the instrument is set up for the disturbance, the AUTO DISK function can be started. Each time the disturbance occurs, it is measured and the measured data is stored on disk. When pre samples are selected, both samples before and after the moment of disturbance are stored.

The spectrum analyzer is capable to calculate an 8K spectrum and disposes of 6 window functions. Because of this higher harmonics can be measured well (e.g. for power line analysis and audio analysis).

The voltmeter has 6 fully configurable displays. 11 different values can be measured and these values can be displayed in 16 different ways. This results in an easy way of reading the requested values. Besides this, for each display a bar graph is available.

When slowly changing events (like temperature or pressure) have to be measured, the transient recorder is the solution. The time between two samples can be set from 0.01 sec to 500 sec, so it is easy to measure events that last up to almost 200 days.

The extensive possibilities of the cursors in the oscilloscope, the transient recorder and the spectrum analyzer can be used to analyze the measured signal. Besides the standard measurements, also True RMS, Peak-Peak, Mean, Max and Min values of the measured signal are available.

To document the measured signal three features is provided for. For common documentation three lines of text are available. These lines are printed on every print out. They can be used e.g. for the company name and address. For measurement specific documentation 240 characters text can be added to the measurement. Also "text balloons" are available, which can be placed within the measurement. These balloons can be configured to your own demands.

For printing both black and white printers and color printers are supported. Exporting data can be done in ASCII (SCV) so the data can be read in a spreadsheet program. All instrument settings are stored in a SET file. By reading a SET file, the instument is configured completely and measuring can start at once. Each data file is accompanied by a settings file. The data file contains the measured values (ASCII or binary) and the settings file contains the settings of the instrument. The settings file is in ASCII and can be read easily by other programs.

Other TiePie measuring instruments are: HS508 (50MHz-8bit), TP112 (1MHz-12bit), TP208 (20MHz-8bit) and TP508 (50MHz-8bit).

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CIRCLE NO. 116 ON REPLY CARD

Leslie Warwick presents an update on the state-of-the-art in video recorder technology.

VCR advances

With the VCR market now largely a replacement one, manufacturers are having to compete by continually adding new features.

One of the more recent is auto set-up. There are two versions of this in use. In one, the frequency synthesis tuner automatically scans the uhf band for a strong station sync. The station is then identified by its own identity signal and stored in the appropriate channel, i.e. BBC1 on number 1, BBC2 on number 2, etc.

The other auto set-up feature requires the VCR and TV to be linked by digital bus, allowing tuning information to be downloaded from the TV on one SCART pin. This bus also provides a number of one-button shortcuts for combined VCR and TV operations. The VCR then sets the clock from the off-air time signal on channel 1. Some models will also retune the rf modulator if interference is detected.

Post-code security

Post-code security is a still more recent addition. The owner enters the post code in an eprom. If the VCR is an Aiwa model, the name and post code are not seen again unless the electricity has been cut off. In this case, the display remains, but the VCR locks up until the PIN is entered.

With other makes the display comes on briefly every time the VCR is powered up; it cannot be changed without the post code, but the VCR will still operate. Because the eprom contains other software for timer/on screen display in Aiwa machines – removing it disables the machine.

Timer recording has undergone the most changes since VCRs were launched here in the late seventies. This is largely due to *VideoPlus* and programme delivery control, commonly known as PDC.

VideoPlus was developed by Gemstar. It is known as *VCRPlus* in the USA, *ShowView* in Europe, and *G-Code* in Asia.

PlusCodes are now a familiar sight in TV listings. These arbitrary codes of up to eight digits have been chosen by Gemstar to represent particular dates, channels and start/stop times. The algorithm in the *VideoPlus* microprocessor reconstitutes that link.

Many codes can be used to represent the same date, channel and start/stop times. A match between code and clock starts the VCR recording. Once that code has been used, it is again made available to the computer that generates the TV listings.

Recording rescheduled programs

One thing that *VideoPlus* cannot do is protect against late starting or rescheduled programmes. This can only be achieved by PDC. The timer takes the appropriate PDC programme labels from packet 26 data in teletext. It then sets the VCR recording when a label is matched by a PDC start signal from packet 30 data.

This signal is repeated every 30s until the end of the programme; it is then replaced by another code and the timer switches off.

Increasingly, VCRs can switch automatically from standard play to long play recording if there is not enough tape left to complete the programme in standard play. A microprocessor judges this by noting the differential motion between the supply and take-up reels of the cassette.

Timer recordings can also be made from cable and satellite receivers on the AV setting: either using *VideoPlus Deluxe* with the VCR sending out an infrared signal to activate and set the receiver, or by the digital bus.

Better looking VHS

The look of VHS recordings has improved considerably over the years – probably to the pleasant surprise of its inventor, JVC.

One popular improvement is the matching of recording parameters to the characteristics of the tape. This requires the recording and playback of an internally generated test signal. The level of this off-tape signal is compared by microprocessor with a pre-set level.

The difference between them is then output as a voltage that is used to switch and set the various parameters for optimum recording. The higher the signal level, the higher the tape grade.

If this technology is applied to playback as well, then it will adjust to the condition of the recording itself – detail, colour, noise, etc.

Noise reduction is much used in playback. The problem with removing video noise is that it might actually be moving picture detail, and it comes in both luminance and chrominance forms. The most efficient method is first to digitise the signal, briefly store a frame in memory where it can be compared to the next frame. Next, motion detection is used to distinguish between the progressive motion of detail and the random, non-overlapping, motion of noise, **Fig. 1**.

Another form of noise is caused by mistracking. This can usually be corrected by the digital tracking system, which detects the FM envelope from the video head, converts it into a voltage and digitises it. The microprocessor then varies the

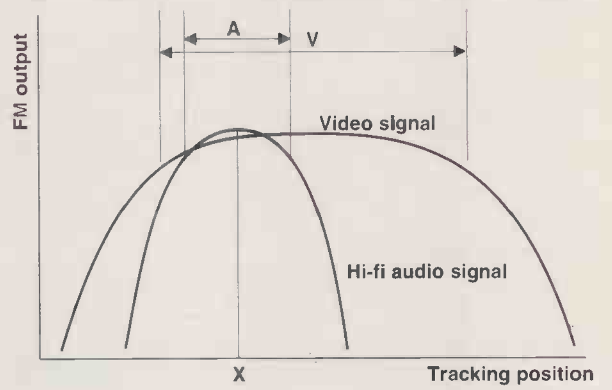

Fig. 2. Based on the same principle as conventional digital tracking, digital audio-visual tracking maintains the best tracking position for both hi-fi audio and video. First, the acceptable tracking range of the video signal is determined, V, and then the acceptable range of the audio, A. From this, the tracking is set within the range of V and A at a point where best audio is obtained, shown as X.

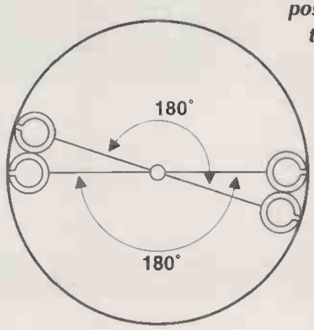

Fig. 3. The double-azimuth four-head system allows clean variable speed playback in SP by utilising two SP/LP head pairs.

Panasonic's NV-DV10000 Digital Video Master VCR has a detachable wireless edit controller that operates the VCR and camera, etc. It also has PCM audio together with IEEE1394 (i-Link or Firewire) for high speed transfer of digital video to a pc and RS232C for transferring digital stills to a PC. In addition to the normal analogue connections, there's a 5-pin connector for S-VHS/VHS, 8mm LANC.

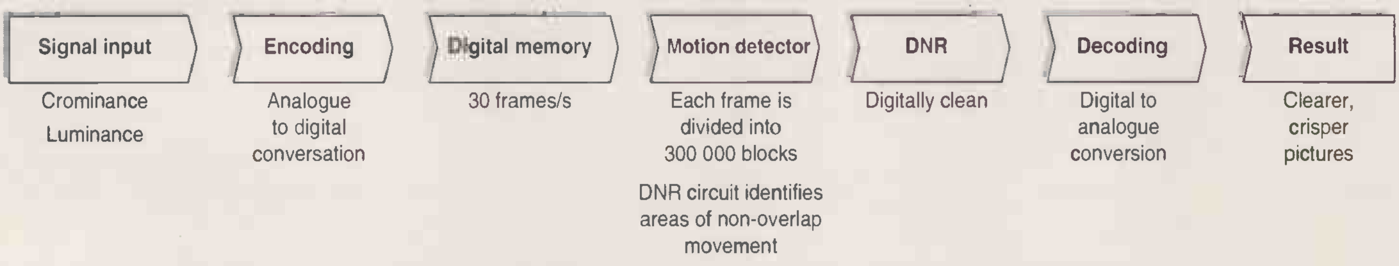

Fig. 1. Noise reduction. Toshiba's DNR circuitry incorporates a motion detector that distinguishes between areas of natural motion and non-overlapping signals such as picture noise. Unlike previous systems, DNR is said to virtually eliminate both luminance and chrominance noise appearing on all VHS recordings. It enhances all tapes, whether or not they were recorded on the VCR with DNR, namely the Toshiba V856B. The worse the picture, the better the improvement.

Good news for potatoes

Gemstar, inventor of VideoPlus, has two new services in the USA but the same services have been delayed in Europe. ShowGuide is a TV guide, also enabling one button VCR timer programming. ShowList is a tape library system.

Gemstar Europe's ShowList, upper photo, will allow consumers to automatically create on-screen programme directories for tapes, using VCRs equipped with the ShowList technology. The table of contents displays the name of the programmes and their running time, together with the amount of blank tape remaining.

To watch a specific recorded show, the user simply selects the chosen title from the on-screen directory using his VCR handset. The VCR automatically searches for this segment of the cassette within seconds, relieving the user of any searching frustrations.

Users of televisions equipped with Gemstar Europe's ShowGuide, lower photo, will have access to a comprehensive electronic on-screen programme guide.

The 'NOW' screen lists programmes currently running on all channels. The actual live programme last viewed by the user will appear in miniature in the top left corner of the screen, with a short description of the programme in the 'Level 1' information box alongside the live picture.

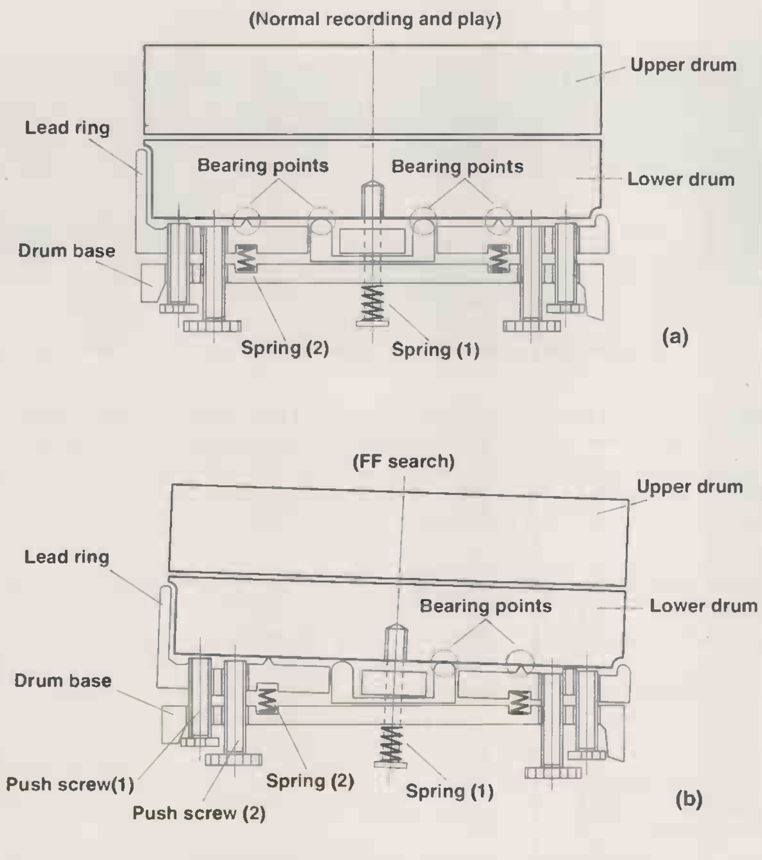

Fig. 4. The dynamic drum system can remove mistracking noise in long-play mode. This breaks with the need for a fixed attitude drum assembly to maintain compatibility. Instead , the dynamic drum tilts by pre-set amounts to keep the heads on track.

capstan speed momentarily to shift the tracks back and forth to arrive at the strongest signal. Next, it memorises this in order to readjust the tracking again should the level fall.

Digital audio-visual tracking also takes into account the hi-fi audio. When the acceptable tracking range of the video has been memorised, the process is repeated for the fm depth multiplex audio and the tracking is set to a point within the acceptable ranges of both, Fig. 2.

If the mistracking is due to a change in tape speed and/or direction, causing the heads to describe a different path, that requires more than just tracking adjustment.

The Double-Azimuth four-head system, or DA4 for short, is one way of dealing with it. Here, opposite azimuth SP and LP heads are combined in a single block, giving two head pairs, Fig. 3. In 'trick' play the off-tape signal is switched through the narrower LP heads to give greater leeway on the SP tracks. Unfortunately, it cannot remove mistracking noise from the LP tracks.

Variable azimuth drums

On the other hand, JVC's dynamic drum system can remove LP mistracking noise. This breaks with the need for a fixed attitude drum assembly to maintain compatibility. The dynamic drum instead tilts by pre-set amounts to keep the heads on track.

The configuration is shown in Fig. **4a**). The lead ring is normally fixed to the lower drum to stop the tape slipping off. In the new design, it is separated and positioned between the fixed drum base and the lower drum, on which the upper rotary drum carrying the heads is conventionally mounted.

In its rest position the assembly is supported by bearings on both the lead ring and drum base. There are four bearings on each – two back, two front – making eight in total. The assembly is held against them by spring pressure to prevent movement during recording and normal playback.

The operation of the dynamic drum system during variable speed playback is shown in Fig. **4b**). The push screws are raised against the spring pressure by a geared motor under the drum base to tilt both the lead ring and lower drum to the required angles – their separate control minimising tape path distortion.

The actual motion is of the order of microns. The effect can be seen in relation to the tape in **Fig. 5a)**. System control is shown in Fig. **5b)**.

More advanced functions such as dynamic track following and single track recording have been promised. And the concept lends itself to narrower video tracks – a trade-mark of digital VCRs.

3D sound and audio at all speeds

JVC's recorders that have the dynamic drum also have audio at *all* speeds. At double the normal froward speed, the sound is digitised, leaving out any blank bits, and compressed. At higher and reverse speeds three second sound clips are played at normal speed. In still mode, the three-second clip is repeated.

In normal playback, VHS audio quality is generally good using depth multiplex fm recording. Although not digital, this technique does justice to digital NICAM and Dolby Pro-Logic.

VCRs are appearing that feature 3D audio output. This is digitally processed stereo with a fraction of each channel added to the opposite channel to produce phantom speakers.

However, to play recordings you first need to find them – and this is catered for by the Video/VHS Index Search System. When recording is started from 'stop' or 'timer' the shape of the synchronising pulses on the linear control track is altered to form a binary code consisting of 63 pulses, **Fig. 6**. These can be located by a half-loaded tape running over the fixed control head but away from the drum.

Some VCRs allow manual recording and erasing of index codes, and some will play for a few seconds when one is located. Incidentally, this search system is not used when recording starts from 'pause' because the control pulses are critical for smooth edits.

A variation on the index search system is beginning to appear in the form of a tape archiving system. Here, the beginnings of recordings can be digitally 'marked' using a menu to select programme type – drama, sport, etc., plus time, date and channel. For playback the tape is wound to the end, and scanned as it is rewound to list its contents on screen.

Alternatively, it may download data from the 'now' and 'next' teletext guide to tape and also into VCR memory holding the contents of all tapes.

Sony has taken a different approach with its *SmartFile* system. A label incorporating an IC memory chip is stuck on to

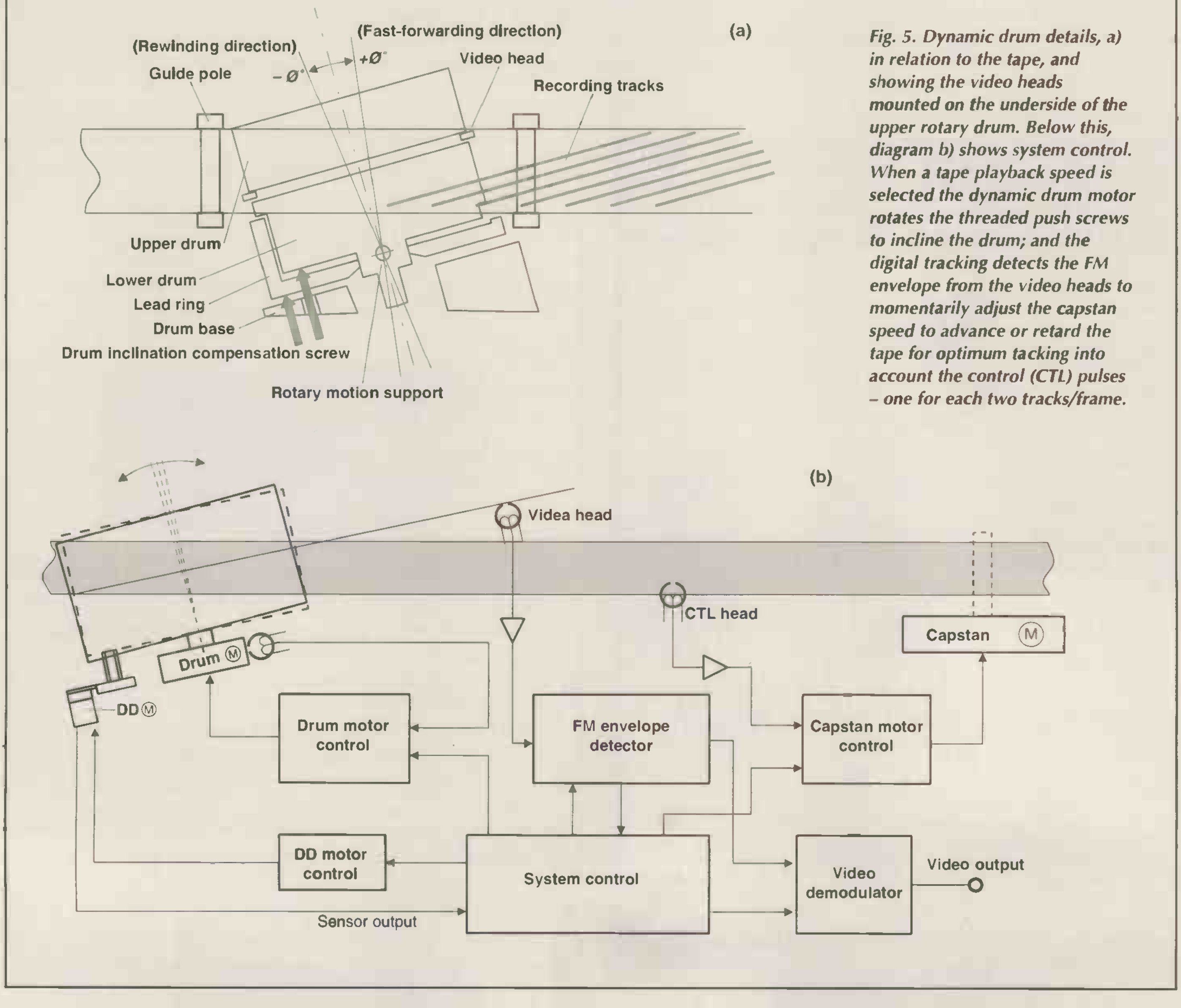

Fig. 5. Dynamic drum details, a) in relation to the tape, and showing the video heads mounted on the underside of the upper rotary drum. Below this, diagram b) shows system control. When a tape playback speed is selected the dynamic drum motor rotates the threaded push screws to incline the drum; and the digital tracking detects the FM envelope from the video heads to momentarily adjust the capstan speed to advance or retard the tape for optimum tacking into account the control (CTL) pulses – one for each two tracks/frame.

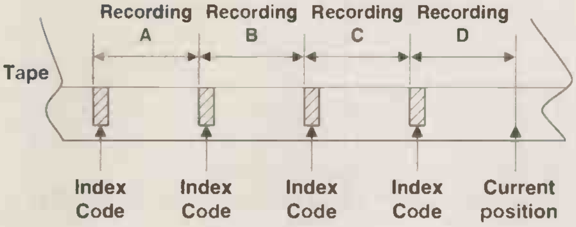

Fig. 6. In the video/VHS index search system; each batch of reshaped control pulses represents the start of a recorded section; index search system can either go to a specified index code or to the first one it finds.

the cassette spine. When a recording is made, programme information is downloaded from teletext, or can be entered manually.

A sensor on the *SmartFile* VCR gives a quick read-out of basic data. Inserting the cassette gives a full read-out – including any blank spaces. The chip can also be set to prevent a cassette from being erased.

Many VCRs will now play American NTSC tapes without requiring an NTSC compatible TV – although only via the video connection, not via the antenna socket. This is achieved by running the head drum at 60rev/s and tape at 33.35mm/s instead of 50rev/s and 23.39mm/s. The colour signal is converted to PAL for output.

However, the 525 lines and 60Hz field rate will not be converted to PAL 625/50 video. This is unnecessary now that TVs can accept a 50 or 60Hz time base. In addition, the difference in line frequencies – 15.75kHz for NTSC and 15.625kHz for PAL – is insignificant. As for the 'missing' lines, some sets will leave a gap while others will compensate and fill the screen.

This leads neatly to the topic of 16:9 aspect ratio recording – the letterbox image. JVC and Philips launched S-VHS machines that recorded anamorphic images when it looked as if D2-MAC was going to be widely adopted. A return to this would give much better quality images than can be realised by expanding a letterbox to fill a wide-screen TV

Lastly, and at least a partial answer to every VCR owner's prayer, there is the recently introduced *Ad-Skip* facility. With it, pushing a button during playback automatically advances the tape by thirty recorded seconds.\

In summary

In convenience terms, the combination of *VideoPlus* and *PDC* is difficult to beat. In terms of viewing satisfaction, the various image enhancements have made it a more relaxed pastime by minimising the distracting imperfections.

Something that will be further addressed with the expected inclusion of Data VHS (D-VHS) into VHS and S-VHS machines in the second half of 1999. This will enable the recording of MPEG-2 bit streams from digital transmissions and bring new features.

Among these are the proposed Home Audio-Video interoperability, or HAVi, standard for networking digital audio-visual and multimedia products.

Another is the digital navigation of tape contents. Here, the D-VHS recorder maintains an index of recorded programmes to allow any recording to be directly addressed via a menu.

While Digital Video VCRs are already becoming available, with additional features and interfaces for editing, the future looks to be a feature-rich one for the VCR. ■

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Embedding Java

Are current implementations of Java too big, too slow, too unpredictable, and functionally incomplete for use in embedded systems? Ron Workman looks at alternative ways to implement Java virtual machines to address these legitimate concerns.

Sun Microsystems estimates there are more than 400000 developers using Java today. While there are many documented success stories of Java's use for corporate or enterprise applications, there are few public illustrations of Java technology for embedded systems development.

In order to look at the current situation more objectively, I will separate the term 'Java technology' into two aspects – specification and implementation.

As a long time developer and provider of virtual machine technologies, it is my opinion that the current specifications for Java – including Enterprise Java, Personal Java, and Embedded Java – are not at fault, **Fig. 1**. But rather, most current implementations – particularly for Personal Java and Embedded Java – are not viable for many embedded systems.

Sun Microsystems introduced Java in 1995 as a new programming language and runtime environment ideally suited for Internet-related applications. Building on its long-standing corporate themes, 'The network is the computer,' Sun recognised that more powerful microprocessors were beginning to be used in many consumer devices, and increasingly, they have been connected to networks.

Network connectivity began with workstations and personal computers, but was quickly followed by printers, scanners, copiers, and various other types of office equipment.

More recently, newer devices such as personal digital assistants, Web televisions, pagers, smart cell phones and even wristwatches have all been enhanced with microprocessors and connected to networks.

Sun's network vision

Prior to Sun's introduction of Java, the network was viewed primarily as a vast system for storing and serving up relatively static information. Then, the phrase, 'The network is the virtual disk drive' was probably more fitting.

Today, Java's promise is to extend the usefulness of networks by providing an efficient means for storing and distributing dynamic and extensible functionality to networked computing devices.

The Java architecture is comprised of several distinct but inter-related technologies, each of which is defined in specifications from Sun Microsystems. These technologies include the Java programming language, the Java virtual machine, and the Java API, **Fig. 2**.

This article focuses on the Java virtual machine and aspects of its implementation that affect Java's suitability for embedded applications.

As with all virtual machines, the Java virtual machine defines an abstract computer. Its specifications define the functionality that every Java virtual machine must provide, but allow almost unlimited freedom to the designers of each implementation.

For example, each Java virtual machine can use any technique to execute Java 'bytecodes'. In fact, the Java virtual machine can be implemented in software or hardware, or varying degrees both. This flexibility in the specification for the Java virtual machine was intended to allow for implementation on a wide variety of computers and embedded devices.

Classes at the top

At the top level, a Java virtual machine's primary purpose is to load Java class files and execute them, **Fig. 3**. During execution, there are two aspects of any Java virtual machine implementation that have the most impact on the suitability of Java for the specific application. One is the methods used for executing the bytecodes, and the other the management of system resources – primarily memory.

The default method for executing bytecodes by a Java virtual machine is interpreted execution. Whereas C/C++ applications are compiled to a native instruction set, and are stored in a single executable file, Java applications are compiled to Java bytecodes, and are stored in separate class files for loading and execution by the Java virtual machine.

When the Java application is run, the Java virtual machine loads the class files and interprets the bytecodes as a stream of instructions. Typically, an interpreted-only method for execution by a Java virtual machine will result in performance which is 10 to 15 times slower than an equivalent natively compiled C/C++ program.

In the plus column, an interpreted-only version of a Java virtual machine generally has a relatively small memory footprint – implementations are typically 1/2 to 2Mbyte of ROM.

However, there are other techniques that can improve the speed of bytecode execution. For example, just-in-time, or JIT, compiling can enhance application performance up to ten times over interpreted-only execution.

Rather than only interpreting bytecodes, each time the Java

virtual machine encounters new bytecodes for the first time, it invokes the JIT compiler to compile that code to native instructions. These native instructions are then stored by the Java virtual machine and are reused the next time the code is required by the Java application.

Performance comes at a price though. JIT technology typically requires four times the amount of memory of an interpreted-only version of a Java virtual machine. It compiles all code that it encounters, and often requires a disk and virtual memory for paging the compiled code segments.

Because of this overhead, JIT-based execution is suitable for computing platforms that have powerful processors, substantial system memory – 32Mbyte or more – and generally a fast disk drive to support swapping. It is not suitable, however, for the vast majority of embedded systems which are generally far more resource constrained.

Java for embedding

A bytecode execution method more suitable for embedded systems is 'adaptive dynamic compilation'. Similar to the just-in-time alternative, adaptive dynamic compilation uses on-the-fly compilation technology to improve the performance of bytecode execution.

Unlike a JIT implementation however, adaptive dynamic compilers are generally smaller, more selective of the bytecodes that they compile to native code, do not require virtual memory, and adapt to the available system memory.

The size of an adaptive dynamic compiler is typically measured in terms of tens of kilobytes of memory for the compiler itself. During interpreted execution of the bytecodes, the Java virtual machine monitors the application and determines where the execution bottlenecks reside. The Java virtual machine then invokes the adaptive dynamic compiler – which may be implemented as a thread – to compile the segment of bytecodes that are executing repeatedly.

Depending on the implementation, the adaptive dynamic compiler may compile the entire class, a single method, or only a block within a method. The resulting native instructions are stored in memory only for fast access.

The Java virtual machine may then find and invoke compilation for the next most frequently executed code. This process is repeated until all available code buffers have been used.

Because the dynamic compiler is adaptable, when it encounters code that is executing at greater frequency than some previously stored native instructions, it will compile these new bytecodes. It will then store them in a code buffer containing less frequently used code.

The user can configure the amount of system memory used

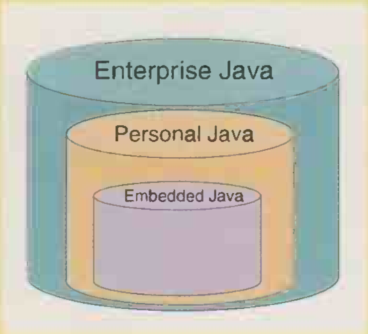

Fig. 1. There's a version of Java to suit all needs.

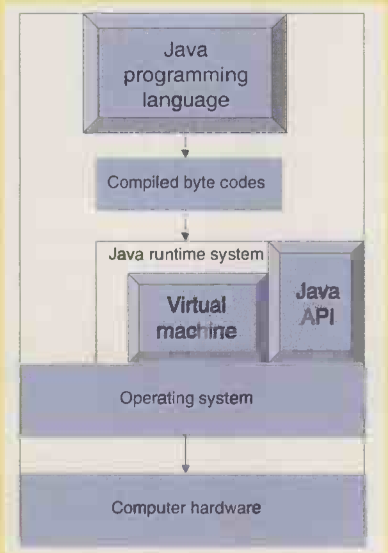

Fig. 2. Java's architecture comprises several distinct but inter-related technologies.

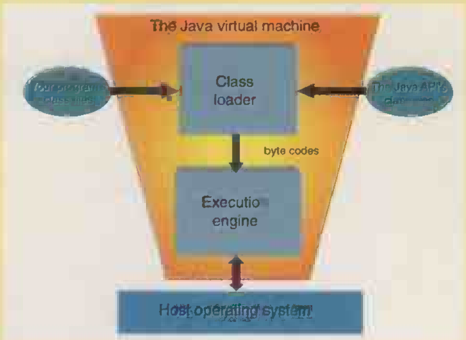

Fig. 3. At the top level, a Java machine's primary purpose is to load Java class files and execute them.

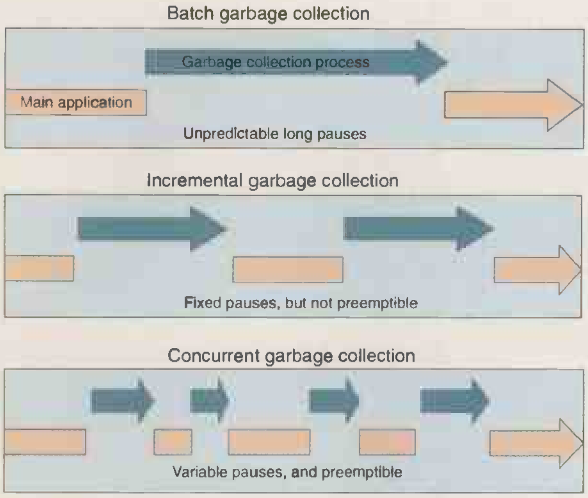

Fig. 4. In Java, garbage collectors aid the task of memory management. There are different ways of implementing garbage colectors, and not all are suitable for embedded applications.

for compilation, and the size and number of code buffers used for the compiled native instructions. Applications may also be given explicit control over the adaptive dynamic compiler's thread priority during execution for greater predictability, providing more suitable behaviour for embedded systems.

Reliability issues

The efficient management of memory is particularly critical for embedded systems, where predictable behaviour is required. The Java virtual machine plays the central role in managing memory. In fact, the application itself only makes requests for memory allocation for new objects and does not explicitly release unnecessary memory.

The release of memory is managed automatically by the Java virtual machine. Each Java virtual machine implements a 'garbage collector' to provide the memory management facilities.

There are several different implementations of garbage collectors, and some are more suitable for embedded systems than others, Fig. 4. One of the primary concerns of embedded systems developers is that if the garbage collector runs a complete batch cycle, and cannot be preempted, this will render Java unsuitable for the embedded application. In other words, it will make it unpredictable.

Technical support

Insignia Solutions is a leading provider of virtual machine technology that dynamically optimises the use of available system resources. *JENE*, Insignia's implementation of Java specifically designed for embedded systems, allows developers to create reliable, efficient and predictable embedded devices that are enabled by the company's 'embedded virtual machine.' The publicly held company's US headquarters are in Fremont, California, and its main research and development facilities are in High Wycombe, England. Sales and marketing departments are located in Fremont and High Wycombe.

For additional information on Insignia and its products, call 800/848-7677 in the United States and +44 1628 539 500 in Europe, or visit the company's web site at http://www.insignia.com.

Some implementations of garbage collectors are referred to as 'incremental.' This suggests that they can recycle memory in a stepwise fashion rather than garbage-collecting all memory in a single pass. Although this garbage collector may not be preemptible, this type of implementation should lead to more predictable behaviour than a batch garbage collector.

Since the incremental garbage collector may still block the application, however, the risk remains that the pauses will impact the application. If the garbage collector is defined as 'concurrent,' this suggests that it performs garbage collection incrementally, that it is fully preemptible, and that it should provide the most predictable behaviour of all.

In addition to its mode of execution – i.e. batch, incremental, or concurrent – garbage collectors may perform their duties with varying degrees of efficiency and effectiveness.

There are two basic approaches to separating live objects from garbage: 'reference counting' and 'tracing.' Reference counting is an older garbage collection technique. It involves maintaining a reference count for each object on the heap. Essentially, the reference count is incremented for each new reference to a given object and decremented when the reference to an object goes out of scope.

All objects with a reference count of zero can be garbage collected. However, among other disadvantages, reference counting suffers from the overhead of incrementing and decrementing the reference count each time the object is referenced.

Tracing garbage

A more suitable method for Java virtual machines is the tracing garbage collector technique.

Tracing garbage collectors trace the object reference tree starting with root nodes. Objects that are encountered during the trace are marked. After the trace is complete, unmarked objects can be collected as garbage.

During the tracing process, garbage collectors may either use either a 'precise' or a 'conservative' approach to identifying references to objects. The conservative garbage collector may not distinguish between genuine object references and look-alikes – 32-bit integers for example.

Although this approach may be slightly faster, it may also lead to memory leaks. A precise garbage collector, on the other hand, understands the differences between true object references and look-alikes, and frees all unreferenced objects appropriately.

One final important aspect of garbage collection to consider is whether the garbage collector has a strategy to combat heap fragmentation. Given the limited amount of memory available for most embedded systems, a concurrent, precise, compacting garbage collection strategy should provide for the most predictable system behaviour.

In summary

The specifications for the various Java platforms have generally been well conceived. If not perfect at first, they are certainly evolving in the appropriate direction to address the requirements of the identified classes of computing devices.

Now that the specifications are stabilising, and the vendors are getting down to the business of delivering suitable implementations of Java, I expect to see an increase in the use of Java for embedded systems.

With the implementation of the appropriate technologies described in this article, many embedded developers may soon discover that the benefits of Java can be delivered in a package that is small enough, fast enough, and predictable enough for their next embedded development project. ■

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RF mixing

Having examined the basics of rf mixer operation, and demonstrated the basic single-ended diode mixer, consultant Joe Carr now looks at a few of the more important performance parameters, and a circuit or two. First, mixer distortion products...

Because mixers are non-linear, they will produce both harmonic distortion products and intermodulation products. Our main interest at this point is the intermodulation products, which from hereon, I will shorten to IPs.

Intermodulation products

The spurious IP signals generated when two signals, F_1 and F_2, are mixed non-linearly are shown graphically in **Fig. 1**, assuming input frequencies of 1MHz and 2MHz. Given input signal frequencies of F_1 and F_2, the main IPs are:

Second-order:	$F_1 \pm F_2$
Third-order:	$2F_1 \pm F_2$ $2F_2 \pm F_1$
Fifth-order:	$3F_1 \pm 2F_2$ $3F_2 \pm 2F_1$

The second-order and third-order products are those normally specified in a receiver mixer design because they tend to be the strongest.

In general, even-order intermodulation distortion products, 2, 4, etc., tend to be less of a problem because they can often be ameliorated by using external filtering ahead of the receiver mixer – or tuned rf amplifier if one is used. Pre-filtering tends to reduce the amplitude of out-of-channel interfering signals, reducing the second-order products within the channel.

Third-order IM distortion products are more important because they tend to reflect on the receiver's dynamic range, and its ability to handle strong signals. On the whole, the third-order products are not easily influenced by external filtering, so must be handled by proper mixer selection and/or design.

When an amplifier or mixer is overdriven, the second-order content of the output signal increases as the square of the input signal level, while the third order responses increase as

Fig. 1. Spurious mixer products occur when F_1=1MHz and F_2=2MHz are mixed non-linearly.

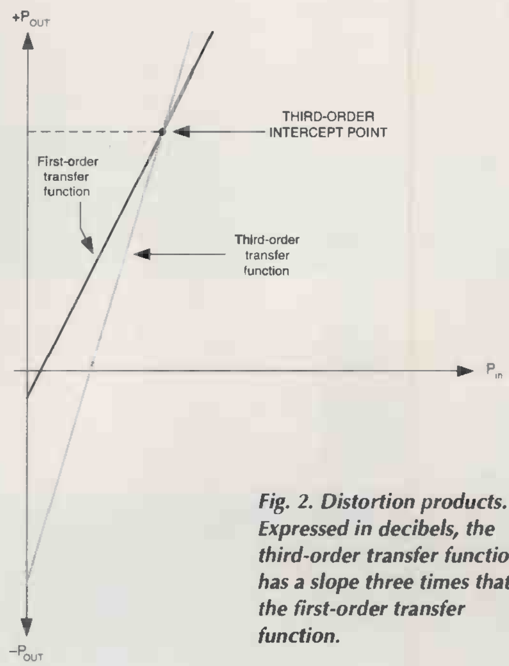

Fig. 2. Distortion products. Expressed in decibels, the third-order transfer function has a slope three times that of the first-order transfer function.

the cube of the input signal level. When expressed in decibels the third-order transfer function has a slope three times that of the first order transfer function, **Fig. 2**.

Consider the case where two hf signals, F_1=10MHz and F_2=15MHz are mixed together. The second-order IPs are 5 and 25MHz; the third-order IPs are 5, 20, 35 and 40MHz; and the fifth-order IPs are 0, 25, 60 and 65MHz. If any of these are inside the passband of the receiver, then they can cause problems.

One such problem is the emergence of 'phantom' signals at the IP frequencies. This effect is seen often when two strong signals F_1 and F_2 exist and can affect the front-end of the receiver, and one of the IPs falls close to a desired signal frequency, F_d. If the receiver were tuned to 5MHz, for example, a spurious signal would be found from the F_1-F_2 pair given above.

Another example is seen from strong in-band, adjacent channel signals. Consider a case where the receiver is tuned to a station at 9610kHz, and there are very strong signals at 9600kHz and 9605kHz. The near (in-band) IP products are:

Third-order:	9595kHz	(ΔF=15kHz)	
	9610kHz	(ΔF=0kHz)	[on-channel!]
Fifth-order:	9590kHz	(ΔF=20kHz)	
	9615kHz	(ΔF=5kHz)	

Note that one third-order product is on the same frequency as the desired signal, and could easily cause interference if the amplitude is sufficiently high. Other third and fifth-order products may be within the range where interference could occur, especially on receivers with wide bandwidths.

The IP orders are theoretically infinite because there are no bounds on either m or n. However, in practical terms each successively higher order IP is reduced in amplitude compared with its next lower order mate. Because of this, only the second-order, third-order and fifth-order products usually assume any importance. Indeed, only the third-order is normally used in receiver specification sheets.

Third-order intercept point

It can be claimed that the third-order intercept point, or TOIP, is the single most important specification of a mixer's dynamic performance because it predicts the performance as regards intermodulation, cross-modulation and blocking desensitisation.

When a mixer is used in a receiver, the third-order – and higher – intermodulation products are normally very weak. They don't exceed the receiver noise floor when the mixer and any preamplifiers are operating in the linear region. But as input signal levels increase, forcing the front-end of the receiver toward the saturated non-linear region, the IP emerges from the noise, **Fig. 3**, and begins to cause problems. When this happens, new spurious signals appear on the band and self-generated interference arises.

Figure 4 shows a plot of the output signal versus fundamental input signal. Note the output compression effect that occurs as the system begins to saturate. The dotted gain line continuing above the saturation region shows the theoretical output that would be produced if the gain did not clip.

It is the nature of third-order products in the output signal to emerge from the noise at a certain input level, and increase as the cube of the input level. Thus, the slope of the third-order line increases 3dB for every 1dB increase in the response to the fundamental signal.

Although the output response of the third-order line saturates similarly to that of the fundamental signal, the gain line can be continued to a point where it intersects the gain line of the fundamental signal. This point is the third-order intercept point.

Note that in Fig. 4, the gain P_O/P_{IN} begins to decrease near the TOIP. The measure of this tendency to saturation is called the –1dB compression point, i.e. the point where the gain slope decreases by 1dB.

Interestingly enough, one tactic that can help reduce IP levels back down under the noise is the use of an attenuator ahead of the mixer. Even a few decibels of input attenuation is often sufficient to drop the IPs back into the noise, while afflicting the desired signals only a small amount.

Many modern receivers provide a switchable attenuator ahead of the mixer. This practice must be evaluated closely, however, if low-level signals are to be handled. The usual resistive attenuator pad will increase the thermal noise level appearing at the input of the mixer by an amount proportional to its looking back resistance.

The IP performance of the mixer selected for a receiver design can profoundly affect the performance of the receiver. For example, the second-order intercept point affects the half-IF spur rejection, while the third-order intercept point

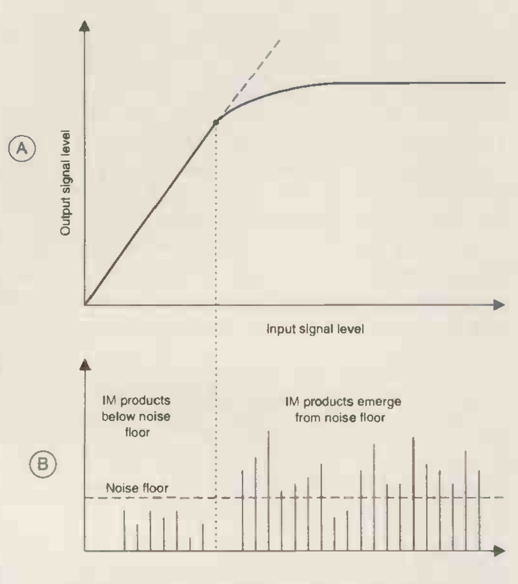

Fig. 3. Intermodulation products rise up out of the noise when critical input level is exceeded.

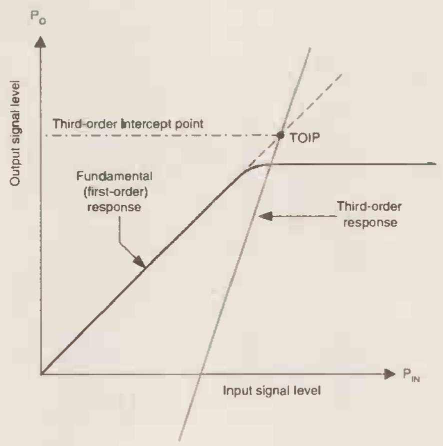

Fig. 4. Third-order intercept point, or TOIP. Note the output compression occurring as the system starts to saturate.

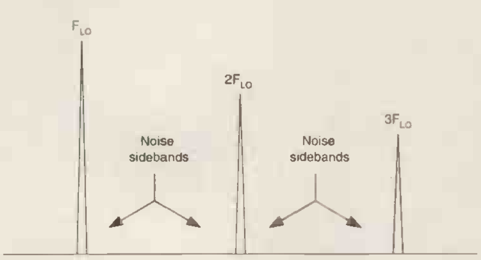

Fig. 5. Noise sidebands surrounding local oscillator and its harmonics can deteriorate sensitivity.

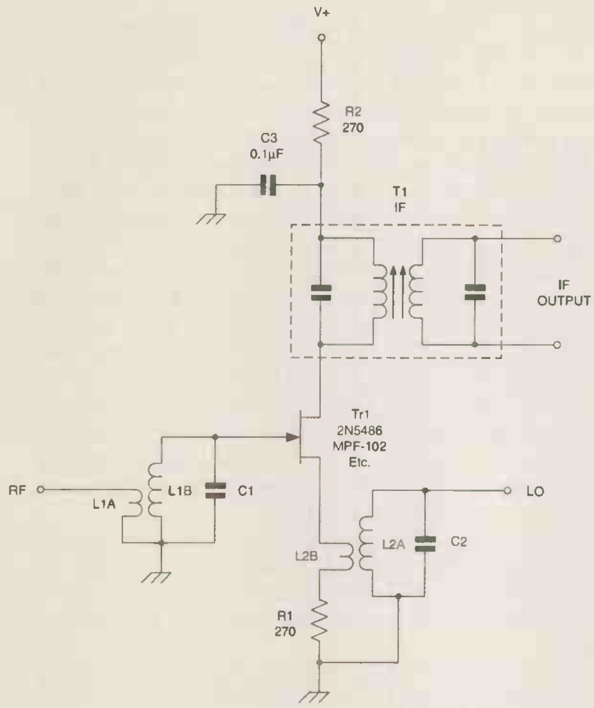

Fig. 6. Single-ended junction fet mixer using a double-tuned LC transformer.

will affect the intermodulation distortion (IMD) performance.

Calculating intercept points

Calculating the *n*th order intercept point can be done using a two-tone test scheme. A test system is created in which two equal amplitude signals, F_A and F_B, are applied simultaneously to the mixer rf input. These signals are set to a standard level of typically –20dBm to –10dBm.

The power of the *n*th intermodulation product, or P_{IMN}, is measured using a spectrum analyser or, if the spectrum analyser is tied up elsewhere, a receiver with a calibrated S-meter. The *n*th intercept point is:

$$IP_N = \frac{NP_A - P_{IMN}}{N-1} \qquad (1)$$

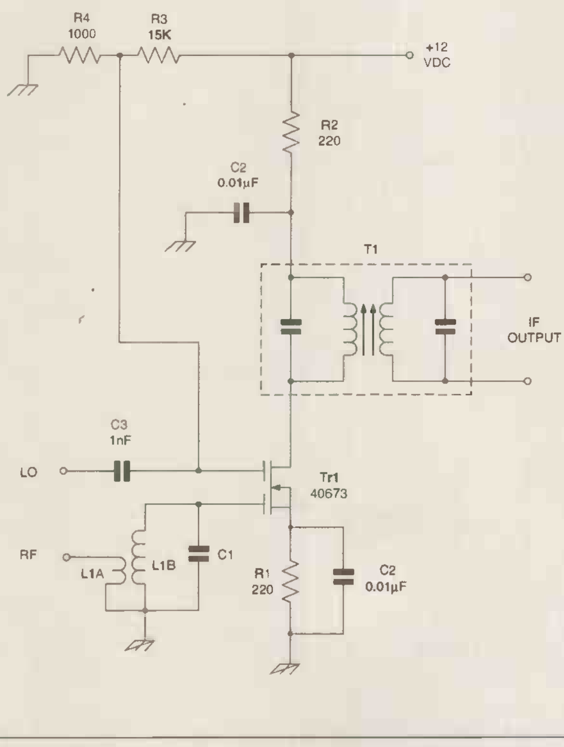

Fig. 7. Single-ended mosfet mixer in which the local-oscillator signal is applied to gate 2.

where IP_N is the intermodulation product of order N, P_A is the input power level, in dBm, of one of the input signals and P_{IMN} is the power level in dBm of the *n*th IM product. Power P_{IMN} is often specified in terms of the receiver's minimum discernible signal specification.

Once the P_A and P_{IM} points are found, any IP can be calculated using the above equation.

Mixer losses

Depending on its design, a mixer may show either loss or gain. The principal loss is conversion loss, which is made up of three elements: mismatch loss, parasitic loss and junction loss, assuming a diode mixer.

Conversion loss is simply a measure of the ratio of the rf input signal level and the signal level appearing at the intermediate-frequency output, P_{IF}/P_{RF}. In some cases, it may be a gain, but for many – perhaps most – mixers there is a loss. Conversion loss L_C is,

$$L_C=L_M+L_P+L_J \qquad (2)$$

where L_C is conversion loss, L_M is the mismatch loss, L_P is the parasitic loss and L_J is the junction loss.

Mismatch loss is a function of the impedance match at the rf and intermediate-frequency ports. Mixer port impedance Z_P and the source impedance Z_S should be matched. If they are not, a voltage-standing-wave ratio, or vswr, will result that is equal to the ratio of the higher impedance to the lower impedance. Depending on which ratio is greater than or equal to 1, $VSWR=Z_P/Z_S$ or $VSWR=Z_S/Z_P$.

The mismatch loss is the sum of rf and intermediate-frequency port mismatch losses. Or expressed in terms of vswr,

$$L_M = 10\times\left[\log_{10}\left\{\frac{(VSWR_{RF}+1)^2}{4VSWR_{RF}}\right\}+\log_{10}\left\{\frac{(VSWR_{IF}+1)^2}{4VSWR_{IF}}\right\}\right] \qquad (3)$$

Parasitic loss is due to action of the diode's parasitic elements, i.e. series resistance, R_S, and junction capacitance C_J. Junction loss is a function of the diode's *I*-versus-*V* curve. The latter two elements are controlled by careful selection of the diode used for the mixer.

Noise figure

Radio reception is largely an issue of signal-to-noise ratio, also known as SNR. In order to recover and demodulate weak signals the noise figure, or NF, of the receiver is an essential characteristic.

The mixer can be a large contributor to the overall noise performance of the receiver. Indeed, the noise performance of the receiver is seemingly affected far out of proportion to the actual noise performance of the mixer. But a study of signals and noise will show, through Friis' equation, that the noise performance of a receiver or cascade chain of amplifiers is dominated by the first two stages, with the first stage being so much more important than the second stage.

Because of the importance of mixer noise performance, a low noise mixer must be designed or procured. In general, the noise figure of the receiver equipped with a diode mixer first stage – as is common in microwave receivers – is,

$$NF=L_C+IF_{NF} \qquad (4)$$

where NF is the overall noise figure, L_C is the conversion loss and IF_{NF} is the noise figure of the first IF amplifier stage.

To obtain the best overall performance from the perspective of the mixer, the following should be observed:

1. Select a mixer diode with a low noise figure. This will address the junction and parasitic losses.
2. Ensure the impedance match of all mixer ports.
3. Adjust the local-oscillator power level for minimum con-

version loss. Local oscillator power is typically higher than maximum rf power level.

Noise balance

There is noise associated with the local-oscillator signal, and that noise can be transferred to the IF in the mixing process. The tendency of the mixer to transfer AM noise to the IF is called its noise balance.

In some cases, this transferred noise results in loss that is more profound than the simple conversion loss, so should be evaluated when selecting a mixer.

The total noise picture, **Fig. 5**, includes not simply the AM noise sidebands around the local oscillator frequency, but also the noise sidebands around the local oscillator harmonics. The latter can be eliminated by imposing a filter between the local-oscillator output and the mixer's local-oscillator input.

The noise sidebands around the local oscillator itself, however, are not easily suppressed by filtering because they are close in frequency to F_{LO}. The use of a balanced mixer, however, can suppress all of the local-oscillator signal in the output, and that includes the noise sidebands. In the usual way noise balance is specified, the higher the number in decibels the more suppression of local-oscillator AM noise.

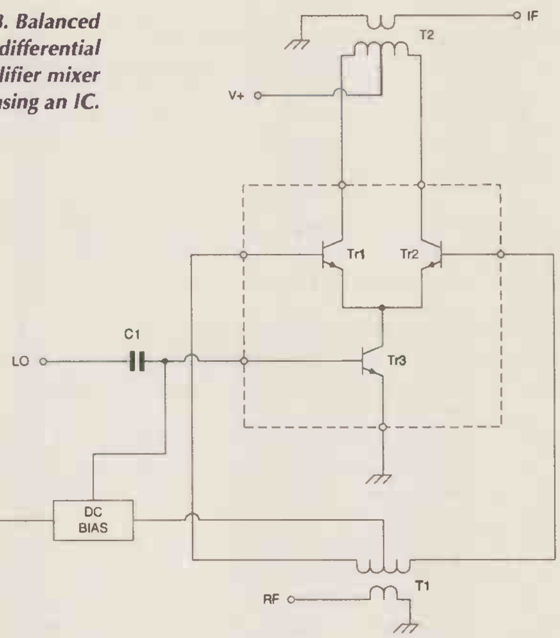

Fig. 8. Balanced n-p-n differential amplifier mixer using an IC.

Single-ended active mixer circuits

So far, the only mixer circuit that has been explicitly discussed is the diode mixer. The diode is a general category called a switching mixer because the local-oscillator switches the diode in and out of conduction.

Now I will look at active single-ended unbalanced mixers. **Figure 6** shows the circuit of a simple single-ended unbalanced mixer based on a junction field effect transistor, or JFET, such as the *MPF-102* or *2N5486*.

The rf signal is applied to the gate, while the local-oscillator signal is applied to the source. If the local-oscillator signal has sufficient amplitude to cause non-linear action, then it will permit the JFET to perform as a mixer.

Note that both the rf and local oscillator ports are fitted with bandpass filters to limit the frequencies that can be applied to the mixer. Because these mixers tend to have rather poor local-oscillator-to-rf and rf-to-local-oscillator isolation, these tuned filters help improve the port isolation by preventing the local-oscillator from appearing in the rf output, and the rf from being fed to the output of the local-oscillator source.

In many practical cases, the local oscillator filter may be eliminated because it is difficult to make a filter that will track a variable local-oscillator frequency. In some cases, the receiver designer will use an untuned bandpass filter, while in others the output of the local-oscillator is applied directly to the source of the JFET through either a coupling capacitor or an untuned rf transformer.

The output of the unbalanced mixer contains the full spectrum of $mF_{RF} \pm nF_{LO}$ products, so a tuned filter is needed here also. The drain terminal of the JFET is the IF port in this circuit.

The usual case is to use either a double-tuned *LC* transformer, T_1 in Fig. 6, or some other sort of filter. Typical non-*LC* filters used in receivers include ceramic and quartz crystal filters, and mechanical filters.

A MOSFET version of the same type of circuit is shown in **Fig. 7**. In this circuit, a dual-gate MOSFET such as a *40673* is the active element. The rf is applied to gate 1, and the

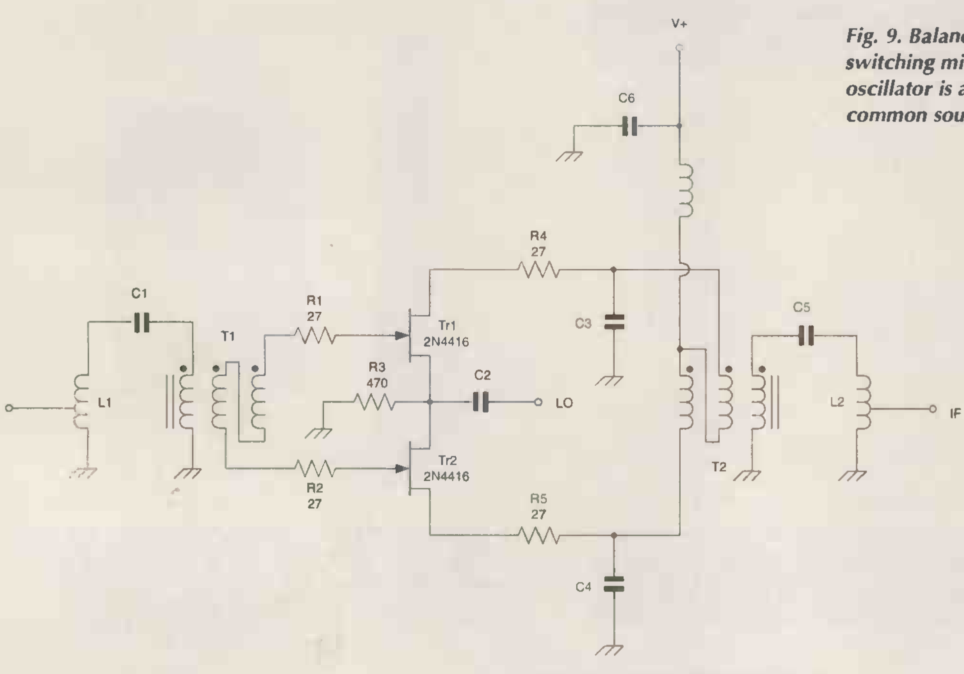

Fig. 9. Balanced junction fet switching mixer. Here the local oscillator is applied to the common source.

local-oscillator is applied to gate 2.

Local oscillator signal level needs to be sufficient to drive Tr_1 into non-linear operation. A resistive voltage divider R_3/R_4 is used to provide a dc bias level to gate 2. The source terminal is bypassed to ground for rf, and is the common terminal for the mixer.

In this particular case the local-oscillator input is broadband, and is coupled to the local-oscillator source through capacitor C_3. A resonant bandpass filter, L_{1B}/C_1, on the other hand, tunes the rf input.

Balanced active mixers

There is a number of balanced active mixers that can be selected. Many of these forms are now available in integrated circuit form.

Because of the intense activity being seen in the development of telecommunications equipment – cellular, PCS and other types – there is a lot of IC development being done in this arena.

One of the earliest types of rf IC on the market was the differential amplifier. **Figure 8** shows the use of one of these ICs are a mixer stage. Two transistors, $Tr_{1,2}$, are differentially connected by having their emitter terminals connected together to a common current source, Tr_3.

The rf signal is applied to the bases of Tr_1 and Tr_2 differentially through transformer T_1. The local-oscillator signal is used to drive the base terminal of the current source transistor, Tr_3. The collectors of Tr_1 and Tr_2 are differentially connected through a second transformer, T_2, which forms the IF port.

Figure 9 shows one rendition of the Sabin double-balanced mixer used in hf receivers. It offers a noise figure of about 3dB. Dating from around 1970, the Sabin mixer features a push-pull pair of high pinch-off voltage junction fets, $Tr_{1,2}$. These are connected in a common source configuration. The local-oscillator signal is applied to the common source in a manner similar to Fig. 7.

The gate circuits of $Tr_{1,2}$ are driven from a balanced transformer, T_1. This transformer is trifilar wound, usually on either a toroid or binocular balun core. The dots on the transformer windings indicate the phase sense of the winding.

Note that the gate of Tr_1 is fed from a dotted winding end, while that of Tr_2 is fed from a non-dotted end. This arrangement ensures that the signals will be 180° out of phase, resulting in the required push-pull action. Some input filtering and impedance matching the 1.5kΩ junction fet input impedance to a 50 or 75Ω system impedance, as required, is provided by L_1/C_1.

The IF output is similar to the rf input. A second trifilar transformer T_2 is connected such that one drain is to a dotted winding end and other is to a non-dotted end of T_2.

Compare the sense of the windings of T_1 and T_2 in order to avoid signal cancellation due to phasing problems. Intermediate-frequency filtering and impedance matching is provided by C_5 and L_2. The tap on L_2 is adjusted to match the 5.5kΩ impedance of the junction fets to system impedance.

In the final article of this set I will take a look at a number of circuits for single and double balanced mixers, including the passive diode version that is so popular with designers.■

The phase-sensitive detector

Michael Slifkin and Asaf Schlesinger **believe that the phase-sensitive detector – useful for recovering small signals from noise among other things – does not get the attention it deserves. Their discussion culminates in a full design for a vector-computing phase-sensitive detector.**

The phase sensitive detector, also known as lock-in amplifier, is a useful instrument that has been around for a long time. Surprisingly though, a number of electrical and electronics engineers and scientists I have encountered have no knowledge of it.

Many well-known textbooks on electronics either do not refer to it at all or give it a passing mention. There is only one book exclusively devoted to this instrument, written by Mike Meade.[1] This book is out of print and is not widely available. What follows here is a simplified account together with some historical background culminating in the design of a novel vector-computing detector.

The phase-sensitive detector, often called a lock-in amplifier or voltmeter, is an instrument for measuring a signal of a definite frequency, even when the signal is buried deep in the noise. Figures of 100dB below noise are regularly quoted. It can also be used for measuring phase.

Many engineers when asked to do the first task will think at once of using a high-Q amplifier. Unfortunately very high-Q amplifiers are difficult to build and even more difficult to keep on frequency unless kept in a constant temperature oven. If the signal shows small changes in frequency, then it becomes an impossible task using such an amplifier. The only answer is to use a phase-sensitive detector.

Although I have spoken about using a psd for measuring

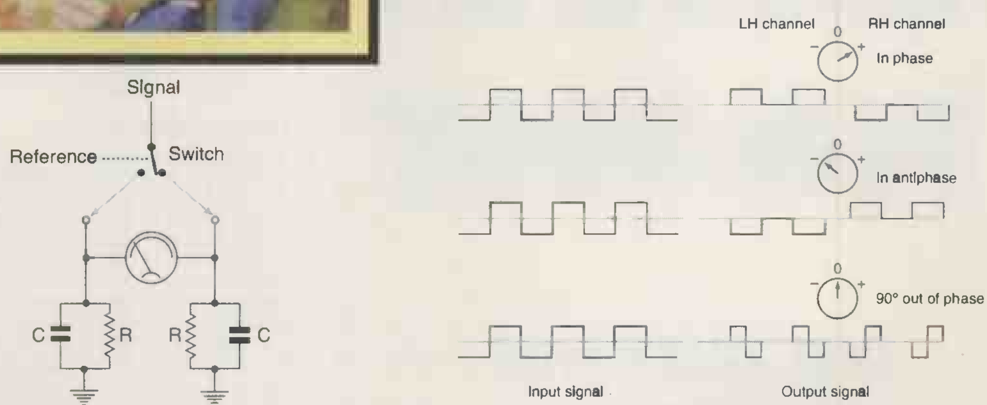

Fig. 1. In a), the basic phase-sensitive detector, the switch operated by the reference signal feeds the input signal to each of the two RC networks alternately. Signal relationships are shown in b).

signals at a specified frequency, it is just as likely to be used to measure very small dc signals. Because of the inverse dependence of noise on frequency, maximum noise occurs at the lowest frequencies. Also, there is a problem with dc amplifiers in that they are subject to zero-point drift. It is very difficult to prevent this.

On the other hand, alternating signals do not suffer in this way as the signals always adjust themselves so that they are equally positive and negative. Hence the base line doesn't shift. For this reason, it is usual to convert small dc signals to alternating signals by chopping them at some frequency.

At one time, the conversion was done using a vibrating reed relay, but these were noisy and of limited life. Nowadays electronic switching would be used.

How the psd works

Figure 1a shows a schematic diagram of a psd. Basically it is simply a switch operated by a reference signal, which has to be in the form of a rectangular wave at the signal frequency. Usually the device used to modulate the signal provides the reference.

Chopped signals will be rectangular. When the reference signal is exactly in phase with the received signal then all the positive halves are switched to one channel and the negative halves to the other channel.

At the same time, each channel has a low-pass filter which can be thought of also as an integrating circuit so that the signals are accumulated over the length of time given by the time constant of the low pass filter *RC*. These time constants can be quite long. Commercial instruments can have time constants of up to 100 seconds.

If you consider what happens to signals at some other frequency, they will have both negative and positive parts appearing in both channels so that they will tend to cancel each other out. So you can see that this switching device acts like a filter. It is possible to show mathematically that the equivalent bandwidth of this device is $1/4RC$ for a simple 6dB per octave roll-off filter.

A more complex two-stage low-pass filter having a 12dB per octave roll-off has half the bandwidth. Thus for a time constant of three seconds not inordinately long at all, one has an equivalent band width of $^1/_{12}$Hz, something which would be almost impossible to achieve using conventional high-Q amplifiers. It should be noted that it takes about four times the time constant for the signal to settle down after a disturbance for the simple low pass filter and eight times for the two stage low-pass filter.

Additionally, should there be some drift in the chopping frequency, the psd will still follow the signal without loss of amplitude or change of phase, more or less. This is the reason why this device is nowadays called a lock-in amplifier or voltmeter as it locks onto the signal.

Harmonic effects

You can probably see from the description that the detector will respond to odd harmonics of the signal, should it not be a pure sinusoid. However, there will be both positive and negative parts of these signals in both channels so that these odd harmonics will be attenuated.

The third harmonic will be attenuated by nine and the fifth harmonic by 25. In addition, noise at these harmonic frequencies will also leak through to the output.

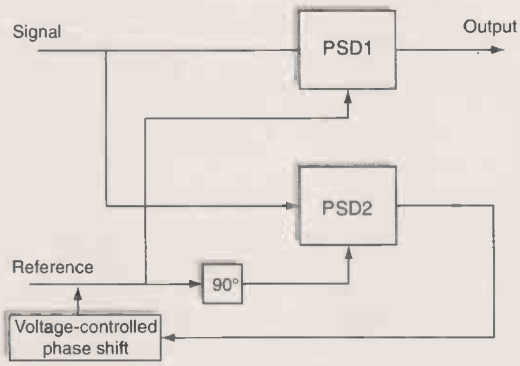

Fig. 2. Vector-tracking lock-in amplifier. Output from PSD2 feeds the voltage-controlled phase shifter via a long time constant. This shifter ensures that output from PSD2 is always zero and output from PSD1 is always maximum because of the 90° shifter.

It will be usually necessary to filter out these higher harmonics using a-low pass filter at the input. A tuned filter will not work. There is a phase shift through such a filter that varies with frequency.

Readers who read the homodyne/synchrodyne receiver article by Slifkin and Dori in the November 1998 issue will recognise that the phase-sensitive detector is simply synchronous detection using a dual channel rather than a single channel mode. One could certainly build a detector in which one channel is earthed and this would be an exact analogue of the synchronous detector.

From the simple model, you can also work out what happens if there is a phase difference between the signal and the reference. A maximum positive signal is produced when the two are in phase, as in Fig. **1b**).

When they are exactly out of phase there will be a maxi-

Chopping through history

These modulation techniques were very well understood in the forties. Unfortunately, textbooks on instrumental techniques from this period are very difficult to find.

Chopping techniques are certainly very old. Alexander Graham Bell used chopped light in his experiments on the photoacoustic effect in the 1870s.

An early instrument to measure the lifetime of phosphorescent crystals was the phosphoroscope. This consisted of two wheels mounted on a common axle. They had windows so that they could produce a square wave from a light source.

The crystal was placed in between the two wheels and the light intensity passing through measured as a function of the angle between the two wheels. This is an exact analogue to the psd used as a phase detector.

Mike Meade[1] refers to the experiments of Dicke the founder of radio astronomy in the 1940s. He wanted to measure very weak signals from outer space. His arrangement involved an antenna pointed at his subject and a dummy antenna at the same temperature. The two were switched between for many hours, integrating the signal.

Similar experiments were carried out slightly later at the Radio Astronomy department of Manchester University at Jodrell Bank. In their earliest experiments scientists there integrated the outputs over many hours by using an electrochemical cell and weighing the amount of metal deposited which was proportional to the integrated received signal.

Another technique they used slightly later was to build an up down counter. The radio signals were received in the form of small pulses, the counter would count up when connected to the real antenna and count down when connected to the dummy antenna.

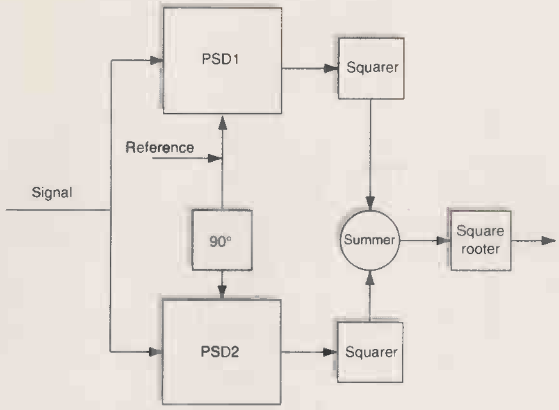

Fig. 3. Vector computing lock-in amplifier. This scheme is easier to implement, but has lower dynamic range than that of the vector tracker.

mum negative signal and when they are exactly 180° out of phase, there will no signal although there may well be some residual fluctuation due to noise.

Overall it is easy to accept that the relationship between the maximum signal V_{max} and the output signal V is given by $V=V_{max}\cos\phi$. This is why the phase is so important and why the instrument is sometimes called a phase-sensitive detector.

If we had a situation in which the input signal amplitude was always constant then the output amplitude would simply be a measure of the phase.

The phase-sensitive detector is not only useful for measuring very small signals in a noisy background. However, it can also be used to measure the time delay or phase shift of an electrical device by comparing the phase of the signal before it entered and after it left the device.

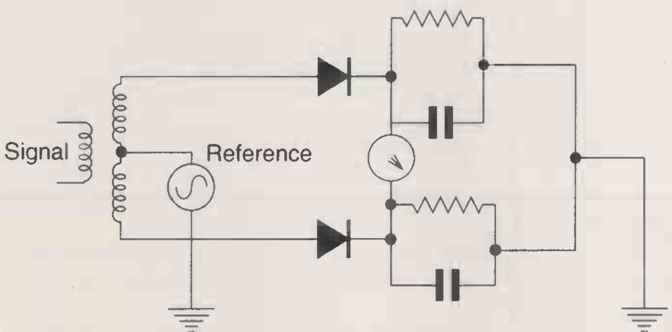

Fig. 4. Diode-operated phase-sensitive detector. The early versions performed well, but their frequency response was limited due to the inductance of the transformers.

How you would build an accurate phase shifter to work over a range of frequencies will not be dealt with here.

Measure between the zeros

It is much more accurate to measure the phase between the zeros or the signal rather than the difference between maxima of the signals. A cosine/sine waveform has its greatest change passing through the zero. At its maximum, it has its minimum change. A cosine/sine waveform is almost flat at the peak. The relationship between the phase shift and time is given by the relationship $\arctan\theta=2\pi ft$.

In general, measurement of phase is not that accurate. An alternative way of using the phase-sensitive detector is to measure the amplitude of the signal as a function of the frequency with an input signal having the same phase as the reference signal.

It can be shown mathematically that the output of the system under test will be a sigmoidally shaped curve – also called a logistic curve – having the form,

$$V = \frac{k2\pi ft}{1+4\pi^2 f^2 t^2}$$

where V is the signal, f is the chopping frequency, t is the delay time and k is some instrumental constant. The value of t can then be found by a variety of methods including plotting $1/V$ against $(2\pi f)^2$ which gives a straight line with a slope of t/k and an intercept of $1/kt$.

A more sophisticated method would be to use a curve fitting program with a computer which would give the value of t directly. These types of methods are much more accurate than a simple measurement of phase.

For a versatile instrument, one requires that one can obtain automatically a maximum signal, the in-phase signal, or the out-of-phase signal. There are several ways of doing this. Of those, the vector tracking method seems to be the one now used commercially.

There is however another method – namely the vector computing method. While inferior because of its limited dynamic range (dynamic range is explained in the panel), it is easier to implement. We present a prototype later that we have designed and built.

Note that any of these methods requires the use of two detectors.

Vector tracking

A schematic of the vector tracking method is shown in **Fig. 2**. The device works as follows.

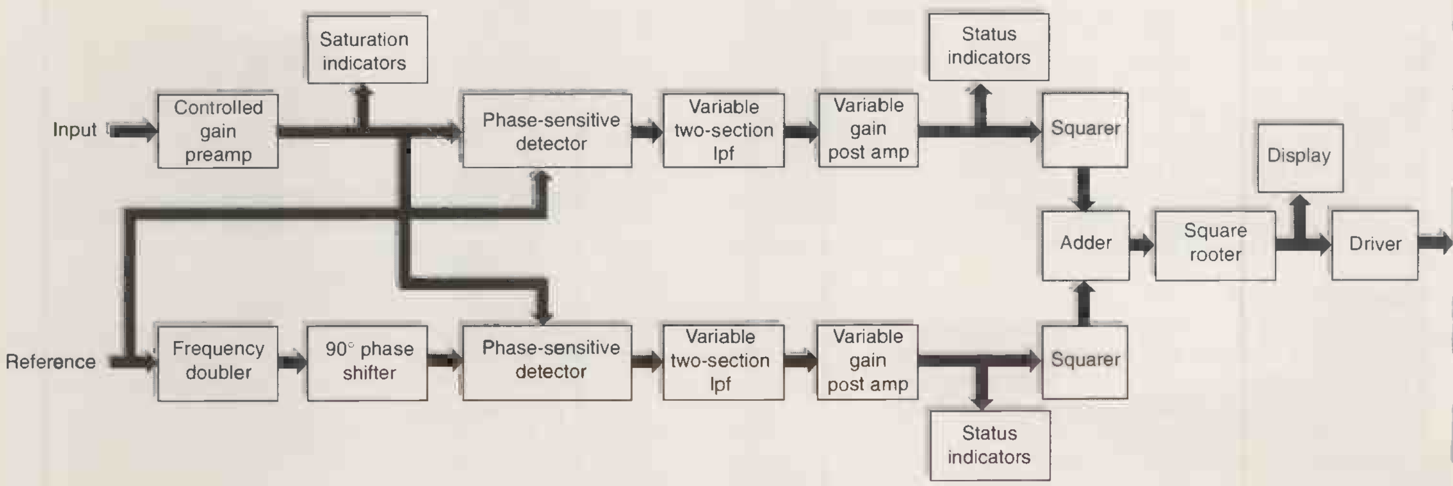

Fig. 5. Block diagram of the vector-computing phase-sensitive detector – the subject of the main circuit, Fig. 6.

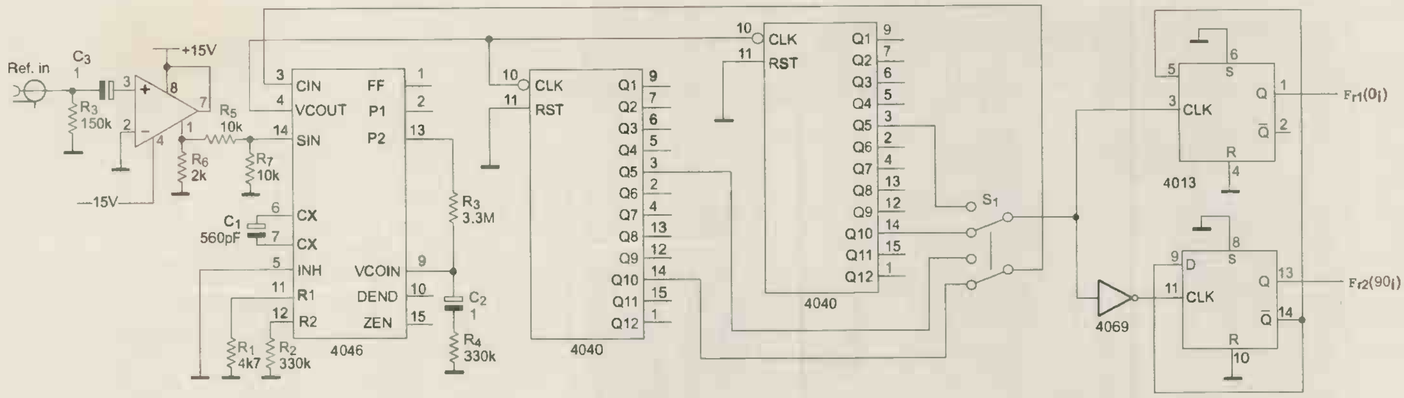

Fig. 6a). Input section and digital 90° phase shifter of the phase-sensitive detector.

Output from the lower detector is fed back using a long time constant to control a voltage controlled phase shifter. It is fed back in such a way that the output from this channel is always zero and hence because of the 90° phase shifter the upper channel is always a maximum.

This arrangement enables good dynamic reserve to be obtained. Amongst other possible methods is the vector computing method this is illustrated in **Fig. 3**. If the original signal is $V_{max}\cos\theta$ then the 90° phase shifted signal is $V_{max}\sin\theta$. When the two signals are first squared and then added, we obtain V_{max}^2 as $\cos^2+\sin^2=1$ and thereafter V_{max} following square rooting.

This is a relatively simple technique and easy to implement using modern integrated circuitry. It suffers the problem of lower dynamic range than that of the vector tracking method. This is because the vector tracking method obtains the signal from one psd only at optimum signal to noise ratio. The second detector channel merely serves to condition the reference channel.

By contrast, the vector computing method obtains the signal from both channels which in itself will give increased noise. In addition the signals will not be at optimum signal-to-noise ratio in both channels and the extra computing circuits all combine to degrade the signal to noise ratio

A more complex version is the heterodyne psd. In this technique, the detector works at a high fixed frequency and the incoming signal is heterodyned with the incoming signal to the psd frequency.

This has the big advantage that the odd harmonics are now so high that they lie outside the range of the instrument. There remains only the fundamental signal and the noise at the fundamental frequency at the output. In addition, AC amplification is more efficient at frequencies higher than a few hundred hertz so that this technique is doubly useful with low frequency signals.

Some modern lock-in amplifiers incorporate a microprocessor and can be linked directly to a computer and operated from it.

Finally, dsp lock-in amplifiers are now coming on to the market. With these instruments, the incoming signals are converted to digital signals using a-to-d converters and then are mathematically processed to give the required signals. Their manufacturers claim that they are superior to analogue lock-in amplifiers.

The earliest phase-sensitive detectors

The earliest form of phase sensitive detection involved mechanical switching using either vibrating reeds or synchronous electric motors with a cam opening and closing microswitches.

The first electronic phase-sensitive detector dates to the early fifties and consisted of a centre-tapped transformer and diodes as in **Fig. 4**. These performed quite well but were limited in frequency because of the inductance of the transformers. In addition in order to get identical channels, it was essential to use very high grade centre tapped transformers.

The next generation used transistor switching. With the introduction of integrated circuits, it was now possible to obtain switching with gain.

It can be shown mathematically that the phase-sensitive detector action is simply a multiplication between the reference and the signal. Modern practice is to use high-grade IC multipliers or high specification IC mixers.

The first commercial lock-in amplifiers were built as part of nuclear magnetic resonance apparatuses and were not sold as stand alone instruments. One made by JEOL in the early fifties had plug-in peak tuned filters at the front end, although this would appear to be completely contrary to the phase-sensitive detector philosophy.

Other lock-in amplifiers of a slightly later period, such as those made by PAR, also used high-Q filters at the front end.

The first instruments sold as general purpose lock-in amplifiers in the UK were probably the ones by Brookdeal in the early sixties. These used individual transistors and provided

Integrated circuits involved

IC_1	4046
IC_2	4040
IC_3	4040
IC_4	4069
IC_5	4013
IC_9	OP27
IC_{11}	AD534
IC_{12}	AD534
IC_{14}	AD534
IC_{15}	LM311
IC_{16}	AD524
IC_{19-26}	OP27

Dynamic reserve

All the forms of synchronous switching that we have described in this article will work adequately – particularly at low frequencies.

What distinguishes a good lock-in amplifier from a poor one is the dynamic reserve. This is defined in various ways. However, a useful definition is given by Mike Mead[1] as the maximum allowed peak to peak level of asynchronous input divided by the peak to peak value of the full-scale synchronous signal. In other words, it is a measure of the worst-case signal-to-noise ratio that can be applied to the input of the instrument to give a full-scale signal at the output.

The better the dynamic reserve the better the instrument at measuring a signal buried in noise. This is a function of the quality of the amplification filtering and inherent noise in the instrument.

Another factor that is clearly related is the input overload level, i.e. that signal which will cause the instrument to overload or go into a non-linear mode. Most commercial instruments have some means of indicating when the overload point is reached, since output above this point is no longer reliable.

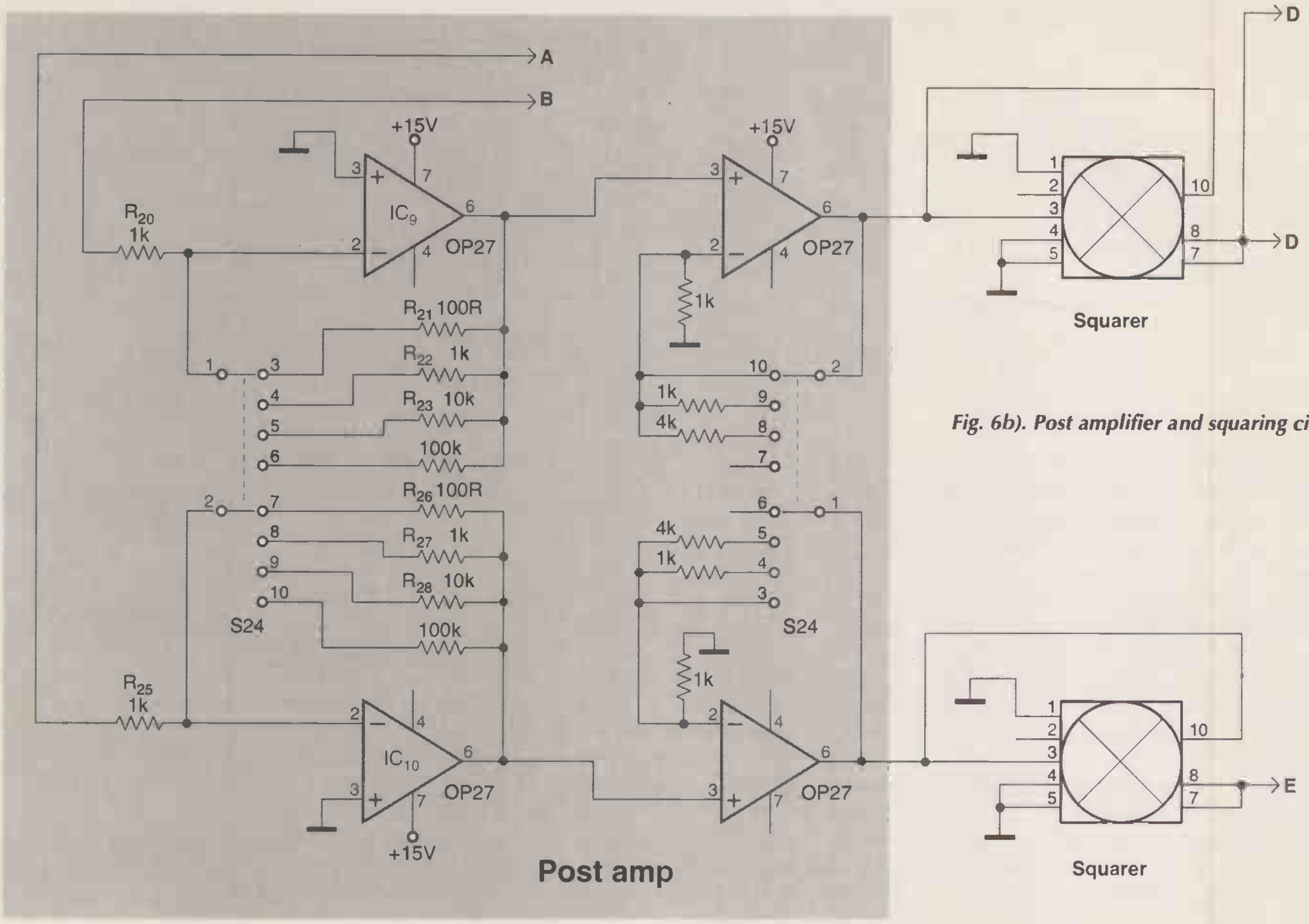

Fig. 6b). Post amplifier and squaring circuits.

no means of phase shifting.

Some lock-in amplifiers have a built-in reference oscillator so that one can for example obtain noise spectra by measuring the output as a function of the reference frequency. Nowadays there is a wide selection of lock-in amplifiers with all kinds of features. Dynamic reserves for such instruments are quoted as being in the range 100 to 130dB.

Implementing the psd concept

In this final section, we describe a computing vector lock-in amplifier using modern integrated circuitry. The instrument has an input that handles anywhere between a few microvolts and a few volts. Its frequency range is 10Hz to 3kHz and its linearity 2%.

Although this instrument performs quite well, it cannot be compared to the state-of-the-art vector tracking lock-in amplifiers. However it is relatively easy to build and certainly far cheaper than the commercial instruments. A block diagram is shown in Fig. 5 and the circuit diagram in Fig. 6.

If you want to build a single-channel phase-sensitive detector, you can easily adapt the circuit diagram. It would then be preferable to include a manual phase shifter in the reference channel so that the output can be maximised.

The main ICs are manufactured by Analog Devices. There are three identical computing elements incorporating the *AD534* four-quadrant multiplier. These are used as squarers and square rooter.

The same element could also be used as the psd but the *AD630* is cheaper and intended specifically for use as a high-grade mixer. It is simply a two-quadrant multiplier.

The precision instrumentation amplifier, *AD524* is also taken from the Analog Devices range. It has a low offset

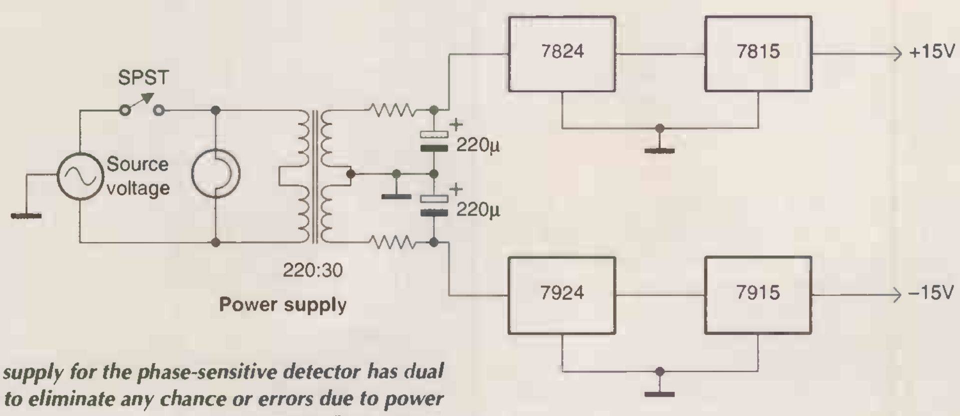

Fig. 6c). Power supply for the phase-sensitive detector has dual regulators on each rail to eliminate any chance or errors due to power supply fluctuations.

voltage. In addition, it can be configured to give automatic zero offset with some additional circuitry. We avoided doing this because of the increased complexity of the circuit.

Although this is an analogue psd, we have chosen a digital technique for the 90° phase shifter, as this is by the far the best available. The reference is frequency doubled and then passed to the CLK input of two D-type flip flops, one input being inverted.

The D-type flip-flops are configured as divide-by-two circuits. Thus, the Q outputs are at the original frequency but one is shifted by 90° relative to the other. This works very well over a wide frequency range.

Frequency doubling is obtained from a *4046* digital phase lock loop with a *4040* divide by two ripple counter in the feedback loop. This generates a frequency exactly twice that of the input frequency.

An explanation of the phase lock loop is given in the article on the synchrodyne/homodyne receiver mentioned earlier. One could replace this digital phase lock loop with an analogue phase-locked loop such at the *NE565*.

The low-pass filters are active devices to give idealised behaviour. We have used second order Chebyshev filters to give decreased bandwidth. You may prefer to use a simple *RC* filter depending on your particular application.

Some might prefer to sacrifice bandwidth for settling time and simplicity. We have provided time constants of 0.3, 1, 3 and 10 seconds.

There is both pre amplification and post amplification. Pre-amplification has fixed values of 1, 10, 100 and 1000. Post-detection amplification is 1, 2.5 and 5.

We have included saturation indicators for the preamplifiers. When these are fully on then the amplifiers are overloaded and should not be trusted.

However, the instrument is usable during low-frequency flashing of the leds. We have also included high and low detectors for the phase sensitive detector itself.

The signal presented to the psd should be neither too high nor too low. The high and low level indicators come on when these conditions are violated. Again, low-frequency flashing of these indicators is no problem.

There is an output driver should you want to observe the signal on for example a chart recorder. This can be very useful. It is much easier to get an estimate of noisy signals by examining the trace on a chart recorder than by trying to read a varying digital display.

We have not included the output display in our circuit diagrams as there are many alternatives around. You could even use a digital voltmeter.

A useful addition would be a frequency meter in the reference channel. ■

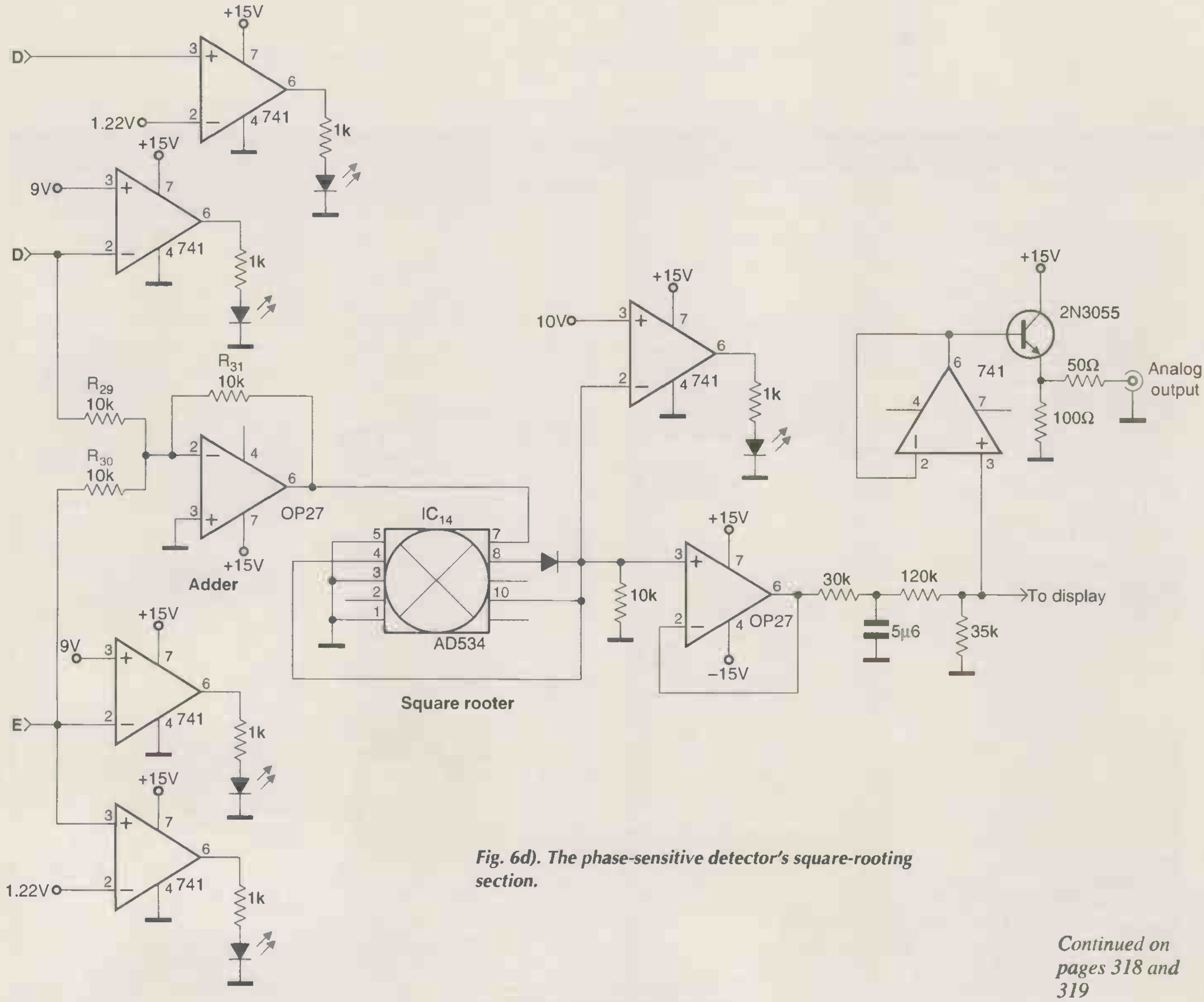

Fig. 6d). The phase-sensitive detector's square-rooting section.

Continued on pages 318 and 319

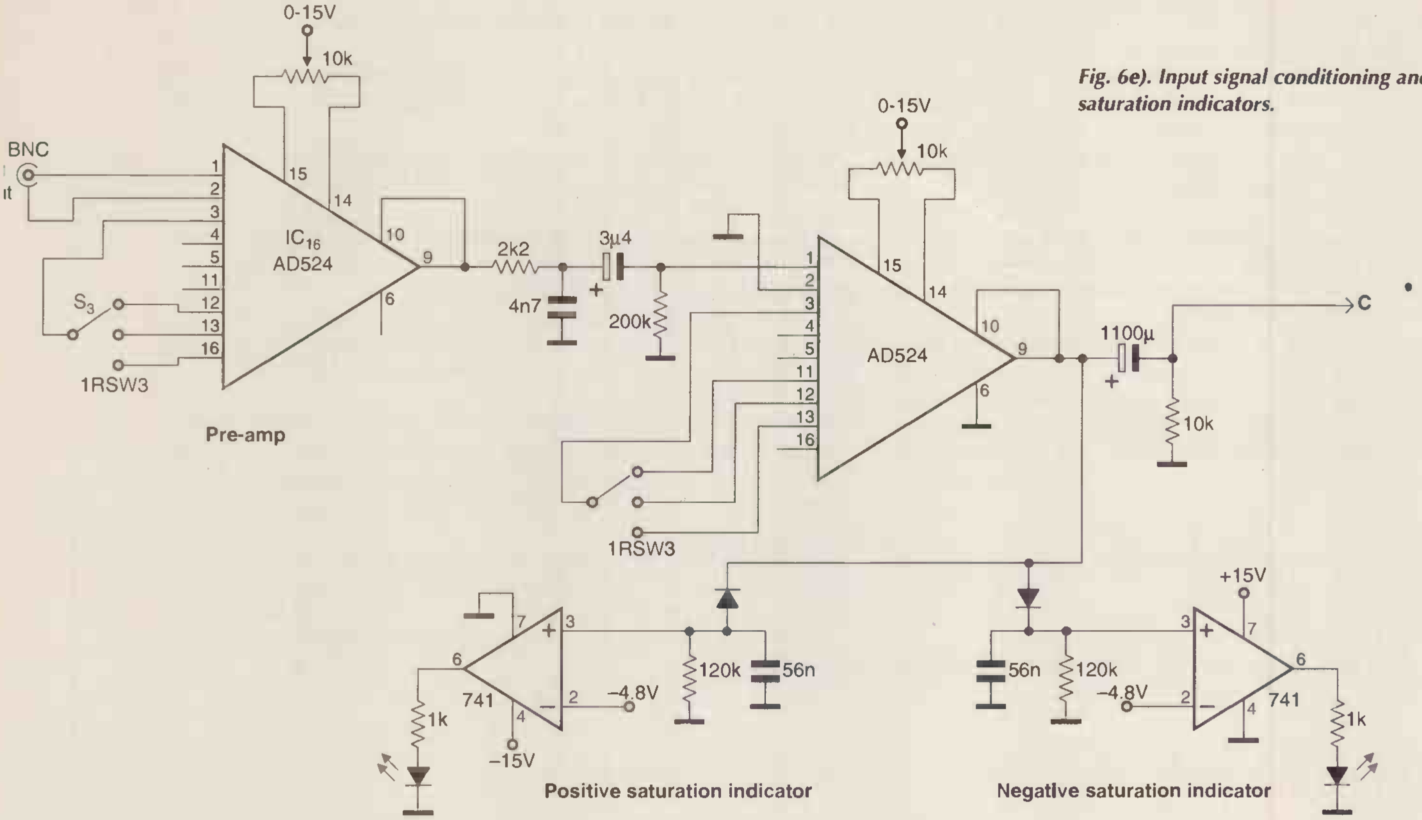

Fig. 6e). Input signal conditioning and saturation indicators.

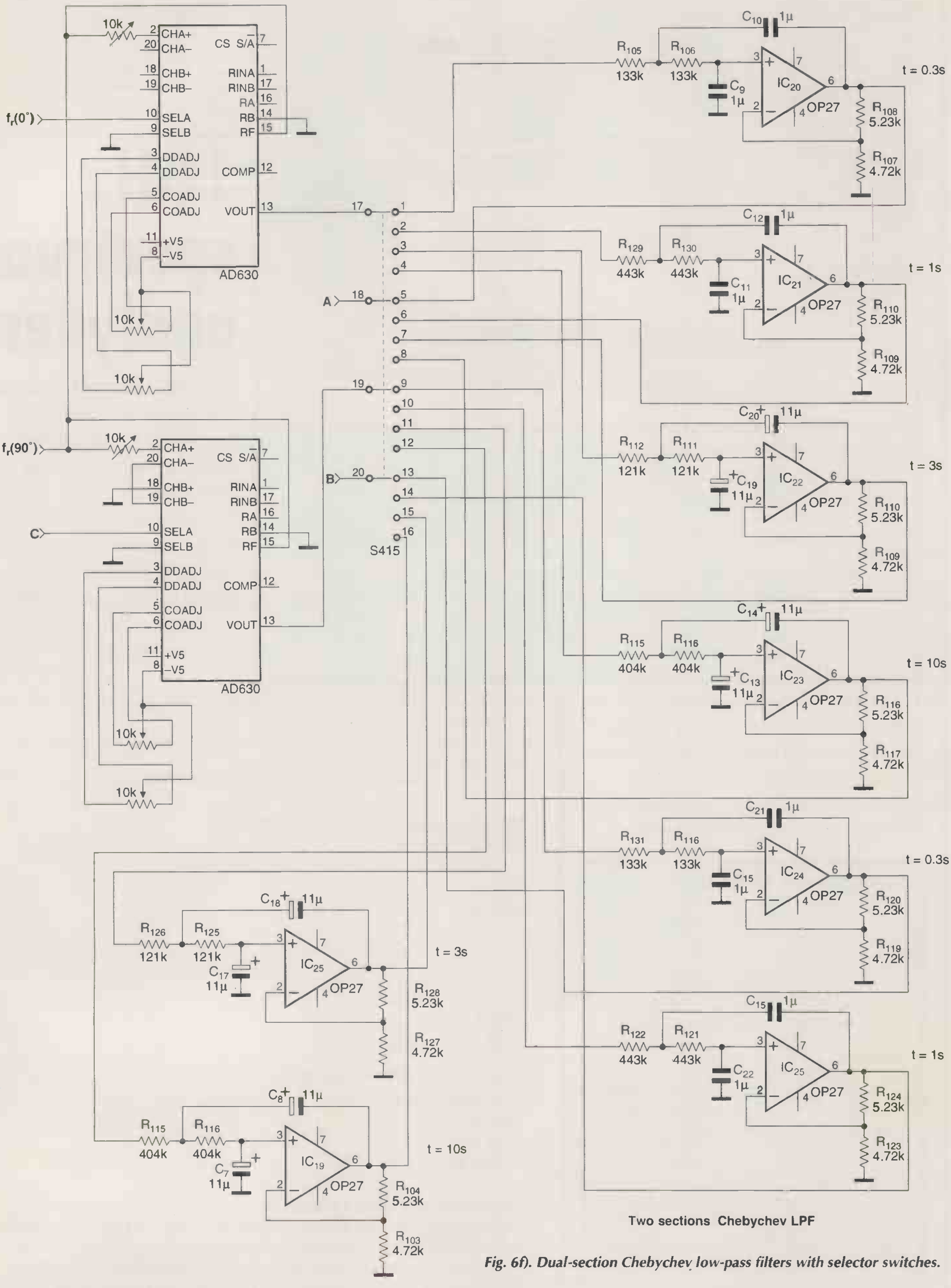

Fig. 6f). Dual-section Chebychev low-pass filters with selector switches.

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Designated the TSA1000, this spectrum analyser is in the form of an adaptor that converts any standard oscilloscope into a 1GHz spectrum analyser.

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A built-in crystal-controlled marker provides a precision means of frequency and amplitude calibration. The centre frequency can be adjusted over the full 0-1GHz range using a ten-turn control, and is displayed on a large 3.5-digit liquid-crystal display.

Scan width is fully variable between 10MHz and 1GHz, and the scan rate can be set anywhere between 10Hz and 200Hz.

Easy to connect and use

The adaptor connects to the oscilloscope via two BNC connectors using true 50Ω impedance for minimal vswr. A calibration button allows a standard –30dBm 50MHz marker signal to be superimposed for precise amplitude and frequency checks.

The TSA1000 is supplied with an operating manual describing the basics of spectrum analysis and EMC measurements. Its normal price is £581 including VAT in the UK. Electronics World readers can obtain it for just £499 – including VAT and carriage.

TSA1000 key specifications

Frequency range	400kHz to 1000Mhz
Centre adjust	0MHz to 1000MHz
Bandwidth	250kHz (–6dB typical)
Meter accuracy	1% of reading +1MHz
Calibration marker	50MHz fundamental, harmonics to 1GHz
Scan width	1MHz to 100MHz/div
Scan speed	0.5ms to 35ms/div
Amplitude	
Input impedance	50Ω
Amplitude range	–70dBm to 0dBm nominal
Amplitude scale	Logarithmic, 10dB/div
Amplitude linearity	Typically ±2dB
Amplitude flatness	Typically ±1.5dB 4MHz to 1000MHz
Max. input level	+10dBm
Calibration marker	–30dBm ±1dB at 50MHz
Oscilloscope requirements	
Oscilloscope mode	X-Y mode, DC coupling; bandwidth not critical
X-Input sensitivity	0.5V/div
Y-Input sensitivity	0.5V/div

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Mouse holes

Have you ever thought what it would be like to have a Windows pointing device that never sticks? With electronics designers spending ever more time at the pc, Rod Cooper looks at less frustrating alternatives to the standard mass-produced mouse, broaching health issues along the way.

At the start of my recent series on pcb CAD, I mentioned the digitising tablet as a good alternative to the mouse for drawing schematics and interactively routeing tracks on pcb artwork. The attraction of the tablet is that it has no moving parts. This makes it far more reliable in the long run, and consistently precise in operation.

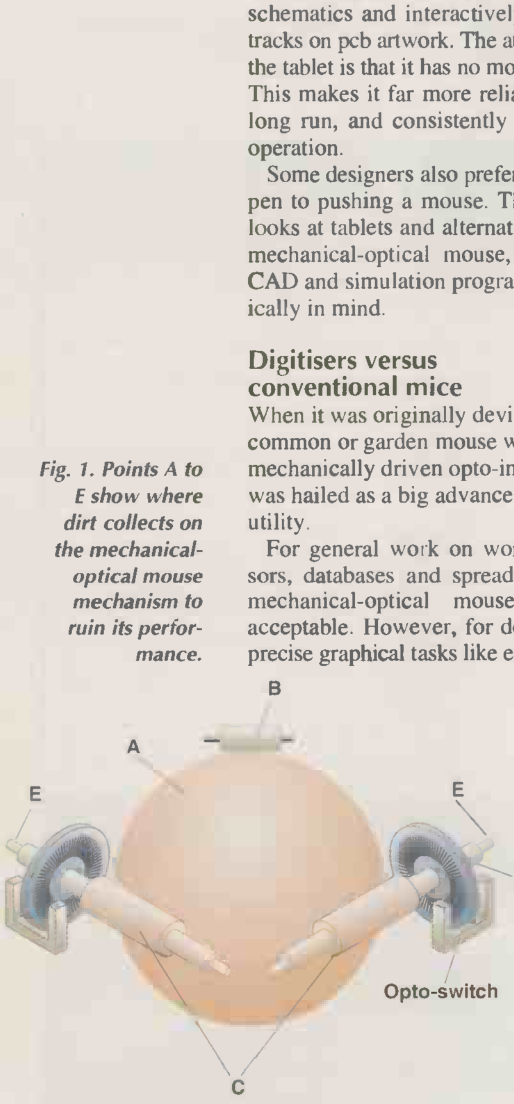
Some designers also prefer holding a pen to pushing a mouse. This review looks at tablets and alternatives to the mechanical-optical mouse, with pcb CAD and simulation programs specifically in mind.

Digitisers versus conventional mice

When it was originally devised, the common or garden mouse with its mechanically driven opto-interrupters was hailed as a big advance in pc utility.

For general work on word processors, databases and spreadsheets the mechanical-optical mouse is still acceptable. However, for doing more precise graphical tasks like engineering drawings, for artistic work, and for pcb-cad the conventional mouse as illustrated in **Fig. 1** leaves a lot to be desired.

Fig. 1. Points A to E show where dirt collects on the mechanical-optical mouse mechanism to ruin its performance.



Friction and stiction are the bugbears of the conventional mouse. These two forces exist between the rubber ball, A, and the mouse-mat and between the ball and the interrupter disc spindles, C. There may also be a contribution from rubber-ball support B when the ball is rolling in the wrong direction to make the support turn.

When the mouse is new, these problems are minimal and with a good-quality mouse it is possible to ignore them for a while. But as everyone who uses these mice already knows, dirt is readily picked up from the mouse mat by the rubber ball, which by its very consistency tends to do this extremely well. This dirt is transferred to the spindles of the interrupter discs.

Dirt also accumulates on the spindle bearings, E, increasing their resistance to turning, and on the support bearings, B. If you examine a mouse that has been used for a long while it will show significant wear at the bearings, due in part to the ingress of dirt.

The random and uneven nature of the dirt deposits causes erratic mouse operation. Most trackballs, which are just inverted mice, have the same problems. So, any device like this has to be taken apart and cleaned regularly if it is to be used with any program needing accuracy. But cleaning will not correct play in the spindle bearings caused by dirt and fair wear and tear.

It is only possible to tolerate increasingly erratic operation if you are using something like a word processor. I see people doing so every day. However, for pcb CAD this is not the way to do things.

The only thing to be said in favour of the mechanical-optical mouse is that, with mass production and increasing competition between manufacturers, it has become very low cost.

The alternative to the mouse is to use a device with no moving parts in the positioning mechanism. Preferably, the device should have no moving parts in its left and right button switches, although this latter aspect is not so important.

On the conventional mouse, the button microswitches do not give anywhere near the amount of trouble that the ball and rotating interrupters do.

Until recently, these all-electronic alternatives have been expensive, but there are now some excellent, low-cost devices that are almost perfect for both pcb CAD and simulator programs. This review concentrates on these low-cost products.

There are several different methods of operation in common use, all of which can offer a big improvement over the conventional mouse. Which one you choose is a matter of personal preference and depends to some extent on what else you do on your pc besides pcb CAD and simulation. The review looks at three systems: graphics tablets, the digital trackball, and the digital mouse.

How is a mouse specified?

A digitiser''s specification for resolution may be in lines per inch, abbreviated to lpi, or dots per inch, dpi. Alternatively, a simple overall resolution such as 2048 by 2048 may be quoted. Rarely, you may have an accuracy specification such as ±1 pixel.

The resolution of digitisers is generally better than that of the mechanical-optical mouse, which is around 400 dpi when new. For the vast majority of programs, including pcb-CAD and simulators, this resolution is perfectly adequate, so anything more is a bonus.

No product reviewed here needs to be powered from the mains or needs batteries. They all draw the small amount of power needed to run them from the pc.

Take the tablet...

The digitising tablet consists of a hand-held pen typically connected by a lightweight cable to a flat tablet, which can measure anything from 100mm by 80mm to 300mm by 450 mm or more.

There are cord-free pen designs available. Many prefer not to have a cable on the pen, regarding it as a hindrance. However, there are sound reasons for preferring a cabled pen. A cabled pen cannot get lost under a mound of paper on your desk-top, it cannot fall on the floor to be chewed by the dog, and it cannot accidentally find its way into the waste paper bin.

As you would expect, the screen pointer moves when the pen is moved across the surface of the tablet, but unlike a mouse on a pad, tablets are so-called absolute devices. A point on the tablet corresponds exactly to a point on the screen. This has the advantage that an overlay can be placed on the tablet giving a graphic representation of the screen, which can make operations like selecting items from the toolbar easier.

Some tablet makers provide overlays for popular CAD programs like KeyCad and AutoCad. Absolute operation also enables tracing from hard copy. The original is simply placed over the tablet and the design traced with the pen.

Although the digitising tablet is intrinsically an absolute device, certain tablets have software features that allow them to be changed to relative working, if that is what you prefer.

Pcb CAD – a black sheep

You may think that for any graphical-type program the larger the tablet the better, but this is not always true. An artist may prefer broad sweeps of the pen, and a draughtsman working on detail on a large engineering drawing may prefer a big tablet, but for pcb CAD this is not strictly necessary.

Pcb CAD is a strange hybrid, occupying a niche between artistic drawing and engineering drawing. Symbols in pcb CAD are usually already drawn for you. Moreover, program tools such as snap-to and autowirers heavily assist in the drawing of connections between symbols. So this type of CAD can hardly be called an artistic endeavour even though the final product of circuit diagram or pcb trace may look artistic.

A small tablet can actually be an advantage when used with pcb CAD. Consider your hand at rest holding a mouse on a mat, with the wrist resting on a pad. Can you easily reach from side to side of the screen with the pointer and maintain the required accuracy without moving your wrist from the pad? If so, you will most likely find this both convenient and comfortable for all facets of the pcb CAD program.

You will probably find that lifting your hand to move the mouse to increase the range of the screen pointer is not at all desirable. It takes extra effort without increasing accuracy. The same applies if holding the pen of a digitiser.

Much depends on the size of your hand, and on your own personal technique, but I suggest that a digitiser tablet of 45 mm x 60 mm up to 100mm x 125mm is about right for pcb-CAD. Some tablets have software drivers that allow you to reduce the size of the active area. This could enable individual hands to be accommodated, to make continuous working more comfortable.

In conclusion, this is an area where bigger is not necessarily better.

Tablet options

Graphics tablets of the type reviewed here typically use a grid of interesecting conductors and a capacitively or electromagnetically coupled pen to determine position.

The range of this system can be up to 25mm above the board. Beyond this, the pen ceases to function.

Since this type of circuit reports continuously to the pc, it is an advantage to take the pen out of range when not using it, to remove the overhead on the cpu. On slower pcs this may well give a noticeable increase in performance, An out-of-range pen holder is therefore usually a feature on most tablets.

On larger tablets, a device often referred to as a puck is provided as an alternative to the pen. This performs the same duty as a mouse, but usually has more features, extra buttons for example. None of the reviewed products has a puck.

The surface of the tablet is of prime importance. There are typically switches on the barrel or tip of the pen corresponding to the right and left buttons of the mouse. If the surface of the tablet is glass smooth, it will be difficult to operate them without inadvertently moving the pen.

Even if you tense your hand to hold the pen steady while you finger the buttons, you will not always succeed in keeping the pen in the right place on the tablet, resulting in a mistake. With practice, it can be done, but continually tensing your hand to operate the left/right buttons is highly undesirable even if you do appear to be able to manage it, as will be explained later.

If the tablet has a rougher surface to provide some friction, it is then more feasible to keep the pen still while you press the buttons. There is clearly a compromise position between having the surface too friction-laden and too smooth. Some manufacturers have not only achieved this, but have taken this a stage further. For example, some Calcom and Wacom tablets have a surface that gives a remarkably similar feel to real pen and paper.

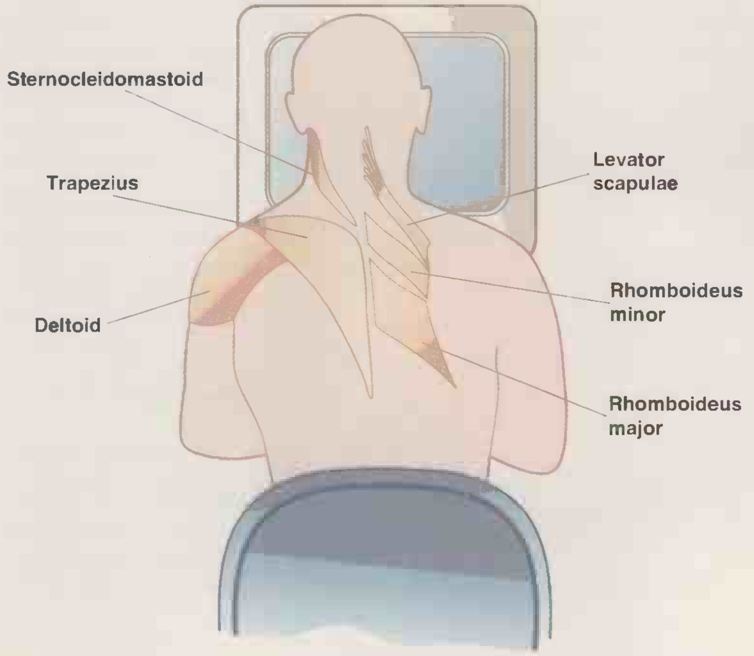


Fig. 2. Shows the groups of muscles at risk for a right-handed mouse user. Note that they are not necessarily where a layman would expect muscular problems. The least stressful position seems to be when both hands are in your lap. This does not preclude doing useful work! It's a viable position for using a small tablet, such as the Genius EasyPen, and some people like to operate a trackball this way. Mouse pads that rest on the lap or leg have now appeared and recently, a pad that clips onto the upper leg was demonstrated on 'Tomorrow's World'.

Some users suggest roughening up the surface of tablets that are too smooth with emery paper, to provide a bit of friction, but I would not recommend it.

A less drastic solution is to fix a piece of 100gsm paper on the tablet with a semi-permanent glue like Pritt-stick if you want to improve the friction. It will not interfere with the efficiency of the coupling between pen and tablet, and it has the advantage that you can put your own overlay on it if you wish.

Duplicator paper, copier paper and glazed paper can provide three levels of friction, and if you want to reverse the process you can easily remove the paper and wipe off the Pritt-stick with alcohol.

Using your free hand

Of course, if the left and right buttons are not on the pen at all, but somewhere else, this situation is radically altered. In this case, it can be very pleasant to have a freely sliding pen. The left hand, which is nearly always idle when the right hand is working the pen, could then click the left and right buttons.

I tried an experiment with a tablet, which normally has both buttons on the pen, by adding a small module designed to be held in the left hand. The module had two thumb-operated microswitches on top of a pistol grip as shown in photo 2) and was attached to the tablet by means of a short extension lead.

This system not only completely transformed the speed and ease with which the tablet could be operated but reduced the overall amount of effort required. In particular, the smooth surface of the tablet became an advantage.

There may also be a medical benefit in this two-handed approach, as explained in the final section. Here, it makes no sense to have the right hand doing all the work while the left hand does none.

However, it appears the concept of this style of operation is lost on the manufacturers, so if you want to try it you will have to make your own left-hand switch. Note that if the pen is attached to the tablet by a connector, rather than directly cabled, it is relatively easy to break in with a connector/socket extension in order to add such a device.

Tablet conflicts

On pcs where the mouse is connected to COM1, most tablets will connect to COM2 by default. You will then usually be able to have the mouse and tablet in joint control of the screen pointer. This could be a desirable state of affairs if you want-

Review 1 – *EasyPen*

Produced by Genius-Kye, *EasyPen* is a small inexpensive digitising tablet with a cabled pen, which is electromagnetically coupled. There are no connectors, the pen cable and PC cable being permanently fixed to the tablet.

The active area is 105 mm by 75 mm, i.e. 4in by 3in, and resolution 2540 lpi. I found this combination fine for pcb-CAD. At 140 mm by 160 mm overall, the tablet is small enough to rest on your lap, or knee. If you design on the move using a laptop pc the compact size of this tablet could make it a very attractive proposition. It weighs only 250g.

The tablet driver comes on a self-starting cd and installation was simple. With a mouse on COM1, and tablet on COM2, both could be operated. There is no manual for this product, simply an installation card. In place of a manual, help and read-me files are installed from the cd to the start-up menu. The driver file icon is inserted into Window's control panel, and any configuration of the tablet is done from there. These drivers are for WIN3.x, 95, 98 and NT.

The software allows the tablet to be altered for absolute or relative motion, and provides good control over the double-click setting, reversal of button function, and resolution. The orientation for portrait or landscape can be set, as can the working area of the tablet. Generally, the amount and usefulness of driver configuration was excellent.

There is a microswitch on the tip of the pen, which usually emulates the left mouse button. A press-switch on the barrel of the 10mm diameter pen emulates the right button, although this system can be reversed via the software.

The tip switch is quite sensitive. I found that if I used anything more than a light touch, the button activated when I didn't want it to. Unless you are particularly heavy handed, this should not bother you.

Bumps while travelling also sometimes activated it. However, it was easy to prevent this by keeping the pen slightly above the tablet, with the index finger running on the surface of the tablet. Introducing this small gap did not stop the pen operating as it has a range of about 15mm.

The tablet has a smooth, low-friction surface. I mentioned earlier how you might modify this. A green led indicates when the tablet is powered. It flashes when the pen is out of range and stays on when within range. An inkpot-type stand is used for standing the pen in, when not in use. It was a little too light to be completely stable, but it could easily be made heavier by removing the felt base and putting, for example, epoxy filler in the empty spaces.

On a 21in screen, I found the small size of the active area of the tablet no disadvantage at all when running pcb CAD. Overall operation, once I had got used to the sensitive tip-switch, was precise and smooth even with this large screen. When used with a 'paint' program, for example, drawing sketches and handwriting, the feel seemed quite natural. Note that there is no pressure sensitivity with this tablet i.e. pressing harder on the pen will not produce thicker lines.

In summary, this is a well-designed product with good software. It is a viable proposition if you design when on trains, planes and ships, but also well worth considering for a regular desktop set-up. At only £29.50 recommended retail price, this isn't going to break the bank. In my view, it would be nice to have control over pen tip sensitivity, but you may disagree.

The Genius EasyPen – good, compact product, comprehensive software.

ed to use the mouse for word processors, spread sheets, etc., and then use the tablet for CAD without having to go through any change-over procedure.

If you have a modem on COM4, there may be an IRQ conflict with COM2. Whether or not there is will depend on how your pc is set up, but it is a common situation. If there is a conflict, you won't be able to use the modem while the tablet driver is active, and *vice versa*.

There are several ways round this situation. You can buy special COM port cards that designate a separate IRQ to COM1,2,3 and 4, but you will have to do some searching round suppliers to find one.

Alternatively, you can find an unused IRQ and alter the COM port setting to suit, but this may require some time and effort unless you know exactly what you're doing.

Cradle benefits

Another method – the one I use because it has many collateral advantages – is to have two hard drives in separate removable cradles. Such cradles are now inexpensive items, at between £10 and £20 readily available from most pc component suppliers.

Only one drive is inserted at any one time. On the first hard drive, you put the operating system and your pcb-CAD and other CAD or graphics programs needing a tablet, and of course the tablet driver but no modem set-up.

On the other drive, you put the operating system again, your Internet browser, fax software and whatever other modem programs you have, but omit the tablet driver. For this drive, you would use the mouse only.

For this to work well, you need a bios that will automatically recognise which hard drive you are using, assuming they are different, and set up accordingly. If you have an older bios that cannot do this, the alternative is to use two identical hard drives. Either system works well.

There are many advantages to this system. Firstly, you can crash the operating system on the modem hard drive without affecting your pcb-CAD and other programs, so you are never in the position of being at a total standstill. I find the Internet a frequent source of operating system crashing material – including viruses – whereas you can go a long while without a software fault if you use CAD applications from reputable sources, so this is a significant factor.

Accepting that one disk is going to crash once in a while, you can take extra precautions – like a frequent backup using a scheduler, and one of

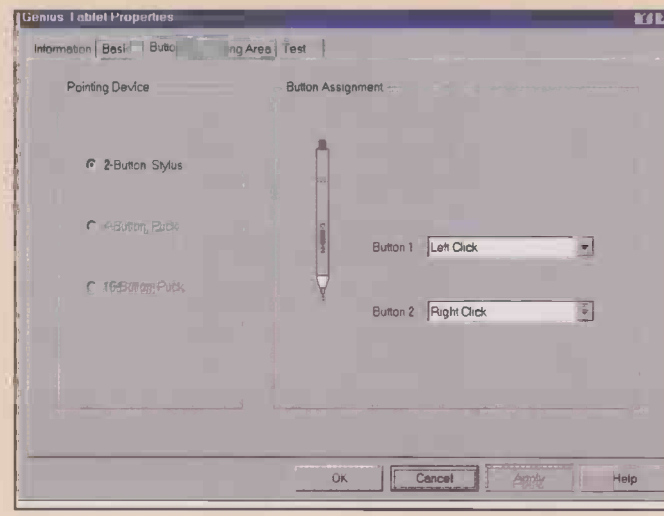
Supplier; Laton Technology, phone 01424 422562, fax 01424 423460.

There is a similar tablet from Genius called *EasyPainter*, which is a bigger brother to *EasyPen*. Operation is the same, but the active area measures 127mm by 127mm and the whole tablet 205mm by 235mm. Its resolution is 1016 lpi. By virtue of its larger size, and being almost twice the weight of *EasyPen*, this tablet is obviously intended for desktop use.

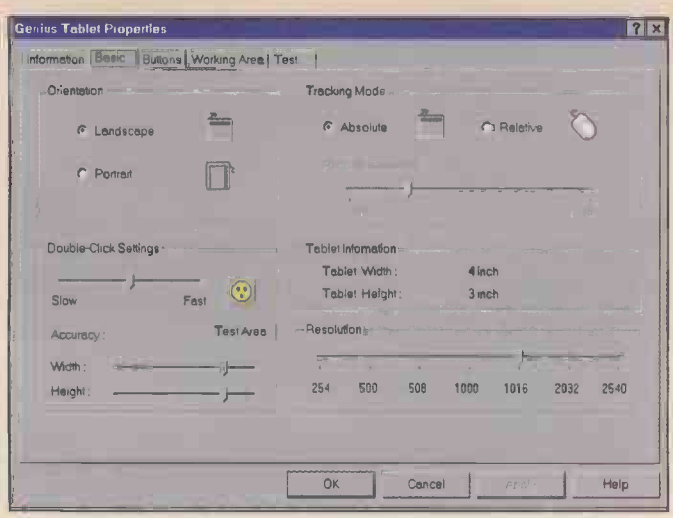
Unlike *EasyPen*, the pen in *EasyPainter* is attached to the tablet via a mini-din connector and instead of having a separate holder the pen sits in a built-in recess in the tablet when not in use. The pen barrel is slightly thicker at 11.5mm diameter.

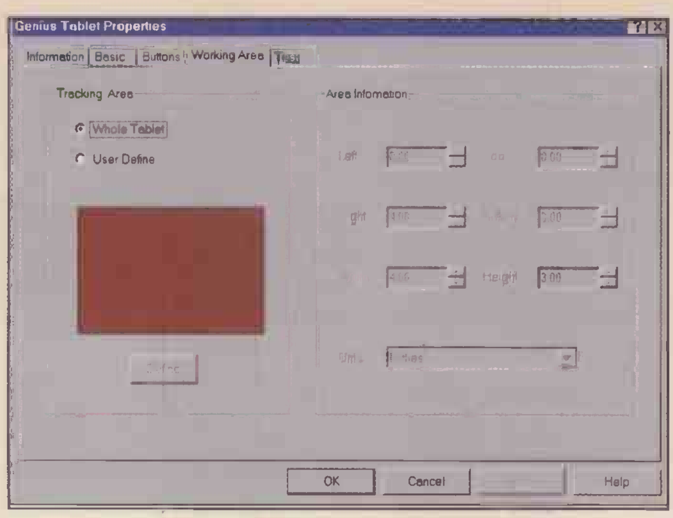
A short operator's manual is provided, and the product is bundled with a small 2.7Mbyte paint program by WordStar. There are also some Dos drivers provided and some specific drivers for AutoCAD and *AutoSketch*. All the software is on 3.5in disks.

EasyPainter is around £42 rrp plus VAT.



The most versatile and useful software drivers came with the Genius EasyPen.





the rescue packages such as WinRescue, and good and regularly up-dated virus checker. You can also designate this disk for transient programs – shareware, stuff from cover disks, etc., and other material that may tend to crash your system.

Secondly, if you use cradles, both drives can be removed to a secure place – a fire safe for instance – when not in use, so all your data is protected if your PC is stolen, or if you have a fire. Thirdly, you can use a different operating system on each drive if you wish, without resorting to boot managers or dual-boot arrangements.

Digital trackballs

Strictly speaking, digital trackballs cannot claim to have no moving parts because the rotating ball is by definition an intrinsic component. In a digital trackball however, there is no mechanical coupling with the signal generator, and this radically transforms its performance.

The trackball is the device of choice for many pc users – they simply like the feel of it. The hand only needs to move a little to operate it. Trackballs certainly need less space, so they can be moved into the centre in front of the keyboard, which as you see later is desirable from an ergonomic point of view.

Unlike a mouse, a trackball cannot annoyingly run off the edge of the pad. And you can use it on your lap if you want. But if you are used to using a mouse and have never experienced a trackball, my advice is to try one out before buying. The feel and technique is certainly different.

The enemy of the trackball until now has been dirt, not picked up from the mat but from the fingers. Recently, some remarkable technology has been applied to it that overcomes the contamination problem, and this system is described in detail in the review.

Trackballs plug into the PS/2 mouse port or COM1 so there are usually no IRQ conflicts.

Of mice and digits

At first glance, digital mice look exactly like ordinary mice, but if you turn one over you will discover that there's no ball. If fact, there is very little to see on the under surface as a digital mouse has no moving parts, thus escaping from the mechanical-optical mouse's defects. Digital mice have been around for some time but as they have been rather expensive compared to the conventional mouse, they have never really caught on.

If you use a variety of applications as well as pcb CAD or simulators then a digital mouse may be the best compromise. If you already use a mouse, you don't have to learn a new technique, as you are obliged to with tablets and trackballs.

The digital mouse is a direct replacement for the mechanical-optical mouse. Just like an ordinary mouse, it plugs into the COM1 or PS/2 port, making it the easiest of devices to install. The digital mouse reviewed doesn't even have a separate driver. It uses the standard Microsoft mouse software, so there is no installation process.

Accordingly, this mouse can be used in Dos as well as Windows, so if you are holding onto a favourite Dos pcb CAD or simulator program you can continue to take advantage of it.

The digital mouse is so called because it generates the digital signal directly from the mouse mat instead of through an analogue rubber ball and interrupter spindles. These mice have a special gridded pad to slide on instead of a mouse mat, and typically this grid is illuminated by leds and focussed via a lens/mirror system onto a CCD.

As you may imagine, this system is rather prone to accidental damage – dropping the mouse usually ended its life. However, a new generation of these mice uses fibre optics instead of lenses or mirrors. It is not only cheaper but is said to be more robust. If you opt for a digital mouse, this is the type to look for.

Choosing a digitiser

Although this review is oriented towards pcb CAD and simulators, your choice of digitiser – whether a tablet, trackball or a digital mouse – should be influenced by what other functions you might use the pc for, both now and in the future. This a field where some compromises may be required.

If you intend to buy a digital camera, for example, and want to edit shots on-screen – removing red-eye is a good instance – a tablet and pen may be preferred over a mouse. If you have an artistic bent and use a painting pro-

Review 1 – Tabby 2

From Micrograf, *Tabby 2* measures 166mm by 176mm overall and weighs 250g. The active area is 125mm by 132mm with a resolution of 2048 by 2048. In size, it occupies a half way position between the small Genius *EasyPen* already reviewed and larger *EasyPainter*.

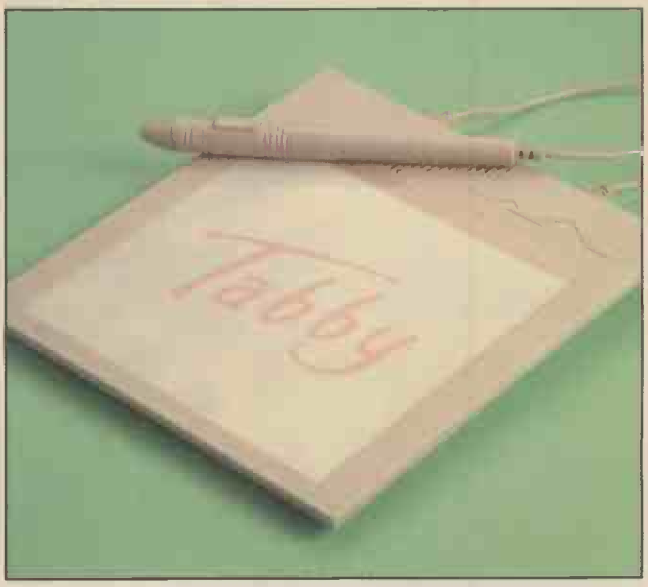
At first glance, construction seems similar, but there are some differences. At 12.5mm diameter the pen is slightly thicker and instead of being cabled directly to the tablet, it is attached via a 6-pin connector. The cable connection to the pc is made via a similar connector.

But the main difference between the Genius and Micrograf designs is that the *Tabby 2* pen has no switch in the tip. Both left and right mouse buttons are activated by a single rocker switch on the pen.

Which side the switch is rocked to give left and right clicks is set in the configuration software. The switch needs a small but positive amount of pressure to operate it and I found it was easy to use. Although the surface of the tablet seemed smooth and slippery, there was sufficient friction between tablet and pen to keep position while clicking.

The pen is capacitively coupled to the tablet, and I discovered that I needed to keep my hand away from the tip of the pen to avoid jittering of the screen pointer. Similarly, I found it best to keep my hand off the tablet surface.

The range of the pen was about 10mm. A pen holder is provided. This is a self-adhesive type that can be fixed to the tablet or anywhere



Tabby 2 – well constructed, pleasant to use and fair value for money.

gram, a tablet may again be preferable, but perhaps one responding to pressure would be best.

These tablets are similar in operation to those already discussed, but, typically, have a pen with a pressure sensor in the tip. This makes it possible to create thicker lines by applying more pressure.

If you are keen on the Internet then a tablet can make programs like Microsoft's *NetMeeting* come to life. Here, the tablet can be used with the electronic white-board. Instead of having to type messages, they can be hand-written, with sketches freely added in a natural way that cannot be achieved with a mouse. To illustrate this, try signing your name with a mouse or trackball then with a pen.

Survey results have shown that users provided with both mouse and tablet prefer the tablet for graphics work, but choose the mouse or a trackball for general-purpose pc use. You could of course use both.

Of mice and men

Few pc users will not know about 'repetitive strain injury' arising from the keyboard. But what about mouse strain?

Most people who use a mouse put it to one side of the keyboard. Are you one of these? If you are, then you are probably damaging your neck, shoulder and back muscles without even realising it; until it's too late, that is, **Fig.** 2.

Research from the USA shows that the majority of regular users of a pc, or those who use it for long periods at a stretch – as is often the case with pcb CAD and simulators – can expect trouble.

With a standard keyboard, using the mouse to one side apparently puts the human arm too far away to avoid damage to these muscles. The longer the keyboard, the worse the effect. It does not take much imagination to realise that a digitising tablet or trackball could produce the same effects if used in this position.

According to Dr E. Peper, of California State University, who wrote an article on this subject in the journal *Ergonomics*, even the effort of muscles being held tense at a mere 18% of maximum effort reduces blood flow through the tissue by 80%. Medically speaking, it seems that this is not good news for many pc users.

The tight muscles can also pinch nerves causing pain in wrists and hands. Peper has discovered that people's muscles start to tense up within a minute of sitting at the pc and that they may be unaware of what is going on.

One possible cure suggested by Peper is to bring the input device into the centre, in front of the keyboard, or if this is not possible then at least closer in to the body. A short keyboard – one without the numeric pad – or a split keyboard could be answer but both of these are much more expensive than the standard keyboard. And people may be reluctant to pay out even if there is a possibility of harm.

With a standard keyboard, bringing a cabled mouse into the centre can cause problems with the cable. Putting the cable to one side or underneath the keyboard restricts mouse movement too much, and it can hardly run over the top of the keys.

I have tried raising the keyboard by 1cm on pads so that the cable runs freely underneath, and this works well. You might think this raises the keyboard too much, but with a wrist-pad this can be adjusted out. With a split keyboard, the cable can run in between.

The cable problem does not exist if you use a tablet or trackball as the cable does not need to move and so can go underneath the keyboard.

The least stressful position seems to be when both hands are in your lap. This does not preclude doing useful work! It's a viable position for using a small tablet, such as the Genius *EasyPen*, and some people like to operate a trackball this way. Mouse pads that rest on the lap or leg have now appeared and recently, a pad that clips onto the upper leg was demonstrated on 'Tomorrow's World'.

Any of these solutions is preferable to the position where the mouse, tablet or trackball is to one side of the keyboard, but unfortunately, this is still the most frequently used set-up. Dr Peper's research seems well founded, so the designers of the standard keyboard have much to answer for. ■

out of range of the tablet.

In use, there is slight delay between the movement of the pen and its corresponding screen pointer displacement. The pc used for the tests is a 133MHz Pentium. This did not hinder operations and after a while I became used to it. On faster machines, this effect should be imperceptible.

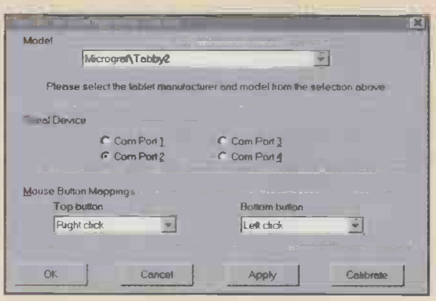
Drivers for the tablet come on a single 3.5in disk. This caters for Windows 95, 98 and NT. No Windows 3.1 driver was sent for review.

Installation of the software was simple. Both mouse and tablet ran together with the mouse on COM1 and tablet on COM2. Setting up was also easy. The software offers just the ability to turn the driver on and off, set left/right buttons, the active area, and choose a COM port.

When I tried to set up the active area for my 1024 by 768 monitor, the tablet area could not be extended beyond 100mm by 110mm. This is presumably because of a restriction imposed by this particular screen resolution.

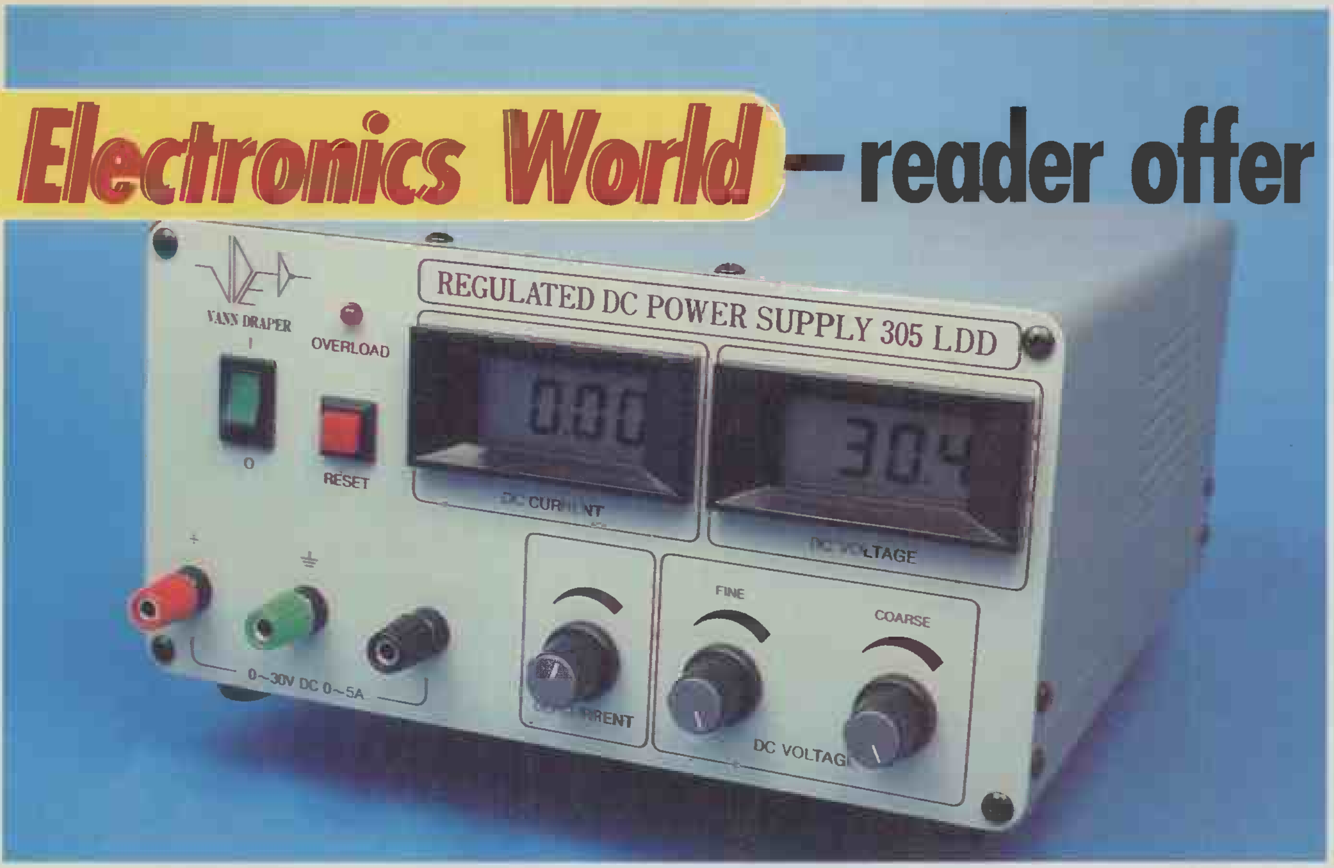
In summary, the *Tabby* is well constructed and the friction between tablet and pen is about right. Overall, I found the *Tabby 2* and its rocker-switch pen pleasant to use. It is fair value for money at £49.95 all inclusive.

Supplier; Micrograf International Ltd, tel 0181 838 3750, fax 0181 838 3650.



Tabby 2's software offers just the ability to turn the driver on and off, set left/right buttons, the active area, and choose a COM port.

Electronics World – reader offer



30V, 5A bench power supply with dual displays – 25% discount

For a limited period, Vann Draper is offering over 25% discount on the 305 LDD – a bench power supply featuring digital display of both voltage and current. Normally, the 305 retails at £186.82 including VAT but it is available to *Electronics World* readers filling in the adjacent coupon at the 25% discount price of £139 – fully inclusive of VAT *and* delivery.

Infinitely variable between 0 and 30V – with coarse and fine controls – and adjustable between 0 and 5A, the 305 LDD has a ripple figure of typically 10mV. Its load regulation is also excellent, at typically ±0.2%.

Accuracy of the supply's dual 3.5-digit liquid crystal displays is 0.1 decimal digit. The output can handle a continuous short-circuit, overloading at 5.5A ±0.5A. When the overload circuit is activated, it causes both audible and visual alarms, resettable via a push-button on the front panel.

Dimensions of the 305 LDD are 310 by 260 by 120mm and its weight is 5.5kg. Housed in a light-grey steel enclosure, the unit is built to comply with UL, CSA and TUV safety standards.

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Hands-on Internet

Maths on waves. Cyril Bateman looks at circuits for multiplying and dividing signals, and outlines two novel uses for low-cost digital panel meters.

Like most designers, I often need to perform mathematical functions on two or more voltages. While addition and subtraction are straight forward, multiplication, division, raising to powers and calculating roots, are not.

Many dedicated 'multiplier/divider' integrated circuits are available. We also have an abundance of microprocessors able to perform such tasks, but allowing for software development, is this approach always cost effective?

I was recently presented with the need to economically display the result of dividing two slowly changing, relatively small, direct voltages. Recalling the once popular log/antilog mathematical circuits described in the 'Non-linear circuits handbook', published in 1974 by Analog Devices,[4] I decided to use the Internet to investigate this type of circuit and to investigate other options.

When calculation speed is essential, a linearised transconductance multiplier/divider integrated circuit based on the Gilbert Cell is usually the chosen method.[5] Based essentially on two cross-coupled differential pairs of transistors, these circuits are able to multiply or divide in all four quadrants, **Fig. 1**.

Such circuits can be configured to multiply or divide two signals, or to calculate the square or square root of a signal. Accuracy can be excellent unless signal amplitude is too small. When the amplitude is too small, the result is affected by offset voltages which limit the dynamic range.

The log/antilog methods can perform the same mathematical functions for low-frequency or dc signals. When small signals are involved, this method offers the best accuracy over a dynamic range of 5 to 6 decades.

For those of you unfamiliar with this technique, using the logarithmic voltage/current response of a diode in the feedback path of an op-amp provides a voltage output that corresponds to the logarithm of the voltage input. Accuracy can be improved by using either a diode connected transistor, or a trans-diode arrangement in which the transistor base is earthed.

This simple arrangement is temperature sensitive. As described in the 'Non-linear circuits handbook' mentioned earlier, its scale factor changes by around 0.33% per °C near room temperature.[4]

A second matched transistor can be arranged to compensate for change of reference current with changing ambient temperature. A positive temperature coefficient feedback resistor on the output amplifier completes the room temperature

A free operating system

As the release date for *Windows 2000* – previously known as *NT5* – slips towards the third quarter this year, *Linux 2.2* has already been released.[1] Both are multiprocessor-capable systems, but Linux will still run well using a single '386' or '486' processor with only 4Mbyte of memory.

In the past year, due to its reputation as a system not prone to crashes, *Linux* has started to become popular for running servers in addition to its existing use in desk-top computers.

Uniquely, *Linux* is free, and is supplied with source code. This allows you to tailor the operating system precisely to your needs, then re-compile it for installation and use.

Linux was invented by Linus Torvalds and remains under his control, but it is the contributed work of countless unpaid programmers. A choice of Windows-like graphical user interfaces are available for it, including the popular UNIX 'X-Windows' and 'Xfree86'.

Linux can be downloaded from the Internet, but most people prefer to buy it, together with many applications, on a low cost cd rom. The operating system is free. You pay only for the materials and distribution costs.

Under its free software 'GNU' licence, users are encouraged to add further program modules, which must then be offered to other Linux users.

In common with its free software approach, much of its application software is also free and can be downloaded from Internet or bought at nominal cost on cd.

Many of Linux's contributors are University programmers and a wide choice of Linux utilities and conventional 'office' applications are available free. Even Berkeley *Spice 3f4* can be downloaded free of charge.[2]

Interested in a free operating system? Visit this site to check out Linux's hardware and software compatibility.

Searching for application notes

Marshall Industries, one of the largest component distributors, hosts the Electronic Design Center site.[3] This is a free service focusing on the design and information needs of the engineering community, together with on-line ordering. This well organised site allows you to download data sheets, application notes and software from its well stocked library. It also provides on-line laboratories, selection guides and industry news, with links to related product and technology information.

Try out the description search provided by this, the fourth largest component distributor's site.

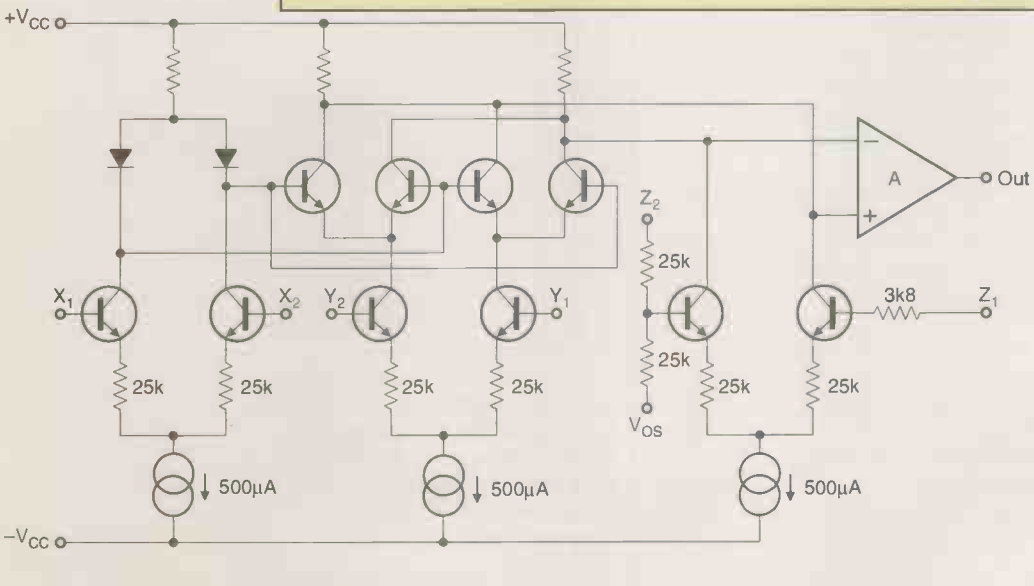


Fig. 1. Simplified diagram of the calculation cell used in Burr-Brown's MPY100 multiplier/divider.

compensations.

A similar diode arrangement connected in series between the input signal and the input of another op-amp generates the anti-logarithm of its input voltage, **Fig. 2**.

Adding logs

Multiplication of two voltages requires only the addition of the two logarithms followed by the anti-logarithm function on this sum. Similarly, division of two voltages can be performed by subtracting the logarithm of the divisor from that of the numerator, followed by taking the anti-logarithm of this difference.

Obviously the above techniques can as easily calculate the square or square root of any voltage by first doubling or halving the logarithm voltage, before deducing the anti-logarithm. By multiplying or dividing the logarithm by the appropriate number, any power or root can be calculated.

These procedures exactly replicate using the old fashioned books of log/antilog tables or the A to D scales of a slide rule – essential tools before pocket calculators became common.

The dynamic range of such log/antilog circuits can be exceptional. Five or even six decades of log current linearity can be attained without trimming.[6]

Described as a 'one-chip slide rule', Analog Devices' *AD538* integrated circuit offers a 1000 to 1 dynamic range and a 400kHz small signal bandwidth.[4] This versatile 'real-time analogue computational unit' on a chip as they call it tackles one-quadrant multiplication and one and two-quadrant division. It also calculates powers and roots of ratios. Like all analogue computers, it runs in real time, so can be used to linearise transducer signals.

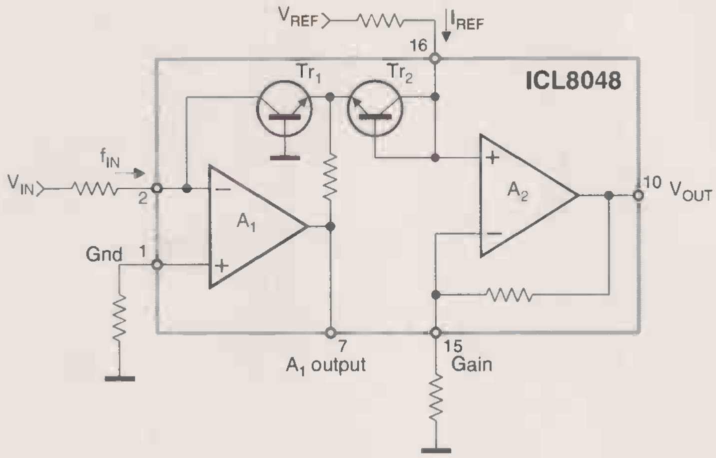
This integrated circuit provides two log input circuits connected to a difference amplifier to form a log ratio circuit. Also on chip is a dedicated antilog converter, a current-to-voltage converter output buffer and two reference voltage generators which can be used to set multiplication and division scaling factors, **Fig. 3**.

While these log/antilog circuits could easily satisfy my needs, I really needed a simpler, cheaper method.

Novel uses for a digital panel meter

I already had a 3.5 digit pre-packaged liquid crystal display, based on the *7106* integrated digital voltmeter chip, as recently offered in *Electronics World* as the *PM-128*. Many years ago, to measure light absorbance of various materials, I had modified a *7107* application circuit to display the logarithmic ratio of two voltages. The *'07* is a version of the *'06* with led rather than lcd drivers by the way. Could a similar re-arrangement work this time?

The *7106* dvm chip has several makers so I downloaded fresh data from Telcom Semiconductors,[7] Harris[8] and Maxim[9] to find out. Two of these data sheets included a circuit to measure the ratiometric values of a quad load cell. This made me consider how best I could use the differential input and differential reference voltage facilities for my needs, **Fig. 4**.



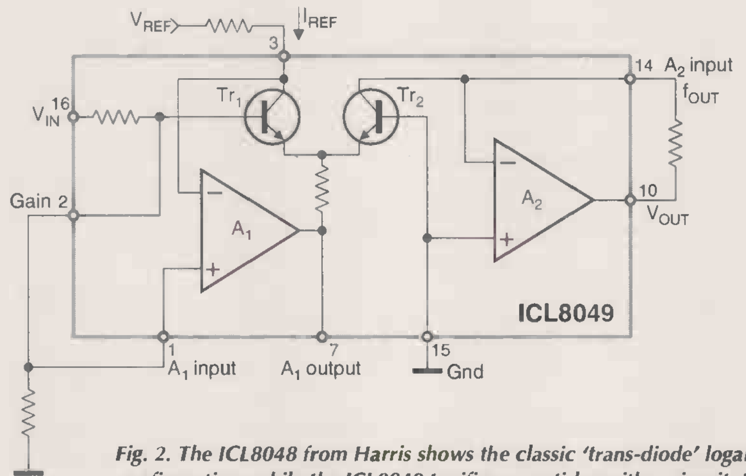


Fig. 2. The ICL8048 from Harris shows the classic 'trans-diode' logarithmic converter configuration, while the ICL8049 typifies an anti-logarithm circuit. Both offer 60dB of voltage range while the ICL8049 claims a 120dB dynamic current range.

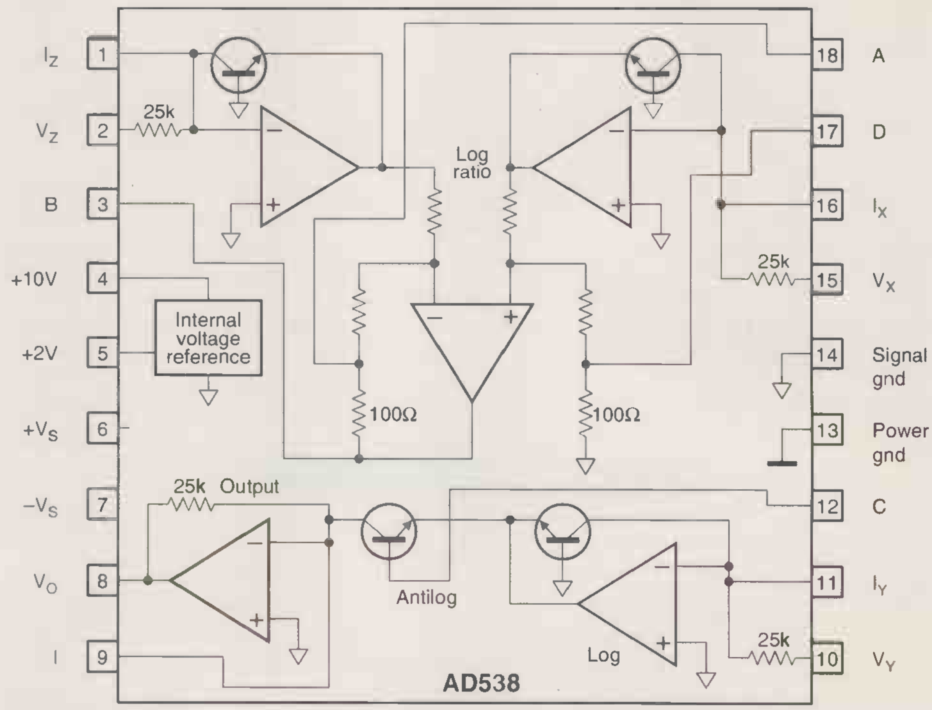


Fig. 3. All the required logarithm and anti-logarithm circuits are packaged together in Analog Devices' unique 'One-chip slide rule'. This versatile analogue computer performs your transducer corrections in real time.

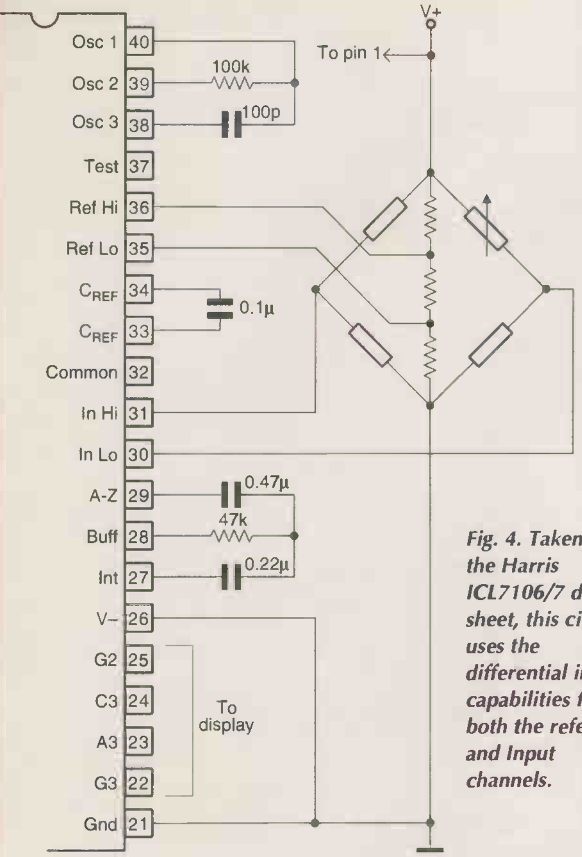


Fig. 4. Taken from the Harris ICL7106/7 data sheet, this circuit uses the differential input capabilities for both the reference and Input channels.

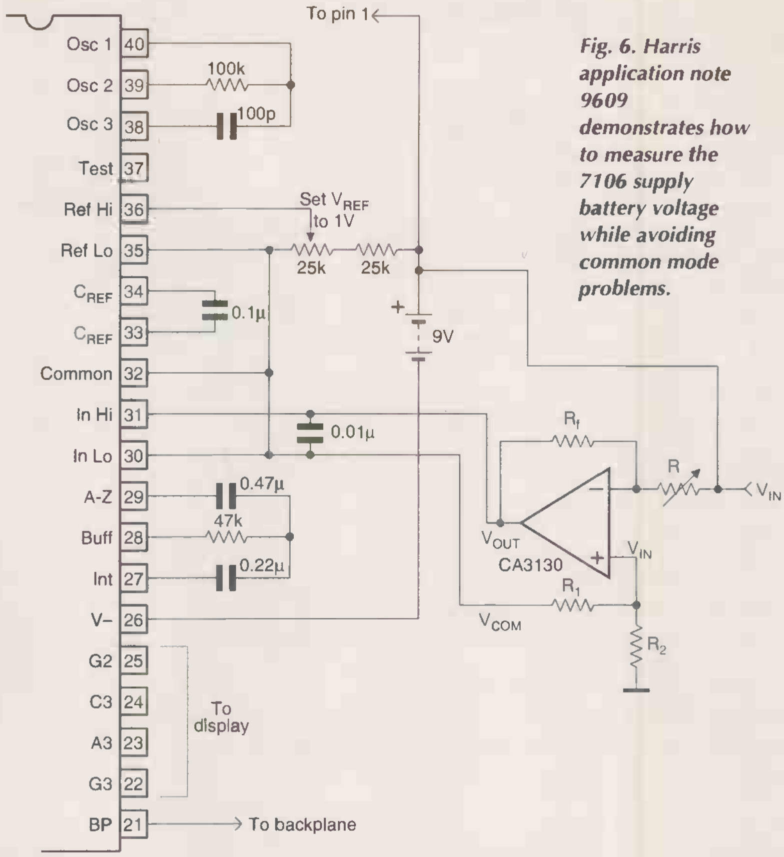


Fig. 6. Harris application note 9609 demonstrates how to measure the 7106 supply battery voltage while avoiding common mode problems.

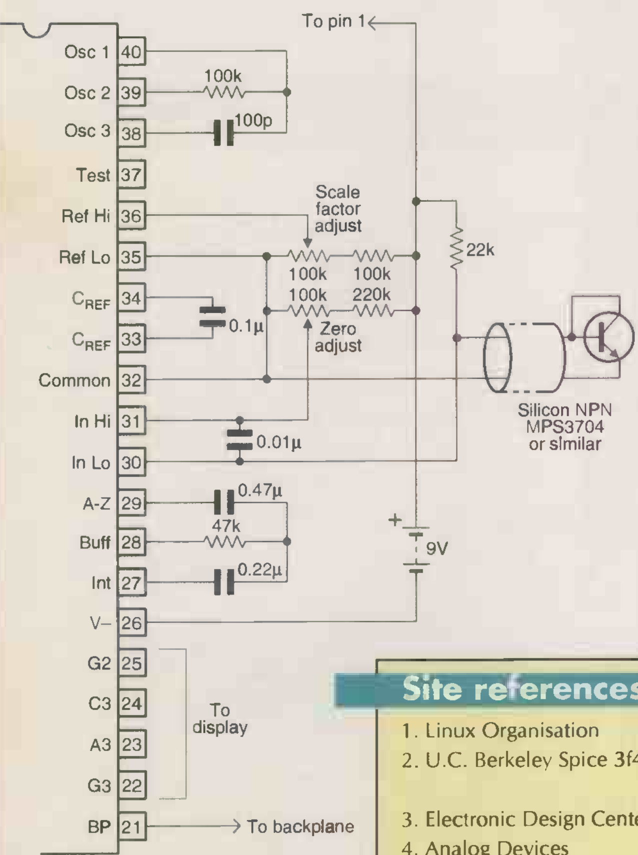


Fig. 5. Possibly the simplest ever celsius thermometer, easily built and calibrated.

Supplied to measure voltages, my *PM-128* digital panel meter's voltage inputs were connected to IN-Hi and IN-Lo, with the on-board reference voltage going to REF-Hi, as usual. The reference voltage is set to one half the displayed full-range input.

The display output reads 1000 when the input voltage equals the reference voltage. In other words the chip displays the ratio of the input voltage divided by the reference voltage. Ohm meter checks confirmed that REF-Lo, IN-Lo and Common of my display formed a common ground.

Removing resistors R_2 and R_3 to free up the REF-Hi input terminals, I applied an adjustable voltage to this point and a second adjustable voltage to IN-Hi, while monitoring these voltages using a dvm. The *PM-128* provided an accurate display of the ratio of these voltages, satisfying my immediate need at no additional cost.

The only disadvantage was the necessity to float the *PM-128* circuit's 9V supply using a battery.

I expect this arrangement is not unique, but I did not find a similar one in my Internet or data sheet research.

My interest now aroused, I sought other interesting applications for this versatile dvm chip. Two in particular looked most useful. First is the digital thermometer circuit in Telcom's datasheet.[7] This needs only three fixed resistors, one potentiometer and a diode connected n-p-n transistor, to convert my *PM-128* module into a simple but accurate thermometer, **Fig. 5**.

Secondly, application note 9609 from Harris Semiconductor discusses common-mode issues with suggested solutions.[8] Using an inverting op-amp, this note shows how a battery operated *7106* can be arranged to monitor its own battery voltage, **Fig. 6**. ■

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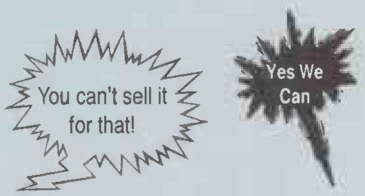

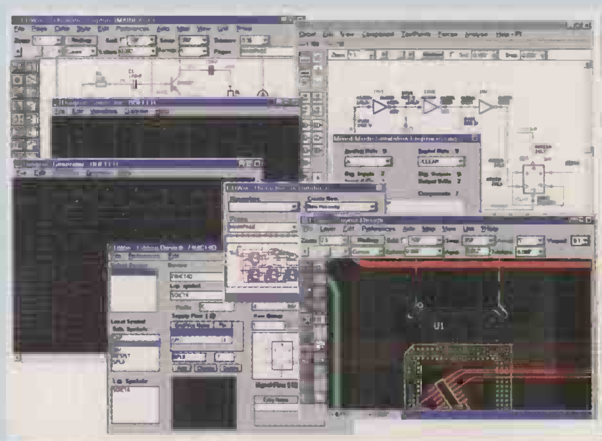

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333

Electronics World Cover CD

Technical data on *all* products from Finder –
the largest manufacturer of European-made general-purpose relays

Installing the catalogue CD

The minimum requirements for running the CD are a 33MHz 486 PC with 8Mbyte RAM, 12Mbyte free disk space, a VGA monitor, Windows 3.xx and a mouse.

To install the catalogue, insert the CD and run the file install.exe from the root directory of the CD rom. You can run this file from by double clicking on its entry in file manager or similar program, or you can type d:\install.exe at the 'run' command, where d is the drive letter of your CD rom drive.

From here, click on the Finder icon and follow the installation instructions. Once the CD rom has been installed, double click on the Finder icon to run the catalogue.

This month's cover mount CD rom* is the newly updated technical catalogue from Finder – a company currently producing around 150 000 relays and timers a day.

New on the 1999 CD

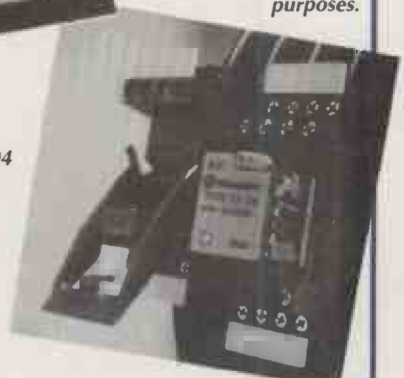
Among the new product innovations on this CD are the 34 series ultra-slim PCB relay and the 41 series low-profile PCB relay.

Two interface modules make existing relay series easier to specify, implement and maintain while the 87 Series Timer offers monofunction and multifunctions available in 10 time scales from 0.5s to 60h. Functions include on delay, true off delay and star delta. Multi voltage ranges: 24-48VDC, 24-240VAC.

In addition, there are a number of new socket options, socket timer modules and supply status indication and coil protection modules for the 94.02, 94.04, 95.03 and 95.05 sockets

The new 87 Series Timer switches up to 8 amps and is multifunctional with time scales up to 60 hours.

The new feature on the Finder 55 Series, a lockable pushbutton allows the relay state to be determined for commissioning purposes.



The 58 Series interface modules utilising the new 9404 socket enhances the relay by allowing easy connection, easy wiring identification and optional diode, varistor and status led connection.

For more information, fax Finder UK on 01785 815500 or phone 01785 818100.

* UK readers only.

NEW PRODUCTS CLASSIFIED

Please quote *"Electronics World"* when seeking further information

PASSIVE AND ACTIVE COMPONENTS

Discrete active devices

Power mosfets. Having drain/source voltages up to 800V and typical on resistances down to 0.08Ω, the TO-220FN *2SK* range of power mosfets is meant for high-speed switching duty in motor drives and switched-mode power supplies, ups systems and lighting ballast. The *2SK2740*, for example, is a 600V, 7A type having a typical $R_{DS(on)}$ of 1Ω and designed for use in high-voltage power supplies and crt drives. These are silicon n-channel devices with current capability of 2A-16A, all having been designed with a wide safe operating area. Power dissipations are 20W or 30W and all will handle a ±30V gate-source voltage.
Rohm Electronics UK Ltd. Tel., 01908 282666; fax, 01908 282528; web, www.rohm.co.jp.
Enq no. 501

High power in SOT323. The *Super323* series of 1.5A, 500mW transistors by Zetex are packaged in the small SOT323 package, the range being based on an improved matrix geometry, the Super-b emitter process and a new lead frame. There are n-p-n and p-n-p complementary types with $V_{CE(sat)}$ down to 0.2V at 1A. As an example, the *ZUMT617* n-p-n type has an h_{FE} of 75 with a 5A current pulse. Collector-emitter ratings for the series lie between 12V and 50V.
Zetex plc. Tel., 0161 622 4422; fax, 0161 622 4420; web, www.zetex.com.
Enq no. 502

Displays

Two-level leds. DIN 41494-compatible, 2mm, bi-level board-mounted leds by Dialight snap into arrays or are available without pins to act as stand-alone or end-of row units. Colours include red/red, red/green, green/green, yellow/green and yellow/yellow, as well as custom combinations and arrays. Intensity at 10mA is between 12.6mCd and 8.7mCd and forward voltage at 20mA 2V-2.1V. Viewing angle is 38°.
Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095; e-mail, gothic@gcrellon.co.uk.
Enq no. 503

Hardware

PCI system subrack. Schroff has a new range of PCI system subracks from 3U to 6U that contain all the main components such as power supplies, backplanes, drive units, and guide rails. Shielded and unshielded versions are available, assembled and wired, if required. A ten-layer backplane with connectors for power supplies is incorporated and there are stiffening rails to give the extra stability needed for PCI system backplanes. Rear and front access to units is possible and plug-in units may also be mounted horizontally; shielded drives may be placed in a number of locations. Thermal management takes the form of a 1U axial fan at the bottom.
Schroff UK Ltd. Tel., 01442 240471; fax, 01442 213508.
Enq no. 504

Controllable fans. Sunon has introduced open-collector fans in its range of 40 by 40 by 10mm and 50 by 50 by 10mm dc-powered types, the open-collector design by providing a low starting voltage of 4.5V dc and lower power consumption. Since the fans are dc-powered by a new type of motor, speed is proportional to voltage. This means the speed and therefore airflow may be controlled by reference to the ambient temperature to give less noise, lower power consumption and longer life.
Thermaco Ltd. Tel., 01684 566163; fax, 01684 892356; e-mail, thermaco@compuserve.com
Enq no. 505

Enclosures. Rittal *CR Series* 19in enclosures from Minitran are floor standing or wall-mounted types with lockable 4mm safety-glass doors that have steel surround and quick-release hinges. The basic frame is of 1.2mm sheet steel and the units come in sizes 27 to 47U. All panels are removable and the corner panels may be use to house the cables. All are available in any combination of 600mm and 800mm overall width and depth and there is a range of accessories such as wire management panels and brackets, vented and adjustable shelves, telescopic shelf slides, fan mounts and mains socket strips. The *VR Vario Rack*, with enhanced appearance, is also available.
Minitran. Tel. and fax, 01279 757775.
Enq no. 506

Linear integrated circuits

Track-and-hold amplifier. Having a sampling rate of 100Msample/s and a power consumption of only 75mW (single-ended), the *SPT9110* from Signal Processing Technologies enhances the dynamic performance of a-to-d converters in high-resolution radar receivers, direct if down-conversion and other applications. Input range is 1.5-3.5V. There is an inverting amplifier with a gain of –1

and a 2.5V bandgap reference; the device works from a 5V rail. Operational modes are single-ended and full differential. Sampling bandwidth is 400MHz, track slew rate is 700V/ms and hold-mode distortion is –66dB at a 50Msample/s rate at 25MHz input.
Signal Processing Technology. Tel., 01932 254904; fax, 01932 254903; e-mail, spt@intonet.co.uk.
Enq no. 507

Memory

SuperFlash eeproms. Eeproms in a new family from Silicon Storage Technology use the company's *SuperFlash* technique, a cmos-compatible process conferring lower costs of manufacture. First available are the *SST39SF020*, which is a 2Mb, 256K by 8 device and the 4Mb, 512K-by-8 *SST39VF040*, both in the *Multi Purpose Flash 39 Series*. A different programming scheme that eliminates page buffers to support page write renders the devices useful for applications needing low-cost general-purpose flash memory where small sector size and page write are not necessary. Voltage needed is 5V for the *39Fxxx* types and 2.7V for the *39VFxxx* devices, access times being 70ns for the *39SF020* and 90ns for the *39VF040*.
Silicon Storage Technology Ltd. Tel., 01932 221212; fax, 01932 230565; e-mail, rsawer@ssti.com; web, www.ssti.com.
Enq no. 508

Microprocessors and controllers

16-bit microcontroller. Hitachi has a low-voltage, i.e. 3V, version of its *H8S* range of controllers, the *H8S/2237*, which is also a low-power, low-radiation type, being designed for use in portable, battery-powered equipment such as mobile telephones. The device runs at 10MHz. Battery life is extended by the use of standby modes of operation controlled by a second watchdog timer running at 32kHz. There is a

Arrays

Miniature transistor array. With two transistors and three bias resistors in a single package, Rohm's *IMD10A* and *IMD16A* digital transistor arrays are meant for use in power management and regulators. Each array has an n-p-n and a p-n-p transistor, the circuit being housed in an SOT23 package. The arrays simplify design and reduce component count in voltage generation and regulation at currents up to 500mA.
Rohm Electronics UK Ltd. Tel., 01908 282666; fax, 01908 282528; web, www.rohm.co.jp.
Enq no. 509

16-bit cpu that delivers 10Mips at 10MHz for single-cycle execution of basic instructions and 128Kbyte of otp or mask rom with 16Kbyte of fast dram. A flash version is promised for later in the year. Peripherals include a timer with six channels of 16-bit timers and 16 input-capture/ output-compare units, analogue-to-digital and d-to-a conversion, four serial channels and the company's Data Transfer Controller.
Hitachi Europe Ltd. Tel., 01628 585163; fax, 01628 585160; web, www.hitachi-eu.com.
Enq no. 510

Mixed-signal ics

10-220MHz frequency synthesizers. A family of synthesizer ics, the *Model M2110-M2230* devices by MF Electronics, develop software-programmable frequencies in the 10-220MHz range to within 1 in 4×10^{10} resolution. Output frequencies are phase locked to a built-in crystal-stabilised reference or to external signals including fm and swept frequency inputs. Rapid change of frequency in response to an external reference renders the synthesizers suitable for testing

Please quote *"Electronics World"* when seeking further information

frequency-agile communications equipment and the ability to use a swept input as reference allows their use in the detection of resonances . Windows software is supplied with the ics, the pc then being able to calculate and store the control inputs to achieve any frequency.
Mega Electronics Ltd. Tel., 01223 893900; fax, 01223 893894; e-mail, sales@megaelect.demon.co.uk; web, www/megaelect.demon.co.uk.
Enq no. 511

DVD on a chip. *Pantera-DVD* is claimed by Mediamatics to be the first Ic to contain the back end of the DVD processing functions, including host functions. There is also a manufacturing kit with complete system software. Functions so integrated include data stream processing, CSS decoding, MPEG video decoding, and one or more cpus for control. Processing functions are carried out by a Mediamatics 32-bit risc processor, audio risc dsp, hardware for MPEG, 10-bit video d-to-as and a graphics and NTSC/PAL encoder.
National Semiconductor. Tel., 0049 0180 5327832; fax, 0049 0180 5308586; e-mail europe.support@nsc.co; web, www.harvard.co.uk.
Enq no. 512

Passive components

Snubber capacitors. Power Products produces a range of snubber capacitors for insulated-gate bipolar transistors that have 5μm aluminium foil electrodes to produce less than 10nH inductance. Impregnated polypropylene film construction isolates the foil, eliminates corona and assists in size reduction. The capacitors are rated at up to 2kV dc or 750V ac and come in values to 3μF.
Power Products International. Tel., 01732 866424; fax, 01732 866399.
Enq no. 513

Motors and drivers

Ministepper indexer drive. *PDFX* from Parker Hannifin is a combination of ministepping drive unit, intelligent switched-mode power supply and an indexer. The indexer was developed with the intention to reduce programming time and cost and uses an event-driven motion-control language, in which a program to make alternative moves in response to two independent events needs only 10 commands. The package is available with 2.5A or 5A power stages and may be used with all two-phase stepper motors up to frame size 34, the drive producing up to 3Nm. There is also a choice of output resolution from 200steps/rev to 4000steps/rev. *Parker Hannifin plc, Digiplan Division. Tel., 01202 699000; fax, 01202 695750; e-mail, sales@digiplan.com; web, www.parker-emd.com.*
Enq no. 514

Optical devices

Electro-optical converters. Harting has a range of converters in the form of transmitter/receiver modules for board mounting. They are meant for use with 1mm polymer optical fibre when isolation between input and output In industrial applications is required. Metal FH-ST, F-SMA and Quick-Fit receptacles allow transmitter or receiver integration at board level and the converters may be integrated into DIN41612, D-Sub and F-TNC connectors. In a D-Sub connector shell, the converter provides a way of making an optical-fibre data link for a path of up to 60m at 660nm wavelength.
Harting Elektronik Ltd. Tel., 01604 766686; fax, 01604 706777; web, www.harting.com.
Enq no. 515

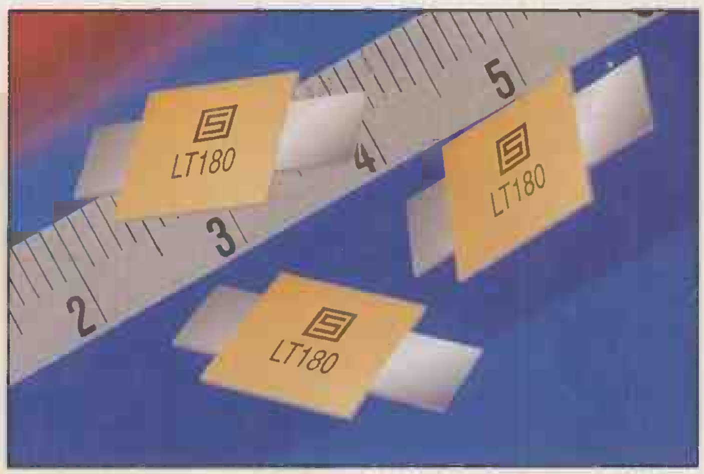
Oscillators

Stable, surface-mount oxco. Capable of improving on the Stratum IIIE holdover stability requirement, the *CFPO-11* series oven-controlled crystal oscillators from C-MAC are meant for use in GSM and other base stations and in fixed-line SDH/SONET switching. This is a true surface-mounted device in a case measuring 25 by 22 by 14mm and provides stability to within ±5 in 10^9 over the –10°C to 70°C temperature range, improved stability being available to order. Frequencies between 8.192MHz and 13MHz are offered in the series. The oven heats rapidly, reaching operating temperature within five minutes, consuming under 5W during warm-up and less than 1W when steady. Power rails are 5V, 9V, or 12V.
C-MAC Quartz Crystals Ltd. Tel., 01460 74433; fax, 01460 72578; e-mail cfp@europe.cfpwww.com; web, www.cfpwww.com.
Enq no. 516

Passive components

Tantalum chips. Capacitors in Siemens' new *B45* range of polar tantalum chip electrolytic devices have a height of only 2mm in the Case V. They are claimed to have the lowest ever profile. The chips are designed to work at more than 300kHz and possess good frequency characteristics and low inductance, in addition to good temperature stability. There is also a 150-400mW type.
Siemens plc. Tel., 0990 550500; fax, 01344 396721.
Enq no.518

Wire mesh emi gasket. Chomerics has introduced a new highly resilient wire mesh emi gasket, *SPRINGMESH*, offering the resilience typically associated with wire mesh over elastomer core, but without the bulk or expense of a core. This new wire knitting technique results in a gasket capable of being compressed to over 80%, with remarkable recovery. Gaskets are constructed of 0.004in tin-plated-steel wire formed into a hollow cylinder and are available in single or double layer form, with the double layer construction providing optimum emi shielding and compression-deflection performance. Compression set is less than 30% when deflected up to 80% of its original size. The gaskets have a round cross section and are intended to be installed in grooves.
Parker Hannifin plc, Chomerics Division. Tel., 01628 486030; fax, 01628 476303.
Enq no. 519



Protection devices

Ptc fuse. Schurter's *PFLT* positive temperature coefficient fuse, one of a range of resettable types, is a strap-leaded, conductive-polymer-based device with a lower trip temperature of 100°C for faster action. It comes in ratings from 1A to 3.4A with interrupt ratings of 100A and 24V.
Schurter AG. Tel., 0041 413693111; fax., 0041 413693333; e-mail, contact@schurter.ch; web, www.schurter.ch.
Enq no. 517

Switches and relay

High-power relay stays cool. While capable of handling a current of 100A, Teledyne's *HETP Series* of three-phase, solid-state relays is not only made using the company's fused copper process to enhance heat dissipation, but also has a thermal cut-off mechanism. This mechanism operates in case of a fan failure. Additional features include a 1.6kV voltage rating, a status led, ac or dc input and optical isolation between control inputs and outputs.
Teledyne. Fax, 01634 863494.
Enq no. 520

EQUIPMENT

Audio products

Tapeless recorder. Panasonic's *RR-DR60 IC* memory recorder is a hand-held device for the recording of memos and meetings. It uses no tape, but stores input in flash dram after compression, being capable of storing up to 99 files to a total of 60 minutes recording time. Each file is automatically given a time stamp to provide rapid access with no need for rewind of fast forward. There is an lcd to indicate recording dates and times, battery status and remaining recording time. A voice-activated start function is included, as is a scan feature to play the first seconds of all files in sequence for identification. Slow and fast playback of ±50% is possible, since the recording process is digital and the flash memory holds data when the battery dies.
Panasonic UK Ltd. Tel., 0500 404041; web, www.panasonic.co.uk.
Enq no. 521

20-bit audio codec. *AK4526* by AKM is a 20-bit multi-channel codec with a dynamic range of 100dB for use in digital surround sound and car systems. Inputs accepted include IIS and there are two channels of a-to-d conversion with a wide dynamic range and 64 times oversampling. There are also six of d-to-a conversion using a switched-capacitor filter to provide low noise and tolerance to jitter. Each has 128 times oversampling and individual attenuation control from zero to –20dB in 1dB steps. Master clock required is 256, 384 or 512f_s and the device provides de-emphasis for 33, 44.1, 48 and 96kHz.
Asahi Kasei Microsystems Co., Ltd. Tel., 01923 226988; fax, 01923 226933 .**Enq no. 522**

Please quote *"Electronics World"* when seeking further information

Production equipment

Protection against static. An air ionisation system by Meech Static Eliminators operates at a distance of 600mm without movement of air to dissipate charges built up during manipulation of assemblies and packaging. This avoids the movement of dust and cold hands caused by conventional blowers. The Meech *Compact 977* pulsed dc system uses two separate emitters to allow the polarity ratio to be variable and the frequency to be tuned to suit the application.
Meech Exair Ltd. Tel., 01993 706700; fax, 01993 776977; web, www.meech.co.uk.
Enq no. 523

Power supplies

Low dropout regulator. From Cherry, the *CS8156* low dropout, high-current linear regulator which, among other features, has reverse battery protection, over-voltage and thermal shutdown and current limit. It also has delayed reset in which an n-p-n transistor is controlled by a low-voltage inhibit circuit and a delay. An external capacitor is only provided with charging current when the low-voltage inhibit circuit sees an output above the reset threshold. At other times, it is fully discharged. Charging time thereby imposes a delay on reset.
Electronics Ltd. Tel., 01635 298574; fax, 01635 297717 e-mail, info@clere.com; web, www.clere.com
Enq no. 524

Radio systems

Radio for MaxDaq. For users of *MaxDaq* telemetry and measurement units, Wood & Douglas has introduced narrow-band radio modules that are in all ways compatible with the *MaxDaq* products. They allow a radio link to be added to *MaxDaq* data acquisition and control equipment. These modules conform to the *MaxDaq* interface bus connectivity layout so they can be daisy-chained in any combination.
Wood and Douglas Ltd. Tel., 0118 9811444; fax, 0118 9811567; e-mail, info@woodanddouglas.co.uk; web, www.woodanddouglas.co.uk.
Enq no. 526

Dc-dc converter accessories. Two new modules by Vicor are for use with the company's second-generation 48V dc-to-dc converters. Firstly there is the *FiltMOD* filter module, which meets EN55022 B and FCC A requirements and can take up to 75V dc input or 100V for 100ms, being available in 8 and 12A versions. Secondly, the *IAM2* input attenuator to give inrush current limiting and protection against input transients and surges; this comes in 10A and 20A versions.
Vicor UK. Tel., 01276 678222; fax, 01276 681269, e-mail vicor@vicr.com; web, www.vicr.com.vicoruk@vicr.com.
Enq no. 525

Triple-output, 3W voltage converters. Newport Components' *NMT* range of dc-dc converters produce 3W and have triple outputs of –24V, –48V and –72V, the 3W being shared between outputs or taken from one, the devices being intended for use in ISDN and SLIC interfaces. Input needed is 5V or 12V and power density is 1.41W/cm^2. There is a shutdown control pin for reduced power. A toroidal winding minimises external fields. No external components are required.
Newport Components Ltd. Tel., 01908 615232; fax, 01908 617545; web, www.newport-comps.com
Enq no. 527

Test and measurement

Fast ac milliohmmeter. Hioki's *Model* 3560 ac milliohmmeter reads out at 60 measurements per second and provides comparator functions, external input for use in automatic test systems and an RS232 interface. Measurement resolution is 1μΩ on the 30mΩ most sensitive range and the top range is 3kΩ. Measurements are made at a frequency of 1kHz, open-terminal voltage being 20mV maximum with the limiter on. The instrument will also measure direct voltage. Options include a GPIB interface and a printer capable of statistical processing, histogram and graphics printing. A range of test leads, gold-plated, four-wire leads is supplied as standard.
Telonic Instruments Ltd. Tel., 01734 786911; fax, 01734 792338.
Enq no. 528

True-rms multimeter. New from Thurlby Thandar, the Tektronix *TX* range of hand-held multimeters is equipped with data storage. With this memory, data may be recalled or downloaded to a pc using the optional *WaveStar for Meters* interface package, which provides real-time data logging and documentation on Windows 95/NT platforms. They all have a large display and are said to be particularly suitable for use in maintenance work. Measurement range is between 5000 and 50000 counts, updated at four per second or one per second, maximum resolution being 10μV, 10nA and 0.01Ω. There are also capacitance ranges resolving to 1pF and a frequency range to 1MHz to a resolution of 0.001Hz.
Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409; e-mail, sales@ttinst.co.uk.
Enq no. 529

Bench digital multimeter. Grundig's *DM-100* 4.5-digit, autoranging multimeter is controlled by microprocessor to provide a wide range of features while remaining simple to operate. Functions include ac/dc volts from 200mV to 1kV to within 0.05% and with a resolution of 10mV, resistance from 220Ω to 20MΩ, resolved to 10mΩ and to within 0.05% and current from 20mA to 10A with a resolution of 10nA. Options on measurement speed and a selection of maths modes, including B reading, are presented on a menu. An RS-232 interface allows control from a pc. With optional software, and a combination of other instruments, an automatic test system can be set up.
Vann Draper Electronics Ltd. Tel., 0116 2771400; fax, 0116 2773945; e-mail, @vanndraper.co.uk; web, vanndraper.co.uk.
Enq no. 530

***LCR* meters.** Wayne Kerr's *4200* series automatic *LCR* meters are simple and straightforward in operation, providing a wide range of frequencies and voltage levels. Other attractions are IEEE-488 or RS-232 interfaces, many measurement functions and a component handling feature. Three models comprise the range, the *4270* and *4265* offering the widest frequency range, from 50/60Hz for primary power components to 1MHz. Voltages are variable from 2V to 50mV and dc bias may be used from an internal source or from an external one up to 40V dc.
Wayne Kerr Electronics Ltd. Tel., 01243 825811; fax, 01243 824698; e-mail, sales@wayne-kerr.co.uk.
Enq no. 531

COMPUTER AND DATA HANDLING

Data acquisition

Plug-in dataq boards. National Instruments has introduced three plug-in data acquisition boards intended to lessen the cost and complexity of getting physical measurements into a computer for analysis, display and networking. They are compatible with application software including *LabView* and *LabWindows/CVI*. The *6023E*, *6024E* and *6025E* are 12-bit, 200ksample/s boards with 16 single-ended and eight differential analogue inputs, the two latter also having two 12-bit output channels. All have two 24-bit, 20MHz counter-timers, eight digital i/o lines, digital triggering, the 6025E having 24 lines of digital i/o.
National Instruments UK. Tel., 01635 572400; fax, 01635 524395;e-mail, info.uk@natinst.com; web, www.natinst.com/uk
Enq no. 532

Data communications

Uart-PCI bridge. Combining a quad uart and a PCI bridge in a single 150-pin TQFP chip, the Oxford *OX16PC1954* halves the cost of a typical PCI-based serial/parallel expansion card, lessens complexity and improves performance. Throughput is up to 15Mb/s per channel in asynchronous mode and 60Mb/s in isochronous mode using an

Computers

Flat-panel computer. Datasound Laboratories introduces the *ZF netDisplay* oem computer, which is based on the single component computer combining system hardware, software and solid-state mass storage in one device the size of a large ic. The unit consists of a PC/AT-compatible motherboard, an lcd flat-panel and a 10baseT Ethernet interface and is suitable for both networked and stand-alone use. There are 8in passive or 12in touch-screen colour displays. The motherboard includes serial and parallel i/o, digital i/o, floppy and EIDE disk controllers, an SVGA controller, accessible flash memory, a CompactFlash socket, PC/104 expansion buses, Dr-dos and embedded DOS rom by General Software.
Datasound Laboratories Ltd. Tel., 01462 675530; fax, 01462 482461.
Enq no. 533

Please quote *"Electronics World"* when seeking further information

Development and evaluation

68HC12 debugger with flash. A family of development tools from Noral for use with Motorola's 68HC12 range of microcontrollers now includes a background debug mode debugger with flash-mode programming for the *68HC12DG128 CAN* microcontroller. The hand-held *BDM/68HC12DG128* is intended as a development aid for automotive applications and its 128K of flash memory can all be programmed without recourse to extra hardware or a separate programming voltage. The unit integrates an intelligent background debug mode cable and Noral's high-level debugger, so that CAN data is displayed and updated in real time, the status of CAN and other special-function registers being displayed in plain English.
Noral Micrologics Ltd. Tel., 01254 682092; fax, 01254 680847.
Enq no. 535

external clock. Features are a PCI-bus interface, four Oxford *16C950* uarts, a bi-directional parallel port and an 8/32-bit pass-through expansion bus interface for Local Bus. Each also has an IrDA-compliant modem. Configurations for Subsystem Vendor ID and Subsystem ID may be set up on the device pins, but an external eeprom may be used for this purpose if necessary.
Oxford Semiconductor Ltd. Tel., 01235 824900; fax, 01235 821141; web, www.oxsemi.com.
Enq no. 534

Ethernet controller. BVM's *BVME410* is now updated to offer several interface choices to connect to Ethernet networks. There is dual-ported fast ram to buffer data on the card without the use of system memory. The module only interrupts the host cpu when valid packets are in memory and when the cpu can act on the data with no need to transfer large buffers to main memory. A front-panel BNC connector is provided for 10baseT lans and an AUI drop cable connector allows the use of thick wire and twisted pair networks by way of low-cost transition modules.
BVM Ltd. Tel., 01489 780144; fax, 01489 783589; e-mail, sales@bvmltd.co.uk; web, bvmltd.co.uk.
Enq no. 536

Interfaces

Custom i/o PCI card. The Acromag *APC862PCI* bus board from Crellon interfaces up to five *Industry-Pack Ansi/Vita-4* modules to a pc. By installing analogue, digital and serial i/o modules on the carrier card in any combination, users may select from many third-party IP modules to develop i/o boards with high channel density, thereby saving card slots. OLE control software for Windows simplifies the integration of IP modules into data and control applications with an object-oriented interface. These software components replace specific drivers to allow access to IP module i/o data for use in OLE-compatible programs such as Visual Basic and C, Office 97 and others.
Crellon Microsystems. Tel., 01734 776161; fax, 01734 776095; e-mail, crellon@gcrellon.co.uk; web, www.crellon.co.uk.
Enq no. 537

Mass storage

Hard drive on a card. The *Callunacard Type III* PCMCIA card is said to be the first available 1Gbyte hard disk drive of its type. This is a twin-platter drive using four magnetoresistive heads and the PRML read-channel technique to provide larger storage and high-speed random access. All these cards include an automatic idle mode for low power consumption and a 68-pin IDE interface to enable usage as embedded storage in other applications.
Premier Electronics Ltd. Tel., 01992 634652; fax, 01992 634616; e-mail, sales@premierelect.co.uk; web, www.premierelect.co.uk.
Enq no. 538

PUBLICATIONS

Catalogues

Cooling power transistors. *Max Clips* by Thermalloy replace the conventional screw or rivet mounting methods. Screws and rivets have been known to damage transistors and they do not help conduct the heat away in the most efficient manner. *Max Clips* can be used with a wide range of heat sinks and retain the transistor in intimate contact with the sink, without excessive force being applied.
Redpoint Thermalloy Ltd. Tel., 01793 537861; fax, 01793 615396.
Enq no. 539

Intermetall. Intermetall's *Summary 99* is available both as a printed catalogue and as a cd-rom. Both contain comprehensive product information on the company's range of mixed-signal ics and Hall-effect sensors. The cd-rom uses the PDF format for easy retrieval of around 2000 pages of information.
Micronas Intermetall. Tel., 0049 761 5172577; fax, 0049 761 5172799; e-mail, docservice@intermetall.de; web, www.intermetall.de.
Enq no. 540

GSM semiconductors. Toshiba has a brochure on the selection of devices for use in GSM mobile telephone equipment. Included in it are rf and baseband ics, sram and flash memory and batteries. Information is also given on supporting components such as leds, saw filters and logic ics.
Toshiba Electronics UK Ltd. Tel., 01276 694730; fax, 01276 694800.
Enq no. 541

Application notes

32-bit risc cpu. NEC can supply two free cd-roms on the selection and use of the 32-bit risc cpu core of the company's *V800* series of microcontrollers. On one of them are data sheets and applications information on this device family and others from NEC, including a search function, directory of parts and other information, readable by Adobe Acrobat, which is supplied. The second disk provides demonstration versions of pc-based software development tools for the *V850* series.
Sunrise Electronics Ltd. Tel., 01908 263999; fax, 01908 263003; web, www.sunrise.co.uk
Enq no. 542 ■

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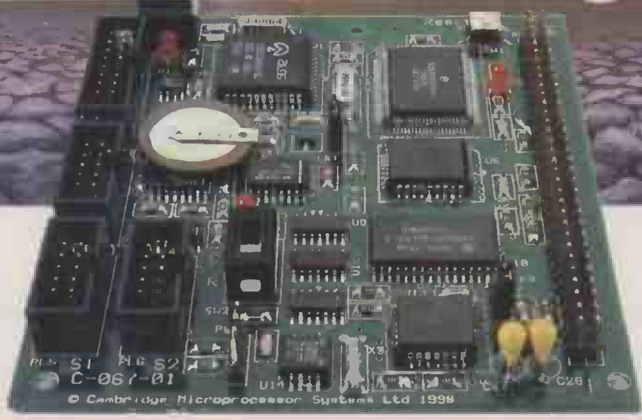

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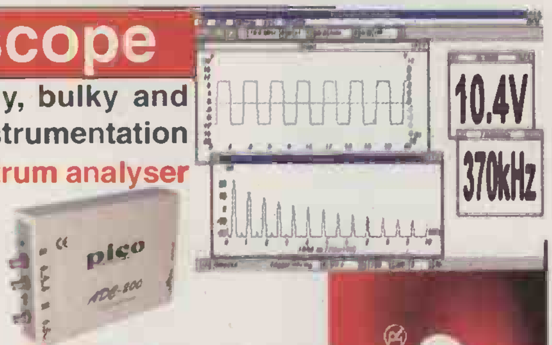
CIRCLE NO.134 ON REPLY CARD

The Alternative Oscilloscope



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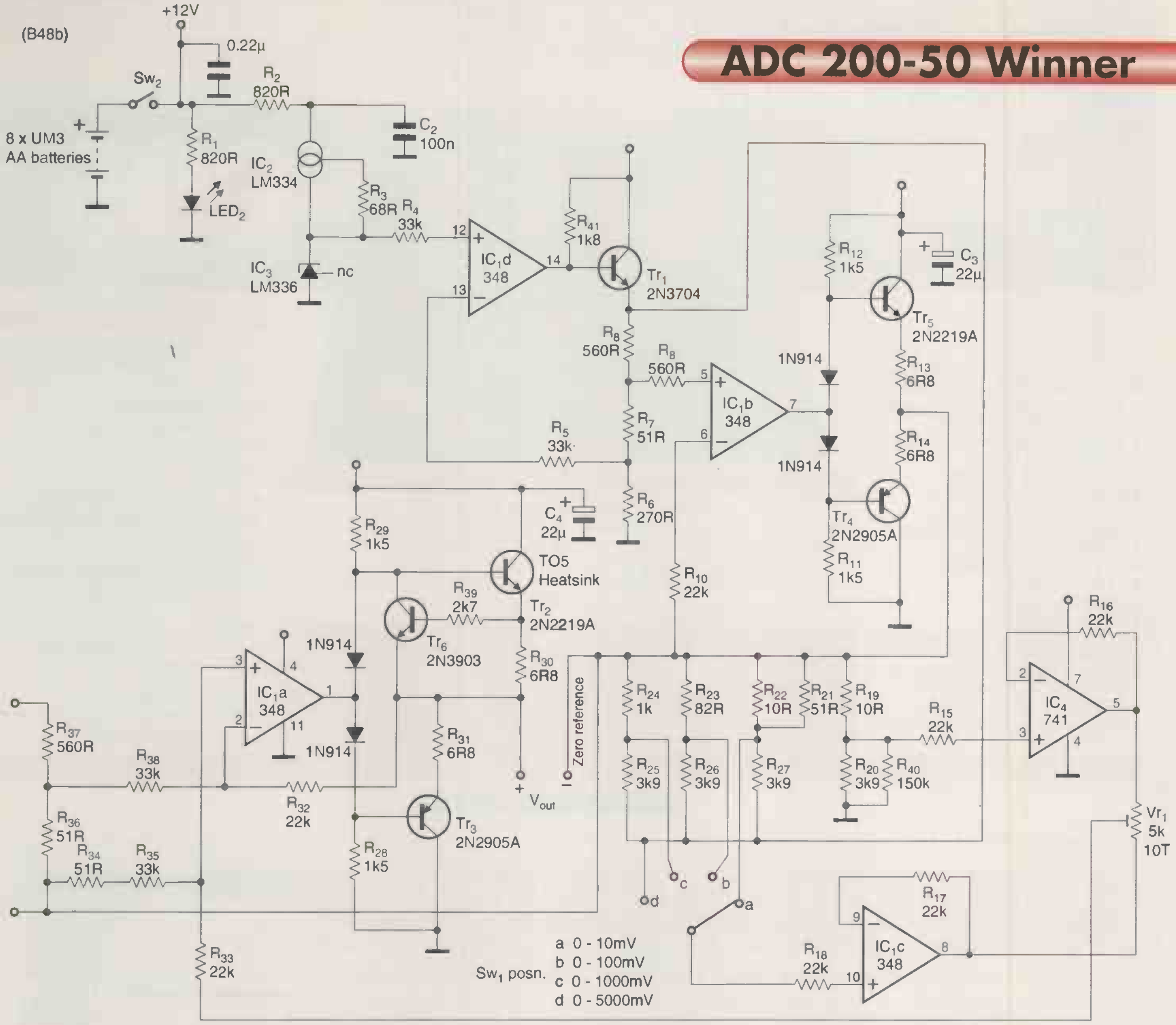
CIRCLE NO.143 ON REPLY CARD

ADC 200-50 Winner

(B48b)



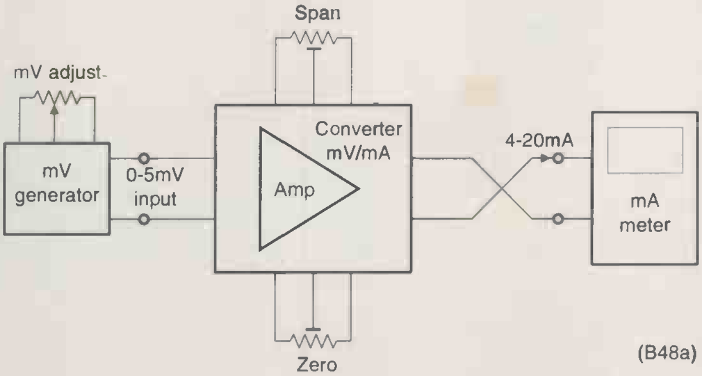
Variable millivolt generator

Providing up to 5V in four ranges, the smallest being 0-10mV, this battery-powered generator has very low output impedance and will source up to 100mA in any range. It is stable, variable and may be modulated. Drift is less than ±10µV on all ranges.

Two ics, the *LM334* programmable current source used to provide current to the *LM336* 2.5V reference, are responsible for the generator's stability and relative independence of the battery voltage.

The reference voltage is buffered in IC_{1d}, the output from Tr_1 being 3V to IC_{1b}, which provides the zero reference and 8V to give the various ranges by means of potential dividers, whose outputs are then buffered in IC_{1c} after selection by Sw_1. The output of IC_4 is slightly negative of zero, being driven by a potential derived from the battery zero and the zero reference to give a negative swing to the output of about 6mV. Potentiometer Vr_1 is a ten-turn type, the output going to the Class AB amplifier to provide the output, Tr_2 being protected by Tr_6.

Modulation input is attenuated by 22dB for my particular application, but may be varied by $R_{36,37}$, bearing in mind that R_{36} must equal R_{34}. I recommend the use of 1% resistors throughout.



(B48a)

D Heywood
Buckley
Flintshire
(B48)

Low loss current sharing for batteries

With multiple parallel batteries, system the discharge rate is different for each pack due to construction, age and temperature etc. The standard solution is to use blocking diodes and a resistor in series. This can waste a great deal of useful energy.

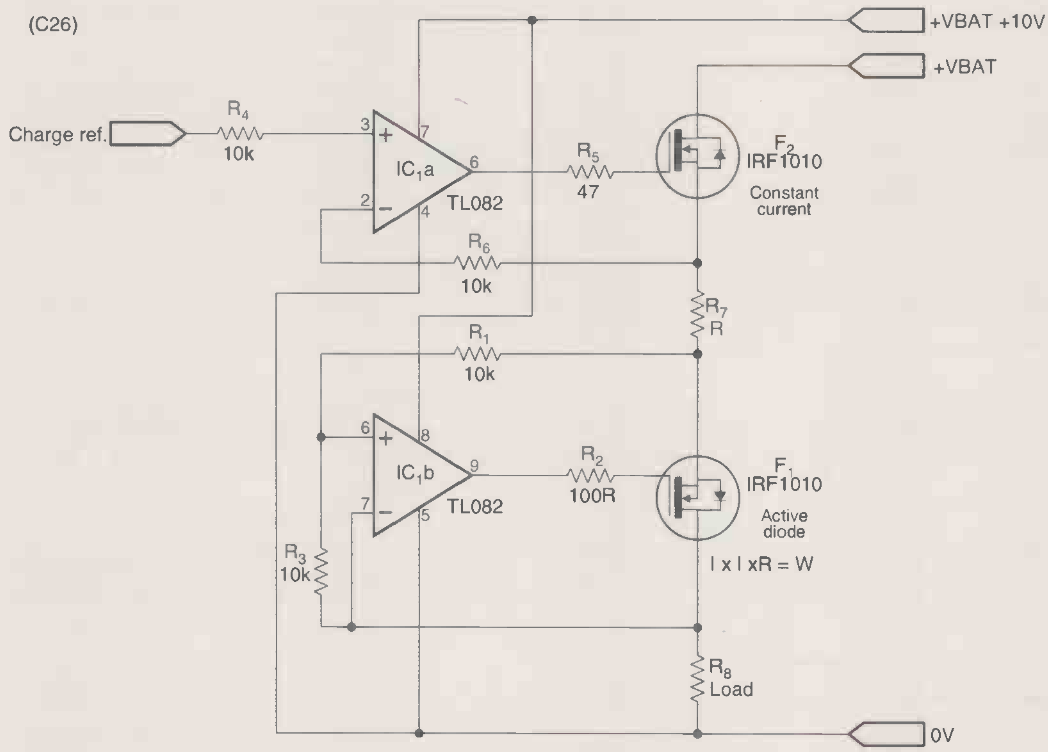
The circuit shown can extend the working time of the system.

Assume a 0.2Ω resistor and a standard diode with just two batteries at 3A. Battery voltage is 14V. Resistor dissipation is $3A^2 \times 0.2\Omega$, i.e.1.8W. Add to this the diode loss of three $V_f \times 3$ and you get 3.7W. Consumption is 42W and 9% is lost.

If you use an active diode, F_1, with an 8mΩ on resistance and an R_{sense}, i.e. R_7, of 10mΩ, when F_2 is hard on, dissipation becomes twice $3A^2 \times 0.008\Omega$, which is 144mW, plus $3A^2 \times 0.01\Omega$ which totals 324mW.

This raises efficiency to 99.4%, which is significantly better.

Colin J Wonfor
Bay Designs Consultants
Dunfermline
Scotland
C26



Using an active diode instead of an ordinary diode in a shared battery circuit significantly reduces losses due to diode voltage drop.

Logic-driven programmable fuse

£50 Winner

This programmable fuse uses a mosfet as the current switch, the *MAX233* RS-232 driver being used to drive the mosfet from a logic level input derived from a transistor on a 5V rail, since 9V gate drive is required to turn the mosfet fully on.

Current sensing resistor R_s in series with the load senses load current, the voltage thereby developed turning the zener on and off. Since the zener provides base current for the transistor and since the transistor drives the *MAX233*, gate drive to the mosfet from the 233 is dependent on load current. Diode D_1 isolates the gate of the mosfet from the negative 9V from the 233.

While load current is low enough, no current flows in the zener, there is no drive to the transistor, input to the *233* is low and its output 9V, so D_1 conducts and so does the mosfet to supply load current. During a fault condition, the zener conducts turning the transistor on, output of the *233* is high at –9V, the diode is off and the mosfet off.

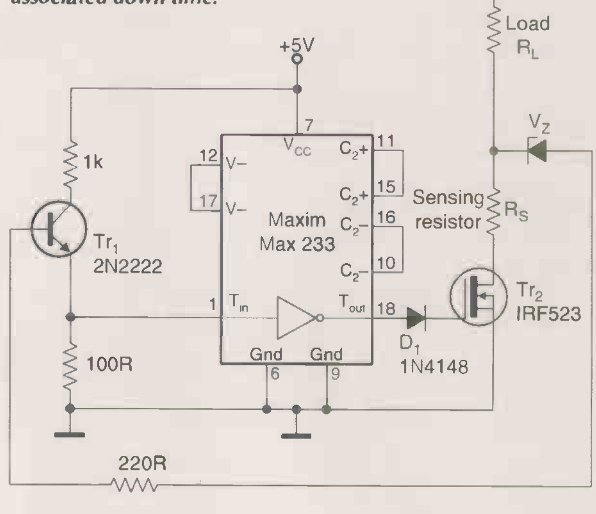
$$I_{lf}=[V_z/(R_s+R_{DS(on)})]$$

where I_{lf} is the load current to actuate the fuse and V_z zener breakdown voltage. As an example, assuming I_{lf} is 2A, $R_{DS(on)}$ is 0.3Ω and R_s is 1Ω, voltage $V_z<(1+0.3)\times 2$. As a result, $V_z < 2.6V$.

Taking a standard zener voltage of 2.4V, $I_L<(2.4/1.3)$ so $I_L<1.85A$ – the load current up to which the fuse will not be activated.

V Lakshminarayanan
Bangalore
India
C39

Electronic fuse is non-latching, is programmable and avoids all that business of fuses blowing and the associated down time.



Fast, adaptive delta modulator and demodulator

Although delta modulation possesses the advantage of only needing one bit to transmit each sample of the signal, there is the disadvantage that it can be left behind by a rapidly changing analogue signal. Adaptive delta alleviates this error somewhat, but some error remains and the circuitry becomes complicated. This circuit is a high-speed adaptive delta modulator.

Figure 1 shows the arrangement. Whenever the accumulated signal is below the analogue input, a positive step is imposed, and *vice versa*. At the next clock, if the accumulator is still below the analogue input, a further positive step of twice the size is generated and so on until the accumulator is above the analogue input, after which the next step is a negative one.

In this circuit, the steps progress from a single step to one eight times the size. The result is a pulse output ADM(n) as shown.

In **Fig. 2**, 4AS is a four-bit adder/subtractor operating as an accumulator and a four-bit serial shift-left register (STR) to generate the step size.

Accumulator output always builds up towards the analogue input; depending on the control input SUB, this is added or subtracted from the STR by the adder/subtractor 4AS. The next clock input strobes the result to the accumulator, whose output goes to the d-to-a converter as the analogue value of the data for comparison with the analogue input in C.

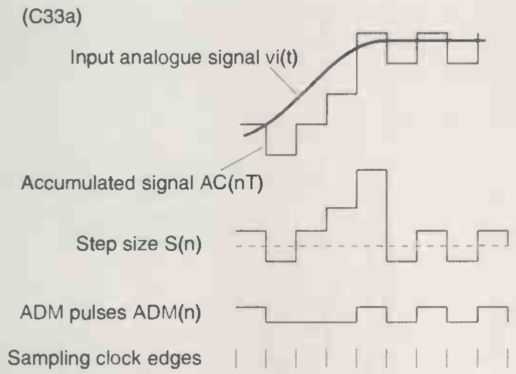


Fig. 1. Signals in the adaptive delta modulator. Slope overload error is reduced by an increasing step size to cope with fast-changing analogue signal.

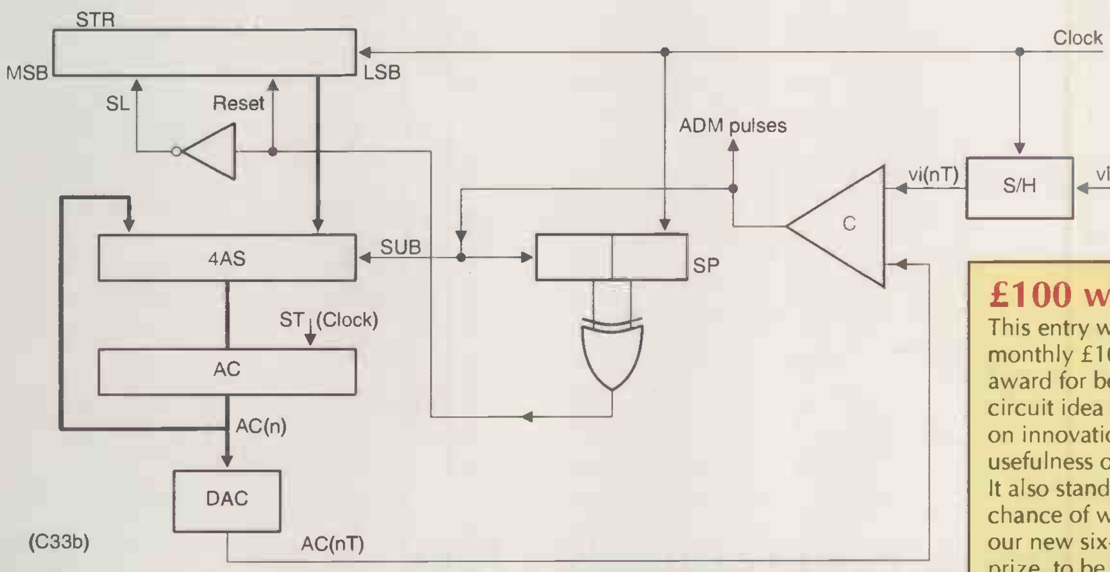


Fig. 2. Block diagram of the modulator. Output is a train of pulses at ADM and input vi(t) to the sample-and-hold.

£100 winner
This entry wins our monthly £100 award for best circuit idea based on innovation, usefulness or effort. It also stands a chance of winning our new six-monthly prize, to be announced soon.

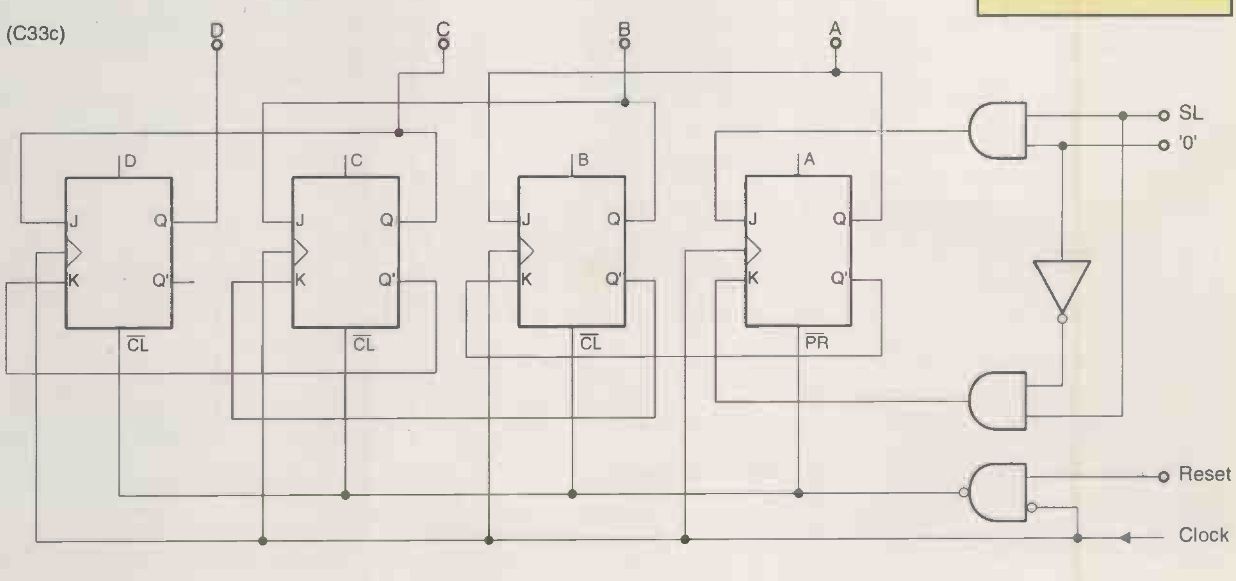


Fig. 3. Shift-left register circuit that generates the increasing step size, when called upon to do so by the equality or inequality of the bits held in the two-bit shift-right register SP.

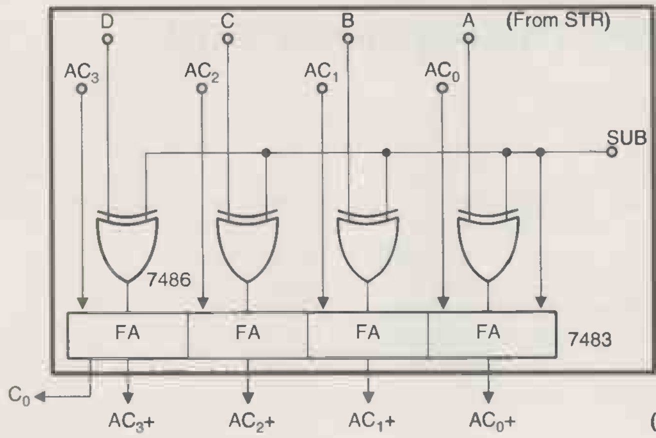


Fig. 4. The adder/subtractor.

Resulting output from the comparator forms the output pulse train and provides the SUB control for the adder/subtractor, as shown in the table.

To generate step size, the two most recent bits of the output pulse train are held in the SP register. The exclusive-ored result from these bits becomes the reset of the STR register, its inverted form being the shift-left signal, so that either reset or shift-left occur at any instant.

If the SP bits are not alike, then step size is unity, since the register is reset to 0001; if they are alike, the data is shifted left to give a register content 0010 to give a double-size step, and so on.

The STR register is shown in **Fig. 3**. A zero on SL shifts all bits to the left by one step and when reset is 1 the next clock resets the data to 0001. **Figure 4** is the adder/subtractor, which subtracts by two's-complement addition.

The demodulator in **Fig. 5** is virtually the reverse of the modulator. Received pulses become the input to the SP register and, after a 1-bit delay, are the SUB signal to the adder/subtractor, reset and shift-left inputs to the STR register being derived as before. The d-to-a output is the demodulated version of the input pulse train.

K Balasubramanian
H Camur
European University of Lefke
Turkish Republic of Northern Cyprus
C33

Table. SUB control for the adder/subtractor

AC(nT)	vi(nT)	C,SUB	Action
AC(nT)	<	0	add
AC(nT)	>	1	subtract

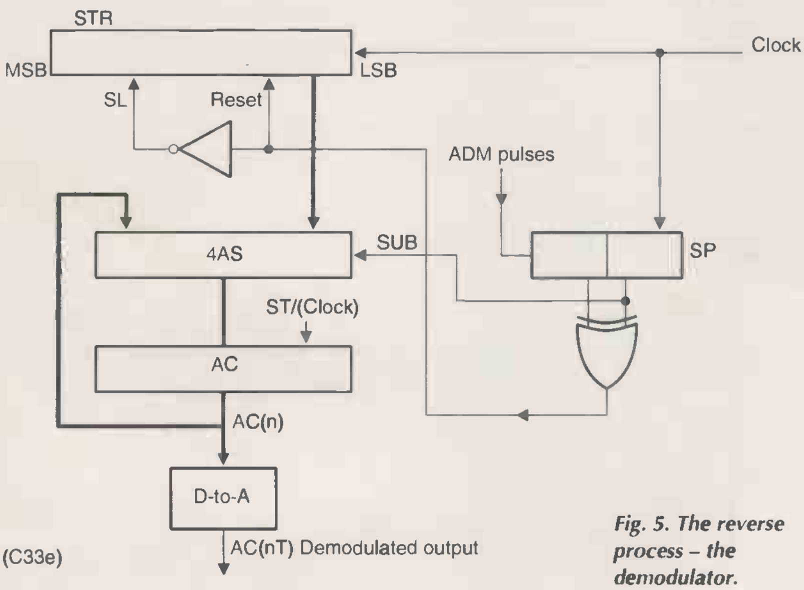


Fig. 5. The reverse process – the demodulator.

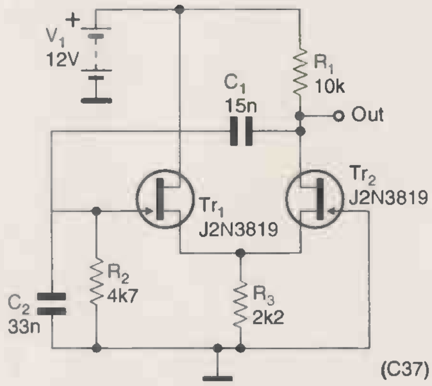
Frugal Wien-bridge oscillator

This oscillator was designed to provide a sinusoidal drive to an am modulator and uses only seven components. It provides an 8V pk-pk output at about 1kHz.

Total harmonic distortion is around 10% and may be lessened by increasing the value of R_3, which will also reduce the output swing and may make starting more uncertain.

Best output reference rail is positive. Any resistance in the drain of Tr_1 will probably reduce performance.

Davor Virkes
Zagreb
Croatia
C37



Very simple Wien-bridge oscillator for use as a modulator drive. Output is 8V pk-pk at 1kHz.

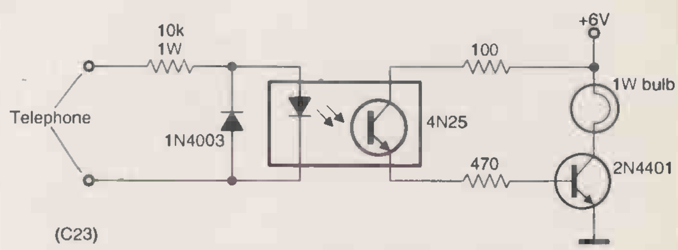
Telephone night light

When the telephone handset is lifted to make or answer a call, the circuit lights a lamp.

If the handset is taken off-hook, direct current flows through the subscriber loop and, in this case, through the optocoupler. The coupler led conducts and turns on the coupler transistor, so supplying current to the output transistor and lamp.

An extra diode across the coupler input prevents the ac ringing voltage from causing reverse breakdown in the coupler led. A 6V NiCd cell charged from the ac mains is sufficient to power the circuit.

V Lakshminarayanan
Bangalore
India



Avoid fumbling in the dark when someone rings you at three in the morning with this simple telephone lamp switch.

PA switching from the microphone end

With the intention of switching on and off an extra pair of speakers from the microphone of a public address system, this circuit allows the transmission of switching information across balanced lines with no extra switch wiring.

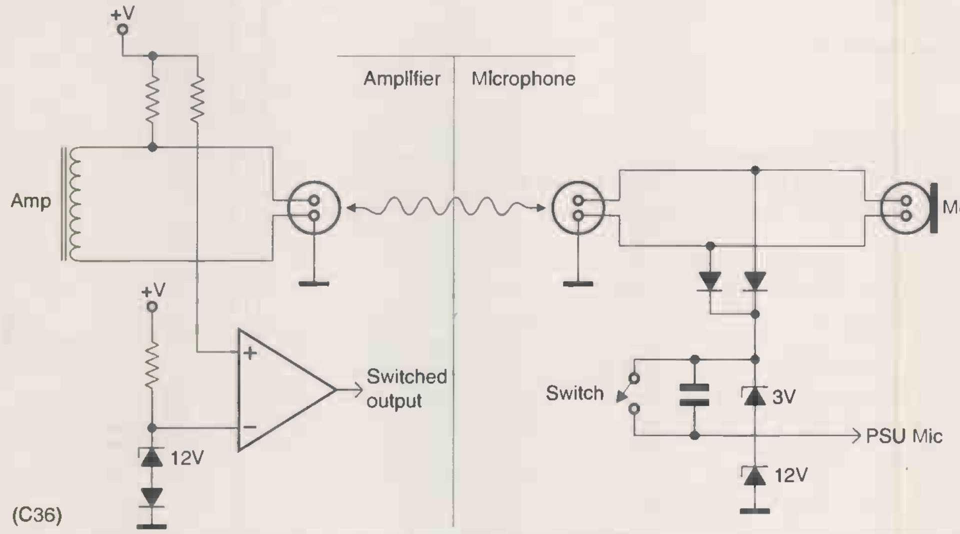
Phantom power for condenser microphones is well established already, avoiding the need to fit a battery at the microphone; this circuit will tolerate anything from 12V to 48V. The zener diode in the microphone power take-off circuit or an added one in the case of dynamic microphones allows the voltage between the signal lines and screen – supplying the phantom power – to be regulated from the end of the line.

Varying the value of the combined zener with switch and detecting this change at the amplifier terminals allows the transmission of signals in this way, since the amplifier positive voltage comes via a pair of resistors.

It may be possible to send more signals by varying the number of zeners switched.

Robert Hunt
Louth
Lincolnshire
C36

Switch things on and off via a two-wire microphone cable.



(C36)

Model traffic lights

This is for use with toy cars. Each set consists of two systems – one for traffic and one for pedestrians. At switch-on the system goes through a cycle without the need to press switch S_2 since time delays are activated, S_2 setting the first time delay.

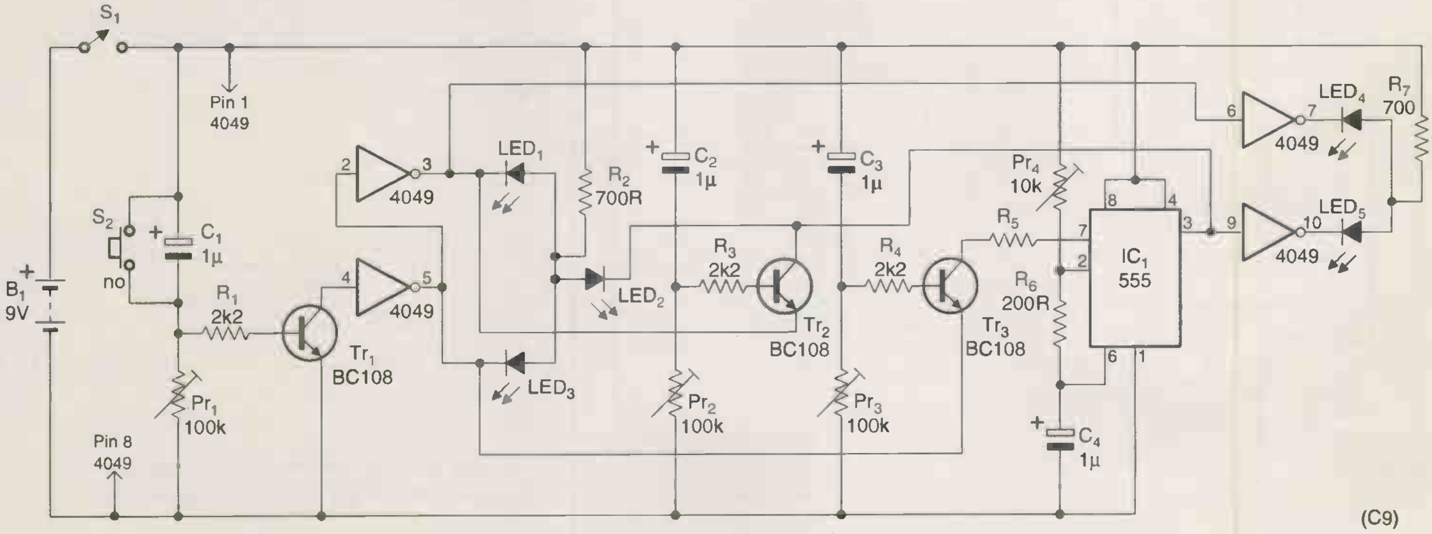
Pedestrian indicators Led_4 (red) and Led_5 (green) are driven by an inverter, so that when the red Led_1 is on, Led_4 is off; when Led_3 (green) is on, Led_5 is off.

When the first time delay around Tr_1 is activated, Led_3 is turned off by an inverter (the three presets for each delay allow a maximum of 100s delay). Red led Led_1 is driven by an inverter to make Led_1 go off when Led_3 is on.

The same components are used in the second time delay circuit, orange Led_2 turning on the delay. Output from the third delay operation, still using the same components, goes to R_5 to enable the *555* flasher. Time constants of the second and third delays should be equal.

James Stuart (13 years old)
Romford
Essex
C9

Traffic lights for toy cars. Use either cmos or ttl, but 9V for cmos and 4.5V for ttl.



(C9)

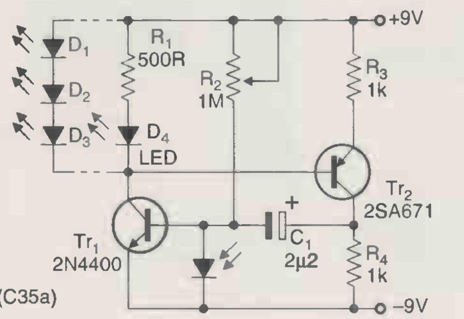
Dark-sensitive oscillator

Figure 1 shows an *RC* oscillator that will only begin to operate when the photodiode is not illuminated. The leds flash at a frequency set by the value of C_1 and the sensitivity to illumination is controlled by R_2. When the oscillator is off, supply current is under 0.05mA.

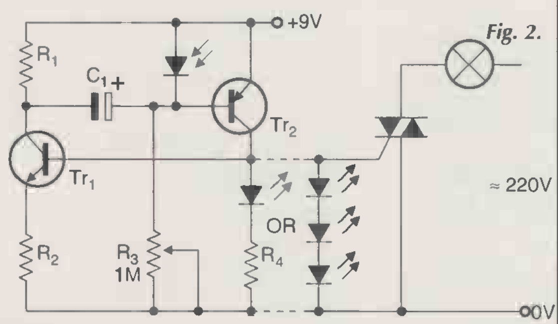
Alternatively, the circuit of Fig. 2 shows an inverted arrangement, adapted to drive a thyristor, while flashing.

Vasiliy D Borodai
Zaporozhje
Ukraine
C35

Fig. 1.



(C35a)



(C35b)

If you have a tendency to lose your dog in the dark, this circuit fastened to his collar should help locate him. (Not the mains version please – Ed)

Water level controller

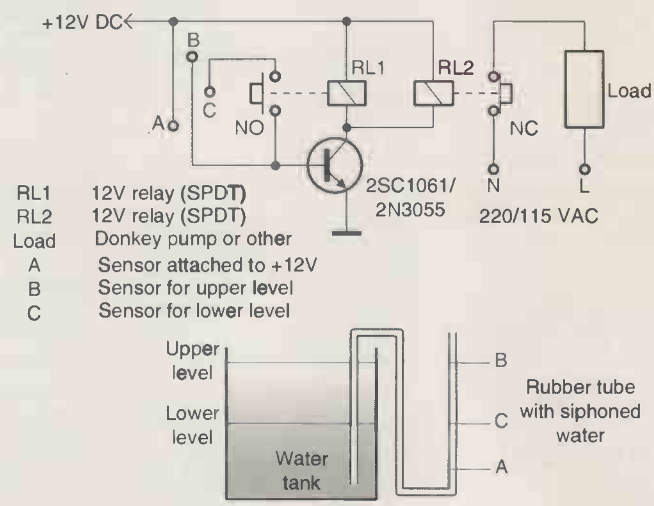
This single-transistor circuit controls the level of water in a tank fed by a pump, maintaining the level between two set points.

Electrodes attached to the rubber tube detect the presence of water and control the transistor base current. Starting with a full tank and electrode B covered, the transistor is forward biased and conducting, both relays are on, RL_2 contacts are open and no current goes to the load. If the level is just above C, the transistor is still on and the load still not taking current, since transistor current flows in RL_2.

As level fall further past C, transistor current is cut off, both relays go off and the load – i.e. pump – takes current, water level rising again up to B, since below that level RL_1 is still off. At B, the cycle repeats.

Ejaz Ur Rehman
Pinstech
Islamabad
Pakistan
C47

£50 Winner



Extremely simple water level controller maintains level in a tank between two preset points.

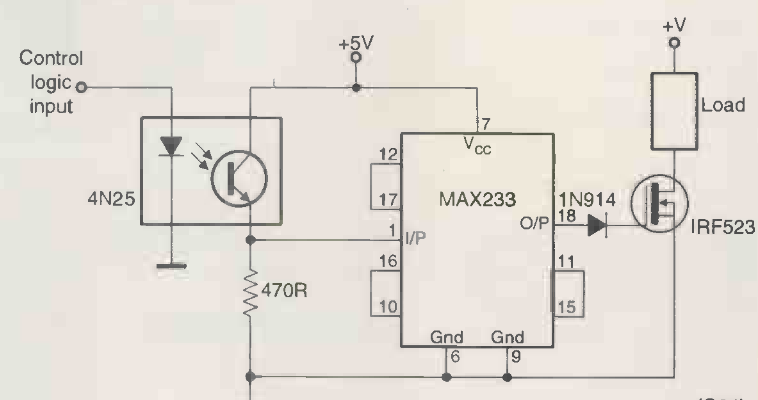
Logic-driven, contactless relay

Using no mechanical contacts, this relay will not wear, chatter or generate noise.

Input logic interfaces with the driver by way of an optocoupler, which drives the input of a *MAX233* RS-232 driver, here arranged as a mosfet driver. This works from one 5V supply and puts out ±9V levels – low input 9V, high input –9V.

When input is low, the opto transistor is off, keeping the driver input low, its output being 9V to forward bias the diode and turn the mosfet on. With a high input, the driver output goes to –9V to reverse bias the diode and turn the mosfet off, the diode being present for protection of the mosfet gate against the –9V.

V Lakshminarayanan
Bangalore
India
C34



(C34)

5V logic drives a relay via this RS-232 driver, here disguises as a mosfet driver.

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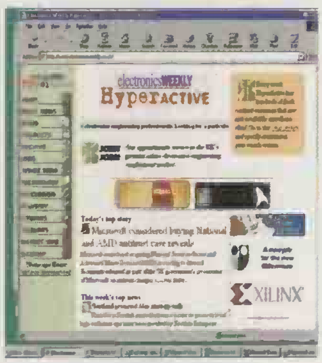

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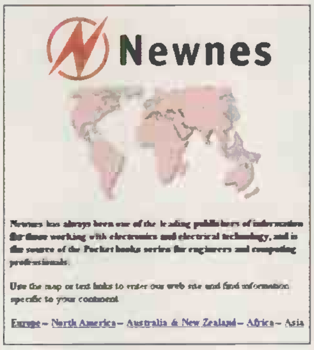

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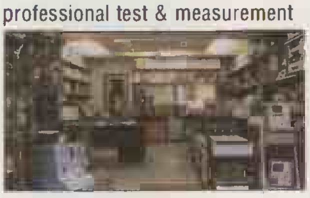

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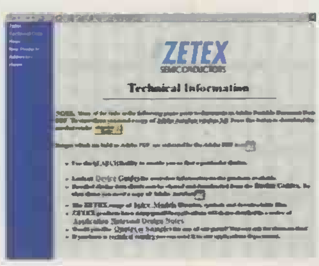
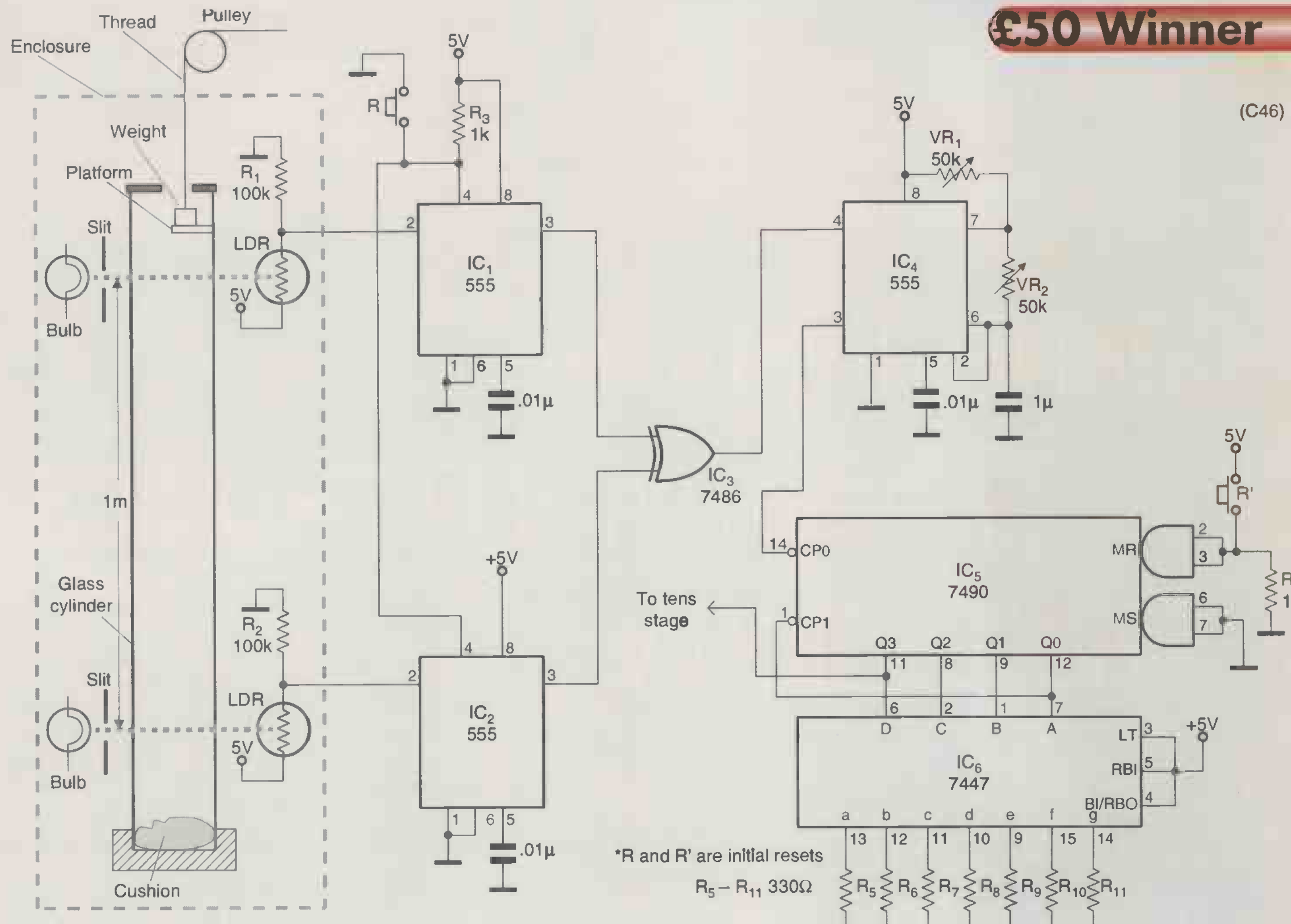
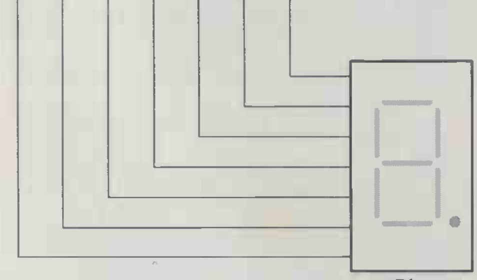


£50 Winner

(C46)





Measuring acceleration due to gravity by a falling weight.

Measuring g

This is a method of measuring the g of a falling body. A glass cylinder of just over 1m in height is closed at both ends and provided with a cushion at the bottom. Spaced at a vertical distance of exactly 1m are bulbs, slits and light-dependent resistors. These detect the passing of the falling body, which is initially kept in place by a removable platform and further retained by a thread when the platform is taken out.

Signals from the ldrs trigger bistable flip-flops in the *555* timers. The outputs of these are exclusive-ored to reset an astable flip-flop in the third *555*, *IC₄*, so that these 50ms pulses are produced during the time the body is falling. The number of pulses produced is counted, passed to a decoder-driver, and displayed.

Distance (s), time of fall (t) and initial velocity, which is zero (u) are now known.

$$s=ut+gt^3/2,$$

$$g=2(s+ut)/t^2$$

Over a 1m fall, the counter displays 9 pulses of 50ms each, so the period is 450ms.

Acceleration due to gravity is therefore 9.877 m/s^2. ■

V Gopalakrishnan
National Aerospace Laboratories
Bangalore
India
C46

Need an extra isolated low-voltage supply?

For one-offs, prototypes and experiments it is often possible to add an extra mains transformer secondary by threading wire round the transformer's outer insulation – but only where the mains transformer isn't being run to its limits.

Better decoupling for through-hole boards

When designing a through-hole prototype board, forget drilling holes for 100nF decoupling capacitors.

Just run the power rail tracks closer to each other on the under side of the board and drop a surface-mount capacitor on. That way you have less drilling to do, capacitance can be added very easily if you find out you need more, and capacitor lead inductance is eliminated. No special tools are needed.

To apply the capacitor, tin the copper where the capacitor is going to sit then wipe a little resin to the tinning. Hold the capacitor in position with a suitable piece of plastic or wood then touch each capacitor electrode with a hot, cleaned, tinned and fluxed iron. Bigger, cheaper SM capacitors are best here.

Tips like this could earn you between £10 and £50 – Ed.

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