Exclusive - 20% discount on LCR meter

ELECTRONICS WORLD

+ WIRELESS WORLD

June 1995 £2.10

A REED BUSINESS PUBLICATION
SOR DISTRIBUTION

Versatile £220 i/o controller for £99

Audio special

Tri-modal audio power

Microreflex loudspeaker

Audio power ICs exposed

Researching via Internet

New concept in i/o control

Generating waveforms

Denmark DKr. 65.00
Germany DM 15.00
Greece Drs.760
Holland Dfl. 14
Italy L. 7300
IR £3.30
Spain Pes. 780
Singapore S$ 12.60
USA $4.94
FREE SOFTWARE UPGRADES! - KEEP UP TO DATE WITH NEW DEVICES

Before you choose your programmer, check out the cost of ownership. While other manufacturers charge for every update or require expensive libraries and modules, ICE Technology programmers support the whole range of devices at no extra charge. And keeping up to date is FREE for life at no charge on our BBS service. Just dial on: +44(0) 1226766181, and download the latest version.

Disk based upgrades are available free in the first year, and a small administration charge made for each subsequent disk. * for DIL, up to 40 pins.

PROGRAM 8 CHIPS IN THE TIME IT TAKES FOR ONE!

As £645 costing around half the price of slower gang programmers, the Speedmaster 8000 gang programmer uses a simple 2 button operation in stand-alone mode. PC operation gives comprehensive file handling and editing functions. Capable of gang and set programming it supports 32 pin EPROMs to 8M with no adaptors required. Programming cycle times of only 23 seconds for 827C010's mean your throughput can now be faster than ever before.

ROM/RAM EMULATOR PLUG IN CARDS

Using these expansion cards your programmer can run as if there's an EPROM or RAM plugged into the target socket. Available as 8 bit wide 128K x 8 as standard, upgradable to 512K x 8, and 16 bit capable of emulating 40 pin EPROMs. They can emulate both 5V and 3.3V devices.

PACKAGE ADAPTORS

A full range of package adaptors is available for non DIL devices and parts with more than 40 pins. Prices from £65.

AT LAST, AN AFFORDABLE 3V AND 5V UNIVERSAL PROGRAMMER!

The latest universal programmers from ICE Technology, the Micromaster LV and Speedmaster LV, now support programming and verification of 33V devices, now you can test devices at their actual operating voltage.

They offer wider device support than ever before, the majority requiring no adaptors. They will operate from battery or mains power, making them flexible enough whatever your programming needs.

Not only that, as new devices come onto the market we give free software upgrades and the units' modular design, with easy upgrade path, protects your investment.

Available now and priced from £495 they are everything you'll need for programming, chip testing and ROM emulation.

Features

- Widest ever device support including: EPROMs, EEPROMs, Flash, SPIROMs, BPROMs, PALs, MACH, MAX, MAPL, PEELs, EPLDs, Microcontrollers, etc.
- High speed programmes a PIC16C54 in 0.5 secs (Micromaster LV).
- Up to 84 pin device support with adaptors.
- Connects directly to parallel port - no PC cards needed.
- Built in chiptester for 7400, 4000, DRAM, SRAM.
- Lightweight and operates from mains or battery.
- Optional 8 or 16 bit wide ROM/RAM emulators.
- Designed, built and supported in the UK.
- FREE software device support upgrades via bulletin board.
- Next day delivery.

Call now to place your order, for more details or a free demo disk, or call our bulletin board to download the latest demo. Alternatively clip the coupon or circle the reply number.

Name: Phone: 
Position: Fax: 
Company: Email: 
Address: 
Tel: 
Fax: 

All major credit cards accepted

FREE SOFTWARE UPGRADES! - KEEP UP TO DATE WITH NEW DEVICES

Before you choose your programmer, check out the cost of ownership. While other manufacturers charge for every update or require expensive libraries and modules, ICE Technology programmers support the whole range of devices at no extra charge. And keeping up to date is FREE for life at no charge on our BBS service. Just dial on: +44(0) 1226766181, and download the latest version.

Disk based upgrades are available free in the first year, and a small administration charge made for each subsequent disk. * for DIL, up to 40 pins.

PROGRAM 8 CHIPS IN THE TIME IT TAKES FOR ONE!

As £645 costing around half the price of slower gang programmers, the Speedmaster 8000 gang programmer uses a simple 2 button operation in stand-alone mode. PC operation gives comprehensive file handling and editing functions. Capable of gang and set programming it supports 32 pin EPROMs to 8M with no adaptors required. Programming cycle times of only 23 seconds for 827C010's mean your throughput can now be faster than ever before.

ROM/RAM EMULATOR PLUG IN CARDS

Using these expansion cards your programmer can run as if there's an EPROM or RAM plugged into the target socket. Available as 8 bit wide 128K x 8 as standard, upgradable to 512K x 8, and 16 bit capable of emulating 40 pin EPROMs. They can emulate both 5V and 3.3V devices.

PACKAGE ADAPTORS

A full range of package adaptors is available for non DIL devices and parts with more than 40 pins. Prices from £65.

AT LAST, AN AFFORDABLE 3V AND 5V UNIVERSAL PROGRAMMER!

The latest universal programmers from ICE Technology, the Micromaster LV and Speedmaster LV, now support programming and verification of 33V devices, now you can test devices at their actual operating voltage.

They offer wider device support than ever before, the majority requiring no adaptors. They will operate from battery or mains power, making them flexible enough whatever your programming needs.

Not only that, as new devices come onto the market we give free software upgrades and the units' modular design, with easy upgrade path, protects your investment.

Available now and priced from £495 they are everything you'll need for programming, chip testing and ROM emulation.

Features

- Widest ever device support including: EPROMs, EEPROMs, Flash, SPIROMs, BPROMs, PALs, MACH, MAX, MAPL, PEELs, EPLDs, Microcontrollers, etc.
- High speed programmes a PIC16C54 in 0.5 secs (Micromaster LV).
- Up to 84 pin device support with adaptors.
- Connects directly to parallel port - no PC cards needed.
- Built in chiptester for 7400, 4000, DRAM, SRAM.
- Lightweight and operates from mains or battery.
- Optional 8 or 16 bit wide ROM/RAM emulators.
- Designed, built and supported in the UK.
- FREE software device support upgrades via bulletin board.
- Next day delivery.

Call now to place your order, for more details or a free demo disk, or call our bulletin board to download the latest demo. Alternatively clip the coupon or circle the reply number.

Name: Phone: 
Position: Fax: 
Company: Email: 
Address: 
Tel: 
Fax: 

All major credit cards accepted
CONTENTS

462 TRIMODAL POWER AMP
Douglas Self's latest power amplifier design - probably unique - is capable of working in class A, AB or B.

469 BIGGER BASS SMALLER BOX
Jeff Macaulay explains a method of extending bass loudspeaker response that doesn't involve a large enclosure.

477 DATA RATER - POWER ICS ON TRIAL
Ben Duncan analyses seven audio power amplifier ICs to see whether they match up to what their manufacturers claim.

483 TWO-CHIP VIDEO DIGITISER
A flash a-to-d converter and a ttl logic chip are all the ICs needed to digitise low-resolution - but moving - images from a composite-video source.

488 SURFING WITH INTENT
It's easier than you might think to use the Internet for research, as Cyril Bateman has been finding out.

495 WHOSE HETERODYNE?
Tom O'Dell has been searching the archives trying to find out who really invented the heterodyne.

506 WAVEFORM GENERATION TRIO
Precision waveforms from cmos logic, current sink extends vco frequency range and running a programmable oscillator without a micro.

509 PLC ON A CHIP
A new approach to i/o control is a chip that turns single-key commands from a pc into signals that drive stepper motors, control analogue converters, feed SPI bus, switch i/o and more.

513 ANTI_ALIASING WITH MIXED-MODE FILTERS
Eric Margan describes how the right combination of analogue and digital circuitry improves filter performance.

REGULARS

451 COMMENT
Tired old cable.

452 NEWS
Blue semiconductor lasers, silicon shortage scare, bendy superconductors.

457 RESEARCH NOTES
More punch for video games, much cheaper fibre, organic led advances, defuzzing images.

500 LETTERS
More fuel for the audio debate, Tesla and the transistor - was it invented or discovered?

520 CIRCUIT IDEAS
Fluid-flow monitor, microphone preamplifier, half-duplex-to-RS232 converter.

527 NEW PRODUCTS
Pick of the month - classified for convenience.

Can the Internet work for you? See page 488.

Two exclusive EW+WW reader offers - 20% discount on this LCR meter, page 487, and a £220 designer's controller board for £99, page 509 onwards.

Next month:
Heart-rate monitor, dual current mirror for faster audio power amplifiers, designing interface cards for the pc.

JULY ISSUE - ON SALE 29 JUNE
If you've got one of these

**COM 1**

AND ONE OF THESE

1) **THE ITC-232-A CHIP**

2) **THE I/O-232 BOARD**

Drive all of these

AND SENSE ALL OF THESE

Using only one of these

AND NONE OF THIS

```
main()
{
    char cv;
    int tv1 = 321;
    float tv1, tv2;
    /* lost precision
```

£300 TO JUST £30
TIMELY TECHNOLOGY LIMITED
TEL: 01536 791269, FAX: 01536 790730
MILLBANK, KETTERING ROAD
LITTLE CRANSLEY, NORTHANTS NN14 1PJ

CIRCLE NO. 104 ON REPLY CARD

---

**KESTREL ELECTRONIC COMPONENTS LTD**

☆ All items guaranteed to manufacturers' spec.
☆ Many other items available.
☆ 'Exclusive of V.A.T. and post and package'

<table>
<thead>
<tr>
<th>Code</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>27C64-15</td>
<td>2.00</td>
</tr>
<tr>
<td>27C128-15</td>
<td>2.40</td>
</tr>
<tr>
<td>27C256-15</td>
<td>2.20</td>
</tr>
<tr>
<td>27C512-15</td>
<td>2.20</td>
</tr>
<tr>
<td>27C1024-15</td>
<td>3.60</td>
</tr>
<tr>
<td>27C2048-15</td>
<td>6.00</td>
</tr>
<tr>
<td>27C4096-15</td>
<td>8.60</td>
</tr>
<tr>
<td>80C31-12</td>
<td>2.10</td>
</tr>
<tr>
<td>8255A-2</td>
<td>2.00</td>
</tr>
<tr>
<td>8748H</td>
<td>5.00</td>
</tr>
<tr>
<td>8749H</td>
<td>5.00</td>
</tr>
<tr>
<td>75176BP</td>
<td>1.35</td>
</tr>
<tr>
<td>65C21P2</td>
<td>2.00</td>
</tr>
</tbody>
</table>

74LS, 74HC, 74HCT Series available
Phone for full price list
All memory prices are fluctuating daily, please phone to confirm prices

178 Brighton Road,
Purley, Surrey CR8 4HA
Tel: 0181-668 7522. Fax: 0181-668 4190.

CIRCLE NO. 105 ON REPLY CARD

---

**COMPONENTS & SYSTEMS FROM Iosis**

INDUSTRIAL SPEC COMPONENTS AND SYSTEMS
386SX-40 All-in-one CPU Board on PC half card from £215. Requires only display adapter and RAM to complete the core of a PC-compatible system. PC/104 or ISA bus expansion. PC/104 display adapter from £135. Desktop LCD mono VGA monitor with display adapter and passive backplane from £499. Please enquire for complete systems. Prices exclude VAT and carriage.

2c Chandos Road, Redland, Bristol BS6 6PE, UK
Tel: 0117 973 0435 Fax: 0117 923 7295

CIRCLE NO. 106 ON REPLY CARD

---

ELECTRONICS WORLD+WIRELESS WORLD June 1995
Tired old cable

Why was cable described as 'Tired' by Wired magazine? Perhaps maps showing the coverage of the country by cable services give some clue. Penetration in the Cambridge area, for example, has the appearance of a monstrous spider with its body resting on the city and its legs trailing out into the surrounding countryside. Some key villages are missed out completely; others, with perhaps only one road connection, are served as they are on a straight line between Cambridge and another large town. The idea that today you telephone a person rather than a place seems to have lost something in the translation to cable.

While coverage is one issue, take up of services and churn rates (lapsed subscriptions) also cause concern. In the Cambridge area there are now 130,000 homes which could be connected to the cable network. So far 28,000 have taken television and 30,000 have taken telephone services. These figures fall short of those achieved by Bell Cablemedia who also operate in the East of England. They have taken up of 22.3% for television and 25.7% for telephone – and still Bell Cablemedia made a loss last year of over $25 million.

Anne Campbell, who is Labour MP for Cambridge, said in a recent interview that she was 'alarmed at the way that the cable companies are being allowed to "cherry-pick" the lucrative urban areas, leaving large tracts of the rural countryside untouched by the information revolution'. She feels that "We should be imitating the US, where cable companies are being allowed to cherry-pick the lucrative urban areas, leaving large tracts of the rural countryside untouched by the information revolution". She feels that "We should be imitating the US, where some States have refused to allocate franchises unless the cable companies were prepared to cable up the loss-making areas as well as the profitable ones".

A few years ago the idea of doing to BT what the US administration did to AT&T seemed to make sense – unfortunately the world has moved on. Globalisation has happened and Europe has happened. BT is about the right size for a regional operator if the European Telecoms market is taken as a whole. However, it is unlikely the UK government sees it this way. The EU sees it this way but is too afraid of upsetting anyone to knock the whole thing into shape – too many equipment suppliers on too many committees. The American model will not work in the UK alone – in America a local call costs only the connection charge – whether a call is 3 minutes or 24 hours it costs the same. The UK's local tariffs are based on a cost per minute which stunts the growth of on-line services. BT could provide US style local tariffs if it was allowed to provide services to subsidise them.

Cable companies may, eventually, provide the US model but perhaps for only a maximum of 70% of the population. Whether they make a profit in doing so or even in some cases survive remains to be seen. For some, the battle to wire the country with cable may end up being a switch too far.

Peter Kruger

The full interview with Ann Campbell quoted here is online and can be accessed on the World Wide Web at http://www.gold.net/lanes/20 - ed.
**JVC announces D-VHS**

JVC plans to launch a digital VHS system next year, for simple data stream recording and playback. It will not in itself produce pictures, but will have to be used in conjunction with other equipment to provide digital to analogue conversion. With encrypted broadcasts, such as DirecTV in the US, where it will first be marketed, the D-VHS VCR will record the compressed, encrypted data as received from the satellite, and play it back into the receiver at the same stage in the conversion process - before the signal is decrypted, re-expanded and converted to analogue for feeding to a TV set.

D-VHS uses virtually the same head mechanism as existing VHS and VCRs will still be able to play and record analogue material, though there will be no cross-over between the two modes. D-VHS capacity will add about £250 to the price of whatever type of VCR it is built into. JVC believes D-VHS has computer and multimedia applications, but mainly as a back-up. "We are not trying to compete with the disc format in multimedia - disc has quick access, but tape has high capacity and low cost," said planning manager Kazuo Kohda. Data capacity of a reusable E240-D-VHS video recorders will record compressed, encrypted data as received from the satellite, and play it back into the receiver at the same stage in the conversion process - before the signal is decrypted, re-expanded and converted to analogue for feeding to a TV set. D-VHS uses virtually the same head mechanism as existing VHS and VCRs will still be able to play and record analogue material, though there will be no cross-over between the two modes. D-VHS capacity will add about £250 to the price of whatever type of VCR it is built into. JVC believes D-VHS has computer and multimedia applications, but mainly as a back-up. "We are not trying to compete with the disc format in multimedia - disc has quick access, but tape has high capacity and low cost," said planning manager Kazuo Kohda. Data capacity of a reusable E240-D-VHS video recorders will record compressed, encrypted data as received from the satellite, and play it back into the receiver at the same stage in the conversion process - before the signal is decrypted, re-expanded and converted to analogue for feeding to a TV set.

D-VHS video recorders will record compressed, encrypted data as received from the satellite, and play it back into the receiver at the same stage in the conversion process - before the signal is decrypted, re-expanded and converted to analogue for feeding to a TV set.

**Single panel optical system**

Video projectors have proved a boon to those needing a large screen display. Unfortunately, achieving a bright image has meant using a large and expensive system, while those without the space and cash have had to put up with viewing in a darkened room.

A new development from Sharp boosts light output of the compact and comparatively inexpensive single LCD panel projector. Incorporated in a recently launched projector unit, this technology involves a single-panel optical system featuring "filter-less" technology. Instead of using a mosaic of red, green and blue filters over the pixels to provide colour from a white light source as is the case with conventional panels, the single panel system employs three dichroic mirrors to first separate the light into its primary colours and then pass through clear pixels. The dichroic mirrors selectively reflect and transmit the light: the first...
Telephone-line tv advances

Video compression and transmission technology must be available on a single chip costing less than $90 for video over telephone lines to become a commercial reality, according to Motorola.

The company also believes it now has the technology to achieve this with the licensing of the discrete multi-tone modulation scheme, DMT, developed by specialist Californian designer Amarti Communications.

Amarti’s DMT analogue line modulation scheme will be incorporated into a single chip transceiver for the asymmetrical digital subscriber line, ADSL, systems which operators like BT plan to use to deploy video-on-demand services operates over existing telephone lines.

Current ADSL systems, including those being evaluated by BT, support one-way video transmission to the subscriber using a 2Mbit/s digital channel. Amarti claims that its DMT-based technology will support a 6Mbit/s channel to the same subscriber and a 640kbit/s return channel to the exchange. As well as supporting multiple tv channel transmission, an integrated DMT transceiver could reduce the cost of ADSL hardware.

Motorola, which plans to market its first DMT chips in 1996, has set a target price for ADSL hardware. Motorola, which plans to market its first DMT chips in 1996, has set a target price for ADSL hardware. Motorola, which plans to market its first DMT chips in 1996, has set a target price for ADSL hardware. Motorola, which plans to market its first DMT chips in 1996, has set a target price for ADSL hardware.

One possible drawback with DMT is the duplication of the dps functions across the 256 transmitters. But according to Amarti the FFT carrier generation is more efficient than the adaptive equalisation techniques used in fixed-band QAM transmission. The company suggests that its FFT-based ADSL design is five times less complex than a 200 tap equaliser needed to implement a 1.5Mbit/s QAM ADSL channel.

Richard Wilson, Electronics Weekly

Cateyes gain intelligence

An innovation from Doncaster-based r&d firm Astucia could save the European Union over £2bn, and more than 2500 lives per year, claims Martin Dicks, Astucia’s managing director.

The invention is a light-emitting catseye, named Intelligent Road Stud, IRS, that can warn drivers of impending dangers on the road. The IRS circuit consists of couple of microcontrollers, a solar cell and an array of sensors powered by daylight, car headlights or a battery.

Depending the danger the IRS will emit red, blue, orange or white light respectively. Dicks said the DoT is interested in evaluating the device.
Silicon shortage scare

Another shortage scare looks set to hit the electronics industry, with reports that demand for polycrystalline silicon is about to outstrip supply.

Concern about the supply of polycrystalline silicon—the raw material for monocrystalline ingot production—is growing as the continuing boom in chip sales spurs semiconductor manufacturers to step up demand for wafers.

According to reports last week in Japanese trade paper Japan Chemical Week, the world demand for polycrystalline silicon this year is estimated to be 13,500 tonnes whereas total production is unlikely to exceed 12,000 tonnes.

The scare follows reports earlier this year that tantalum capacitors are in short supply, and last year’s scare of a chip packaging shortage after a fire at the major resin supplier’s factory. However, some observers suspect the shortage stories are a ploy designed to push up prices.

A source within the polycrystalline silicon supply industry said: “Polysilicon is not in such short supply that wafer manufacturers should worry.” He went on to explain: “There is still room for process improvement and the major companies are expanding cautiously without discussing it.”

Steve Bush, Electronics Weekly

Bending superconductors around the corner?

US Government researchers claim to have created a breakthrough superconducting material that is flexible rather than brittle and can be used in a wide number of applications.

Scientists at the Los Alamos National Laboratory in New Mexico, described the new material at a meeting of the Materials Research Society in San Francisco recently.

They demonstrated a flexible metal and ceramic foil that they said can be made into wires with a huge current carrying capacity at liquid nitrogen temperatures.

The superconductor is a ceramic material based on yttrium barium copper oxide deposited on a nickel tape to give it flexibility. Previous superconducting materials have been too brittle to form wires.

Dean Petersen, head of the Los Alamos National Laboratories’ Superconductivity Center, said that the superconducting material can carry more than a million amperes per square centimetre compared with No 12 copper wire that carries 800A/cm².

Blue lasers get the green light

The US Advanced Research Projects Agency is funding development of blue-light laser diodes by Philips subsidiary, Philips Laboratories and Cree Research.

ARPA has given a $4m grant for a two year project to develop blue-light laser diodes based on gallium-nitride materials on silicon carbide wafers. One focus of the project will be to develop higher capacity optical data storage devices.

“In a system that is constantly looking for ways to increase storage capacity, the blue laser is a significant missing link,” said Neal Hunter, president of Cree Research.

Other firms are also trying to find ways to build blue laser diodes cheaply. Advanced Technology Materials is working with Hewlett-Packard to develop blue laser diodes, also using gallium nitride. Japanese firm Nichia Chemical Industries says it is already sampling blue laser diodes for about $30.

First distributor on the Net

SEI is the first European distributor to use Internet to make its product information available to customers across Europe. The company believes the Internet project will ultimately transform pan-European distribution. It will change how customers internationally do their business,” said Wim Teunissen, a member of SEI’s European managing board. A full system including on-line pricing and ordering will be available before the end of the year.
LOW COST PC - ALL ENCAPSULABLE - ALL PC COMPATIBLE

Limited quantity! Only 128MB Hi GRADE 256MB systems available at a Shell, or pass the specification, the system was
made in the USA to an industrial specification, the system was
guaranteed and operate from standard voltages and are of standard
stated) are BRAND NEW or removed from often brand new equip-
ments.

At this price - Don't miss it!!

Superb quality & speed 400K virtually new, Ultra Smart
Less than Half Price!

Top quality 12" rack cabinets made in UK by Optimus
Cabinets Ltd. Made with a designer, smoked acrylic lockable front
door, full width rear access panel, side panels. All doors and
removable side panels. Fully adjustable internal shelving and
configuration of equipment mounting plus rear access panel. (All
switched makes distribution strip make these cabinets

All prices over £100 are subject to 10 working days clearance. Carriage charges (A)=£3.00, (A1)=£64.00,
All prices for £50.00 UK Mainland. UK customers add 17.5% VAT to TOTAL order amount. Minimum order £10. Bona Fide account orders accepted from Government, Schools,
Universities and Local Authorities - minimum account order £50. Cheques over £100 are subject to 10 working days clearance. Carriage charges (A)=£3.00, (A1)=£64.00,

For MAJOR SAVINGS - SAE or CALL FOR LATEST LIST

Tough Screen System

The Tough Screen System technology made by the experts
Micro-Touch Systems Ltd. is now available at Surplus
always

Surplus always

For in-fo / list. Call with your requirements.

KME 10" high definition colour CRT display with 0.28 dot pitch and guaranteed resolution of 1024 x 768. A
variable inputs allows connection to a host of
computers including IBM PCs in CEGA, EGA &
COMMODOREs (including

Call for in-fo / list.

For Sponsors, Clubs, Dubs, etc. in

The Telebox consists of an attractive fully cased mains powered
unit, containing all electronics ready to plug into a host of video moni-
tors you will ever see -

SPECIAL INTEREST

Call with your requirements.

For Cable / hyperband reception Telebox MB should be connected
to a PC for a myriad of applications including: control pan-

Special Offer save £16.55 - Order TELEBOX ST & KMC1045 - together giving you a quality colour TV & AV

The Telebox consists of an attractive fully cased mains powered
unit, containing all electronics ready to plug into a host of video moni-
tors you will ever see -

SPECIAL INTEREST

Call with your requirements.

For Cable / hyperband reception Telebox MB should be connected
to a PC for a myriad of applications including: control pan-

Special Offer save £16.55 - Order TELEBOX ST & KMC1045 - together giving you a quality colour TV & AV

The Telebox consists of an attractive fully cased mains powered
unit, containing all electronics ready to plug into a host of video moni-
tors you will ever see -

SPECIAL INTEREST

Call with your requirements.

For Cable / hyperband reception Telebox MB should be connected
to a PC for a myriad of applications including: control pan-

Special Offer save £16.55 - Order TELEBOX ST & KMC1045 - together giving you a quality colour TV & AV

The Telebox consists of an attractive fully cased mains powered
unit, containing all electronics ready to plug into a host of video moni-
tors you will ever see -

SPECIAL INTEREST

Call with your requirements.
At last, professional schematic and PCB design software for Microsoft Windows is available at prices that won't break the bank. CADPAK for Windows offers entry level schematic and PCB drafting whilst PROPAK for Windows adds netlist integration, multi-sheet schematics, highly effective autorouting, power plane generation and much more.

ISIS Illustrator was the first schematic drawing package for Windows and it's still the best. Illustrator's editing features will enable you to create circuit diagrams as attractive as the ones in the magazines.

- Runs under Windows 3.1.
- Full control of drawing appearance including line widths, fill styles, fonts, colours and more.
- Automatic wire routing and dot placement.
- Fully automatic annotator.
- Comes complete with component libraries; edit your own parts directly on the drawing.
- Full set of 2D drawing primitives + symbol library for logos etc.
- Exports diagrams to other applications via the clipboard.

ARES for Windows provides all the functionality you need to create top quality PCB layouts under Microsoft's GUI. Combining the best of our DOS based PCB layout technology with the best of Windows, this package is our most powerful and easy to use PCB design tool to date.

- True 32 bit application under Windows 3.1.
- Advanced route editing allows modification or deletion of any section of a track.
- Unlimited number of named pad/track styles.
- Comprehensive package library for both through hole and SMT parts.
- Full imperial & metric support including all dialogue forms.
- Gerber, Excellon and DXF outputs as well as output via Windows drivers. Also includes Gerber viewer.
- Multi-strategy autorouter gives high completion rates; power plane generator creates ground planes with ease.

Low Prices!

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>CADPAK for Windows</td>
<td>£149</td>
</tr>
<tr>
<td>CADPAK for DOS</td>
<td>£79</td>
</tr>
<tr>
<td>PROPAK for Windows</td>
<td>£495</td>
</tr>
<tr>
<td>PROPAK for DOS</td>
<td>£395</td>
</tr>
</tbody>
</table>

Call us today on 01756 753440 or else fax 01756 752857 for a demo pack - please state DOS or Windows as these products are available for both platforms.

63-65 Main St, Grassington, N. Yorks, BD23 5AA
RESEARCH NOTES

Jonathan Campbell

Fibre comms comes to the front door

Simple laser/fibre linking technology, a tenth the cost of current approaches but putting into a fibre more than seven times the level of light than competing systems, has been developed by BT Laboratories, Martlesham (BTL). Advantage of the technique is that it overcomes the alignment problems which dog today’s systems and make fibre links so expensive. With such a dramatic reduction in price – down from £100 to perhaps £10 – the prospect of high speed fibre optics finding their way into individual homes has become several steps closer. For consumers that means huge increases in the volumes of data they will be able to access down the telephone line.

The reason fibre optic links are so costly now is that optically-efficient attachment of the semiconductor laser to the fibre is difficult. To work effectively, optical fibres must be aligned to within less than 1µm. An offset of only 1.2µm halves the amount of light that can be coupled into the fibre. Normally this requires expensive active alignment, with each laser having to be turned on while the fibre is moved around in front of it to maximise the coupled light. Fixing the fibre in place then involves computer-controlled welding using a high power laser.

But BTL has redesigned the shape of the laser to incorporate of a taper allowing light to coupled directly to the cleaved fibre with efficiencies around 50%. At the same time, a special cleaving technique allows the position of the laser active region relative to the edge of the chip to be known to 25µm.

The final task has been developing a micro-machined silicon mount to sit the laser on. This incorporated a silica stop, to which the laser is aligned simply by pushing it in until contact is made, and a precision etched V-groove in which the fibre may be glued. Ian Lealman, part of the BTL team, says so far research samples have been tested and the search is on for a ‘down-stream’ comms company to develop the technology.

Organic leds: colour limits pushed aside

Researchers in Japan and Sweden have pushed back the old colour limits on leds just a little further with announcement of an organic white light device that could glow as brightly as a fluorescent tube, and a polymer blend led that promises emission of any colour simply by adjusting the voltage.

Various multi-layer systems have been proposed before to obtain different colours. But white-light devices have always caused a problem because of the dearth of white fluorescent dyes.

Now Junji Kido, Masato Kimura and Katsutoshi Nagai at Yamagata University in Japan have used thin film technology to create a device that simultaneously emits blue, green and red wavelengths to produce bright white light (Multi-layer white light-emitting organic electroluminescent device, Science, 267, pp.1332-1334).

Conventional leds comprise an emitter layer and a carrier transport layer. But doping the emitter layer with a different coloured fluorescent dye can produce light that is mix of the two emissions.

Carrier recombination can also be controlled so that emission takes place in two different layers. A hole-blocking layer inserted between the electron transport layer and hole transport layer, can force carrier recombination – and so light emission – to occur in both layers.

The Japanese white light led puts both methods to work. Onto a hole-injecting indium-tin-oxide-coated glass substrate (ITO), are vacuum deposited a series of layers beginning with TPD (triphenyl-diamine derivative) showing emissions at 410-420nm, in the blue region. Next comes a 1,2,4-triazole derivative layer that transports electrons but blocks holes; and this is followed by three layers of an electron-transporting aluminium complex (Alq) that emits at 520nm, green. The middle Alq layer is also doped with nile red, emitting at 600nm. Finally, a magnesium-silver alloy is used as the hole injecting electrode.

Applying dc voltage, with ITO positive, produces white light visible through the glass substrate.

The researchers report that luminance starts at around 6V, improving up to a maximum of 2200cd/m² at 16V. Optimisation of structure and materials could lead to devices exceeding the 8000cd/m² of fluorescent lamps.

Uses for such white light devices include lightweight applications such as aircraft or space shuttles. But they could be useful as backlights.
Research in Sweden into polymer blends could enable any colour to be generated simply by changing the voltage.

for liquid crystal displays and, with suitable micropatterned colour filters, in full colour displays too. Another led advance aimed squarely at colour displays is a polymer-blend device being developed by Magnus Berggren and colleagues in Sweden (Light-emitting diodes with variable colours form polymer blends, Nature, 372, pp.444-446). His team’s design strategy has been to control the geometry of a thiophene polymer main chain, producing a family of blends combining materials with different band gaps. Colours ranging from blue to near infra-red, with green, orange and red as intermediate steps can be produced, with intensity ratio of the peaks being determined by the voltage applied and stochiometry of the polymer blend.

So far, the precise mechanism for the phenomenon has not been positively established, but the researchers say they can easily combine colours such as red and blue, green and red, orange and blue and expect soon to be able to combine red, green and blue. When perfected, the simplicity of forming multi-colour screens with passive addressing of individual multi-colour pixels could make the technology irresistible to display engineers.

Nanowires must still have a little flab

Scientists at Georgia Tech in the US and Universidad Autonoma de Madrid in Spain are warning researchers that there are limits to how small the wires can be made in miniaturised components. Those nanowires must still have a little flab. Scientists at Georgia Tech in the US and Universidad Autonoma de Madrid in Spain are warning researchers that there are limits to how small the wires can be made in miniaturised components. Those nanowires must still have a little flab.

Adding a spark to video games

Virtual reality may have brought added realism to computer combat games. But there is still one aspect of life in silicon city that just doesn’t ring true: where’s the pain? Exchanging karate kicks with on-screen adversaries is only another empty experience without the physical jolt of heads cracking and ribs breaking.

Fortunately, El Segundo-based Aura Systems may have shown us the solution. Aura has developed a special combat vest to be worn during game playing. It responds to sound, so that when, for example, a fist thuds into vital organs, the vest vibrates to give the player a stronger taste of the action.

Unfortunately, some of the first kids to try out the new hardware were a little less than grateful, plainly expecting more from a former defence company. One teenage tester complained disappointedly that it was hard to tell a punch from a cheering crowd.

So the race is still on to develop a computer peripheral that can convey to the compulsive electronic combat kid some of the real fun and excitement of going to war, whether it’s with alien invaders or local bandanna-wearing street fighters.

Maybe EW + WW readers could connect up something these desperate children really need. Though surely those reaching for their March issue and the article on Tesla coils have got completely the wrong idea.
When Jack becomes a telecomms design engineer he won’t have to climb a beanstalk or brave a giant to find the leading-edge telecom solutions he needs.

Ambar Components supplies and supports the broad range of Mitel Semiconductor telecom system solutions - from analogue switches to ISDN interfaces, from DTMF receivers to high capacity switches, from industry standard to full custom devices.

Ambar Components has it all, and with the best application support service to boot! Be quicker and smarter than Jack and call 01844 261144 today for a comprehensive Mitel Semiconductor information pack.

Ambar Components Ltd
A Metec International Components Group Company

17 Thame Park Road,
Thame,
Oxon OX9 3XD
Tel: 01844 261144
Fax: 01844 261789
New leds promising for flat panel displays

Organic leds demonstrating a 30-fold improvement in stability and significantly lower operating voltages – and so power consumption – have been developed by researchers at AT&T Bell Laboratories in the US. The improvements were achieved in a class of devices where an electron transporting layer (ET) is incorporated into the design to improve quantum efficiency by confining holes to the emissive layer and ensuring that both holes and electrons are generated. The ET layer also boosts power efficiency by aiding electron injection from the cathode. What the Bell team has done (Science, Vol 267, pp.1969-1971) is to develop a new ET material that boosts power efficiency by almost a factor of 10, producing devices that have a low turn-on voltage of 6 to 10V, compared to 30V normally. The figure is similar to that for devices without an ET layer, but of course with all the efficiency advantages of the layer retained. The researchers also established conclusively that the most important factor in determining diode stability is the electron transporter used. Several new ET materials were investigated as part of the study and compared with conventional ET layers. Best performance was achieved with a poly(aryl ether) layer and this compound was also able to pass as much as 3A/cm² before failure.

All the leds were composed of the two thin layers of organic material – PPV (poly(p-phenylenevinylene)) and the polymeric ET layer – sandwiched between indium tin oxide (ITO) and aluminium electrodes. The scientists say the improvements demonstrate the strong promise of this type of device in indicators and flat panel displays etc.

Video stills lose their fuzz

Many video enhancement techniques take account of motion that occurs between frames. But a new technique developed by workers at the University of Rochester, New York, and Eastman Kodak attempts to compensate for movements within a single frame. Results are said to dramatically improve picture quality and allow single images from fast moving scenes to be output to a printer without blurring. Such a facility is likely to become more important with the growing integration between tvs, videos and computer systems. The method should also reduce some of the drawbacks experienced in transferring film to tv, problems that are not discernible on a normal tv set but which could become apparent on hdtv.

Rochester postgrad Andrew Patti, who with a Kodak colleague has filed four patents related to the technique, summarises how the process operates: "The one image you want is related to all the images before and after it. We extract that information and use it to clarify our image", he says. The technique could also find application in forensics and satellite imaging; or anywhere there is need to generate a clear frame from a video.
For all your Power Distribution
Olson offer a varied choice

Distribution Units

DISTRIBUTION PANELS
FUSED WITH RCBO
AND DOUBLE POLE MCB PROTECTION

Distribution Units

FUSED WITH RCBO
PROTECTION AND DOUBLE POLE MCB PROTECTION

OLSON Distribution
Office Furniture
Fused with 16AMP FUSE
SHUTTERED SOCKETS

The Rank Range
Panel with 16 x 16 AMP
Standard NC AR.

Mains Distribution Panels
INTERNATIONAL RANGE

Distribution
Units

Earthing
Distribution
Units

Earth Leakage
Distribution
Units

INDUSTRIAL RANGE
16 AMP 110V AND 230V
TO BS 4343/IEC 309

OFFICE FURNITURE

OLSON ELECTRONICS LIMITED

FOUNTAYNE HOUSE, FOUNTAYNE RD., LONDON N15 4QIL
TEL: 0181-885 2884 FAX: 0181-885 2496
I present here my own contribution to global warming in the form of an improved Class-A amplifier that I believe is unique. It not only copes with load impedance dips by means of an unusually linear form of Class-AB, but will also operate as a 'blameless' Class-B engine. The power output in pure Class-A is 20 to 30W into 8Ω, depending on the exact supply rails chosen.

Initially, I simply intended to provide an updated version of the Class-A circuit published in reference 1, in response to requests for a PCB for the Class-A amplifier designed with my methodology. I decided to use a complementary-feedback-pair, or cfp, output stage for best possible linearity, and some incremental improvements have been made to noise, slew rate and maximum dc offset.

Naturally, the Class-A circuit bears a very close resemblance to a 'blameless' Class-B amplifier. As a result, I decided to retain the Class-B V<sub>be</sub> multiplier, and use it as a safety-circuit to prevent catastrophe if the relatively complex Class-A current-regulator failed. From this the idea arose of making the amplifier instantly switchable between Class-A/AB and Class-B modes. This gives two kinds of amplifier for the price of one, and permits of some interesting listening tests. Now you really can do an A/R comparison...

In the Class-B mode the amplifier has the usual negligible quiescent dissipation, but in Class-A the thermal efflux is naturally considerable. This is because true Class-A operation is extended down to 6Ω resistive loads for the full output voltage swing, by suitable choice of the quiescent current.

With heavier loading the amplifier gracefully enters Class-AB, in which it will give full output down to 3Ω before the safe-operating-area, SOAR, limiting begins to act. Output into 2Ω is severely curtailed, as it must be with only one output pair, and this kind of load is not advisable.

In short, the amplifier allows a choice between being firstly very linear all the time - blameless Class-B - and secondly ultra-linear most of the time - Class-A - with occasional excursions into Class-AB.

The amplifier's AB mode is still extremely linear by current standards, though inherently it can never be as good as properly-handled Class-B, and nothing like as good as A. Since there are three possible classes of operation I have decided to call the design a Trimodal power amplifier. It is impossible to be sure that you have read all the literature on an area of tech-
nology; however, to the best of my knowledge this is the first ever Trimodal amplifier. As I said earlier, designing a low-distortion Class-A amplifier is in general a good deal simpler than the same exercise for Class-B. All the difficulties of arranging the best possible crossover between the output devices disappear. Because of this it is hard to define exactly what 'blameless' means for a Class-A amplifier.

In Class-B the situation is quite different, and 'blameless' has a very specific meaning; when each of the eight or more distortion mechanisms has been minimised in effect, there always remains the crossover distortion inherent in Class-B. There appears to be no way to reduce it without departing radically from what might be called the generic Lin amplifier concept. Therefore the 'blameless' state appears to represent some sort of theoretical limit for Class-B, but not for Class-A.

However, Class-B considerations cannot be ignored, even in a design intended to be Class-A only, because if the amplifier does find itself driving a lower load impedance than expected, it will move into Class-AB. In this case, all the additional Class-B requirements are just as significant as for a Class-B design proper. Class-AB can never give distortion as low as optimally-biased Class-B, but it can be made comparable if the extra distortion mechanisms are correctly handled.

My correspondence has made it abundantly clear that EW readers are not going to be satisfied with anything less than state-of-the-art linearity, and so the amplifier described here uses the complementary-feedback-pair type of output stage, which has the lowest distortion due to the local feedback loops enclosing the output devices. It also has the advantage of better output efficiency than the emitter-follower version, and inherently superior quiescent current stability. It will shortly be seen that these are both important for this design.

Half-serious thought was given to labelling the Class-A mode 'distortionless' as the thd is completely unmeasurable across most of the audio band. However, detectable distortion products do exist above 10kHz, so sadly, I abandoned this provocative idea.

Before putting cursor to CAD, it seemed appropriate to take another look at the Class-A design, to see if it could be inched a few steps nearer perfection. The result is a slight improvement in efficiency, and a 2dB improvement in noise performance. In addition the expected range of output dc offset has been reduced from ±50mV to ±15mV, still without any adjustment.

The power and the glory

The amplifier is 4Ω capable in both A/AB and B operating modes, though it is the nature of things that the distortion performance is not quite so good. All solid-state amplifiers — without qualification, as far as I am aware — are much happier with an 8Ω load, both in terms of linearity and efficiency; loudspeaker designers please note.

With a 4Ω load, Class-B operation gives better thd than Class-A/AB, because the latter will always be in AB mode, and therefore generating extra output stage distortion throughgm-doubling. This should really be called gain-deficit-halving, but somehow I don’t see this term catching on. These not entirely obvious relationships are summarised on the right.

Figure 1 attempts to show diagrammatically just how power, load resistance, and operating mode are related. The rails have been set to ±20V, which just allows 20W into 8Ω in Class-A. The curves are lines of constant power, ie V²/I in the load, the upper horizontal line represents maximum voltage output, allowing for V_ref, and the sloping line on the right is the SOAR protection locus; the output can never move outside this area in either mode. The intersection between the load resistance lines sloping up from the origin and the ultimate limits of voltage-clip and SOAR protection define which of the curved constant-power lines is reached.

In A/AB mode, the operating point must be left of the vertical push-pull current-limit line for true Class-A. If we move along one of the impedance lines, when we pass to the right of the push-pull limit the output devices will begin turning off for part of the cycle; this is the AB operation zone. In Class-B mode, the 3A line has no significance and the amplifier remains in optimal Class-B until clipping or SOAR limiting occurs. Note that the diagram axes represent instantaneous power in the load, but the curves show sine-wave rms power, and that is the reason for the apparent factor-of-two discrepancy between them.

Health and efficiency

Concern for efficiency in Class-A may seem paradoxical, but one way of looking at it is that Class-A watts are precious things, wrought in great heat and dissipation, and so for a given quiescent power it makes sense to ensure that the amplifier approaches its limited theoretical efficiency as closely as possible. I was confirmed in this course by reading

<table>
<thead>
<tr>
<th>Load</th>
<th>Mode</th>
<th>Distortion</th>
<th>Dissipation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Ω</td>
<td>A/AB</td>
<td>very low</td>
<td>high</td>
</tr>
<tr>
<td>4Ω</td>
<td>A/AB</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>8Ω</td>
<td>B</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>8Ω</td>
<td>B</td>
<td>medium</td>
<td>medium</td>
</tr>
</tbody>
</table>

Note that in the context of this sort of amplifier, 'high' means about 0.002% thd at 1kHz and 0.01% at 10kHz.
AUDIO DESIGN

CLASS-B BIAS/CLASS-A SAFETY CIRCUIT
MODE SWITCH

Fig. 2. Basic current feedback output stage, equally suited to operating Class B, AB and A, depending the magnitude of Vbias. The emitter resistors Re may be from 0.1 to 0.47Ω.

Fig. 3. PSpice simulation showing how positive clipping occurs in the current feedback output. A higher sub-rail for the voltage amplifier cannot increase the output swing, as the limit is set by the minimum driver Vce, and not the voltage amplifier output swing.

of another recent design⁴ which seems to throw efficiency to the winds by using a hybrid bjt/fet cascode output stage. The voltage losses inherent in this arrangement demand ±50V rails and sixfold output devices for a 100W Class-A capability; such rail voltages would give 156W from a 100% efficient amplifier.

Voltage efficiency of a power amplifier is the fraction of the supply-rail voltage which can actually be delivered as peak-to-peak voltage swing into a specified load; efficiency is invariably less into 8Ω due to the greater resistive voltage drops with increased current.

The Class-B amplifier I described in reference 3 has a voltage efficiency of 91.7% for positive swings, and 92.5% for negative, into 8Ω. Amplifiers are not in general completely symmetrical, and so two figures need to be quoted; alternatively the lower of the two can be given as this defines the maximum undistorted sine-wave. These figures above are for an emitter-follower output stage, and a complementary-feedback pair output does better, the positive and negative efficiencies being 94.0% and 94.7% respectively.

The emitter follower version gives a lower output swing because it has two more Vbe drops in series to be accommodated between the supply rails; the complementary-feedback pair is always more voltage-efficient, and so selecting it over the emitter follower for the current Class-A design is the first step in maximising efficiency.

Figure 2 shows the basic complementary-feedback pair output stage, together with its two biasing elements. In Class-A the quiescent current is rigidly controlled by negative-feedback; this is possible because in Class-A the total voltage across both emitter resistors Re is constant throughout the cycle. In Class-B this is not the case, and we must rely on "thermal feedback" from the output stage, though to be strictly accurate this is not "feedback" at all, but a kind of feed-forward.

It is a big advantage of the complementary-feedback pair configuration that quiescent current, IQ, depends only on driver temperature, and this is important in the Class-B mode, where true feedback control of quiescent current is not possible. This has special force if low-value emitter resistors such as 0.1Ω, are chosen, rather than the more usual 0.22Ω; the motivation for doing this will soon become clear.

Voltage efficiency for the quasi-complementary Class-A circuit of reference 1 into 8Ω is 89.8% positive and 92.2% negative. Converting this to the complementary-feedback pair output stage increases this to 92.9% positive and 93.6% negative. Note that a Class-A IQ of 1.5A is assumed throughout; this allows 31W into 8Ω in push-pull, if the supply rails are adequately high. However the assumption that loudspeaker impedance never drops below 8Ω is distinctly doubtful, to put it mildly, and so as before this design allows for full Class-A output voltage swing into loads down to 6Ω.

So how else can we improve efficiency? The addition of extra and higher supply rails for the small-signal section of the amplifier surprisingly does not give a significant increase in output; examination of Fig. 3 shows why. In this region of operation, the output device Tr7 base is at a virtually constant 880mV below the positive rail, and as Tr6 driver base rises it passes this level, and keeps going up; clipping has not yet occurred.

The driver emitter follows the driver base up, until the volta
dage difference between this emitter and the output base, ie the driver Vce, becomes too small to allow further conduction; this choke point is indicated by the arrows A-A. At this point
the driver base is forced to level off, although it is still about 500mV below the level of the positive rail. Note also how the voltage between the positive rail and TR3 emitter collapses. Thus a higher rail will give no extra voltage swing, which I must admit came as something of a surprise. Higher sub-rails for small-signal sections only come into their own in fet amplifiers, where the high Vgs for fet conduction (5V or more) makes their use almost mandatory.

Efficiency figures given so far are all greater for negative rather than positive voltage swings. The approach to the rail for negative clipping is slightly closer because there is no equivalent to the 0.6V bias established across R13; however this advantage is absorbed by the need to lose a little voltage in the RC filtering of the negative supply to the current-mirror and voltage amplifier stage. This filtering is essential if really good ripple/hum performance is to be obtained.

In the quest for efficiency, an obvious variable is the value of the output emitter resistors Re. The performance of the current-regulator described, especially when combined with a complementary-feedback pair output stage, is more than good enough to allow these resistors to be reduced while retaining first-class $I_e$ stability. I took 0.1Ω as the lowest practicable value, and even this is comparable with pcb track resistance, so some care in the exact details of physical layout is essential; in particular the emitter resistors must be treated as four-terminal components to exclude unwanted voltage drops in the tracks leading to the resistor pads.

If Re is reduced from 0.22Ω to 0.1Ω then voltage efficiency improves from 92.9%/93.6%, to 94.2%/95.0%. Is this improvement worth having? Well, the voltage-limited power output into 8Ω is increased from 31.2 to 32.2W with ±24V rails, at absolutely zero cost, but it would be idle to pretend that the resulting increase in sound-pressure level is highly significant. It does however provide the philosophical satisfaction that as much Class-A power as possible is being produced for a given dissipation; a delicate pleasure.

The linearity of the complementary-feedback pair output stage in Class-A is very slightly worse with 0.1Ω emitter resistors, though the difference is small and only detectable open-loop; the simulated thd of an output stage alone (for 20V pk-pk in 8Ω) is only increased from 0.0027% to 0.0029% This is probably due simply to the slightly lower total resistance seen by the output stage.

However, at the same time, reducing the emitter resistors to 0.1Ω provides much lower distortion when the amplifier runs out of Class-A; it halves the size of the step gain changes inherent in Class-AB, and so effectively reduces distortion into 4Ω loads.

Figures 4 & 5 are output linearity simulations; the measured results from a real and 'blameless' Trimodal amplifier are shown in Fig. 6, where it can be clearly seen that thd has been halved by this simple change. To the best of my knowledge this is a new result; my conclusion is that if you must work in Class-AB, keep the emitter resistors as low as possible, to minimise the gain changes.

Having considered the linearity of Class-A and AB, we must not neglect what effect this radical Re change has on Class-B linearity. The answer is, not very much, but there is a slight reduction in thd, Fig. 7, where crossover distortion seems to be slightly higher with Re at 0.2Ω than for either 0.1 or 0.4Ω. Whether this is a consistent effect - for complementary-feedback pair stages anyway - remains to be seen.

The detailed mechanisms of bias control and mode-switching are described in the second part of this article.
Improving noise performance

In a power amplifier, noise performance is not an irrelevance. It is well worth examining just how good it can be. As in most amplifiers, noise is set here by a combination of the active devices at the input and the surrounding resistances.

Operating conditions of the input transistors themselves are set by the demands of linearity and slew-rate, and there is little freedom of design here; however the collector currents are already high enough to give near-optimal noise figures with low source impedances—a few hundred ohms—that we have here, so this is not too great a problem. Also remember that noise figure is a weak function of \( I_c \), so minor tweaking makes no detectable difference. We certainly have the choice of input device type; there are many more possibilities now that we have relatively low rail voltages. Noise performance is, however, closely bound up with source impedance, and we need to define this before device selection.

Looking therefore to the passives, there are several resistances generating Johnson noise in the input, and the only way to reduce this noise is to reduce them in value. The obvious candidates are input stage degeneration resistors \( R_{2,3} \) and \( R_b \), which determines the output impedance of the negative-feedback network. There is also another unseen component; the source resistance of the preamplifier or whatever upstream.

Even if this equipment were miraculously noise-free, its output resistance would still generate Johnson noise. If the preamplifier had, say, a 20kΩ volume pot at its output—not a good idea, as this gives a poor gain structure and cable dependent high-frequency roll-off point. A major stumbling block for subjectivist reviewing, one would have thought.

The presence of input degeneration resistors \( R_{2,3} \) is the price we pay for linearising the input stage by running it at a high current, and then bringing its transconductance down to a useable value by adding linearising local negative feedback. These resistors cannot be reduced, for if the hf negative-feedback factor is then to remain constant, \( C_{dc} \) would have to be proportionally increased, with a consequent reduction in slew rate. Used with the original negative feedback network, these resistors degrade the noise performance by 1.7dB. Like almost all the other noise measurements given here, this figure assumes a 50Ω external source resistance.

If we cannot alter the input degeneration resistors, then the only course left is the reduction of the feedback network impedance, and this sets off a whole train of consequences. If \( R_b \) is reduced to 2.2kΩ, then \( R_b \) becomes 110kΩ, and this reduces noise output by only -93.4dBu. Note that if \( R_{2,3} \) were not present, the respective figures would be -95.2 and -98.2dBu. However, \( R_f \) must also be reduced to 2.2kΩ to maintain dc balance, and this is too low an input impedance for direct connection to the outside world.

If we accept that the basic amplifier will have a low input impedance, there are two ways to deal with it. The simplest is to decide that a balanced line input is essential; this pushes the opamp stage before the amplifier proper, buffers the low input impedance, and can provide a fixed source impedance to allow the high and low-frequency bandwidths to be properly defined by an RC network using non-electrolytic capacitors. The common practice of slapping an RC network on an unbuffered amplifier input must be roundly condemned as the source impedance is unknown, and so therefore is the roll-off point. A major stumbling block for subjectivist reviewing, one would have thought.

The other approach is to have a low resistance dc path at the input but maintain a high ac impedance; in other words to use the fine old practice of input bootstrapping. Now this requires a low-impedance unity-gain-with-respect-to-input point to drive the bootstrap capacitor, and the only one available is at the amplifier inverting input, ie the base of \( T_{33} \). While this node has historically been used for the purpose of input bootstrapping, it has only been done with simple circuitry employing very low feedback factors.

There is good reason to fear that any monkey business with the feedback point, at \( T_{33} \)’s base, will add shunt capacitance, creating a feedback pole that will degrade stability. There is also the awkward question of what will happen if the input is left open-circuit...

Figure 8 shows how the input can be safely bootstrapped.

**Fig. 7.** Proving that emitter resistors matter much less in Class-B. Output was 20W in \( R_0 \), with optimal bias. Interestingly, the bias does NOT need adjusting as the noise figure is a weak function of \( I_c \), so minor tweaking makes no detectable difference. We certainly have the choice of input device type; there are many more possibilities now that we have relatively low rail voltages. Noise performance is, however, closely bound up with source impedance, and we need to define this before device selection.

Looking therefore to the passives, there are several resistances generating Johnson noise in the input, and the only way to reduce this noise is to reduce them in value. The obvious candidates are input stage degeneration resistors \( R_{2,3} \) and \( R_b \), which determines the output impedance of the negative-feedback network. There is also another unseen component; the source resistance of the preamplifier or whatever upstream.

Even if this equipment were miraculously noise-free, its output resistance would still generate Johnson noise. If the preamplifier had, say, a 20kΩ volume pot at its output—not a good idea, as this gives a poor gain structure and cable dependent high-frequency roll-off point. A major stumbling block for subjectivist reviewing, one would have thought.

The presence of input degeneration resistors \( R_{2,3} \) is the price we pay for linearising the input stage by running it at a high current, and then bringing its transconductance down to a useable value by adding linearising local negative feedback. These resistors cannot be reduced, for if the hf negative-feedback factor is then to remain constant, \( C_{dc} \) would have to be proportionally increased, with a consequent reduction in slew rate. Used with the original negative feedback network, these resistors degrade the noise performance by 1.7dB. Like all the other noise measurements given here, this figure assumes a 50Ω external source resistance.

If we cannot alter the input degeneration resistors, then the only course left is the reduction of the feedback network impedance, and this sets off a whole train of consequences. If \( R_b \) is reduced to 2.2kΩ, then \( R_b \) becomes 110kΩ, and this reduces noise output by only -93.4dBu. Note that if \( R_{2,3} \) were not present, the respective figures would be -95.2 and -98.2dBu. However, \( R_f \) must also be reduced to 2.2kΩ to maintain dc balance, and this is too low an input impedance for direct connection to the outside world.

If we accept that the basic amplifier will have a low input impedance, there are two ways to deal with it. The simplest is to decide that a balanced line input is essential; this pushes the opamp stage before the amplifier proper, buffers the low input impedance, and can provide a fixed source impedance to allow the high and low-frequency bandwidths to be properly defined by an RC network using non-electrolytic capacitors. The common practice of slapping an RC network on an unbuffered amplifier input must be roundly condemned as the source impedance is unknown, and so therefore is the roll-off point. A major stumbling block for subjectivist reviewing, one would have thought.

The other approach is to have a low resistance dc path at the input but maintain a high ac impedance; in other words to use the fine old practice of input bootstrapping. Now this requires a low-impedance unity-gain-with-respect-to-input point to drive the bootstrap capacitor, and the only one available is at the amplifier inverting input, ie the base of \( T_{33} \). While this node has historically been used for the purpose of input bootstrapping, it has only been done with simple circuitry employing very low feedback factors.

There is good reason to fear that any monkey business with the feedback point, at \( T_{33} \)’s base, will add shunt capacitance, creating a feedback pole that will degrade stability. There is also the awkward question of what will happen if the input is left open-circuit...

Figure 8 shows how the input can be safely bootstrapped.
The total dc resistance of $R_1$ and $R_{boot}$ equals $R_b$, and their centre point is driven by $C_{boot}$. Connecting $C_{boot}$ directly to the feedback point did not produce gross instability, but it did seem to increase susceptibility to sporadic parasitic oscillation. Resistor $R_{iso}$ was added to isolate the feedback point from stray capacitance: this seemed to effect a complete cure.

The input could be left open-circuit with no apparent ill-effects, though this is not exactly good practice if loudspeakers are connected. A value for $R_{iso}$ of 220Ω increases the input impedance to 7.5kΩ, and 10Ω raises it to 13.3kΩ, safely above the 10kΩ standard value for a bridging impedance. Despite successful tests, I must admit to a few lingering doubts about the high-frequency stability of this approach, and it might be as well to consider it as experimental until more experience is gained.

Another consequence of a low-impedance negative feedback network is the need for feedback capacitor $C_2$ to be proportionally increased to maintain the low-frequency response, and prevent capacitor distortion from causing a rise in THD at low frequencies; it is the latter constraint that determines the value. This is a separate distortion mechanism from the seven previously considered, and I think deserves the title Distortion 8. This criterion gives a value of 1000µF, which necessitates a low rated voltage such as 6.3V if the component is to be of reasonable size. As a result, $C_2$ now needs protective shunt diodes in both directions, because if the amplifier fails it may saturate in either direction.

Close examination of the distortion residual shows that the onset of conduction of back-to-back diodes will cause a minor increase in THD at 1kHz, from less than 0.001% to 0.002%, even at the low power of 20W/85Ω. It is not my practice to tolerate such gross non-linearity, and therefore four diodes are used in the final circuit, and this eliminates the distortion effect, Fig. 8. It could be argued that a possible reverse-bias of 12V does not protect $C_2$ very well, but at least there will be no explosion.

We can now consider alternative input devices to the MPSA66, which was never intended as a low-noise device. Several high-beta low-noise types such as 2SA970 give an improvement of about 1.8dB with the low-impedance negative feedback network. Specialised low-$R_b$ devices like 2SK737 give little further advantage – possibly 0.1dB – and it is probably better to go for one of the high-beta types, the reason why will soon emerge.

It could be argued that the complications of a low-impedance negative feedback network are a high price to pay for a noise reduction of some 2dB; however, there is a countervailing advantage, for the above negative feedback network modification significantly improves the output dc offset performance. The second and final part of this article shows how, and also gives full details of the mode-switching and bias control systems, and the performance of the complete amplifier.

References
UNKOWN/UNREADABLE/INVALID/INCOMPLETE DOCUMENT
Seventy years after its invention, the loudspeaker is still the weakest link in the audio chain. In particular, the bass response is usually severely compromised; the bottom two octaves are a special problem. It is hard to see why the audio fraternity places so much emphasis on reducing distortion levels in power amplifiers and yet ignores the gross errors inherent in speakers.

Typically, 99% of the carefully cultivated signal delivered to a speaker heats the voice coil, the remaining 0.1% being mangled by the phase shifts and amplitude variations imposed by loudspeaker and associated crossover. What emerges from the speaker is a distorted version of the driving signal, no matter how perfect the input may be.

At the risk of being lynched by irate audiophiles and engineers, I must point out that the laws of physics dictate that a flat-response audio system cannot be produced simply by driving speaker systems from flat-response amplifiers! With current speaker systems, the only way to produce a system with a flat frequency response is to use amplifiers with a non-linear response.

An ideal speaker would behave as a pure piston, regardless of the signal frequency. No such animal exists. Practical speaker units have a cone with mass which resonates with the compliance of the surround to produce a fundamental resonance. Below this resonance, the response falls away rapidly, while above it pure piston operation is maintained over a restricted band of frequencies before the response starts to roll off again.

Designing an enclosure
At frequencies where the speaker’s diameter is less than a wavelength of the sound emitted, antiphase waves from the rear of the cone diffract around it to cancel out the wanted radiation from the front.

This is the reason why some kind of enclosure has to be used, the simplest method being to mount the speaker in a sealed enclosure. Unfortunately, the enclosed air possesses stiffness which adds to that of the speaker surround and raises the resonant frequency, which is obviously undesirable as well as unavoidable. To get an extended low-frequency response one has to enlarge the enclosure. An alternative would be to use a

Considering the speaker as part of the electronics leads to a tailored amplifier frequency response, extended bass and relatively small size — as Jeff Macaulay demonstrates with his ‘Microreflex’ full-range loudspeaker design.
Fig.1. Crossover filter board, using three quad op-amps. This, together with enclosure design, is responsible for the extended bass – an extra octave – and small size of the speaker.

Cutting list:
- Panel A: 2 pieces 512 x 152 x 15mm
- Panel B: 2 pieces 512 x 305 x 15mm
- Panel C: 2 pieces 275 x 150 x 15mm

All dimensions in mm unless otherwise stated

Vent: see text
Pod: standard 6in dia. terra cotta flower pot

Fig.2. Enclosure construction, using medium-density chipboard and lots of glue, not to mention a flowerpot.

speaker with a lower free air resonant frequency, but the efficiency of a speaker is proportional to the cube of that frequency.

Alternatively, there is the reflex enclosure, in which a duct is cut into the enclosure. The mass of air in the duct and the compliance of the air in the enclosure form a mechanical tuned circuit which is excited by the cone’s rear radiation. Duct output is out of phase with the rear radiation from the cone and in phase with the wanted output from the front. Hence, over a restricted range of frequencies, the duct or vent augments the bass output from the speaker.

Below the enclosure resonance, the radiation from the vent moves out of phase with the speaker and in consequence the extreme bass output falls off more rapidly than that from a sealed box. The transient response of the system is therefore poorer. On the plus side, though, the resonant frequency of the speaker is hardly raised from its free air value, leading to lower distortion.

A further advantage of reflex operation is that the cone excursion for a given output is greatly reduced at and near the enclosure resonance. This is because the speaker ‘sees’ the high mechanical impedance of the enclosure’s resonant circuit.

Owing to the pioneering work of Theile\textsuperscript{1}, extended by Small\textsuperscript{2}, it is a simple matter to design a good reflex speaker, although design is constrained by the characteristics of the bass units available. Again, a greatly extended low-frequency response is usually only obtainable at the expense of a large enclosure.

This state of affairs dictates that nearly all available speaker systems of a reasonable size exhibit a tendency to have little or no useable output below 60Hz, thereby losing almost two octaves of the audio band. What can be done?

There is a widespread belief that real bass cannot be generated in small boxes. However, as my neighbours will testify, this is not the case. It is simply that such performance is impossible using the techniques already described. However, several solutions have been devised, the best known probably being motional feedback, in which a small transducer is attached to the speaker cone and the resulting signal fed back into the driving amplifier’s feedback loop. This is used both to correct the low frequency roll-off and reduce harmonic distortion. A good example of this technique is shown in reference 3.

Another method, used in this design, is the 6th-order reflex speaker system in which the low-frequency response is extended by the use of an underdamped high-pass filter, commonly in the form of an op-amp circuit between preamplifier and power amps. According to Keele, the response can be extended by half an octave in exchange for 3dB less maximum drive signal\textsuperscript{4}. Other variations on the theme can be found, for example, sub-resonant speaker systems after Linkwitz\textsuperscript{5} and Harcourt\textsuperscript{6}.

What really limits the bass extension of a driver is the volume of air that can be shifted – a direct function of cone area and peak-to-
peak excursion limits. So long as the unit can be equalised to a flat response, the cabinet dimensions can be kept small without affecting the overall response. As the response curves of both sealed and reflex cabinets can now be accurately calculated, we are in a position to extend the low-frequency response of small speaker systems. All that is required is to sacrifice the sacred cow of flat-response electronics.

In reality, using filter techniques to flatten system response is both simple and inexpensive. Intellectually, it is no stranger than equalising the response of a magnetic pickup cartridge. It does, however, require a leap in thinking from the current piecemeal approach to designing a system to a more holistic view in which the acoustic performance is incorporated into the electronic design process. From such an approach comes the realisation of overall system responses that are simply impossible to achieve by purely mechanical means.

Choosing drivers
Designing a speaker system is the simultaneous solution of several, often mutually entangled problems. At best, the individual responses of the drivers used resemble asymmetrical band-pass filters, with unwanted resonances thrown in for good measure. These responses need to be modified and harnessed so that the system response resembles a band-pass filter with a flat response across the audio frequency range.

From the wide choice of possible drivers for the system, I chose Audax units for their consistent Thiele/Small parameters. The HT210FO bass and HT130FO were designed to be used together, as is evidenced by their closely matched reference efficiencies. They are also supplied in pairs, computer matched to within <0.3dB, so that gain matching between them is unnecessary.

One of the design aims was a smooth treble response and accurate integration of driver responses. After trying several tweeters, including titanium and hard-dome types, I chose the Morel MDT29, a soft-dome unit with an excellent, smooth and resonance-free response combined with an equally smooth low-frequency roll-off. It is also a robust ferro fluid-cooled unit capable of high power handling on transients.

It is now well established that a wide stereo

Due to the electronic bass-driver compensation, this full-range loudspeaker has a -3dB point of 25Hz. Response is ±3dB over the whole 25Hz to 20kHz range while power handling of the bass unit is 70W continuous.
image requires good horizontal sound dispersion. This requires a narrow enclosure, and to obtain the minimum front baffle dimensions, the bass driver is mounted on the side of the enclosure. This does not cause problems because, below 100Hz, the bass driver’s response is omnidirectional.

The mid-range driver needs its own enclosure. In three-way designs, it is common practice to mount this sub-enclosure within the main enclosure and, after a lot of head-scratching, I chose a common-or-garden 6in diameter terracotta flower pot. Although the choice may seem strange, the non-parallel shape ensures that, within the mid driver’s range, standing waves cannot occur within the sub-enclosure. This is the major cause of colouration in most enclosures and its removal tightens the sound considerably.

Mounted in this way, the HT130FO’s bass resonance is raised from 48Hz to 144Hz, with a consequent increase in Q from 0.25 to approximately 0.73, the natural choice for the crossover point between the mid-range and bass drivers. Rolling off the bass unit at this frequency also ensures that the cabinet is acoustically small. That is to say, the wavelengths of the sound radiated by the driver are much longer than the largest enclosure dimension. In consequence, standing waves cannot be generated within it.

Crossover considerations

Designed in this way, the system is without standing-wave problems and needs no exotic construction technique. A further advantage of this crossover point is that the peak output power in musical and speech signals occur around this point. Since both drivers are radiating, peak levels are some 6dB greater than continued over page

Active crossover

In a conventional passive crossover, the designer alters the Q of the network by varying the ratios of the reactive components, bearing in mind the – hopefully – resistive load presented by the speaker. In practice, this is hard to achieve because of reactive effects in the drivers.

In contrast, active crossovers are easily fabricated without recourse to inductors and are independent of driver loading. Although several possible filter configurations exist, the most suitable for active crossovers are the Sallen and Key types, in particular the ‘equal-component’ and ‘unity-gain’ variations, shown in Fig. A1.

Standard op-amps are used for the active elements and a large variety of types are available; the TLO series, used in this design, are well tried and tested and recommended for development work. In the unity-gain circuit, the op-amp is wired as a buffer. Component values for the high-pass version can be determined by the following equations.

1. Choose a convenient value for $C$, then: $R_3 = a/(1.257 \times 10^{-6} f_0 C)$.
2. $R_1 = 1/(3.142 \times 10^{-6} a f_0 C)$, where $a$ is $1/Q$ and $C$ is expressed in μF.

For the low-pass version:

3. Choose a convenient value for $R$, then: $C_1 = a/(12.57 f_0 R)$.
4. $C_2 = 1/(3.142 a f_0 R)$.

In the equal component filter:

5. $f = 159155/RC$, where $R$ is expressed in ohms and $C$ in μF.

This equation holds true for both high and low-pass filters. The Q of the filter is set by the voltage gain of the circuit, set by the ratio of $R_3$ and $R_1$. $R_3$ should be $(3-1/Q+1)|R_1$.

Higher order filters are obtained by cascading 2nd-order filters; the Q of a cascaded pair is equal to the product of the Qs of each section. Figure A1 shows the effect of Q on the response shape of a 2nd-order filter, in this case a high-pass type; the response of low-pass filters is a mirror image. Underdamped filters of Q>0.7 show a peak in the passband, while overdamped filters with Q<0.7 do not.

Filters with a Q of 0.7 are Butterworth types, which possess the flattest passband response combined with no peak. However, it can be shown that best transient response is obtained with a Q of 0.5, regardless of filter order; hence the popularity of crossovers with this Q. The standard Linkwitz-Riley crossover uses a 4th-order filter for both high and low-pass sections. A further advantage of the 4th-order filter is that the phase difference between sections is zero.
Best rf article ’95

Following the success of 1994's Writers Award, Electronics World and Hewlett-Packard are launching a new scheme to run from January to December 1995.

Only articles which have an element of rf design will be eligible for consideration by the judging panel. It is hoped that this year's award will focus writer interest on rf engineering in line with the growing importance of radio frequency systems to an increasingly cordless world.

The aim of the award scheme is to locate freelance authors who can bring applied electronics design alive for other people.

Qualifying topics might include direct digital synthesis, microstrip design, application engineering for commercially available rf ICs and modules, receiver design, PLL, frequency generation and rf measurement, wideband circuit design, spread spectrum systems, microstrip and planer aerials... The list will hopefully be endless.

All articles accepted for publication will be paid for – in the region of several hundred pounds for a typical design feature.

Win a £4000 programmable signal generator from Hewlett-Packard

The prize for the coming year's award is a £4000 Hewlett-Packard HP8647A 1GHz programmable signal generator. It features HPB interface, solid state programmable attenuator and built in AM-FM modulation capability.

For further details about our quest for the best, call or write to:
Martin Eccles, Editor, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS
Tel 081-652 3128
could be supplied by a single driver.

At the high end, the MDT29s have their fundamental 'bass' resonance at 900Hz. These units possess the frequency response of a high-pass filter which, since Q is 0.5, is critically damped. To obtain the best transient response from the system as a whole, pay careful attention to the crossover. Of the available alternatives, the best is the 4th-order Linkwitz-Riley filter, which ensures the minimum overlap between driver outputs, maintains in-phase operation and is critically damped for best transient response. Cascading two 2nd-order sections forms the 4th-order filter; in the case of the mid-range and tweeter, one of these sections is the mechanical roll-offs imposed by the mid-range enclosure and tweeter roll-offs.

In most multiway speaker systems, the crossover frequency between the mid-range and tweeter is set too high, caused by fears over the power handling of modern-day 25mm tweeters. The result is that the mid-range driver has to respond at frequencies above its piston range, where 'cone break-up' can occur; sections of the cone resonate, producing a rough response. Obviously, this is to be avoided and one cure is to lower the crossover frequency.

With the cone tweeters used in the 'fifties and early 'sixties, crossover was usually done at as low a frequency as possible. Modern dome tweeters are not so robust, although their response is considerably better, but it is still perfectly possible to run a dome tweeter down to its fundamental resonant frequency, provided that the rate of roll-off is sufficiently fast to avoid overload by low frequencies. A sealed dome tweeter acts as a 2nd-order high-pass filter. The MDT29 resonates at 900Hz, where the average power contained in a musical signal is about 10dB down on the peak, which occurs about 120Hz. By feeding the tweeter from a 2nd-order high-pass filter, the power required is reduced by a further 6dB. This is well within the rating of the unit and no overloading occurs.

A further advantage of using a lower crossover, around the 1kHz point, is that the critical upper mid-range band, 1 to 5kHz, is handled by a unit with low moving mass, ensuring superior transient response. Phase anomalies due to the usual 2-3kHz crossover are also reduced.

### Electronics

I intended the speakers to be used directly from the line outputs of a pre-amp or cd player, the entire audio system consisting of just the signal source and the speakers, and decided that the easiest way to achieve this is to mount all the electronics within the enclosure. To avoid reinventing the wheel, I used ILP HY60 amplifier modules, which provide a wide frequency range, low distortion and noise levels, and integral heat sinking. Of course, if you have three stereo amplifiers already these can be pressed into service, fed by the active filter, but anyone who does this must take care for equalising signal levels etc. themselves.

With only five connections apiece, wiring is reduced to manageable levels. I built the equalisation and crossover electronics on a stand-alone basis, with no interference with the main amplifiers.

### Extending small-speaker bass

A myth has grown up about the supposed inability of small speaker systems to produce bass in large quantities. Probably the best way of dispelling this myth is to examine the behaviour of a small speaker radiating bass in a domestic environment.

At low frequencies we want our speaker to operate as a piston. Its maximum output is determined by the volume of air that can be displaced which, in turn, is determined by the maximum cone excursion. For the typical small driver, the maximum undistorted excursion is 6mm pk-pk.

Sound pressure level, measured at 1m in free-space conditions, is given by the formula:

\[ p = 20 \log_{10} d + 20 \log_{10} R + 20 \log_{10} a_{pp} \]

where \( p \) is the SPL measured at 1m, \( a_{pp} \) is the peak to peak excursion and \( d \) is the diameter of the driver, \( a_{pp} \) and \( d \) being expressed in millimetres. To take the case of a 30Hz input and 6mm \( a_{pp} \), a 200mm diameter driver will generate an SPL of 86dB - hardly impressive. However, in practice, at very low frequencies, both woofer channels radiate in phase, so we can add 6dB to the figure to give an SPL of 86dB.

This calculated value assumes free space radiation in a sealed box. Making use of floor and wall reflections by putting the drivers within a wavelength of the floor and wall, 5.74m at 30Hz, will add another 6dB to the SPL, giving a very respectable 92dB SPL. Again, in practice there will also be reinforcement from ceiling side and rear walls adding to the SPL generated.

As is indicated in the equation, the lower in frequency you go the less SPL you get for a given excursion; the converse is also true. Since very few recordings, with the possible exception of organ works, generate full power at these low frequencies, this is the worst case. Maximum sound-pressure level increases at 12dB/octave up to the limit set by the available electrical power.

The second misconception regarding speaker behaviour at low frequencies is that an enormous amount of power is required. In fact, above resonance, for every halving of frequency with a given drive voltage, cone excursion will increase fourfold. Below resonance the cone excursion levels off and to compensate the drive voltage must rise proportionally. This means increased gain at low frequencies with a consequent increase in power supplied. In practice, it is very seldom that the amplifier runs out of steam. What tends to happen is that the cone excursion exceeds prudent limits on overload unless care is taken.

With a reflex enclosure, the situation is similar, although complicated by both the sound contribution of the port and the reactive loading of the cone. Generally, the same arguments apply, but the available SPL can be some 6dB higher in the deep bass.

By whatever means bass extension is produced, the clinching argument for it is that, without it, unacceptable errors of 20dB or more have to be tolerated.
piece of stripboard; using the well known TL074 quad op-amp allows the whole circuit to be constructed with three chips per channel.

Circuit details
Figure 1 shows that line-level inputs are applied to the volume control VR, and thence to the buffer amplifier built around A1. From here the signal is fed three ways. Amplifier A2 is configured as a high-pass filter with a turnover frequency of 28Hz and a Q of 2.82, primarily to provide bass equalisation for the woofer. Bass loading is 6th-order and the bass enclosure is tuned to a low frequency, 35Hz, which produces an overdamped 4th-order filter response. Low-frequency boost applied by A2 levels the response, ensuring a -3dB point for the system at 32Hz. Reflex here the signal is fed three ways. To the buffer amplifier built around A1. From Circuit details to be constructed with three chips per channel. A sharp filter roll-off ensures that subsonic frequencies are sufficiently attenuated to avoid overload. Attempts to push the response down below this frequency result in excursion limit problems.

Crossover between the bass and mid-range drivers is handled by A3 and A4, which form a 4th-order, low-pass filter from two 2nd-order sections. Q of the final filter is 0.5, the condition of critical damping combining the best transient response with rapid stop-band attenuation.

Characteristics of the mid-range enclosure dictate the choice of crossover point. The mid-range driver, mounted in its ceramic pod, rolls off at the bass end at 144Hz, producing much the same response as a 2nd-order filter with a turnover frequency of 144Hz and a Q of 0.73. On its own, the high Q of this resonance would give rise to an undesirable peak well above the resonant frequency. To tame the response the drive signal goes through a high-pass filter, A7, which has the same turnover frequency but a Q of 0.68. Resulting acoustic output is the required 4th-order high-pass crossover response.

To avoid pylon breakup effects in the HT130F0, the crossover between this and the MDT29 is set at a low frequency possible. Since the MDT29 has a high-pass acoustic response centred at 900Hz and with a Q of 0.5, this is the natural frequency to choose. To provide the required 4th-order response, the tweeter is driven from the output of A2, which is wired as a 2nd-order, high-pass filter with a Q of 1. Mid-range output is rolled off at 900Hz by the 4th-order filter comprising A8 and A9.

Because the driver's acoustic centres are in different planes, time delay using all-pass filters is needed to compensate. (This apparent contradiction in terms is applied to circuits which provide a flat frequency response but a fixed time delay.)

Two of these filters are used in the circuit. The first, built around A9, compensates for the time delay between the woofer and mid-range units. This is equivalent to a -24° phase shift at 144Hz. The second compensates for the time delay between mid range and tweeter. Here a -50mm offset is compensated for by A11 and the associated circuitry. Finally, the tweeter has a 1dB higher sensitivity than the HT130F0 and this is compensated for by the gain of A10.

Implementing the Microreflex
Because my woodworking skills end at butt joints, I kept the enclosure, shown in Fig. 2, simple. I used standard 15mm thick medium-density chipboard, which is available from local hardware stores in a variety of finishes. Unless you have an extensive range of woodworking tools and enjoy using them it is best to go to a store where you can get the panels cut accurately to size. I realise there are components which require rather use a different type or thickness of timber for this project, this is not a problem provided that the internal volume of the cabinet is kept at 19 litres. Whatever timber you choose, accuracy is very important. Flat-pack cabinets for this project are available from Wilmalow Audio.

To make it easy to access the electronics and to keep the enclosure airtight, amplifiers, filter and power supply were mounted in an ABS box, 220 by 150 by 60mm, on the outside of the rear panel. ABS is an extremely easy material to work with and the necessary holes can easily be made. Connection to the drivers is by six M5 by 40mm-long screws fitted into the rear of the speaker enclosure; electrical connections are taken via solder tags. These screws also hold the electronic package in place on the rear panel, 'pigggy-back' fashion.

Construction proper begins with the front baffle. This has to take both the HT130F0 and the MDT29 as well as the mid-range pod. Mark out the apertures for both the drivers on the inside surface. However do not drill the mounting holes yet. This is important, particularly in the case of HT130F0. The T bolts provided are not used because they would foul the ceramic pod; instead, both the drivers are secured by 12mm long No 6 self-tapping screws. Before cutting the wood, position the pod over the HT130F0 aperture and draw around it. Roughen the panel's surface where the pod's rim is to be attached to provide a key. At this stage cut out the apertures for the HT130F0 and the tweeter; position both drivers and mark out the mounting holes using the drivers as templates.

Drill pilot holes to a depth of 10mm with a 3mm drill bit, before mounting the units, mount the pod using Araldite Rapid spread around the roughened surface; mix enough to take up the excess. The aim is a tight-fitting vent. The rest of the cabinet construction is straightforward. Use butt joints and plenty of glue to obtain an airtight case, except for the vent.

Aftermath
After all the work involved, is it worth it? Definitely. The stereo imaging of this system is excellent and the absence of standing waves improves the detail rendition of the system. Using the drivers substantially within their piston regions and the sharp roll-offs of the crossover contribute to seamless driver integration. The extra bass octave delivered allows music to reproduced with the correct weight and authority.

In short, I have listened to the speakers for nearly a year now and have had no urge to change them for any others, regardless of price.

References
BULB FLOODLIGHTS, BUILT IN CHARGER AND AUTO SWITCH. FULLY CASED. 6V 8AH £49.95. IDEAL FOR LAPTOPS OR A CHEAP UPGRADE. WE ALSO CAN SUPPLY THIS HY2401S, HY2460S, 24VAC ADJUSTABLE FROM 0-60 SECS, £2.99 HY241S, 24VAC ADJUSTABLE FROM 0-1 SECS. £2.99 MINI MICRO FANS 12V DC 1.5" so just £39 each. REF EF199.

CIT PRINTERS Eco, 6pin matte, setalpaper/PROLINT, 3.4 x 1.9" £3.25.

MICROSOFT TRACKBALL AND MOUSE Combined unit with 4 buttons and trackball, PS2 type connector. Complete with software, leads etc. £14.99 REF: MAG13P1.

REUSEABLE HEAT PATCHES Ideal for fisherman, outdoor enthusiasts, warming food, other items. Priced pipes etc reasonable up to 10 items, rates up for 8 hours up to 2.2000 items. 2 for £1.95 each. Price is £2.99 or £2.19 each. REF: MAG19P3.

SWITCHED POWER SUPPLIES TOP of the range UPS system providing protection for your computer system and software, relays, PCB etc. £23.50 £19.99.

LIGHTPORTER-NEW brand new, complete with instruction booklet. £4.99 REF: MAG6P8.

DRINKING BIRD Remember these? Hook onto wine glass (supplied). £3 a pair. Ref EF29.

PORTABLE RADIATION DETECTOR A Hand held personal Gamma and X Ray detector. 30K eV to over 1.2M eV and a measuring range up to 2 km in open county. Units measure 224.5 x 155 mm. £12.99 REF: MAG13P1.

WE BUY SURPLUS STOCK FOR CASH 0345-326009 try before you buy! Current retail price is £129, windowing, networkable up to 10 stations, multiple cash books etc. £59.99 REF: MAG15P5.

FUTURACOMPUTER.COM MADE BY PHILIPS, COMPLETE WITH INTERNAL MODULAR SYSTEMS INCLUDING PRINTER, FAX, TELEPHONE LEAD, MAINS LEAD, MANUAL AND COMMS SOFTWARE, MADE TO ILLUSTRATE WITH 12 VOLT 2 AMP LAPTOP PSU'S 110 X 55 X 40 MM (INCLUDES STANDARD RASTER BOARD, SWITCHED MODE PSU etc. CGA/TTL INPUT (15 WAY D), IEC CONNECTOR £29.99 REF: MAGSP3.

PLUG IN POWER SUPPLIES £2.99 each REF MAG3P9.

PLUG IN PSU 9V 200mA DC £2.99 each REF MAG39.

PLUG IN ACORNS 19V AC £2.39 REF MAG30.

POWER SUPPLIES 24VAC AVAILABLE. 17DC 900mA OUTPUT. BARGAIN PRICE £5.99 each. REF: MAG10P3.

ARCHIMEDES PSU £3.49 CRANK UP TO UNOVS, SELECTABLE TO 12V DC £2.99 each. REF MAG11P3.

24V DC POWER SUPPLY Standard input type 150mA in DC load and DC plug for £2.99 each. REF MAG13P9.

FRAUD ALERT £14.99 each. Cash per card or £12.99 each. Ref MAG14.

FM BUG KIT (NEW DESIGN WITH PCB) £14.99 each. Ref MAG14.

FM CORDLESS MICROPHONE Small hand held unit with a range up to 2km in open country. Units measure 224.5 x 155 mm. £12.99 Ref: MAG13P1.

FM CORDLESS MICROPHONE £6.99 small hand held unit with a range up to 2km in open country. Units measure 224.5 x 155 mm. £12.99 Ref: MAG13P1.

FM CORDLESS MICROPHONE £6.99 small hand held unit with a range up to 2km in open country. Units measure 224.5 x 155 mm. £12.99 Ref: MAG13P1.
How good is the current crop of power ICs? Ben Duncan finds some claims for high quality music reproduction simply do not measure up.

How do the “new” devices stack up against older ones previously reviewed, with each other and with a “benchmark” LM12?

In every case, the advertised slew rates are a poor relation in comparison to the 300V/µs from modern mosfet topologies, or even the 50V/µs from the common Lin topology, with Self’s improvement. This may not matter if all portal rf filtration is good and you avoid certain classes of music.

All of the circuits (Figs 1, 2 & 4 to 7) except PA42 (Fig. 7) show some benefit from using a regulated (or just strongly ripple-filtered) psu. In every case, the effects are strongest below 1kHz – but only because the psu noise spectrum is itself strongest from 50Hz to 500Hz.

Recently published pruning of improvement techniques are of scant use here, but might be useful later, if such ideas are incorporated into future integrated circuits.

Several measurements show distinct 30Hz features that cannot be ac power harmonics and appear to be the artefacts of thermal distortion.

The high quality audio claim for the Boomer ics (4860/61) does not appear justifiable as %thd is always over 0.1%, worst of all in the mid-band. However, the absolute level and structure of the harmonics is anything to go by.

Protection against death by adverse loading and output abuse is important whatever the ic cost, and even though music drive is usually benign. The LM3875 and 3886 have the most comprehensive and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.

Noise performance

The LM4861 with input shorted, (Fig. 9) shows quite high, ragged noise despite the quiet regulated supply and the output being loaded with 16Ω. Connecting a 100+5R zobel to the output greatly reduces noise, especially above 200Hz. An unregulated supply – lightly loaded so it has only 7mV ripple – does not improve matters and a +5V pc supply could be far noisier. A large reservoir and correct supply noding will help. The rf oscillation in the absence of an output zobel naturally increases the unregulated noise plot greatly.

These noise plots were initially disputed by NSC, as they could not be corroborated. But restesting demonstrated that the noise is correct for the conditions. The excess at low frequencies is particularly at 50 and 100Hz is caused solely by the 5m of unshielded test load cabling.

How do the devices compare?

The LM3875 and 3886 are the most comprehensible and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.

Noise performance

The LM4861 with input shorted, (Fig. 9) shows quite high, ragged noise despite the quiet regulated supply and the output being loaded with 16Ω. Connecting a 100+5R zobel to the output greatly reduces noise, especially above 200Hz. An unregulated supply – lightly loaded so it has only 7mV ripple – does not improve matters and a +5V pc supply could be far noisier. A large reservoir and correct supply noding will help. The rf oscillation in the absence of an output zobel naturally increases the unregulated noise plot greatly.

These noise plots were initially disputed by NSC, as they could not be corroborated. But restesting demonstrated that the noise is correct for the conditions. The excess at low frequencies is particularly at 50 and 100Hz is caused solely by the 5m of unshielded test load cabling.

Protection against death by adverse loading and output abuse is important whatever the ic cost, and even though music drive is usually benign. The LM3875 and 3886 have the most comprehensive and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.

Noise performance

The LM4861 with input shorted, (Fig. 9) shows quite high, ragged noise despite the quiet regulated supply and the output being loaded with 16Ω. Connecting a 100+5R zobel to the output greatly reduces noise, especially above 200Hz. An unregulated supply – lightly loaded so it has only 7mV ripple – does not improve matters and a +5V pc supply could be far noisier. A large reservoir and correct supply noding will help. The rf oscillation in the absence of an output zobel naturally increases the unregulated noise plot greatly.

These noise plots were initially disputed by NSC, as they could not be corroborated. But restesting demonstrated that the noise is correct for the conditions. The excess at low frequencies is particularly at 50 and 100Hz is caused solely by the 5m of unshielded test load cabling.

Protection against death by adverse loading and output abuse is important whatever the ic cost, and even though music drive is usually benign. The LM3875 and 3886 have the most comprehensive and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.

Noise performance

The LM4861 with input shorted, (Fig. 9) shows quite high, ragged noise despite the quiet regulated supply and the output being loaded with 16Ω. Connecting a 100+5R zobel to the output greatly reduces noise, especially above 200Hz. An unregulated supply – lightly loaded so it has only 7mV ripple – does not improve matters and a +5V pc supply could be far noisier. A large reservoir and correct supply noding will help. The rf oscillation in the absence of an output zobel naturally increases the unregulated noise plot greatly.

These noise plots were initially disputed by NSC, as they could not be corroborated. But restesting demonstrated that the noise is correct for the conditions. The excess at low frequencies is particularly at 50 and 100Hz is caused solely by the 5m of unshielded test load cabling.

Protection against death by adverse loading and output abuse is important whatever the ic cost, and even though music drive is usually benign. The LM3875 and 3886 have the most comprehensive and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.

Noise performance

The LM4861 with input shorted, (Fig. 9) shows quite high, ragged noise despite the quiet regulated supply and the output being loaded with 16Ω. Connecting a 100+5R zobel to the output greatly reduces noise, especially above 200Hz. An unregulated supply – lightly loaded so it has only 7mV ripple – does not improve matters and a +5V pc supply could be far noisier. A large reservoir and correct supply noding will help. The rf oscillation in the absence of an output zobel naturally increases the unregulated noise plot greatly.

These noise plots were initially disputed by NSC, as they could not be corroborated. But restesting demonstrated that the noise is correct for the conditions. The excess at low frequencies is particularly at 50 and 100Hz is caused solely by the 5m of unshielded test load cabling.

Protection against death by adverse loading and output abuse is important whatever the ic cost, and even though music drive is usually benign. The LM3875 and 3886 have the most comprehensive and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.

Noise performance

The LM4861 with input shorted, (Fig. 9) shows quite high, ragged noise despite the quiet regulated supply and the output being loaded with 16Ω. Connecting a 100+5R zobel to the output greatly reduces noise, especially above 200Hz. An unregulated supply – lightly loaded so it has only 7mV ripple – does not improve matters and a +5V pc supply could be far noisier. A large reservoir and correct supply noding will help. The rf oscillation in the absence of an output zobel naturally increases the unregulated noise plot greatly.

These noise plots were initially disputed by NSC, as they could not be corroborated. But restesting demonstrated that the noise is correct for the conditions. The excess at low frequencies is particularly at 50 and 100Hz is caused solely by the 5m of unshielded test load cabling.

Protection against death by adverse loading and output abuse is important whatever the ic cost, and even though music drive is usually benign. The LM3875 and 3886 have the most comprehensive and believable all round soa/ads protection I have seen in any ic. They and the Boomer and LM12 are also thermally protected. The LM12 also shuts down if the supply exceeds 60V but is under 80V. But all seven ics can be killed by marginally excess supply volts.

The PA42 is well protected against output abuse by proven, minimum mosfet techniques. PA45’s one-slope protection solely averts over-current into a resistive load. Without added protection, a prolonged bad phase angle (such as driving bass-heavy music into a difficult speaker) might destroy it.
In effect, the balanced output, while rejecting rail noise, is unusually emi sensitive. The voltage dip on load demonstrates that Zo is quite high, about 0.5Ω, giving a damping factor of 20. This may frustrate bass performance into the better miniature speaker designs.

LM12, tested with supply ripple at 6mV p-p and 20mV (+10dB) shows a noise increase of at least 3dB below 500Hz (Fig. 10). The LM3886's noise is lower than the LM12 at hf and slightly higher where it matters most, in the mid-band (Fig. 11). The high 50Hz spike may be ameliorated by refined layout and optimised shielding. PSR is generally better than LM12.

When the PA42 is used alone, as an high voltage op-amp, its performance is exemplary (Fig. 12). Noise is uniformly low across the spectrum, particularly the low sensitivity to 50/75/150Hz magnetic field frequencies and no special precautions needed to be taken. Similarly, the PA445 shows a strong 50Hz sensitivity but commendably low noise (~140dB) at the mid/high frequencies where it matters most (Fig. 13). Degradation that occurs by using an unregulated supply indicates limited psr and a high sensitivity to magnetic fields - though a large hum spike at ~125dB is probably not so audible as it appears.

**Total harmonic distortion and power**

Power (right hand axis) and %thd (left hand axis) were plotted for each device. With a regulated supply, thd of LM4860 shows only small differences between 8 and 16Ω loads (Fig. 14), at 0.5dB below clip, but more than halves with the same loads at ~5.5dB below clip. The 16Ω spike suggests some emi susceptibility to the pc's vdu, 0.7m away.

Power is confirmed at about 800mW and 300mW into 8Ω, at the two test levels.

Using an unregulated supply, (Fig. 15) %thd figures are about 3-6dB greater, particularly at lf. A dynamic %thd plot shows that the %thd baseline is higher when the supply is unregulated (cf Fig. 9). The poor psr is unusual for a bridged output and is not caused by load cable pinking.

For LM12, just below clip, %thd is passable (Fig. 16). But a rise below 50Hz could be thermal distortion or hf-triggered if instability.

Mid-band output delivery during the %thd plot is confirmed at about +27.5dBu, alias 42W into 8Ω. Dynamically, %THD at 1kHz changes threefold in the top 1dB below clip, whereas at 10kHz, the change over 18dB is barely 1x.5.

The LM3886's %thd is much better than the LM12 at hf (Fig. 17), at just 0.02%. But residue at 10kHz has club spikes. There are also traces of narrow cross-over spikes in the noise at 1kHz, while if distortion now rises
Data sheet warnings

- All the power ic makers are guilty of overstating the quality of their slew limits. Today, when even vfb op amps and even audio amps are slewing at 350V/µs and more, designating a slew limit of under 20V/µs “fast” raises my eyebrows.
- Other than the Apex ics (which are not power specified), there isn’t the rail voltage leeway that discrete component power amplifier designers are used to. Due to the over-focus on power output figures, the ics have power output specifications that are only available close to the part’s limits. Attaining these powers proves dicey without supply regulation or over-voltage protection. Also, the max supply specification for LM12, 3875 and 3886 is literally dangerous, being quoted higher without signal – hardly a valid test condition. Even when LM3875 is operated below its maximum realistic rail rating of ±42V, and is mounted on the generous heat sink used, it can’t deliver a continuous test signal cleanly into 8Ω until the supply is set at or below ±35V, a consequence of the Spike soa protection working properly.
- The Boomer data clearly states that no (output) zobel is needed, apparently as the design team expect amplifiers will always be used with an adjacent, permanently connected speaker. How can they be so sure?

Gently from 200Hz, the residue at this point being highly angular.

As one of few major differences between the LM3886 and LM12 circuits is the output devices and their heat transfer values, thermally induced cross-over distortion is a reasonable hypothesis – though the repeated 30Hz spike seen also on the LM12’s response begs explanation.

Dynamic %THD behaviour was similar to LM12. %thd for the PA42’s solo is good below 1kHz, and quite passable at 20kHz (Fig. 18) – provided the current limit is set generously enough to suit the load; Near vertical take-off at 14kHz indicates how a 680Ω CL resistor can make the ic proof against continuing shorting with dc but also starves the output at <8mA, the load being just 100Ω and 1nF of analyser plus cable capacitance.

Setting CL to 30Ω, a value chosen for driving the external mosfets, produces no vertical take off, but an intermediate value would be needed to provide some abuse protection, at

Fig. 5. LM3875’s lineage is apparent after reviewing the LM12. Most changes are details around vas. The related LM3886 is almost identical in the lower half, but above the input pair are nested long tailed pairs and sources, and output monitoring, all added for protective muting purposes.

Fig. 6. Inside the PA42 driver ic, all is mos. Input protection zeners prevent excess Vgs. The source biasing is shown as an unspecified (and possibly noisy?) zener. Note the output is really at pin 7, which is linked to pin 10 via a protective, current sensing resistor.

Fig. 7. PA42 requires its own output stage. Apex literature offers some suggestions with v-lets, but lateral mos offers the simplest solution, requiring just hv current sources and a gate spreader for robust audio performance. The Exicon ECF output mosfets, also recently introduced, are of UK design and manufacture, and are second sourced by Semelab. This circuit gave the cleanest results in the group, akin to the better discrete designs.
least above 20Hz. The dynamic plot showed that both 1kHz and 10kHz %thd hardly varied in the 18dB below clipping. With lateral mosfets added, and CL set at 30Ω (a safe value when driving one pair of lateral mosfets) the PA42’s %thd is hardly changed (Fig. 19). %thd reduces only minutely when the biasing (for one output pair) is increased from 40mA to 75mA, and is only slightly lower into 16Ω.

Noise (not shown) is very similar to Fig 16, and a 7dB increase in ripple has no effect except at 100 and 200Hz, where noise increases by some 7dB.

The PA45’s %thd is impressive when unloaded (Fig. 20), at ±63V and 1dB < clip, with a notch in the residue decreasing markedly as the supply increases past ±60V. Alas, the highest current limit R value (0R17) that still assures short protection (5A) is not able to handle continuous drive into 8Ω at these voltages (56Vpk/8 = 7A) – at least without a fattier heat transfer bracket. Loaded percentage thd is more acceptable when drive is ~11dB below clip, 16Ω, rather than ~1dB < clip. A 1% rise is assumed to be a thermal distortion artefact.

The power plots show about 120W wrt 8Ω when loaded with 16Ω, hence really 60W.

Noise performance: Figs 9 to 13 show noise spectra with shorted inputs, with differing power supplies and amounts of ripple used to demonstrate spot psr. Except for Fig. 9, each graph has a 40dB window. The AP’s residue is -135dB flat across the band with the test set-up environment.

![PA45 schematic](image)

Fig. 8. PA45. A mixture of mosfets and bjt's. It differs from the PA42 by naturally having larger die area output mosfets (Tr7,17), more elaborate protection (Tr2,5,9,14, etc), and more biasing and clamping zeners.

Continued on pages 482 & 531

Fig. 9. Output noise spectra, showing effects of rf instability and poor psu rejection for LM4861: upper with input shorted and regulated psu, middle, with 100m+5R zobel added, lowermost, using an unregulated supply. The excess at 1kHz particularly is caused solely by the 3m of unshielded test load cabling.

Fig. 10. Noise spectra of LM12. The two plots are with an unregulated supply, but in one plot supply ripple is increased from 6mV p-p to 20mV (+10dB) by resistive loading. There is an increase of at least 5dB below 500Hz.

Fig. 11. The LM3886's noise is lower than the LM12 at hf and slightly higher in the mid-band. Powering is from an unregulated supply: A is 5mV ripple voltage and B is 15mV pk-pk.

Fig. 12. Exemplary noise performance of the PA42.

Fig. 13: PA45 noise spectra. A strong 50Hz sensitivity but commendably low noise (-140dB) at the mid/high frequencies. Upper plot shows the degradation with the unregulated supply having 30mV pk-pk ripple (at least 30dB worse) and set at ±63V.

---

480 ELECTRONICS WORLD + WIRELESS WORLD June 1995
Percentage thd and power bandwidth: Figs 14 to 20 show %thd vs frequency and also the power into 8Ω (right hand side) at just below clip, and at some lower output. Analyser bandwidth is 80kHz, so the 20kHz sum truncates above the 4th harmonic. Several plots demonstrate hives at 15 that are most easily explained as thermal distortion. Others demonstrate clear differences as supply ripple changes on one or both rails, demonstrating that psrr is a real issue too.

![Graph](image1)

Fig. 14. LM4860 with regulated supply. A (8Ω) and B (16Ω) show small differences at 0.5dB below clip. C and D show how %thd more than halves with the same respective loads at -5.5dB below clip. Power curves E and F, G and H respectively confirm about 800mV and 200mV into 8Ω, at the two test levels. Retesting demonstrated that thd was not influenced by noise pickup susceptibility in the load cabling.

![Graph](image2)

Fig. 15. Unregulated supply and LM4860. All-round %THD figures are about 3 to 6dB greater.

![Graph](image3)

Fig. 16: LM12’s %thd is passable at below 0.06%, 20kHz into 8Ω just below clip but shows a rise below 50Hz. Lower curve shows 16Ω response. The upper pair of curves confirm a midband output delivery during the %thd plot of about +27.5dBu.

Fig. 17: Compared to LM12, the LM3886's %thd is better at hf, at 20kHz into 8Ω. Thermally induced cross-over distortion could be causing problems.

Fig. 18: PA42 %thd is satisfactory though the current limit must suit the load. Curves A show result of a 68kΩ CL resistor; and curve B shows CL set to 30kΩ. A ±61V unregulated supply was used. Residue was mostly quite angular, and increasingly complex above 2kHz. A(f) and B(f) show frequency response.

Fig. 19: PA42 with lateral mosfets added, and CL set to 30kΩ: %THD is hardly changed. It reduces only minutely when the biasing (for one output pair) is increased from 40mA (A) to 75mA (B). (C) shows only slightly lower %THD into 16Ω.

Fig. 20: PA45’s impressive %THD when unloaded (lower plot, A) at ±63V and 1dB < clip. Upper %thd plot (B) shows drive into 16Ω -1dB < clip. Middle curve (C) shows a more acceptable result when drive is -11dB below clip. Power bandwidth is plotted on the right.
Spectral behaviour: These plots show harmonic spectral behaviour -1dB below onset of clip (judged from spikes in the thd residue), then at the lower level more typical of most listening levels, together with some examples of supply regulation effects. Each graph has a 100dB window. All dBs are referred to the fundamental.

- Fig. 21: LM4861 spectra 1dB below clip into 8Ω.
- Fig. 22: Fatiguing sonics suggested by 4861’s spectra at 18dB below clip.
- Fig. 23: LM4860 spectra possibly as a result of a faulty IC.
- Fig. 24: At onset of clip, most of the LM12 products are just below 100dB.
- Fig. 25: 25dB below clip, the noise floor has increased, and harmonics above it have changed.
- Fig. 26: The LM3875’s spectra just below clip are similar to LM12.
- Fig. 27: At -25dB below clip, LM3875 spectra are very like LM12 under similar conditions.
- Fig. 28: Just below clip, spectra of PA42 and added mos output stage is ragged but nearly all below -90dB.
- Fig. 29: At -26dB below clip the only PA42 harmonic readable is a tiny amount of second.
- Fig. 30: 0.5dB below clip with ±51V rails, and 16Ω, the PA45 mainly makes odd harmonics which will be very prominent by ear.
- Fig. 31: PA45 with 16Ω load, but at -25dB below clip with ±31V rails. Odd harmonics still dominate the evens.
- Fig. 32: PA45 with ±62V rails, other conditions the same as Fig. 31, all the harmonics are reduced - excellent sonics should be the result.
Two chip video digitiser

Given a PC of reasonable performance, it is possible to grab 25 frames a second of standard composite video frame using little more than a flash converter and LPT port D connector. Steve Webb explains how most of the image reconstruction work is done via software.

Commercially available video digitisers are an expensive luxury, with most models costing upward of two hundred pounds. For experimenters, and applications such as shape recognition, this may be off-putting. This article describes how anyone with a 286 or better can capture video on a shoe string.

Performance of the digitiser is not brilliant. But on the other hand, useful results are possible, Fig. 1, and the cost makes the circuit ideal for applications such as counting cars or intruder detection. The design was conceived to provide a simple means for experimenting with computer vision. A key design criterion was minimum hardware, in order to keep costs down and to allow the interface to be easily removed. This lead to a circuit based on the PC LPT printer port. The port is pushed to its limit, but the results are rewarding.

Performance of the digitiser is not brilliant. But on the other hand, useful results are possible, Fig. 1, and the cost makes the circuit ideal for applications such as counting cars or intruder detection. The design was conceived to provide a simple means for experimenting with computer vision. A key design criterion was minimum hardware, in order to keep costs down and to allow the interface to be easily removed. This lead to a circuit based on the PC LPT printer port. The port is pushed to its limit, but the results are rewarding.

Design overview
The interface acts as a free-running a-to-d converter providing asynchronous samples to the printer port. The whole video signal — including sync pulses — is digitised to five-bit resolution.

Video grabber specifications
- Host computer: 286 PC, or better
- Connection: LPT1 printer port
- Eff. frame size: 150 hor. (depends on bus speed) 100 vert.
- Grey levels: 20
- Frame rate: 25/s (486DX33, 3x1 filtering, all assembler)
- Power supply: Obtained from port (15mA)

Fig. 2. With little more than a CA3306 a-to-d converter, it is possible to capture video signals for displaying or processing on a PC. Although low in resolution, images captured can be used for recognition.
PC INTERFACING

Fig. 3. Video digitiser prototype plugs directly into the printer port.

Electrical design
Figure 2 is the full interface schematic showing how the design revolves around a CA3306 six-bit flash a-to-d converter. Power supply is derived from the eight port data output lines, suitably ballasted together via 330Ω resistors. Total current consumption is around 15mA. This method of deriving power is unconventional, but I have found it more than adequate. Assuming the port uses a standard 74LS latch driver, then 2.5mA per line is typically available.

An adjustable voltage reference is derived from the series-connected led and 1N4148 diode, feeding the a-to-d converter via the 2N2222 emitter follower. The led also indicates interface operation when activated by the software. A low current device was selected to conserve current.

The reference is adjusted for a typical 1V pk-pk video signal. A standard video signal is terminated with 75Ω and capacitively coupled into the CA3306. A low impedance dc clamp is formed by another emitter follower and diode combination. Thus the tips of the video synchronising pulses are referenced to ground, and in a suitable form for the data converter. Decoupling is provided by 0.1μF capacitors as shown.

In practice, the port is the limiting factor, so I decided to make the a-to-d converter free run and provide samples asynchronously to the pc processor. A simple clock is generated by the 74HC14 schmitt inverter, and set to an arbitrary 7MHz.

The clock was chosen to be greater than the bus sampling rate to help reduce patterning. On my pc, port read times of around 1.2μs per sample were typical, but this is likely to be machine specific.

There are only five input data lines available for reading via the status register. These would normally indicate PAPER OUT, DEVICE ERROR, etc, but in this application they are connected to the five most significant bits of the data converter. In this way the whole video signal - sync pulses and all, is digitised to a five-bit resolution.

The decision to digitise rather than extract the sync pulse will make sense once you have studied section. It should be noted that the most-significant bit connected to DEVICE BUSY is inverted by the port circuitry so the software takes this into account. Using one of the spare inverters to correct this situation, was unsuccessful due to gate delay.

There is little more to the hardware, other than what has been described here. Prototypes have been built in the small gender-changer sized boxes as part of a DB25 connector. It is possible to do this with Veroboard although some unconventional construction techniques and patience are required as it can take some time, Fig.3.

Analysis of digitised signals
A typical monochrome video signal is 1V pk-pk. With the top 70% representing the grey level where white is 1V and black is 0.3V. The blacker than black sync pulses are below 0.3V, Fig. 4.

For the 625 line system, a complete image is

---

While

Black

Sync

1V

0.3V

4.7μs

64μs

Fig. 4. Representation of a monochrome composite video signal. The digitiser captures the whole signal and it is up to the software to separate the syncs.

Fig. 5. Digitised video is made available in the status register at port base address plus 1. This is the bit structure.

---

Initialise port (for psu)
Allocate memory
Set video mode for Ox13
Make grey scale
Wait for frame sync
Grab one frame of data once detected
Look for line sync in data
Convert line into grey scale
Interleave 3 lines into one
Averge with line from previous frame
Keep processing until end of frame
Filter interleaved data
Display on screen

Fig. 6 Flowchart for digitiser software

---
formed by two interlaced frames each of 312.5 lines. A longer frame sync pulse is at the start of each frame. The whole video signal is digitised by the circuit to five bits resolution, so allowing 2\(^5\) = 32 effective grey levels to be represented. It is up to the software to detect and synchronise to the sync pulses in order to display a stable picture.

The digitised signal is made available via the status register. This is port base address plus 1, or 378\(_{16}\)/1 on most computers, an address obtainable via the bios, Fig. 5. As stated, bit seven is inverted by the port hardware, so this needs to be accounted for.

Software

The software reads a packet of data from the port and then post processes it during the interface frame. In effect, this gives 312 lines each of around 53 samples including sync pulses. Obviously such an aspect ratio is undesirable, but it is the post processing that makes the scheme viable.

In order to read the port and process data at an appropriate rate, it is necessary to use assembler. 'C' has been used for higher level set-up where speed is not critical. The simplest way of explaining the digitiser software is to start with a flow-chart, Fig. 6.

The port is initialised by outputting FF\(_{16}\) to the Data register at address 378\(_{16}\), so setting all data lines high for the interface port. Correct operation is indicated by the led.

Suitable sized arrays are allocated for sampled data and a workspace. The screen mode is set to vga mode 320x200, 256 colours by a dos call Ox10. The 21 level grey scale is also generated as required.

Once initialised, the port is read repeatedly until the start of a sync pulse is detected. Reading continues until the software is sure that a frame sync has been detected. A complete frame's worth of data is sampled immediately after the sync pulse.

Disabling system interrupts ensures the processor gives undivided attention to the port using the efficient REP INSB instruction, Fig. 7.

Due to the low port bandwidth, no information should be discarded, despite the elongated aspect ratio. The chosen algorithm involves taking the first pixel from three successive lines and depositing them, in order, to the workspace. This is repeated for the second pixels and so-on, Fig. 8.

Additionally pixels from the current frame are averaged with those of the previous to reduce 'twinkle' noise. Samples from successive lines are staggered relative to each other to the left or the right, the trick being to decide which way. Suggestions on how to improve the scheme would be welcome.

Interleaved data contains striations that are a natural product of the process. To make a picture more acceptable it is recommended that some form of low-pass filtering is implemented. In practice the picture will have comparably good vertical resolution compared to the horizontal, so you will find that a simple 3x1 average is more than adequate. A 3x3 average tends to defocus the image. A 3x3

---

Fig. 7. Simplified code for driving the low-cost video grabber via LPT1.

```c
void DoScreen(void); char Grab(void); void Interleave(void); void Display(void);

unsigned char far *video=(char *)Oxa0000000L; //Base address of screen
unsigned char *grab; //Sample array
unsigned char *interleave; //Interleave workspace array

void DoScreen(void)
{
    //Main routine to repeatedly grab, interleave, and display smoothed frame
    void main(void)
    {
        grab=(unsigned char *)malloc(GRABSIZE*sizeof(char));
        if((grab==NULL)11(interleave==NULL))
        {
            printf("Unable to allocate memory.\n\n");
            free(grab);
            free(interleave);
            exit(1);
        }
        DoScreen();
        outportb(DataLPT1,0xff) //Setup display
        while(!kbhit()) //Set data lines high (for PSU)
        {
            if(Grab()) //Keep going until keypress
            {
                Interleave(); //Grab one frame of data
                Display(); //Filter and display interleaved data
                else
                {
                    gotoxy(5,5); //Revert to text mode
                    printf("* No Sync *");
                }
            }
            //Clear keyboard buffer
            getch();
            outportb(DataLPT1,0x00); //Switch digitiser off
            outportb(DataLPT1,0x00); //Retract to text mode
            free(grab);
            free(interleave);
            exit(0);
        }
        //Setup display to VGA320x200x256 and make palette
        void DoScreen()
        {
            static union REGS In_Regs;
            static union REGS Out_Regs;
            float j=0;
            In_Regs.b.ah=0;
            In_Regs.b.al=Ox13; //VGA mode 19
            int86(0x10,&In_Regs,&Out_Regs);
            
            outportb(0x03C8,1); //Switch digitiser off
            outportb(0x03C9, (int)(j+0.5)); //Red
            outportb(0x03C9, (int)(j+0.5)); //Green
            outportb(0x03C9, (int)(j+0.5)); //Blue
        }
        //Wait for V-Sync and Grab frame to buffer array
        void main()
        {
            asm {
                cli //Disable interrupts to reduce jitter
                mov bx,TIMEDOUT //Max number of samples with no sync
                mov dx,StatusLPT1 //Port address
            }
        }
```
median filter has been performed with good results, but is computationally intensive for real-time applications. Results of simple filtering are shown in Fig. 9.

Code execution will obviously be processor related. In the interests of brevity and understanding, the source given in this article is not the full assembly language program I have developed. Nevertheless, frame rates of 10Hz will be realised with a typical set-up. It is possible with optimisation and assembler to reach 25Hz on a 486DX33 with filtering. In the program, the choice of the constants GRABSIZE and LINELENGTH may have to be adjusted for faster/slower ports.

The design is a basis for a very cheap computer imaging system. Results may be limited, but will certainly allow experimentation with different enhancement and filtering techniques. An interesting application for the digitiser could be as an intelligent trigger for a security system video recorder. Colour capture is another possibility, by taking three successive red, green and blue frames.

More detailed assembler source code, including a simple movement tracking program, is available from the author. Send cheque for £12.50 UK or £15.00 overseas to S.M. Webb, Selborne, Station Road, Clive, Shrewsbury, Shropshire SY4 3LD. A 3.5in disk will be dispatched, unless otherwise requested. Allow 28 days for delivery. Suggestions for improvements or optimisations are welcome.

Please direct all enquiries regarding this software, accompanied by an sae please, to Steve Webb at the above address - Ed.

Fig. 8. Technique of interleaving sampled data. Samples from successive lines are staggered relative to each other, to the left or to the right. The trick is to finding out which direction the stagger is.

Fig. 9. "Its perfectly simple Watson" - no filter compared with averaging at 3x1 and 3x3.
A computerised index of *Electronics World*+*Wireless World* magazine is now available. It covers the five years 1990 to 1994 – volumes 96 to 100 – and contains over 1400 references to feature articles, circuit ideas and applications, with a synopsis for each. The software is easy to use and very quick. It runs on any IBM or compatible PC with 512K ram and a hard disk. Each disk is scanned before shipping with the current version of Dr Solomon’s Anti-Virus Toolkit.

For the UK, the five year index is priced at £20. Please specify 5 1/4 or 3 1/2 in format. This price includes UK postage and VAT. Add an extra £1 for overseas EC orders or £5 for non-EC overseas orders.

Photo copies from back issues of *EW+WW* are available at 50p per page plus VAT (in EC) and a flat postage charge of 50p (UK), £1 (rest of EC), and £2 (rest of world). For enquiries about photo copies send an s.a.e to Video Interface Products.

Please allow up to 28 days for delivery. Cheques should be made payable to Video Interface Products, not *EW&W* or Reed Business Publishing.

Please post your request to Video Interface Products Ltd, 1 Vineries Close, Cheltenham GL53 0NU, UK.

Unique *EW+WW* reader offer

20% discount on TTI’s TC200A digital LCR meter

<table>
<thead>
<tr>
<th>Capacitance Range</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1pF</td>
<td>1pF</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>1pF</td>
<td>10pF</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>10pF</td>
<td>1nF</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>1nF</td>
<td>10nF</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>10nF</td>
<td>100nF</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>100nF</td>
<td>1μF</td>
<td>2%±1 dig</td>
</tr>
<tr>
<td>1μF</td>
<td>10μF</td>
<td>2%±1 dig</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inductance Range</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>20pμH</td>
<td>0.1μH</td>
<td>2%±1 dig</td>
</tr>
<tr>
<td>1μH</td>
<td>10μH</td>
<td>2%±1 dig</td>
</tr>
<tr>
<td>10μH</td>
<td>100μH</td>
<td>2%±1 dig</td>
</tr>
<tr>
<td>100μH</td>
<td>1mH</td>
<td>2%±1 dig</td>
</tr>
<tr>
<td>1mH</td>
<td>10mH</td>
<td>2%±1 dig</td>
</tr>
<tr>
<td>10mH</td>
<td>100mH</td>
<td>3%±2 dig</td>
</tr>
<tr>
<td>100mH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistance Range</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1mΩ</td>
<td>10mΩ</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>10mΩ</td>
<td>100mΩ</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>100mΩ</td>
<td>1μΩ</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>1μΩ</td>
<td>10μΩ</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>10μΩ</td>
<td>100μΩ</td>
<td>1%±1 dig</td>
</tr>
<tr>
<td>100μΩ</td>
<td>1mΩ</td>
<td>2%±2 dig</td>
</tr>
<tr>
<td>1mΩ</td>
<td>10mΩ</td>
<td>2%±2 dig</td>
</tr>
</tbody>
</table>

Measure 0.1μH to 200H inductance, 100pF to 20mF capacitance and 1mΩ to 20MΩ on one hand-held meter for the fully inclusive price of £99.99*.

Thurlby Thandar’s TC200A hand-held LCR meter is a precision instrument featuring nine capacitance ranges, eight resistance ranges and seven Inductance ranges. In addition to the standard LCR functions, the TC200A is also capable of displaying dissipation factors in the range 0 to 1.999 for both capacitance and inductance.

Measuring 177 by 88 by 40mm, the pocket sized TC200A weighs just 400g. It has 3.5-digit high-contrast display with 0.5in high characters and runs from a single, standard 9V battery. The meter is also designed to provide a fast measurement response time.

*UK only price. The normal UK price of this meter, including vat, would be £123.23, assuming £5 postage and packing.

Detailed specifications available – send s.a.e. marked LCR Meter Details to *EW+WW*, Room L330 Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

The TC200A LCR meter is a hand-held precision instrument featuring nine capacitance ranges eight resistance ranges and seven Inductance ranges.

Full-inclusive price UK £99, Europe £104, rest of world excluding USA £109. Cheques payable to Reed Business Publishing Group Ltd please, and posted to *EW+WW*, Room L330 Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. A probe specially designed for measuring surface-mount component is available. Please add £29.38 to your order if you require this probe.
Accessing Internet for useful research is easier than you might think, as consultant Cyril Bateman has been finding out.

**With intent**

With a modern computer and a telephone line, the world’s largest reference library is available 24 hours a day. This library – the Internet – resides on a large number of computer systems, in nearly every country in the world, and is available almost for free.

If it is the world’s largest, just how big is it? In England, for public reference, we have the Science Reference Library and the Patent Office, at Holborn in London. Both house large collections of books and papers going back over many years. Imagine this information, indexed in computer searchable format, accessible by telephone, then multiply the amount of information a thousand fold.

For me as a consultant, losing the Norwich Library and sub-Patent Office by fire last autumn was a disaster. My nearest public reference alternatives are a three hour journey away. So I decided to find out whether the Internet would provide an alternative source.

Reading the various specialist computer magazines, and the two most recommended books, left me with the impression this was not so. It seemed the Internet had three main uses – sending E mail, obtaining shareware programs and participating in newsgroups. Encouraged by last autumn’s price reductions for modems however, I decided to find out for myself. I bought a Zoom 144X modem and installed the easy to use and excellent communications software included with OS/2 Warp in the Bonus Pack – free.

I found that the Internet was not only the largest library, but was also easily accessible. What then is Internet? It is the name for a group of world-wide information resources, located in universities, technical colleges, schools, public libraries, businesses, government offices, patent offices. These resources, or their indexes, are stored on computer systems, linked by networks. Amazingly, no one owns or controls Internet.
and by and large the services are available for the cost of the telephone call to the service provider used. Each resource e.g. at a university, is created, controlled, and managed for use on the campus by their own staff. Much of the information is supplied voluntarily.

Obviously, in order for each computer to communicate, an operating-system independent 'protocol' has been devised. This, supervised by the National Science Foundation, is perhaps the only controlled aspect of the Internet.\(^3\)

When visualising a network, most people assume that there is one central controlling server computer, implying a 'big-brother' supervising and controlling access. So why does no one control Internet?

Very simple. The 'Internet' has no central server. It is organised like a 'peer-to-peer' network, computers both giving and receiving outside access. Each has a unique address. Data is sorted and passed on to its destination. Public access to the Internet requires the services of a 'service' provider, acting either as a
'poste-restante' mailbox or telephone switchboard.

One's costs are the telephone calls to this service provider and the providers charges. Two levels of connectivity are commonly available:

- **BBS 'dial-up'** is generally restricted to E-mail, a number of news groups, file transfers, and Telnet. Access is indirect, the BBS computer intercepting all data, for subsequent retransmission both to and from the Net.

- **SLIP/PPP 'dial-in'** provides direct access to all Internet services. The 'provider' acts as a switch-board connecting your computer directly to the Internet. All data is handled in both directions in real time. Local use of the graphical browser called the World-Wide Web is used to access sources. This level of service is essential for any serious scientific reference searching.¹

---

**Origins of the Internet**

In 1969 the US military needed to connect four computers in such a way as to maintain a level of service assuming one or more computers or links, were damaged. It was to be known as the Darpanet. With time, the name changed to Arpanet as more computers were added.

With the number of University sites connected by the early '80s, this network had grown to such extent it was decided to segregate military and research systems. In 1984, the National Scientific Foundation NSFNet was established to link together five supercomputer centres, each located at a university, making the information contained accessible to any desiring US educational facility that needed it.

This access was later broadened to include other countries, allies of the USA. By 1990, the Internet had begun, and access was opened up to anyone having the means to connect. From a beginning with some 5000 users it has grown to the present estimate of over 30 million.

While Unix was dominant initially, with this level of expansion all operating systems are now included across some 62 countries.
Hypertext and World-Wide Web

The idea of hypertext is not particularly new. Hypertext is data that contains links to other relevant data. The World-Wide Web concept was developed at the CERN research centre, Switzerland, to disseminate information.

In 1980, Tim Berners-Lee devised Enquire Within - a program for his own use, designed to facilitate insertion and cross-referencing of data links in technical reports. These basic ideas expanded in 1991 into a text based interface called the Mosaic graphical user interface for Unix in February 1993, and was subsequently translated for all other platforms.

In the present day World-Wide Web, clicking on hypertext highlighted keywords takes one directly to the next link. This happens regardless of changes in host computer, country or even communication methods. All are transparent to the user, Fig. 1.

As an example, you want to transfer a file to your computer. The Web link will dial the required host computer, log in to the file-transfer service FTP, commence FTP on your computer and download the file for you. All of this is autonomous - even if the host is running Unix and the receiving computer is running Windows, OS/2, System 7, or whatever.

In 1993, the World-Wide Web began with a Unix server at CERN in Switzerland, to disseminate information. The World-Wide Web concept was developed at the CERN research centre, Switzerland, to disseminate information.

Internet service providers

While Internet can be accessed in many ways, for Scientific reference, two methods only are considered. The first - dial-up access requires a minimum of computer skills. Access through a BBS is generally more restricting, and can require memorising a number of Unix commands to perform searches. Note the Unix directory structure, involving a forward slash as opposed to the back-slash used in dos, Figs 6 and 7.

Some popular national providers, taken from the Paola Kathuria list, Feb 95 are:

- Dial-in providers (SLIP/PPP):
  - Atlas, £12/month and £25 start up fee
  - BBC, £12/month and £25/35 start-up
  - Cityscape, £180/year and £50 start-up fee

- Direct, £10/month, unlimited time, no hourly charge, software less refined, £12.50 start-up fee.

- Demon, £10/month, unlimited time, no hourly charge, software less refined, £12.50 start-up fee.

- IBMnet, £10/month to 3/month, then £3 subsequent, super software fee with OS/2 Warp, 1st month/3h free, no start-up fee. BBS providers
  - CompuServe, £6.65/month and £1.20/h CIX, £6.25/h to 1h 45 min (2h 30min off peak) then £0.06 (£0.04 off peak) per minute, £25 start-up fee.
  - DELPHI, £10/month to 4h, then £4/h, 1st 5h free, no start-up fee.

How do I join Internet?

Given a suitable computer, for example a pc running Windows, OS/2 Warp, Macintosh, System 7, Archimedes Risc-OS, etc. and a modem are the only essentials.

Examine your intended use. Most facsimile machines work at 9600 baud. Many BBS now work at 28,800 baud. Most UK Internet service providers work at 14,400 baud but depending on 'traffic' the 'Internet' connection can be slower.

If running Windows, unless your computer uses a 16550A serial chip, your system can limit the actual run rate. OS/2 Warp accesses the serial port more efficiently than does Windows. It provides a 5Kbyte receive buffer, better interrupt handling, resulting in faster serial data transfer (see the modem panel).

Choose a service provider, tell the provider your credit card details for billing service charges, install the software and log on (see the providers panel).

Bit rates in practice

Accessing a UK bulletin board at 14,400baud using Zmodem protocol, data transfers at around 100Kbyte per minute. With the same hardware, Internet achieves around 60 to 100Kbyte per minute.

One aspect that confused me initially was the relationship between the Modem's claimed data rate and the computer serial port transfer rate. This is a setting required to install most communications software. As a rule of thumb, with a 9,600 baud modem, set 9,600 bps rate. With a 14,400 baud modem set to three or four times this rate, 57,600 bit/s for example, or as fast as the system will accept in practise.

Data transfer

All Internet transfers make use of the Transmission Control Protocol/Internet Protocol, TCP/IP, which started life as the UNIX networking standard. As a protocol for networking it has spread into conventional networks. During 1992, an open standard for TCP/IP under Windows was defined, known as Winsock. Today versions exist for most operating systems.

Using the system is like sending a letter, one page at a time in individually addressed envelopes. One page is a maximum of 1500 bytes of data, addressed to the receiving computer. Pages can arrive out of sequence and must be sorted by the receiving computer. Any garbled pages are automatically resent, transparently to the operator, who sees a record of the reception in bytes.

What can be found on the Internet?

Basically data of any form can be found on the Internet. This may be correspondence, program files, databases, graphics, audio, video - in fact anything which can be stored or processed in a computer. In addition, there are over 7000 news groups.

Internet has many libraries. One of these, the Internet Library, contains some 6 million articles. Searching can take many forms:

- by journal, title and contents page
- by authors of articles
- by keywords within the article
- by article title or summary.

See Fig. 5.

Searching for resources

Certain specialist computers are called servers since by acting as a librarian, searching records and pointing you in the right direction, they 'serve' the 'Internet' to you. Each maintains very large databases routinely updated by accessing each computer's files. These servers are dedicated to perform specific searches.

Archie. Many computers allow the public to log on anonymously, read their directories, and download files. Some estimates suggest over 1000 such computers now exist, housing nominal charge. This data-base presently contains over some 20,000 Journal Titles - mainly scientific - spanning 1988 to date. In total this represents some 6 million articles. Searching can take many forms:

- by journal, title and contents page
- by authors of articles
- by keywords within the article
- by article title or summary.

Join the ‘Virtual Instrument’ Revolution

Pico’s Virtual Instrumentation enable you to use your computer as a variety of useful test and measurement instruments or as an advanced data logger.

Hardware and software are supplied together as a package - no more worries about incompatibility or complex set-up procedures. Unlike traditional ‘plug in’ data acquisition cards, they simply plug into the PC’s parallel or serial port, making them ideal for use with portable PCs.

Call for your Guide on ‘Virtual Instrumentation’.

NEW SLA-16 Logic Analyser
Pocket sized 16 Channel Logic Analyser
- Connects to PC serial port
- High Speed Sampling - up to 50MHz
- Internal & external clock modes
- 6K Trace Buffer
SLA-16 with software, power supply and cables £219

NEW ADC-100 Virtual Instrument
Dual Channel 12 bit resolution
- Digital Storage Scope
- Frequency Meter
- Data Logger
ADC-100 with PicoScope £199

The ADC-100 offers both a high sampling rate (100kHz) and a high resolution. It is ideal as a general purpose test instrument either in the lab or in the field. Flexible input ranges (±200mV to ±20V) allows the unit to connect directly to a wide variety of signals.

NEW PicoScope
‘virtual instrument’ software

PicoLog Advanced data logging software.

Pico Technology Ltd. Broadway House, 149-151 St Neots Rd, Hardwick, Cambridge. CB3 7OJ UK.
Tel: 01954 - 211716 Fax: 01954 - 211880

Phone or FAX for sales, ordering information, data sheets, technical support. All prices exclusive of VAT. Carriage Overseas £9
<table>
<thead>
<tr>
<th>Part</th>
<th>Price</th>
<th>Part</th>
<th>Price</th>
<th>Part</th>
<th>Price</th>
<th>Part</th>
<th>Price</th>
<th>Part</th>
<th>Price</th>
<th>Part</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEY92</td>
<td>8p</td>
<td>BU206</td>
<td>45p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>10p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADY55</td>
<td>6p</td>
<td>BU210</td>
<td>45p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>10p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR102</td>
<td>6p</td>
<td>BU279</td>
<td>50p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR128</td>
<td>6p</td>
<td>BU278</td>
<td>50p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR212</td>
<td>6p</td>
<td>BU279</td>
<td>50p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR143</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR153</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR175</td>
<td>6p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR187</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR198</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR212</td>
<td>6p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR225</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR225</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR225</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
<tr>
<td>ADR225</td>
<td>4p</td>
<td>BU245</td>
<td>25p</td>
<td>BF595</td>
<td>45p</td>
<td>MU201</td>
<td>40p</td>
<td>2N3904</td>
<td>50p</td>
<td>2N3641</td>
<td>50p</td>
</tr>
</tbody>
</table>

**PLEASE PHONE US FOR TYPE NOT LISTED HERE AS WE ARE HOLDING 30,000 ITEMS AND QUOTATIONS ARE GIVEN FOR LARGE QUANTITIES.**

Please send E1 P&P and VAT at 17.5% to Govt, Colleges, etc.
Orders accepted. Please allow 7 days for delivery. Prices quoted are subject to stock availability and may be changed without notice.
TV and video parts sold are replacement parts.

Access & Visa Card accepted

WE STOCK TV AND VIDEO SPARES, JAPANESE TRANSISTORS AND TDA SERIES. PLEASE RING US FOR FURTHER INFORMATION.
## Electronic Designs Right First Time?

**NEW! - LAYAN - Affordable Electromagnetic Simulation**

For less than £1000!

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>360/720K 5.2&quot; TEAC BBC compatible disk drives</td>
<td>£30.00</td>
</tr>
<tr>
<td>360/720K 5.2&quot; TEAC BBC compatible disk drives</td>
<td>£30.00</td>
</tr>
<tr>
<td>720K disk drives</td>
<td>£30.00</td>
</tr>
<tr>
<td>High quality 750 MHz video card 100 mhz</td>
<td>£22.00</td>
</tr>
<tr>
<td>Sony P' colour monitor Treiber super fine pin model</td>
<td>£50.00</td>
</tr>
<tr>
<td>Fine flash memory cards 100 to 900</td>
<td>£10.00</td>
</tr>
<tr>
<td>Total equipment planning for CFD details</td>
<td>£20.00</td>
</tr>
<tr>
<td>HP 74179A, RS232ICCIT C-22 graphics/CAD plots</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 427A voltmeter</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 9705x</td>
<td>£20.00</td>
</tr>
<tr>
<td>HP 431C power meter cable and head</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 3225B frequency meter</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 1332 A-Y display with options 215/300/315/570/63</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 425C sweep scope 4-8 GHz</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 1003A probe</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 311B diagram analyser</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 4155B smtirfert</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 82103 A pin probe</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 100/1000 test set</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 2351A transmission test set</td>
<td>£15.00</td>
</tr>
<tr>
<td>HP 16010 Logic Status Analyzer</td>
<td>£15.00</td>
</tr>
<tr>
<td>SONY 144A BPI 3.5FIDKA drives</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK 7615A empl plug</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK 7715A curve plug</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK 1041-2 standard waveform-calibrator</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK swept frequency meter 015-017-00</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK 914C AD converter plug</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK 914M4 multimeter</td>
<td>£15.00</td>
</tr>
<tr>
<td>TEK 184 kong mark generator</td>
<td>£15.00</td>
</tr>
<tr>
<td>DATA 1220 Universal Programmer 160k, 608A</td>
<td>£15.00</td>
</tr>
<tr>
<td>DATA 10 Rambam data (in VLSI)</td>
<td>£15.00</td>
</tr>
<tr>
<td>DATA 10 Rambam data (in VLSI)</td>
<td>£15.00</td>
</tr>
</tbody>
</table>

**Able to be ADD 17.5% VAT. TO ORDER: RING FOR C/P PRICES NOT SHOWN:**

**OFFICIAL ORDERS AND OVERSEAS ENQUIRIES WELCOME**

---

## Affordable Electronics CAD

**LAYAN: NEW Electromagnetic Layout Simulator. Links to EASY-PC Pro’ XM and ANALYSER III Pro’**

**EASY-PC Professional: Schematic Capture and PCB CAD. Links to ANALYSER III and PULSAR.**

**PULSAR: Digital Circuit Simulator**

**ANALYSER III: Linear Analogue Circuit Simulator**

**Z-MATCH for Windows: Smith Chart based problem solving program for R.E. Engineers**

**FILITECH: Active and Passive Filter design**

**STOCKIT: NEW, Comprehensive stock control program for small / medium size businesses**

**EASY-PC: Entry level PCB and Schematic CAD**

**Technical Support FREE for life!** Prices exclude P&P and VAT.

**Special discount schemes for education**

---

## Number One Systems

**Ref: WW, Harding Way, St. Ives, Huntingdon, Cambs. PE17 4WR, UK.**

For Full Information Please Write, Phone or Fax.

**Tel: +44 (0) 1480 461778**

**Fax: +44 (0) 1480 494042**

---

**SMART CARD READER/ PROGRAMMER**

On board ISO 7816 Card Reader Socket (Videocopy etc). Software runs on IBM/PC enabling the user to Read & Write to ISO7816 and 2128 Dm Osic carte boards. Card. All systems contains a PIC 16CH34 programmer. Ideal smart card development tool. £79.95 Requiers external power 15-20v AC or DC @250 ma. (optional extra £6.50).

**MICRO ENGINE MCS8/35 Development board**

Tiny 872m x 42m PCB contains socketed 44 pin cpu., turned pin Rom Soccer at 12 MHz and port. 1 socket on IDC connector. Ideal for stand alone project or development work. Supplied with CIRCUIT & MCS8/35 development software. £99.95

**PIC ICE III In Circuit Emulator for PIC16C54-55-56-71-84,****

Replicates all 18 or 28 pin PICs. All ports and directions, OSC 2 output, RTCC input. On board A/D converter for PIC16C71. Supplied with PICDEV54 and PICDEV71 software, manual, leading cables & headers. ASIM examples, and hardware精确 work. £185.95

**PIC ICE Std In Circuit Emulator for 18 pin PICs only so A/D**

Plugs into the printer port, appears on the target system as a normal PIC device including OSC2 and RTCC outputs. Runs in real time from the IBM PIC changes made to File registers reflected on target. Supplied with Development software PicDev 54-57 and PicDev 71/84 £69.95

**PIC PROGRAMMER** Programs Pic16C54-56-57-71-84. Centronics port interface. Powerful editing software to Read, Write & Copy PIC devices including data memory in PicDev54. Top quality components used throughout including production 2Z socket. Now includes a Pic Editor/Assembler for all above PIC. Requires external power 15-20v AC or DC @250 ma. (optional extra £6.50)

**MEGAPROM programmer, EPROMS, EPROMS, and FLASH memories from 2k (2716) to 8 Meg (27C256).** Runs on IBM/PC via the centronics port using standard printer cable. Works on all PC compatibles, laptops, and notebooks. No special port requirements. Top quality components used throughout including production 2Z socket. £199.95 Requires external power supply 18-20v AC or DC @250 ma. (optional extra £6.50).

**EPROM EMULATOR Works on any computer with centronics printer port. Data sent to printer port appears in the target board Eprom socket. Emulates from 1k to 32K Byte (27C256) roms, board switchable. Very fast download. Works with or without our Development software. £59.95**

---

## DEVELOPMENT SOFTWARE

Develop software for your IBM/PC or other Microprocessors, Controllers, Pic's etc. Software has fully integrated Text Editor, Assembler, Disassembler, and Simulator. Code can be downloaded directly to your EPROM Emulator. All software supplied with sample ASM files, and user documentation manual. Available for the following:**

**MICRO/51S2/52**

**MC8084/49**

**PIC16C45A/56**

**R4052**

All hardware carries a 12 months parts and labour Guarantee. No VAT payable. Please add £1.50 for carriage.

---

**CREDIT CARD ORDERS SAME DAY DESPATCH**

**JOHN MORRISON DEPT WW**

4 REIN GARDENS, TINGLEY,

WEST YORKSHIRE WF3 1JR

TEL (or FAX) 01132 537507**
Watt's steam engine? Baird's television? Bardeen, Brattain and Shockley's transistor? The truth is that all advances in technology really depend on multiple contributions and previous research. With this in mind Tom O'Dell surveys the archives to find where the real credit belongs for the birth of the heterodyne.

Heterodyning, mixing a weak incoming signal with a local oscillator to produce an intermediate frequency, is taken for granted today. The front ends of nearly all radio, television and radar receivers exploit it and it has also been applied to optical comms receivers.

According to the Oxford English Dictionary, John Erskine Murray coined the word heterodyne to describe "one of the most interesting of Professor Fessenden's many inventions". He was referring to an electrodynamic telephone receiver that R A Fessenden (1866-1932) patented in 1913.

Certainly, the original patent specification does describe the idea of producing a beat-frequency. But despite what Fessenden claimed (see Fessenden's heterodyne), it is unlikely that his device ever worked at radio frequencies.

Instead, the first successful heterodyne system to be used in wireless telegraphy appears to have been developed in Germany by Rudolf Goldschmidt.

Sound-wheel rectification

Rudolf Goldschmidt graduated as an engineer in 1900 and joined AEG's engineering laboratories, first in Berlin and later in Prague. In 1907 he left industry to become a lecturer at the Technical University in Darmstadt, and it was from there, in 1909, that his most important invention was patented as the Goldschmidt high-frequency alternator.

Goldschmidt alternators were used as transmitters for the German wireless telegraphy service between Germany and the USA, set up in late 1913. The machine at Tuckerton, New Jersey, had an output of 120kW at 50kHz, while the Eilvese transmitter, near Hannover, had a power of 150kW.

During the first months of the Great War, after the British had cut German transatlantic submarine cables, this link became vital: the US did not join the War until April 1917.

In Goldschmidt's system, the cw signal from an aerial is connected to an LC input circuit tuned to signal frequency, $f_s$. A tap on the tuning inductor takes the signal on to the tonrad (sound-wheel), which is a commutator of N segments driven at an angular velocity $2\pi f_0/N$. $f_0$ corresponds to the local oscillator frequency. Goldschmidt's tonrad had 800 segments and was driven at 3750rpm.

The tonrad connects headphones to the radio frequency source for only half the time, at frequency $f_0$. If $f_0$ is made identical to $f_s$, then the incoming signal undergoes synchronous rectification. Under these conditions, no audible
sound would be produced in the high-impedance headphones because the mean current flowing would be a constant. If the tonrad is now slowed down slightly, the current flowing in the headphones will have a mean value that varies at the beat-note frequency, \( f_s - f_o \). In the original system this frequency was 1kHz, at which the human ear is most sensitive. The high-impedance resonant-reed type headphones could then be tuned for maximum sensitivity at the beat-note frequency.

Synchronous detection and heterodyning is very familiar to us today, with bilateral switches operating at up to several MHz and available as cheap integrated circuits in cross technology. But in 1913 all this kind of signal switching had to be done mechanically.

However, mechanical rectifiers were well established in power engineering at that time, providing low voltage dc supplies for battery charging and electroplating. No other rectifier had such a low voltage drop across it during conduction.

Goldschmidt was a power engineer and, doubtless, would have considered his tonrad to be an extension, to radio frequencies, of the well-established technique of mechanical rectification. Although it was a first-class piece of mechanical design, the tonrad did not introduce any really new ideas, and no application was made for a patent.

His high-frequency alternator, on the other hands, was a radically new step forward and was patented in several countries.

Voyage of discovery

About one year after the Goldschmidt system began working traffic between the USA and Germany, a completely different kind of ‘heterodyne’ circuit began to appear in the literature. In it, the input circuit is tuned to signal frequency, \( f_s \), and a local oscillator, at frequency \( f_o \), is coupled into the diode circuit and is of sufficient strength to turn the diode on hard during alternate half cycles. Effectively, this is Rudolf Goldschmidt’s tonrad realised electronically. A potentially fast diode switch has replaced the slow mechanical one,

Fessenden’s heterodyne

In his patents Fessenden gave no design detail on the electrodynamic headphones needed for his heterodyne system. But in the text he describes them – and represents them in his circuits – as two simple coils.

One coil was to be mounted on the headphone diaphragm cone, and the other to be fixed close to the first. Fessenden’s reasoning was that the force between the two coils would be proportional to the product of the two currents, \( i_1 \) and \( i_2 \), flowing in the two coils. If \( i_1 \) were made the rf signal current from the aerial, and \( i_2 \) was obtained from the local oscillator, a multiplicative mixer would result as far as the force on the cone was concerned, and a beat note at the difference frequency would be produced as audio output.

By making the cone couple into a Helmholtz resonator and tuning the resonator to the beat note, Fessenden imagined excellent results would be obtained with a powerful local oscillator. He, and Hogan, wrote of an ‘amplification’ of the small signal \( i_1 \) by the local oscillator current \( i_2 \) because audio output would depend on the product \( i_1 i_2 \).

But the argument collapses when practical design ideas are introduced into the problem.

The best geometry would be two really thin, flat, pancake-style coils, separated by as small a distance as possible. The force between two such coils is:

\[
F_1 = \pi \mu_0 i_1 N_1^2 r/a
\]

where \( N_1 \) and \( N_2 \) are the number of turns on each coil, \( a \) is the width of the coils and \( r \) is their mean radius.

In a conventional moving coil headphone that uses a permanent magnet, the moving coil again has \( N_1 \) turns and carries current \( i_1 \). The magnetic field around the moving coil, \( B_0 \), is now constant instead of varying at the local oscillator frequency and is provided by the permanent magnet. Signal current in this second case must be the rectified rf signal current and carry only the low frequency modulation on this rf. Force on the cone is now

\[
F_2 = 2\pi \mu_0 i_1 N_1 B_0
\]

Comparing \( F_1 \) and \( F_2 \) shows that the ‘amplification’ claimed by Fessenden and Hogan could just as easily be claimed for the permanent magnet design. The constant magnetic field, \( B_0 \), is producing the same multiplying effect as \( i_2 \).

The designs can be compared by making the above equations for \( F_1 \) and \( F_2 \) equal to one another and solving for \( i_2 \). \( i_1 N_1 \) may be cancelled out because it is going to be about the same in both designs, even though impedances, current levels and frequencies will be quite different.

In the two-coil design, \( i_1 \) is the microamp level aerial current, and \( N_1 \) must be small because of the high frequency. In the permanent magnet set-up, \( i_1 \) is the nanoamp level crystal detector current, but \( N_1 \) may be several thousand turns.

The result is:

\[
i_2 = 2\pi \mu_0 i_1 N_1 B_0
\]

and this shows how large local oscillator current \( i_2 \) must be to make Fessenden’s design as useful as the conventional moving coil headphone. \( B_0 \) could be made as high as 1Tesla, and a 10mm, accommodating 100 turns of 100\mu m wire. Such a winding would not have too high an inductance, but the above equation shows that \( i_2 \) would have to be over 150A if the same order of audio output were to be obtained from both Fessenden and conventional designs.

Hardly surprising then that Fessenden’s heterodyne never saw wide application. To have 150A of rf current so close to one’s ear – even if the associated cooling problems could be solved – is not a good idea.
opening up the high-frequency and microwave applications that are now so familiar.

In 1913, JL Hogan published a paper mainly concerned with Fessenden's electrodynamic telephone idea but briefly mentioning the diode mixer in connection with some tests that had been made on behalf of his employers, The National Electric Signalling Co of Pittsburgh, Pennsylvania, during a voyage across the Atlantic. That was the voyage of the USS Salem, which sailed from Philadelphia on February 15, 1913, for Gibraltar. On board were National Electric Signalling personnel and Navy radio specialists. Their purpose was to test new receiving equipment, working with two transmitters - a Federal Telegraph 35kW arc and an NES 100kW rotary spark - installed on the military reservation at Arlington, Virginia. The three receivers on board the Salem were a Fessenden heterodyne from NES, a Wireless Speciality Apparatus Co crystal receiver and a 'tikker' receiver from Federal.

Tests were to be made as the Salem crossed the Atlantic and, when she arrived at the British base in Gibraltar, arrangements had been made with the Royal Navy for experiments to be continued using the very large aerials that were available there on shore.

As part of the deal with the British, the US Navy had agreed to allow a Royal Naval Officer to board the Salem once she arrived at Gibraltar and work alongside the Americans during March 8-11, 1913. The officer concerned was Captain Willis, RN from HMS Vernon, Portsmouth, which at that time was a major Royal Navy r&d establishment. Captain Willis' report concentrated on what he called "the heterodyne". But from his account of the apparatus, this clearly was not the Fessenden heterodyne. Instead, he describes a local oscillator loosely coupled to "the usual crystal/tallite receiving circuit".

The local oscillator - a pretty fearsome arrangement 'placed as far as possible' from the receiving circuits - was almost certainly the one belonging to Fessenden's heterodyne system. Captain Willis describes it as an "apparatus... to produce undamped continuous oscillations by means of the electric arc in a hydrocarbon atmosphere". DC power input to this arc was over 100W.

But what appears to have happened on the Salem as she crossed the Atlantic was that the operators found experimentally that the Wireless Speciality Apparatus crystal receiver worked far better when Fessenden's heterodyne system was working at the same time. What Willis was actually seeing was the birth of the local oscillator/crystal receiver combination that later began to find its way into the literature.

The suggestion that the experts on the Salem were engaging in much more general research than merely testing for the local oscillator "should have been completely enclosed in an earthed metal case". But when he witnessed the experimen-
two notes are added together may be considerably greater than the amplitude of one of the component waves... We have frequently obtained amplifications of as much as ten times in current and correspondingly as much as a hundred times in energy".

Their conclusion is, of course, nonsense. Only a multiplicative mixer can produce effects of this kind. Adding and rectifying can, at best, produce a beat of the same amplitude as the weakest input signal.

But the results of these early experiments should not be discounted today as "nothing but a bit of rf bias". The use of bias on crystal detectors to take the detector onto the most sensitive point of its characteristic was well established at the time, as Stanley's well-known Text book on wireless telegraphy, Proc. IRE, 6, 275-84, 1918.

By using the detector diode at high forward current, instead of the normal quiescent levels normally found in a crystal receiver, Hogan and his US Navy colleagues removed the enormous power loss that was normally associated with simple crystal detectors. A much greater fraction of the received power could now be passed on to the headphones, translated using the local oscillator/crystal detector combination that has a negligible power loss that was normally associated with simple crystal detectors. The correct explanation for the remarkable improvement in sensitivity discovered by these early workers may be considerably greater times in energy".

Other authors of the time attempted to explain the action of the diode mixer by using a square law model for its forward characteristic, an approach that continued for some time and can still be found in some student texts.
NEW LOW PRICE – NEW COLOUR

HP141T SPECTRUM ANALYSERS

TESTED

HP141T + 852A or B IF - 8535B RF - 1kHz - 110Mc/s - A IF £600 or B IF - £700.

HP141T + 852A or B IF - 8535B RF - 100kHz - 1250Mc/s - A IF £800 or B IF - £900.

HP141T + 852A or B IF - 8555A RF - 10Mc/s - 18GHz - A IF £1400 or B IF - £1600. The mixer in this costs £1000, we test every one for correct gain before shipment.

HP + 852A or B IF - 8556A RF - 20Hz - 300kHz - A IF £600 or B IF - £700.

HP ANZ UNITS

AVAILABLE SEPARATELY NEW COLOUR – TESTED


HP8443A Tracking Generator Counter - 100kHz - 1MHz - £300 - £400.

HP8445B Tracking Pre-selector DC - 18GHz - £400 - £600 or HP8445A - £250.

HP8444A Tracking Generator - £750 - 1300Mc/s.

HP8444A Opt 059 Tracking Generator - £1500 - 1500Mc/s.

SPECIAL OFFER - 14 ONLY

HP 1401T (NON-STORAGE)

Mainframe Plus 8552A IF Plug-In Plus 8558B RF Plug-In 20Hz - 3000kHz Plus 8553B RF Plug-In 1kHz - 110Mc/s. Tested with instructions - £700.

Marconi TF2091 - AM-FM signal generator – also sweep – 10k/s - 1kHz to 4GHz - £200 – tested to £400 as new with manual – probe kit in wooden carrying box.

Marconi Vector Voltmeter type BVM 1520A £40 - £600 to £600 or new or colour.

Marconi Sweep Oscilloscope type 8651A B & C + keys from 10MHz to 18GHz also 18GHz – £2000. P.O.R. Description...

Marconi Network Analyser type 8407A + 8421A + 8410A £1000–110Mc/s – £1000 – £1100. Description...


Marconi Digital Modulation Meter type 5015 – £1500. Description...

Racal/Dana Signal Generator 9082H £1500 – £2000. Description...

Racal/Dana Signal Generator 9082 £1500 – £2000. Description...

Racal/Dana Modulation Meter type 9009 £1250. Description...


HP 8410A – B – C – D – E – F – G £500 – £1000. Description...

HP 8410 – A – B – C – D – E – F – G £500 – £1000. Description...

HP 8410 – A – B – C – D – E – F – G £500 – £1000. Description...

HP 8410 – A – B – C – D – E – F – G £500 – £1000. Description...

Readers are encouraged to evaluate their requirements and get in touch with us for any additional information, including prices or specific product availability. We welcome feedback and are always happy to provide assistance.

CIRCLE 121 ON REPLY CARD

June 1995 ELECTRONICS WORLD+WIRELESS WORLD

499
Dynamic cut...

As a recording engineer and designer I follow the subjectivist/objectivist audio battle with interest, with some sympathy for both camps. However, in his article on slew rates (April E+W+W) Ben Duncan shoots himself in the foot by overstating his case, where on Earth does he get the idea that 20 years ago classical recordings were made with dynamic mic's? As far back as 1959 I was using Neumann M49 and U47 condenser mics as well as AKG C12s and Telefunken M25s! All of which are and still used by many classical engineers today. The Ampex 300 valve tape machine had a record/repair response extending beyond 20 kHz (the test tape stopped at 20k) while 20 years ago Ortofon offered a disc cutting head (G0741; DSS 731) with a range of 10Hz-25kHz. In the next breath he states that on direct cut vinyl discs information can extend to 200kHz. I have to say that no cutterhead has been designed with such a range; the Ortofon above has the widest range of a production head. In any case, the polishing facets of the cutting stylus would erase any signal with the curvature of a 20kHz wavelength at any reproducible level.

S W Davis

Wembley

...heading for change...

Ironically, Ben Duncan's article ('Simulated attack on slew rates', E+W+W April 1995, p. 303) shows exactly why the slew rates of audio amplifiers are of limited relevance. According to Mr Duncan, a very unpleasant distortion can begin when an amplifier's slew limit is approached by a factor of two, or even ten. An amplifier with a 12V/μs slew rate which does not generate substantial sub-slew or soft TIM up to half its slew rate must be superior to an amplifier with 50V/μs slew rate which already generates substantial TIM at a tenth of its slew rate.

Hence, applying a test signal whose rate of change is equal to the worst rate of change expected and measuring the distortion generated under these conditions, gives far more useful information than a slew rate measurement. The simplest usable test is a thd test with a full-amplitude sine wave of sufficiently high frequency. Douglas Self's amplifiers perform quite well under these tests, as the graphs in his 'Distortion in power amplifiers' series show.

Marcel van de Gevel

Haarlem, The Netherlands

...slewing from reality

Doug Self comments on Ben Duncan's article, 'Simulated attack on slew rates' (April 1995). I read Duncan's essay at self-rebuttal with mounting alarm as it veered further and further from reality. I suppose I should be flattered that my work has received so much attention, but I'm not sure that disseminating Duncan's material, which is neither accurate nor constructive, has done audio much of a service.

Duncan's first contention seems to be that hf levels in music are higher than conventional wisdom suggests. Facts are facts. It is wrong to suggest that hf levels in music, live or otherwise, are anywhere near those at the bass end; if they were, it would simply be intolerable to listen to. As for using an Iron Maiden gig as an audio reference - words fail me. It is fallacious to say that the rise of digital keyboards has brought about a significant increase in the hf content of musical material. Digital keyboards, being digital, have reconstruction filters after their d-to-a converters, and usually internal sampling frequencies lower than 44kHz cd standard.

As a believer in reason and experiment rather than blind dogma, I hooked up my Roland (26) keyboard to a spectrum analyser to check the ultrasonic output. Apart from a -80dBm spur at 27kHz, presumably the sampling frequency, the output was commendably clean, with nothing above the -90dBm noise floor. No manipulation of the controls or programming could produce any output above 27kHz, which did not come as a total surprise. A moment's thought shows that in fact you are much more likely to get ultrasonics from real instruments which have no inherent bandwidth limitations but with the possible exception of dog whistles, ultrasonic output is likely to be low.

No input rf filtering was used in my simulations or real measurements, because the aim is to approach the slew-rate of the amplifier alone. The upper bandwidth limit of an audio system must be defined somewhere and I must admit I thought this was a little obvious to need further repetition. As I have explained several times before, it cannot be done properly by just slamming an RC network on the amplifier input unless you know that it will be driven from a defined source impedance.

I am afraid Duncan's slew-rate simulations of my circuitry are completely worthless because:

1) The VAS beta-enhancer emitter resistor has been omitted from Fig. 4. This component is essential to pull charge carriers out of the base of the VAS transistor and therefore has a major effect on slewing behaviour.

2) The test signal is already slewrate limited before it reaches the amplifier. Mine is not.

3) The top output emitter resistor is the wrong value; though this mistake may not affect slewing much.

4) For reasons we can only guess at, all the transistors have been changed for different types. Since slew behaviour depends on the magnitude of currents, transistor beta may affect it significantly. For comparative purposes, this change alone renders the results meaningless.

After this, to be told that the simulated circuit 'precisely follows' the one that I published can only be described as hilarious. In view of all the discrepancies there seems no point in quibbling about the numerical results, but the long settling tails on Duncan's outputs are definitely erroneous. There simply do not exist either in competent simulation or real life. I suppose the probable cause is overloading of some internal circuit node.

I think Duncan may be under the impression that I am advocating the generic/Lin configuration as the best possible for all parameters under all circumstances. This is not and has never been the case. However, the generic/Lin is also deeply degrading the bass for 95% or more of the amplifiers that have ever been built, and so the obvious place to start enquiries into amplifier design.

 Unexpectedly, my investigations into the linearity of this architecture revealed that it was capable of much lower distortion than is normally believed possible, with input impedance of 0.00015% at 1kHz, while still using safe and modest amounts of negative feedback. There is still no deep-dive source to this, (unlike Duncan's preferred circuitry) but it does require a clear appreciation of the various distortion mechanisms, and a knowledge of the cheap and simple approach can be used to minimise it. It is perfectly possible, and even likely, as my writings have already said, that faster slewing can result from different amplifier configurations.

Having disposed of this not-so-ubiquitous shower of destractive but fallacious criticism, I thought we would at last find out the superior but secret circuit methods that Duncan has trailed before us for so long. I was astonished to see that the relevant circuit was concealed in an op-amp sub-circuit in his simulation, and only described as a "discrete op-amp". It strikes me that to continue to protest that you know a better way, and then after everything refuse to reveal it, can only invite ridicule. The diatribe on differential amplifiers is also deeply depressing. Duncan does not choose to disclose the details of the circuit he is simulating, but the quantity of high-order harmonics seems to indicate that there is an output stage present generating crossover distortion. As far as I can follow it, his contention seems to be that a carefully-tuned one is possible, and even likely, which allows some harmonics of the crossover distortion to be manipulated in amplitude by partial cancellation.

This sort of tuning appears to introduce another trim control, which will be deeply unwelcome on production lines, and also assumes that the 'quiescent current' is exactly set and exactly maintained to ensure that the output stage generates...
Letters

Ben Duncan replies:

I am surprised that Douglas is upset.

Although my work has been criticised and even described as ‘putative’ in his series of articles, I have praised in print what I have found to be good (a substantial proportion) and, in my most recent piece, tried hard in the limited space to set matters in perspective. Even if I have additionally misrepresented his RC values (easily done when scaling three circuits back and forth), the octave they are out by is a negligible misrepresentation in the scheme of bass delay. In Self’s circuit in E+WW, Sept. 1994 (p.761), there are two HP filters, both –3dB at about 5kHz, which is enough to neutralize the minute misrepresentation of which I am accused.

As my whole article is based on HP filtration in the total audio path it is true that I have been accused of assuming that the tiny differences being argued over affect my conclusions.

Self on Hawtin

In his latest letter, Mr Hawtin seems to be trying to establish that an amplifier with fets in can have low distortion. Of course this is true and was never in dispute. What I have said is that for a given amplifier architecture, fets would always distort more than the equivalent circuit using bipoles.

I really can’t see how this can be disputed, the $V_{th}$ law of fets compels the crossover distortion to be much worse than for bipoles in any straightforward output stage. This does not mean that it is not possible to add complications that make the overall performance good, an example of this is Robert Cordell’s design which includes extensive error-correction circuits in the output stage to linearise the fets. By the way, his output stage gain plots look much like mine, sharp corners and all.

In the selected data given, (which I do not accept as a representative statistical sample) I assume that “hybrid” means bipolar-driver combined with fet output devices. The purpose of this is of course to make the $500mV/fets$ behaviour more like power bipolar. As I have previously written,[4] the hybrid combination is a good deal better than fets alone, though nothing like as good as the purely bipolar equivalent, because the sharp gain changes that always seem to appear in fet outputs still persist.

One difficulty with the second-hand test reports that are referred to is that no test conditions are given; measurement bandwidth can make a major difference to the numerical results. In particular, the figure of 0.0002% needs a good deal of explanation, because this would be below the noise floor of even a quiet amplifier, and impossible to measure with any test equipment I have ever come across.

I have no intention of commenting on the rest of the examples given, without details of the circuitry a raw “thd figure teaches us nothing.”

I find it undervaluing to overrate the basics of electronic theory in E+WW, particularly to those who seem to have no interest in learning it. If Mr Hawtin has failed to notice the disentangling bandwidth and slew rate then any elementary textbook would put him straight.

It is true that as frequency is increased and an amplifier goes into slew-limiting, the output waveform will become triangular, and eventually its rms level will fall by 6dB; to call this “bandwidth” would be madness; apart from anything else it would be level-dependent.

The word has a precisely defined meaning which is not going to change, the first half of my last letter wishes to use it in an idiomatic way. A linear system may have a bandwidth limit, but it cannot exhibit a slew-rate limit because this is a non-linear effect. The distinction is fundamental, and surely not beyond the grasp of someone who feels qualified to lecture us all on amplifier design. Mr Hawtin’s appreciation of fet outputs is also in error. Bipolar transistor beta certainly varies with collector-current, though as I explained at some length [in 3] (which I can only assume Mr Hawtin has never read), beta variations only affect linearity significantly for loads up to 4.2. Whatever the load resistance, the stage remains an order of magnitude more linear than its fet equivalent. I have simulated and measured it. Has Mr Hawtin done either?

Mr Hawtin’s thoughts on bipolar output stages might be more valuable if he appreciated that they do not have a gain of 100x; unity gain is almost universal, for very good reasons. Similarly, the $V_{th}$ law is not very linear, and repetition will not make it so. This claim will be rashly explored in a future article. You have been warned!

Likewise, relentless repetition will not make all transistor amplifiers ‘roollalt 15kHz. They just don’t. I have a production-line making bipolar power amp’s that are flat to 0.1dB at 20kHz. And, just for the record, I opened today reviewed a bipolar amplifier that was -0.5dB at 22kHz.

Can we stop this now, please? I really do have better things to do.

References


....and to Erik Margan (Follow the leader, letters, E+WW, April 1995)

Self questioning

First I wish to congratulate Mr Self on his design procedure. I followed the series and subsequent debate with high interest. I am not a technician, and I think that Mr Self was didactic enough for me to follow his basic ideas.

Some minor queries, however, did arise. Why has Mr Self not used a cbp input stage in his final design? Would using MAT102/0Js here be an improvement?

In the voltage amplifier, why not combine the cascoding and buffering to get the best of both worlds? (Figs 4d, D) My suggestion is shown in the diagram.

Good linearity is claimed for ‘ring-emitter’ power transistors. Would there be any benefit from using, say, the 2SA1095 and 2SC2365 in his design?

Referring to ‘Distortion off the rails’, why not use a separate supply for the input and voltage amplifier stages, and/or stabilisation?

These questions may sound naïve, but then I am a psychiatrist, not an electronics engineer. Thank you for your splendid work – it has helped my understanding.

Simon Rambert

Bern, Germany

Mr Margan says that Subjectivism has been around long enough, without much concrete progress. I think it would be truer to say that it has been around more than long enough, without making any progress at all; if anyone feels that they have made genuine headway in comprehending how the unmeasurable avoids being inaccessible, then they are keeping awfully quiet about it.

Talking of progress, just how much should we expect when dealing with a ‘subject’ that claims to be so ineffably subtle as subjective audio, and which has been around about twenty years? A comparison may be instructive. At the end of the last century, atoms
were still regarded as the inextricable billiard-balls of Dalton; then in 1896 Becquerel discovered that atoms exist. This was certainly a subtle phenomenon, undetectable by human senses, and it was also a radical one because it revolutionised classical physics.

In the succeeding twenty years, physicists discovered alpha and beta emission, showed that atoms were composed of a flimsy electron shell with a massive nucleus, measured the energy levels within that nucleus, and went on to demonstrate the transmission of elements through nuclear decay - from scratch.

This is an impressive record; in the case of Subjectivism, however, two decades of hand-waving seem to have brought no progress at all, and this gives a strong indication that the effects 'studied' do not in most cases exist.

I also differ mildly on the diagnosis: Mr Mangan feels that the phenomenon of subjectivism is a consequence of failure of communication between two groups of people. I would say that there are three groups of people here: engineers, subjectivists and musicians. This is an obvious simplification, with overlap between the categories, but perhaps it is nearer the truth.

While the attitudes of engineers and Subjectivists have been examined at interminable length in these pages, I find musicians (and I accept that is a broad category) have a distinct approach of their own. A musician is interested in the sound, by which he means the sound of a dominant seventh versus a flattened fifth, or pwm versus fm in the oscillator of a digital synthesizer. He doesn't mean the crossover distortion, nor indeed the superb capabilities of human hearing. As I have written in the past, an open-loop bandwidth of 10kHz means that discussion needs to be the case, and I suspect it is true of very few amplifiers indeed.

I felt less enthusiastic about one statement that Mr Brown made: "Most importantly, open-loop bandwidth of the amplifier must cover the audio frequency range." I am sure there are individuals in an orchestra. Laboratory equipment does not begin to approach such a level of performance. We do not know which features of an amplifier may be critical to prevent our analytical ability being impaired by the existence of electronic devices in the signal path.

I agree with Douglas that slew-rate should not be a problem in a reasonably-designed amplifier. Slew-rate and bandwidth are not directly related, although low figures of each tend to go together. The fascination of audio circuits is that laboratory measurements are not the final arbiter of performance. One day this may not be the situation and it may be established what is, and what is not, important. Until then I consider that wide open-loop bandwidth should be regarded as desirable in audio amplifiers.

Douglas Self
London

Ivor replies: Thank you to Douglas Self for his comments. I must plead guilty to having been careless in my choice of words. To say that the open-loop bandwidth of audio power amplifiers must cover the whole audio frequency range is incorrect. I should have written that it should cover the whole range, but I do not think this simple change will satisfy, I offer three reasons for my opinion. Note that I have used the word opinion. As explained below, the relevance of many points in the design of audio systems to subjective assessment of musical performance is by no means fully understood.

Compare the analytical performance of laboratory instruments with that of the human ear and brain. We respond to two pressure waveforms that may contain components from many sources.

Analysts reveal the components that come from the individual sources. With monophonic reproduction this is reduced to one waveform, yet we are able to detect the individual instruments in an orchestra. The technical equipment does not begin to approach such a level of performance. We do not know which features of an amplifier may be critical to prevent our analytical ability being impaired by the existence of electronic devices in the signal path.

Negative feedback is used in amplifiers to obtain a more linear reproduction. This is achieved by applying a voltage to the input signal to cancel out any distortion in the output signal. Feedback voltage is subtracted from the system input to get the net input to the amplifier. Consider an extreme case where the input is a fast transient and limited open-loop bandwidth prevents the feedback signal from immediately following the system input. For a short time the lower gain amplifier has a new input some ten times the normal; the higher gain one ten times that.

This momentary large input must cause an increase in the distortion products produced in the amplifier, with more production in the higher gain amplifier. A large short-term signal will not appear if the open-loop bandwidth of the amplifier is of the same order as the bandwidth of the input signal to the system. This requirement becomes more critical as the ratio of closed-loop to open-loop gain is reduced. The extreme case described is hardly likely to be found in practice, but it serves to illustrate the principle.

Finally, the amplifier described in the April 1990 issue started as an exercise to design a power amplifier with what seemed to be all the right features, including wide-open-loop bandwidth. Communications from readers and others who have built the design have, without exception, been favourable. In particular, comments have been made about clarity, definition and separation of sources within the stereo image.

I agree with Douglas that slew-rate should not be a problem in a reasonably-designed amplifier. Slew-rate and bandwidth are not directly related, although low figures of each tend to go together. The fascination of audio circuits is that laboratory measurements are not the final arbiter of performance. One day this may not be the situation and it may be established what is, and what is not, important. Until then I consider that wide open-loop bandwidth should be regarded as desirable in audio amplifiers.

Ivor Brown
Uxbridge, Middlesex

Increasing momentum
Re R Lerwill's letter (EW+W/W Apr 95) on the uncompensated increase in momentum of cathode rays, the problem does not arise if, instead of mass being regarded as a scalar quantity, it is regarded as a vector quantity. This is counter-intuitive, but not absurd when one considers the ways in which mass may be measured. If it is measured as a body's resistance to force, then the force is a vector and so must be measured. If it is measured as the source of gravitational attraction, then this, although expressed in all directions when measured, must be associated with one in particular.

R Lerwill's accelerated electrons
Quad speed reduced

The article by Guruprasanna and Lanka Kumar in EWRW, March 1995, Quad speed RS232 contains some interesting ideas but the suggested implementation is flawed because the issue of discontinuous phase-shift at the symbol boundaries has been completely ignored (at least within the published text).

While the system described does indeed reduce the baud rate required, it fails to achieve the underlying objective, which is a reduction in the bandwidth needed to carry the signal.

Studying figure 4 shows that if any of the phase signals 0 to 7 (which all end at a high level after 8 cycles of the main clock) is followed by a symbol encoded by phase 9 (which is low after main clock period 8 but goes high at the end of clock period 9), a very narrow negative pulse is transmitted. This pulse is only half as wide as one bit-period of the original data stream, so is more likely to suffer corruption due to noise than the original data would have been, had it been transmitted at the 'raw' bit-rate.

In other words, the bandwidth required on the RS-232 link has been doubled, rather than reduced by a factor of four as desired. This is the opposite of what the authors of the article intended to achieve, illustrating that when extending concepts from modulation theory down to hardware, one must be careful not to get caught out.

That the frequency content of the data stream can be reduced at the expense of allowing data transitions to occur during a larger number of more tightly defined time windows is an interesting idea. Practically, it would require a more subtle coding scheme than that shown.

Duncan Learmonth
Chelmsford, Essex

Making the point

Many of your readers will know that the transistor was discovered by Bardeen and Brittain of Bell Laboratories in late 1947. I use the word 'discovered' rather than 'invented' because the device which they accidentally created, the point-contact transistor, was nothing like what they were looking for!

Working junction transistors, which is what Shockley, the Bell Labs theorist, was really seeking, were made some four years later.

Bell's point-contact technology was licensed to many commercial firms, and millions of point-contact transistors were made although operation of the device was very poorly understood in theoretical terms, and its production employed a highly empirical technique: 'forming'.

Forcing the point contacts to the germanium die using current pulses. The resulting structure, usually of prepolarity, had a common-base current gain ('alpha') considerably more than 1!

While the majority of point-contact transistors were made in the USA, a number were made in England by the General Electric Company. Many small commercial firms (particularly laboratories such as Harwell, but a few others) were only offered to government laboratories such as the ORNL, the most interesting information or anecdotes from that period, data books or sheets, circuit cards or early semiconductor devices (particularly point-contact transistors), I would like to hear from them. All letters will be acknowledged.

Dr. Andrew Wylie
Purley, Surrey

Safe discharge

In my circuit idea, Safe NiCd battery pack discharger, in the April issue, an error has crept into the text at some point. The final sentence should read... "To take any number of cells up to a maximum of 12, the zener voltage should be 2/3 the final terminal voltage and discharge current adjusted by R2 to 0.5A".

Bill Hume
Newmilns, Ayrshire

Tesla driven

Re the article I recently wrote on Tesla Coils, please note that the voltage equation I included is not valid for pulse-driven coils. The correct equation observes conservation of energy and is:

\[ V_c = \frac{V_o}{\sqrt{\frac{C}{C}}}, \quad \text{or} \quad \frac{L}{Z} = \frac{Z}{Z} \]

For this ideal to be reached, secondary loading must be minimal. It is also obvious that a lot of power is needed to reach voltages much higher than half a million or so, even if the Q of a coil reached 300 (most coils would get between 150 and 250). An analysis of the system shows that with a pulse repetition frequency of 100Hz (number of mains half-cycles/s), the energy has dissipated by the next capacitor discharge. The spark gap sets primary capacitor voltage and also capacitor energy storage. Maximum voltage must therefore depend on the amount of energy available to charge the secondary capacitance from each primary capacitor charge. In practice, spark formation would prevent this ideal being reached.

The coupling constant recommended ensured that voltage peaks (caused by impedances reflected from secondary to primary and vice versa) would not occur too far down the coil, overtreating secondary insulation. The height at which a peak will occur may be crudely described as:

\[ h_{pk} = h_w \times (1-k) \]

where k is the coupling constant.

Running a coil with a well regulated transformer (e.g. a micro wave transformer) will necessitate current limiting effective at 50Hz (the rf chokes are quite ineffective at mains frequency). The example coil used a high leakage inductance C-core demonstration transformer made by German firm, Leybolds.

Limiting means that the simple sparkgap arrangement shown in the article shorts the transformer when it fires. A better arrangement would alternate between charging the primary capacitor and discharging into the coil, eliminating the need for any current limiting.

M.J. Watts
Wellington, New Zealand.

Reference

WHERE CAN YOU BUY

- 2u 300mm Rackmount Enclosure for £28.51
- Seperate Internal Frame and Chassis
- External Cover Panels
- Removable Front and Rear Control Panel
- Free Standing or Rackmount

1u x 300mm depth £25.20
2u x 300mm depth £28.51
3u x 300mm depth £31.24

Prices exclude VAT and carriage.

System Enclosures Ltd
Manufacturers for the Electronics Industry
Dene Industrial Park, Kingstone, Herefordshire, HR2 8NP
Tel: 01981 251484 Fax: 01981 250187

For some of the lowest prices in the UK.

Other standard products:
- Small Free Standing Enclosures
- Consoles and Cabinets.

Other services:
- C.N.C punching on control panels.
- Powder Coating
- Screen Printing
- Design service for your special requirements.
Reference books to buy

For Audio Engineers

Audio Engineer's Reference Book

Subjects include
- Recording, microphones and loudspeakers
- Digital audio techniques
- Basic audio principles
- Acoustics and psychoacoustics
- Audio and television studios and their facilities
- Radio and telephony

Invaluable reference work for anyone involved with audio - from broadcast consultant to serious enthusiast. Audio Engineer's Reference Book is written by an international team of experts and edited by Michael Talbot-Smith - previously a trainer of audio engineers at BBC Wood Norton and now a freelance audio consultant and technical writer.

For TV & Video Engineers

TV & Video Engineer's Reference Book

Subjects include
- Fundamentals of colour TV
- TV studios
- High definition TV
- Satellite broadcasting
- Distribution of broadband signals
- TV receiver servicing
- Video and audio recording and playback
- Teletext

The TV & Video Engineer's Reference Book will be of immense value to anyone involved with modern TV & video techniques - in particular broadcast engineers. The new format makes it an excellent reference for students.

Edited by KG Jackson and GB Townsend from contributions written by acknowledged international experts.

Please supply me copies of the Audio Engineer's Reference Book,
(ISBN 0 7506 0386 0)
Fully-inclusive price - UK £62.50, Europe £68, Worldwide £78. Please add vat at local rate where applicable.

Please supply me copies of the TV & Video Engineer's Reference Book,
(ISBN 0 7506 1953 8)
Fully-inclusive price - UK £42.50, Europe £48.00, Worldwide £58.00, Please add vat at local rate where applicable.

Remittance enclosed £
Cheques should be made payable to Reed Business Publishing Group Ltd

Please return to: Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Please debit my credit card as follows:
Access/Master Barclay/Visa Amex Diners

Credit Card No. ____________________________
Exp date ____________________________
NAME (Please print) ____________________________
ADDRESS ____________________________
POST CODE ____________________________
DATE ____________ TEL ____________

SIGNATURE

VAT RATES
6% Belgium, 25% Denmark, 6.5% France, 7% Germany, 6% Greece, 4% Italy, 3% Luxembourg, 6% Netherlands, 5% Portugal, 3% Spain. FOR COMPANIES REGISTERED FOR VAT, PLEASE SUPPLY YOUR REGISTRATION NUMBER BELOW (customers outside the EEC should leave this part blank)

VAT NO. ____________________________

If in the UK please allow 28 days for delivery. All prices are correct at time of going to press but may be subject to change.

Please delete as appropriate. I do/do not wish to receive further details about books, journals and information services.

Business purchase: Please send me the book listed with an invoice. I will arrange for my company to pay the accompanying invoice within 30 days. I will attach my business card/letterhead and have signed the form below. Guarantee: If you are not completely satisfied, books may be returned within 30 days in a resalable condition for a full refund.

Credit card orders accepted by 'phone. Call 0181 652 3614
If you have followed our series on the use of the C programming language, then you will recognise its value to the practising engineer.

The book is a storehouse of information that will be of lasting value to anyone involved in the design of filters, A-to-D conversion, convolution, fourier and many other applications, with not a soldering iron in sight.

To complement the published series, Howard Hutchings has written additional chapters on D-to-A and A-to-D conversion, waveform synthesis and audio special effects, including echo and reverberation. An appendix provides a 'getting started' introduction to the running of the many programs scattered throughout the book. This is a practical guide to real-time programming. The programs having been tested and proved. It is a distillation of the teaching of computer-assisted engineering at Humberside Polytechnic, at which Dr Hutchings is a senior lecturer.

Credit card orders accepted by phone. Call 0181 652 3614.

A disk containing all the example listings used in this book is available, Please specify size required

Please supply ______ copies of INTERFACING WITH C Price £14.95
Please supply ______ copies of Disk containing all the example listings £29.96

Remittance enclosed £______

Interfacing with C can be obtained from Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 SAS

Cheques should be made payable to Reed Business Publishing Group Ltd

Please debit my credit card as follows:
Access/Master Barclay/Visa Amex Diners

Credit Card No.
Exp date
NAME (Please print)
ADDRESS
______________________________
______________________________
______________________________
POST CODE
DATE TELE

SIGNATURE

VAT NO.

If in the UK please allow 28 days for delivery. All prices are correct at time of going to press but may be subject to change.
Three extra circuit ideas from EDN’s Designer’s Companion.

Waveform generation trio

Precision waveforms from cmos logic

This circuit generates three different waveforms having frequencies less than 1Hz: triangle waves, positive ramps, and negative ramps. At very low output frequencies, the circuit’s input frequencies almost completely determines the output waveform’s linearity. Gate IC6, exclusive-or logic, beats input frequency fIN against reference frequency fREF, thus producing a train of pulses whose periods increase gradually until the frequency sources are completely out of phase. Then, the pulses’ periods decrease until the sources are again in phase. Flip-flops IC1A and IC1B produce 50% duty cycle inputs for exclusive-or gate IC3.

The op-amp and its surrounding components form a third-order, low-pass filter, whose $f_c$ is 1kHz. This filter averages the output of pulse buffer IC4 to produce a triangle waveform having a peak amplitude of $V_{cc}$ and a frequency of $f_{IN}-f_{REF}+2$. Be sure to select low-dielectric-absorption capacitors for the filter circuit.

Ramps are generated by the circuit in a similar manner, except that the phase comparator of the set-reset flip-flop, formed by IC2A and IC2B, replaces the exclusive-or gate. The phase comparator sets on every other negative transition of fIN and resets on every other negative transition of fREF. If fIN’s frequency is greater than that of fREF, then the width of the Q output pulse of IC2B will gradually increase. This increase produces a positive-going ramp at the circuit’s output. If frequency of fIN is less than fREF, the output will be a negative-going ramp. Note that the filter’s step response controls the ramp’s reset time. Selecting a frequency greater than 100kHz for fIN and fREF attenuates the pulse’s ripple. This relaxes the reset-time restrictions.

Michael A Wyatt
Honeywell SSO, Clearwater, FL

By beating two high-frequency input-pulse frequencies against each other and then integrating the resulting beat-frequency pulse train, this circuit produces low-frequency analogue waveforms having good linearity.
Current sink widens vco frequency range

Output frequency span of the familiar HC4046 voltage-controlled oscillator, vco, is about one decade, and the device exhibits fairly good linearity over an input voltage range of 1 to 4.75V.

This circuit widens this frequency span to three decades. It replaces the single frequency-determining resistor from pin 11 to ground with a precision voltage-controlled current sink comprising an LM358 op-amp and transistor Tr. The current sink overcomes the limitations of the integrated current sources normally responsible for charging and discharging the timing capacitor.

A fixed level of 2.5V is applied to the vco input at pin 9. Because the voltage on pin 11 cannot exceed 2V, the current sink must operate below this level. To meet this requirement, resistors R1 and R2 divide the input signal before it reaches the current sink’s input.

The graph compares the frequency-versus-voltage characteristics of the standard circuit with those of the new circuit. By using the voltage-controlled current sink, the linear tuning range spans three decades.

At the low-frequency end, output phase noise is quite noticeable because the current sink operates at very low current levels. When the loop is locked to a clean reference, the feedback reduces this noise. A better way to remove this output phase noise is to operate the vco near its maximum frequency and then divide the output digitally. This technique reduces the phase noise by the amount of the division.

Antonio Tagliavini
Applicazioni Digitali e Analogiche, Bologna, Italy

Programmable oscillator runs without a micro

Using a clever scheme adaptable to other programmable devices, this circuit allows you to operate the ML2035 programmable sinewave generator, IC3, without a controlling microprocessor.

A 74HC4060 counter, IC1, provides the sinewave

Counter IC1 first clocks in an 8-bit programming code via shift register IC2, subsequently clocking the sine-wave generator IC3 generator’s clock and a gating pulse to shift register IC2. When IC1’s Q3 output, on pin 5, goes high, IC2 begins shifting eight hard-wired bits into the sine-wave generator to program it. After IC2 shifts the eight bits, Q3 goes low, enabling normal operation. The circuit can produce both 50 and 60Hz outputs from an NTSC colour-burst crystal operating at 3.579545MHz. The table lists binary codes for other crystal frequencies. The sine-wave generator’s output exhibits a maximum of 0.5% thd.

By substituting a voltage-controlled current sink for the standard circuit’s fixed 10k2 resistor (a), the circuit in (b) extends the HC4046 vco’s frequency range.

#### Shift-register values and frequency errors for standard crystal values.

<table>
<thead>
<tr>
<th>Crystal Frequency (MHz)</th>
<th>fCLK (10MHz)</th>
<th>D10</th>
<th>D11</th>
<th>ABCD</th>
<th>EFGH</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.00</td>
<td>50</td>
<td>105</td>
<td>69</td>
<td>1001</td>
<td>0110</td>
<td>0.14%</td>
</tr>
<tr>
<td>4.00</td>
<td>60</td>
<td>126</td>
<td>7E</td>
<td>1000</td>
<td>0001</td>
<td>0.14%</td>
</tr>
<tr>
<td>4.194304</td>
<td>60</td>
<td>100</td>
<td>64</td>
<td>1001</td>
<td>0111</td>
<td>0%</td>
</tr>
<tr>
<td>4.194304</td>
<td>60</td>
<td>120</td>
<td>78</td>
<td>1000</td>
<td>0111</td>
<td>0%</td>
</tr>
<tr>
<td>6.00</td>
<td>50</td>
<td>70</td>
<td>46</td>
<td>1011</td>
<td>1000</td>
<td>0.14%</td>
</tr>
<tr>
<td>6.00</td>
<td>60</td>
<td>84</td>
<td>54</td>
<td>1010</td>
<td>1010</td>
<td>0.14%</td>
</tr>
<tr>
<td>8.00</td>
<td>50</td>
<td>52</td>
<td>34</td>
<td>1100</td>
<td>1011</td>
<td>-0.82%</td>
</tr>
<tr>
<td>8.00</td>
<td>60</td>
<td>63</td>
<td>3F</td>
<td>1100</td>
<td>0000</td>
<td>0.14%</td>
</tr>
</tbody>
</table>

Jon Klein
Micro Linear, San Jose, CA
PIC 16/17Cxx DEVELOPMENT TOOLS

High Specification PIC Tools from PARALLAX

ClearView In-Circuit Emulators

20-MHz in-circuit debugging for PIC 16C5x/64/71/84/.. Set breakpoints, step through code, modify registers. Friendly DOS and Windows software. From £399 (separate units for "5x" and "xx" PICs)

PIC Programmer Pack

Programmer for PIC16C5x/64/71/84/.. Documentation on disk. User supplied cables and power supply. Just £89

NEW BASIC STAMPS

Stamp-sized Computer Modules Run BASIC

BS1-IC
8 I/O
100 line capacity. 4-MHz Clock
£29

BS2-IC
16 I/O
600 line capacity. 20-MHz Clock
£49

Two NEW BASIC Stamp Controllers offering even more flexibility to Industry, Education and the Hobbyist. Both run Parallax "PBASIC" with familiar BASIC commands plus serial I/O, pulse measurement and button debounce. The BS2-IC includes additional support for LCDs, keypad, DTMF encoding/decoding, X-10 transmit and external time clocks. The BASIC Stamp programming package at £66 contains editor software, cables, manual and extensive application notes; everything you need to program Stamps using your PC.

MILFORD INSTRUMENTS

CIRCLE NO. 123 ON REPLY CARD

the new CRICKLEWOOD Electronics

Very Interesting CATALOGUE

ASTRONOMICAL RANGE AT DOWN TO EARTH PRICES

- TRANSISTORS+ICs+SEMICONDUCTORS
- RESISTORS+CAPACITORS+INDUCTORS
- SURVEILLANCE+SECRET+SECURITY
- PLUGS+SOCKETS+LEADS+CONNECTS
- TV & VIDEO SPARES (inc Video Heads)
- HI-FI+DISCO+HI-FI GADGETS+SPEAKERS
- AUDIOFILE COMPONENTS (inc Capacitors)
- IN CAR AUDIO+SPEAKERS (inc Bass tubes)
- COMPUTER ACCESSORIES+BOARDS
- TOOLS+TEST EQUIPMENT+BENCHWARE
& much much much more (over 10,000 lines).

SEND TODAY FOR THE VERY INTERESTING CATALOGUE

Pay by PO, Cheque, Credit Card or tape Coins to Paper

Please send me ......copies of the 1995 Cricklewood Catalogue. I enclose £2.50 per copy (UK & Europe). £5.00 overseas

Name
Address

Please Charge my Credit Card.no

Pay by PO, Cheque, Credit Card or tape Coins to Paper

Bar-code Reader

£12.95

AC Power Supply
£4.95

Keyboard Overlay
£1.00

Unknown Program
£3.00

Memory Modules
£3.00

Complete kit of HP71B, Bar-code Reader and power supply
£99.50

Other products at give-away prices

Numeric keypad for 'AT' computer
£5 + £2 Carriage (Carriage FREE if ordered with above).

SPECIAL OFFER

Buy 2 Kits For £59.00

INTERCONNECTIONS LTD

Unit 51, InShops, Wellington Centre, Aldershot, Hants GU11 5DB
Tel: (01252) 341900 Fax: (01293) 822786

CIRCLE NO. 125 ON REPLY CARD

HEWLETT PACKARD HP71B

BARCODE READER

Packaged

£29.95

£32.95

£4.95

£1.00

£3.00

£99.50

£3.50

£99.50

£5.00

£5.00

£99.50

SPECIAL OFFER

These are second user systems ex DHSS are fully tested and working but have to be programmed (THAT IS UP TO YOU)

H71B $69.95

Bar-code Reader $32.95

AC Power Supply $4.95

Other products at give-away prices

Numeric keypad for 'AT' computer £5 + £2 Carriage (Carriage FREE if ordered with above).

Other products at give-away prices

Numeric keypad for 'AT' computer £5 + £2 Carriage (Carriage FREE if ordered with above).
One chip – programmable in simple language via a pc serial link – interfaces both analogue and digital i/o subsystems.

There are two main drawbacks to designing a microcontroller into a control application. One is the need to learn a high or low-level language in order to program the device. The other is finding a means of getting the code from the platform it was written on into the controller.

A new controller from Timely Technology – the ITC232-A – is intended to overcome both these problems, in addition to being highly integrated. According to the device’s distributors, it can reduce the implementation of many standard programmable logic controller applications from days to hours.

Programming is carried out via a simple serial link to a PC running a low-cost terminal-comms package. As you will see from the panel, the ITC232 is programmed via simple, user-friendly, commands since the chip has its own key-stroke to machine-code translator.

Although the device can be programmed for wide variety of control tasks, a number of fully worked specific applications have already been developed. In addition to the three applications outlined in this article, there are notes describing how to analyse active filters, control remotely via modem and implement an optical fibre link. Further notes discuss error processing, pulse-data handling, multiple addressing, frequency counting and data conversion. Figure 1 gives you an idea of the device’s level of integration.

The device only has 40 pins, most of which are dedicated to i/o. But should the number of i/o lines be a restriction, additional control functions can easily be added via the device’s SPI bus, for which there is already a wide variety of compatible i/o chips.

Keystrokes – not compilers

Commands to the controller are typed at the command prompt of any terminal program, or stored in batch files to be sent to the board when needed. Complex command structures can be achieved without software via ‘dial-up scripting utilities’ found in most terminal and communications packages.

Many of you will find that you already have such a package, even if you have never used it. Most of them offer commands including decrement, getstring, if, jump, string monitor and search.

The scripting utility in PFS:WindowWorks offers all of these features, and more within its terminal program, for around £60. Others are more sophisticated, but all of them should save you a lot of time and money in getting complex applications up and running quickly without resorting to compilers and debuggers.
Triple stepper motor control

It is possible to be rotating up to three stepper motors within an hour of connecting the board to COM1. This capability is depicted in slow motion by a software simulator supplied with each evaluation board. The simulator is supplemented by a tutorial on stepper motor basics, including monophase, biphasic and half-stepping modes.

By simply typing SAL100 at the prompt on your pc, for example, you will turn the stepper motor on port A 100 steps to the left. The chip takes care of all housekeeping, including the provision of automatic and programmable last-pulse braking.

A power driver and current controller like the L298 and L297 respectively, are all that you will need to complete your hardware design. Such a design, one port of which is outlined in Fig. 2, is covered in detail in an existing application note.

The digital i/o ports are arranged as three eight bit ports whose pins are individually programmable as inputs or outputs and each capable of sinking 25mA. This makes them just as suitable for controlling relays and leds as reading the status of switches, counters and encoders. These pins and ports can be written to as easily as read - with single keystrokes. Typing PWA254 on your keyboard for example, will write the decimal value 254 to Port A. Binary and hexadecimal values can be read or written just as easily.

The board can be programmed and left to run as a stand-alone reactive controller, configured to raise an alarm if conditions change beyond its ability to suppress them. However, some applications may demand that a host pc is alerted. This too has been accommodated in the chip design via two interrupts which send a single ascii identification back to the host via the three-wire RS232 command interface, at 300 to 115,200 baud.

Flexible, interrupt driven, pwm

The chip has a pulse-width modulation output on pin 35. Properties of this function are also detailed in the software simulator. Frequency limits are 10Hz and 10kHz and the duty-cycle range is 0 to 100% in 1% intervals.

The pwm signal is interrupt driven; that is the ITC232 can do other things while the pwm is on, except that when the stepper motor is on, in this case the pwm remains high or pulled low while stepping takes place.

At the simulator prompt, typing W1000 followed by the enter key causes an audible 1kHz tone, produced by the simulator. In addition, you will see an 'oscilloscope' on the screen. Alt-S toggles the sound while Alt-O turns the scope on and off.

The default duty cycle is 50% and a mes-
sage $f=0.0999$ is returned by the ITC232. This is the actual frequency resulting from rounding errors and crystal resolution.

Three main uses for this feature are:

- Generating an analogue voltage by integration with an RC network.
- Varying the speed of a dc motor.
- Producing a given number of pulses by feeding the pwm pin output to an interrupt request pin and counting the lows or highs received by the computer.

Reading resistance or capacitance

Time constant of a series RC network can be read directly by the ITC232. One end of the resistor connects to $V_{cc}$, and one end of the capacitor to ground. Pins PC.0 to PC.3 connect to the junction between the capacitor and the resistor.

Command $<R>$, for resistance, is sent to the device, followed by a $<0>$ or $<1>$ or $<2>$ or $<3>$ for each bit, and finally the enter key. The controller pin is turned into an output and brought low, discharging the capacitor. Next, the pin is turned back into an input and the time to reach the low to high transition is sampled and sent back to the terminal as a time constant in the range 0-32767. Units are arbitrary.

Further application notes explain how you might read the conductance of a solution, as well as measure various sources of capacitance.

Control command summary

These are the single-key commands needed to control the ITC i/o control processor. Items within $<>$ symbols are mandatory while items within $[]$ are optional:

$<B>$ n sets serial bit rate to n, which is between 300 and 115200baud.
$<H>$ calls the help function.
$<OFF>$ returns DISCONNECTING ASCII(#7) and makes PA.0 an input (to hang up the phone). Only available if in phone mode (baud pin is low and IRQL asserted before a command is received after reset or power-up).
$<P>$ or $<C>$ configure $<A>$ or $<B>$ or $<C>$ or $<D>$ or $<S>$ $[B,%D,H,S]$ $<value>$ sends value to the port specified.
$<P>$ $<S>$ serial $<R>$ read or $<W>$ write or $<A>$ or $<B>$ or $<C>$ or $<D>$ or $<S>$ $[B,%D,H,S]$ $<value>$ configures serial i/o. PCSO disables the serial port.
$<P>$ $<S>$ or $<B>$ or $<C>$ or $<D>$ or $<S>$ $[B,%D,H,S]$ $<value>$ configures serial i/o. PCSO disables the serial port.
$<P>$ or $<C>$ or $<B>$ or $<C>$ or $<S>$ $[B,%D,H,S]$ $<value>$.
$<RESET>$ is equivalent to a hardware reset.
$<R>$ $<0>$ or $<1>$ or $<2>$ or $<3>$ reads resistance on port C pins 0-3.
$<W>$ followed by H or L sets the pwm line high or low. Decimal suffix between 10 and 10000Hz instead of H or L determines pwm frequency. Duty cycle is 1:1 unless the frequency is followed by an integer between 0 and 100.

These are the single-key commands needed to control the ITC i/o control processor. Items within $<>$ symbols are mandatory while items within $[]$ are optional:

$<S>$ $<E>$ $<A>$ or $<B>$ or $<C>$ $<M>$ monophasic or $<B>$ biphasic or $<H>$ half step $<Speed>$ initiates the stepper procedure on A, B or C ports. $<Speed>$ is in steps/s (10-4000). $<Stop delay>$ is in steps (0-255).
$<S>$ $<E>$ $<A>$ or $<B>$ or $<C>$ $<S>$ $[B,%D,H,S]$ returns the configuration, the active steppers and the last value written to each.
$<S>$ $<E>$ $<A>$ or $<B>$ or $<C>$ $<S>$ $[B,%D,H,S]$ $<value>$.
$<S>$ $<E>$ $<A>$ or $<B>$ or $<C>$ $<S>$ $[B,%D,H,S]$ $<value>$. Monophasic, biphasic and half step $<Speed>$ makes the motor step.
$<S>$ $<E>$ $<A>$ or $<B>$ or $<C>$ $<S>$ $[B,%D,H,S]$ $<value>$. Monophasic, biphasic and half step $<Speed>$ makes the motor step.
$<S>$ $<E>$ $<A>$ or $<B>$ or $<C>$ $<S>$ $[B,%D,H,S]$ $<value>$. Monophasic, biphasic and half step $<Speed>$ makes the motor step.

Special offer – stand-alone i/o board for £99

ITC232 – a new concept in i/o control that adds a versatile and easily programmable logic i/o controller to your pc or terminal.

The I/O232 evaluation board described in this article has a normal list price of £195. For a period limited to 7 July 1995, EW+WW readers can obtain this board at the special launch price of £99. In addition, the chip is being offered at the special price of £19.99 as opposed to the usual price of £29. Prices exclude VAT and postage and packing at £2.50.

Each board is supplied with applications notes, software simulator, manuals and diagrams, power supply and an RS232 COM1 cable.

The ITC232 incorporates an on chip keyboard to machine-code translator, which makes programming easy. Via a ready-implemented RS232 links, the i/o232 can connect your application to windows in minutes rather than weeks. Standard routines and simple in-built keystroke-to-machine-code software shorts design cycles, resulting in cost savings.

Technical features

- Serial command and control interface, 300 to 115,200 baud
- 10 channels of analogue i/o
- 24 digital i/o individually configurable as input or output and organised as three ports.
- Pulse-width modulated output 10 to 10,000µs, 0 to 100% duty cycle in 1% steps.
- 3 stepper-motor outputs, 10 to 4000 steps per second, monophasic, biphasic and half step
- 2 edge sensitive interrupts, IRQL and IRQH.
- Direct reading of capacitance and resistance
- On board help and error files
- 50mA power consumption.

Order form

Please send me: I/O232 evaluation board including ITC232 chip at £99.00 £

ITC232 chip at £19.99 £

Postage and packing £2.50 £

I enclose a cheque ☐ Debit my Access ☐ Visa card

Card number:

Exp. ☐

Total £

Please send this order to Timely Technology Ltd at Millbank, Kettering Road, Little Cransley, Northamptonshire NN14 1PJ. This offer excludes the USA.

June 1995 ELECTRONICS WORLD + WIRELESS WORLD 511
M & B RADIO (LEEDS)
THE NORTH'S LEADING USED TEST EQUIPMENT DEALER

ALL PRICES PLUS VAT AND CARRIAGE - ALL EQUIPMENT SUPPLIED WITH 30 DAYS WARRANTY

Tel: (0113) 2435649 Fax: (0113) 2426881

| ELECTRONICS WORLD + WIRELESS WORLD | June 1995 |

**SPECTRUM ANALYSERS**
- HP8513B
- HP8514G
- HP8515D
- HP8538A
- HP8538G
- HP8538H
- HP8582C
- HP8581B

**GIGA GR 1101A**

**MARCONI TF2015 10mhz-520mhz Generator**

**HP 11710A Down convertor**

**HP 5004A Signature analyser**

**HP 3468A 5.5 Digit multimeter/electronic auto calibrator**

**HP 3465A 4.5 Digit multimeter (LED)**

**HP 3406A 10khz-1200mhz Broadband sampling voltmeter**

**HP 3403C True RMS voltmeter**

**HP 0405A 1mhz-100mhz Vector voltmeter**

**HP 3780A Pattern generator/error detector**

**HP 5342A 500mhz-18ghz Microwave frequency meter**

**BRUEL & KJAER 4709 Frequency response analyser**

**BRUEL & KJAER 1022 Beat frequency oscillator**

**GAY MILANO Fast transient monitor**

**FLUKE 333013 Frog constant current/voltage calibrator**

**TEST EQUIPMENT**

**SYSTEMS VIDEO 1152/1155 Compact 19" waveform monitor**

**MARCONI TF2306 Programmable interface**

**MARCONI TF2432A 100mhz-520mhz Frequency counter**

**MARCONI TF2914A Insertion signal generator**

**MARCONI TF2I60 20hz-20khz Monitored AF attenuator**

**MARCONI TF2603 50khz-1500mhz RF millivoltmeter**

**MARCONI TF2008 10khz-510kHz Generator/sweep**

**RACAL RA 1218 30mhz Receiver**

**RACAL DANA 488 IEEE -STD Bus analyser**

**RACAL DANA 9921 10hz-1100mhz Frequency counter**

**RACAL DANA 9919 10hz-1100mhz Frequency counter**

**RACAL DANA 9916 10hz-560mhz Frequency counter**

**RACAL DANA 9915 10hz-560mhz Frequency counter**

**RACAL 9063 Two tone oscillator**

**NARDA 3001 450mhz-950mhz Directional coupler 10db 20db or 30db 1100**

**FARNELL TOPS 3D Triple output digital power supply**

**BIRD 8329 Coaxial 2000 watt 30db attenuator.**

**BIRD 81B Termaline 80 watt coaxial resistor.**

**RADIO-TECH EME 129A Multi through/short switch.**

**RADIOMETER TRB11 RLC Component comparator**

**WAYNE KERR CT4% LCR meter battery portable**

**SYSTEMS VIDEO 1152/1155 Compact 19" waveform monitor**

**Experiment Inc. SPICE 3F based Simulator (AC, DC, Transient, Temperature, Noise, Distortion, Fourier, Monte Carlo, and Sensitivity (AC/DC) analyses)**

**Native Mixed Mode - includes 12 state Digital Logic Simulator**

**Interactive Parameter Sweeping and Measurements**

**Real Time Cross Probing Directly on the Schematic**

**Over 600+ Models Available including Special RF and Vendor Libraries**

**Multiple Platform Support - Windows (32's), Windows NT on the PC, Digital Alpha & MIPS, DOS, Macintosh, and Power PC**

**Call or write for free information and eval Sw:**

**Technology Sources Ltd - Falmouth Avenue - Newmarket - Suffolk CB8 OIZ**

Ph: 01638-561460 Fax: 01638-561721

**M & B RADIO (LEEDS)**

**THE NORTH'S LEADING USED TEST EQUIPMENT DEALER**

**TEKTRONIX 5113 Dual beam storage mainframe (new).**

**TEKTRONIX 7403/7A18/7A13/7B53A Scope**

**TEKTRONIX SCS04/TM503/OM501 80mhz scope/digital**

**TEKTRONIX 2445A 150mhz 4 channel cursor readout (as new)......... LI 550**

**OSCILLOSCOPES**

**MARCONI 605581350mhz-2150mhz Signal macro.**

**RACAL 9081**

**WAVETEK 102A 1Hz-4mhz Function generator**

**SAYROSA MA30 10hz-10Khz**

**GIGA GR 1101A**

**M & B RADIO (LEEDS)**

**Third Party Support - Works with all popular schematic entry systems**

**The Future Is Interactive!**
The features of both analogue and digital filters have been used together to improve the bandwidth of samplers. Erik Margan illustrates by example the improvements to be obtained by treating the combination as a single filter.

Analogue and digital filtering in combination can be used in sampling systems to improve system bandwidth, while retaining high out-of-band signal and noise rejection for effective anti-aliasing, without the need to increase the sampling frequency. Alternatively, less complicated, lower order filters can be used for attaining the same performance. A method of optimising the filter requirements is discussed.

As an example, suppose the input signal is to be sampled to 12-bit accuracy with a sampling frequency of 2MHz. In this case, frequencies above the Nyquist frequency (1MHz) should be attenuated by at least $2^{12}$, or about 72dB. Assume also that constraints such as amplifier bandwidth and phase margin, component tolerances, layout parasitics, thermal effects, etc, limit the filter design to a 6th-order type.

Normally, Chebyshev or elliptic (Cauer) filter types are used for effective anti-aliasing, since these provide sharp cut-off and the procedure described here is not required. However, for a perfect transient performance or to preserve a high degree of phase coherence in complex signals, the filter must be of the linear-phase type, leading to a Bessel-type filter, an all-pole equi-ripple phase filter ($\pm0.05°$) or other filter types that can be compensated via phase equalisers.

The use of phase equalisers is limited to band-pass filters, since it is difficult to match the filter phase in wide bandwidth. Bessel filters have a smooth knee in the frequency domain, which makes them a poor choice for anti-aliasing applications. On the other hand, in contrast to the equi-ripple filter types, they can be built from a cascade of relatively low-Q sections, which makes them relatively insensitive to component tolerances. Most importantly, their time-domain performance is ideal.

Although a Bessel filter will be used in the example, calculating the stop-band asymptote of a 6th order Butterworth filter that satisfies the no-alias requirement gives a simple relation from which the required system asymptotes can easily be calculated. The frequency $f_A$ at which the $n$th order Butterworth system reaches the required attenuation $A$ can be calculated from:

$$f_A = 10^{\frac{\log_{10} (A^{1/2n})}{2n}} \quad \text{(1)}$$

Equation 1 assumes a normalised system, with its $-3$dB cut-off frequency $f_c=1$ and the response at zero frequency $A_0=1$. Taking $A=2^{12}$ and $n=6$ results in $f_A=4$.

Now calculate the 6th-order Bessel system polynomial coefficients (see the Bessel panel), divide them by $\sqrt{d_0}$ to normalise the system to have the same stop-band asymptote as the Butterworth filter and extract the polynomial roots to get the poles.

$$f_A = \frac{1}{1.468 f_{Nyq}}$$

Since $f_A$ must be equal to the Nyquist frequency, normalise the system by taking the inverse value of $f_A$, which gives the Butterworth bandwidth relative to the Nyquist frequency $f_{Nyq}$. The poles of the Bessel filter must also be divided by $f_A$, resulting in a $-3$dB bandwidth of 144kHz. This is the reference figure for the analogue-only anti-aliasing filter. If this figure is not high enough and if the choice of the analogue-to-digital converter limits the maximum sampling frequency, use mixed-mode filtering to expand the system bandwidth.

Analogue/digital filters

The idea of using mixed-mode filtering comes from the fact that the total system frequency response is a simple multiplication of the analogue and digital filter frequency responses. Transforming the digital $z$-domain response is trans-
FILTER DESIGN

formed into its s-domain equivalent gives,
\[ H(s) = A(s) \times D(s) \]  

(2)

That is also true for the reverse case (i.e. a system formed from a digital filter, a d-to-a converter and analogue filter). In the time-domain, Eq. 2 becomes the convolution integral of

the analogue signal with the digital filter impulse response and convolution is exactly the process performed by digital filtering, the digital filter coefficients representing the sampled equivalent of the impulse response.

However, as is well known from analogue filters, cascading two separately optimised filters reduces the total system bandwidth more than one would like. It is thus better to use a single filter system but of higher order. Since the limit is a 6th-order analogue filter, calculate a 10th-order filter, assign six of its poles to the analogue part and the remaining four to the digital part. A higher order filter has a steeper stop-band and so its bandwidth can be higher while still satisfying the antialiasing condition, but how much higher is not yet known. Figure 1 shows the optimisation criterion.

Dotted curve A0 is the 6th-order analogue-only reference system, shown along with its pass-band and stop-band asymptotes, A1 and D1 are the analogue and digital part of the mixed-mode filter M1, which is a 10th-order Bessel filter. Of its ten poles (arranged as five complex-conjugate pairs), six of them, in three pairs, have been assigned to the analogue filter A1 and the remaining four in two pairs to D1.

Since A1 is of the same order as A0, its stop-band slope is the same as the reference, allowing easy calculation of the effect of increasing its bandwidth. In Fig. 1, it has been increased by 1.87 and the line shaded frequency band between the Nyquist frequency \( f_{\text{Nyq}} \) and \( 1.87f_{\text{Nyq}} \) will, when sampled, be reflected into the dot shaded alias spectrum between \( f_{\text{Nyq}} \) and \( (2-1.87)f_{\text{Nyq}} \). The difference, in dB, between the a-to-d converter resolution level and the alias spectral envelope gives the minimum required attenuation (shown as the dashed line \( R_q \)) that the digital filter must have to suppress the alias spectrum below the ADC resolution level.

From Fig. 1, one could conclude that optimal performance is reached whenever the mixed-mode response reaches the a-to-d converter resolution level at the Nyquist frequency, but be warned that this will not be so in the majority of cases. Instead, the optimum is achieved by iteration – first, shift upward the analogue and digital frequency responses (the poles multiplied by a factor between 1 and 2), then calculate the alias spectral envelope, take the difference between the a-to-d converter resolution level and the alias spectral envelope and finally compare it to the frequency response of the digital filter. If the filter is much below the required level, repeat the process; if it is above the required level, multiply the poles by...
8 CAVANS WAY, BINKLEY INDUSTRIAL ESTATE, COVENTRY CV3 2SF
Tel: 0203 650702
Fax: 0203 650773
8 CAVANS WAY, BINKLEY INDUSTRIAL ESTATE, COVENTRY CV3 2SF
Tel: 0203 650702
Fax: 0203 650773

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.

SPECIAL OFFER

We have obtained an IMTEC 300 film/aperture card reader/printer which has had very little use. Print on plain paper from tray paper, sizes A5 to A3, including the "B" sizes, and variable. This is high quality equipment, serious offers are invited.
Filter Design

**Fig. 6. Two-pole, voltage-controlled filter example.** Cascade of three such sections needed for the six-pole example of Figs 1 and 2. This is a classic Sallen-Key configuration in which the resistors have been replaced by transconductance amplifier's $g_m$ and each $B_0$-C buffered. Buffer op-amps $ACFB$ must be of the wide-band type (i.e., with current feedback) to prevent parasitic transfer function zeros. $Q$ and frequency of each two-pole section must be adjusted separately, in accordance to the poles selected. Resistive dividers of $4.7k\Omega$ and $47\Omega$ keep the OTAs in the linear range and prevent slew-rate limiting for large signals.

**Aliasing**

In theory, the bandwidth of the sampling system is equal to the Nyquist frequency, which is one-half of the a-to-d converter's sampling frequency. In practice, however, correct waveform spectrum can be found only if the input signal frequencies above the Nyquist frequency are attenuated to levels lower than the a-to-d converter resolution; to avoid 'aliasing' (if the signal contains discrete frequency components above the Nyquist frequency, or broadband noise). This is known in literature as the Shannon's sampling theorem (see Further Reading).

Aliasing can be best understood if the reader remembers the scene from Western movies, where the wheels of the stage coach seem to be rotating backwards, while the horses are running wild to escape from the desperados behind. What is perceived, is as if the wheel's rotate with a frequency equal to the difference between the frequency at which the pictures were taken and the actual wheel rotation frequency.

A wheel, rotating at exactly the same frequency (for its integer multiple or submultiple) as the picture rate, would be perceived as stationary (remember the stroboscope effect). This is the same as if an a-to-d converter is sampling a signal at the Nyquist frequency's sampling frequency — such a signal cannot be distinguished from a d.c. level. Likewise, a signal with a frequency slightly lower than the sampling frequency, could not be distinguished from a low frequency, equal to the difference of the two.

From the shape of the alias spectral envelope it is clear that there is no point in making the digital filter of high order. Likewise, it is advantageous to choose the poles having smaller imaginary part for the digital filter, since this results in a smoother response and consequently greater bandwidth improvement factor. In this example, the mixed-mode system has its -3dB cut-off frequency at 211.5kHz, which is 1.468 times the all-analogue filter bandwidth.

Splitting the filter poles between the analogue and digital part may also be taken into consideration; designers of systems that must operate in real time will look for the pole selection that gives the digital filter a more symmetrical impulse response — every other complex-conjugate pole pair is assigned to the digital filter. This property of symmetry can then be exploited to reduce the required filter coefficients (and consequently the number of multiplications) by half, speeding-up the digital filtering process.

On the other hand, when the available analogue gain-bandwidth product is critical, the designer may prefer to assign the poles with the lower imaginary part to the analogue filter, but at some expense to the bandwidth improvement.

Figure 2 shows the time-domain behavior of the same filters used to produce Fig. 1, with the time scale normalised to the sampling period and the markers on the curves corresponding to actual samples. Analogue step response, with its notable overshoot, convolved with the digital impulse response gives a perfect step response with a rise time shorter than that of the analogue-only filter.

From Fig. 1 it is also obvious that all-pole filters cannot achieve a bandwidth improvement greater than about 1.5, a factor lower than 1 and test the result again.

Since this would require the analogue filter asymptote to approach the sampling frequency at the a-to-d converter resolution level, extending the alias spectrum towards d.c, where it would be hard to eliminate. If the analogue filter is designed to have some stop-band zeros at the sampling frequency and its first few multiples, a greater bandwidth improvement will be possible. One such case is shown in Fig. 3 and Fig. 4, where a six-pole, six-zero analogue filter is combined with an eight-pole equivalent digital filter. Zeros are at 1.5, 2.0 and 4.0 times $f_{Nyq}$ which were not chosen for optimum pass-to-stop band transition, but for narrowing the alias band.

While the bandwidth improvement in both cases may seem small, it will be appreciated by those who use spectrum analysis daily. It must be noted that the resulting improvement in phase linearity is even greater than in bandwidth, since the additional extension comes from the use of a higher order filter. Figure 5 shows how the all-pole, mixed-mode system time-delay, i.e. the phase vs frequency derivative, remains constant up to a frequency more than double that in the analogue-only filter.

If the a-to-d converter system is to be used with different sampling frequencies, the digital filter part can be left unchanged, but the analogue filter must be frequency-shifted accordingly; transconductance operational amplifiers used for frequency control offer the best way of doing this.

**Voltage**

The voltage at the base of $Q_2$ of about ±50mV d.c sets the $Q$ (the imaginary components of the pole pair) and the control voltage at the base of $Q_1$ (ranging from $V_{CC}$-0.7V to about +0.7V) sets the frequency; the magnitude of the pole pair — the ratio of the imaginary to the real component remains unchanged. A cascade of three such sections is needed for the six-pole analogue filter, each section being adjusted separately and the adjustments remaining in fixed proportions as the frequency control voltage is changed. A simpler, but less flexible, solution is to make all the transconductances equal and select the values of capacitors as required by the poles.

I built my experimental filter using RCA CA 3080 operational transconductance amplifiers and Comlinear CLC 400 current-feedback devices. However, the Linear Technology LT 1228, which is a single-chip OTA with current feedback, is the natural choice. Transfer function of the filter in Fig. 6 is:

$$V_{out} = \frac{g_m g_m 2}{s + g_m 2 (k^2 C_1 C_2)}$$

(3)

where $k$ is the attenuation of the OTA input resistive divider (1/101), and $g_m$ is the OTA transconductance, set by the bias currents from the collectors of $Q_1$ and $Q_2$. Comparing Eq. 3 with the general two-pole transfer function:

$$H(s) = \frac{p_2 p_3}{s^2 + p_2 p_3}$$

(4)

and normalising $g_m$ to $g_m=1$ produces,

$$C_1 = k (-p_1 - p_2)$$

and

$$C_2 = \frac{1}{k^2 p_1 p_2}$$

(5)
The new schematic capture program Geswin (GESECA for Windows™) adds more than a pretty face to SpiceAge. Upgrade for £100 + VAT*  
- Geswin DDE links with SpiceAge to provide instant circuit editing. Because this link enables SpiceAge to retain all its simulation settings, the schematic (produced by Geswin) is uncluttered so that you can create clean drawings that may be clipboarded into your other Windows applications.  
- You can clipboard sections of your netlist from SpiceAge back into Geswin’s attribute Inspector if you wish to use patches of existing circuits.  
- Geswin has inherited GESECA’s speed and ease of use. You will find it’s best-loved “bucket of bits” components’ store waiting for your instant use from a special self-replenishing window.  
- The SpiceAge component library has been expanded and re-drawn into "stubbies". The new symbols allow more components to fit within a given screen area without compromising clarity.  
- Multiple windows allow you to scratch pad your designs (simulating as you work) and clipboard them into a fair copy window.  
- File compatible with GESECA: schematics and components from GESECA may be read.  
- Comprehensive HELP provides reference material; tutorial style manual reassures you of your own intuition.  
- Geswin automatically invokes (or switches to) SpiceAge; you can also invoke Geswin from SpiceAge.

Please contact Those Engineers Ltd, 31 Birkbeck Road, LONDON NW7 4BP.
Tel 0181-906 0155, FAX 0181-906 0969.
*upgrade price from GESECA; £2.95 + VAT new

**LOW COST DEVELOPMENT SYSTEM**

ECAL comprises a versatile relocatable assembler with integral editor which runs about ten times faster than typical assemblers. Support includes 4, 8, 16 & 32 bit processor families including 78X, 6502, 6809, 68HC05/11, 8031/51, H8-300, PICs, ST6 & Z80/180, 8000, 80C196, H8-500 & Z280.

ECAL is either available for a single processor family or all families.

Single processor version £295  
Multiprocessor version .... £395

**Overseas distributors required**

**OEMA Ltd.,**  
7 & 7A Brook Lane,  
Warsash,  
Southampton S031 9FH  
Tel: 01489 571300  
Fax: 01489 885853

The PC based ECAL hardware emulator is fully integrated with the assembler. Connection is made to the target through the eprom socket so a single pod can support all processors. Facilities include windows for the inspection or change of registers or memory. You can even watch your program executing at source level!

Download time is about two seconds!

Pods can be daisy-chained for 16/32 bit systems.

Applications include software development, hardware debug, test and, finally, teaching about microcontrollers in education.

ECAL emulator ............... £475

**Quantity discounts of up to 50% make ECAL software ideal for education.**

**Close NO. 131 ON REPLY CARD**

June 1995 ELECTRONICS WORLD+WIRELESS WORLD 517
Table 1. Poles used in the example of Fig. 1 and 2.

<table>
<thead>
<tr>
<th>System</th>
<th>Analogue-only</th>
<th>Mixed-mode system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogue</td>
<td>0.1364 ±0.2494i</td>
<td>0.3886 ±0.1634i</td>
</tr>
<tr>
<td>Digital</td>
<td>0.0470 ±0.0810i</td>
<td>0.0673 ±0.0910i</td>
</tr>
<tr>
<td>Digital</td>
<td>0.2700 ±0.0600i</td>
<td>0.1500 ±0.0600i</td>
</tr>
</tbody>
</table>

Alternatively, normalising $C_1=C_2=1$ produces,
\[ g_m = k(-p_1-p_2) \]
and
\[ g_m = \frac{k^2 p_1 p_2}{g_m} \]  

Poles $p_1$ and $p_2$ are the suitable complex-conjugate pair of the mixed-mode filter poles.

Bessel filters
Bessel filters are optimum in the sense that all the derivatives of the envelope (group) delay response are zero at origin, which results in a maximally flat envelope delay. This means that all the relevant frequencies pass through the system with equal time delay, resulting in a transient response with a minimal overshoot. In the complex frequency plane, a system with pure time delay may be represented by
\[ H(s) = e^{-T} \]  

First, normalise this by making $T=1$; then expand $e^{-s}$ as a polynomial. However, if this is done using the Taylor series expression for $e^t$ and if the polynomial degree exceeds 4, the resulting polynomial would not be of the Hurwitz type, since some of the poles would be in the right-half of the complex plane, making the system unstable. But there is another expression for $e^{-s}$ that we can use:
\[ e^{-s} = \frac{1}{\sinh s + \cosh s} = \frac{1}{1 + \cosh s / \sinh s} \]  

The series for hyperbolic sine function has even powers of $s$ and the hyperbolic cosine odd powers of $s$. When these polynomials are divided using long division, the roots of the resulting polynomial meet the stability requirement. Expressing this as a partial fraction expansion truncated at the $n$th fraction gives an $n$th-order Bessel system. This can be expressed as
\[ H(s) = \frac{d_n}{B_n(s)} \]  

where
\[ B_n(s) = \sum_{k=0}^{n} d_k s^k \]  

$B_n(s)$ is an $n$th order Bessel polynomial which, for different $n$, satisfies the relations,
\[ B_0(s) = 1 \]
\[ B_1(s) = s + 1 \]
\[ B_2(s) = (2n - 1)B_{n-1}(s) + s^2 B_{n-2}(s) \]  

The coefficients $d_k$ of the resulting polynomial can be calculated as,
\[ d_k = \frac{(2n-k)!}{2^{(n-k)}(n-k)!} \]  

Roots of $B_n(s)$ are the poles of $H(s)$. Calculated in this way, the system is normalised to a time-delay of 1 for any $n$, which results in a bandwidth increasing with $n$. In these calculations, a different normalisation is used: the asymptote of the filter stop-band is made equal to that of the Butterworth filter of equal order, by dividing the polynomial coefficients $d_k$ by $n!d_0$.

Bessel filter poles are found in the left-half of the complex plane, on a family of ellipses with one focus at the origin $0+0i$ and the other on the positive part of the real axis. Table 1 shows the poles used in the example of Fig. 1 and Fig. 2. These values are given relative to the Nyquist frequency – to get the true values, multiply them by 1MHz.

**Filter response calculation**
In the frequency domain:
\[ H(s) = \prod_{i=1}^{n} \left( s - p_i \right) \]  

\[ H(s) = \prod_{j=1}^{m} \left( s - z_j \right) \]  

where $s=j\omega$ and $p_1$ and $z_1$ are the zeros (if any). Magnitude in decibels is
\[ M(\omega) = 20 \log_{10} \sqrt{H(j\omega)H(-j\omega)} \]  

In the time domain, calculate the residue of each pole and sum the residues at each time point to get the impulse response. For the step response, each residue is multiplied by $1/\tau$ the Laplace transform of the input unit-step. The residue of the $k$th pole can be calculated as,
\[ R_k(t) = \lim_{s \to p_k} \left( s - p_k \right) \prod_{i=1}^{n} \left( s - p_i \right) \prod_{j=1}^{m} \left( s - z_j \right) e^{pt} \]  

Terms $(s-p_k)$ cancel for $k \neq k$ before limiting. Next, make $s=p_k$, without using the limiting process. By doing so, the general applicability of Eq.14 is lost – it does not hold for systems containing coincident poles, but for all optimised system families the result is still valid. The time $t$ can be chosen to start from 0 up to any desired time, in sampling period increments. Then:
\[ f(t) = \sum_{k=1}^{n} R_k(t) \]  

**In summary**
From all this, one can see that mixed-mode (analogue plus digital) linear-phase filtering can be used effectively to extend the usable spectral bandwidth of sampled signals by about 50% and the phase coherence by more than 100%, while keeping the signal spectral resolution, the sampling frequency and the number of samples unchanged.
Programming Solutions

Multi-Device Programmer
- EPROMs, EPROMs, Flash EPROMs, Serial EPROMs, PLDs, GALs, PEEls, EPLDs, MACHs & WSI PSDs
- Micros - Intel, Microchip, Motorola, Zilog
- Fast programming algorithms.
- Connects direct to pc printer port.
- Simple full colour software.
- No expensive adapters.

Eprom Programmer
- EPROMs, EPROMs, Flash and 8748/51 micros.
- Fast programming algorithms. Simple colour menu operation.

Prices exclude VAT & Delivery

Finally an upgradeable PCB CAD system to suit any budget ...

Board Capture

BoardCapture - Schematic Capture
- Direct netlist link to BoardMaker2
- Forward annotation with part values
- Full undo/redo facility (50 operations)
- Single-sheet, multi-paged and hierarchical designs
- Smooth scrolling
- Intelligent wires (automatic junctions)
- Dynamic connectivity information
- Automatic on-line annotation
- Integrated on-the-fly library editor
- Context sensitive editing
- Extensive component-based power control
- Back annotation from BoardMaker2

BoardMaker1 - Entry level
- PCB and schematic drafting
- Easy and intuitive to use
- Surface mount support
- 90, 45 and curved track corners
- Ground plane fill
- Copper highlight and clearance checking

BoardMaker2 - Advanced level
- All the features of BoardMaker1 plus
- Full netlist support - OrCad, Schema, Tango, CadStar
- Full Design Rule Checking - mechanical & electrical
- Top down modification from the schematic
- Component renumber with back annotation
- Report generator - Database ASCII, BOM
- Thermal power plane support with full DRC

BoardRouter - Gridless autorouter
- Simultaneous multi-layer routing
- SMD and analogue support
- Full interrupt, resume, pan and zoom while routing

Output drivers - Included as standard
- Printers - 9 & 24 pin Dot matrix, HP Laserjet and PostScript
- Penplotters - HP, Graphtec, Roland & Houston
- Photoplotters - All Gerber 3X00 and 4X00
- Excellon NC Drill / Annotated drill drawings (BM2)

Contact Tsien for further information on
Tel 01354 695959
Fax 01354 695957

CIRCLE NO. 114 ON REPLY CARD

June 1995 ELECTRONICS WORLD+WIRELESS WORLD 519
Vhf meter is accurate to 0.1dB

Mixer-type Schottky diodes can detect rf signals between around -35dBm and 20dBm. Response flatness is good to about 1GHz with a cheap BA481 and better with higher frequency-response types; a general-purpose Schottky measures higher powers in a 50Ω system but with a reduced frequency response.

Since the diode output is temperature-variant and somewhat variable between batches, the circuit shown uses two matched detectors, the second one fed with a 1kHz sinewave, adjusted in amplitude by the error amplifier circuit until the outputs are balanced. A chopper composed of four 1N4149 diodes provides the 1kHz square, which is then formed into a sinewave by the op-amp, and also provides a dc level proportional to the amplitude. This is a measure of the rf input level and is read, in this case, on a moving-coil meter calibrated in decibels, though it could easily be digitised. Ranges of 10dB are selected in the 1kHz drive to cover the 55dB dynamic range, and the error integrator capacitors are switched to provide the relevant time constant. The circuit is inherently linear.

The 10kΩ multi-turn pot zeroes the meter. Additional diodes on the meter cope with reverse drive if the integrator is zeroed too low, since the chopper provides only forward drive to the meter. On the integrator output, the 4.7kΩ pot sets maximum meter current. Accuracy to several hundred MHz is about 0.1dB, without the need for stable supplies. Capacitors marked C should be of the same type to match temperature coefficients.

P D Brooking
Ryde, Isle of Wight
YOU COULD BE USING A 1GHz SPECTRUM ANALYSER ADAPTOR!

Got a good idea? Then this Thurlby-Thandar Instruments TSA1000 spectrum analyser adaptor could be yours.
Covering the frequency range 400kHz to over 1GHz with a logarithmic display range of 70dB ±1.5dB, it turns a basic oscilloscope into a precision spectrum analyser with digital readout calibration.
Recognising the importance of good design, TTI will be giving away one of these excellent instruments every six months to the best circuit idea published in the preceding period until further notice. This incentive will be in addition to our £100 monthly star author's fee, together with £25 for all other ideas published.
Our judging criteria are ingenuity and originality in the use of modern components - with simplicity particularly valued.

Half-duplex-to-RS232 converter

Connecting a half-duplex line to a full-duplex RS232 port requires a decision on whether the half-duplex goes to the TD transmit line or the receive line RD.
A truth table for such a converter is constructed as follows. When TD is at logic 1, it is either at rest, 'marking' or transmitting a 1 data bit. If it is in the first state, data might be passing from the half-duplex line to the port and the half-duplex should go to RD. If it is transmitting, RD will be marking at logic 1 and the half-duplex line should go to either RD or TD.

<table>
<thead>
<tr>
<th>TD</th>
<th>RD</th>
<th>Half-duplex</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>TD</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>TD</td>
</tr>
</tbody>
</table>

As the table shows, TD is usable to control switching. The MAX202CPE converts and inverts RS232 levels to ttl levels, the pull-up/down resistors are internal and are shown to illustrate the requirement. For ttl compatibility, the 4066B is run from 5V.

Bill Geake
University of Edinburgh
Royal Infirmary of Edinburgh

Calming a digital display

Annoying ±1 jitter in a numeric display can be reduced considerably by allowing only 0 and 5 to show when the input is under or over 5, but this still leaves the jitter when the input is between 9 and 0 or 4 and 5.
In the arrangement shown, a hysteresis of four counts switches the display to read 5 when the input is greater than 7 and, in the reverse direction, 0 when input is less than 3.
The flip-flop allows clocking of strobed displays and the switch allows '0' to be permanently displayed.

Des Keppel
Ballon
County Carlow, Ireland
High-voltage, frequency-controlled Maxwell bridge

International Rectifier's IR2151 is a bridge driver consisting of an oscillator, with external timing components, and mosfet output. It is used here to drive a Maxwell bridge to measure inductance in the $L_x$ position at a variable frequency and at voltages up to 600V; as a metal detector, it will monitor changes in the value of the inductance when it is brought near a ferromagnetic object.

Frequency is determined by the value of $R$ and lies in the kilohertz range. Maxwell bridges are used in the measurement of magnetic permeability at various frequencies, a process in which the power mosfet output can be an advantage.

Kamil Kraus
Rokycany
Czechoslovak Republic

Fluid-flow monitor with current-loop output

Although zener diodes are linked in the mind with stability, those having a zener voltage of 5.6V and above do show a positive temperature coefficient; the BZX79 8.2V zener, for example, has a 4.6mV/°C coefficient which is linear over a 30°C temperature span. Power dissipation in the device causes self-heating, which makes it difficult to use as a thermometer but, used as a 'hot-wire' anemometer, the effect is useful. Fluid flow across the zener removes heat and its temperature falls, while dissipation is constant due to the reasonably constant breakdown voltage.

In this circuit, two zeners each have a current-limiting resistor $R_{1,2}$, with different values to give different power dissipation in each zener. The one with low dissipation loses all its heat to the fluid at low flow rates, so that its temperature is about the same as that of the fluid; the other takes a higher current, so that a faster flow is needed to remove heat. At high flow rates, both temperatures are the same, but at lower rates, the high-dissipation zener warms and the difference in voltages is sensed by the op-amp. Since the devices are in the flow, response is rapid.

For a remote indication, the op-amp is made to drive a 4-20mA current source, provided by $T_{r1}$. Trimmer $R_{V1}$ provides offset adjustment and $R_{V2}$ adjusts gain. Component values in the circuit shown are for air through an 8mm orifice, flowing at around 2m/s, both zeners being laid across the orifice.

P Harley
Newcastle-upon-Tyne
Tyne and Wear

Temperature coefficient of zener diodes – normally a disadvantage – is used here to provide fluid-flow sensing. Output is a 4-20mA current loop.
Programmable stepper-motor pulse generator

As an alternative to previous circuits for programming the number of pulses for a stepper motor, this is rather simpler. Outputs of a 12-stage binary counter IC2 are taken to the outputs of twelve non-inverting buffers, IC1,3, via resistors R1-12; inputs to the buffers determine the count and, therefore, the number of pulses at the output. Gates 1,2 form an RS flip-flop and gates 3,4 an And gate.

A start signal sets the flip-flop, which in turn resets the counter, which starts to count. While the counter outputs differ from the gate outputs, current flows in one or more of the resistors R1-12, this current flowing to ground via the Vs terminals of the counter and buffers and the base of Tr1, maintaining saturation of Tr1. As counter and buffer outputs equalise, the current stops, Tr1 cuts off and the RS flip-flop resets. This closes the And gate and stops clock pulses at the output.

M S Nagaraj
ISRO Satellite Centre
Bangalore
India

Stable microphone preamplifier

In audio equipment preamplifiers, low noise must often be combined with variable gain. Low-noise op-amps do not, in general, suit low-impedance inputs such as a dynamic microphone and it is therefore common to use either input transformers or low-noise transistors in a feedback loop, an arrangement which can produce instability with large variations in gain setting.

By-passing the input differential pair of the 748, as shown, removes potential instability and the transistor is selected for a low noise characteristic when driven from a 200Ω source, its collector current being adjustable for the same reason. The circuit is remarkable for its low noise, stability and low distortion, in spite of the fairly basic nature of the circuit and the use of the general-purpose op-amp. Resistor R3 adjusts the circuit for symmetry.

Michal Dolezal
Ostrava
Czechoslovak Republic
Electronic lamp flasher

Replacing the usual bimetallic-strip switch in lamp flashers, this circuit only uses power when the lamp flashes and can be used for high-side and low-side switching.

One gate of the Schmitt Nand operates as a 1Hz free-running multivibrator and the other three in parallel as a buffer to switch the BUZ11 power mosfet. Zener 1 isolates the circuit from transients.

At power up, circuit states are such that the mosfet is off and C1 is charging via D1, R2 and the lamp. During this time, C2 charges through R1, eventually toggling the multivibrator, switching the mosfet on and lighting the lamp. Power for the IC is supplied all this time by the charged C1.

Capacitor C2 is now discharging through R1; the reverse process takes place, the mosfet goes off, allowing C1 to charge up again and the cycle repeats.

NK Goodman
Hastings
East Sussex

Adjustable output-resistance amplifier

Line-driving amplifiers conventionally require a series output resistor to pad the resistance which, if the amplifier output impedance is low, causes half the output to be lost and power dissipated. This circuit synthesises the required impedance without these drawbacks.

With the input shorted to ground, a test current Ii forced into the op-amp output flows in one of the power-supply lines, where it is sensed by one of the left-hand current mirrors, depending on its sign. It is then inverted by the relevant right-hand current mirror and forced in Ri, where it causes a voltage drop Vt = IiRi to be developed. Since, due to feedback round the op-amp, Vt = Vi, the output resistance is

\[ R_o = \frac{V_t}{I_i} = R_i \]

The impedance is not exact because of the realistic current-mirror gain, but trimming Ri corrects the error.

Dan Stiurca
Iasi
Romania

Line driver has the required output impedance without loss of amplitude, without an excess of power dissipation and with a rail-to-rail swing.
"moving from schematic to layout could not be easier"

ELECTRONICS World & Wireless World Jan 1995

NEW Extended Library Pack Just £39.00!

quickroute 3.0
Integrated Schematic and PCB Design for Windows 3.1

DESIGNER £99

* Schematic & PCB Drawing * 1/2 layer auto-router * Supports Windows printers/plotters * Full set of libraries * Clipboard support * Designer Special (manual on disk) also available.

PRO £199


PRO+ £299

As the PRO but also includes * Advanced Schematic Capture (Busses, Power rails, etc) * Larger Schematic & PCB Designs * Gerber file IMPORT for File Exchange * Extended libraries including Surface Mount, CMOS, etc.

In any public address system where microphones and loudspeakers are in the same vicinity, acoustic feedback (howlound) occurs if the amplification exceeds a critical value. By shifting the audio spectrum fed to the speakers by a few Hertz, the tendency to howl at room resonance frequencies is destroyed and increased gain is available before the onset of feedback.

- Broadcast Monitor Receiver 150kHz-30MHz * Advanced Active Aerial 3GHz-30GHz * Stereo Variable Emphasis Limiter 3 * 10-Out Audio Distribution Amplifier 4 * PPM10 In-vision PPM and chart recorder * Twin Twin PPM Rack and Box Units * PPM5 hybrid, PPM9 microprocessor and PPM8 RC/DIN + 50+68) drives and movements * Broadcast Stereo Coders * Stereo Disc Amplifiers * Peak Deviation Meter for FM broadcasting
**SEETRAX CAE RANGER PCB DESIGN WITH COOPER & CHYAN AUTOROUTER**

**RANGER2 + SPECTRA £400.00**

RANGER & SPECTRA AUTOROUTER
Together giving the most cost effective PCB design system on the market TODAY! SEETRAX's ease of use combined with COOPER & CHYAN's renowned gridless autorouter, at an outstanding price.

R2 Outputs: 8/9 & 24 pin printers, HP Desk & Laser Jet, Cannon Bubble Jet, HP-GL, Gerber, NC Drill, AutoCAD DXF
Demo Disk available at £5.00 + VAT

---

**RANGER2 £150**

Upto 8 pages of schematic linked to artwork Gate & pin swapping - automatic back annotation Copper flood fill, Power planes, Track necking. Curved tracks, Clearance checking. Simultaneous multi-layer auto-router

---

**COOPER & CHYAN SPECTRA autorouter (SPI)**
Gerber-in viewer, AutoCAD DXF in & out

---

**UPGRADE YOUR PCB PACKAGE TO RANGER2 £60**

---

**TRADE IN YOUR EXISTING PACKAGE TODAY**
Seetraex CAE, Hinton Daubney House, Broadway Lane, Lovedean, Hants, PO8 OSG Call 01705 591037 or Fax 01705 599036 + VAT & P+P

---

**TELFORD ELECTRONICS**

---

**OSCILLOSCOPES**
- Heiden Type: 1108.16 0-16V 0-20A
- Lambda LP0422A FM regulated; DC 0-409.18 0-501
- HP6291A DC 0-400 0-504

**POWER SUPPLIES**
- Rhode & Schwan Type: SUFI
- Adret Type: 22308
- Philips PM5132 function generator 0.1Hz-2MHz AS NEW £350

**REEL TO REEL RECORDERS**
- Racal 996441) 50MHz £125

**FREQUENCY COUNTERS**
- HPI 8534; 8556 1.4MHz
- Aro 111116 .................................................... $215

**ELECTRONICS WORLD+WIRELESS WORLD June 1995**

---

**CALIBRATION EQUIPMENT**
- Nutter Temperature calibrator OTDR emitting light
- Nutter Temperature calibrator OTDR emitting light
- Beta 2000 with source Model MB-8500 with 50 source W-300 £1700
- Laser 9950 Scout to PC £1700
- Colorado P.L. £1700
- High Akt Current source
- Crosstie outdoor dummy
- 150 mV to 1500 mV
- 150 mV to 1500 mV
- 150 mV to 1500 mV
- 150 mV to 1500 mV

**REEL TO REEL RECORDERS**
- Systron Donner 6052 microwave
- Racal 9913 10Hz-200MHz Fitted 13 standard
- HP5342A Microwave 186111 ............ $215
- Solartron 7045 4 5 digit bench meter battery/mains ............ $200
- Aro 8 MK5

**TRADE IN YOUR EXISTING PACKAGE TODAY**
- WITH COOPER & CHYAN AUTOROUTER
- Tel: 01952 605451 Fax: 01952 677978

---

**AN EXTENSIVE RANGE OF TEST EQUIPMENT IS AVAILABLE. PLEASE SEND FOR OUR NEW CATALOGUE**
Postage and packing must be added. Please phone for price. VAT @ 17½% to be added to all orders. Please send large SAE for details.

Telford Electronics, Old Officers Mess, Hoo Farm, Humbers Lane, Horton, Telford TF6 6DJ
Tel: 01952 605451 Fax: 01952 677978

---

**CIRCLE NO. 138 ON REPLY CARD**
NEW PRODUCTS

ACTIVE

Memory chips
Synchronous flash simms. New memory modules from Smart Modular Technologies allow operation with zero wait states at frequencies to 33MHz, using a clock signal to work synchronously, outperforming asynchronous simms and at least equaling dram simms. An on-board chip arranges the optional active reset control so that the simm always powers up in the right state during hot insertion. Since there is no standard pinout for these devices, they use the arrangement for asynchronous types, slightly modified to affect only read. Smart Modular Technologies. Tel., 01604 497735; fax. 01604 497739

Mixed-signal ICs
Pwm stepper controller/driver. Three multi-chip modules by Allegro, the SLA7024M/26M/29M are pwm controller/drivers for two-phase unipolar stepper motors. Each uses four nmos fets for the driver output and, in most cases, external heat sinks are not needed; in case they are, the SLA7026M has an electrically isolated power tab to transfer heat. Inputs are compatible with 5V logic and micro output. Allegro MicroSystems Inc. Tel., 01932 246622.

Microprocessors and controllers
16-bit, 3V controller. Microcontrollers in NEC's 78K4 family carry out 16x16 multiplications in under 1.2us. They are single-chip devices, four versions having no rom, with 128k rom in mask, one-time programmable and uv erasable. Integrated peripherals include urts, high-drive parallel and pwm outputs and a timer unit for stepper-motor control as well as data conversion. Of the 64 I/O lines, 24 sink up to 8mA and eight transistor drive outputs will source 5mA. Source code is compatible with that used in the company's 78K0 and 78K3 devices. NEC Electronics (UK) Ltd. Tel., 01908 691133; fax, 01908 670290.

8-bit, 5mps. Microchip's PIC16C73 field-programmable, risc-based microcontroller has 4096 words of one-time-programmable program memory, a low-power, 5-channel, 8-bit a-to-d converter and operates at up to 5mps. Its Harvard-architecture risc processor has a 200ns cycle time and peripherals include a timer subsystem. Io functions include a synchronous serial port supporting SPI or I/O/Access bus protocols, and a 16-bit PWM with a 12-bit capture/compare feature. The device takes less than 15µA from 3V at 32kHz and under 1µA when asleep. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 852059.

CTV micro. Toshiba has a new member of the TLCS-870 family of 8-bit microcontrollers: the TMP87PM36N one-time-programmable device for colour television receivers and other consumer products; it is programmable by means of a standard eprom programmer and opt adaptor. Features include a four-channel, 6-bit a-to-d converter for afc, an I/O bus with master control, pwm outputs to give 7 or 14-bit resolution and a remote pre-processor. An on screen display function provides 128-character, 24-column by 12-line output with variable positioning. Operating speed is over 33MHz in the voltage range 2.7V-5.5V. Toshiba Electronics (UK) Ltd. Tel., 01276 694600; fax, 01276 691583.

Shrinkling micro. NEC's V53A microprocessor continues its microscopic tendencies with a further reduction in size from 20mm², itself a reduction from 28mm², to 14mm², with a height of 1mm. Everything else remains the same in the chip, which is used for cpu-intensive work like number-crunching and data sorting and now, probably, for cellphones. Package is a 120-pin TQFP with a pin pitch of 0.4mm. NEC Electronics (UK) Ltd. Tel., 01908 691133; fax, 01908 670290.

68040-based multiprocessor. BVM offers the RAMint software package to enable 16 68040 based BVM4000 cpus to be used on one 32-bit backplane, each being able to use all installed memory, which amounts to 512Mbyte if all cpus have the maximum 32Mbyte. Operating system is OS-9. One of the cpus acts as system controller and another looks after io capture, signal conditioning and data processing; others can be committed to other functions such as disk control. Since RAMint is compatible with common real-time comms protocols, the system becomes a super-processor interfacing with other remote systems. BVM Ltd. Tel., 01489 783585; fax, 01489 780144.

Optical devices
Bi-colour led. Dialight's 5551-3508 is a high-powered two-colour led, providing red and yellow or a mixture to give green. It is in a three-lead, in-line package, the 3mm flat-topped led having a viewing angle of ±40°. Luminous intensity is 400cd at 20mA. Dialight. Tel., 01638 662317; fax, 01638 56045.

Oscillators
VCXOs. Voltage-controlled crystal oscillators in IQD's IVCXO-173 range are designed for use in phase-locked loops working at frequencies in the 1-45MHz range. Pulling is a minimum of ±100ppm for a voltage swing of 4V around 2.5V. Power required is 40mA from 5V and the output of the 14-pin di devices is compatible with hcmos/ls/ttl devices. IQD Ltd. Tel., 01460 74433; fax, 01460 72578.

PCMCIA oscillator. With a height of under 1.3mm and a footprint of less than 38mm², Stalekh's CXO-M crystal oscillator is designed for use in PCMCIA cards, working from 3V or 5V. Frequency range is 1.25-70MHz, stability is ±100ppm between -40°C and 85°C and calibration tolerance options ±0.01%, ±0.1% and ±2%. Tighter specification are available. Advanced Crystal Technology. Tel., 01635 520120; fax, 01635 528443.

Stepper driver. From Nanotec-Electronic, the IMT 901, is a driver IC for bipolar, constant-current stepper motors. Supply is 12-40V dc and phase current is suitable using fixed resistors up to 2.5Aphase. Switching allows full, half, quarter and eighth-step stepping to give quasi-sinusoidal output, with automatic current boosting in the half-step mode to give about 15% more power. The 56mm diameter, 50mm high package contains the driver, optional oscillator for low and high frequency, motor connector and screened 14-lead cable for power and data. Nanotec-Electronic GmbH. Tel., 00 49 0121 79992; fax, 00 49 0121 79991.

June 1995 ELECTRONICS WORLD + WIRELESS WORLD
Digital signal processors

Pixel processors. Using field-programmable gate arrays for flexibility, Sundance has produced configurable, high-performance pixel processors, SM7308/9, these first two in the family being meant for use with the TI TMS320C40 general-purpose dsp, conforming to the TMS-40 board module standard. They can be configured to carry out low-level video operations, leaving higher-level functions to dsp software. The processors boost the throughput of the C40 by an order of magnitude, since a few gate delays take up much less time than software instructions. SM7308 digital video board is for high-resolution digital cameras to identify areas of interest in the frame, so that data rates to the video processor are reduced. SM7309 is a run-length encoder for use as a co-processor to the C40, settleable upper and lower limits cutting out unwanted data for a higher processor operating speed. Sundance Microprocessor Technology Ltd. Tel., 01644 431203; fax, 01494 726363.

Programmable logic arrays

40,000-gate fpga. From AT&T comes the AT72C40 field-programmable gate array containing 40,000 gates and claimed to be the highest-density fpga on the market. It is a 0.5um, three-level metal device, available in two speeds having logic cell delays of 5.1ns or 3.8ns, the latter exhibiting a setup time of under 5ns and a zero clock-to-output delay of under 11.3ns, two speeds having logic cell delays of an order of magnitude, since a few gate delays take up much less time than software instructions. AT&T's digital video board is for high-resolution digital cameras to identify areas of interest in the frame, so that data rates to the video processor are reduced. AT&T Microelectronics. Tel., 01734 324299; fax, 01734 328148.

COMPUTER

Data acquisition

16 channels for audio and telecomms. LSI has a 16-channel data acquisition board for use in fast processing of audio signals in test equipment, audio compression and telecomms. Carrier board DBV/DMCB fitted with up to four AM-D16QS daughter modules provides 16, 3KHz, 16-bit-wide channels, data channels being mapped into the system processor memory. The carrier board complies with dbxK32 and can be daisy-chained with up to four other i/o boards. Loughborough Sound Images Ltd. Tel., 01509 634300; fax, 01509 634333.

Data communications

Voice/data multiplexer. SwitchIT is a voice and data switching multiplexer by ML Electro-Optics that integrates voice, fax data and lan traffic to be transmitted on one digital line, the voice switching feature allowing a high-quality, multi-site, private voice network to use 64Kb circuits instead of 256Kb or more. SwitchIT operates on leased-line, dial-up and frame relay services. M L Electro-Optics Ltd. Tel., 0181 627 1100; fax, 0181 678 875644; fax, 01371 876077.

Computer board-level products

16/32-bit controller. CMS's Micro-Midget is a 16/32-bit microcontroller for use in 'intelligent' control systems, using an advanced, real-time operating system supporting high-level languages including C. It has up to 22 digital i/o lines, configurable for input or output, a single serial port operating at 38400baud and driving RS-232/485, and two 16-bit timer counters. Its peripheral expansion bus is usable with SMT308 and SMT309, these configurable, high-performance pixel processors, SM7308/9, these first two in the family being meant for use with the TI TMS320C40 general-purpose dsp, conforming to the TMS-40 board module standard. They can be configured to carry out low-level video operations, leaving higher-level functions to dsp software. The processors boost the throughput of the C40 by an order of magnitude, since a few gate delays take up much less time than software instructions. SM7308 digital video board is for high-resolution digital cameras to identify areas of interest in the frame, so that data rates to the video processor are reduced. SM7309 is a run-length encoder for use as a co-processor to the C40, settleable upper and lower limits cutting out unwanted data for a higher processor operating speed. Sundance Microprocessor Technology Ltd. Tel., 01644 431203; fax, 01494 726363.

Waveform analysis. ACRAView is a software package to enable the analysis of waveforms from Yokogawa's range of oscillographic recorders. Waveforms can be examined and analysed, manipulated, converted to other file formats such as Asci1 or Lotus 1-2-3, presented as colour graphics, formats including X/Y, multiframe, overlap and trend, or as digital data. Up to 32 channels can be handled simultaneously. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 539000.

Computer board-level products

16/32-bit controller. CMS's Micro-Midget is a 16/32-bit microcontroller for use in 'intelligent' control systems, using an advanced, real-time operating system supporting high-level languages including C. It has up to 22 digital I/O lines, configurable for input or output, a single serial port operating at 38400baud and driving RS-232/485, and two 16-bit timer counters. Its peripheral expansion bus is usable with SMT308 and SMT309, these configurable, high-performance pixel processors, SM7308/9, these first two in the family being meant for use with the TI TMS320C40 general-purpose dsp, conforming to the TMS-40 board module standard. They can be configured to carry out low-level video operations, leaving higher-level functions to dsp software. The processors boost the throughput of the C40 by an order of magnitude, since a few gate delays take up much less time than software instructions. SM7308 digital video board is for high-resolution digital cameras to identify areas of interest in the frame, so that data rates to the video processor are reduced. SM7309 is a run-length encoder for use as a co-processor to the C40, settleable upper and lower limits cutting out unwanted data for a higher processor operating speed. Sundance Microprocessor Technology Ltd. Tel., 01644 431203; fax, 01494 726363.

Waveform analysis. ACRAView is a software package to enable the analysis of waveforms from Yokogawa's range of oscillographic recorders. Waveforms can be examined and analysed, manipulated, converted to other file formats such as Asci1 or Lotus 1-2-3, presented as colour graphics, formats including X/Y, multiframe, overlap and trend, or as digital data. Up to 32 channels can be handled simultaneously. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 539000.
PASSIVE

Passive components

Encapsulated transformers. Clairtronic introduces, in its 1995 brochure, a new family of transformers working on the Eurovoltage 230V. Types include thermally protected low-profile units and inherently short-circuit-proof miniature models. All use flame-retardant materials to UL94VO and can be used in products to meet EN60950. Clairtronic Ltd. Tel., 01753 692022; fax, 01753 550506.

SM capacitor arrays. Surface-mounted capacitor arrays in the MVA series by Rohm contain two or four components in standard 0805 or 1206 packages, taking up to 45% less space than discrete SM devices. Dielectrics are COG, X7R and Y5V and the capacitors come in values from 11pF to 68nF. Convex terminations allow easy access of the mounting. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

Connectors and cabling

Pcb terminal blocks. Burin pcb mounted terminal blocks are available in two-piece pluggable form or as a single-piece fixed type. They incorporate a clamping pressure-clamping feature for low contact resistance and reliability, in which clamps compress the wires and serrations form a gas-tight interface. Bodies are in UL94V-O rated polyamide and contacts in tin-plated phosphor bronze. Ratings for the connectors, in 2 to 24-way form, are 15A at 250Vac for the pluggable type and 910A at 250Vac for the fixed variety. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Crystals

Ceramic resonators. Coaxial ceramic resonators by Siemens Matsushita are made in standard and miniature versions and are all based on a quarter-wavelength design in high-permittivity material. Frequency coverage is 450MHz-2.5GHz for the standard type, with Q between 250 and 400; the miniature models, which measure 16 by 4 by 4mm, cover a standard type, with Q between 250 and 400; the miniature models, which measure 16 by 4 by 4mm, cover 6.5A ac at line voltages to 250V, available in both pcb and chassis - mounted terminal blocks are available.

Hardware

Fan trays. Intelligent fan trays, as opposed to the dumb kind, are made by Vero to fit into the top of IMRAK 19-in racks without reducing space available to equipment. They have four dc fans, an autoswarming, universal power supply and a control unit, which is a thermostat to activate the fans if temperature exceeds 35°C, increasing power until it reaches 55°C. If a fan fails or is blocked, the others speed up, an alarm alarm and an indicator indicates, while a ttl signal initiates a controlled shut-down. Vero Electronics Ltd. Tel., 01703 266300; fax, 01703 265126.

Screened enclosures. Measurements on Vero's 3/4U caseframes in the KM6-EC range show excellent attenuation of both E and H fields. With no additional screening, the units exhibit H field attenuation of over 30dB from 10kHz to 1MHz and more than 90dB in the E field at 1MHz down to 40dB at 100MHz. Fitting beryllium copper fingers round the edges of front and rear apertures improved the performance to 60dB at 100kHz in the H field and in the E field over 100kHz at 1MHz. Vero Electronics Ltd. Tel., 01703 266300; fax, 01703 265126.

Burn-in IC sockets. Yamai introduces IC51, a family of IC sockets for test and burn-in, accommodating lcs with pin pitches from 1.27mm to 0.5mm with a parallel clamping device to eliminate strain on the pins. Over 10,000 variants handle most types of package, including custom types. Temperature range is −55°C to 170°C. Radatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

Earth tester. Avo's DET6D is an automatic, three-terminal earth tester for outdoor use. It checks for excessive current and voltage spikes, which can eliminate false results and presents readings on a large lcd. In two automatic ranges, the instrument measures from 100mΩ to 2kΩ. Spike kits for use with two or three terminals, complete with cables, cable winder and clips, are offered. Avo International Ltd. Tel., 01304 202620; fax, 01304 207342.

Frequency standard. FS 700 frequency standard from Stanford Research Systems uses Loran signals, transmitted for navigation and traceable to caesium clocks, to give a long-term stability of 1 part in 10^{-7}. FS 700 uses timing data from the signals to lock its own oscillator to provide a 10MHz output in the form of a ttl-compatible signal adjustable in frequency between 0.01Hz and 10MHz in a 1:2:5:16 sequence. Thurbry Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

Oscilloscope isolation amplifier. Vann Draper's H6001 single-channel isolation amplifier allows oscilloscopes to look at equipment such as motor controls, switch-mode power supplies and power semiconductor circuitry without the need to remove the instrument's earth connection. It employs optical and transformer techniques to handle signals up to 1MHz, and provides a grounding standard oscilloscope probes. Plastics are used in the casing and controls of the amplifier and emi and

NEW PRODUCTS CLASSIFIED

Please quote "Electronics World + Wireless World" when seeking further information.
NEW PRODUCTS CLASSIFIED

Please quote "Electronics World + Wireless World" when seeking further information.

rfi protection is provided. Vann Draper Electronics Ltd. Tel., 0116 2813091; fax, 0116 2570893.

Temperature controller. Brainchild announces the BTC-404 1/4DIN analogue temperature controller, which works with J or K thermocouples to cover the 0-1200°C range. Proportional or on-off control outputs are offered, to an accuracy of ±1% of span, the on-off control coming from a 10A relay. Alternatively, a pulsed voltage output drives a solid-state relay, or there is a 4-20mA linear loop or a 5-10V linear output. Indication is by led digital readout and the unit occupies only 53mm behind the panel. Brainchild Temperature Controllers Ltd. Tel., 01903 216514; fax, 01903 219662.

Goto-go tester for GSM. CTD 52 by Rohde & Schwarz carries out rapid test to verify the mobile's operation. It indicates pass or fail on selectable rf levels. Rohde & Schwarz carries out rapid test to verify the mobile's operation. It indicates pass or fail on selectable rf levels. The mobile is at fault or malfunction is due to another cause. Rohde & Schwarz UK Ltd. Tel., 0116 811377; fax, 01252 811447.

Energy monitoring. Selectek's UPM600 portable energy monitor, which is supplied with software, has a 80-260V AC input range, is usable with three-wire or four-wire systems and reads V, A, VAR, kW, Hz, kVAR and min/max values; it also gives harmonic analysis up to the 25th for voltage and current. Software allows 12 channels to be configured, with simultaneous voltage and current harmonics and up to 30 trend graphs of any of the measured parameters can be displayed on a p.c. Selectek Instruments Ltd. Tel., 01920 871094; fax, 01920 571653.

Printers and controllers

Printer sharing. Swiss firm Rotronic has introduced their ICE printer-sharing switchers through Interconnections Ltd, recently taken over by four models allow either printer sharing between two or four computers or computer sharing between two or four printers. Switching is either manual or by a tnr program, which scans the system for requests after eight inactive seconds. Power comes from the computer. Interconnections Ltd. Tel., 01293 822781; fax, 0293 822786.

Thermal line printers. Two new battery-powered printers by Fujitsu, the FTF-623 and 633, are for paper widths of 2in and 3in respectively, both being powered by NiCd, Ni-MH or lithium-ion packs at voltages between 4.2V and 8.5V. The thermal line dot system said, to be an improvement on the dot matrix type, allows printing speeds to 400 dotlines/s with a density of 800dpi. They are available as mechanisms or complete with interface board or with microcontroller and gate array for complete driver control. Fujitsu Microelectronics Ltd. Tel., 01628 76100; fax, 01628 781484.

Production equipment

Programming in production. Data I/O has introduced an automated handling and programming equipment for production runs. The Profilaster 7500 uses two of the company's AutoSite programmers in an automatic handler, the whole thing turned out, sorted and laser-marked. Devices in both surface-mounting and dip packages with up to 84 pins. Pick-and-place heads in the handler can rotate devices, so that work goes on without regard to orientation. Data I/O Ltd. Tel., 01734 440011; fax, 01734 447800.

Power supplies

Ac voltage stabiliser. An automatic ac voltage stabiliser, the Gardner's AVGU, smooths out extended voltage fluctuations and brown-outs in the mains supply. It copes with inputs up to 20% down on nominal of 220V or 110V, automatically selected, and provides over-voltage suppression and rfi filtering. Rated power of 2kVA can be taken from either the 220V or 110V outputs, which are both present, or shared between them. Further units offer ratings of 850VA, 1kVA, 2.2kVA plus 4kVA. Gardners Ltd. Tel., 01202 422824; fax, 01202 470805.

Battery monitor. Oopaiport Electronics offers a software-based battery monitor, the BA319 in a 3U 19in rack, which observes the current health and predicted behaviour of up to 400 cells, with an option up to 700. It presents a detailed review of every aspect of cell performance and prospects for the future. Oopaiport Electronics Ltd. Tel., 01249 755161; fax, 01249 750562.

Wide range – two sizes. Instead of the usual afterthought approach to pda design, in which the space left available is invariably far too small, this one has been adapted to the Vicor

Cigarette lighter. The new 66-page catalogue from Jensen,趁着你抽烟时，可以显示50K Wh of data. Data produced by the cigarette lighter can be used as a real-time clock for recording events such as portable telephones, camcorders and equipment for navigation. Signals from the 50K Wh NPL transmitter are at 60Hz and are binary-coded decimals in form to give time, date and year information. U4224B accepts 1-3.5-23k at 30µA (1µA after a setup time of 2s, while U4224B takes 2-4.5V at 40µA (0.2µA) and sets up in 2.5s. Macroe Group Ltd. Tel., 01628 608383; fax, 01628 668763/668071.

Cameras

Oem ccd. Sony has produced the NAX-M04E, a low-cost monochrome, ccd camera in board form, designed for conferencing, cockpit and machine vision. It measures 40 x 40 x 25mm and gives a resolution of 320 x lines from a 500 x 582 pixel format, with automatic exposure control and a 0.02s to 4s shutter speed. Power needed is 120mA at 12Vdc; minimum sensitivity 0.3lux; and composite video output 1Vp-p into 75Ω. Standard lens has a 3.6mm focal length, although other lenses are available. Sony Computer Peripherals & Components. Tel., 01932 816000; fax, 01932 817001.

Time-code receiver. Temic U4224B and U4221B, binary, straight-through time-code receivers are intended for use in radio-controlled clocks, receiving the time-code data from the National Physical Laboratory at Rugby. Data produced by the receiver can be used as a real-time clock for recording events such as portable telephones, camcorders and equipment for navigation. Signals from the 50K Wh NPL transmitter are at 60Hz and are binary-coded decimals in form to give time, date and year information. U4224B accepts 1-3.5-23k at 30µA (1µA after a setup time of 2s, while U4224B takes 2-4.5V at 40µA (0.2µA) and sets up in 2.5s. Macroe Group Ltd. Tel., 01628 608383; fax, 01628 668763/668071.
range is to offer over 11,000 different combinations of addcs and input and dc output in only two sizes of baseplate-cooled psu — 25-100W in 58 by 61 by 13mm and 50-200W in 17 by 61 by 13mm. Requirement changes can be coped with by simply using a different module or trimming the output for smaller changes. XP plc, Tel. 01734 841010; fax, 01734 843423.

High-power converter. HPD540 by Gardners is a 5V, 8A, low-profile dc-to-dc converter for mounting in a standard Euro-rack or similar enclosure. A typical use, says Gardners, would be to standby to maintain power to a bank of memory cards during maintenance work, in which case any dc input from batteries to 24V48V72V dc supplies and rectified ac can be used, without too much emphasis placed on stability of the ac. Non-polarised input terminals avoid disaster from reversed connections. Shielding and filtering against noise at both ends is provided. Gardners Ltd. Tel., 01202 482824; fax, 01202 470805.

European power supply. EAO Highland’s new EcoPower psu is, the company believes, the first to carry the European EMC mark, CE. It is an industrial unit, producing 24V, 5A dc and rectified ac can be used, without too much emphasis placed on stability of the ac. Non-polarised input terminals avoid disaster from reversed connections. Shielding and filtering against noise at both ends is provided. Gardners Ltd. Tel., 01202 482824; fax, 01202 470805.

Radio communications products
Power amplifiers. ENI announces the introduction of the Models 50AUL5007, a broadband power amplifier covering the frequency ranges 500kHz-1GHz and 800kHz-1GHz respectively, producing linear outputs of 4W and 7W. Any load vswr from open-circuit to short-circuit is acceptable without damage and the units meet the usual rfemi standards. Holiday Industries. Tel., 01526 478155; fax, 01526 476971.

GSPK demodulator. TDA8204 and TDA82041 from Philips form a two-chip, fully integrated demodulator for quadrature phase-shift keyed signals used in digital video broadcasting and digital telephony and performs all analogue and digital functions. The 8204 demodulator takes input at 150MHz and outputs I and Q signals, which are then digitised in the 8041 controller to record symbol clock and decode the symbols, obtain abc and acg. Phase error is less than 0.5°. Only a tank circuit for the vco and a pair of varicaps are needed externally, an on-chip voltage stabiliser being provided. Philips Semiconductors (Eindhoven). Tel., 00 31 40 722091; fax, 00 31 40 724825.

Switches and relays
Power switches. From BLP Components, the Series 32 Powerpulse relay, designed to meet BS376/Part 1 on lighting requirements and now confirmed in its suitability for use with fluorescent lighting up to 30A, part of the testing being equivalent to switching a 5ft tube 50,000 times. The switch handles relative humidity to 95%, temperatures to over 70°C and voltage to 75V ac. BLP Components Ltd. Tel., 01638 656151; fax, 01636 660718.

Black keyboard. Model 1600 Black Magic by Cherry is a 19-in keyboard in the ‘n’ colours for computing equipment, black and grey, joining the standard 19-in model 3000. It is intended for banks and checkouts, or anywhere where size is important, and can be mounted in a 19-in rack. Models with 101 or 102 keys are available. Cherry Electrical Products Ltd. Tel., 01582 763100; fax, 01582 768883.

Sealed keypads. Silicone-rubber, sealed keypads in the Series 84LS range by Greyhall are but 0.97mm thick overall and come in 10-key and 16-key versions. Contact resistance is 10Ω maximum and is compatible with mos, ttl and dit circuitry. A choice of matrix or single-pole/common-bus circuits is on offer and shielding is optional. EAO-Highland Electronics Ltd. Tel., 01444 236000, fax, 01444 236641.

Transducers and sensors
Control-shaft encoder. For the accurate adjustment of medical and measuring equipment, Panasonic’s optical encoders offer extremely long life and small size, having a height of 8mm. The encoders simply push onto the shaft, one version being provided with 31 leads to indicate position. The devices provide 40 pulses per revolution and operate from 5V. Panasonic Industrial (Europe) Ltd. Tel., 01344 853827; fax, 01344 853803.

Tilt sensors. Absolute inclinometers by Control Transducers in the A-1D range use optical encoders with a unique, rather than Incremental code. From one to 15 encoders may be networked on a six-wire cable at distances of 330m, to an RS-232 port, for which an interface is provided. From 2 to 65536 codes per revolution are available with 5-bit or 12-bit accuracy over 360° at rates from 38.4 to 115.2kbaud. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

DATA RATER Continued from page 482

Spectral behaviour
LM4861’s spectra into 8Ω are the highest (Fig. 21). The second harmonic dominates numerically as might be expected from the thd residue. There are plenty of high level, high order harmonics too, but at least the evens dominate. Spectra for the 4861 at 18dB below clip is quite different (Fig. 22). The second harmonic has not reduced in proportion though the higher harmonics have increased — suggesting fatiguing sonics.

Unfortunately, the LM4860 spectra demonstrated an unexplained noise problem (Fig. 23): a faulty ic is assumed, although %thd is within spec. Only one sample was provided and a replacement was not available in time, but the spectral pattern is recognisably as LM4861.

At the onset of clip, most of the LM12 products are just below 100dB (Fig. 24) — note the dominant third harmonic, while 25dB below clip (Fig. 25), the noise floor is increased. Harmonics poking above the averaged noise are just 2nd, 3rd, 4th and 6th — not unpleasant. Harmonics do not change outside the certainty limits (±2.5dB) when ripple is below 100dB

But at 26dB down, affecting most listening, the only harmonic readable above the averaged noise floor is a tiny 4th at 30dB (Fig. 26).

However, the PA45 mainly makes odd harmonics (Fig. 30). Worse, the high harmonics are almost level with the low order ones and will be very prominent by ear. At -25dB below clip, while cleaner, odd harmonics still dominate the event.

With the supply raised to +62V for the PA45 (still 20% below maximum) all the harmonics are reduced (Fig. 31) and the higher harmonics are particularly suppressed. Under these conditions, excellent sonics should result.

Moral: Those who believe mosfets have high %thd may be using them wrongly.

References
1. B. Duncan, Spectrally Challenged, EW + WW, Oct 93.
2. D. Self, High Speed Audio Power, EW + WW, Sept 94.
3. B. Duncan, Simulated attack on slews, EW + WW, April 1993.
4. D. Self, Distortion off the Rails, EW + WW, March 95.

Acknowledgment
The author would like to acknowledge the assistance given by Audio Synthesis.

June 1995 ELECTRONICS WORLD + WIRELESS WORLD
**WANTED!!**
Top prices paid for your test equipment made by HEWLETT-PACKARD, MARCONI, FISKE, TEKTRONIX, BOONTON, ROHDE & SCHWARZ etc.

From Europe's No. 1 Test Equipment Leader
ROSENKRANZ-ELEKTRONIK, AXEL ROSENKRANZ
GROSS GERAUER WEG 55, 64295 DARMSTADT/GERMANY
Phone: 0049-6151-3998-0 Fax: 0049-6151-3998-18

**CONTACT US NOW!**
You are looking for test equipment? More than 10,000 units in stock for immediate delivery. Call or fax for our new 100 page catalogue today

**WHAT WE DON'T HAVE YOU DON'T NEED**

---

**INDEX TO ADVERTISERS**

| Ambar Components | PAGE 459 |
| Antrim Transformers Ltd | PAGE 511 |
| BK Electronics | PAGE 498 |
| Bull Electrical | PAGE 476 |
| Cricklewood Electronics | PAGE 508 |
| Dataman | PAGE 455 |
| Display Electronics Ltd | PAGE 494 |
| Field Electric Ltd | PAGE 493 |
| Grandata Ltd | PAGE 515 |
| Halcyon Electronics | PAGE 511 |
| ICE Technology Ltd | PAGE 508 |
| Interconnections | PAGE 489 |
| IFOSS | PAGE 450 |
| John Morrison (Micros) | PAGE 494 |
| Johns Radio | PAGE 499 |
| JPG Electronics | PAGE 525 |
| Kestral Electronic Components | PAGE 526 |
| Keytronics | PAGE 515 |
| Lab Center | PAGE 517 |

---

**ADD VALUE AND CREDIBILITY WITH REPRINTS**

Multiple copies of your articles and advertisements published in this magazine make ideal promotional material for sales literature, exhibition handouts, direct mail, new product launches, distributor promotions, Public Relations etc.

You can add your own artwork and copy, utilise the front cover of this magazine, include your list of distributors, and/or your latest advertisement/s. Reasonably priced reprints can be tailor-made to your specific requirements or simply reprinted in their original form. (Minimum order number 250)

For a FREE quotation please telephone Jan Crowther now on: 0181-652 8229 or fax: 0181-652 3978

Reprint Services, Reed Business Publishing,
Room 1006, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS, England

---

**SALE OR SWOP for CD-Rom drive**
Perkin Elmer, infra-red spectrometer, infragraph H12000, working. Phone 01273 553505.

**WANTED:**
pre-war television. Jac Jansen, Hagheam 1170, NL-5104JD Dongen, Netherlands. Tel: (eves) 0031 1362 18158. Fax (office): 0031 13624644.

**TEKTRONIX MODULES 7A26, 7A18, 7B85, 7B80, 7B50A:** Fully tested. Sensible offers please. Ian Stirling, Cottaracre Star. Fife KY7 6LA. 01592 757384.

**FOR SALE:**
Dranetz phase meter, 2Hz - 700 KHz, 0.01 degrees resolution, good for filters, crossovers etc. £350 ono. Tel: Mike 01483 487189 (eves).

**WANTED:**
TEKTRONIX Plug in module. Type AA501 Distortion analyser. Also S505 oscillator. Phone: G. E. Gillard 0115 9846116.

**FOR SALE:**
MAJOR US SEMICONDUCTOR MANUFACTURER

This world leading company has enjoyed success throughout its 30 year history and is currently experiencing another period of sustained growth. A focused approach and commitment to technical innovation are the cornerstones of this company’s philosophy throughout the world. Its core competencies in standard linear and system IC technology are to be further developed in the recruitment of three individuals into the UK Design Centre:

SENIOR IC DESIGN
Operating as part of a dedicated design team, you will take a leading role in developing application specific solutions to process high speed data streams for the computer peripheral and datacom market places. Qualified to degree level in an electronics related discipline, applications are invited from talented digital IC designers with at least 3–5 years’ design experience.

ANALOG IC DESIGN
You will contribute significantly to the further development of a market leading data conversion product range. Applications are particularly welcome from candidates with an appreciation of Sigma-Delta and successive approximation conversion techniques. You should be recently qualified to MSc level in Microelectronics or have at least 1 year’s experience in IC design.

DIGITAL IC DESIGN
Developing application specific products for the computer peripheral and datacom market places, this role will provide an excellent opportunity for an engineer with at least 1 year’s IC design experience or for a recent MSc graduate in Microelectronics. Whilst attitude and aptitude are more important than experience, an understanding of the techniques for processing high speed data streams would be beneficial.

This is an organisation where people really matter, and as such, successful candidates can expect to receive excellent salary and benefits packages.

To find out more about these opportunities and to apply in total confidence, please telephone Andy Clarke on 01273 480088 this week or next up until 7.30 pm or write to him at the address/fax no. below quoting ref. no. 40581.

ERC House, 32/33 North Street, Lewes, East Sussex BN7 2PQ United Kingdom
Telephone: (01273) 480088 Fax: (01273) 480808 Int Code (+44 1273)

INTERNATIONAL TECHNOLOGY RECRUITMENT

TEST and MEASUREMENT

- Spectrum Analysers
- Signal Generators
- Tele/Datacomms Test
- Power Meters
- Radio Test Sets
- Oscilloscopes
- Frequency Counters
- DMMS
- Power Supplies
- Network Analysers
- Modulation Meters
- Logic Analysers
- Mains Analysers
- Sound & Vibration
- Analytical
- Environmental
- Computers

Engineers ➔ Make the move to technical sales

Middlesex

Are you looking for an employment opportunity which rewards you for your considerable test and measurement technical skills? Do you have experience of several of the products listed?

Our client is looking for an outward going, motivated engineer to work in their internal sales department dealing directly with test and measurement sales opportunities and managing them through to sale.

Comprehensive sales training will be afforded to the successful candidate, complementing your existing technical abilities and providing all the skills necessary to succeed in their business.

This responsible role with Europe’s market leader offers a competitive salary and benefits package together with excellent long term career prospects. If you are ready to step up into a challenging sales position working in a close knit friendly team then contact Stephen Lewis at the address below.

Precision Consultants
The Electronics & Broadcast Recruitment Specialists
Britannia House, Leagrave Road, Luton LU3 1RJ
Tel 01582 36500 Fax 01582 38500

£17k–£21k
PACKAGE
THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY
Lae

LECTURER IN COMMUNICATION SYSTEMS
Department of Electrical and Communication Engineering

Vacancies exist in the field of Communication Systems. The successful applicants will be required to teach at undergraduate level, especially on communication theory and modern systems, and to carry out research in a communication field of local relevance. Applicants should offer research and teaching expertise in at least two or more of the following: Signal processing, data communications, computing, satellite communications, radar, microwaves, optical systems and propagation, though consideration will be given to those in area of radio wave propagation. Teaching is to be done at degree level in Electronics and Communications.

The Department has a longstanding programme of research into the effects of tropical rainfall on propagation from satellites at millimetre wavelengths, supported by INTELSAT and the local PTC. Single site and diversity measurements of downlink power are underway and proposals for radar measurements of the vertical and horizontal distribution of rain are planned. Possibilities exist for research in other areas of Electronics and Communications.

For further information contact Mr L Watai, Acting Head, Department of Electrical and Communication Engineering (tel. +675 434701; fax +675 457209).

SALARY (per annum): Lecturer I K30,212 - K32,393; Lecturer II K33,458 - K35,836. (Level of appointment will depend upon qualifications and experience.)

Initial contract period is normally for three years but periods can be negotiated. Other benefits include a gratuity of 30% in the first year, 35% in the second year and 40% in the third year, support for approved research, appointment and repatriation fares; leave fares for the staff member and family after 18 months of service; settling-in and settling-out allowances; six weeks' paid leave per year; salary protection plan and medical benefit schemes available. Staff members are also permitted to earn from consultancy up to 50% of earnings annually.

Detailed applications (two copies) with curriculum vitae and names and addresses, fax/phone numbers of three referees and an indication of the earliest availability to take up the appointment should be received by: The Registrar, PNG University of Technology, Private Mail Bag, Lae, Papua New Guinea by 15 June 1995. Applicants resident in the United Kingdom should also send one copy to Appointments (43884), Association of Commonwealth Universities, 36 Gordon Square, London WC1H 0PF (tel. 0171 387 8572 ext. 206; fax 0171 813 3055; email appts.acu@ucl.ac.uk) from whom further information may be obtained.

THE RADIO SOCIETY OF GREAT BRITAIN seeks to appoint a full-time Advertising Manager, to be based at its Potters Bar Headquarters, to handle the advertising space in its publications, principally the magazine Radio Communication.

Radio Communication is the UK's leading title targeting the licensed radio amateur. Published monthly and circulated to 31,000 members, it is a 100-page, A4 colour production carrying on average 30% of content as display and classified advertising pages.

Applications are sought from those with relevant experience and capability. It will be a significant advantage to be the holder of a current amateur radio licence or to have a practical knowledge of electronics terminology. This is not an opportunity to learn on the job!

Responsibilities will include:
1. Marketing of the space to the trade and agencies.
2. Production work, technical copy writing, layout and typography for trade setting or with an in-house DTP system.
3. Page make-up, proofing, classifieds and setting-house liaison.
4. Administration of orders, schedules and management of accounts.
5. Provision of professional advice to the Society and an impartial complaints service to members and advertisers.

Remuneration will be by a combination of salary and commission. Applications will be considered from established professionals and those with relevant experience.

Applications should be made in writing with an outline of relevant professional experience. Total confidentiality will be observed. Marking your letter 'CONFIDENTIAL' please write to the General Manager at:

Radio Society of Great Britain
Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE

ARTICLES WANTED

WANTED

High-end Test Equipment, only brand names as Hewlett-Packard, Tektronix, Rhode & Schwarz, Marconi etc. Top prices paid.

Please send or fax your offer to:

HTB ELEKTRONIK
Alter Apeler Weg 9, 27619 Schiffdorf, West Germany
TEL: 01049 4706 7044
FAX: 01049 4706 7049

COLOMOR ELECTRONICS LTD
170 Goldhawk Road, London W12 8HJ England.
Tel: 0181 743 0899
Fax: 0181 749 3934

WANTED

Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash.

M & B RADIO
86 Bishopsgate Street, Leeds LS1 4BB
Tel: 0113 2435649
Fax: 0113 2428681

COLOMOR ELECTRONICS LTD
170 Goldhawk Road, London W12 8HJ England.
Tel: 0181 743 0899
Fax: 0181 749 3934

ADVERTISING MANAGER REQUIRED

THE RADIO SOCIETY OF GREAT BRITAIN seeks to appoint a full-time Advertising Manager, to be based at its Potters Bar Headquarters, to handle the advertising space in its publications, principally the magazine Radio Communication.

Radio Communication is the UK's leading title targeting the licensed radio amateur. Published monthly and circulated to 31,000 members, it is a 100-page, A4 colour production carrying on average 30% of content as display and classified advertising pages.

Applications are sought from those with relevant experience and capability. It will be a significant advantage to be the holder of a current amateur radio licence or to have a practical knowledge of electronics terminology. This is not an opportunity to learn on the job!

Responsibilities will include:
1. Marketing of the space to the trade and agencies.
2. Production work, technical copy writing, layout and typography for trade setting or with an in-house DTP system.
3. Page make-up, proofing, classifieds and setting-house liaison.
4. Administration of orders, schedules and management of accounts.
5. Provision of professional advice to the Society and an impartial complaints service to members and advertisers.

Remuneration will be by a combination of salary and commission. Applications will be considered from established professionals and those with relevant experience.

Applications should be made in writing with an outline of relevant professional experience. Total confidentiality will be observed. Marking your letter 'CONFIDENTIAL' please write to the General Manager at:

Radio Society of Great Britain
Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE

WANTED

High-end Test Equipment, only brand names as Hewlett-Packard, Tektronix, Rhode & Schwarz, Marconi etc. Top prices paid.

Please send or fax your offer to:

HTB ELEKTRONIK
Alter Apeler Weg 9, 27619 Schiffdorf, West Germany
TEL: 01049 4706 7044
FAX: 01049 4706 7049

COLOMOR ELECTRONICS LTD
170 Goldhawk Road, London W12 8HJ England.
Tel: 0181 743 0899
Fax: 0181 749 3934

WANTED

Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash.

M & B RADIO
86 Bishopsgate Street, Leeds LS1 4BB
Tel: 0113 2435649
Fax: 0113 2428681

WANTED

Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash.

M & B RADIO
86 Bishopsgate Street, Leeds LS1 4BB
Tel: 0113 2435649
Fax: 0113 2428681

SALARY (per annum): Lecturer I K30,212 - K32,393; Lecturer II K33,458 - K35,836. (Level of appointment will depend upon qualifications and experience.)

Initial contract period is normally for three years but periods can be negotiated. Other benefits include a gratuity of 30% in the first year, 35% in the second year and 40% in the third year, support for approved research; appointment and repatriation fares; leave fares for the staff member and family after 18 months of service; settling-in and settling-out allowances; six weeks' paid leave per year; education fares and assistance towards school fees; free housing. Salary protection plan and medical benefit schemes are available. Staff members are also permitted to earn from consultancy up to 50% of earnings annually.

Detailed applications (two copies) with curriculum vitae and names and addresses, fax/phone numbers of three referees and an indication of the earliest availability to take up the appointment should be received by: The Registrar, PNG University of Technology, Private Mail Bag, Lae, Papua New Guinea by 15 June 1995. Applicants resident in the United Kingdom should also send one copy to Appointments (43884), Association of Commonwealth Universities, 36 Gordon Square, London WC1H 0PF (tel. 0171 387 8572 ext. 206; fax 0171 813 3055; email appts.acu@ucl.ac.uk) from whom further information may be obtained.

THE RADIO SOCIETY OF GREAT BRITAIN seeks to appoint a full-time Advertising Manager, to be based at its Potters Bar Headquarters, to handle the advertising space in its publications, principally the magazine Radio Communication.

Radio Communication is the UK’s leading title targeting the licensed radio amateur. Published monthly and circulated to 31,000 members, it is a 100-page, A4 colour production carrying on average 30% of content as display and classified advertising pages.

Applications are sought from those with relevant experience and capability. It will be a significant advantage to be the holder of a current amateur radio licence or to have a practical knowledge of electronics terminology. This is not an opportunity to learn on the job!

Responsibilities will include:
1. Marketing of the space to the trade and agencies.
2. Production work, technical copy writing, layout and typography for trade setting or with an in-house DTP system.
3. Page make-up, proofing, classifieds and setting-house liaison.
4. Administration of orders, schedules and management of accounts.
5. Provision of professional advice to the Society and an impartial complaints service to members and advertisers.

Remuneration will be by a combination of salary and commission. Applications will be considered from established professionals and those with relevant experience.

Applications should be made in writing with an outline of relevant professional experience. Total confidentiality will be observed. Marking your letter 'CONFIDENTIAL' please write to the General Manager at:

Radio Society of Great Britain
Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE

WANTED

High-end Test Equipment, only brand names as Hewlett-Packard, Tektronix, Rhode & Schwarz, Marconi etc. Top prices paid.

Please send or fax your offer to:

HTB ELEKTRONIK
Alter Apeler Weg 9, 27619 Schiffdorf, West Germany
TEL: 01049 4706 7044
FAX: 01049 4706 7049

COLOMOR ELECTRONICS LTD
170 Goldhawk Road, London W12 8HJ England.
Tel: 0181 743 0899
Fax: 0181 749 3934

WANTED

Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash.

M & B RADIO
86 Bishopsgate Street, Leeds LS1 4BB
Tel: 0113 2435649
Fax: 0113 2428681
Cooke International
SUPPLIER OF QUALITY USED TEST INSTRUMENTS
ANALYSERS, BRIDGES, CALIBRATORS, VOLTMETERS, GENERATORS, OSCILLOSCOPES, POWER METERS, ETC. ALWAYS AVAILABLE

ORIGINAL SERVICE MANUALS FOR SALE COPIES ALSO AVAILABLE

EXPORT, TRADE AND U.K. ENQUIRIES WELCOME, SEND LARGE "A3" S.A.E. + 50P POSTAGE FOR LISTS OF EQUIPMENT AND MANUALS.

ALL PRICES EXCLUDE VAT AND CARRIAGE DISCOUNT FOR BULK ORDERS SHIPPING ARRANGED

OPEN MONDAY-FRIDAY 9AM-5PM

Cooke International
ELECTRONIC TEST & MEASURING INSTRUMENTS
Unit Four, Fordingbridge Site, Main Road, Barnham, Bognor Regis, West Sussex, PO22 0EB

Tel: (+44) 01243 545111/2 Fax: (+44) 01243 542457

EQUIPMENT & ACCESSORIES PURCHASED
CIRCLE NO. 141 ON REPLY CARD

RECRUITMENT

Analogue Design Engineer

BSS leads the world in innovative audio signal processing. We sell to the Live market, Broadcasters, Recording Studios and Installers in every part of the world. We set ourselves high standards, and we usually beat them.

Due to our continued success and growth, a vacancy has arisen in our R&D department for an Analogue Design Engineer to help us to continue developing world class products. You will be surrounded by a small team of specialists in a busy but friendly environment.

You will have at least 3 years' professional experience in analogue design techniques, and a passion for audio electronics. An appreciation of power amplifiers, digital electronics and DSP techniques would be an advantage. An attractive salary package will be offered commensurate with experience.

Please write to: Sarah Lyon, BSS Audio Ltd, Linkside House, Summit Road, Potters Bar, Hertfordshire, EN6 3JB.

WE WANT TO BUY !!

IN VIEW OF THE EXREMELY RAPID CHANGE TAKING PLACE IN THE ELECTRONICS INDUSTRY, LARGE QUANTITIES OF COMPONENTS BECOME REDUNDANT. WE ARE CASH PURCHASERS OF SUCH MATERIALS AND WOULD APPRECIATE A TELEPHONE CALL OR A LIST IF AVAILABLE. WE PAY TOP PRICES AND COLLECT.

R. HENSON LTD.
21 Lodge Lane, N. Finchley, London N12 8JG.
5 Mins, from Tally Ho Corner.
TELEPHONE 081-445-2713/0749
FAX 081-445-5702.

ARTICLES FOR SALE

TURN YOUR SURPLUS TRANSISTORS, ICS ETC, INTO CASH
Immediate settlement.
We also welcome the opportunity to quote for complete factory clearance.

Contact:
COLES-HARDING & CO, Unit 58, Queens Road, Wisbech, Cambs. PE13 2PQ
Tel: 01945 584188 Fax: 01945 475216

HAMEG 203-6 Scope used only few hours. £300. Also Philips SBC 530, Portable Scope, new. Tel: 01702 522929
SIB

ELECTRONIC UPDATE

TF2910 TV Interval timer
TF2910/4 Non-linear distortion (video) test set
0A2805A Porn regenerator test set
6500 Amplitude analyser c/w 2m 6514 waveguide detectors
6460/6421 Power meter & sensor 10MHz-2.4GHz
605X Series signal sources, all in range
2955R As above with sensitive receiver inbuilt
2955 Mobile radio test set
ALL SOLD

HP8593A Portable spectrum analyser to 22GHz IEEE
Price: don't ask

HP8568A High-specification 1.5GHz spectrum analyser
HP8559A 21 GlHz spec in 853A digital mainframe HPIB
HP3582A Audio frequency analyser dual-channel

FLASH: Emulators and OTPs up to BM bit.

IFR Model A-7550 1GHz portable with built-in tracking gen & IEEE ops £5000

SPECTRUM ANALYSERS

MARCONI INSTRUMENTS

0181-652 3620

The system 2000 is an ideal programmer for the production environment. Fast programming results in high throughput and rigorous verification leads to improved quality control. Single key functions and checks against misoperation facilitates its use by unskilled staff.

Mqp ELECTRONICS LTD.
Tel: 0666 825146
Fax: 0666 825141

NATIONAL INSTRUMENTS

1995 CATALOGUE

The 1995 National Instruments catalogue describes more than 900 software and hardware products. Engineers and scientists can use these to develop integrated instrumentation systems for test and measurement process monitoring and control, using industry-standard personal computers and workstations.

NATIONAL INSTRUMENTS FOR FURTHER INFORMATION CALL 01635 523545

Sabre Electronics Limited is a leading manufacturer in the field of mains distribution panels of every shape and size to suit a variety of needs. For use in Broadcasting, Computing, Data Communications, Defence, Education, Finance, Health etc. All panels are manufactured to BS5733. BRITISH AMERICAN, FRENCH, GERMAN GREEK, and many other languages.

All prices subject to VAT and carriage.

OLSON ELECTRONICS LIMITED

Tel: 081 885 2884
Fax: 081 885 2496

CIRCLE NO. 144 ON REPLY CARD
Programming Solutions

SMART Communications offer the best range of low cost programmers for your every need. Unrivalled device support includes the latest MACH, pLSI, MAPL, PIC, WSI, Atmel, Xilinx and Intel parts.

ALL-07 Universal Programmer
Pin driver expansion can drive up to 256 pins.
Supports over 2000 IC's – 3 and 5 volt devices.
EPROMs, EPROMs, Bipolars, Flash, Serial EPROMs
up to 16 Mbits parts, over 150 Microcontrollers
and PLDs, EPLDs, PEELs, PALs, GALs, FPGA etc...
Universal DIL (up to 48 pins), PLCC and gang PACs
- significantly reduces the number of adapters required.
Powerful full colour menu system.
Connects to the pc printer port with its own power supply.
Latest programming algorithms.
Tests TTL, CMOS and SRAM devices
- even identifies unknown parts.
Approved by AMD for their range of programmable logic.
£595

EMP-20 Multi-Device Programmer
EPROMs, EPROMs, Flash,
Serial EPROMs to 16 Mbits.
PLDs, GALs, PEELs, WSI PSIDs.
Intel, Microchip, Motorola
and Zilog Microcontrollers.
Fast programming algorithms.
£325

Erasers & pin convertors
AT-701 – Chiprase
Ultra-violet eraser.
Very compact
16 chip capacity
Built in timer
£95

Pin convertors
from DIL to
PLCC, SOP, SOIC etc...
from £50

PB-10 Programmer
Low cost programmer.
EPROMs, EPROMs, Flash and 8748/8751.
Fast programming algorithms.
Simple but powerful menu driven software.
£139

SMART Communications have a full range of dedicated programmers for the Microchip PIC range of microcontrollers – both single and gang for DIL and SOIC variants.

We also supply a wide range of development tools – Assemblers, Compilers, Simulators and Emulators – for a wide range of microprocessors, especially the Microchip range. Our ROM emulators start at just £99.

SMART COMMUNICATIONS
2 Field End • Arkley • Barnet • Herts • EN5 3EZ • England
Telephone +44 (0)181 441 3890
Fax +44 (0)181 441 1843
CIRCLE NO. 102 ON REPLY CARD
The best by design!

S4'S VITAL STATISTICS:

- Totally handheld programmer/emulator
- Fast approved programming algorithms; eg. program and verify:
  - National 27C512 in 16 seconds
  - AMD 29F010 in only 90 seconds
- EPROMs to 8Mbit, 5v, 12v and BOOT-BLOCK FLASH, EEPROMs and PEROMs
- Three year parts and labour guarantee
- Free next day delivery (UK only)
- 30 day trial available (UK only)
- Full 24 byte on-screen editor
- Continuous programming whilst charging (nonstop operation)
- Moulded designer case - feels as good as it looks
- Rubberised colour-coded full travel keypad
- Big, easy-view 80 character supertwist LCD
- Optional modules available to program PICs, 8751, 16-bit EPROMs, Toshiba 4-bit, Hitachi H8
- Optional sockets for programming and emulating PLCC devices

S4's 32 pin ZIF socket programs a huge library of 8 & 16 bit EPROMs, EEPROMs, FLASH, PICs and other popular microcontrollers using manufacturers approved algorithms. Our free and easily updatable device library enables users to always have the latest software installed. During our sixteen years of designing and selling innovative and fast programming solutions to industry, Dataman has never charged for software updates or technical support.

Built in emulation enables you to see your code running before committing yourself to an EPROM. Load your program from an EPROM or download code from your PC into S4's memory. Plug S4's emulation lead into the target system, press the emulation key and run the system. Changes can be made using S4's powerful editor, and you can re-run the code to test and confirm changes. When the code is proved to be working, it can then be programmed to a fresh ROM.

The S4 package comes complete with mains charger, emulation leads, user's manual, PC software and a three year guarantee.

S4 is always available off the shelf and we ship worldwide on a daily basis. Call now for delivery tomorrow!

CREDIT CARD HOTLINE 01300 320719 for same-day dispatch

Only £495 plus VAT
3yr guarantee
30 day trial
(3Mb upgrade £99 plus VAT)

S4's 32 pin ZIF socket programs a huge library or 8 & 16bit EPROMs, EEPROMs, FLASH, PICs and other popular microcontrollers using manufacturers approved algorithms. Our free and easily updatable device library enables users to always have the latest software installed. During our sixteen years of designing and selling innovative and fast programming solutions to industry, Dataman has never charged for software updates or technical support.

Built in emulation enables you to see your code running before committing yourself to an EPROM. Load your program from an EPROM or download code from your PC into S4's memory. Plug S4's emulation lead into the target system, press the emulation key and run the system. Changes can be made using S4's powerful editor, and you can re-run the code to test and confirm changes. When the code is proved to be working, it can then be programmed to a fresh ROM.

The S4 package comes complete with mains charger, emulation leads, user's manual, PC software and a three year guarantee.

S4 is always available off the shelf and we ship worldwide on a daily basis. Call now for delivery tomorrow!

CREDIT CARD HOTLINE 01300 320719 for same-day dispatch

Bona-fide UK customers can try S4 for thirty days without risk.
18,000 satisfied users worldwide can't be wrong!

Dataman Programmers Ltd
Station Road, Maiden Newton
Dorset, DT2 0AE, UK.
Tel: 01300 320719 Fax: 01300 321012
Telex: 418442 BBS: 01300 321095
Modem: V.34/V.FC/V.32bis
22 Lake Beauty Drive, Suite 101
Orlando, FL 32806, USA
Tel: (407) 649-3335 Fax: (407) 649-3310
BBS: (407) 649-3159 24hr
Modem V32bis/16.8K HST

FREE software upgrades for life
FREE emulation leads
FREE custom terminal software