New preamp concept

Transparent LPT i/o

Enhanced FM detection

Classic valve audio

Switch-mode power module

Matlab's DSP toolbox

Big screens for tomorrow's tv

50Ω matching

EW exclusive – virtual instruments offer
4 reasons why you should choose...

MICRO-PRO

TWO FREE microcontrollers
PSU, parallel cable & data sheets
plus FREE IC extractor tool included

NOW ONLY
£99*

ATMEL AT89C2051
- 20 PIN - 8051 derivative
- FLASH programmable (1000+ times)
- Erase program & verify device in under 5 seconds

(1) FAST data transfer - connects to PC parallel port

(2) Field programmable hardware for FREE future device support

(3) Accepts up to 40 PIN devices directly. Additional adapters available for PLCC.

(4) MICRO PRO is approved by ATMEL for programming their complete range of FLASH microcontrollers

---

THE FULL ATMEL FLASH MICROCONTROLLER RANGE

<table>
<thead>
<tr>
<th></th>
<th>8951</th>
<th>8952</th>
<th>1051</th>
<th>2051</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLASH code ROM</td>
<td>4K</td>
<td>8K</td>
<td>1K</td>
<td>2K</td>
</tr>
<tr>
<td>RAM</td>
<td>128</td>
<td>256</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>I/O</td>
<td>32</td>
<td>32</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Timer/Counter (16 bit)</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Serial Port</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Interrupt Sources</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Pins (DIL/PLCC)</td>
<td>40/44</td>
<td>40/44</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Special features</td>
<td>Timer 2</td>
<td>Comparator</td>
<td>Comparator</td>
<td></td>
</tr>
<tr>
<td>Price (1-24)</td>
<td>£14-85</td>
<td>£16-95</td>
<td>£4-70</td>
<td>£5-85</td>
</tr>
</tbody>
</table>

* Offer includes one AT89C1051, one AT89C2051 and one IC extractor tool.
Offer valid until 31st December 1995 when ordered direct through Equinox Technologies.
All prices shown exclude VAT & VAT plus any bank/credit card charges for overseas customers and remain fixed until 31st December 1995. All items subject to availability.
For further information on our full range of development systems for the ATMEL microcontroller range please contact John Marriott at Equinox Technologies.
CONTENTS

1012 AUDIO PREAMP - SIMPLE BUT SOUND
Reg Williamson demonstrates how an impedance converter helps keep design simple and transparent to the audio passing through.

1015 ENGINE MANAGEMENT
Eric Russel explains how electronic engine management is evolving from the race track to the highways.

1021 A NEW SENSOR FOR MEDICINE
Developed with medical applications in mind, this new opto-electronic technique could speed up diagnosis.

1024 DISPLAYS FOR BIG TV
Large screen tv is going to need a new display technology. Peter Willis looks at two of the contenders.

1026 DEMODULATION - A NEW APPROACH
Capable of improving performance in both am and fm systems, Archie Pettigrew's new detection technique involves an amplitude-locked loop.

1034 CLASSIC VALVE POWER
Morgan Jones presents a few of the classics in valve audio power - including the Williamson and Mullard 5-20.

1040 SIGNAL PROCESSING IN A TOOLBOX
Allen Brown looks at an extension to Matlab specifically designed for solving dsp problems.

1045 TRANSPARENT I/O VIA LPT
The main disadvantage of using the printer port for analogue and digital i/o is that you have to unplug the printer. Or do you?

1058 POWER MODULES FOR QUASI-RESONANCE
Relative to monolithics and discretes, power multi-chip modules represent an excellent compromise for quasi-resonant switch-mode power.

1066 INTERFACING THE GPS RECEIVER
Nigel Gardner presents a low cost read-out interface for Rockwell's Microtracker system.

1071 ADVANCES IN DIGITAL VIDEO
Video developments spotted at the recent broadcast and professional exhibition - Vision '95

1074 IS MATCHING EASY?
Ian Hickman looks at the pitfalls involved when matching source and load impedances.

1084 DO YOU KNOW FOSTER SEELEY?
Amazed at the widespread misunderstanding of how Foster-Seeley's discriminator works, Richard Brice sets the record straight.

1087 ANALYSING AC
Owen Bishop explains how circuit simulators handle various facets of ac analysis.

REGULARS

1003 COMMENT
Waiting for the mobile data train

1004 NEWS
TVS breakthrough, Pentium power down, Pocket video.

1008 RESEARCH NOTES
Hdtv, Commercial micromotors, Chemical weapon, The sun's magnetic field, Organics breakthrough.

1050 CIRCUIT IDEAS
Static noise limiter, Fast logic isolator, Video transmission on vhf, Solid-state relay, Fwm generator, Programmed bandpass filter.

1069 LETTERS
Phone Day fiasco, Field hazards, Is EMC approval needed, Audio power

1079 NEW PRODUCTS
Pick of the month - classified for convenience.

Next month: Orientation via magnetic sensing, Valve power, Duncan on CMR and cable modelling.

JANUARY ISSUE - ON SALE 28 DECEMBER

20% DISCOUNT
EW readers can obtain 20% discount on an RS232 controllable i/o subsystem with 8 analogue inputs, 24 digital i/o lines, power drivers and counting and timing capabilities - page 1023.

Special reader discount of 30%
Plug a Pico module into your LPT port and turn your pc into a spectrum analyser, scope, f-meter, dvm or data logger. Due to exceptional demand, Pico Technology is allowing us to repeat this offer - page 1023.
quickroute 3.5
Schematic & PCB design for Windows 95 and 3.1

"moving from schematic to layout could not be easier" review of Quickroute 3.0 in Electronics World & Wireless World Jan 95

Quickroute, the integrated electronics design solution, available with:

- Schematic capture, net-list import & export, Gerber file import & export, WMF, DXF, SPICE & SpiceAge export.
- Integrated auto-routing on 1, 2 or up to 8 layers. Copper fill for creating regions of copper.
- Engineering change allows changes on a schematic to be propagated forward onto a PCB.
- Prices range from £399.00 down to just £68.00 (prices exclude post&packing, and V.A.T).

quickroute SYSTEMS Limited
14 Ley Lane, Marple Bridge, Stockport, SK6 5DD. UK.
Tel/Fax 0161 449 7101
email info@quicksys.demon.co.uk

SCAN BAR CODES FOR £29.50
HEWLETT PACKARD HP71B
BARCODE READER

As easy to use as a calculator but as powerful as a computer

- A powerful set of basic functions, statements and operators - over 230 in all - many larger computers don't have a set of basic instructions in this complete.
- Advanced statistics functions enabling computations on up to 15 independent variables.
- Recursive subprograms and user defined functions.
- An advanced internal file system for storing programs and data - the HP71 has continuous memory - when you turn the computer off it retains programs and data.
- A keyboard that can be easily customised for your specific application.
- HP-IL Interface pre-installed to create a system that can print, plot, store, retrieve and display information. Control or read instruments or speak to other computers, 5000 bytes/sec. Built in ROM includes 46 separate commands. Interface to HP-IL, HP-IV, RS232C, GPIO or series 80. Includes connection cables.

These are second user systems ex DHSS are fully tested and working but have no programming. (THAT IS UP TO YOU) HP71B Bar-code Reader AC Power Supply (Works from batteries normally) Keyboard Overlay Complete kit of HP71B, Bar-code Reader and power supply (£39.50)

(Prices include VAT - delivery £3.00) (UK only) Allow 7 days for delivery.

SPECIAL OFFER
Buy 2 Kits For £59.00

Other products at give-away prices
Numeric keypad for "AT" computer £5 + £2 Carriage

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

COMPONENTS & SYSTEMS FROM IOSIS

System Components from ISO9001 Source
- Half Size ISA Single Board Computers
- 386SX-40 to 486DX-100 with PC/104, 2 Serial Ports
- IDE & FDD & Printer Port and a variety of on-board functionality's:
  - FLASH/ROM Disc. Cache. VGA CRT/Flat Panel Controller
  - PC/104 Modules:
    - 386 & 486 CPUs, Solid State Disc, Isolated RS232/485
    - VGA CRT/Flat Panel Display & SVGA Controllers
    - PMCIA types I, II & III
- System Enclosures with Passive Backplanes
- Colour & Mono Flat Panel LCD Displays
- System Integration and Support

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

CIRCLE NO. 166 ON REPLY CARD
Waiting for the mobile data train

No one would question the value of mobile communications. The mobile telephone has quickly become a commercial necessity for many business travellers and a vital security tool for the more vulnerable in society.

It is equally self-evident that the transmission of digital speech over the airwaves is little different from the transmission of data files. So why are we still waiting for the mobile phone operators to get there act together and start promoting mobile computing services?

The somewhat cynical view is that the mobile phone operators are reluctant to promote a mobile data which makes less efficient use of their networks. UK cellular phone operators Cellnet and Vodafone can already offer 9600bit/s data transmission on their digital GSM networks. But arguably they have no real incentive to heavily promote that capability while they are so preoccupied with building up their numbers of mobile phone subscribers.

The view of most mobile phone manufacturers is that voice traffic will dominate European networks for a long time yet, and in the view of one European mobile phone manufacturer, mobile data "is still seen as a Christmas tree decoration by many service providers."

One mobile phone supplier has been selling a PCMCIA data modem for its handsets since 1993. But the operators are unimpressed by its £400 price tag -- to which the supplier responds "The operators are still only talking about voice."

While equipment makers blame the operators, who in turn point the finger at the developers of what they call "the necessary applications software" -- whoever they might be. The growing number of laptop computer users must wait a little longer for a service which will allow them to communicate without wires.

One man who is far too astute not to recognise the absurdity of a world without mobile computing is Dr Andy Grove, who sits on top of Intel, the $13bn microprocessor giant. But without a suitable mobile communications network in the US, poor old Dr Grove had to come to Europe and its GSM digital communications network in the US, poor old Dr Grove had to come to Europe and its GSM digital cellular network to demonstrate the type of mobile data services he would like to see making money for Intel in the market.

"I am overjoyed about the existence of the GSM data technology," said Dr Grove. "It is a very significant development and very important for us." Point made.

The point is that the ability to transmit data at standard modem rates of 9.6, 14.4 and even 28.8kbit/s is available today. This isn't rocket science after all.

No longer is the transmission of digital data over radio a question of physics, but making it commercially attractive for programmers to sit down and compile the pages of computer code which will shape the services users want. From questions of interoperability between the various protocols to the design of graphical user interfaces, the mobile computing market is hamstrung by issues which were solved in the desktop market ten years ago.

It will take the commercial might of the PC industry to smash the logjam which has so paralysed the mobile phone community. Only now are there signs that the likes of Intel and Microsoft are looking for action in the mobile computing market.

Richard Wilson
Will pass transistor logic make CMOS obsolete?

Engineers at Hitachi have demonstrated marked savings in power, area and delay characteristics of circuits using its pass transistor logic (PTL). The firm sees PTL as an alternative to CMOS for designing low power, ULSI ICs.

According to Yasuhiko Sasaki, at Hitachi’s Central Research Lab in Tokyo, a PTL adder implementation is twice as fast as an equivalent CMOS implementation, and yields a 40% area saving. “However, to date PTL has been limited to circuits of several hundred transistors only. For larger circuits it does not work well as it is difficult to synthesise,” said Sasaki, speaking at this year’s IEEE symposium on Low Power Electronics in California.

To exploit PTL for larger designs, Hitachi has extended its previous work and developed its ‘multi-level pass transistor logic’ (MPL). Its earlier PTL is based on single-level logic. Here source-drain inputs are connected to each other while gate inputs are driven by the circuit’s primary inputs only. “This results in a lot of unshared logic making it difficult to exploit redundancy,” said Sasaki.

In Hitachi’s MPL approach, gate inputs are either driven by the primary inputs or from the outputs of other pass transistor circuits. This introduces a hierarchy in logic designs enabling circuitry to be shared. Delay is also reduced due to the more parallel circuit operation that results.

In experiments, Hitachi has used MPL to synthesise 27 random logic circuits selected from a microprocessor. “The effect of multi-level optimisation is clearly confirmed for circuits with a longer delay,” said Sasaki.

On average total power was reduced by 23%, the area by 15%, and delay by 12%.

The first commercial use of Hitachi’s successor to CMOS technology – PASS Transistor Logic (PTL) – is due out next year according to Dr Taisugio Makimoto, executive managing director of Hitachi’s chip business.

The first use of PTL in a commercial chip will be for the next generation of Hitachi’s SH series of microprocessors – the SH4. SH4 will show a dramatic five-fold performance increase over the SH3 – an increase in power from the 60 MIPS SH3 to a 300 MIPS SH4. The SH4’s designer, Toshimasa Kihara, said: “PTL is a kind of magic. It reduces transistor count, giving us a 20-30% improvement in die size, power consumption and speed.

PTL is different from CMOS in that, with CMOS, transistors are charged and discharged by nmos, but in PTL they are both charged and discharged by nmos. This reduces both the size and the number of transistors required, considerably saving silicon space.

Data-rate boost for mobile computing is imminent

Developers of digital mobile phone systems on both sides of the Atlantic are proposing new standards which will increase the data rates available for mobile computing on cellular telephone networks.

Nokia Mobile Phones has proposed to the European standards group, ETSI, a new data interface specification for the GSM mobile phone system which will support a 28.8kbit/s data rate. This is the equivalent of the V.34 wireline modem rate and three times the speed of the current 9600bit/s GSM data rate.

Chip set for CDPD

LSI Technology has introduced its first chipset and software drivers for the cdpd data over cellular communications technology currently gaining favour in the US. CDPD (cellular digital packet data) provides 14.4kbit/s data transmission over cellular telephone networks. In the US it is being deployed as an overlay to existing AMPS analogue cellular networks. The development of digital GSM data services has effectively stifled any European market for CDPD.
Field Electric Ltd.

Tel: 01438-353781 Fax: 01438 359397
Unit 2, Marymead Workshops,
Willows Link, Stevenage, Herts, SG2 8AB.

102 Key IBM compatible keyboard terminated to 6 pin m on type Ps2 plug £8.00 c/p £5.75
158Key IBM compatible keyboard with 101 key PS2 plug £12.00 c/p £8.50
Yamaha NS-10s 16 sf high quality loud sound plugs £17.50 c/p £13.50
NEC CMN 1232B 12 colour VGA/SVG 900 x 600 £185.00 Gp £140.00
Sonic 9”outlet Toshott KV1000 data for RGB £200.00 c/p £175.00
12” Mono VGA (paper white) chassis enclosed £30.00 c/p £15.00
AT& T 16” graphics colour monitor terminal 25 pin D connector with keyboard £90.00 c/p £65.00
Cordix DDCG converter new 49v in 5v output £6.00 £2.95
24v to 10v.Wow Trogain transformer auto new £7.00 £3.50
12Vdc Fan 9.1x25mm £3.00 £1.50
Sony videocassette player VPS960 NTSC/PAL SECAM £30.00
Star serial (RS232) interface 8 56 new boxed £10.00 £5.00
Cablecom 2000 display (light case damage) £30.00 £15.00
CDD Barcode reader (ideal for EPoS etc needs high and low density barcode £70.00 £35.00
RS HV Probe F10-381 new boxed £20.00 £15.00
Main conditioners and UPS please ring
HP netlabels printer IEEE 8.5in interface cable £50.00 £30.00
HP 2551a Transmission test set £95.00
Tektronix 7524A 6.35mm COMPARATOR £220.00
Tektronix T714B dual trace amp plug in £75.00 £45.00
Tektronix 7600 dual time base plug in £75.00 £45.00
Tektronix T741A amp plug in £175.00 £95.00
Tektronix T720 T 500MHz scope £450.00 £250.00
Tektronix T712A O 10MHz scope £140.00 £75.00
Tektronix 5404 MFP 5a45/5a13 new boxed £240.00 £150.00
Swordcraft programmer (new qty discounts £1.00 £0.50)
Omni-plot chart recorder £40.00 £20.00
Mainsman Tally 910 laser printer (needs some attention) £150.00 £75.00
Avtec 5A 30-1356 +13B +15F 1A +15A new boxed £3.50 £1.50
AT&T Staten 10 network hub model E £150.00 £85.00
Racal Dana 90316 RF millivoltmeter true RMS £160.00 £85.00
Step up power SE 100 £150.00 £85.00
Ericsson copier/printer EPROW/EPRON editing and interface new boxed £195.00 £100.00
Olivetti 388B4 compatible printer, 11 44M 60MB D52 net serial parallel mono/colour, VGA ports etc £120.00 £65.00
Wandel&Goltermann DC2 measuring set for group delay attenuation receiver £130.00

ALL ITEMS SUBJECT TO AVAILABILITY. TECHNICAL INFORMATION BY TELEPHONE ONLY. ALL PRICES INCLUDE CARRIAGE. NO VAT.

Call or fax today for a demo pack. Please state whether you would like a DOS or Windows pack.
**UPDATE**

**TVS breakthrough handles low voltages**

A new transient-voltage suppressor known as an enhanced punch-through diode is said to offer sharp knee voltages to well below 1V. Developed jointly by Semtech and the University of California, the enhanced punch-through diode is fabricated using IC technology. It comprises a p+n+ zener in series with a pin diode to cut capacitance and leakage current.

The enhanced punch-through diode can be considered as a bipolar transistor with light base doping. This makes punch-through occur at a lower voltage than the conventional avalanche breakdown voltage between collector and emitter. The four layer n+p+n+ structure is responsible for the low clamping voltage, low capacitance and low leakage. The p+ and p layers are lightly doped to prevent the reverse-biased n+p+ junction from avalanching.

The first products to appear will have clamping levels of 4.3, 4.9 and 6.5V at 1A.

---

**British GaAs lags**

The UK is not putting enough effort into GaAs technology despite recent work of companies like Alpine and University's Microelectronic Centre that promises low power, high speed GaAs-based static ram cells.

Dr Ebrahim Bushehri, deputy head of the centre and leader of the vlsi design group said: "Europe is putting more emphasis and spending a lot more money than the UK on high speed GaAs digital circuits and design methodologies."

Dr Bushehri stresses that GaAs is no longer an esoteric technology confined to research labs but a commercial reality. He cites Vitesse's 0.6μm mesfet GaAs technology capable of a million transistor devices as one example.

The centre's SRAM research work also involves collaborative work with the German Fraunhofer Institute for applied solid state physics, and uses high electron mobility transistors, hemts.

The research's motivation follows an idea of the group's for reducing power: "With existing SRAMs, the cell's cross-coupled inverters are used for storing data and driving the bit lines. For fast operation, the inverters need to be large to source and sink the bit-line's currents," said Dr Bushehri.

The centre's adopted design decouples the bit-line's driving inverters from the data storage. This enables the inverter size to be reduced, and the resulting standby current, saving on overall power dissipation.

Based on the centre's simulation work the hemt static ram cell has a standby current of 14pA and an active current of 0.29mA. This contrasts with the traditional six transistor direct coupled fet logic (defl) cell currently used for GaAs that requires 570p A and 1.14mA currents.

Dr Bushehri said that at present the hemt approach is limited to 6000 gates due to yield problems. He believes however that this will soon be solved. The most natural application area for the work is for very high speed cache memory: "We are developing a design methodology that will enable very high performance circuits."

**Roy Rubenstein, EW**

---

**Pentium power down**

A 120MHz Pentium microprocessor aimed at portable computers with integrated power saving features to extend battery life has been released by Intel. The company is also set to unveil a new technology that brings together Internet and video communications.

At least ten major manufacturers of portable computers plan to make new models based on the new Pentium chip. The device features Intel's voltage reduction technology which reduces the inner core of the microprocessor to 2.9V while being used in a 3.3V environment. This can boost power savings by almost one third.

The new microprocessor costs $680 in 1000 unit quantities. Intel will also unveil a technology it calls Interact which combines a cable tv or antenna based video link with an Internet connection. Users of pcs will need a regular Internet connection and a new PCI digital-analogue conversion card that will translate an incoming analogue signal into digital video. Intel will sell the card for about $150.
MICROMASTER LV PROGRAMMER

The Only True 3V and 5V Universal Programmers

Ice Technology's universal programming solutions are designed with the future in mind. In addition to their comprehensive, ever widening device support, they are the only programmers ready to correctly programme and verify 3 volt devices NOW. Operating from battery or mains power, they are flexible enough for any programming needs.

The Speedmaster LV and Micromaster LV have been rigorously tested and approved by some of the most well known names in semiconductor manufacturing today, something that very few programmers can claim, especially at this price level!

Not only that, we give free software upgrades so you can dial up our bulletin board any time for the very latest in device support.

Speedmaster LV and Micromaster LV - they're everything you'll need for programming, chip testing and ROM emulation, now and in the future.

Speedmaster LV £495
Programmes 3 and 5V devices including memory, programmable logic and 8748/51 series micros. Complete with parallel port cable, software, re-charger and documentation.

Micromaster LV £625
As above plus support for over 130 different Microcontrollers, without adaptors, including PICs, 89C51, 68HC705/711, ST6, Z8 etc.

8 bit Emulator card £125

16 bit Emulator card £195
As above but containing 16 bit ROM/ RAM emulator. Configuration: 128K by 16, 256K by 8, 2 by 128K, 8 expandable to 512K by 16/1024K by 8.

FEATURES

- Widest ever device support including EPROMs, EEPROMs, Flash, Serial PROMs, BPROMs, PALs, MACH, MAX, MAPL, PEELs, EPLDs, Microcontrollers etc.
- Correct programming and verification of 3 volt devices.
- Approved by major manufacturers.
- High speed: programmes and verifies National 27C512 in under 11 seconds.
- Full range of adaptors available for up to 84 pins.
- Connects directly to parallel port - no PC cards needed.
- Built in chiptester for 7400, 4000, DRAM, SRAM.
- Lightweight and mains or battery operation.
- FREE software device support upgrades via bulletin board.
- Next day delivery.

For a copy of our catalogue giving full details of programmers, emulators, erasers, adaptors and logic analysers call, fax or dial the BBS numbers below.
Green light for hdtv?

If the making of high-definition tv programmes is ever to become the norm rather than the exception there is a desperate need for a compact high-performance camera that is much lower in cost than anything currently available. Now, researchers at the NHK Science and Technical Research Laboratories in Tokyo think they may have the answer - a completely new image acquisition system that uses four ccds instead of the standard red green blue approach. This dramatically reduces the number of pixels required.

It is cheaper, smaller and lighter than normal hdtv cameras and a prototype was used successfully for news gathering following the Hanshin earthquake.

CCD imaging is increasingly popular for hdtv. But systems need approximately 2 million pixels to satisfy broadcast standards. Unfortunately, using a large number of pixels means the area of each pixel has to be small, narrowing the dynamic range, causing a drop in the aperture ratio, degrading highlight characteristics and lowered yield.

The NHK design uses a 16mm ccd camera - smaller than the usual 25mm format - with only 1.3 million pixels. To compensate for the reduction, the researchers use a fourth ccd to boost the sensitivity of the system in the area where the eye is most sensitive.

Instead of the normal rgb (Yoshihiro Fujita et al, IEEE Transactions on Broadcasting, Vol 41, No 2, pp76-82), two of the four ccds are assigned to green light, with other two being used for red and blue as normal. Putting more emphasis on the resolution of the green signal improves efficiency and makes the system compatible with the human eye which has a much greater sensitivity to luminance signals than chroma signals: 70% of hdtv luminance signals come from the green component.

Colour separation in the four-ccd prism is essentially the same as with an rgb prism, with the addition of a half mirror to separate the green light into two portions. The resulting system meets resolution requirements as two 1.3 million pixel ccds - 2.6 million sampling points - are allocated to the green channel containing most of the luminance information, with 1.3 million pixels for each of the red and blue channels and the chroma information.

The prototype camera is reported to have fully satisfied hdtv requirements, demonstrating a resolution of 1200 tv lines, sensitivity F5 at 2000 lux and a dynamic range of 500%. Signal-to-noise ratio is 52dB. Size of the camera is 96mm by 250mm by 293mm, including the 16mm viewfinder, and it weighs in at 5.7kg.


Cogs turn for commercial micromotors

Cheap and practical micromotors may soon be with us. This follows the news that researchers at Sandia National Laboratories in the US have used conventional microelectronic fabrication techniques to build a micro device that can drive external gearing.

Developing 0.5pW of power delivered through a gear 50μm in diameter, the motor could operate tiny micromedical pumps in drug delivery systems inside the body. It could also act as low-cost, high-performance gyroscope, having a dramatic impact on the design of future automobiles and military systems - both motor and gearing have much less mass than their macro-world counterparts and so can survive impact better.

So far, several hundred million rotations have been demonstrated by the smaller gears. But the breakthrough is in using etching processes and silicon materials already in use in the microelectronics industry to open up the possibility of mass production.

"We believe we are the first to demonstrate a really good silicon micromotor that can connect up with a variety of devices," says Jeff Sniegowski, the scientist who - with engineer Ernest Garcia and group leader Paul McWhorter - has led the effort to build the millimetre-square...
engine and its even tinier gearing. Sandia’s construction method actually extends a technique first developed at the University of California at Berkeley. The basic batch process—which, when perfected, should leave behind thousands of fully assembled, operational microengines—begins on a silicon substrate.

Researchers deposit a layer of electrically insulating material and then a film of polycrystalline silicon, patterned to form electrically conducting lead-ins.

On top of this, a film of sacrificial silicon dioxide serves as a support layer as the remainder of the structure is built. When it is removed, by several etching processes, openings through the oxide allow the next applied layer of polysilicon to anchor to the insulating layer on the substrate. This is how the vertical axes for gears and elastic supports for the engine are formed. Other layerings and subsequent removals of the oxide free the gears and linkages.

During the process, silicon nitride is added, functioning as a grease to let the gears turn more freely. As a final step, hydrofluoric acid is added to remove all the sacrificial supporting layers of silicon dioxide.

The final motor consists of two tiny silicon combs with a shuttle placed between them. The edges of the shuttle also form combs with teeth that interdigitate with those of the stationary combs.

Applying an on-off voltage to energise the stationary combs alternately, pulls the shuttle by electrostatic attraction so that an attached shaft will turn a drive gear in a quarter of a circle during the shaft’s power stroke.

Another comb-drive engine, at right angles to the first, is timed to turn the gear on the second quarter of its rotation. The two drives, alternating their force, turn reciprocating motion into rotary motion to drive the gear completely around.

Electronic circuits not part of the micromotor chip drive the motor. Sandia researchers are currently working to place control circuitry next to the microengine, and to develop a single chip with circuits and machines fabricated side by side.

Paul McWhorter, Sandia National Laboratories, Albuquerque, New Mexico, 87185-0167, USA. Paul_J_McWhorter@smplink.mdlsandia.gov@sass165.sandia.gov

Sandia has used microelectronic techniques to build a microengine that could be mass-produced. The output drive gear is 50μm in diameter.

Chemical weapon—or just a bad egg?

An easy-to-use transducer and receiver system that establishes the acoustic response characteristics of a container and its contents is being used as a non-invasive alternative to normal analysis of chemical weapons.

The (ars) system, developed at the Los Alamos National Laboratory in the US, could also prove useful for much more peaceful applications such as detecting salmonella in eggs or measuring intraocular pressure.

Acoustic resonance spectroscopy is a non-invasive system that uses a sensor head with two transducers attached magnetically to the container being tested. One transducer induces minute vibrations in the container while the other detects the resonance frequencies at which the container naturally vibrates. The pattern of the vibration frequencies is affected by the physical properties of the contents and can be used as an acoustic signature.

Traditional methods of verifying the contents of chemical munitions require a hole to be drilled into the container and a sample of the fill extracted for laboratory analysis. It is time-consuming and has the potential to contaminate the environment and expose workers to nerve gas or other chemical agents.

But, by measuring the acoustic vibrations of an object, the Los Alamos instrument quickly and safely identifies the fill content of chemical weapons or other containers holding toxic substances. To identify the chemical fill, vibration patterns can be matched with signatures in a library, and the entire procedure takes less than a minute and the operator is never exposed to the chemical contents of the container.

Measuring the vibrational modes of objects is a well-established technology. But using acoustic signatures to identify fill materials and the software algorithms that implement this identification put the instrument ahead of traditional technologies.

Originally developed with the Defense Nuclear Agency as a non-invasive inspection tool to verify compliance with treaties on chemical weapons destruction, the detector could prove suitable for any non-invasive identification of fill materials in sealed containers.

Los Alamos says the technique could be extended to quality control applications too, in which defective parts have a different acoustic signature than their good counterparts. Paul Lewis, Los Alamos National Laboratory, California, USA. lewis@lanl.gov

Video holograms showing some of the vibrational resonance modes of a 105mm munition. Each ‘contour’ corresponds to 0.5μm.

December 1995 ELECTRONICS WORLD + WIRELESS WORLD
Picturing the sun's magnetic field

Physicists at Nasa have just released the first instantaneous view of the spiral structure of the solar system's magnetic field. The picture shows how the lines of magnetic force originate in the Sun and extend outward into the solar system.

Nasa's snapshot, assembled from observations of radio waves by a US-French radio receiver on the Ulysses spacecraft, shows the spiral magnetic field extending from the Sun past the orbit of the planet Venus toward the orbit of Earth.

From its vantage point over the south pole of the Sun in 1994, Ulysses was able to track the path of the bright spot of radio waves excited by moving electrons ejected from the Sun at speeds over 62,100 mile/h.

Radio emissions — caused by the fast electrons moving through with the slower solar wind — allow the magnetic lines of force to be traced out in a way similar to deducing the course of a road at night from an airplane by tracking the headlights of individual cars.

A chart of the received radio emissions shows that they follow the expected spiral shape, even including the kinks due to variations in solar wind speed.

Previous radio observations made by space probes orbiting in or near the plane of the Earth's orbit did not provide a good vantage point for observing the spiral shape of the magnetic field. Observations in space are required because the radio frequencies of the solar wind do not get through the Earth's ionosphere.

Goddard Space Flight Center, Greenbelt, MD, USA.

Organics breakthrough into low power devices

Work on thin film organic transistors has produced several p-channel versions based on one combination of materials, and n-channel versions based on others. But researchers at AT&T Bell Laboratories have now announced development of an organic transistor structure with two active materials that permits both p-channel and n-channel operation in a single device.

For the first time, fabrication of complementary circuits — with all their well-known advantages in terms of power dissipation and device lifetime — could now be possible with organic technology.

First active layer of the device, adjacent to the gate dielectric (A Dodabalapur et al., 'Organic Heterostructure Field-Effect Transistors', Science, Vol 269, pp.1560-1562) is alpha-6T, a thiophene oligomer which has been used in p-channel devices. This layer is about 10-20nm thick. Second layer, for n-channel operation, is C60 and is about 20-40nm thick. A third electrically inactive layer is deposited on top of the C60 to protect it.

Energy levels of the highest-occupied and lowest-occupied molecular orbitals of the two materials is such that when the gate is biased negatively with respect to the source, the p-channel material is filled with holes; and when the gate is biased negatively, the n-channel material is filled with electrons.

Other experiments have since been successfully carried out with alternatives to alpha-6T and C60, the only requirement being that the materials have similar highest-occupied and lowest-occupied molecular orbitals.
NEW!

ARIES III PCB Design now offers:
- Polygonal (shape based) Ground Planes, 32 Bit hi-precision database.
- Any Angle Rotate, Extra Layers for mechanical, data, DXF Import, Pads/Tracks and Enhanced track editing.

PROTEUS
The Complete Electronics Design System

Schematic Capture
- Easy to Use Graphical Interface.
- Netlist, Parts List & ERC reports.
- Hierarchical Design.
- Extensive component/model libraries.
- Advanced Property Management.
- Seamless integration with simulation and PCB design.

Simulation
- Non-Linear & Linear Analogue Simulation.
- Event driven Digital Simulation with modelling language.
- Partitioned simulation of large designs with multiple analogue & digital sections.
- Graphs displayed directly on the schematic.

PCB Design
- Unlimited Design Capacity.
- Multi-Layer and SMT support.
- Full DRC and Connectivity Checking.
- Advanced Multi-Strategy Autorouting.
- Output to printers, plotters, Postscript, Gerber, DXF and DTP bitmaps.
- Gerber View and Import capability.

Write, phone or fax for your free demo disk, or ask about our full evaluation kit.
Tel: 01756 753440. Fax: 01756 752857.
53-55 Main St, Grassington. BD23 5AA.

Proteus software is for PC 386 compatibles and runs under MS-DOS. Prices start from £475 ex VAT; full system costs £1495. Call for information about our budget, educational & Windows products. All manufacturers’ trademarks acknowledged.
Audio preamp – simple but sound

Reg Williamson’s preamplifier is possibly the first to use a generalised impedance converter. This reactive block helps keep the design simple and transparent to the audio signal passing through.

Designed to be as simple as possible, this circuit is transparent and provides two basic functions – equalisation and gain control.

A universal interface for almost any programme source and following power amplifier is also provided. Inclusion of an equaliser was an attempt to disprove that even a properly designed equaliser would always subjectively degrade signal quality in some way.

Distortion plus noise is less than 0.05% at 1kHz and 3.5V rms with the gain controls at maximum – and these results are from a source with an inherent 0.03% thd+noise figure. Maximum output swing is 10V rms.

Equalisation and gain control
Despite its apparent simplicity, the design is wholly innovative in concept. It offers flexibility of overall gain, modest equalisation of high and low ends of the audio spectrum around a central point of 1kHz, and gain control.

The whole system is transparent, with no phase inversion – the 'bête noire' of the purists. When set to the electrical centres of their respective controls, the reactive elements of the equalisers are virtually out of circuit. With these settings, the circuit behaves as a unity gain amplifier with 100% negative feedback.

Even so, reactive elements can be switched out altogether with a single double pole on/off.

Mute circuitry combining $D_{1,2}$, $C_{5,6}$, $R_{10}$, $J_3$ and relays A and B is provided as the output IC switch-on can be considerable even with more sophisticated supplies. Maximum delay of the mute is 4s, but can be less if there is a quick off-on sequence. The micro-miniature relays I used have fragile terminals, and care was necessary in fitting. The mute supply is a fast 24V supply across + and – to equalise supply loads and give a reliable mute on switch-off. Mains supply should be rf filtered and transient suppressed.
Does component price make a difference?

Listening tests were carried out involving 31 people with a high quality programme source of varied music material. Some of these were music enthusiasts from the Recorded Music Society, but a few were 'professional listeners'.

The idea was to make two identical preamplifiers. One was built using off-the-peg components and the other had highly expensive alternative components such as super-capacitors and resistors, and even gold plated sockets.

A comparative switching system was also provided to allow the listener to switch randomly between the original programme source and either of the two preamplifier outputs. High quality electrostatic headphones provided the audio output.

In all cases, individual gains were matched at 1kHz within 0.2dB and any equalisation controls set to a measured linear position. The listener did not know which output was which.

The tests demonstrated what we expected - that hardly anyone could tell any difference between all three sources. Of the 341 steps in the test, there were 248 opportunities to detect the inclusion of the preamplifier in the audio chain. Only 24 of these were noticed, and even then, the differences were described as 'slight' or 'doubtful'.

Besides confirming the amplifier's transparency, these tests also indicate that exotic components - whether passive and active - are a waste of money.

switch. In either the midband nominally linear setting or the switched-out position, overall gain of the pre-amplifier is as originally selected by the constructor and is totally flat. Reactive elements for the low end include for the first time, a generalised impedance converter, which simulates an inductor in series with a resistor.

The whole is flexible in design, allowing for variation. However in this instance, circuit parameters selected result in the controls having a shelving action, limiting equalisation to 6dB. Because the same reactive elements are used for both attenuate and accentuate functions, there is absolute symmetry of the two respective curves.

Negative feedback gain control

Gain control adopted is also unusual, being a negative feedback type. For high gain settings, and low signal level inputs, feedback is reduced – for low gain and high level signal inputs, it is increased. While using a linear control, the action is sensibly logarithmic and unlike some other versions, has a genuine zero gain position fully anticlockwise. It contributes a maximum gain of 20dB and has a very low output impedance of 600Ω.

It could be argued that a balance control is redundant these days, but one can be fitted. However, it is easier to fit a concentric gain control which is, fortunately, still available.

To complete the flexible interface requirements, the input is a unity gain buffer stage without phase inversion and 100% negative feedback. Input signals of differing mean levels can be accommodated by a passive L pad at the input. Distortion and noise are negligible and maximum peak-to-peak voltage swing is far in excess of normal requirements.

Further reading


A tribute to Peter Baxandall

This article is offered in tribute to the late Peter Baxandall, my friend and technical mentor for almost 40 years. His observations and evaluation of my design ideas I appreciated highly.

This design was the last valuable service he did for me. With modest deference, I thought my equaliser an ideal replacement for his own 43 year old brain-child that rightly bears his name worldwide. It was with characteristic generosity that he gave my alternative his warm and unstinting approval - accompanied by three A4 pages of detailed analysis.

Peter never failed to find some useful facet of the design procedure that I had overlooked. For virtually half a century, his unique abilities contributed to the art and science of audio engineering.

He will be greatly missed.
Cooke International Services wishes you a Merry Xmas

Santa's storehouse for all your Test Equipment needs
Also operating and service manuals plus accessories

SEND LARGE S.A.E. FOR LIST OF EQUIPMENT AND MANUALS

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tek. 7S11, Sampling Unit</td>
<td>£128</td>
</tr>
<tr>
<td>Tek. 7B71, Delaying Time Base</td>
<td>£130</td>
</tr>
<tr>
<td>Tek. 7B53A, Dual Time Base</td>
<td>£187</td>
</tr>
<tr>
<td>Tek. 7A26, DC-200MHz. Dual Trace Amp Plug In</td>
<td>£350</td>
</tr>
<tr>
<td>Interval and Delayed Sweep Plus</td>
<td>£425</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Tek. 7L5, Spectrum Analyzer</td>
<td>£3600</td>
</tr>
<tr>
<td>H.P. 5328A, Universal Counter</td>
<td>£475</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest Microwave, 294-9, Minipad Attenuator</td>
<td>£65</td>
</tr>
<tr>
<td>Hatfield, 2145, Attenuator</td>
<td>£75</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>AVO, 8. MK II, Universal Ammeter (needs batteries)</td>
<td>£85</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Farnell, B5012, 0-40 Volts, 0-25 Amp, Metered, Variable P.S.U.</td>
<td>£1250</td>
</tr>
<tr>
<td>Thurlby, PL220, Digital Display P.S.U.</td>
<td>£1375</td>
</tr>
<tr>
<td>H.P. 5069A, Spectrum Analyzer, 0.01-22GHz, direct</td>
<td>£1490</td>
</tr>
</tbody>
</table>

Our Elves await your calls on (+44) 01243 545111 or 545112
or Fax: (+44) 01243 542457

ALL PRICES EXCLUDE VAT AND CARRIAGE
DISCOUNT FOR BULK ORDERS. SHIPPING ARRANGED
OPEN MONDAY TO FRIDAY, 9.00 am to 5.00 pm

Cooke International
ELECTRONIC TEST & MEASURING INSTRUMENTS
Unit Four, Forthingbridge Site, Main Road, Barnham
Bognor Regis, West Sussex, PO22 0EB
U.K.
Engine management developments

Eric Russel looks at how electronic engine management systems developed for the race track are affecting performance in the latest cars intended for the nation's highways.

Computerised engine management systems for cars are becoming more and more popular, and as the number on the road rises so do the horror stories. There is no doubt that such systems are effective, but when problems arise, the support leaves a lot to be desired. Stories are already emerging of out-of-warranty charges of £600 for a replacement control unit which, in one case, left the car with its original problem.

Components are comparatively inexpensive and there could be an opportunity for electronics entrepreneurs to look at repairs while garages remain mechanically orientated and equipment manufacturers do not want to repair units.

Increased engine efficiency

Although the principal driving force behind the increased popularity of EMS is pollution legislation, there are other reasons for its use. While noxious emissions can be cut by 10% and fuel consumption improved, driveability is also improved by minimising engine speed oscillations during acceleration, for example. Idle quality is also enhanced because tick-over is more tightly controlled. The Lucas Epic engine management system, for example, has a special software routine called adaptive cylinder balancing which compensates for mechanical tolerance variations and wear to ensure smooth running.

Three dimensional profiling

Computerisation has added an extra dimension to engine control. Whereas mechanical linkages can be regarded as two dimensional, with a direct relationship between throttle position and fuel demand, electronic systems have a three dimensional mapping ability which gives a greater range of options. Instead of following points on a flat graph, engine control follows a contoured 3D profile, illustrations of which shown are on page 1019.

Because the 3D map is more detailed it has to be created individually to suit driver, engine and the driving environment. This takes several hours while engine settings are noted, on a rolling road, for example, for a set number of engine speeds. These points are stored in
As this racing car cutout from Zyte shows, above, there are many electronic links between engine and the rest of the car. This is also the trend in road cars, which will soon have more electronics than mechanical systems. Ride, road holding and performance are now all coming under electronic control and it is the current breed of low cost processors which makes this possible. Microprocessor speeds far exceed mechanical response times so it is easy to control suspension, braking and engine in less time than it takes a wheel partially to rotate or for an engine to complete one revolution.

memory and accessed during a journey, with modifications to the engine controls from sensors around the engine.

With the Bosch Motronic EMS, engine load determines how the electronic control unit, ECU, reacts and is computed from air mass flow and throttle position. Air flow sensors are fitted in the air inlet and consist of a flap attached to a potentiometer. As air flow increases the flap rotates and the changing resistance in the potentiometer is measured by the ECU. An air temperature sensor is also connected to the ECU which can then calculate the volume of air entering the engine.

Hot wire or hot film meters can be used to provide an index for mass air flow. A heated element in the air stream is cooled by the air and the heating current needed to return the element temperature to a pre-set value, as measured by an integral sensor, provides the data. The system automatically compensates for variations in air density, a factor that determines the amount of warmth the air absorbs from the heated element.

A ‘knock’ sensor can also be fitted to an engine to cut pre-ignition problems. Knocking occurs when fresh mixture in the cylinder

Aided by comprehensive and interactive electronic systems, this 4.2l V8 engine – the TVR AJP 8 – can develop 350bhp at 6500 rev/min.
ignites spontaneously before the controlled flame front arrives from the spark plug. This creates a flame velocity some seventy times faster than normal and the resulting high pressure shock wave is picked up by a knock sensor which again feeds back to the ECU. Pre-ignition causes thermal stresses which can result in mechanical damage.

In the exhaust system a lambda oxygen sensor monitors excess air in the exhaust and feeds back to the ECU which then controls the air to fuel ratio. To complete the monitoring, battery voltage has to be sensed as it affects the operating times of devices such as electromagnetic fuel injectors.

**Integrating injection**

After a century or so of mechanically operated carburettors, electronically controlled fuel injection seems set to take over as part of a complete concept – computerised engine management. The accent is on software. The engine department is comprehensively monitored and the computerised control of air, fuel flow and ignition timing means optimum combustion.

Optimisation provides the best combination of power, fuel consumption and exhaust emission for any given driving situation. It also means the smoothest idling and maximum engine efficiency during cold running. Systems respond to varying driving and atmospheric conditions as a journey progresses in contrast to mechanical adjustments which are fixed beforehand.

Engine management is the latest development in a trend which began with transistorised ignition in the early 1970s and has been helped by the lower costs of fuel injection due to volume sales. Motor sport’s con-

---

Weber’s engine-management system takes into account a wide variety of engine parameters from fuel flow to water temperature. The result is faster engine response, more efficient combustion and fewer noxious emissions.

Zytek’s EMS3 has a 32bit Motorola processor allowing dynamic modifications to engine maps. Watertight housing is critical to successful microprocessor operation. Damp, dirt, dust, condensation and extremes of temperature are all enemies of electronics but are the standard environment for car computers. Vibration can also affect in time, pcb mountings, connectors and soldered joints. But car manufacturers demand lightweight control units – an additional problem for designers.
tinual quest to shave fractions of a second off lap times has helped drive development and that harsh environment has ensured robust products. The result has been a radical rethink of engine control, which is now spinning-off into volume cars.

Yet higher integration
One of the leading companies in the field, Weber Concessionnaires, has taken EMS a step further with a system that has even greater flexibility and versatility - Alpha Plus. It is a development of the Alpha Engine Management System that is specified, amongst others, by Opel Racing on all their Class 2 touring cars, including the Vauxhall Dealer Sport team, Aston Martin and Caterham for their JE special. John Clelland has just won the British Touring Car championship for Vauxhall using an Alpha system. He clinched the title with two races in hand which indicates how far ahead the Vauxhall was.

A complete Alpha Plus kit can include - fuel injectors, engine speed sensor and trigger disc, high-resolution throttle position sensor, inlet air temperature sensor, barometric pressure sensor, water temperature sensor, lambda sensor, electronic control unit with integrated ignition amplifier and option of static or capacitive ignition system, cold start extra air valve, fuel pressure regulator, high pressure fuel pump, throttle bodies, wiring harness, inertia safety switch, ignition coil, fuel filter and connector unions, fuel hoses, manifolds, inlet air trunking, air filter mounting flanges and adjustable throttle linkage.

It can monitor external air temperature, turbo-boosted or barometric air pressure, water temperature, throttle angle, engine speed, camshaft timing, gear selection, idle setting and battery voltage. The on-board computer in the ECU processes all these inputs and can control injector opening, spark position, camshaft timing and variable inlet track length. The result is faster engine response, more efficient combustion and less noxious emissions.

To convey engine speed, the trigger disc is bolted to either flywheel or pulley. It is a flat ring with teeth on the outside, one per cylinder and one to indicate top dead centre, and has to be fitted with a concentricity of ±0.1mm. This accuracy, combined with the ring’s low mass in comparison to crankshaft mass, means that no re-balancing is required. The speed sensor is a proximity type and generates a pulse every time a tooth passes. A similar sensor is required on the camshaft to identify cylinder status.

A potentiometer fixed to the end of the throttle spindle conveys driver action on the accelerator immediately to the ECU which controls engine devices through robust power transistors. These buffer the pcb components from such problems as transient spikes on the vehicle electrics.

Memory for more torque
The microprocessor board also holds a memory chip which contains the calibration settings. These are the optimum settings for a range of driving conditions - up to 256 different combinations of engine speed and throttle position in the case of Alpha Plus. The result is a wider power curve, which provides more torque at low and high revs, and an increase in mid-range performance.

Alpha senses engine load from the throttle position sensor rather than monitoring air flow. This means an immediate response to changed throttle settings because there is no delay while air pressure changes. It is also felt that sensors in the air flow create turbulence and affect volumetric efficiency of the engine, reducing the benefits of EMS.

There is no one combination of settings to suit all drivers so an ECU has to be trained for the vehicle it works with. First, in a calibration session that takes several hours, an engineer feeds into a portable computer up to 256 settings of ignition, air and fuel against a range of throttle positions and engine speeds.

For calibration, either the engine is mounted on a test bed or the car is run on a rolling road where wheel speed, torque, bhp and exhaust emissions are monitored. The application

engineer runs the engine at a series of set speeds and tunes ignition timing and fuel injection using Weber Concessionaires' own software to store settings in a portable computer. These settings are logged against throttle positions and engine speeds.

Once the overall engine performance meets the customer's requirements, the settings are transferred to a memory chip, generally erasable-prom. This is then plugged into the EMS control unit on the car. The electronic control unit now knows the precise settings for the customer's requirements, the settings are logged against throttle positions and engine speeds.

Computerised engine management has to monitor and control in real time. This means that the microprocessor has to act immediately on any input. Generally, computers store instructions while the central processor is busy, which then implements them after a short delay. While this may not be noticed in an office application, for example, it could be critical in open-loop engine management, where the computer uses information from combustion in one cylinder to adjust control settings.

Further features the new system include monitoring and self learning of exhaust gas mixture. This helps catalytic converters perform more efficiently and maximises life expectancy.

Alternative management systems
Zytek also supplies sports car engine management systems and its EMS3 system is now 32bit, using the Motorola 68332 processor. Different set-ups can be stored on disk to suit individual drivers or racetracks. There are facilities to switch from one to two injectors per cylinder at a pre-determined engine condition and to transmit engine data over a telemetry link. Carbon fibre also has a place, in a lightweight housing for the ECU. The company also supplies Aston Martin and Rolls Royce.

MBE Systems designs, develops and manufactures engine management systems. Its 941 ECU is a fuel injection and distributorless engine management system for use at serious club and works level motor sport on engines with up to 12 cylinders. Here reliability can win championships as well as speed because regularly collected points can beat irregular first places. For this reason MBE Systems EMS allows users to retain the manufacturer's original parts for reliability and this also helps with availability of spares.

The main ignition and fuel injection maps on the 941 system are arranged with map points every 250rev/min with up to 16 programmable throttle points. There are also maps with up to 16 programmable pressure points. Cold start and warm up maps are available and alterable by the user. The system can compensate for inlet air temperature variations.

Fuel is cut off during overrun and a gearshift light acts as a driver prompt. Weight of the unit has been trimmed to 750g. MBE has developed all its software and hardware in-house and the management systems need a PC installed with the company's Easimap software, which runs under Windows, and a mapping console. MBE says that using a proven system such as theirs enables vehicles to be certified for road use first time.

16-bit control
A 16-bit microcontroller controls all ECU functions including communication with the company's 933 Traction Control System. This was developed in conjunction with Vauxhall Dealer Sport for the Astra F2 Rally Car. It measures all four wheels speeds, lateral G forces and can also accept footbrake and handbrake positions. Twelve levels of traction control can be selected from ice through gravel to tarmac. A serial link connects it to the ECU which then controls engine power output. It differs from many traction control systems by finely adjusting engine characteristics rather than simply cutting ignition or fuel.

Cars manufactured by TVR use EMS from MBE Systems. The current range includes Cerbera, Griffith 500 and Chimaera. All can reach 60mph in a fraction over four seconds with engines between 4 and 5 litres developing some 340bhp and providing a top speed about 160mph. TVR Engineering has just developed its own engine, the AJP 8. This is an all aluminium 4.2 litre V8 which develops 350bhp at 6500rev/min.

Rover Group has developed its own EMS but sells it with an engine. This combination powers Morgans, the Lotus Elite and Reliant Scimitar.

A smooth ride has low priority in racing cars but this is not the case for luxury cars. In the latest Jaguar models, the automatic transmission can control ignition through the engine management system. Ignition timing is retarded during gear shifts to give seamless gear changes and to increase transmission life by smoothing the load on the gearbox components.

Vehicle security is also enhanced because fuel, ignition and cranking are inhibited when the ignition key is removed and computers cannot be hot wired. A coded transponder in the ignition key has over 1000 billion combinations to ensure a robust system.

Exhaust emissions are continuously monitored by sensors in the exhaust system. These communicate with the management system and the mixture to the engine is automatically adjusted to compensate.
Another problem for the ECU to solve in a Jaguar is the extra load from air conditioning compressors. When these switch on during idling, for example, engine speed has to increase to compensate for the extra load.

Wiring it up
Interconnection between ECU, sensors and engine devices increasingly uses serial transmission. Although the principle is the same as the long established RS232 standard, signals have to be much more robust to withstand the harsh electrical environment in cars. Controller Area Network, CAN, is the accepted standard in the automotive industry.

With 8km of cable harness in some cars at the moment, replacement by twisted pair will mean a great weight saving. Power is wired separately to the 10-metre-long wiring harness because it runs as a ring main to all devices there is further weight saving over conventional harnesses. The communications protocol is complex to eliminate the problem of collisions of data on the network and the system can distinguish between permanent hardware failure and occasional soft errors. Defective nodes are automatically switched off the bus, implementing a fail-safe procedure.

Electronic management systems are in turn breeding advanced mechanical devices. Siemens Automotive has just announced one of the fastest acting injection valves and a lambda probe which fits into an exhaust to monitor emissions. The injector valve has been developed because engine management systems demand faster response from the engine to make use of the available increased efficiency.

Siemens has achieved a response time of 0.1ms compared with 0.6ms of electromechanically operated counterparts. A multilayer stack of piezoelectric material expands to provide mechanical motion from an applied voltage. The amount of movement is measured in micrometres.

And the future?
Once engine control systems are fully established, interest will turn to vehicle handling and the ECU will process inputs from additional sensors. The most advanced system yet proposed comes from Mercedes.

This company’s ECU is linked to engine, automatic transmission, brakes, accelerator, steering and a yaw sensor through a CANbus. The accelerator is electronically linked to the engine management system, bringing the Mercedes close to drive-by-wire. A variable resistor is rotated as the accelerator is depressed to give a much finer control than with mechanical linkage.

Mercedes’ system prevents skidding by applying brakes to individual wheels to maintain the car’s balance. Control signals to the brakes derive from a computer which compares steering wheel position with the car’s direction of travel. When under- or over-steer is detected, the appropriate brakes are momentarily applied and engine torque is reduced. This brings the car back on line.

Key to the system is a solid-state gyro which acts as a yaw detector. Housed under the rear seat of a car it gives an output signal proportional to the rate of rotation about a vertical axis. A database holds all the parameters for optimum handling stability.

Engine management could also work in conjunction with anti-collision radar to reduce engine speed when a vehicle is too close to one in front. It already interacts with intelligent cruise-control systems.

Whether it is through direct involvement or through general interest there is more and more in today’s cars to attract the electronics enthusiast.

**UHF TUNED LINEAR POWER AMPLIFIERS**
Tuned to your specified frequency in the range 250-470MHz. 500mW input. 5 watts output...

- 5 watts input. 25 watts output... £545
- 8 watts input. 50 watts output... £1045

**TUNED LINEAR POWER AMPLIFIERS**
Tuned to your specified frequency in the range 20-250MHz.

- 10mW input. 1 watt output... £302
- 50mW input. 10 watts output... £385
- 3 watts input. 30 watts output... £545
- 5 watts input. 50 watts output... £1045

**PHASE LOCK LOCK FREQUENCY CONVERTER**
Up-down converter. Up & o/p frequencies 20MHz to 2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW. £302

**PHASE LOCK SIGNAL SOURCES**
Freq. as specified in the range 20-250MHz. O/p 10mW. £250

**WIDEBAND AMPLIFIERS**
100KHz-500MHz. NF 26dB. Output 12.5dBm, 10mW. 50 ohms... £175

**NARROW AND BROADBAND GASFET LNA’s**

- 5MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 0.7dBm. £420
- 100MHz-1GHz. NF 2dB at 1GHz. Gain 20dB. 50 ohms... £395

**DERIVED FROM THE POWER AMPLIFIERS**

- Gasfet. 10MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 0dBm, 50 ohms... £175
- Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 50 ohms... £195

**PHASE LOCK LOOP FREQUENCY CONVERTER**
Up-down converter. Up & o/p frequencies 20MHz to 2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW. £302

**NARROW AND BROADBAND GASFET LNA’s**

- 5MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 0.7dBm. £420
- 100MHz-1GHz. NF 2dB at 1GHz. Gain 20dB. 50 ohms... £395

**PHASE LOCK SIGNAL SOURCES**
Freq. as specified in the range 20-250MHz. O/p 10mW. £250

**WIDEBAND AMPLIFIERS**
100KHz-500MHz. NF 26dB at 500MHz. Output 12.5dBm, 10mW. 50 ohms... £175

**DERIVED FROM THE POWER AMPLIFIERS**

- Gasfet. 10MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 0dBm, 50 ohms... £175
- Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 50 ohms... £195

**PHASE LOCK LOCK FREQUENCY CONVERTER**
Up-down converter. Up & o/p frequencies 20MHz to 2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW. £302

**PHASE LOCK SIGNAL SOURCES**
Freq. as specified in the range 20-250MHz. O/p 10mW. £250

**WIDEBAND AMPLIFIERS**
100KHz-500MHz. NF 26dB at 500MHz. Output 12.5dBm, 10mW. 50 ohms... £175

**DERIVED FROM THE POWER AMPLIFIERS**

- Gasfet. 10MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 0dBm, 50 ohms... £175
- Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 50 ohms... £195

**PHASE LOCK LOCK FREQUENCY CONVERTER**
Up-down converter. Up & o/p frequencies 20MHz to 2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW. £302

**PHASE LOCK SIGNAL SOURCES**
Freq. as specified in the range 20-250MHz. O/p 10mW. £250

**WIDEBAND AMPLIFIERS**
100KHz-500MHz. NF 26dB at 500MHz. Output 12.5dBm, 10mW. 50 ohms... £175

**DERIVED FROM THE POWER AMPLIFIERS**

- Gasfet. 10MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 0dBm, 50 ohms... £175
- Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 50 ohms... £195

**PHASE LOCK LOCK FREQUENCY CONVERTER**
Up-down converter. Up & o/p frequencies 20MHz to 2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW. £302

**PHASE LOCK SIGNAL SOURCES**
Freq. as specified in the range 20-250MHz. O/p 10mW. £250

**WIDEBAND AMPLIFIERS**
100KHz-500MHz. NF 26dB at 500MHz. Output 12.5dBm, 10mW. 50 ohms... £175

**DERIVED FROM THE POWER AMPLIFIERS**

- Gasfet. 10MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 0dBm, 50 ohms... £175
- Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 50 ohms... £195
A new sensor for medicine

Currently, there is a need for simple and rapid techniques to detect antigens of medical and veterinary importance. The immune system reacts to attack by producing specific antibodies which will only react with one intruding antigen. They will not react with structurally related compounds, in the same way that only a single key amongst many will fit a given lock. This is the central process of antibody immunoassay.

In the past, immunoassay has involved the use of radionuclides or sensitive detection of fluorescently labelled molecules. However, these methods are now considered unfavourable. They are also slow. As a result, the use of non-labelled molecules has both practical and psychological advantages over traditional techniques.

An optoelectronic solution
Optoelectronics is taking a leading role in the field of optical sensors, where changes in optical intensity – due to variations in sample environment such as refractive index or absorption – offer the opportunity of on-line sensors for clinical and industrial applications.

Semiconductor technology has allowed the fabrication of monolithic integrated chips to be combined with total internal reflection within glass waveguides.

Total internal reflection sensors utilise the existence of the so-called evanescent wave. At

![Diagram of optical sensor](image-url)
The boundary between two dielectric media, light incident from a denser medium may be reflected from a rarer medium if the incident light approaches at an angle greater than the critical angle. This angle is $\theta_c$, where $\sin \theta_c$ is $n_2/n_1$. Values $n_1$ and $n_2$ are refractive indices of the denser and rarer medium respectively.

In an evanescent wave, the electromagnetic field decays exponentially with distance from the reflecting boundary. It then probes above the glass surface to about a wavelength's depth into the surrounding medium. This medium may be, for example, a sample of body fluid.

Intensity of the surface wave may be amplified significantly via surface plasmon resonance - an electromagnetic wave travelling along a metal/dielectric surface.

Optical excitation of a surface plasmon resonance is achieved when radiation undergoes total internal reflection at the interface between the glass waveguide and a thin metal film deposited on top.

In the case of a planar waveguide, resonant coupling depends critically on the refractive index of the fluid adjacent to the metal. This technique can monitor small changes in index caused by either deposition of charged ions in an electric field, Fig. 1 or by antibody-antigen binding near the surface of a waveguide, Fig. 2. The deposition technique was reported at OFS9 in Florence 1993 while the binding method is more recent.

Summary

Several advantages can be gained from using sensitive surface plasmon resonance optical sensors. These are small size, optical fibre compatibility, cheap production costs, and disposability.

Use of such multifunctional integrated optical sensors for rapid medical sensing – with monitoring of real-time antibody-binding and detection in minutes – is thus a realistic expectation before the end of this millennium. However, psychological aspects of rapid diagnosis of HIV, pregnancy and indeed any other immune response has not yet been considered fully.

---

**Fig. 2.** Transmitted output power of the waveguide (TM/TE) is recorded as a function of time for the following sequence of antibodies bound to the waveguide – a) anti-human raised in goat, b) anti-goat raised in rabbit, c) anti-rabbit raised in goat and d) anti-goat raised in rabbit. As each subsequent layer binds to the preceding layer the transmitted output power is observed to rise in each case.
Suitable for data acquisition and computer control, the Experimenter can form the basis of ATE, automation or process-control applications.

For a limited period, Milford Instruments is offering the Experimenter i/o subsystem to EW+WW readers for 20% discount on the normal list price of £149.

Compatible with any PC or Mac with an RS232 interface, the Experimenter has in-built intelligence and operates from simple ASCII commands. It provides:
- Eight 10bit analogue inputs, 0-5V
- 24 digital input/output lines
- Pulse counting
- Pulse-width modulation
- 8A, 30V SPDT relay
- Eight I/O power drivers

Programming is via a standard RS232C link operating at 300 to 38.4kbaud, the Experimenter is controlled by simple ASCII codes via commands.

Power input and output is eight current sources and sinks up to 1A each. These use an external 4.5 to 36V dc power source. All eight incorporate output clamping diodes and thermal overload protection. The unit also has an SPDT relay with 8A, 30V capability.

Low-level inputs are eight analogue inputs that sense signals between 0 and 5.115V with a resolution of 5mV. Each of the 24 digital lines can be programmed as inputs or outputs with CMOS drive and level compatibility.

Counting and timing involves four counter timers, each with 10µs resolution, settable for durations between 250µs and 655.35ms. These can be used to measure period, pulse width and channel-to-channel delay. Counting capability is 65,535 counts between 0 and 1kHz.

Supplies include the Experimenter’s on-board regulator that provides 5V for the logic from an external 5.5 to 15V dc supply. This is a low-dropout regulator. Board space is provided to allow additional a quiet, precise 5.12V reference and power supply for analogue measurements and circuits.

Mechanical details include measuring 160 by 135mm, Experimenter is supplied without case and power supply, but including an extensive 76-page manual and sample software.

PC i/o ordering details include the following:
- Experimenter - built & tested, normal price £199, 20% off price £149
- Experimenter - kit, normal price £149, 20% off price £119
- Case £35
- 12V dc power plug £12
- RS232 cable £9

Please state whether you need DOS, Windows or Mac software on your order and add £3pp, plus VAT to the total price if ordering from the UK.

Order via credit card, postal order or cheque payable to Milford Instruments. Ordering by credit card please state card type, card number, expiry date and address of card holder.

Please post your order to Milford Instruments at Milford House, 120 High Street, South Milford, Leeds LS25 5AQ. For enquiries ring 01977 683665 or fax 01977 681465.

The Pico Technology ADC-11 and ADC-100 are versatile a-to-d converters for the PC – outlined in this issue. These printer-port plug-ins are supplied complete with software and have a normal list price of £95 and £219 respectively, exclusive of VAT and postage. While stocks last, EW+WW readers can obtain the ADC-11 for only £66.50, and the ADC-100 for £153.30, excluding VAT and postage.

ADC-11 has eleven analogue input channels and takes up to 15000 samples a second. It plugs directly into the pc printer port. This 10bit converter takes inputs in the range 0 to 2.5V and has a digital alarm output. Data-logging software is supplied with the ADC-11 as standard.

ADC-100 is a high-performance 100kHz sampling a-to-d converter that plugs into the pc printer port via its supplied lead. Resolution is 12 bits and nine input ranges cover 50mV to 20V full-scale. Each unit is shipped complete with virtual instrument software for turning your pc into a spectrum analyser, frequency counter, dvm or storage oscilloscope. Data-logging software is also included.
For current domestic tv sets, cathode-ray tubes still have no competitors. But crt technology will have to be replaced when large-screen tv comes on line. Peter Willis looks at a few of the options.

Technology for big

High-definition television needs large screens to display it – larger than is practical or feasible with cathode ray tubes. Flat panel displays using liquid-crystal displays have been in development for years, but have so far not been produced in sizes much above 20in, i.e. 50cm.

Now though, a variety of approaches appears capable of producing large flat panels – the commonly agreed target diagonal is 50in or 127cm – in the very near future. Several prototypes were on show at the Berlin IFA during August and September.

Some use plasma discharge, the result of passing high voltage through gas. Thomson showed a plasma screen deploying this phenomenon in the traditional way, as a light source, exciting further light from phosphors. Several Japanese companies are working on similar technologies.

Sony’s Plasmatron however, uses plasma discharge as an electronic switch similar to a transistor, to control lcds in front of an independent source of light. The plasma switch takes the form of a channel across the screen, equivalent to a single scanning line, and inputs image signals for that line instantaneously into the liquid crystal.

The system, called PALC, – plasma addressed liquid crystal – was developed by Sony in conjunction with Tektronix. According to Sony it has the advantage of relative simplicity and relatively low-cost production. Sony was showing three 30in prototypes in Berlin, and aims to have the first Plasmatron sets in production next year. However, the eventual size of these displays is not yet defined and the name not confirmed.

Each pixel is a rotating mirror
An entirely different technique developed by Texas Instruments has been adopted by Nokia who demonstrated it in Berlin. It uses an array of tiny movable mirrors, one for each pixel, which when
Greatly enlarged structure of a plasma-addressed liquid crystal switch element.

CONSUMER ELECTRONICS

range of uses, including cinema projection, means that the volume and yield of production can be quickly increased, and costs brought down. Eventually consumer products costing under £1000 are thought to be feasible.

Nokia is the first consumer manufacturer to publicly adopt the system, and plans to launch a big-screen set in early 1997. Other partners of Texas Instruments so far announced include cinema, home cinema and business equipment firms but, interestingly Sony is also included. The system is particularly kind to large-scale vdu screens and ohp's. Talks are understood to be in progress with a number of other companies.

In the contest to produce the definitive flat-panel large-screen display - or even a reliable, affordable one - digital light processing may prove to have one clinching advantage over plasma-based systems. It does not rely on high-voltage pulses which could contravene regulations on electromagnetic interference.

Is mechanical breakdown a problem?

The reliance on what are in effect a great number of mechanical components might give some concern. One stuck mirror could create a dark, or more obtrusively, a bright spot on the screen. But according to Texas Instruments digital light processing manager, Adam Kunzman, the torsion hinge on which the micromirror's operation depends has been extensively tested and has "never failed". Nor is it expensive. Applicability of the system to a wide
Demodulation
a new approach

Archie Pettigrew's new demodulator concept uses amplitude-locked loop techniques to produce significant improvements in the quality of fm and am reception.

The amplitude-locked loop was developed to overcome a number of fundamental difficulties which have existed since the inception of both amplitude and frequency modulation - am and fm.

With the radio spectrum becoming more crowded each year, and carrier frequencies moving inexorably higher, two basic problems with am and fm transmission become more obvious. Amplitude modulation becomes highly distorted when the carrier fades - or in certain cases, vanishes altogether. Frequency modulation becomes highly distorted and unintelligible when another fm signal arrives at the antenna at the same time as the wanted signal which is equal in amplitude and of a similar frequency.

Both these breakdown processes are caused by interference in the form of multi-path1 Doppler or quasi-synchronous2 reception. All these forms become worse as frequency of the carrier is increased i.e. as wavelength is shortened and/or as transmission becomes mobile3. By using an amplitude-locked loop and associated circuitry, many of these interruptions can be avoided, and more reliable communications achieved.

This article describes in detail the operation of two demodulators, one for am and the other for fm, using the amplitude-locked loop.

Amplitude-locked loop
The amplitude-locked loop, ALL, is the dual of the phase-locked loop, PLL. It works in the magnitude domain rather than the phase or frequency domain. It consists of a linear multiplier contained inside a high gain, high bandwidth servo loop4,5,6.

A phased-lock loop is similar in that it consists of a voltage controlled oscillator contained in a high gain, high bandwidth servo loop. Figure 1 shows a diagram of the amplitude-locked loop.

Carrier from the intermediate frequency stage of the radio enters the ALL at the first port of the linear multiplier. The second port of the multiplier is set to a nominal value of unity. The modulated carrier passes through the multiplier to the modulus detector which accurately detects the modulus of the carrier down to white noise levels.

A dc reference voltage compares and subtracts the incoming modulus voltage and a difference or error voltage is generated, $e(t)$. This voltage is integrated and reversed in sign. Output of the integrator is added to the restoration voltage which sets up the operating conditions - or bias conditions - of the loop.

When no carrier amplitude is present, the loop is out of lock. The integrator drifts to its maximum voltage and the multiplier is at maximum gain awaiting an input. When the carrier appears, an initial transient occurs as the loop pulls into lock. Servo feedback causes the carrier amplitude at the output of the multiplier to be fixed or locked to an amplitude defined by the loop reference voltage.

Let a simple amplitude modulated carrier $v_i(t)$ be described as,

$$v_i(t) = [1 + m(t)] \sin \omega t$$

Where $m(t)$ is the modulation index.

When the loop is closed, envelope variations of the carrier are reduced to insignificant proportions due to servo action and an error signal called the inverse modulus is produced.

Figure 1. Amplitude-locked loop consists of a linear multiplier, modulus detector and a high gain integrator. When the loop is closed, envelope variations of the carrier are reduced to insignificant proportions due to servo action and an error signal called the inverse modulus is produced.
after some mathematical analyses, a number of amplitude-locked loop identities become evident. Assuming that open-loop gain is sufficiently high that servo theory is valid, ie the value of K in the integrator is greater than 100 at the maximum frequency of interest, the stabilised carrier, \( v_{sc}(t) \), becomes,

\[ v_{sc}(t) = |1 + e(t)| \sin \omega t \]

where \( e(t) \) is the loop error voltage which becomes insignificant due to the high open loop gain. That is, \( v_{sc}(t) = |10| \sin \omega t \)

Voltage \( v_{sc}(t) \) represents a stabilised carrier with no envelope variations. Voltage at the second input to the multiplier must therefore be the reciprocal of the input modulation. As a result, \( v_{sc}(t) = 1 |1+m(t)| \) and \( v_{sc}(t) = -m(t)|1+m(t)| \) by subtracting unity.

Three signals have been obtained – the unmodulated carrier, the inverse of the modulus and the inverse modulus with the dc term removed. Unfortunately, there is no requirement to recover the unmodulated carrier in amplitude modulation. The demodulated signal is the reciprocal of the modulation which is a highly distorted version of the original signal. The signal at the integrator output is simply the reciprocal of the modulation but with an average value of zero. At first sight, nothing seems to have been achieved by this circuit so why investigate further?

Much the same arguments were used for the PLL when it was first suggested. For example, the PLL could easily have been replaced by a piece of wire and a much lower cost etc.

Perhaps for the above reasons the concept of the ALL has never been investigated, even in the valve or tube era of electronics. If the ALL is not directly suitable for demodulation of an, can it be used to replace the limiter-filter in the demodulation process? Indeed it can as will be explained.

**Application to fm demodulation**

When two fm carriers of equal amplitude are added, their envelope increases to twice the individual size and reduces to zero at the instantaneous difference frequency. This envelope variation will be eliminated by the servo action of the ALL. This is similar to the action of a hard limiter and a filter and fulfils the first requirement in fm demodulation – that amplitude variations must be removed before demodulation.

A second signal is also available which is the inverse of the modulus of the two carriers. Could this second error signal be used constructively to improve fm demodulation?

**Operating limits**

Before continuing, it would be sensible to define the limits of operation of the first ALL unit. Starting with an intermediate frequency of 455kHz, amplitude and phase information is updated at twice the carrier frequency or 910kHz.

In a closed-loop feedback system, instability starts to occur at about one tenth of this frequency or 91kHz. So the ALL unity gain bandwidth was set to 91kHz giving an open loop gain at say 1kHz of 91 or 39dB. This was improved later by using a double integrator.

The dynamic range of the ALL was determined by the offsets and the characteristics of the linear multiplier, the Exar 2208. This was found to be +25dB (10) to -6dB (0.5) or a linear lock range of 26 dB.

In practice, the ALL will track 26dB of amplitude variation up to a frequency of about 20kHz without significant error. This was found to be more than adequate for all narrowband fm speech channels. The lock-in transient is very short since the ALL is more linear than a PLL. Typically it was measured at about 4µs, i.e. the time required to reach 95% of the steady state value of stabilised amplitude.

Using a simulation package called MATRIXx, optimum circuit operation was established before any hardware was constructed. A much improved loop was designed using a double integrator with suitable phase advance for stability. This is described further in reference 8.
Applying the amplitude-locked loop

The first application of the ALL is to improve the amplitude modulated double side-band suppressed carrier. This represents the ultimate in carrier – or Rayleigh – fading since the carrier vanishes at every silence of the speech waveform, by definition.

The core of this problem is the recovery of a stable carrier. There is no carrier present during the silence between speech. The worst case occurs at the lowest modulating frequency and lowest amplitude of the signal.

Doppler effects may cause the carrier to be shifted by say 100Hz so that high-Q filters are not permitted due to their rapid phase changes at resonance. Should the system lose lock, then reliable re-lock must occur within say one cycle of the lowest operating frequency, say 300Hz, or in about 3ms.

The carrier recovery circuit must also be able to track frequency variations up to 100Hz to an absolute phase accuracy of less than say 45° error between the modulated carrier and reference carrier. Assuming that a PLL is available to regenerate the carrier at 455kHz, then two conflicting conditions need to be met simultaneously.

Since amplitude of the DSSC signal is continuously varying, the envelope must first be controlled.
made constant. The PLL must have a wide capture and track range for fast lock-in and frequency tracking, yet it must have an extremely narrow noise bandwidth for stability during every speech silence.

The solution to these seemingly conflicting requirements is shown in Figs 2 and 3 in block diagram form and in circuit form in Fig. 4. This could be done by limiting and filtering which would be successful at high instantaneous amplitudes. A major problem occurs at low amplitude and low frequencies with noise. Noise captures the limiter, the voltage controlled oscillator becomes unstable and the phased-locked loop loses lock. System failure ensues. If the limiter is replaced by an ALL, a different process takes place.

At high instantaneous amplitudes, the large negative feedback of the loop flattens the amplitude variations giving a constant envelope at the output of the linear multiplier. At low instantaneous amplitudes, the ALL drops out of lock since its track range has been exceeded.

Gain of the 'loop' drops to the gain of the multiplier alone and not the combined gains of the multiplier, modulus detector and the integrator. At 300Hz, this represents a change from 80dB to 20dB. The noise level is not amplified, and in effect, the system closes down.

White noise is not permitted to overtake the signal, as would happen in a limiter. This is the advantage of the in-out action of servo feedback.

**Carrier generation**

A pure squaring device follows the analogue locked loop to generate a coherent carrier at 2o. When the ALL is out of lock, the PLL is being driven by a zero level carrier. Since the bandwidth of any linear PLL is a direct function of the input amplitude, its closed loop bandwidth drops to zero.

The voltage controlled oscillator free wheels on the long open-loop time constant of the PLL since there is no significant noise energy to cause perturbations. After a divide-by-two circuit, normal demodulation takes place.

Thus the PLL has effectively two bandwidths. The first is with signal present and the ALL in lock. With values suggested in Fig. 3 this bandwidth measures about 500Hz. When no carrier is present, i.e. with the ALL out of lock, there is no signal present at the input to the PLL.

The effective open loop gain of the PLL is reduced to zero assuming a linear phase detector.
Stability of the voltage controlled oscillator is then determined solely by the time constant of the filter following the phase detector. This can be made large ie of the order of one second.

Carrier stability is thus maintained due to this very long time constant. By use of the ALL, phase-capture transients are very short when signal is present and phase loss transients are long when the signal is absent. By this technique, the coherent carrier can be recovered reliably even during periods of poor carrier-to-noise ratio. The circuit diagram of this system is shown in Fig. 4.

The ALL is contained in the hybrid block U1. The circuits which follow the ALL represent the normal synchronous AM demodulation technique, namely, a pure squaring device (U2) followed by a narrow track range PLL (U3), a divide-by-two, (U4) and finally a synchronous multiplier (U5).

Results obtained for this demodulator are presented in Fig 5. Figure 5 shows the comparison between a demodulator using a limiter and filter in place of the ALL. Whereas the limiter-filter ceased to operate effectively at about 3dB carrier-to-noise ratio, the ALL circuit still maintained synchronism until well into noise. Cycle slipping occurs in both demodulators at about the same relative position but does not result in complete loss of intelligibility.

It is interesting to note that there is no threshold effect present as would be the case in FM or angle demodulation. The output signal-to-noise ratio tracks the input carrier-to-noise ratio in a linear manner.

Results obtained from the above demodulator exceeded the performance of the normal synchronous demodulator in that carrier recovery could be achieved down to and below unity carrier-to-noise ratios. Figure 6 shows an oscilloscope trace of a 300Hz sine wave signal which is being gated on and off at 6 and 4ms intervals. Carrier-to-noise ratio with signal present was 0dB. Noise and carrier amplitudes were equal.

Due to carrier stability, system white noise is demodulated in a coherent manner. The PLL has an effective phase capture bandwidth of 500Hz and a phase release bandwidth of 0.1Hz. This phase capture-release phenomenon is a direct consequence of utilising the two in-lock and out-of-lock characteristics of the ALL and PLL simultaneously to make a near perfect AM demodulator. This represents a major improvement in the state of the art on AM demodulation.

This demodulator operates reliably and completely independently of the presence or absence of carrier. It is therefore ideal for the reception of AM during multipath or quasi-synchronous conditions.

FM demodulation

Frequency modulation is transmitted at constant amplitude. Any amplitude variation at the point of reception must be due to interference or noise acquired en route.

According to perceived wisdom, amplitude variations must be removed by hard limiting and filtering of the carrier on reception. If not, two forms of degradation will occur at the demodulator output. The first is due to envelope variation and the second to phase variation.

In reality, the FM carrier is degraded not only by naturally occurring phase noise but also by amplitude noise. This is converted to phase noise in the limiting process. These two processes combine as the input carrier-to-noise ratio approaches a low value of typically 12dB.

The catastrophic FM threshold effect begins and rapid deterioration of the output signal-to-noise ratio then follows. This same effect causes FM reception to be rendered unintelligible if two FM transmissions arrive at the antenna at equal or near equal strength to each other - assuming co-channel frequencies.

The corrupting carrier may be another transmission - co-channel - or a delayed version of the wanted carrier - multipath. It could even be a version of the same broadcast from an equidistant transmitter - simulcast or quasi-synchronised reception. Harsh acoustic spikes are demodulated which are inband and cannot be filtered.

Capture effect

In the past, much has been made of the 'capture effect' in FM. Generally, this means that if one carrier is say 10% stronger than the other, say 1dB, then capture takes place and the weaker station is completely suppressed. This was the argument put forward by Edwin Armstrong during the invention of FM. It is true - but it is not the whole story.

The unwanted carrier is suppressed but not into silence, which would be ideal. On the contrary, the co-channel interference is demodulated into strident noise, or large impulses which are intolerable to the ear and destructive of all intelligible communication. So destructive is this interference that all FM transmissions start to break down in the region where either carrier is within 6dB of the other. This is sometimes called the 'distortion zone' - when its existence is admitted. The 'capture effect' is not an advantage but is in fact a major disadvantage of FM in a crowded radio spectrum.

Frequency modulation works well when:
- carrier strength is high,
- there is only one single carrier,
- there is no co-channel interference,
- there is only one direct signal path,
- modulation depth is virtually unlimited,
- transmission power is virtually unlimited.

These conditions prevailed some fifty years ago, but unfortunately not in today's overcrowded spectrum.

Ideal requirements of the modern demodulator would be a circuit technique which would make FM demodulation linear at low carrier-to-interference ratios but still have the co-channel rejection properties at high carrier-
to-interference ratios. Quasi-sync and multipath reception would then be improved by the addition of the intelligence in the carriers and co-channel reception would be equivalent to crossed lines in telephones.

The Ampsys FM201 demodulator

Using an amplitude-locked loop for the first time, an fm demodulator has been designed and tested which demonstrates the above requirements. It is designated the Ampsys FM201. Its block diagram is illustrated in Fig. 7 and a system diagram in Fig. 8.

In the FM 201 demodulator there are four separate processes or stages. The first process, after the normal intermediate frequency filtering, is to stabilise the wanted carrier and the interfering carrier to a fixed average value using a slow automatic gain control circuit. This process is necessary in order to present the ALL with a fixed average signal level.

The fm was originally transmitted as a fixed amplitude and the automatic gain control restores this long term average. Saturating limiting is always avoided. The automatic gain control block has a bandwidth of 10Hz.

In the second stage, block 2, the ALL removes all short term variations leaving the carrier similar to the output of a hard limiter and filter. This stabilised carrier is then applied to the input of the PLL, block 3, which is regarded as normal demodulation.

A second output from the ALL, the modulus, reciprocal less the dc term, is applied to a multiplier in the analogue signal processing stage, block 4, Fig. 7. Output of the PLL is applied to the second port of this multiplier. A product is formed at the output of this circuit - the 'impulse alone' signal. 'Impulse' refers to spikes superimposed onto the baseband signal by the demodulation process.

This new baseband signal is scaled in size and subtracted from the original PLL output. Care must be taken to ensure that any phase delays through the ALL and the PLL are equal otherwise subtraction will not be possible.

A demodulated signal is created which is free of harsh spikes and is now perfectly intelligible even when the carrier and interference are identical in magnitude. A simplified version of the relevant waveforms is shown in Fig. 9a-d. Voltages $v_1(t)$ to $v_4(t)$ correspond to those marked on Fig. 8.

Worst-case fm reception

Figure 10 is an oscillograph of the demodulator output when the interfering carrier is located at the centre of the intermediate frequency passband and is of equal amplitude to the wanted carrier. This represents one of the worst case conditions in fm reception. It would result in the carrier vanishing and doubling alternately at the instantaneous frequency. It is equivalent to a fade of infinite depth.

The normal output signal-to-noise figure is much less than zero and is unmeasurable by normal instrumentation. Acoustically, all intelligence is lost and the channel would be muted. With the FM201 demodulator, signal-to-noise ratio rises to about 14 dB unweighted. This is acceptable in a communication channel and represents 100% intelligibility.

The link has been preserved, so avoiding the call being dropped. In normal demodulation when Gaussian white noise is added or when both carriers become weaker, distortion and noise effects become even more severe and generally intelligibility is lost just after the fm threshold point. This means that there can be a 'distortion zone' or failure gap as wide as 12dB. In simple terms this means that if one carrier is more than one quarter the size of the other at the antenna, failure ensues rapidly.

With the FM201 demodulator however, the spikes are removed, as are the 'Rician' spikes due to Gaussian white noise. The net result is a much improved communication channel with almost 100% intelligibility well below threshold. Further testing has given the following observations.

- When the interfering frequency is offset from the centre of the passband, similar subtruction can be achieved by inserting an offset voltage at the input to the final multiplier. The interfering frequency however must be fixed.

- When quasi-synchronous reception occurs, baseband signals combine and an improvement in the signal-to-noise ratio of approximately 26dB is measured at the equal amplitude reception point. Multipath distortion causes a small reduction in signal-to-noise ratio.

- When two modulated carriers are present, the result is similar to that of a crossed line in a telephone. Although this is not ideal, it is preferable to complete loss of intelligence.

- With a very weak carrier, harsh spikes are removed and noise subjectively more acceptable. White noise can never be removed since there is never enough unique information.

- When the carrier-to-interference ratio is high, the 'impulse-alone' product diminishes rapidly since there are no envelope variations. The weaker transmission is suppressed as in normal demodulation and all beneficial charactersitics of fm are retained, for example, quieting and channel suppression.

To summarise

A new circuit concept has been proposed called the amplitude-locked loop which can be used in conjunction with a phase-locked loop to improve the quality of fm demodulation.

By using the fundamental property that fm is transmitted at fixed amplitude, and that a unique relationship exists between the reciprocal of the modulus and the fm phase perturbations, a new signal has been derived called the 'impulse-alone' signal.

By a simple subtraction process this new signal can be used to eliminate spikes generated in fm demodulation. A fundamentally improved method of fm demodulation has been proposed which meets the criteria set out above for fm demodulation in today's over-crowded radio spectrum. Two demodulators using the ALL have been built and tested and are available for evaluation purposes, from Ampsys, one for am demodulation and the other for fm.

Acknowledgments

I would like to thank Dr T. J. Moir of the Department of Electrical and Electronic Engineering at the University of Paisley for his help in the preparation of this paper and to the Governors of the University of Paisley for their support in the development.

References

**MIXED-MODE SIMULATION.**
**THE POWER OF VERSION 4.**

**New Version 4**

**Analog, Digital & Mixed Circuits**
Electronics Workbench**
Version 4 is a fully integrated schematic capture, simulator and graphical waveform generator. It is simple to mix analog and digital parts in any combination.

**Design and Verify Circuits... Fast!**
Electronics Workbench’s simple, direct interface helps you build circuits in a fraction of the time. Try what if scenarios and fine tune your designs painlessly.

**Incredibly Powerful. Incredibly Affordable.**
If you need mixed-mode power at a price you can afford, take a look at this simulator and graphical waveform generator that mixes analog and digital with ease.

**More Power**
Simulate bigger and more complex circuits. Faster. On average, Electronics Workbench Version 4 is more than 5 times faster than Version 3.

**More Parts**
Multiple parts bins contain over twice the components of Version 3.

**More Models**
Over 350 real world analog and digital models are included with Electronics Workbench. And, if you need more, an additional 2,000 models are available.

With over 20,000 users world-wide, Electronics Workbench has already been tried, tested and accepted as an invaluable tool to design and verify analog and digital circuits. With Version 4 true mixed-mode simulation is now a reality with incredible simplicity.

**Electronics Workbench™**
The electronics lab in a computer™

**Order Now! Just £199* 44-(0)1203-233-216**

**RR Robinson Marshall (Europe) Plc**

**Nadella Building, Progress Close, Leofric Business Park, Coventry, Warwickshire CV3 2TF**
**Fax: 44 (0)1203 233-210**
**E-mail: rme@cityscape.co.uk**

Shipping charges UK £5.99. All prices are plus VAT.
All trade marks are the property of their respective owners. Electronics Workbench is a trademark of Interactive Image Technologies Ltd., Toronto, Canada. 30 Day money-back guarantee.

**Australia:** 2-519-5953  **Brazil:** 11-455-5988  **Cyprus:** 262-1068  **Denmark:** 33-250-109  **Finland:** 0-297-5053  **France:** 14-908-9000  **Germany:** 711-62-7740  **Greece:** 1-524-9881

**Hungary:** 1-215-0002  **India:** 11-564-1545  **Israel:** 3-677-5615  **Italy:** 11-637-5549  **Japan:** 5-382-3136  **Malaysia:** 03-77791954  **Netherlands:** 18-051-7606

**New Zealand:** 9-267-1756  **Norway:** 22-16-70-45  **Portugal:** 1-836-6609  **Singapore:** 662-0900  **Spain:** 61-317-830  **South Africa:** 2-2-222-3431  **South Korea:** 2-2-222-3431

**United Kingdom:** 203-23-3216

**INTERACTIVE**

**CIRCLE NO. 120 ON REPLY CARD**

---

True mixed-mode simulation: Simultaneous AM transmission, digitization and pulse-code modulation of a signal.
Williamson's valve power amplifier was published in *Wireless World* in 1947, and set a standard of performance that was years ahead of its time.

The input stage is the standard common cathode triode with 20dB of global negative feedback applied from the loudspeaker output to the cathode. The phase splitter is a concertina circuit, direct coupled from the input stage. It feeds a differential pair using both halves of a 6SN7, Fig. 1.

**Operating in Class-A**

The output stage is a push-pull pair of KT66 beam tetrodes operated as triodes. These provide 15W output in Class AB1, operating mostly in Class A. In Fig. 1, the left hand potentiometer adjusts the dc balance of the output valves in order to minimise distortion due to the transformer core. The second potentiometer sets quiescent current to 125mA for the entire stage.

Rather than breaking a wire to insert an ammeter, quiescent current can be set by adjusting the second potentiometer for 18.75V across the 150Ω resistor; the amplifier should then be allowed to warm up and stabilise. The amplifier should then be switched off, and the true – hot – value of the 150Ω resistor measured. From this, a corrected voltage for 125mA could be calculated and set.

Linearity and drive capability of each stage is good due to the careful choice of operating points. Because this amplifier has four stages enclosed by the feedback loop, stability needs to be taken very seriously. The input stage initially has an output resistance of 7.5kΩ, but this is raised by feedback to around 47kΩ. In combination with 12pF of input capacitance from the concertina, this gives a high frequency cut-off of about 280kHz.

However, this has been modified by adding step compensation components – an R and C in series – to the left-hand anode circuit of the dual triode. This circuit puts a step in the amplitude response which begins to fall at approximately 130kHz, but phase response remains virtually unchanged until 280kHz.

Output resistance of the concertina is approxi-
Fig. 1. Williamson's amplifier set a standard of performance that was years ahead of its time.

mately 1kΩ from the cathode and 22kΩ from the anode. As a result, there is an imbalance of high-frequency cutoffs in driving the 60pF input capacitance of the driver stage. This is because the anode cut-off is around 120kHz, while the cathode cut-off is 2.6MHz.

In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.

At low frequencies it is more useful to consider time constants rather than -3dB points. Since the input stage is direct coupled to the input, the time constant of the feedforward loop can be increased. The feedforward feeds the driver stage with a CR of around 22ms, as does the driver to output stage.

The output transformer is set to 48ms. In practice, since the driver stage is a differential pair, as opposed to a cathode-coupled phase splitter, its gain will only fall by 6dB from 120kHz to 2.6MHz. At this point, it will fall at the normal 6dB/octave. The net result is very similar to the step compensation in the input stage. In this amplifier, adding a build-out resistor to the cathode will probably cause oscillation, and is not recommended.

The driver stage has an output resistance of ~8.7kΩ, with 55pF of input capacitance from the output stage, cut-off is ~330kHz, and the output transformer is specified to have a cut-off of 60kHz.

Step networks

The number of hf cut-offs within the feedback loop have not been minimised, and the dominant hf cut-off is too close to the next most dominant. The only remaining way to achieve stability at hf is to adjust the phase response independently of amplitude response by means of step networks.
driver stage has only 10dB of overload capability. When output stage gain begins to fall – due to cathode feedback or input capacitance of the EL34 loading the driver – global feedback will try to correct this by supplying greater drive to the output stage. This margin will quickly be eroded.

Driver circuitry was designed to produce an amplifier of high sensitivity – even after 30dB of feedback had been applied. This has forced other factors to be compromised. Whereas the Williamson sacrificed stability for linearity, the Mullard 5-20 achieves stability at the expense of linearity.

Ultra-linear output

The output stage is a pair of EL34 in ‘ultra-linear’ configuration, with 43% taps for minimum distortion. Unlike the Williamson, there is no provision for adjusting or balancing bias, and this might seem to be a backward step. Bias adjustment implies connecting the cathodes together and using a proportion of grid bias to provide balance adjustment. Because biasing is firmly set by the potentiometers, there is no self-regulation of bias current. As the valves age, balance will need to be reset.

In short, providing this adjustment ensures that it has to be used regularly. By contrast, the Mullard 5-20 has separate cathode bias resistors and relies on automatic bias to hold the anode currents at their correct, and therefore equal, levels.

In practice, this works quite well, although it does not quite achieve the low transformer core distortion of a freshly balanced adjustable system.

System drawbacks

A disadvantage of this system is that the individual cathode bias resistors applies series negative feedback to the output valves, raising their output impedance.

The output transformer could be redesigned to maintain the match to the load, but this is undesirable as it would require a higher primary-to-secondary turns ratio. This makes a high quality design more difficult to achieve.

Because of this, the cathode bias resistors are usually bypassed by capacitors, resulting in several problems.

The capacitor is a short circuit to ac and so prevents feedback. But, as in the simple common cathode triode amplifier, at very low frequencies it will no longer be a short circuit, and will allow feedback.

Because the output stage is load matched, feedback causes an immediate rise in distortion and reduction of output power due to the mismatch. The obvious solution to this is to fit a large enough capacitor to ensure that the low frequency cut-off for this combination is below all frequencies of interest, say 1Hz.

Remembering that the resistance that the capacitor sees is $R_k$ in parallel with $r_k$, you can calculate the value required. For a pentode, $r_k$ is 1Ω; a typical output pentode has a $g_m$ of 10mA/V at its working point, so $r_k$ of around 100Ω. This is in parallel with a bias resistor of 300Ω, giving a total resistance of 75Ω. For 1Hz, a capacitance of 2000µF is needed.

Capacitors rated at 2000µF, 50V were simply not available at the time, and were not fitted. They are readily available today but there are two reasons why you might wish to use a smaller value.

- A 2000µF capacitor will have considerable inductance, allowing feedback at high frequencies. By using low inductance electrolytics designed for use in switch-mode power supplies, and/or by bypassing with smaller values, this problem can be overcome.

- If the output stage is driven into Class B by overload, each cathode then tries to move more positively than negatively. It cannot turn off any further, but it can certainly turn on harder. The capacitor smooths these changes into a gently rising dc bias voltage, which biases the valve further into Class B, and the problem continues.

The effect of this is that a momentary overload can cause distortion of the following sig-
nals — even though they would normally have been within the capabilities of the amplifier. As the cathode bias capacitor becomes larger, this recovery time from overload lengths. Theoretically, one never overloads amplifiers, and this would not be a problem, but occasional overload is inevitable, and should be considered.

The ideal way to deal with all of these problems is to reduce the cathode bias resistor to an ohm or less such that it no longer causes noticeable feedback, and measure the current through it using an op-amp. This signal then feeds an asymmetrical clipper. When the valve strays into Class B and clips one half-cycle, the clipper removes an equal amount from the other half-cycle before feeding the processed signal to an integrator. The integrator can have an RC time constant of almost any value — 10s is not unusual.

Output of the integrator is a smoothed dc voltage proportional to anode current. This can then be compared to a fixed reference. The difference between the two levels drives an RC variable resistor in order to allow for fine adjustment of anode current. Although this circuit was designed to provide —11V bias, this can easily be changed by returning the bias transistor’s collector load to a more negative supply as necessary; no other changes are required.

Quad II power amplifier

The Quad II is an unusual design, which at first sight does not look too promising, but works because the design is synergetic. In this design, the phase splitter has been combined with both the driver stage and input stage. In order to achieve the necessary gain, pentodes have been used. Output impedance is therefore high, as is input noise. To make matters worse, a variation of the see-saw phase splitter has been used. The output stage has local feedback, which increases the voltage swing required to drive the load.

Driving the loudspeakers

A pair of KT66 beam tetrodes with anode and cathode loads split in the ratio 9:3.75:1 comprise the output stage. The cathode therefore provides little drive to the loudspeaker. This may be considered to be series feedback from the output transformer. Cathode current in the output transformer however is the sum of the anode and g2 currents. It has been found that this summation reduces third harmonic distortion by a further 8dB over that due to the negative feedback.

The effect of this feedback on output resistance is the opposite to what might be expected (Williamson and Walker, 1954). If a cathode resistor is left unbypassed it will generate series feedback which increases r in, whereas the transformer coupled feedback reduces r in. This can easily be explained by assuming a short circuit as a load.

Clearly, the output stage will be unable to drive any voltage into this load, but conversely, there will be no feedback signal applied to the cathodes. The grids are then driven by the full input signal, rather than the input signal minus the feedback. Therefore the output stage is driven harder as it attempts to maintain its output into a short circuit. This action is directly equivalent to reducing output resistance. The new value of output resistance can be found using the normal feedback equation.

Transformer primaries are equivalent to 3kΩ anode to anode. With tetrodes, this low value of anode load results in a reduction of third harmonic distortion, and an increase in second harmonic. This is then cancelled by the output transformer.

There is no provision for balancing anode current, and the automatic bias is shared. As a result, you can expect an increase in distortion at low frequencies due to saturation of the transformer core. Curiously, the cathode resistor was only rated at 3W, yet it dissipates 3.8W. If your Quad II is distorting, a burnt out transformer core may well be the cause.

Even with pentodes, there is not a great deal of gain from the driver circuitry, and input sensitivity is low, at 1.4V for full output. This is an excellent choice of input sensitivity for a power amplifier. It not only guarantees impeccable noise performance — even from a pen-

![Fig. 4. The Quad II is different. Not only is the phase splitter combined with the driver, but it is also combined with the input stage. Circuit courtesy Quad Electroacoustics.](image-url)
tode – but it also means that the input is far less susceptible to hum and noise from input cables or heater circuitry.

The Quad II was only beaten in signal-to-noise performance by the Williamson, which was quieter because it had a triode input stage.

Balanced output

Although the phase splitter is a variation of the see-saw phase splitter, it does not rely on feedback for balance, and its operation is quite elegant. Output valves must each have a grid leak resistor, so instead of applying additional loading to the driver valves, a tapping is taken from one of these to provide the input for V2.

In theory, if this tapping had an attenuation equal to the gain of V2, then the output of the phase splitter would be balanced. Because of component variation, this will not always be true, and so the cathodes of the two valves are tied together to improve balance.

This has been further modified by applying global feedback to the other end of this potential divider, which is why the gain of V2 is not equal to 680kΩ/2.7kΩ.

Pentode over triode

Pentode stages have output resistances approximately equal to Rg. Since Rg for the Quad is 180kΩ, this would appear to be very poor at driving the 30pF input capacitance of the output stage, resulting in a cut-off of around 30kHz.

Apart from the output transformer, this is the only high-frequency cut-off in the circuit, and is therefore not a problem. Each output valve requires a swing of around 80V pk-pk. This is easily provided, because pentodes can approach 0V more closely than triodes. Also, LC filtering is used on the ht line, rather than RC filtering, which would reduce available ht.

This LC filtered supply also feeds g2 of the output valves. This has the valuable advantage of reducing hum, since the anode current of a tetrode or pentode is dependent on g2 voltage rather than anode voltage.

In the input stage, pentodes need to have g2 decoupled to ground. Instead of each valve having a capacitor to ground, one capacitor is connected between each g2. This has three advantages:

- If you had two individual capacitors, they would effectively be in series with a centre tap to ground. Since each valve is supplying an equal but opposite output, the centre tap would be at ground potential even if it were to be disconnected from ground. Disconnecting the centre tap from ground results in two capacitors in series. These can be replaced by a single capacitor whose value is equal to half that of one of them.

- Since this one capacitor is connected between two points of equal potential, it need not necessarily have the full voltage rating to ground. However, it is as well to consider the effect of fault conditions when determining the voltage rating. As a result, this is not a great advantage.

- Connecting g2 of each valve together at ac helps maintain balance in the same way as commoning the cathodes.

Although substituting one stage that combines the functions of input, phase splitter and driver does not achieve the linearity of purpose designed stages, it achieves better linearity than the Mullard circuit. This is because less gain is demanded from it.

With only a simple driver circuit and output stage within the feedback loop, the Quad II has no stability problems.

Further reading


ULTlboard, one of the leading PC based design systems, is supplied worldwide via a network of ULTlmate Technology offices & distributors. ULTlboard's success with professional designers is primarily due to its superior interactive functionality.

REAL TIME Placement Help, REAL TIME Design Rule Check, Reroute-While-Move and Trace Shoving, are all features which will dramatically reduce your design time.

Integration with ULTlcap guarantees smooth data flow between Schematic and PCB editing. The inclusion of third party netlist interfaces ensures ULTlboard will fit into any design environment.

Another of ULTlmate Technology's strengths is our flexible growth path. Users may start with a low cost ULTlboard Challenger and grow, step by step, to a 32-bit Advanced Design system including Ripup and Retry Autorouting.

ULTlboard's success with professional designers is primarily due to its superior interactive functionality. Your move ideas are quickly captured using the ULTlcap schematic design tool. ULTlcap uses REAL-TIME checks to prevent logic errors. Schematic editing is painless; simply click your start and end points and ULTlcap automatically wires them for you. ULTlcap’s auto snap to pin and auto junction features ensure your netlist is complete, thereby reducing you of tedious netlist checking.

If you need partial ground planes, then use the DOS extended board system. You can automatically create copper polygons simply by drawing the outline. The polygon is then filled with copper of the desired height. All correct pins are connected to the polygon with thermal relief connections and user defined gaps are respected around all other pads and tracks.

ULTlboard's backannotation automatically updates your ULTlcap schematic with any pin and gap changes or component renumbering. Finally, your design is post -processed to generate pen / photo plots, dot matrix/laser or photo plots, dot matrix/laser or custom drill files.

ULTlboard's backannotation automatically updates your ULTlcap schematic with any pin and gap changes or component renumbering. Finally, your design is post -processed to generate pen / photo plots, dot matrix/laser or photo plots, dot matrix/laser or custom drill files.
Allen Brown reviews an extension to the maths modelling package Matlab, which is intended for designers of dsp circuitry.

PC software package Matlab - reviewed in EW+WW, March 1995 - is a product designed, amongst other things, for the modelling and simulation of physical processes. Whether solving electrical, biological, mechanical or economical problems, Matlab is a versatile tool for tackling a whole range of modelling requirements.

To support the package, its makers, Math Works, provide a range of 'Toolboxes' designed for specific applications. A number of these - one of which is the signal processing toolbox - are likely to be of interest to electronics engineers.

Over the past ten years, signal processing has aroused a considerable amount of interest, due in part to the availability of high-performance digital signal processors, both fixed and floating point. Also, the pc is playing a significant role in realising signal processing operations. The wealth of high speed data acquisition expansion cards and the availability of high quality software is contributing to the continuing interest in signal processing.

Normal engineering practice involves the modelling of electronic circuitry before it is constructed and it is customary to use such software packages as PSpice or Electronics Workbench for this purpose. For signal processing modelling the designer, who is familiar with Matlab, has the option of using the signal processing toolbox. This comprises a library of prewritten signal processing functions that can be evoked from the command line within the Matlab environment.

The toolbox has over one hundred functions whose operations cover the spectrum of commonly used processes. Groups of processes include filter analysis, linear systems transformations, digital filter design, transforms, statistical processing, windowing and parametric modelling. In fact, the range is as extensive as you are likely to find in any pc signal processing software.

Analysing filters

There is a number of interesting tools in the filter analysis group for analysing systems. It should be emphasised that the toolbox is not constrained to digital operations only - it is also possible to model system behaviour in the analogue Laplace S domain. For example, determining frequency response of the following transfer function,

\[ H(s) = \frac{0.2s^2 + 0.3s + 1}{s^2 + 0.4s + 1} \]

The command line code for this task is,

```matlab
b=[0.2 0.3 1];a=[1 0.4 1];
w=logspace(-1, 1);
freqs(b, a, w)
```

Fig. 1. Using the signal processing toolbox, a transfer function in the Laplace S domain can be easily realised in a plot.

Fig. 2. Transfer function generated graphically in the digital z domain.
The graphical result, Fig. 1, shows the magnitude of the response and the phase in degrees. Coefficients of the transfer function are defined in the first line and log spacing for the plot in the second line. The freqz function in the third line performs plotting in the frequency domain. Plotting the response of a digital filter is just as easy, consider a sixth-order lowpass elliptical filter with a cut-off frequency of 300Hz and a 3dB ripple sampling at 500Hz. The command line code would be,

\[
[b, a]=\text{ellip}(6, 0.05, 80, 0.4); \\
\text{freqz}(b, a, 512, 1000)
\]

The first line defines the specifications of the filter, and freqz in the second line performs transfer and plotting in the z domain. The graphical result is shown in Fig. 2. You will also notice that a pleasing feature of the phase plots of the signal processing toolbox is the absence of fly-backs at the 360° boundary.

Fly-backs are customary on almost all signal processing software and confuse the information in the phase plot. It is good to see that this product eliminates this problem. The user may be interested to see the impulse response of the filter. This can be accomplished via the impz function. For example,

\[
[b, a]=\text{ellip}(10, 0.05, 80, 0.4); \\
\text{impz}(b, a, 50)
\]

The command line code defines a tenth-order elliptical filter with a 0.05 ripple in the pass band, a 80dB attenuation in the stop band with a normalised cut off frequency of 0.4. A normalised frequency of 0.5 is equivalent to half the sampling frequency. The graphical result of the above instructions is shown in Fig. 3. Including the instruction zplane(a, b) produces the pole/zero plot of Fig. 4.

Alternatively within the linear systems transformations group of instructions there are some powerful operations for changing one system representation into another. These can be evoked with relative ease. For example, state-space to transfer function, ss2tf, or zero-pole to state-space, zp2ss. All in all some useful features for analysing system responses in both analogue and digital domains.

**Designing digital filters**

Functions for designing finite impulse response and infinite impulse response digital filters are included in the signal-processing toolbox. Infinite impulse response filters comprise the well known Bessel, Butterworth, Chebychev, elliptical and the not so well known Yule-Walker. There are also instructions for determining the order of the filters. This example illustrates how the instructions are used. Consider designing a bandpass Chebychev II filter (ripple in the stop band), transmission from 100-200Hz with a 3dB ripple and a stop band attenuation of 100dB. Given a sampling frequency of 1000Hz, the instructions are shown with comments in Table 1 and graphical output for the filter in Fig. 5.

Once the user has learned the command line syntax, it is a relatively straightforward task to design filters. However, there does not appear to be any function for quantising coefficients — usually to 16bit — and converting them for use with a fixed point format for digital signal processing. It is sometimes necessary to model the performance of the filter once the coefficients have been quantised — there appears to be no function in the signal processing toolbox for performing this operation directly.

The option of designing finite impulse response filters using the Parks-McClellan method, based on the Remez Exchange Algorithm, is not as clean as it could be. There

**Table 1. Instructions required to design a bandpass Chebychev infinite impulse response digital filter.**

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rp=3; Rs=100;</td>
<td>Specify the passband and the stopband corner frequency ranges,</td>
</tr>
<tr>
<td>( [n, Wn] = \text{cheby2ord}(Wp, Ws, Rp, Rs); )</td>
<td>Filter order n and the actual corner frequencies</td>
</tr>
<tr>
<td>([b,a] = \text{cheby2}(n, Rs, Wn); )</td>
<td>Perform the design and calculate the raw coefficients</td>
</tr>
<tr>
<td>([sos] = \text{zp2ss}(z, p, k); )</td>
<td>Convert the pole zero values into second order coefficients</td>
</tr>
<tr>
<td>( \text{freqz}(b, a, 512, 1000) )</td>
<td>Plot the frequency characteristics of the filter</td>
</tr>
</tbody>
</table>

Fig. 3. When subjected to a single impulse, the impz function allows the response of the system to be visualised with ease.

Fig. 4. Determining the positions of the poles and zeros in the z-plane unit circle gives information on possible problems that may occur for poles lying close to the perimeter. If through quantisation effects they should stray outside the unit circle the system becomes unstable.

Fig. 5. Graphical results from the design of a digital filter using the instructions in Table 1. This example shows that Elliptical filters are unsuitable for systems which require linear phase response.
is now a well established method of specifying the required filter characteristics. However the two functions remez and remezord in the toolbox have to be set up in a manner which departs from conventional wisdom thus rendering them less amiable than they could be.

Analysis of spectra
The toolbox has a number of useful functions for investigating the spectral content of signals, both periodic and signals contaminated by noise. In addition to the usual FFT, DFT there is a choice of the Chirp z-transform and a reasonable array of window functions to pre-process the data before performing spectral analysis.

An interesting function also included is specgram ie is a spectrogram for analysing speech signals. It displays frequency and magnitude information versus time. Figure 6 is an example of the spoken word *matlab*. Magnitude is colour coded – red for the largest magnitude and blue for the smallest. For noise contaminated signals, the user can first perform auto-correlation, xcorr, on the data before subjecting to the Fourier transform. In many instances this improves performance of the spectral analysis.

Generally the toolbox has a reasonable array of spectral analysis tools, however one deficiency is the waterfall function. This function would partition a signal into several segments, perform a FFT on each segment and display a three dimensional plot – magnitude versus frequency versus time. There is however a feature for partitioning a signal into segments only and displaying them as a strip plot, strips. An example of its output is shown in Fig. 7.

The signal processing toolbox possesses a number of alternative tools for deriving spectral information. These are categorised as parametric modelling and are useful for analysing non-stationary signals – for example speech.

User manual
The manual accompanying Toolbox is well written, beginning with a tutorial section covering each group of the signal processing toolbox’s functions. In the reference section of the manual there are the all important examples which can save an enormous amount of time when trying to master their use. The manual is quite indispensable when using this package.

Conclusion
Most functions in the signal processing toolbox can be accessed with relative ease and incorporated into a user’s *Matlab* model. They are not as comprehensive as I would like and there are some noticeable omissions such as adaptive filters.

There could also be more functions for implementing lattice filters. However, in general this package will prove a very useful tool for the electronics engineers involved in digital signal processing and systems design.

Availability
Toolbox is available from Rapid Data, Crescent House, Crescent Road, Worthing, West Sussex BN11 5RW. Tel. 01903-202819, fax. 01903-820762. Price of *Matlab* package is currently £1376 and Signal Processing Toolbox is £325, both excluding VAT. These prices include documentation and technical support. Add £25 for delivery of *Matlab* with the signal processing Toolbox or £15 for the Toolbox alone.
SINGLE IN LINE 32 WAY CAN BE GANGED FOR USE WITH ANY PLASTIC 3055 OR 2955 equiv 50p

POWER FET IRF9531 8A 60V TRANSISTORS

£1

LM350K (VARIABLE 3A)

£2.50

2732-45 USED £2.10 per 100

2708 USED £1.60 per 100/10

24402 -15 80C31 MICRO 041256C-15 2561041 PULLS 9 FOR £5

S9900 NEW AMD EQUIVALENT

COMPUTER ICS

TEL. 01279-505543

PO BOX 634

CIRCLE NO. 122 ON REPLY CARD

SEND £1 STAMPS FOR CURRENT IC + SEMI STOCK LIST - ALSO AVAILABLE ON KEYSTONE

IC SOCKETS 200/£1

IC MODELS 2/£1

POLYESTER/POLYCARB CAPS 300p/10 0.63 CONDENSERS 1020p 0.63 RATED 105°C ±10%

RF BITS

337S.2HZ 3 IRF510 2N3904 40 Transistor Kit 2.5A 15W TOP QUALITY

MONOLITHIC CAPACITORS 1000/£6 (EH 20%)

PHOTO DIODES

351A 1N3330 UNIF AC COOLING MODULES 50 μA /250mW £10

TRANSISTORS 2N4427, 2N3866 VIOLET ALL TRIMMERS

FEED THRU CERAMIC CAPS 1000pF £1

BAR 1/2 AA SIZE 100/£3 1004030

CENTRONICS 36 WAY IDC PLUG £2.50

BA158 1A 400V fast recovery 100/£3

CERMET MULTI TURN PRESETS 1/8 each 20/£4 1200/£20 5% TOLERANCE 1004030

200/£1 30V 2.2μF BUTTERWORTH 5% TOLERANCE

2μF 25μF 1μF 10μF 22nF 100nF 1μF 10μF 22nF 100nF

DISPONIBILIDAD DE DIODOS PNP Y NPN EN EL MERCADO

SEND £1 STAMPS FOR CURRENT IC + SEMI STOCK LIST - ALSO AVAILABLE ON KEYSTONE

SPORTS CARPETS

102/£1

RF BITS

337S.2HZ 3 IRF510 2N3904 40 Transistor Kit 2.5A 15W TOP QUALITY

MONOLITHIC CAPACITORS 1000/£6 (EH 20%)

PHOTO DIODES

351A 1N3330 UNIF AC COOLING MODULES 50 μA /250mW £10
19" RACK CABINETS
Superb quality 600 4 UOTV
Virtually New, Ultra Smart
Less than Half Price!
Top quality 19" rack cabinets made in UK by Optimum. Complete with MCBs, socket outlet, and power distribution. Only £99 +VAT (inc). Optimised design, smoke acrylic lockable door, full height venting, low profile adjustable rear panel. Supplied complete with integral fans to the sub plate etc. Other features include: fitted integral fans to the sub plate etc. Available with or without integral fans. Power cable / connector access etc. Supplied in excellent, slightly used condition. Overall dimensions: 77.5 x 492 x 108.5. Includes 48 x 1U mains and 4 x 0V leads. Rrp: £195.00

32U - High Quality - All steel RackCab
Made by Eurocredit Enclosures Ltd to the highest possible spec, rack is made from steel cold rolled sheet. Supplied complete with side panels, front and back doors. Front and back doors are hinged. Three 32U 19" wide cabinets, each fitted with a fully secure lever barrel locks. The door is constructed of double wall welded steel with a removable face plate. The 32U monitor with full face plate can be fitted with a removable front. The two movable vertical fixing struts are provided so that the face plate can be mounted at any angle in a manner not available in the popular 'cage nets'. A major feature of the panel distribution integral mounted to the bottom rear panel. The 32U is intended for fitting of integral fans to the sub plate etc. Other features include; fitted integral (on request) 6 x 1U power input, integral fans to the sub plate etc. Cabinet size: 4U, 1000mm x 600mm x 600mm. Rrp: £279.00 (ex VAT)

SOLD AT LESS THAN A THIRD OF MAKER'S PRICE!!
A superb buy at only £195.00 (G)
Over 1000 racks in all sizes 19" 22" & 24" 3 to 44U.
Available from stock!!
Call with your requirements.

TOUCH SCREEN SYSTEM
The ultimate in "Touch Screen Technology" made by the experts. MicroTouch- but sold at a price below cost It System consists of a full translucent glass laminated panel measuring 29.5 x 23.5 cm complete with computer interface. The system is designed to accept a standard RS232 or TTL output which continuously gives you control over a myriad of applications including: control panels, monitor devices, game controllers for the disabled or virtually every type of power sense. The Display Electronics PC99 system comprises of fully compatible 1.4Mb 31/2" floppy disk drive (instead of 1.2 Mb) and 51/2" SEAGATE ST-238R 30 mb RLL I/F Refurb £69.95

3½" CONNER CP3044 40mb IDE I/F (or equiv.) RRP £89.00 C

Virtually every type of power sense. The Display Electronics PC99 system comprises of fully compatible 1.4Mb 31/2" floppy disk drive (instead of 1.2 Mb) and 51/2" SEAGATE ST-238R 30 mb RLL I/F Refurb £69.95

SUPPLEMENTARY ISSUE - ISSUE 13

FOR MORE INFO, CALL FOR FREE LEAFLET or WRITE ON OUR ORDER FORM

**END OF PAGE**
The main disadvantage of using the printer port for analogue and digital I/O is that you have to unplug the printer. Or do you? Alan Bradley explains.

The usual way of expanding a pc is via an internal card. This has the disadvantage of requiring an accurately made double-sided pcb with gold-plated edge connectors, and the designer needs to understand the pc’s 8/16bit expansion bus signals.

An easier way is to use the Centronics parallel printer port. This port is standard, whereas internal expansion buses vary from ISA, PCI, MCA, to none at all. Extra Centronics printer cards are very cheap - between £9 and £18, and a pc can support up to three such ports if required.

In this design, a printer pass through facility is included, allowing a printer to share the same port. This obviates the need to open the pc to insert an extra LPT expansion card, and prevents the possibility of address clashes.

The printer port has eight data output lines. Since most pcs don’t have bidirectional data lines, the printer port’s status lines are used as input lines instead. For example, 8bit data can be read as four bits at a time using four of the port’s five input status lines.

The LPT port also has four control output lines. These can be used as digital output lines and for selecting either the upper or lower input nibble.

The pc’s LPT port

Each LPT parallel printer port has three 8bit registers – the data latch, the status register and the control register.

Writing to the data register, D_L, causes the byte sent, to be latched and to appear on the parallel port’s 25way D connector, pins 2-9. In this design, this data is then sent to either the d-to-a converter or digital output port.

Normally, reading this register returns the contents of the latch. The status register, B_L, is a read-only register holding the state of BUSY, ACK, PE, SLCT and ERROR input lines from the printer. These are on lines b_3 respectively. Input BUSY is inverted between the D-connector, pin 11, and the register. Bits b_2 are unused.

The control register is an output latch holding the four printer control signals – /SLCT-INV, /INIT, /AUTOFEED and /STROBE. These are bits b_4 respectively. Interrupt bit b_4 determines whether an interrupt is generated by a falling ACK input – 0 represents interrupt disabled. I always disable this bit as it is rarely used by printer software. This leaves IRQ channels 5 and 7 available for other expansion cards.

Bits 0, 1 and 3, ie /STROBE, /AUTOFEED and /SLCT-INV, are inverted between register and the D-connector output pins. This inversion is corrected again when the control register is read. Parallel port signals are at ttl levels and are presented on a 25-way D connector, shown on the circuit diagram.

The pc parallel port is specified as having open collector outputs, but the pcat version uses standard ls-ttl devices. The three sets of addresses that can be assigned to parallel ports LPT1, LPT2 and LPT3 are,

Groups of pc i/o addresses reserved for LPT use.

<table>
<thead>
<tr>
<th>Port</th>
<th>Data</th>
<th>Status</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPT(n)</td>
<td>378_{16}</td>
<td>379_{16}</td>
<td>37A_{16}</td>
</tr>
<tr>
<td>LPT(n)</td>
<td>27B_{16}</td>
<td>27B_{16}</td>
<td>27A_{16}</td>
</tr>
<tr>
<td>LPT(n)</td>
<td>3BC_{16}</td>
<td>3BD_{16}</td>
<td>3BE_{16}</td>
</tr>
</tbody>
</table>

Note that register addresses assigned to each parallel port vary depending on the pc type.

Information on parallel port addresses and the number of ports fitted can be found in the Bios data area, Bios addresses containing information on pc parallel port address locations.

<table>
<thead>
<tr>
<th>Address Description</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base address of parallel port 1 (LPT1), low byte</td>
<td>0:408_{16}</td>
</tr>
<tr>
<td>High byte for above</td>
<td>0:409_{16}</td>
</tr>
<tr>
<td>Base address of parallel port 2 (LPT2)</td>
<td>0:40A_{16}</td>
</tr>
<tr>
<td>High byte for above</td>
<td>0:40B_{16}</td>
</tr>
<tr>
<td>Base address of parallel port 3 (LPT3)</td>
<td>0:40C_{16}</td>
</tr>
<tr>
<td>High byte for above</td>
<td>0:40D_{16}</td>
</tr>
<tr>
<td>Hardware info., bits 15-14 = No of LPT ports</td>
<td>0:410_{16}</td>
</tr>
<tr>
<td>High byte for above</td>
<td>0:411_{16}</td>
</tr>
</tbody>
</table>

Useful ICs

While designing the interface, I have found the following 74 series ICs useful. Each is available in a variety of forms, including LS, ALS and HCT. The type chosen will depend on a number of criteria, including budget, speed and power consumption.

The ’139 is a 2-4 line decoder useful for selecting between four interface i/o ports while the ’138 decodes three lines to eight and is useful for applications with eight ports. Selection between the upper and lower nibbles of the input byte can be carried out by a ’157 quad 2-1-line multiplexer. Alternatively, a ’241 dual or ’244 quad tristate buffer can select the upper or lower nibble.

A ’573 or ’373 octal transparent latch can form an 8bit digital output port. With its enable pin high, the outputs follow the inputs; when it is low outputs are held latched. For 8bit digital input, a ’245 octal transceiver can be used. A
'541 or '244 buffer can also be used here, depending on which produces the most convenient pcb layout.

When reading data through the status port, the busy bit must be inverted, for example by exclusive-or-ing it with 10000002. On fast machines, the interface-controlling program may need software delays to allow the parallel port control lines to settle after a change.

**Design details**

This design provides a fast 8bit a-to-d converter with integral sample and hold, a fast 8bit d-to-a converter and a pair of 8bit digital i/o ports. The a-to-d and d-to-a converter are both capable of audio sampling and playback.

In my prototype, the lower D-type plug shown in the drawing was pcb mounted. This plug connects to the pc printer port. The upper D-type, also pcb-mounted, connects to the printer, providing the 'pass through' facility.

Note that IC6 – a 74LS157 quad 2 to 1 line multiplexer – must be a ttl type as its inputs are left floating when neither the a-to-d converter nor digital input port are selected. In addition, IC14, and IC9 should be ls-ttl types, as cmos ICs would require input static protection circuits.

The remaining pcb-mounted D-type socket brings out both 8bit digital ports, the digital ground rail and +5V into the real world.

Analog Devices AD7569JN, IC10, is an 8bit a-to-d converter with integral sample and hold facilities and configured for mode 2 operation and for an input range of 0-2.5V. Bringing the read line low when chip select is active low selects the a-to-d converter, starting the conversion. The converter’s busy line is not used so a software delay is needed to determine when the conversion will be complete. Conversion time should be less than 2.6µs.

Eight-bit a-to-d converter IC11, a ZN558, has an integral transparent latch and a range of 0-2.5V. Single supply op-amp IC12, an LM358, buffers the d-to-a converter output and its 2.5V reference.

Resistors R25,26 help prevent the op-amp from oscillating due to cable capacitance and also protect it from short circuits. A dc path to ground to prevent cross-over distortion is provided by R24.

A further LM358, IC13, is configured as a unity gain buffer to protect the AD7569 voltage input. The 7569’s input pin sources approximately 10µA and R27 helps the op-amp sink this near 0V.

Analogue input and output combined with eight digital inputs and outputs – all controlled via the pc’s LPT port. Unlike most interfaces relying on LPT i/o, this design allows the printer port to be used for printing without physically changing connections.
I/O interface key components

<table>
<thead>
<tr>
<th>IC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC4</td>
<td>74ALS244</td>
</tr>
<tr>
<td>IC5</td>
<td>74ALS139</td>
</tr>
<tr>
<td>IC6</td>
<td>74ALS157</td>
</tr>
<tr>
<td>IC7</td>
<td>74ALS240</td>
</tr>
<tr>
<td>IC8</td>
<td>74ALS573</td>
</tr>
<tr>
<td>IC9</td>
<td>74ALS244</td>
</tr>
<tr>
<td>IC10</td>
<td>AD7569/N a-to-d</td>
</tr>
<tr>
<td>IC11</td>
<td>ZN558 d-to-a</td>
</tr>
<tr>
<td>IC12</td>
<td>1LM358</td>
</tr>
<tr>
<td>IC14</td>
<td>7805, 1A version</td>
</tr>
</tbody>
</table>

For easier pcb layout, broadside ICs could be used - for example IC4, IC7, IC8, IC9, IC10, IC12, IC13, IC11.

C1, C2, 5-15 0.1 pF cer.
C1, C3, C4 led 5mm red
D3 IC14
IC12, IC13
IC11
IC10
ICs could be used - for example IC1, IC8, IC10, IC11, IC12, IC13.

Interface board register usage

Data lines do,1 are used for the d-to-a converter and digital output port. The four status input lines, BUSY, ACK, PE and SLCT, b1-b4, are used to read the upper or lower nibble of the input byte. The four control output lines are used to select either the upper or lower input nibble. They also control printer pass through, analogue input or output and digital input or output.

In the control register, bits 0, 1, and 3 are inverted before the control register and corresponding D-con- nector output pins. The SLCTINP line is normally used to select or deselect the printer, a low level signifying selection. It has therefore been used to switch between the analogue and digital i/o circuitry and the printer pass-through facility, selected when SLCT-INP is low as normal. Analogue and digital i/o circuitry is selected when SLCTINP is high, and the printer is deselected.

Consequently, when b3 of the control register is high, the corresponding pin 17 on the D connector is high and IC3,4 are tri-stated. The enable pin RSLCTINP is held high.

Resistor RSLCTINP pulls the printer SLCTINP pin low, ie printer deselected. Alternatively, when line b3 of the control register is low, the corresponding pin 17 of the D connector is high and IC3,4 are tri-stated.

The four status buffer pins of IC3, b1-4, are selected when SLCT-INP is low as normal. The enable pin is held high.

Resistors R90-51 in series with the output buffers driving the printer need to be 332.

The pc parallel port is now connected via buffers to the printer thus allowing normal use of the printer. Resistors R90-51 in series with the output buffers driving the printer need to be 332.

Control software example

This QBASIC program demonstrates how the analogue and digital i/o circuitry can be controlled. It reads the a-to-d converter, prints the value on the screen then sends it to the d-to-a converter.

```
DEFINT A-Z

\* string ch$ \* int uppernibble, advalue, dloop \* int d is used in dummy INP loads \* int PDATA, PSTATUS, PCONTROL hold \* LPT1 reg addresses

DEF SEG = 0
\* FIND ADDRESSES of Lpt1
PDATA = (PEEK(48109) + 256) * PEEK(48108)
\* PDATA + a to d output buffer \* PDATA = (PEEK(48109) + 256) * PEEK(48108)
\* PDATA = PSTATUS + 1 \* PRINT PORT
PCONTROL = PDATA + 2 \* \* PRINT RESISTORS
PRINT NE1X(PDATA)
\* OUT PCONTROL, 4H \* d = PDATA \* correct BUSY inversions \* 'ie invert bits 7 and 3
PRINT 'ACC input byte is", advalue
\* OUT PDATA, advalue \* set up DAC value
d = INP(PDATA)
\* wait for lines to finish\* \* REM latch into DAC
PRINT "Press Q key to quit. Any other to continue"
ch$ = INPUT$(1)
\* LOOP until ch$ = 'Q' or ch$ = 'q'
OUT PCONTROL, 4H \* \* 'dis IRQ,0,upper nibble,sel DAC,0000
1000 \* REM latch into DAC
PRINT "Enter upper nibble of DAC byte"
\* OUT PDATA, advalue / 16 \* 'set up dac value
advalue = INP(PDATA) AND $FF \* 'dis IRQ,0,upper nibble,sel DAC,0000
\* \* 'AD7569JN a-to-d converter is configured for \* \* \* 'mode 2 operation. Bringing read low while chip-select \* \* 'is low selects the device and starts conversion.
\* \* 'Since the converter's busy line is not used a \* \* 'software delay is needed to determine when \* \* 'the conversion will be complete. Conversion time should \* \* 'be less than 2.6us.
```

Applying the design

The LM358 input and output buffers have a slew rate of 0.5 V/µs so limiting the analogue input and output frequencies to approximately 50kHz. Maximum frequency is given by,

\[ f_{\text{max}} = \frac{\text{slew rate}}{2\pi \times \text{sinewave amplitude}} \]

where slew rate is in volts/s.

The AD7569/N a-to-d converter is configured for mode 2 operation. Bringing read low while chip-select is low selects the device and starts conversion.

Since the converter's busy line is not used a software delay is needed to determine when the conversion will be complete. Conversion time should be less than 2.6us.
When Performance is more important than size:
two new re-programmable BASIC Stamp Computers.

**BS1-IC**
- 8 I/O lines
- up to 100 program lines
- 2,000 lines/sec
- Comms to 2400 baud
- **£29** single price

**BS2-IC**
- 16 I/O lines
- up to 600 program lines
- 10,000 lines/sec
- Comms to 9600 baud
- **£49** single price

Programming package **£66**

Milford Instruments Tel 01977 683665 Fax 01977 681465

---

**DID YOU KNOW?**

More than half the world's PCs
wake up to our BIOS!

And we're doing pretty well
with hardware products too!

**Motherboards:**
- TITAN - 2 x P5 EISA/PCI
- ATLAS - P5 ISA/PCI
- APOLLO - P5 Triton ISA/PCI
- ATLAS LPX - P5 Triton ISA/PCI

**Peripherals:**
- MegaRAID™ - PCI/SCSI/RAID

And more...Call us for more information!
**PLUS - Coming soon PC-CARE™**
(AMI迪ag for Windows)
Watch this space!

OEM enquiries welcome on all products,
Hardware / Software and BIOS.

American Megatrends Intl. Limited
Unit CS, Worth Corner, Pound Hill, CRAWLEY, W. Sr. RH10 7SL
Tel 01293 882288 - Fax 01293 886550

---

**SYNTHESISED SIGNAL SOURCE**

An innovative design from an established 'Off-Air' Company
- Custom designed chip set
- Sinewave output (0dBm into 50Ω)
- Can be run independently or genlocked to external source
- dc to 16MHz in 0.1Hz steps, with option 0.0001 Hz steps
- Freestanding rack mounting, or OEM options available
- Increased resolution and increased stability options available
Models available October, contact us for prices

**‘OFF-AIR’ FREQUENCY STANDARD**

**NEW from Halcyon**

**CIRCLE NO. 126**

Variants from
**£249+VAT**

---

**TEST EQUIPMENT**

We are well known for our quality, new and used Test Equipment. Our list is extensive, ranging through most disciplines. Call for details and a complete list

**CIRCLE NO. 128**
CIRCUIT IDEAS

Do you have an original circuit idea for publication? We are giving £100 cash for the month’s top design. Additional authors will receive £25 cash for each circuit idea published. We are looking for ingenuity in the use of modern components.

Static noise limiter

Noise limiters usually rely on either low-pass filtering or companding methods. Both of these methods have disadvantages in either cost or performance.

This alternative uses a peak detector. The signal diagrams on the right show an ideal principle, in which the noise superimposed on the sine wave is averaged to leave just the signal – shown by the heavy line.

Since I have not found a way to do this, the alternative adopted is to detect the noise-plus-signal peaks to produce an approximation of the original signal, bottom right.

In the circuit shown, the input op-amp buffers the signal, which is applied to the bases of the peak-detecting transistors through $C_1$. Bias is provided by $V_R_1$ and $R_2$. On a positive signal, $C_2$ charges via $R_3$ and $C_2$ holds positive peaks; when signal goes negative, negative-going peaks are held on $C_2$, which now charges through $R_4$. An output buffer completes the circuit.

The amount of limiting is set by $V_R_1$ and the dead zone is adjustable by $V_R_2$ over a wide range. Some distortion is caused by the transistor switching, but in many circuits is less troublesome than noise.

J Macaulay
Chichester,
Sussex.

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.
Tinsley Transportable Voltage Reference - £500.

TEK FG5010 Programmable Function Generator 20Mc/s - £600.

Tektronix Mixers are available for above ANZ to 60GHz.

TEK 7L5 + L3 - Opt 25 Tracking Gen - £900.

TEK 7L5 + L1 - 20Hz-5Mc/s - £700.

TEK 496P 1KHz-1.8GHz - £4k.

December 1995


Racal/Dana 9301A - 9302 RF Millivoltmeter - 1.5-2GHz - £500.

HP Frequency Counter type 5340A - 18GHz f1000 - rear output £800.

HP Amplifier type 8447A - 1-400Mc/s £200 - HP8447A Dual - £300.

HP Frequency comb generator type 8406-6400.


HP54200A Digitizing Oscilloscope.

HP745A+746A AC Calibrator - £000.

FLUKE 51028 AC-DC Calibrator - £4k.

ROTEK 320 Calibrator + 350 High Current Adaptor AC-DC - £000.

TEK A6902A also A69026 Isolator - £000-£400.

Racal/Dana 9303 True RMS Levelmeter + Head - £450. IFFE - £500.

Racal/Dana 1250-1261 Universal Switch Controller + 200Mc/s PI Cards.

Racal/Dana 2101 Microwave Counter - 10Hz-20GHz - £2k.

Marconi TF2305 Modulation Meter - £2.3k.

Marconi TF2442 Microwave Counter - 26.5GHz - £2k.

Marconi TF2370 as above but late type Brown Case - £1000.

HP8901A Modulation Meter AM - FM - also 890113.

HP59501B Isolated Power Supply Programmer.

HP5335A Universal Counter A+B+C.

HP5316A Universal Counter A+B.

HP3779A Primary Multiplex Analyser.

HP10513 Quartz Oscillator - £400.

HP8182A Data Analyser.

HP3770B Telephone Line Analyser.

HP3770A Amplitude Delay Distortion ANZ.

HP Plotters 7470A - 7475A.

HP461A-465A-467A Amplifiers.

HP8640A Signal Generators - 1024Mc/s - AM FM - £800.

Systron Donner 1618B Microwave AM/FM Synthesizer 50Mc/s 2-18GHzs

HP8673D Signal Generator .05-26.5GHz - £20k.

TEK 492 - 50KHz -18GHz Opt 1+2 - £4k - £4.2k.

HP Mixers are available for the above ANZ's to 40GHz.

HP8569B 10Mc/s-22GHz ANZ - £6k.

HP8443A Tracking Generator Counter 100KHz-110Mc/s - £300.

HP8554B RF 100KHz to 1250Mc/s - £500.

HP 855213IF - £000.

HP ANZ Units Available separately - New Colours - Tested

Special Offer just in from MOD Qty 40 HP8555A RF Units 10Mc/s - 18GHzs.

HP141T + 855213 IF + 8554B RF - 100KHz-1250Mds - £900.

SMALL SELECTION ONLY LISTED - EXPORT TRADE AND QUANTITY DISCOUNTS - RING US FOR YOUR REQUIREMENTS WHICH MAY BE IN STOCK

40GHz - £1000 or PI only £600. MF only £250.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.

£250-£350. 400Mc/s to 18GHz.
Fast-logic isolator avoids ground problems

Two circuits, working at clock frequencies up to 100MHz, isolate the ground currents between two instruments to prevent the transmission of noise currents. Both circuits use twisted-pair lines. Ecl-ttl and ecl-ecl logic types are both catered for.

Opto-isolators do, of course, perform this function, but not at this frequency; their bandwidth is limited to around 40kHz. Therefore, a transformer is needed, the type

<table>
<thead>
<tr>
<th>Input waveform</th>
<th>Jumper setting</th>
<th>Note:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Period: pulse width limit 100:35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i.e. for every 100µs period (1MHz) the maximum pulse width is 350µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Period: pulse width limit 100:40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i.e. for every 100µs period (1MHz) the maximum pulse width is 400µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tolerance of duty cycle ratio of the squarewave waveform ±30%</td>
</tr>
</tbody>
</table>

This jumper function diagram applies to both the ttl and ecl-output isolators.

Circuits to isolate or break the path between instruments and host computer to avoid ground currents interfering with analogue equipment.

Richard Payne
Wimbledon
London

December 1995 ELECTRONICS WORLD + WIRELESS WORLD
HART Audio Kits and factory assembled units use the unique combination of the very best audiophile components, and our own engineering expertise, to give you the best performance for your money. We have always led the field for easy home construction to profes-
sional standards, and our kit customers are a regular source of praise to us when Hart audio was still using the wire. Many years of experience and innovation, going back to the early Sixties, produce units which use new design technology as a basis for the field. The full cost can be credited against your subsequent purchase of a kit or a factory assembled unit. The Hart way. The CLASSIC WAY.

**K1100 AUDIO DESIGN 80 WATT POWER AMPLIFIER.**

This kit is your way to get OK performance at bargain basement prices while building a Hart kit is a real pleasure, resulting in a piece of equipment that will last for many years. Hart Audio Kits and factory assembled units use the unique combination of high quality components and ease of construction. Useful options are stereo LDO power supplies, front and rear jacks, and a versatile variable resistor.

**ALPS “Blue Velvet” PRECISION AUDIO CONTROL.**

Now you can throw out those messy ratcheted potentiometers and replace them with the Hart exclusive ALPS “Blue Velvet” range of precision pots. Not only can these unique components be used in the top flight of high-end audio amplifiers, but also in the most demanding pro audio applications. Their precision and reliability are incredible and will be a real eye-opener for any audiophile. Hart Audio Kits and factory assembled units use the unique combination of high quality components and ease of construction. Useful options are stereo LDO power supplies, front and rear jacks, and a versatile variable resistor.

**“Andante” SERIES 20VA AUDIOPHILE POWER SUPPLIES.**

Specially designed for matching audio power supplies ability in the maximum range. This kit is your way to get OK performance at bargain basement prices while building a Hart kit is a real pleasure, resulting in a piece of equipment that will last for many years. Hart Audio Kits and factory assembled units use the unique combination of high quality components and ease of construction. Useful options are stereo LDO power supplies, front and rear jacks, and a versatile variable resistor.

**TECHNICAL BOOKSHELF.**

Following the enormous success of our “Art of Linear Electronics”, this latest offering is the all-new edition of “Audio Electronics”, now entirely written by the master himself. Understanding audio techniques and equipment is a world of electronics that determines the quality of our music. For anyone interested in designing, adapting or using digital or analogue audio equipment under optimal conditions, this book is invaluable. It is destined to become the standard reference for all who work, or are interested in, the much neglected field of linear electronics. This unique and comprehensive work is a must for any audiophile.

**SOLDERING.**

The size of modern components makes the right soldering equipment essential for good results. Everything we offer after we actually use in our own workshops. Our lists for the full range. 845-820 X5240 (240-287). This is the ideal MIG-purist rungs the bit is designed to totally surround the element giving the best possible performance over a worn head. Only the fact that wear can impair the frequency response and distortion levels. Our soldering iron kit has been designed to meet the highest standards of quality, such as durability and efficiency. The excellent performance of modern cassette recorders depends totally on the quality of the B.P. head. Even the smallest amount of wax can impair the frequency response and distortion levels. Our soldering iron kit has been designed to meet the highest standards of quality, such as durability and efficiency.

**HART SUPEROGRAPHIC SILVER SOLDER.**

Hart Super Audiograde Silver Solder has been specially formulated for the serious audiophile. Not only does it give beautiful easy-to-melt solder great freedom to flow but reduces the possibility of thermal damage to components or the need for special high temperature coats. A very low residue flux makes perfect joints easy but eliminates the need for heat building after assembly.
Video transmission on vhf

Only two transistors are needed to transmit audio and video to a tv capable of receiving channel 4 on vhf.

Transistor Tr1 is a channel 4 oscillator and mixer. The second transistor is simply a 5.5MHz oscillator.

The coils are critical. Inductor L1 is eight turns of 24SWG copper wire wound on a 1cm air-cored former. Coil L3 is a ready-made and readily available SW1 oscillator coil. Five turns of 36SWG, wound around L3, form L2. Capacitor and resistor leads should be kept as short as possible.

To calibrate the transmitter, first set L1 by stretching or compressing its coils until it is tuned to channel 4. The screen will blank when tuning is correct. Next set the 5.5MHz oscillator using either a frequency meter or a short-wave radio. Using a short-wave radio tuned to 5.5MHz, rotate variable-capacitor C11 and, if necessary the core of L3, gently until you hear a hiss on the radio. The circuit is now ready to operate. Finally, with video and audio sources connected and with a tv tuned to channel 4, adjust R3 for best results.

Raj K Gorkhali
Kathmandu
Nepal

Capacitorless solid-state relay

In this solid-state relay, there are no capacitors, hence no time dependencies. This, and the fact that the circuit can be made small, make the design suitable for implementing as a monolithic or hybrid IC.

Bridge D14 with the zener diode clamp the voltage, providing the opto-isolator with a supply lower than its breakdown voltage. The isolator and its associated transistor act as a load for diode bridge D5G. They change the equivalent ac resistance across the input of the bridge.

Because of this, the firing pulses always have the same polarity as the anode voltage and they appear every half wave to ensure a symmetrical output waveform. In this way, any load specified for ac will not be damaged by rectified mains voltage.

Zero-crossing circuitry, comprising two discrete transistors, reduces interference, increases reliability and provides soft starting. When the zener diode turns off, the transistors shut down the corresponding part of bridge D5G. Current is limited by R3.

In the case of an inductive load, voltage at the anode of the triac is displaced by 90°. Because of this, the supply for the opto-isolator is taken from the anode and not from the line, to ensure correct phase of the firing pulses.

T. Manov
(address not supplied)
Hewlett Packard 8683D

Solid State

Microwave Signal Generators

2.3-13 GHz Freq

Range Wideband

FM for satellite

AM/FM & pulse

modulation

Built in pulse generator Options 001/003 fitted

£2,950 + Carriage + VAT

Supplied fully tested in as new condition.

With 30 days parts & labour warranty.
Simpler, but linear, pwm generator

Since the width of an exponential rise and fall varies linearly with voltage, it can be used to replace a linear sawtooth in some applications. Here, it replaces the sawtooth in a pulse-width modulator, shown in the smaller diagram, where the sawtooth is taken to one input of a comparator and a direct voltage to the other. Mark-space ratio of the resulting constant-frequency square wave varies linearly with the direct voltage level.

In the second diagram, the exponential waveform across the capacitor of a standard op-amp relaxation oscillator is used for the same purpose; linearity with control voltage over the full range of zero to unity is within 0.5%. In this way, the circuit is cheaper than the sawtooth variety, since an accurate sawtooth generator in its simplest form consists of an integrator and comparator in a feedback loop. At frequencies of less than a few kilohertz, an LF353 dual op-amp is adequate, giving an economical design. For higher frequencies, a high slew-rate op-amp such as the LM53 I is needed and an LM311 fast comparator will provide steep edges on the output.

D K Hamilton  
Department of Engineering Science  
University of Oxford

Programmed bandpass filter

Clock frequency applied to a switched-capacitor filter determines the -3dB frequency, which means that such filters are programmable. It also means that, if two filters have slightly differing clock frequencies, a bandpass filter can be made.

If the output of one filter is made to be 180° out of phase with the other, by inverting in an op-amp, and the two outputs added, circuit output is low at low frequencies because the two outputs cancel. At high frequencies, output is again low because the filters have a low-pass configuration; and in the band between the two corner frequencies output is high since they do not cancel, one being too low in amplitude.

Here, the MAX292 eighth-order, low-pass Bessel filter, which contains an uncommitted op-amp, exhibits a corner frequency of \( f_{\text{eq}}/100 \), two 4017 counters \( IC_1 \) and \( IC_2 \) dividing the clock input by 9 and 10 respectively.

Input goes to both filters, the output of \( IC_3 \) being inverted by the internal op-amp and added to the output of \( IC_3 \) by the device's op-amp, the resulting output having the characteristics described above. The table shows what happens; the curve is steeper above the centre point than below, due to the behaviour of the eighth-order filters. Frequency of the centre-point depends solely on the clock frequency.

Yongping Xia  
Torrance California USA

Peak frequency of this switched-capacitor bandpass filter is determined only by the clock frequency.

---

Prom and logic array in harmony
Due to an editorial error the last line in this piece should have read "of the prom on the address line A14". Our apologies if this was misleading.
Programming Solutions

Multi-Device Programmer
- EPROMs, E'PROMs, Flash EPROMs, Serial E'PROMs, 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.

Universal Programmer
- Uses standard pc printer port works with notebook and handbook pc's
- Pin driver expansion can drive up to 256 pins.
- Supports over 2000 IC's – 3 and 5 volt devices.
- EPROMs, E'PROMs, Bipolars, Flash, Serial EPROMs over 150 microcontrollers, WSI/Philips PSDs, PLDs, EPLDs, PEELs, PALs, GALs, FPGAs including MACH, MAX, MAPL & Xilinx parts
- Universal DIL (up to 48 pins), PLCC and gang PACs
- Powerful full colour menu driven software.
- Approved by AMD, TI, NatSemi, etc...
- Tests TTL, CMOS and SRAM devices (including SIMMS)

Eprom Programmer
- EPROMs, E'PROMs, Flash and 8748/51 micros.
- Fast programming algorithms. Simple colour menu operation.

EMULATORS • SIMULATORS • COMPILERS • ASSEMBLERS PROGRAMMERS • 8051 8085 Z8 68020 77C82 80C552 320C25 68HC11 6301 6502 87C751 65816 780 6809 PIC 7720 MIPS etc.

STABILIZER 5

In any public address system where microphones and loudspeakers are in the same vicinity, acoustic feedback (howlround) 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 4kHz-30MHz * Stereo Variable Emphasis Limiter 3 * 10-Outlet Audio Distribution Amplifier 4 * PPM10 In-vision PPM and chart recorder * Twin PPM Rack and Box Units * PPM5 hybrid, PPA9 microprocessor and PPM6 IEC/DIN – 50+/24dB drivers and movements * Broadcast Stereo Coders * Stereo Disc Amplifiers * Peak Deviation Meter for FM broadcasting

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh GU6 7BG
Phone: 01483 275997 Fax: 276477

PORTABLE PROGRAMMER & EMULATOR
PROGRAMS EPROMS/FLASH TO 40 PINS WITHOUT ADAPTORS EMULATES 8 & 16 BIT SYSTEMS

Its an easy touch for anyone

Ideal for R&D or small volume production. ISO 9002 manufacture and strict use of manufacturers algorithms guarantees reliable programming.

Lloyd Research Ltd.
7 & 7a Brook Lane, Warsash, Southampton, Hampshire S031 9FH, England.
Tel: +44 (0)1489 574040.
Fax: +44 (0)1489 885653.

CIRCLE NO. 133 ON REPLY CARD

2 Field End • Arkley • Barnet • Herts • EN5 3EZ • England
Telephone +44 (0)181 441 3890 Fax +44 (0)181 441 1843

CIRCLE NO. 132 ON REPLY CARD

December 1995 ELECTRONICS WORLD+WIRELESS WORLD

CIRCLE NO. 137 ON REPLY CARD

1057
Power modules for quasi-resonance

Relative to both monolithic and discrete technologies, power multi-chip modules provide an excellent compromise for quasi-resonant switch-mode power conversion. Paul Greenland, M. Ueki and M. J. Lee explain.

This article describes a new power multi-chip module – pmcm – which has evolved from consumer electronics applications and has considerable potential in general switch-mode power-supply designs.

Design of the module involves a complete systems discipline which has until now not been addressed by power device manufacturers. A single-ended, quasi-resonant flyback approach is described, along with an application-specific pmcm solution.

Successful power multi-chip module design is a 'holistic' procedure involving power-circuit, thermal and mechanical design. Until recently, non-monolithic approaches to power-circuit integration have been relatively unsuccessful. This is because traditional 'hard-switched' pulse-width modulated, pwm, power stages do not lend themselves to integrated packaging. The main reason for this is the high-frequency harmonic content of the characteristic current and voltage waveforms found in pwm circuits.

One principal reason that monolithic power integrated-circuit design is so difficult is that parasitic effects are omnipresent, and must be considered at all stages of the design process. Fortunately, several conventional power topologies can be modified to reduce harmonic content without compromise on efficiency and component count. Furthermore, in most cases, savings elsewhere in the system would be greater with this approach.

Fig. 1. Within the power multi-chip module packaging a common copper heat sink carries the power switch and an alumina substrate with the control circuitry.

* Paul Greenland, Allegro MicroSystems, Inc.
M. Ueki and M. J. Lee, Sanken Electric Co.
COMPONENTS

Fig. 2. Flyback power stage showing major parasitic elements.

Fig. 3. Characteristic discontinuous flyback converter waveforms.

Fig. 4. Block schematic of the Allegro Microsystems STR-S6700 quasi-resonant off-line flyback converter.

may be significant – particularly when power-supply ripple rejection of the load system is questionable.

Power module packaging

Originally developed for consumer electronics applications and used in areas such as TV sets, the 3GR series package incorporates the control and power switching elements of a single-ended quasi-resonant flyback converter. The package, Fig. 1, includes an internal plated copper heatsink carrying the switching power device—a bipolar transistor, mosfet or igbt.

The power device exhibits a thermal resistance to the mounting surface equivalent to what it would show in an over-moulded TO-247 package—typically no greater than 2°C/W. The copper heatsink also carries the control circuit on an alumina substrate with laser-trimmed thick-film resistors, discrete small-signal and driver devices, and local decoupling and timing capacitors. All active devices on the substrate—including the monolithic control IC—use flip-chip interconnections.

Flip-chip interconnection reduces bond-wire count, and allows the monolithic control IC designer to optimise layout. Bond-wire parasitics are also eliminated. A drawback of flip-chip interconnect is that the active surface of the control IC is capacitively coupled to the collector or drain on the back side of the power device, which is subject to high dV/dt in conventional single-ended pwm topologies.

This effect can be reduced significantly by including an rf "catcher" plate in the substrate. This will lower control-node impedances and includes blanking or switched attenuator circuits that reduce node sensitivity during the commutation interval.

These solutions, however, raise costs and reduce reliability. A better way is to introduce quasi-resonant techniques which make the switching transitions resonant, cut high-frequency harmonic content and reduce switching losses—applicable if fixed-frequency operation can be sacrificed. Moreover, these techniques make positive use of parasitic elements which can never be totally eliminated.

Parasitic elements

Figure 2 shows a flyback power stage with its major parasitic elements—leakage inductance \( L_p \) and primary capacitance \( C_p \). In this circuit, \( L_m \) is the primary magnetising inductance, \( N_p \) and \( N_s \) are the numbers of primary and secondary turns, and \( V_d \) is the forward drop of the secondary rectifiers.

The leakage inductance is a result of imperfect coupling between the primary and secondary windings. It may be as high as 5% of the value of \( L_m \) in a typical off-line power supply with a primary/secondary isolation of 3750V rms and a 4mm winding margin. The main effect of leakage inductance is to delay transfer of energy stored in the primary inductance during the 'on' time to the secondary during the 'off' time. During this delay, there is a voltage overshoot at either the collector or drain of the power switch, and the energy resonates between \( L_1 \) and \( C_p \) with a frequency \( f_1 \) given by the equation:

\[
f_1 = \frac{1}{2\pi \sqrt{L_p C_p}}
\]

After the energy stored in the leakage inductance is exceeded, the voltage on the switch settles to the referred value \( V_{fb} \), given by the equation:

\[
V_{fb} = V_{in} + \left( V_d N_p \frac{N_f}{N_s} \right)
\]

The peak overshoot voltage is given by the sum of \( V_{fb} \) and \( V_{ring} \).
COMPONENTS

\[ V_{in} = V_{pb} + V_{cm} \]
\[ = V_{pb} + \frac{L_m}{C_p} \]

Once the energy has been transferred to the secondary and the secondary rectifier ceases to conduct, residual energy resonates between \( L \) and \( C_p \) with a frequency \( f_z \), settling to \( 1/1 \) before the next conduction time,

\[ f_z = \frac{1}{2\pi \sqrt{L_m C_p}} \]

The primary capacitance is the sum of the capacitance of the power switch, the transformer's intra-winding capacitance and any stray capacitance. It is discharged at the beginning of power-switch conduction, and dissipates energy at turn-on.

Each parasitic element poses a problem in conventional PWM flyback converters – leakage inductance causes overvoltage, and primary capacitance causes overcurrent.

Making use of parasitics

Quasi-resonance makes use of these undesirable parasitic elements. The primary voltage and current waveforms are shown in Fig. 3. The point of lowest potential on \( C_p \) occurs one half-cycle after the core has unloaded its energy and the secondary rectifier has ceased to conduct. If conduction time commences at this point, turn-on loss will be at a minimum. Similarly, as turn-off loss occurs during the overlap of voltage and current at the end of conduction time, reducing the \( \Delta V/\Delta t \) with a primary capacitor at turn-off is beneficial.

In order to achieve these ends, independent control of 'on' and 'off' time is essential. In the pncm, Fig. 4, 'on' time is controlled to a preset maximum by the voltage feedback loop. 'Off' time is controlled to a preset maximum by detecting the point at which the core has unloaded energy. This is achieved by monitoring the auxiliary winding referred to the primary, and then applying a half-cycle delay. Using this technique, all benefits of quasi-resonance can be realised in a manner which is predictable in high-volume manufacture.

Power module realisation

Figure 4 is the block diagram for the STR-S6700 power modules. These use the physical construction of Fig. 1. In this device the control circuit is subject to an undervoltage lock-out, with hysteresis, which allows low-power startup from energy stored in the auxiliary capacitor fed by a high-value start-up resistor. Start-up current is not greater than 200µA.

Comprehensive protection is ensured by temperature-compensated cycle-by-cycle current limiting, latching overvoltage shutdown and thermal shutdown – which acts to protect the controller and the power switch. Latching functions are subject to a predetermined delay to prevent nuisance tripping. The oscillator has predetermined maximum on and off times. Inclusion of a triple-diffused npn switching transistor rather than a mosfet may seem a retrograde step. This is not the case however, as the use of a proportional drive technique ensures the device is well matched to the application, and a \( V_{ce(sat)} \) of 400mV gives low conduction loss.

Casual inspection of the primary current waveform reveals that it starts from zero – neglecting the leading-edge spike caused by discharging \( C_p \). Fast switching at this point is undesirable, as this leads to excessive auxiliary current and high electro-magnetic interference. Furthermore, it is useful to have some proportionality between base to collector current for the leading portion of the primary conduction time to cater for a wide load range. Turn-off should be rapid to minimise switching loss, and a reverse bias should be applied.
to the base during turn-off voltage overshoot for reliable operation.

Figure 5 shows the proportional drive circuit and its associated waveforms. At switch-on, capacitor C3 charges up, ramping the base current to a maximum set by RD. At the end of the primary conduction time, current ceases to flow through pin 5, and the transistor drawing current from pin 4 switches on. This reverses polarity on the drive capacitor Cb, which has charged to a level set by D5 in anti-parallel with the base/emitter junction of T3.

Figure 6 shows the proportional drive waveforms, together with the collector voltage and current. Switching characteristics and low conduction loss of the bipolar switching device are matched to its application.

One of the main reasons that bipolar transistors have gained a poor record for reliability in switch-mode power-supply applications is the drive technique for the ringing-choke convertor used in early designs. This can be seen from the drive waveforms in Fig. 7, which exhibit a large current at switch-on, creating a large switch-on current pulse as Cb is discharged.

During primary conduction, there is no proportional element, resulting in overdrive at light loads and excessive storage time. The turn-off is slow, resulting in large switching loss, and the reverse bias during the voltage overshoot on the collector is small. It is therefore hardly surprising that the major cause of failure in many ringing-choke converters is the bipolar power transistor.

Making energy transfer complete
Detection of demagnetisation, known as ‘complete energy transfer’, is a crucial element in establishing quasi-resonance.

In Fig. 8, the auxiliary winding has a sampling network connected ahead of the auxiliary rectifier. The sampling network applies a voltage to the inhibit pin, pin 8, during the auxiliary/secondary conduction time. Once this voltage exceeds VTH1, the drive to the power switch is suspended, and as it exceeds VTH2 the ‘off’ time is pre-terminated.

Once the core has unloaded its energy, the voltage at the inhibit pin, VINH, drops, delayed by Cinh. As VINH falls below VTH, the ‘off’ time capacitor and the proportional drive capacitor are re-initialised. Once VINH falls below VTH1, the drive to the power switch is enabled and primary conduction commences. Figure 9 shows the complete timing sequence.

This technique allows quasi-resonance to be established, with the consequent benefits of lower switching loss, lower electromagnetic interference than with conventional ringing-choke converters Fig. 10, and utilisation of hitherto undesirable parasitics.

The negative aspects of quasi-resonance are a slight increase in conduction loss, a higher fundamental frequency component in the conducted harmonics, and a small increase in high-frequency ac loss in the transformer. The latter can be virtually eliminated by use of high-frequency transformer winding techniques – Litz, multifilar bundling and inter-winding – to reduce ac losses.

Primary magnetising inductance is modified from the conventional value calculated in the classic ringing-choke converter transformer design procedure, as shown by the equation,

\[ L_p = \frac{(V_{in}D)^2}{\eta + \frac{2P_{aux}}{f_s} + V_{in}f_{s}D_{p}C_{po}} \]

where \( L_p \) is primary inductance adjusted for quasi-resonance, \( P_{aux} \) is the output and auxiliary power in watts, \( f_s \) is the minimum switching frequency, \( \eta \) is efficiency, \( D \) is the duty cycle at minimum ac line potential and \( V_{in} \) is the minimum dc input voltage.

Isolated voltage feedback and regulation are achieved by augmenting the current charging \( C_{po} \) with opto-coupler current proportional to the error signal generated at the secondary.
Thus, as the secondary load decreases or the applied line voltage increases, the slope of the voltage ramp on \( C_{\text{Ton}} \) increases, reducing primary conduction time. In most cases, simple integrator compensation around the secondary error amplifier will suffice. However, if more control-loop agility is required, pole/zero compensation and primary high-frequency bypass may be employed.

A useful feature of the STR-S6700 series is standby operation. Originally intended for TV applications, the standby feature minimises the incremental power drawn by the converter during light load operation. This feature is a by-product of the oscillator design and the quasi-resonant timing technique employed—refer to Fig. 11.

In standby mode, current normally drawn through \( R_{11} \) and \( D_9 \) is diverted into the base of \( T_{33} \), turning it on. As current flows through \( R_{12} \) and \( D_{10} \) and \( T_{32} \) is switched on, output and auxiliary voltages fall, and stabilise when \( S_1' \) reaches \( V_s \) where \( V_s = V_{R11} + V_{D10} + V_{BEQ3} \). At this time, standby power is supplied by \( C_{11} \) charging from the collector of \( T_{32} \). As voltage on the auxiliary windings \( d_1 \) and \( d_2 \) tracks the secondaries, auxiliary power is supplied from the linear regulator transistor \( T_{11} \) on \( d_2 \). In addition, as \( V_{TH} \) drops below \( V_{THL} \) during the off time, the oscillator defaults to its maximum off time of typically 50\( \mu \)s.

In standby mode, the power supply operates with pulse ratio control, in which the 'on' time varies and the off time is held constant. This keeps the incremental power consumed by the power supply to an absolute minimum. This principle can be applied to save energy in printers or copiers which switch to standby mode if the system is inactive for a period.

A variant of the device without the standby mode is shown in Fig. 12. The STR-S5700 Series is intended for indirect feedback applications using a primary referred sense winding, and component count is reduced at the expense of regulation.

Conclusion
This article has shown that integration of the primary power switch and control elements of the oscillator design and the quasi-resonant timing technique employed—refer to Fig. 11.

In standby mode, current normally drawn through \( R_{11} \) and \( D_9 \) is diverted into the base of \( T_{33} \), turning it on. As current flows through \( R_{12} \) and \( D_{10} \) and \( T_{32} \) is switched on, output and auxiliary voltages fall, and stabilise when \( S_1' \) reaches \( V_s \) where \( V_s = V_{R11} + V_{D10} + V_{BEQ3} \). At this time, standby power is supplied by \( C_{11} \) charging from the collector of \( T_{32} \). As voltage on the auxiliary windings \( d_1 \) and \( d_2 \) tracks the secondaries, auxiliary power is supplied from the linear regulator transistor \( T_{11} \) on \( d_2 \). In addition, as \( V_{TH} \) drops below \( V_{THL} \) during the off time, the oscillator defaults to its maximum off time of typically 50\( \mu \)s.

In standby mode, the power supply operates with pulse ratio control, in which the 'on' time varies and the off time is held constant. This keeps the incremental power consumed by the power supply to an absolute minimum. This principle can be applied to save energy in printers or copiers which switch to standby mode if the system is inactive for a period.

A variant of the device without the standby mode is shown in Fig. 12. The STR-S5700 Series is intended for indirect feedback applications using a primary referred sense winding, and component count is reduced at the expense of regulation.

Conclusion
This article has shown that integration of the primary power switch and control elements of

Fig. 10. Comparison of conducted EMI - ringing choke versus quasi-resonant techniques.

Fig. 11. Quasi-resonant switching power converter based on the STR-S6700. In the application, standby mode helps save power.
an off-line switching power supply is viable once a true systems approach is adopted. Quasi-resonance can also be employed in off-line flyback converters to good effect. Furthermore, this technique brings the 'lowly' flyback converter to the forefront of off-line power-conversion applications below 200W. It can be shown that reduction in high-frequency harmonics, offsets many disadvantages of variable-frequency operation. The quasi-resonant technique can also be adapted to current-mode control through a dual-purpose current limit which reduces pin count and is competitive with implementations using conventional controllers plus discrete components.

**PERRYBEE (UK) LTD**

We offer a comprehensive service designed to assist the OEM in the procurement of components and the search for new export markets.

- With our own office in Germany, we offer access to all types of German products.
- Component sourcing for actives and passives.
- Market research service.
- Export documentation and consolidation service.
- Prompt and professional response guaranteed.

Perrybee (UK) Ltd,
Maple House, 8 Keveral Gardens, Seaton, Torpoint, Cornwall PL11 3JH
Tel: 01503 250354 Fax: 01503 250657
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

£395

**Board Maker**

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

£95

BoardMaker2 - Advanced level
- All the features of BoardMaker1 plus
- Full netlist support - OrCad, Schema, Tango, CardStar
- 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

£395

**Board Router**

BoardRouter - Gridless autorouter
- Simultaneous multi-layer routing
- SMD and analogue support
- Full interrupt, resume, pan and zoom while routing

£200

Output drivers - Included as standard
- Printers - 9 & 24 pin Dot matrix, HP Laserjet and PostScript
- Plotters - HP, Graphicel, 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

£100

**Kenwood**

Test & Measuring Instruments
A superb range of over 100 quality instruments.
Available from B.K. Electronics

FM-AM Signal Generators
Colour Pattern Generators
Video Signal Analyser
Video Timing Analyser
Video Noise Meter
Distortion Meter
Waveform Monitors
Vectorscopes
Audio Generators
Wow and Flutter Meters
Electronic Voltmeters
Digital Multimeters
Function Generators
Frequency Counters
Bus Analyser
Resistance Attenuator
Oscilloscopes
Fully Programmable Digital Storage Oscilloscopes
Regulated D.C. Power Supplies

A free, 50 page colour brochure, including price list, is available on request. Please make your request on company headed notepaper, by post or by fax to:

B.K. Electronics
Unit 1 Comet Way
Southend-on-Sea
Essex, SS2 6TR
Tel: 01702 527572 Fax: 01702 420243

For users of PCs, 8051 & 68000

**The Micro Module**

A new low cost controller that gives you customisation for as little as £95

**FEATURES**

- 16/32 bit 68307 CPU for fast operation
- Up to 1 Mbyte of EPROM space onboard
- Up to 512Kbyte 8KB RAM space onboard
- 32 Kbyte SRAM fitted as standard
- RS232 serial with RS485 option
- MODBUS & other protocols supported
- Up to 22 digital I/O channels
- 2 timer/counter/match registers
- port or Mbus & Watch dog facilities
- Large Proto-typing area for user circuits
- Up to 5 chip selects available
- Program in C, C++, Modula-2 & Assembler
- Real Time multitasking Operating System
- 0S9 or MINOS with free run time license option
- Manufacturing available even in low volumes
- A full range of other Controllers available

P.C. 'C' STARTER PACK AT ONLY £295 + VAT

The Micro Module will reduce development time for quick turnround projects and with the P.C. 'C' Starter pack allow you to start coding your application immediately, all drivers and libraries are supplied as standard along with MINOS the real time operating system all ready to run from power on.

The 'C' Starter pack includes: A Micro Module with 128 Kbyte SRAM, PSU, Cables, Manuals, C Compiler, Debug monitor ROM, Terminal program, Downloader, a single copy of MINOS, Extensive example software, and free unlimited technical support all for £295 + VAT.

Cambridge Microprocessor Systems Limited
Unit 17-18, Zone 'D', Chelmsford Road Ind. Est., Great Dunmow, Essex, U.K. CM6 1XG
Phone 01371 875644 Fax 01371 876077

CIRCLE NO. 136 ON REPLY CARD
New capabilities include:
- Interactive 2-D and 3-D graphics (scatter, bar, polar, vector, contour & parametric surface plots)
- Programming operators for building programs in Mathcad
- User Defined Notation
- Lotus Notes enabled
- Multi-dimensional matrices
- Locked/Password protected sections
- Electronic mail-enabled
- Hyperlinks to Mathcad worksheets (local, Notes, Web)
- Windows '95 Compatible
- Function Libraries
- Data Smoothing
- Quicksheets
- OLE Support
- Animation
- Web Linking and more!

Mathcad PLUS 6.0

New Mathcad PLUS 6.0 has the intuitive, interactive visual interface that Mathcad is famous for. Plus it now has the power and flexibility to elegantly handle an even wider range of tougher problems. Over half a million people worldwide - engineers, scientists and mathematicians - already use Mathcad as their preferred calculation tool because it's interactive visual user interface is easy to learn and intuitive to use.

Mathcad PLUS 6.0 builds on its usefulness in three key areas:

**USABILITY**

Mathcad PLUS 6.0 has an updated look and feel. New Quicksheets help new users to learn Mathcad PLUS 6.0 and provide shortcuts for frequently used mathematics.

**POWER**

Mathcad PLUS 6.0 has a new set of procedural operators integrated into Mathcad’s user interface to give you a robust way of solving sophisticated problems. Other new power capabilities include user defined notation, animation, enhanced visualisation and expanded statistical functionality.

**COLLABORATION & COMMUNICATION**

Mathcad PLUS 6.0 is Email enabled, so you can share your Mathcad worksheets over the Internet; Lotus Notes enabled so you can build and manage Notes databases of project-specific Mathcad documents; Web aware so you can publish and interact with live technical information over the World Wide Web.

For further information call Adept today!

Tel: (01462) 480055 Fax: (01462) 480213
Email: mathcad@adeptscience.co.uk
WWW: http://www.adeptscience.co.uk

(01462) 480213 FastFax

Mathematics Made Easier

Mathe"matics Made Easier
Building on August's article describing a GPS receiver, Nigel Gardner presents a low-cost read-out interface for Rockwell's MicroTracker system.

**Interfacing**

the GPS receiver

I chose the PIC microcontroller as the basis of this MicroTracker interface because of its ease of use and low development cost. It will handle all serial comms, sorting out and formatting of information, and display driving functions, needing a minimal number of external components to function.

The MicroTracker LP has two data output modes - binary and NMEA. This design is based on the NMEA format at 4800bit/s and interfaced to a PIC16C74. If data manipulation is required on the GPS information, then the binary format is the better option as there is a software overhead converting to and from the NMEA ASCII format. However, if the interface is only used to display and store data, the NMEA format is easier to work with.

This application is intended purely to display information, with no calculation done on information received.

**Hardware design**

The heart of the design is the PIC16C74 microcontroller running at 4MHz, Fig. 1. An RS-232 link interfaces to the GPS serial interface module featured in the August 1995 issue and uses a MAX232A driver chip to level shift to the PIC.

Other items needed for the PIC are a 78L05 regulator, a 4MHz resonator and a few passive components for decoupling and reset. Power is drawn from the GPS serial interface board via a connection to the active antenna supply and is in the region of 15mA at 12V. This breaks down into 12mA for the MAX232A, 2mA for the LCD display, and 1mA for the PIC16C74. If the RS-232 interface is removed to give TTL connections between the MicroTracker and the PIC, a saving can be made on both current and components.

A reset switch is added to the PIC to assist in software development, but it could be eliminated. If the GPS serial interface module is used in conjunction with this design, then set the dip switches on the board to 1-5 on, 6-8 off. This sets NMEA mode at 4800bit/s on power up.

The LCD module is the Hitachi LM041L or LM044L. These have four lines of 16 or 20...
Fig. 1. Display controller for the MicroTracker is based on a PIC microcontroller and incorporates a liquid-crystal display module.

characters respectively and are interfaced in the 8-bit mode with full handshaking. This method of interfacing provides the fastest display update times but uses eleven i/o lines. If this design is transported to a 28-pin 16C73 then the 4bit write only approach can be taken with the display using only six i/o lines.

Software requirements

The flowchart for this program, Fig. 2, shows the basic operation. Source code is available from the TDC bulletin board for those wishing to evaluate the program and modify to their own requirements.

Following initialisation of the ports and other registers, the display is cleared and a sign on message sent. For this application, the default message formats of 'ggg' and 'vtg' are turned off and 'rmc' turned on. The 'rmc' message format includes latitude, longitude, time, date, speed, heading, magnetic variation and magnetic heading. Other message formats can be enabled easily and relevant information extracted from the data string.

The 'rmc' message contains the following data - start field, 'utc' time, data valid, latitude, longitude direction, longitude, longitude direction, speed, heading, date, magnetic variation, magnetic direction, checksum <CR><LF>. Each field is comma delimited and will typically look like.

SGPRMC,234215.24,A,3339.686,N,11751.66,7,W,0.620,293.8,180595,14,0,E,"79

Other message formats include information on altitude, number of satellites in use, track made good and ground speed. It can also be enabled and set to broadcast at increments of a second.

PIC object software for the GPS receiver display module.

<table>
<thead>
<tr>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>08000000</td>
<td>02288200202402034C</td>
</tr>
<tr>
<td>08000004</td>
<td>02246E6C347536563498</td>
</tr>
<tr>
<td>08000008</td>
<td>02266F693724634347</td>
</tr>
<tr>
<td>0800000C</td>
<td>0220034735034533406</td>
</tr>
<tr>
<td>08000010</td>
<td>02200203420403443C7C</td>
</tr>
<tr>
<td>08000014</td>
<td>02280613474324034004B</td>
</tr>
<tr>
<td>08000018</td>
<td>0230040C346E6342043A4F</td>
</tr>
<tr>
<td>0800001C</td>
<td>023B030003464324034348</td>
</tr>
<tr>
<td>08000020</td>
<td>023F040003454693434238</td>
</tr>
<tr>
<td>08000024</td>
<td>024400034546934342384E</td>
</tr>
<tr>
<td>08000028</td>
<td>024804066F0209A208008F</td>
</tr>
<tr>
<td>0800002C</td>
<td>024C000350A000087A2B6</td>
</tr>
<tr>
<td>08000030</td>
<td>024F0800890183800600</td>
</tr>
<tr>
<td>08000034</td>
<td>02500000B029A20800801DB</td>
</tr>
<tr>
<td>08000038</td>
<td>0253050542542543434946</td>
</tr>
<tr>
<td>0800003C</td>
<td>02570800890183800600</td>
</tr>
<tr>
<td>08000040</td>
<td>025C0000890183800600</td>
</tr>
<tr>
<td>08000044</td>
<td>02600000B029A20800801DB</td>
</tr>
<tr>
<td>08000048</td>
<td>02630000B029A20800801DB</td>
</tr>
<tr>
<td>0800004C</td>
<td>02670000B029A20800801DB</td>
</tr>
<tr>
<td>08000050</td>
<td>026B0000B029A20800801DB</td>
</tr>
<tr>
<td>08000054</td>
<td>026F0000B029A20800801DB</td>
</tr>
<tr>
<td>08000058</td>
<td>02730000B029A20800801DB</td>
</tr>
<tr>
<td>0800005C</td>
<td>02770000B029A20800801DB</td>
</tr>
<tr>
<td>08000060</td>
<td>027B0000B029A20800801DB</td>
</tr>
<tr>
<td>08000064</td>
<td>027F0000B029A20800801DB</td>
</tr>
</tbody>
</table>

Parasitic capacitance is important in the circuit diagram above. A +12V battery monitor option is provided. The LCD screen is driven by a 16bit microcontroller.
second. See the designer’s guide on the MicroTracker LP for full specification and programming information.

Character input from the RS-232 port is examined to look for the 24 hour ‘$’ symbol, signifying the start of the message string. On receipt of the ‘$’ symbol, the characters are stored in the PIC’s ram. On receipt of an end of message character – ie carriage return, 0D16 – the software branches into display mode. Information from the MicroTracker arrives at a minimum of 1s intervals providing enough time for the display to be updated.

The display section of the program looks at the characters in memory and when a comma, 2C16 is identified – field delimiter, the message type is then determined from a lookup table and sent to the liquid-crystal display. Additional text messages are sent prior to the received information to clarify to the user what is being displayed.

At the end of the information processing, the program jumps back to look for the next ‘$’ symbol.

Bit rate calculation for the PIC serial comms port is straightforward. After transposing the formula in the data sheet, for low rates it is,

$$\text{Divide ratio} = \frac{\text{clock frequency}}{\text{baud} \times 64}$$

This works out for 4800bit/s and a 4MHz clock at 12. This value is loaded into the SPBRG register and is common for both transmit and receive.

Designing a board
The prototype was built using a standard PIC16C64174 development board – Farnell order code 630-639 – with the display bolted on. This enables full access to all PIC pins and reduces development time and cost.

Laying out a board for the circuit in Fig. 1 should not present problems, but care should be taken in placing the resonator and 100nF capacitor as close to the PIC as possible.

Where next?
If an external electrically erasable prom is added to the PIC and connected via the inbuilt PIC interface, data could be logged in the eeprom upon closure of a switch providing a positional logging and ident system. Using an external eeprom, the MicroTracker LP can be updated on power up with the last positional information – speeding up the time to first fix.

As the 16C74 has eight analogue inputs, one could be used for monitoring battery voltage via a potential divider. This will alert the user to the time remaining before total loss of supply.

If cost is an issue, the MicroTracker LP can be connected directly to the PIC, bypassing the ‘logic to RS-232 to logic’ conversion circuitry and interface board. This brings component cost down to the MicroTracker LP, antenna, PIC, display and power supply.

Technical support
Rockwell MicroTracker LP Designer’s Guide, contact Telecom Design Communications BBS. Phone 01256 332800 for connection details.

Beginners Guide to the Microchip PIC, Rev 2, ringing 01628 777960 for details.

Microchip Databook 1994, Farnell/Rs/Maplin. The author runs Bluebird Electronics, 01380 725110 providing PIC training and support.

This article is based on his forthcoming book ‘PIC Cookbook – Vol 1’.
LETTERS

Letters to “Electronics World” Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

PhoneDay fiasco

At last, the dawn of realisation has broken over OfTEL. As suspected, the new telephone number scheme introduced in April is what most of us who have to phone the USA have suspected—a great big waste of money.

I do not know how many telephones there are in the UK, but in the USA, with a population five times the size of ours, they have a simple and therefore easy to remember, three-digit area code, three-digit exchange code and four-digit number system.

There are far more phones per head of population there than here, and they even have the luxury of an exchange code for film and tv programme makers (555) to stop the nuts dialing the number on the tv.

Can any one explain why we couldn't have adopted such a simple scheme for our telephone numbering system? I don't want to appear too cynical but I can't help suggesting "not invented here".

Nic Houldspit

Birmingham

Field hazards?

Proof please

Your correspondent Roger Coghill—May 1995—has suggested that the IEE Working Party’s conclusion that there is no proven harmful effect due to low-level, low-frequency electromagnetic fields is the result of power-utililty bias in its membership. As IEE Chief Executive, Dr. Williams, has pointed out—EW+WW August 1995—that accusation is demonstrably untrue.

What is true is that Mr. Coghill’s own business has been concerned with advertising devices to reduce the effects of power frequency magnetic fields. It might be thought to be in his commercial interest if any biological effect could be demonstrated. It is perhaps disingenuous of him not to mention this.

Bernard Jones—Oct 1995—is “confident that magnetic fields produce brain cancer etc.” Although he gives no evidence to support his views. I hope Mr. Jones understands that in science it is impossible to prove that something does not exist—there may always be some statistically insignificant effect that is masked by other sources. It is possible to show that an effect does exist when an effect that is statistically significant can be measured consistently.

Whatever your correspondents may say there is very little evidence that we have reached this stage. If they know otherwise perhaps they will refer you to the evidence.

Meanwhile, as an active, but independently minded, member of the IEE let me assure Messrs Coghill and Jones that whenever real significant evidence is available to support the hypothesis that low-level electric or magnetic power-frequency fields have a significant effect upon our health then 1—along with many of our members —will work to ensure that the IEE gives it the widest possible publicity. Until then it will be in the public interest to stick to known facts rather than creating unnecessary concern.

Collin W. Davidson

Edinburgh

Is EMC approval necessary?

The recent IEC directive on emc requires all electrical equipment to be tested for radiation levels. There are solid theoretical grounds for declaring that all equipment below a certain power automatically meets the requirements. This is because the radiated power cannot exceed the total power absorbed.

The standard does not make such an exception. If an exemption were made, and the power levels turned out to be reasonable ones, then the savings for electronics companies could be huge.

A piece of equipment uses so much power. If all that power were converted into radiated electromagnetic field, you could calculate from theory the maximum possible field strength according to distance from the device. So, for example, a device that absorbs only 2W could only ever radiate 2W of power as a maximum. In fact, it is hard to make a transmitter with 50% efficiency so it is reasonable to assume that only half the total power could possibly be radiated as electromagnetic radiation. If heat dissipation of the equipment is known so you can subtract the heat power from the possible radiated power.

This would permit the radiation limit to be calculated purely from theory, based on the total power absorbed. For many items, that use very little power and so could never possibly radiate too much, such a calculation could avoid costly tests which would otherwise be necessary.

One might argue that the radiation field could be shaped in such a way that a tightly focused beam is emitted, so that the field in one direction might be very much higher than a theoretical average. To argue thus seems to me perverse, given that the equipment is not designed to generate focused beams and the difficulty of generating a focused beam.

Also, if the equipment involved is small while the measurement distance is relatively large—10m is the European standard—then you might argue that the field would be relatively uniform at this distance from the object.

Similarly, the physical size of the equipment would have an effect—equipment that is small compared with the wavelength could not possibly generate a focused beam. European standards make no allowance for such a theoretical calculation. I would be interested to know if such a calculation would be reasonable so that one can argue for a change in the standard or an automatic exemption—thus saving companies a lot of money.

I am not enough of an rf engineer to make the relevant calculations. However from my university text book on electromagnetic theory, it seems that if the equipment were a perfect dipole radiator then anything under 2W could not possibly exceed the emc limits. As a result, it would not need testing.

It would be interesting for someone with some expertise on this field to make the calculations.

Chris Bore

Audio Analyser

Sallen & Key distorted

Mr Ryder’s conclusion that the Sallen and Key filter configuration is not generally usable for hi-fi would be worrying if it were true—especially in view of the fact that I used this circuit repeatedly in the LA100 Audio Analyser. This unit probably features more than any other, worldwide, in the automated checking of distortion and quality on the broadcast and studio equipment that originates his “hi-fi”.

The truth is that the Sallen and Key filter has much to commend it, including low component count and unity gain—precise unity gain; for ever. These features are regardless of component values or temperature. This is especially valuable in multistage measuring equipment accurate to a hundredth of a decibel, but it is also useful in maintaining accurate gain and channel balance in multistage audio equipment without trimming.

The second-harmonic distortion problem he has discovered is not a direct result of frequency responses, but is caused by a varying common mode capacitance which shunts his 470pF input capacitor. This causes signal-dependent modulation of its value which probably originates in reverse biased substrate-isolation or protection diodes in the op-amps. These behave as varicaps.

The effect can be puzzling because it only occurs near the cutoff frequency. At this point, the capacitors are working hardest. The effect arises mostly as a result of amplitude-dependant modulation of the filter phase shift.

Mr Ryder’s choice of a high Q emphasizes the problem in two ways: by requiring a large capacitance ratio, and hence a low value input capacitor, and by generating a large phase shift. His choice of values is far from optimal. Changing the 110kΩ resistors to 3.3kΩ, with a corresponding increase in capacitor values, will swamp the effect and produce very acceptable figures without loading the op-amp output too much.

In most applications, where a capacitor ratio of three or four to one is more common, the TL072 works well. For critical applications, the NE5532 performs much better in this respect, at the cost of higher power consumption.

Peter J Skirrow

Lindos Developments

Suffolk

Re-inventing the wheel

After reading the article ‘maximising power in class-C’ I must conclude that each generation of radio engineers is intent on re-inventing the wheel.

I was surprised to find that there was no reference to W.L. Everitt’s book ‘Communication Engineering’
the second edition of which was published in 1937. In it he gives a complete mathematical treatment for maximum power output from class-B and class-C amplifiers. I cannot say if the same analysis appeared in the first edition of 1931.

Shropshire

Modulating misguidedly?

I have just read ‘Modulating linearly’ by Ian Hickman in your July 1995 edition. While presenting an interesting method of reducing the intermodulation products at the modulator, I believe that the effort is misplaced. It is out of band products from the transmitters that are offensive and cause adjacent channel interference.

Most ssb transmitters employing direct or linear power modulators pass the signal through an ssb filter. This removes the unwanted sideband, frequencies outside the required modulating bandwidth, and incidentally out of band intermodulation products generated by the modulator. The offending out of band intermodulation products are usually generated at the power amplifier final stage where trade-offs between linearity efficiency, and distortion are made.

Surprising though it may seem, in-band intermodulation products may be of advantage in voice ssb transmission improving modulation efficiency and transmitted power.

By way of expiation of my statement it is speech processing incorporated in many ssb transmitters that proves this point. The peak to average form factor of the voice waveform is high which leads to low average transmitted power. Voiced sounds consist of harmonics of the vocal chord vibrations amplified and frequency shaped by resonant cavities in the vocal tract, head and chest. This results in a multi-tone spectrum of which a few tones are dominant in the mid-audio band of similar frequency to those used by Hickman in his article i.e. 1kHz and 1.2kHz. If one applied these tones of equal level after ssb filtering to a ssb transmitter with auto level control so that peak to peak amplitude were the same as for a single tone, transmitter average power would be 50% that of a single tone.

Speech processing is often accomplished by clipping the ssb signal in the intermediate frequency after a stage of ssb filtering and removing the out of band products in a second stage of ssb filtering.

In this instance a high degree of in band intermodulation is produced and it is in the intermodulation products that the additional transmitted power is contained.

These intermodulation products are not related to the frequencies present in the original modulation and the brain interprets them as though the resonant cavities of the vocal tract were of lower Q and thus correlating the frequencies to produce additional intelligibility in poor signal to noise conditions.

John West

Audio power – is current feedback the solution?

John Watkinson’s letter in the October issue highlights the trend of designing ever-more complex audio amplifiers while the loudspeaker system remains the largest source of distortion.

Admittedly some amplifiers can handle the complex and variable impedances of various speaker systems better than others, but none seem to overcome the basic problems caused by the conventional moving coil speaker. Several manufacturers have attempted to improve speaker performance by using motional feedback or an active cross-over with separate amplifiers. However, this requires careful matching of both electronics and hardware.

The main purpose of an audio amplifier is to push current through the voice coil in order to move the cone. Traditional amplifiers use voltage feedback to ensure that the voltage applied to the speaker is controlled accurately while hoping that its impedance remains reasonably constant. Obviously any variation of impedance, either with frequency or cone excursion will cause some non-linearity in the current thus causing distortion. A look at the impedance curve of any good quality speaker will show surprising variations.

One possible solution that does not appear to have been considered is the use of current feedback rather than the more common voltage feedback.

A similar problem arose in the design of television receivers, where the vertical deflection coils are driven with a 50 or 100Hz waveform. Any linearity or amplitude errors are easily visible on the screen.

Early designs used a conventional voltage amplifier – often very similar to the audio amplifier – however the current amplitude and thus picture size usually varied as heating of the deflection coil caused its resistance to change. Thermistors were often added to try to compensate for temperature effects. However, the modern solution is to use current feedback which overcomes the problem of any change in load impedance: refer to circuit diagram.

Using current feedback should, in theory, null the effects of resistance changes caused by voice coil heating or by using different lengths or sizes of speaker leads. An additional advantage should be good short circuit protection without the clipping or distortion of a conventional protection system.

The current sensing resistor will cause some power loss, but in an 80W 8Ω system this would amount to less than 1W with a 0.12 resistor.

It would be interesting to hear if anyone has tried this approach and if it produced any improvement in the overall performance.

Bradford

Square-law rules – OK

Ian Hegglun is to be congratulated – not only for the content and design performance achieved but also, for actually quoting power output stage open loop performance measurements supported by waveform traces.

Prior to reading ‘Square-law rules’ in the September issue, the existence of an ongoing controversy and the absence of any reasonably comprehensive or explicit open-loop performance data had lead me to the conclusion that, as currently used, neither bits or modes were the ideal audio power output stage device and that I would have to design my own avoiding current design conventions.

My own approach to a linear power output stage – ie not worse than 1% thd – was to investigate a fully differential solution using a self balancing active bridge configuration. An experimental prototype output module using power Darlington bjt has been tried. Provisional results with this output stage configuration have shown that nearly constant open-loop unity gain, ie \( V_{out} / V_{in} = 0.99 \), is achievable. This is subject to gain/symmetry trimming, for a voltage swing of ±18V into a 15Ω resistive load.

Open loop frequency response is flat to at least 20kHz, output resistance was 0.5Ω, and input impedance around 600-800Ω. Quiescent power consumption was low, at 6 to 8W, from a single 25V dc supply.

This reflects an open circuit bias setting Normal Class B/AB or A preconceptions do not apply to this circuit.

Listening tests confirmed measured expectations. These were effected by terminating one channel of my existing stereo amplifier (0.2% at 1kHz and 10W) using the module as a relay amplifier to drive the right-hand speaker.

This was a vintage 15Ω Goodmans Maxim.

Performance of this module is such that only a relatively modest amount of global feedback at a maximum of 36dB need be applied to the preceding voltage/impedance transformation stage. The level of 36dB is also the maximum theoretical global feedback that will maintain a critically damped response in a single dominant pole design.

Thus for a cost effective solution I consider the answer to lie more in matching circuit to device and in designing the system to meet the needs of the application. This includes matching speaker ratings to amplifier ratings and speaker system to audio equipment.

Crossing Brookenhurst, Hanshire.

Considering a valve design?

For readers considering a valve design, I would mention that an ultralinear connection enables a pair of EL34s to deliver up to 30W with less than 1% thd rather than 4% thd without feedback. This also compares with 14W max from triode connected EL34s at less than 1% thd.

A suitable push-pull output transformer for this connection, Gardners Type AS 7034, might still be obtainable from Gardners Radio, Christchurch. This had both 20% and 43% screen grid tappings.

I had also used the ultralinear connection to very good effect, many years ago, in a two valve 3.5W EF86/EL84 single-ended Class A design for mono but regretfully replaced this with a pair of 10W Toby/Dinsdale when stereo was introduced.

EJ C

Toby high power

Jeff Macaulay’s article ‘Hot audio power’ in the October issue contained two errors in the caption. Grid resistors \( R_\text{A} \) should be 560kΩ, not 60kΩ and \( R_\text{B} \) is 680Ω, not 6kΩ. Apologies.
Reg Miles discusses developments highlighted at the broadcast and professional exhibition - Vision '95.

The first camcorder to use hard disks instead of tape is here. Developed by Avid and Ikegami for news gathering, its advantage lies in its facility to randomly access any part of the disk. This enables recorded clips to be viewed, modified and edited into sequences in the field for transmission by microwave or satellite link to the studio - as well as providing all normal functions.

Called CamCutter, the recorder itself has no moving parts. These are confined to a removable, sealed and shock-proof pack containing two 1.2Gbyte disks. These provide up to 20 minutes of storage.

Video is recorded in component form, compressed at 7:1. Four 48kHz 16bit audio channels are available - although fewer can be used to increase recording time. An optional unit accepts up to three disk packs for editing and broadcasting in the studio.

Digital editor with pc interface
Hi Tech Systems' Altus Digital Disk Recorder is a rack mount/desk system, designed to be a cost effective alternative to the video tape recorder. As with CamCutter there is random access to the recorded material so that frames and clips are instantly available, allowing a variety of playback functions. In addition, there are all usual functions. Configuration and set-up is simply achieved using 'soft' keys - including adjustment of the compression ratio.

Connecting the recorder to a pc provides further controls over monitoring, playback and recording, using a suite of Windows programs. There is a choice of 2.1, 4.3 or 9.1Gbyte disks, recording approximately 10, 20 or 40 minutes depending on file size and image complexity. An SCSI bus connector is provided to connect an external RAID (redundant array of inexpensive disk drives) system.

Material from CamCutter can be broadcast immediately, brought back to the studio for editing, or stored on a central media server for enterprise-wide access.
Altus provides comprehensive control facilities and inputs and outputs. It also offers potential for expansion via a PC interface or SCSI.

Recordings are stored as clips in a directory and can be played in any sequence of frames according to play lists.

First digital video tape for domestic use
The first digital video format for the consumer market is Digital Video Cassette, created by a consortium of manufacturers. It is intended to be all-encompassing, with four variations. The Standard Definition version records analogue TV broadcasts and camcorder uses, including professional acquisition. The High Definition version covers applications of the standard, plus industrial and medical applications. The two remaining versions are for directly recording compressed digital broadcasts from the American ATV high definition system and the European DVB system.

With this breadth of usage in mainly cost-conscious markets, tape was the obvious choice due to its high storage capacity and low cost.

Specifications for ATV and DVB have yet to be finalised. Those for the SD version include a newly developed double layer metal evaporated tape, 6.35mm wide, in small and large cassettes giving up to 1 and 4.5 hours; component recording with 5:1 compression; a 2-head drum rotating at 9000rev/min recording 12 tracks per frame in PAL (10 in NTSC), with a track pitch of 10μm; 16 and 12 bit PCM audio modes; and a Copy Management System.
The basic recording mechanism for digital VCR is the same as that for analogue VCR. The digital signal is recorded using a helical scanning system. However, the recording pattern for digital VCR is different. To record 10 (NTSC) or 12 (PAL) tracks on one frame, the digital VCR drum rotates at 9000rpm (for both NTSC and PAL). This is five times faster than analogue VCR drum rotation.

DVCPRO differs in using more robust metal particle tape, which is run at double speed to increase track pitch to 18μm, and the addition of a control track and cue channel. The HD version uses metal-evaporated ME tape run at double speed to record twenty 10μm tracks per frame. Horizontal resolution is about 500 lines for SD — 25% greater than Hi8/S-VHS — and 600 lines for HD, with double the vertical resolution.

Developments in video editing

Tape based video editing is a laborious process requiring scenes to be copied from player(s) to a recorder in real-time. Each scene has to be found by winding the tapes. This is linear editing. Recently non-linear editing has been developed to exploit the random access facility of hard disks.

In non-linear editing, the video and audio is digitised, usually compressed, and transferred to disk. Each scene is represented on-screen by a still, and these scenes can be instantly accessed in any order, rearranged, trimmed, the audio edited, and effects and captions added. If it is not right it can be returned to a previous 'undo' level — instead of starting again as with tape. And systems can be networked for several editors to work at once.

The completed programme can then be output to tape, disk or to air. Alternatively, the computer can generate an edit decision list which tape machines can use for automatic linear editing. Some systems are linear/non-linear hybrids, capable of editing with video recorders and hard disk.

Non-linear editors are available as either plug-in boards and software or a complete computer system. A new trend is systems packaged for specific uses. One of the main focuses is on news, with systems from Avid, Lightworks and Quantel.

Sony's new system is intended for live broadcasts: two channels of hard disk storage provide quick replay and editing of highlight scenes while the live video continues to be recorded. An endless recording capability enables recording until the disk is full and then re-recording from the beginning. It can store up to one hour of video with 160kB per frame, 6:1 JPEG compression. The JPEG file size are selectable from 60:1-6:1. Additional drives can be installed to expand capacity to five hours.

JPEG is a popular method of compression, but it does rely on large, fast hard disks to function at speed. Eidos' new system takes a different approach, employing removable 1.3Gbyte magneto-optical discs, as well as hard disks. This change is made possible by Eidos' proprietary compression engine, Optimizer, which is more efficient than JPEG and thus compensates for the lower performance of MO discs. This can be swapped as easily as tape cassettes.

Non-linear editing began in the broadcast field and is working its way down through professional applications to consumers — with their lower quality requirement.
Is matching easy?

On the surface, matching a circuit's output to the next one's input appears straightforward, but as Ian Hickman shows, this important technique can be a source of loads of problems.

Matching a load to a source or vice versa ensures that the maximum possible power will be transferred, as stated by the well known Maximum Power Theorem.

In electronic signal processing, the matched condition is usually preferred, but this is not necessarily so in other applications. For instance, internal resistance - 'source resistance' - of a new 1.5V cell is around the 1Ω level, whereas the resistance of a 1.5V 300mA lens-end flashlight bulb is 5Ω when lit. This ensures that five sixths of energy supplied by the cell finishes up where it is wanted, producing light. In the matched case, a Ω bulb might produce more light, but 50% of the energy would be wasted simply warming up the battery. If you want extra light, it makes more sense to use more cells in series and a higher bulb voltage, which still only draws 300mA.

In other cases, a source is, by design, simply incapable of supplying a matched load, a good example being a 660MW turbo-alternator.

Binomial theorem

If \( R_l \) in Fig. 1a) increases by 1% to 1.01Ω, then total circuit resistance - \( R_s \) being Ω - increases by 0.5%. Thus current decreases by 0.5%. Power \( P \) dissipated in \( R_l \) is given by \( P=\frac{V^2}{R_l} \). If \( i \) decreases by 0.5%, then \( i^2 \) decreases by 1%. But \( R_l \) has increased by 1%, so the product is - virtually to a first order - unchanged. This is a result of the Binomial Theorem, but can equally be verified by working out \( \frac{V^2}{R_l}(2/1+1.01) \) on a pocket calculator.

Some results from the Binomial theorem:

\[
\begin{align*}
(1+\delta)^2 &= 1+2\delta \\
(1-\delta)^2 &= 1-2\delta \\
(1+\delta)^{-1} &= 1-\delta \\
(1-\delta)^{-1} &= 1+\delta \\
(1+\delta)^n &= 1+n\delta \\
(1-\delta)^n &= 1-n\delta \\
(1+\delta)^{-n} &= 1-n\delta \\
(1-\delta)^{-n} &= 1+n\delta
\end{align*}
\]

Note that these results only apply if \( \delta \ll 1 \) and \( n \) is smallish, so that second order and higher terms are insignificant.

With this, the design minimum value of the load is about 30 or more times the internal resistance - overload protection devices would trip long before the matched load condition were met.

Matching standards

In the design phase of electronic modules where matching is important, such as TV camera signal processing chains, telephony cable repeaters, radio receivers and a variety of transmitters, extensive use is made of test equipment such as signal generators, spectrum analysers etc.

Sources are designed to produce an accurately known output level, such as -10dBm, into a matched load. A -10dBm level is a level of -10dB relative to a power of 1mW delivered to a matched load, or 100μW. In telephony, where a 600Ω impedance system is common, 1mW corresponds to 0.775Vrms.

Telephone engineers often define 0dBm as meaning 1mW in 600Ω. But the more common usage is to define it as 1mW in whatever the system design impedance is. This corresponds to 225mV in a 50Ω system, common in rf equipment, 273mV in 75Ω, common in TV baseband signal working, or 387mV in 150Ω, in twisted pairs in underground cables. In radio-frequency testing, a module's input port is commonly driven by a signal generator with a purely resistive output impedance of 50Ω, and its output port is terminated in the 50Ω resistive input impedance of a spectrum analyser. In the case of the module's input, power delivered to it will be very close to that delivered to a 50Ω resistor. This occurs even if the module's input impedance departs fairly markedly from 50Ω resistive.

This is illustrated in Fig. 1a) and b), where things have been normalised to unity, i.e. a generator with a 1Ω source delivering 1W to a
nominal 1Ω load. For reasons explained in the panel, provided $R_s=1Ω$, the power in the load is close to 1W even if $R_L$ varies. If $R_L$ is one third of an ohm, or $\Omega_2$, power dissipated internally in the source, and hence total power supplied by the 2V ideal generator, varies markedly. Figure 1 b) shows that total power supplied by the 2V generator varies from 4W for a short circuited load, down to zero when $R_L$ equals infinity. Figures 1a) and b) show the situation at 0Hz, or dc, where the effect of any incidental reactive terms in $R_s$ and $R_L$ can be ignored. The maximum power theorem applies equally at ac, but with the added complication that in general we are dealing with impedances rather than pure resistances. This is shown in Fig. 1c), where inductive and capacitive components are shown in $R_s$ and $R_L$ respectively. However, it could equally well be the other way round, or both reactances could be of the same sign – positive for inductances and negative for reactances.

**Conjugate matching**

Using Fig. 1c), assume that reactance of inductive component $L$ of the source equals that of the capacitive component $C$ of the load at the frequency of the sinewave source $E_{source}$. In this case the two cancel each other out, power in the load being determined purely by the values of $R_s$ and $R_L$. This is known as the conjugate matched condition and can only occur at the one frequency – conjugate matching is inherently narrow band. For this reason, signal generators are designed such that $Z_L$ is as nearly as possible purely resistive, any $L$ or $C$ being ideally zero. A similar comment applies to the input impedance of measuring instruments, such as power meters and rf spectrum analysers.

If $Z_L$ in Fig. 1c) is purely resistive and equal to the system design impedance, power in the load is relatively independent of its exact value. But what if the dotted line in Fig. 1c) had been drawn horizontally? This makes what is now $Z_L$ the load (exactly 1Ω, say) and variable $Z_s$ is now the source resistance.

Considering the dc case, power in a fixed load of $Ω_2$ as $R_s$ varies from zero to infinity is now given by the vertical distance between the curve and the sloping line of Fig. 1b). If $R_s$ varies, power in the load varies wildly, even if the load is a pure resistance equal to the system design impedance. Is this important? The following cautionary tale shows that it is.

**Is matching input to output enough?**

Some years ago, the company I worked for was developing modules for an advanced all-band surveillance receiver. One engineer designed the front-end half-octave filter module, another the rf amplifier and first mixer module, another the first IF and so on through the second and third mixers an IFs.

The design aim was that during servicing, replacing any or all of the modules should leave the overall performance within specification. To this end, a voltage standing wave ratio tolerance was placed on the input and output impedances of each module. As development progressed, insertion loss or gain of each module was checked using a signal generator and spectrum analyser, or a network analyser, as available. The analyser was also used to check port impedances. Thus module inputs were driven from a respectable 50Ω source, and their output checked with a faultless 50Ω load. Nevertheless, complete receivers exhibited a range of performance which was outside the specification limits.

Unlike the situation on test where each module port is connected to a 50Ω interface – at the interface between modules in use – both port impedances could be different from 50Ω. Graphs documenting this effect have appeared in an issue of the Marconi house magazine but I have failed to unearth it. So I worked it out again for the simplified case where both $R_s$ and $R_L$ vary, but both are resistive. Figure 2 shows how power in the load $R_L$ varies with the value of $R_L$ for a series of different values of $R_s$ from 0.25 to 2Ω. Source emf behind $R_s$ is 2V as in Fig. 1a) – call this Case I.

When $R_s$ is 1Ω, maximum power naturally results in a matched 1Ω load. This curve is the same as in Fig. 1b). In accordance with the maximum power theorem, when $R_s$ equals 0.25Ω – top curve – maximum power of 4W occurs in the load when its value is also 0.25Ω. To a nominal 1Ω load, an $R_s$ of 0.25Ω delivers 2.56W or +4.1dB. Significantly, the power changes rapidly for small deviations of $R_s$ from unity. Likewise, when $R_s$ is 2Ω, maximum power of 0.5W occurs in a 2Ω load, while when $R_L$ is 1Ω, output is –3.5dBW.

Case I applies where source emf is what it should be – twice the voltage across a matched load – but source resistance $R_s$ is incorrect. This corresponds to the case of a signal generator where the output impedance defining resistor is damaged. The instrument is otherwise unchanged from new, perhaps a rather unusual case, or perhaps due to the inadvertent application of rf power to the signal generator’s output.

**Where output impedance is poor**

A different set of circumstances arises in Case II. A module with a poor output impedance has been set up to deliver its rated output to a resistive load equal to the system design impedance, for example 50Ω. In this case, internal emf $E_{source}$ will have been effectively adjusted – in terms of the normalized circuit of Fig. 1 – to something other than 2V, so as to deliver 1W into a 1Ω load. Thus if $R_L$ is lower than $Ω_2$, $E_{source}$ will have been set to less than 2V, and to more than 2V if higher. Power delivered to the load $R_L$, as a function of the value of $R_L$ for various values of $R_s$, is shown in Fig. 3.

Since $E_{source}$ has been adjusted to deliver 1W into $Ω_2$, whatever the value of $R_L$ happens to be, all curves pass through 1W when $R_L$ is 1Ω. But only in the case where $R_s$ equals $Ω_2$ is the curve horizontal for $R_L$ of $Ω_2$. This gives the relative independence of load power versus $R_L$ that obtains when the value of $R_L$ is correctly set at the nominal system impedance. Nevertheless, the variations of power delivered with variation of both $R_s$ and $R_L$ are much less in this case than Case I, permitting the results for Case II to be plotted in Fig. 3 with a vertical scale twice that of Fig. 2.

**Matching in filter designs**

Correct matching is particularly important where filters are concerned, as the following illustrates. Some time in the '80s, my then boss had a crisis with the company's new hf receiver - which was already over budget and overdue. The 20-30MHz sub-octave filter was far too narrow, and excessively lossy to boot. "It's got to be fixed, but don't spend more than a week on it, even if the conclusion is that we have to relax the specs."  

Having spent the rest of the morning getting the necessary test equipment together, I was
able to report half way through the afternoon that the filter was now working fine. So it should, for it was a seven pole elliptic design straight out of the reference.

Checking the values on the circuit diagram confirmed that the engineer who had designed it had done his denormalising sums right. Capacitors on the board were also all correct, and the coils all capable of being tuned by means of their slugs to the correct inductance. Output of the filter module was normally connected to the rf/first mixer module, which

presented a good low voltage-standing-wave ratio input. But before getting there, output of the 20-30MHz filter, when selected, had to pass through a number of band-select relays and board tracking - which looked distinctly capacitive. As far as the filter was concerned, this capacitance was part of the load, which should have been purely resistive but wasn't.

Reducing the value of the final shunt capacitor in the filter effected an improvement, and further reduction made it better still. In the end, it turned out that no capacitor was needed at all, the circuit strays equaling the design value of the filter’s final shunt capacitor. But in the end I settled for 1pF, to avoid C0 on the circuit diagram being shown as 0pF.

The final capacitor in the 15-20MHz was also reduced in value somewhat, the lower frequency filters being in spec. due to the much larger values of their final capacitors.

Reference
LEN COOKE ENTERPRISES
UNIT 5, SOUTHLAND ENTERPRISE CENTRE, BRIDGE ROAD, SOUTHAL, MIDDLESEX UB2 4AE, ENGLAND
TEL: 0181 813 9946 FAX: 0181 574 2339

We Buy, Sell, Service & Export Used Test Instruments

HP 3060A Spectrum Analyser £1,250
Tektronix 7023A/7123A 1GHz to 2GHz £2,200
Tektronix 7023A/7123A 1.5GHz to 2GHz £3,500
Tektronix T5010 Tracking Generator £1,200
HP 3938B Tracking Generator £850
Tek Calibrator TM503/PG506/SG503/ TG501 £1,800
HP 8118A Pulse Generator £450
HP 9082A Pulse Generator £1,220
HP 2148B Pulse Generator £1,500
HP 1630G Logic Analyser £1,200
Thurby LA160B Logic Analyser £250
HP 3476A Multimeter £750
Beckman 560 Bench Multimeter £165
Datron 1061A Bench Multimeter £950
Datron 1061A Bench Multimeter £950
Marconi 2018 AM/FM Sig. Generator £750
Recal 9002 AM/FM Sig. Generator £550
Wavetek 162A Fun. Gen. 0.1MHz to 40MHz £195
Jupiter 501 Function Generator £100
Jupiter 2100 Function Generator £150
HP 3311A Function Generator £225
Farnell LF44 Generator £200
Farnell LF1 Generator £125
Philips PWM187 Fun. Gen. 1MHz to 1MHz £200
HP 2040 Oscillator £220
Gould J8B Oscillator £125
Tektronix 4610 Scope 100MHz £450
Tektronix 465B Scope 100MHz £450
HP 1740A Scope 100MHz £375

When Performance is more important than size:–
two new re-programmable BASIC Stamp
Computers.

BS1-IC
8 I/O lines
up to 100 program lines
2,000 lines/sec
Comms to 2400 baud
£29 single price

BS2-IC
16 I/O lines
up to 600 program lines
SPI, DTMF
Comms to 19.2k baud
£49 single price

Programming package £66

Milford Instruments Tel 01977 683665 Fax 01977 681465

Electronic Designs Right First Time?

LAYAN - Affordable Electromagnetic Simulation

Affordable Electronics CAD

LAYAN: Electro-magnetic layout
Simulator. Include board parasites in your
Analogue simulations.
$950.00 £945.00

EASY-PC Professional: Schematic
Capture and PCB CAD. Links directly to
ANALYSE III, LAYAN and PULSAR.
$375.00 £195.00

PULSAR: Digital Circuit Simulator
- 1500 gate capacity
$195.00 £98.00

ANALYSE III, LAYAN and PULSAR.
Include board parasites in your
Simulator. Include board parasites in your

Z-MATCH for Windows: Windows based
Smith-Chart program for RF Engineers.
$476.00 £248.00

FILTECH: Active and Passive Filter Design
$275.00 £145.00

EASY-PC: Entry level PCB and Sch. CAD
$195.00 £98.00

We operate a no penalty upgrade policy.
Technical support is FREE FOR LIFE.
Special prices 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

When Performance is more important than size:–
two new re-programmable BASIC Stamp
Computers.

BS1-IC
8 I/O lines
up to 100 program lines
2,000 lines/sec
Comms to 2400 baud
£29 single price

BS2-IC
16 I/O lines
up to 600 program lines
SPI, DTMF
Comms to 19.2k baud
£49 single price

Programming package £66

Milford Instruments Tel 01977 683665 Fax 01977 681465

Electronic Designs Right First Time?

LAYAN - Affordable Electromagnetic Simulation

Affordable Electronics CAD

LAYAN: Electro-magnetic layout
Simulator. Include board parasites in your
Analogue simulations.
$950.00 £945.00

EASY-PC Professional: Schematic
Capture and PCB CAD. Links directly to
ANALYSE III, LAYAN and PULSAR.
$375.00 £195.00

PULSAR: Digital Circuit Simulator
- 1500 gate capacity
$195.00 £98.00

ANALYSE III, LAYAN and PULSAR.
Include board parasites in your
Simulator. Include board parasites in your

Z-MATCH for Windows: Windows based
Smith-Chart program for RF Engineers.
$476.00 £248.00

FILTECH: Active and Passive Filter Design
$275.00 £145.00

EASY-PC: Entry level PCB and Sch. CAD
$195.00 £98.00

We operate a no penalty upgrade policy.
Technical support is FREE FOR LIFE.
Special prices 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

December 1995 ELECTRONICS WORLD + WIRELESS WORLD
### TRANSDUCERS

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Price</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD133</td>
<td>30p</td>
<td>Resistors</td>
</tr>
<tr>
<td>BD124</td>
<td>30p</td>
<td>Inductors</td>
</tr>
<tr>
<td>BCY70</td>
<td>30p</td>
<td>Capacitors</td>
</tr>
<tr>
<td>BC548</td>
<td>30p</td>
<td>Transistors</td>
</tr>
<tr>
<td>BC446</td>
<td>30p</td>
<td>Diodes</td>
</tr>
<tr>
<td>BC238</td>
<td>30p</td>
<td>Other Parts</td>
</tr>
<tr>
<td>BB205</td>
<td>30p</td>
<td>Specialized</td>
</tr>
<tr>
<td>ACV18</td>
<td>30p</td>
<td>Accessories</td>
</tr>
<tr>
<td>AC141K</td>
<td>30p</td>
<td>Connectors</td>
</tr>
<tr>
<td>GRAN DATA LTD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Arrays
5Mgate asics. Up to five million gates and 10Mb of memory, or nearly 50 million transistors can be shoehorned into the G10 series of ic's from LSI Logic; to point these figures up, LSI say that such a density is equivalent to more than eight Intel P6s. Gate delays are down to 50ps. There is a library of complex elements such as three- transistor memory structures and mixed-signal circuitry providing 12- and 270MHz for data conversion. LSI Logic Europe plc. Tel., 01344 426544; fax, 01344 481039.

Fpgas. Xilinx offers the XC8100 family of field-programmable cmos gate arrays using the company's MicroVia antilute technique and sea-of-gates architecture to provide virtually 100% of 1000-9000 usable gates. Logic cells are configurable to carry out synchronous, combinational and three-state logic functions. Supply is 5V and 3.3V. Xilinx Ltd. Tel., 01932 394091; fax, 01932 394499.

Microprocessors and controllers
PICs with voltage comparators. Microchip's PIC16C622 eprom-based PIC has two analogue comparators, a programmable-voltage reference and the first 4V low-voltage protection to be offered. It uses the risc-like architecture common to the series, although here, the program and data are in different memories, so that separate buses are used to fetch and execute in one cycle. There is 2K/14 on-chip programmable memory. Polar Electronics. Tel., 01525 377093; fax, 01525 378967.

Graphics accelerator. Advance Logic introduces the AL2G2042 dram-based, 64-bit PCl graphics accelerator, which contains graphics engine, d-to-a converter, clocks and BIOS in the one 208-pin package, with two 256K/16 drams, the accelerator forms a complete graphics sub-system that can be up-graded by simply increasing memory to 2Mb. Silicon Concepts Ltd. Tel., 01426 751617; fax, 01426 751603.

Graphics controller. CL-GDS436 is the fastest of Cirrus's dram-based graphics controllers, having a 64-bit graphics engine and enhanced bit-BlT capability with larger, double-buffered registers for faster performance with Windows, NT and OS/2, in 24-bit colour. Features include a direct, glueless interface to the PCibus and the device supports extended burst cycles on the bus. It can be used with PowerPC and other PCI-based systems as well as PCs. Graphics modes up to 1024x768 in true colour and 1280x1024 in 256 colours. Cirrus Logic Inc. Tel., 01727 872424; fax, 01727 875919.

486 embedded processor. A family of 486 processors intended for use in equipment other than pcs is announced by National Semiconductor. The NS468 has a three-stage pipeline, against the pc version with five, and has no co-processor. It does have extra peripherals, including a dama controller, programmable interrupt controller, Iod controller, PCMCIA controller, etc, and the device gives a compatible 486 instruction set, a 32-bit core, 25MHz working and 12mips performance. Power-saving modes are included. National Semiconductor GmbH. Tel., 0049 1405 327832.

16-bit microcontrollers. Hitachi has the H8S series of 16-bit devices, which achieve 1Dhrystone mips at 5V with a 20MHz clock, a multiply or multiply-and-accumulate instruction taking 200ns, and provides 67mips/W at 2.7V (48 at 5V). Power savings have been obtained by making some of the internal clock-driven functions into event-driven logic circuits, not needing a constant clock signal. Benefits are lower switching frequencies, giving lower power consumption, and lower ecm power dissipation is 75mW at 10MHz. Peripherals provided include a 11x7 10-bit a-to-d converter, a 32-bit data transfer controller needing no cpu intervention or dma controller and an enhanced memory interface capable of accessing fast page-mode dram and burst-mode rom. Hitachi Europe Ltd. Tel., 01628 585163; fax, 01628 585160.

C-programmed controller. Greening Technology's Micro Genius microcontroller is smaller than a credit card and costs £35 for one off. Programmed in C, it has 14 functions needed for CD, MD and mix-signal circuitry providing three-transistor memory structures and mixed-signal circuitry providing 12- and 270MHz for data conversion. LSI Logic Europe plc. Tel., 01344 426544; fax, 01344 481039.

Audio processor. Philips offers the TDA1546T single-chip audio processor, which includes Bitstream filters for digital de-emphasis, volume and tone control, Bitstream d-to-a converters and headphone amplifiers, providing all audio functions needed for CD, MD and DC personal stereo players. It is comparable to the TDA1561 or LSB justified serial input data and provides 1.7Vpk-pk audio into 32Ω. Low voltage and the need for splicing on site. Each panel takes 144 fibres and is mounted in a 19in or 23in relay rack; a selection of adaptor interfaces provides flexibility in configuring the system. Molex Electronics Ltd. Tel., 01420 477070; fax, 01420 478185.

Passive components
Silver mica capacitors. ACL's D-15 range of high-voltage, precision silver mica capacitors are in resinous and/or clear epoxy and come in 100Vdc, 300Vdc and 500Vdc ratings, in values in the 1-500pF, 1-820pF and 1-510pF ranges respectively. Temperature coefficient is low and tolerance is 0.25% and 0.5%. Four operating classes are available, from —40°C to 85°C to —55°C to 150°C. Europa Components & Equipment plc. Tel., 0181-963 2376; fax, 0181-207 6946.

Connectors and cabling
Optical-fibre distribution. Molex pre-distributed termination panels for optical fibres provide high-density connections and versatility and avoid the need for splicing on site. Each panel takes 144 fibres and is mounted in a 19in or 23in relay rack; a selection of adaptor interfaces provides flexibility in configuring the system. Molex Electronics Ltd. Tel., 01420 477070; fax, 01420 478185.

Displays
Better led. Crystaloid has improved the readability of liquid-crystal displays. In earlier types, the indium/tin oxide electrodes carrying current in the display have a tendency to reflect light, making inactive segments of the display appear active. Crystaloid has a new index-matching technique in which a coating is applied over all the areas to match the reflections, so that contrast in the reflections is virtually zero. The technique also eliminates short segments of the display appearing inactive. Lumeq Opto/Components Inc. Tel., 001 708 359-2970; fax, 001 708 352-8904.
NEW PRODUCTS CLASSIFIED

Please quote "Electronics World + Wireless World" when seeking further information.

Coating thickness meter. Tor Technologies offers the PostiTector 100, which is a hand-held coating thickness gauge that uses ultrasonics to measure coatings on concrete, lacquer, varnish, paint, ceramic glazing, etc. Operation is by two buttons, since there is no need to select coating or substrate and the instrument is auto-calibrating, also providing audible and visual alarms and switched Imperial/metric readings. Optional statistical and memory capabilities allow the storage of up to 1500 readings in 99 groups, with maxima, minima, tolerances, average and standard deviation appearing on the display. There is an RS232 port and infrared connection to the HP-IR printer. Tor Applied Technologies Ltd. Tel., 01455 844114; fax, 01455 844116.

Analogue/digital oscilloscope. OX8620/8627 from Matrix are combined 100MHz analogue and 40MHzample/s digital instruments. Front panels are familiar, since the microprocessor interface allows the use of rotary knobs and touch buttons with leads to confirm selection. Auto-setup is provided, setups being stored at switch-off. They are both dual-channel, dual-timebase instruments, capturing and recording up to four waveforms, each having 8000 points; OX8627 also has glitch capture down to 50ns. Stored data can be processed in various ways in both analogue and digital modes, and there is RS232 (OX8620) and IEEE 488-2 (OX8627) communication for control or output. Matrix UK Ltd. Tel., 01256 311877; fax, 01256 23659.

Waveform analyser. Nicolet's new 2850 waveform analyser is a complete system for multifaceted transient recording and analysis; it has a 486 processor, a large colour display and Windows-based software. It takes the form of a mainframe with plug-ins for up to 24 channels with a number of input capabilities. Sampling rates are up to 10MSample/s and memory length up to 8Msample/channel. In the X direction, there is split timebase and several trigger modes to cope with complicated waveforms and a high-speed data transfer system allows the display of waveforms within fractions of a second after acquisition. Complete experiments, including the use of external programs, are supported. Nicolet Technologies Ltd. Tel., 01908 679903; fax, 01908 677331.

Filters

Inlet filters. Capable of being fitted to existing equipment, BLP's ST200 series is a general-purpose type meeting IEC 320 and measuring 39.4mm in length. Space is further saved by placing the connectors on top of the body, so that the filters occupy about the same area as a non-filtered type. Versions available handle 1A, 3A or 6A at up to 250Vac. BLP Components Ltd. Tel., 01638 665161; fax, 01638 660718.

Electromechanical components.

Rendal has published its 1995/6 catalogue of connectors, cordsets, fans, switches, etc. New this time are 10A IEC320 power inlets, an extended Striplock range and a chip fan for Pentium processors. Rendal Ltd. Tel., 01243 866741; fax, 01243 841486.

Materials

Degresser. From MMCC(UK) comes Biosane T212, which is a fast, cold-process degreasing agent that is environmentally and biologically safe. Its surface tension is 50% lower than that of 1.1.1 Trichlornonane and it dries quickly at room temperature. A further advantage is its high settling power, which means that debris sinks to the bottom of the tank so that components do not have to go through it, eliminating the vapour rinse normally needed. It also possesses a 99% recycling capability. MMCC(UK) Ltd. Tel., 01707 336282; fax, 01707 336290.

Metal-substrate pcb's. IMS is a printed board on an insulated metal substrate, produced by the French company CIRE. The material dissipates heat and provides
insulation between circuitry and metal, consisting of a single-sided pcb with aluminium (or copper), thermally conductive adhesive, circuit copper and a solder mask, the aluminium being open to the air for cooling. Double-sided boards can be produced. Insulation depends on the material used and its thickness, but it can be up to 4.8kV. CIRE/BREE. Tel., 0033 38 30 53 62; fax, 0033 38 30 21 30.

Production equipment
Solder paste inspection. Automatic solder paste inspection system, Dek Inspector 2 by Dek Printing Machines, has a set of new features to improve its versatility without adversely affecting speed. It lifts boards off the belt-feed transport rails, other boards continuing to travel forward while the selected one is inspected by a combination of pattern recognition and laser scanning, as many areas of the board being inspected as possible until it is needed further along the line. It then replaces the board, picks up the next board and continues with next Inspection area, adding to the original inspection database in each case. Programming is effected by means of a graphical/menu-driven screen and a library of patterns, the user setting the areas to be examined and tolerances to observe. Flash lighting freezes residual motion and special lighting differentiates between paste and pads, a laser measuring paste height. Refrigeration to -40°, hot air vents, a range of compressed-air technologies for swarf removal or cooling air, a new air moving device for desk-top use, is now produced. Insulation depends on the aluminium being open to the air for cooling. Dek Printing Machines Ltd. Tel., 01305 760760; fax, 01305 760123.

Air nozzles. New company Meech-ARTX is to manufacture air nozzles for swarf removal or cooling air, a new design saving up to 90% of the compressed air normally used and providing an airflow 25 times that given by a normal design. There is also a range of compressed-air powered vortex tubes to handle heats of 5000kW and cool refrigeration to -40°, hot air exhausts from one end and cold air at the other. Meech-ARTX Ltd. Tel. 01993 760760; fax, 01993 760777.

Power supplies
High-voltage. Farrel Hivolt has the first of the FSM10 Series of high-voltage supplies for applications needing a precise source. Current and voltage monitoring is provided and there is an output inhibit. Outputs are 2, 5, 10 and 15kV and the FSM10/202 and /53 provide positive or negative output of 10V-2kV at 5mA and 150V-15kV at 665mA. Ripple is less than 20mVpk-pk at 2kV and under 1.5Vpk-pk at 15kV, with drift at under 500ppm°C. For a 2V change in the 24V input, regulation is 0.1V at 2kV and 0.75V at 15kV. Farrel Hivolt Ltd. Tel., 01234 841888; fax, 01234 845898.

S-m regulator. With the aim of only using four external components, the new Banlack S41-01 surface-mounted power regulator ic forms a complete switched-mode power supply. It gives an output of up to 4.5A at 5V from 7-33V, with 80mV stabilisation and 30mV regulation. Switching frequency is 50kHz. Allegro MicroSystems Inc. Tel., 01993 233355; fax, 01992 246622.

High-current switcher. Having an output rated at 1.25A and switching at 42kHz, Cherry's CS-3972 is meant for use in both computers and car systems, in which it serves as the pulse-width control element in any of the standard forms of switches or relays. Input range is 3-60V and output up to 60V at 1.25A at a 50% duty cycle. Undervoltage, thermal and current-limit protection is included. Cherry Semiconductor. Tel., 01401 865350; fax, 01401 865786. Internet info@cherry-semi.com.

Frugal regulator. Z87BL.05 is a 5V voltage regulator having a quiescent current of 350mA, which is about one-fifth that of standard 78L types, also polarising up and continuing with next Inspection area, adding to the original inspection database in each case. Programming is effected by means of a graphical/menu-driven screen and a library of patterns, the user setting the areas to be examined and tolerances to observe. Flash lighting freezes residual motion and special lighting differentiates between paste and pads, a laser measuring paste height. Refrigeration to -40°, hot air vents, a range of compressed-air technologies for swarf removal or cooling air, a new air moving device for desk-top use, is now produced. Insulation depends on the aluminium being open to the air for cooling. Dek Printing Machines Ltd. Tel., 01305 760760; fax, 01305 760123.

Mighty mouse. Interlink Electronics announces that DuraPoint, a fully sealed, stainless steel, resistive pointing device for desk-top use, is now available in Europe. It is impervious to fluids, other contamination, vibration and human beings, has no moving parts or mechanical assemblies and therefore does not become clogged up with filth from the mouse mat. It uses the company's VersaPoint technology, in which a touch on a button or joystick is transferred to a force-sensitive resistor. Consequently, direction of cursor movement is determined by direction of the applied force on the button and speed of cursor movement by the amount of force applied. Interlink Electronics Ltd. Tel., 01670 528200, fax 528212.

Satellite terminal. Magnavox has added to its range of satellite systems with the MX4042, a desk-top instrument featuring a terminal providing voice, 2400b/s fax and data. It consists of a remote antenna (25ft cable) and a two-wire dtmf desk set with handset, signal strength bar graph, keypad and loud speaker, to find the satellite by means of a map display on the lcd and synthesised voice prompts operation in English and six other languages. Magnavox Electronics System Co. Tel., 001 310 618 1200.

Transducers and sensors
Annunciators. Appello programmable voice annunciators have been improved to provide better sound reproduction, more facilities and easier message creation and storage. Three versions gives 16 messages, two of 8 with alarm tones and four of 64s in total. Options such as pause length and number of repetitions are defined by the user and an external microphone input is provided for improved recording of speech. Analogue inputs are stored directly in non-volatile memory, with no a-d conversion, a technique that provides better quality and wider bandwidth than often found in conventional equipment, as well as being cheaper and quicker. European Safety Systems Ltd. Tel., 0171 743 8880; fax, 0171 740 4200.

Radio communications products
Radio-controlled clock. Model RM913 alarm clock from Oregon Scientific is radio controlled by the 60kHz signal from MSF Rugby, which itself is referred to a caesium standard at the National Physical Laboratory. Data carried by the transmission automatically sets time and date and copies with 30/31-day months, summer time and leap years. The alarm brings on a backlight to thelcd and a separate alarm is useful for reminders during the day and there is a second time zone. The clock is battery-powered. Oregon Scientific Ltd. Tel., 0181 903 2886; fax, 0181 903 2369.

Tilt sensors. Absolute-encoded tilt inclinometers in the A-ID by Control Transducers give an output of 4096mV in 1mV steps over a 360° arc while turning continuously. Encoders are of the optical absolute type, needing no zero reference or resetting and use a pendulum for gravity reference. Control Transducers. Tel., 01234 371704; fax, 01234 371083.

Vision systems
Video conferencing. Nokia offers an integrated monitor, camera, microphone and speakers for video communication. MediaStation includes the NVC-100 software codec for video and audio telephony and is designed for both local and wide-area.
Computer board-level products

110MHz single-board computer. SES-110 from Sun SPARC is a new member of the SPARCengine 5 family, this one having the 100MHz version of the MicroSPARC II processor, running at 140Dhrystone. 1.1 mips for networking, telecomms and imaging. Interfaces for fast SCSI, floppy and 10/100 Ethernet, serial and parallel data are built-in. A local 64-bit bus allows fast data transfer from memory to video for graphics, effectively a fourfold increase in data transfer speeds. Sun Microsystems Ltd., Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.

Computers

Industrial computer. AMC's ErgoTouch Computer HL is certified to Class 1 Division 2 and rated to NEMA 4X on all surfaces and needs no air supply or purging/pressurisation enclosure; it is a complete PC contained in a 4.5in deep housing, has a touch panel and can be mounted anywhere - wall, panel, boom or desk. Advanced Modular Computers Ltd., Tel., 01753 580660; fax, 01753 580653.

Data communications

Data/fax modems. Rockwell has the SMV288ACW, V.34, a new member of the Socket/Modem family of oem units. Performance is increased to a data handling throughput of 115kb/s from memory to video for graphics, and parallel data are built-in. A local computer board-level fax, 0046 87938441. standard. Nokia Consumer Ltd. Tel., 01276 451440; fax, 01276 451267.
Hierarchical or flat schematic linked to artwork. Unlimited design size, 1 micron resolution. any shaped pad, definable outline library. pin, gate & outline swapping - auto back annotation. Split power planes, switchable on - line DRC.

**COOPER & CHYAN SPECTRA**
autorouter (SP2)

Inputs: OrCAD, Cadstar, PCAD, AutoCAD DXF

Outputs: Postscript, Windows bit map


**TRADE IN YOUR EXISTING PACKAGE TODAY**

Seetra CAE, Hinton Daubney House, Broadway Lane, Lovedean, Hants, PO8 OSG

Call 01705 591037 or Fax 01705 599036 + VAT & P P

All Trademarks Acknowledged

---

**SEETRAX CAE RANGER PCB DESIGN**

WITH COOPER & CHYAN AUTOROUTER

**RANGER3 - DOS**

- Windows/NT

- £2500

- £2900

---

**RANGER2 - £150**


---

**RANGER2 UTILITIES - £250**

COOPER & CHYAN SPECTRA auto-router (SPI)

Gerber-in-viewer, AutoCAD DXF in & out

---

**UPGRADE YOUR PCB PACKAGE TO RANGER2 - £60**

---

---

---

---

---

---
Amazed at the widespread misunderstanding of how the Foster-Seeley discriminator works, Richard Brice sets the record straight.

Despite the increasing use of phase-locked-loop FM detectors, the Foster-Seeley discriminator and its cousin the ratio detector still enjoy widespread use.

Sadly, familiarity has bred contempt for the principles at work in this apparently simple circuit, top right. It is still common to see descriptions of the operation of the discriminator which refer — without qualification — to the 90° phase-shift which exists between the primary and secondary of a tuned transformer.

Yet such a phase shift only occurs under special circumstances. As a student, I found explanations of the circuit confusing. Rather than challenge the principles given, I opted to believe that a phase shift must exist between the primary and secondary voltage of all tuned transformers.

This fallacious belief was finally laid to rest when some empirical investigations proved this was not the case. A little research has uncovered that this confusing explanation of the Foster-Seeley discriminator has a long and distinguished history.

"...operation is dependent on the 90° phase shift which occurs at resonance between primary and secondary voltages of a tuned transformer."²

"It will be seen that both primary and secondary windings of the IF transformer are tuned. Now, when they are both tuned to resonate to the incoming signal (i.e., the normal carrier frequency) the voltage across the secondary, $V_s$, lags the voltage across the primary, $V_p$, by 90°."²

"Conventional discriminators use the composition of two vectors at right angles when there is no frequency deviation and when the frequency departs from its state of rest the angle between the vectors departs from 90°. Figure 2.6 [similar to diagram top right, next page] shows an elementary balanced discriminator. Capacitors $C$ tune the inductances to resonate at the centre frequency of the intermediate frequency band of the receiver... At resonance the voltage $V_1$ $[V_p]$ will be in quadrature with the voltages in each half of the secondary winding."²

Foster-Seeley discriminator analysis

$$i_{A-C} = V_o\left(\frac{1}{R} + j\omega C\right)$$

$$V_{A-B} = V_o\left(1 + j\omega \frac{(1+k)}{R} - \omega^2 L(1+k)C\right)$$

$$i_{A-B} = V_o\left(\frac{1 + k}{\omega L} - j\omega C\left(1 + \frac{1+k}{k}\right)\right)$$

$$V_{in} = V_{A-B} + j\omega L(1+k)(i_{A-C} + i_{A-B})$$

$$V_{in} = V_o\left(1 + \frac{k}{R} - \omega^2 L(1+k)C\right)\left(\frac{1+k}{k}\right)$$

$$V_{in} = a\angle \theta$$

$$\tan\theta = -\frac{\omega^2 L C}{\frac{2 + 2k}{k} - 1 - k - 2}$$

$$= \frac{\omega^2 L C}{\frac{1}{k} - k - \frac{1}{1+k}}$$

$$= \frac{\omega^2 L C}{\frac{1}{k} - k - \frac{1}{1+k}}$$


---

Do you know Foster-Seeley?
But, how can any phase-shift exist between the primary and secondary of a transformer if the flux closely couples both coils? The answer is — in the Foster-Seeley circuit it does not.

Circuit action relies on there being a very loose coupling between primary and secondary windings of the intermediate-frequency transformer. The diagram bottom left, and the associated working presents a more rigorous analysis. Analysis also shows that when coupling between a transformer primary and secondary is perfect — equal to 1 — no phase shift exists between primary and secondary voltages. This is regardless of whether the windings resonate with parallel capacitances or not.

M. G. Scroggie in *Foundations of Wireless* appears to be one of the few writers who deemed it necessary to bother the reader with this crucial aspect of the discriminator’s operation,

"...because both windings are tuned exactly to the carrier wave and coupled only very loosely, voltages across them are 90° out of phase."

Some authors, perhaps sensing murky waters but being unsure as how to clear them, simply eschew explanation altogether. A recent, and widely set textbook describes the Foster-Seeley discriminator thus,

"... provides a single tuned circuit in a fiendishly clever diode arrangement to give a linear curve of amplitude output versus frequency over the IF bandpass."

This explanation is unlikely to leave today’s students crystal clear as to the operation of the circuit. Its author appears to use words as did Lewis Carroll’s Humpty Dumpty who argued, “when I use a word... it means just what I choose it to mean — neither more nor less.”

References
4. Private correspondence with my friend Brian Pethers.
ANCHOR SURPLUS Ltd
The Cattle Market Depot
Nottingham NG2 3GY. UK
Tele: +44 (0115) 986 4902/
  +44 (0115) 986 4041 24hr answerphone
Fax: +44 (0115) 986 4667

RADIO EQUIPMENT
REDIFON DU500 Transmitter Drive Unit c/w PU200 Power Supply....
LA200 HF Power Amplifier... & Controller... Matching Transmitter for the R500 HF Receiver. Excellent Condition... Complete £995
PLESSEY PR1553 HF Receivers... Limited Quantity of these excellent Receivers available now
Ex-Stock for Only £495
RACAL RA1792 HF Receivers... Complete with all Filters (5 off).
  Fully Aligned and Tested... Excellent Condition... Available Ex-Stock at Only £845
RACAL MA1720 Synthesised HF Transmitters... HF Coverage... Numeric Switch selection...
  Remotable... Few available Ex-Stock Only £245

HP Coaxial Frequency Meters
HPX 532B 8.2Ghz-12.4Ghz... New and Boxed Only £85
HP 536A 0.94Ghz-4.20Ghz Only £85  HP 537A 3.7Ghz-12.4Ghz Only £85

BIRD RF EQUIPMENT
BIRD 8325 TENTULINE 50 Ohm Attenuators 30db 500W Only £95
BIRD 6154 TERMALINE 25Mhz-1000Mhz 0-150W 50 Ohm Only £75
BIRD 43 c/w Case and 6 Sensors (100H, 250H, 1000H, 5D, 25C, 25D) Only £195
BIRD 43c/w Case and 3 Sensors (100H, 250H, 1000H) Only £175

LORAL-NARDA 8841C-01 RF DETECTORS
1-18Ghz... Sensitive to levels > 1mW/cm2... Belt Mounted... Audio/Visual Alarm
  Incl. Case and Earpiece Only £75

SOLARTRON 7150 SYSTEMS DMMS
6.5 Digit... IEEE fitted... LCD Display... 100n V-750VAC... 1uA-2ADC... 10uA-2AAC (true rms)
  10mR-20Mr (2/4 wire) Fully Programmable... Only £145

TEK 2210 Digital Storage Oscilloscopes
DC-50Mhz Non-Storage bandwidth... 20MS/sec per ch Storage Rate
Dual Trace... Reference Traces... Excellent Condition... Fitted Rack Kit
  Limited Quantity Special Offer for One Month Only £625

FLUKE 27/FM LCD DMM’s with 80K-6 (6000V Probe)
3.5 Digit Analog/Digital... Min/Max Readings... Relative Mode
  Including Case and Manuals... One Month Special Offer... As New Only £175

OPEN SEVEN DAYS A WEEK
Mon-Fri 9am-6pm  Sat 8am-4pm  Sun 10am-4pm
NO APPOINTMENTS NEEDED. CALLERS ALWAYS WELCOME
All Prices are Ex VAT & Carriage
All items are Fully Tested with Verified Calibration
and carry our Unique 30 Day Un-Conditional Warranty
Analysing ac is mainly concerned with the effects of frequency on the operation of a circuit. This article looks at the way that the Micro-Cap IV simulator handles analyses in the ac group.

Operating under dos, Micro-Cap IV is a well-established implementation of Spice2. It accepts netlists in conventional Spice format, but it is also able to work from a schematic using a very comprehensive schematic editor. Nodes are numbered automatically—they can also be given names if preferred—with the ground node being node zero. In Micro-Cap IV or MC4, wires that cross are taken to be connected, so jumpers are used where crossing lines are not joined.

Analysing op-amps
Figure 1 shows a low-pass active filter with Chebyshev response. Component values were calculated on paper using the conventional capacitor-ratio tables for a 10kHz Chebyshev filter with 1dB ripple in the pass-band.

The purpose of the simulation is to confirm the behaviour of the filter, and to investigate the effects of using different types of op-amp. The user has the option of allocating each component a name, or simply specifying its value.

In Fig. 1, most components are specified by their values, but the voltage source and op-amp are given names. The MODEL statements for these appear below the schematic. If necessary, these can be edited when parameters need to be changed.

Parameters in the sine-wave voltage source specify—in order—a frequency of 1MHz, amplitude of 1V, dc offset zero, and phase shift zero. Note that Spice does not distinguish cases. Both ‘m’ and ‘M’ mean ‘milli’. For ‘mega’, Spice uses ‘meg’ or ‘MEG’. Other parameters may be specified but their default values are satisfactory in this example.

Note that parameter symbols used here are not standard Spice symbols for these parameters. The operational amplifier model is specified by its model name, LF355, model type, OP4, and some relevant parameters. The term LF355=3 indicates that the most complex op-amp model should be used while TYPE 3 specifies n-channel junction-fet inputs.

Other parameters specified are open loop gain, $2 \times 10^5$, positive and negative slew rates, 5V/µs, and gain bandwidth, 2.5MHz.

Performing ac analysis
The netlist also issues commands for the ac analysis. The second term in the .AC command determines frequency points for which the results are calculated.

There are three options. The term DEC stands for ‘decade’ meaning the frequency range is to be divided into decades. The total range is 100Hz to 1MHz divided into four decades—100Hz to 1kHz, 1kHz to 10kHz, 10kHz to 100kHz and 100kHz to 1MHz. The number of frequencies within each decade is specified by the number following DEC, in this case 20.

These points are automatically located on a logarithmic scale. Instead of DEC, I could have stipulated LIN to perform an analysis over a linear range.

Spice commands
These Spice statements are available for ac analysis.

.AC initiates an ac analysis, with an ac frequency sweep. Small-signal response of the circuit is calculated for each point on a specified range of frequencies, assuming that the circuit is linear.

Spice begins the analysis by computing the dc operating point—refer to ‘Analysing dc via Spice,’ EW+1/1/14/ Oct 1995—and uses the results of this to provide the voltage levels with reference to which all non-linear components are linearised.

.NOISE calculates noise response for input and output.

.PZ performs a pole-zero analysis—available only in Spice3.

.DISTO analyses distortion caused by non-linearities in semiconductor devices.

.PRINT AC calls for the results of the analysis to be printed as a set of tables—not in Spice3.

.PLOT AC calls for the results of the analysis to be plotted as a graph—not in Spice3.
Netlists in Micro-Cap IV

Micro-Cap IV is able to use a standard Spice netlist, which may be typed on the Editing screen, then saved as a .CKT file. Alternatively, it will import a Spice netlist from another simulator or typed on a word-processor, provided that it is saved as an ascii file without special headers.

The most convenient technique is to draw the schematic, add .MODEL and other statements, then work with this combined schematic-netlist, using the interactive Limits boxes, of which there is one each for dc, ac, Fig. 2, and transient analyses.

On request, MC4 prints out a netlist but this is not a Spice netlist and can not be used to run a simulation. It is a compact statement of the circuit and parameters, excluding command statements.

Under the statement line OPTIONS, it lists the values of a number of parameters currently being used by Spice. These include GMIN, the minimum conductance value used in calculations, and RELTOL, a tolerance level used to determine when Spice has performed sufficient iterations.

These and other parameters have default values which it is not normally necessary to alter.

Fig. 1. Typical schematic drawn with Micro-Cap IV includes definitions of models and optional command statements for the analysis.

Fig. 2. The ac analysis dialogue box allows analyses to proceed interactively.

Fig. 3. AC response of the circuit of Fig. 1 shows the typical response of Chebyshev low-pass filter.

Fig. 4. The upper graph shows real and imaginary components of the output of the filter of Fig. 1. The lower graph shows phase response.

have the frequency range divided on a linear scale. Spice also has a OCT option, not available in MC4, in which the range is divided into octaves, the end of each sub-range having twice the frequency of its beginning.

Command statements shown on the netlist are optional, as MC4 has an 'ac analysis limits' dialogue box which allows the analysis to be set up and modified interactively. If command statements have been entered on the netlist, they appear in the dialogue box and can be used as the basis for an analysis.

Otherwise, and more usually, analyses are controlled from the box, Fig. 2. To reach this from the schematic screen, select the Run menu, then item 2:AC Analysis. The upper panel holds run parameters, beginning with the frequency range and listing the final and starting frequencies. The default number of steps is 51, giving 50 equal intervals throughout the range, and overrides the Spice command given on the netlist.

The lower part of the box controls graphical output. Enter details of the curve or curves to be plotted. Checking in column N gives a numeric printout. Its format — number of places before and after the decimal point — is set by the numbers in the 'fmt' column. The X and Y columns specify logarithmic scales if checked or linear scales if unchecked.

Expression X is usually frequency, F, in ac analyses. Expression Y has a variety of forms.

Expression X is usually frequency, F, in ac analyses. Expression Y has a variety of forms.

In Fig. 2, the first line states that the y-variable is to be the magnitude, MAG, of the voltage, V, at node 6, plotted on a decibel scale. The second line calls for the imaginary component of the voltage at node 6, plotted on a decibel scale. The third line asks for the phase of the voltage at node 6. Click on 'Limits' and select 1:Default all, to enter 'auto' in the X range and Y range columns. The software now calculates suitable limits for the graphs.

To plot only the magnitude-frequency graph, select the table's first row by typing '1' in the plot column, P. Fig. 2. Click on the square in the Limit box top left corner and select 6:Close. The ac analysis screen is revealed. Click on AC and select 1:Run. This gives Fig. 3.

The magnitude scale is a little difficult to interpret. This is because the second grid line down is at ~3.6dB, but the pass-band shows an output of 0dB from 100Hz up to about 9kHz. There is one large ripple between about 1.5kHz and 7kHz. The ~3dB frequency is 10kHz, as required. Roll-off is from ~3dB at 10kHz to about ~66dB at 80kHz, or about -21dB/octave.

Fig. 5. Output noise analysis of the filter of Fig 1 shows a strong peak at 10kHz.

Anneal routines are used for calculating noise parameters of circuits such as the attenuator network of Fig. 7.
Figure 4 shows the result of returning to the ‘analysis limits box’, and making a few amendments. Edit the Y expression in the first line to dB(RE(V(6))), to plot only the real component of the output voltage. Type ‘1’ into the P column of the first two lines, so that both real and imaginary components are plotted on the same graph. Type ‘2’ in the P column of the third line to obtain a separate graph of the phase. The result is Fig. 4.

There are some interesting changes of amplitude between 6kHz and 10kHz, when the phase lag is rapidly swinging from ~90° to ~180°. The phase curve follows a ‘wavy’ line, typical of a Chebyshev filter.

For more precise values than can be read from the graphs, return to the ac analysis Limits box and check the N column of the appropriate graphs. The graphical display is then accompanied by a numerical printout. Table 1 shows part of the results of printout of the curve of Fig. 3, locating the −3dB point at 9.85kHz, which is reasonably close to the designed value.

The earlier part of the printout shows a local minimum (~0.863dB) at 4.57kHz, and a local maximum (+0.207dB) in the pass-band, confirming the expected 1dB ripple.

Component substitutions
Once the schematic/netlist has been prepared, it takes only a few minutes to investigate the effects of substituting different components. Replace the LF355 with a bjt-input op-amp, the LM301A, which costs only half as much. On the schematic, click on ‘Select’ at the bottom of the screen, then double-click on the MODEL line. A text box opens near the top of the screen, containing the current model definition. Edit this to,

MODEL LM301A OPA (LEVEL=3
TYPE=1 A=16E+04 SRP=5E+005
SRN=5E+005 GBW=1E+006)

The new op-amp is type 1, i.e. with a bipolar transistor input. It has lower open-loop gain, a much slower slew rate and a narrower, though still adequate bandwidth. Running ac analysis produces curves of much the same shape as before, but the −3dB point is now at 9.45kHz, and the roll-off above that point is about 22dB/octave. There would appear to be no advantage in using the LF355.

The original calculations specified capacitors to a high degree of precision. Edit the schematic to replace the capacitors with E12 values. Replace 40.9nF with 39nF, 25811F with 2581nF and leave the 1nF capacitor unchanged. The analysis printout shows the −3dB point at 9.25kHz with roll-off still at 22dB/octave. There would appear to be no advantage in using the original values.

Simulating noise
Spice is able to simulate noise generated by resistors and active components. Thermal, shot and flicker noise are represented by appropriate voltage sources in the component models. Their total effect at the circuit output is obtained by using the command line,

ONOISE V(N) Vname n

Here, N is the output node number, Vname is the name of the input voltage source (this can also be lname, for a current source), and n is the number of points in the frequency range for which a noise report is required. Noise reports for output and input noise are called up by the command statement,

.PRTINT NOISE ONOISE INOISE

By default, ONOISE and INOISE are expressed as voltages. But if ONOISE and/or INOISE are followed by (DB), the values are in decibels.

At each point, the analysis lists the thermal noise from resistances, shot noise generated in semiconductor devices – thermal noise from resistances, shot noise

Spice output variables
Syntax used by MC4 is not applicable to other Spice simulators. Standard Spice variable names for output voltages at a given node are,

VM Magnitude of complex voltage
VR Real part of complex voltage
VI Imaginary part of complex voltage
VP Phase of complex voltage
VDB Magnitude of complex voltage, in dB.

The corresponding variable for output current begins with I instead of V. Variable name of an output voltage is followed by the node number, in brackets. If two nodes are quoted in brackets, the variable refers to the difference in voltage between the two nodes.

The variable name of an output current is followed in brackets by the name of the voltage source through which the current is to be found. This may be a dummy source - refer to ‘Deeper into dc analysis,’ EW+WW Nov 1995.

PC ENGINEERING

<table>
<thead>
<tr>
<th>F</th>
<th>dB(mag(V(6)))</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.690</td>
<td>-2.632</td>
</tr>
<tr>
<td>9.770</td>
<td>-2.857</td>
</tr>
<tr>
<td>9.850</td>
<td>-3.088</td>
</tr>
<tr>
<td>9.930</td>
<td>-3.322</td>
</tr>
<tr>
<td>10.010</td>
<td>-3.560</td>
</tr>
<tr>
<td>10.170</td>
<td>-4.044</td>
</tr>
</tbody>
</table>

| Table 1. Part of the printout of the ac analysis locates the −3dB point. |

Table 2. Results of using NoiseParameters to analyse the attenuator circuit of Fig. 7.

<table>
<thead>
<tr>
<th>Fmin</th>
<th>Rnmin</th>
<th>NFmin</th>
<th>Fmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.9794</td>
<td>25.11</td>
<td>25.11</td>
<td>25.11</td>
</tr>
<tr>
<td>312</td>
<td>312</td>
<td>312</td>
<td>312</td>
</tr>
<tr>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Gammaopt</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 7. A π-network is the subject of the noise analysis reported in Table 2.

Fig. 8. A three-dimensional plot of the noise figure of the attenuator helps the engineer to see how noise is related to source resistance and impedance.

Fig. 9. Poles and zeros of this band-pass filter are analysed by a Nodal routine in Fig. 10.
from currents across junctions and flicker noise. These noise levels are expressed as mean squares (V^2/Hz). Their total is calculated, and the square root of this is also printed, to give rms values.

Finally, the transfer function of the circuit is evaluated and the equivalent noise at the input, INOISE, is obtained by dividing the rms output noise by the transfer function. All of this is repeated at each frequency point, so a complete noise analysis extends to several pages of printout. A detailed analysis such as this is useful for identifying the major sources of noise, with a view to reducing their effect. For a more overall view, the .PLOT command produces a graphical printout of rms values for each point.

A graphical display is obtained in MC4 by completing the two ‘noise’ entries in the ‘ac analysis limits’ box of Fig. 2. Enter ‘VIN’ as the noise input source and ‘6’ as the noise output node. In the curve table, enter ‘1’ under P, ‘F’ under X expression, and ‘ONOISE’ under Y expression. Select default limits. In the ac analysis window, select Run.

Graph Fig. 5 shows the noise level peaking at 270nV/Hz at 10kHz. Run an analysis for INOISE in the same way. This results in a similar peaked curve, reaching its maximum of 85µV at 105kHz.

To investigate the effects of temperature on noise, return to the ‘Limits’ box and alter the temperature setting — in a regular Spice netlist, this is done by a .TEMP statement. Increasing the temperature from the standard 27°C to 50°C raises the peak of the ONOISE plot from 270nV to 280nV. Decreasing the temperature to 0°C reduces it to 257nV.

Reset temperature to 27°C, then substitute an LTI028AM op-amp, described as an ultra-low noise op-amp, for the LF335 and run an ONOISE analysis. The peak comes at 10kHz as before, but now the noise level is only 160nV/Hz, confirming that the description of the op-amp is appropriate.

**Measuring generated noise**

A widely used measure of the noise generated in a circuit is noise figure. Spice does not provide a direct calculation of noise figure, but it can be found via *Mathematica*. Last month I demonstrated a routine from the *Electrical Engineering Pack*.

An even more extensive collection of *Mathematica* functions and utilities is published by Macallan Consulting under the title *Nodal*. Figure 6 shows a *Mathematica* Notebook which demonstrates two of the several Nodal functions associated with noise calculations. Run Mathematica, load the notebook then click on the first line followed by the Evaluate button, to load *Nodal*.

One of the most frequently used *Nodal* functions is *NodalNetlist*. Just as in a Spice netlist, a circuit is described in *NodalNetwork* by listing its components and the nodes to which it is connected. As in Spice, node 0 is the ground node.

A netlist can be quoted in full in any functions in which it is used or, to save typing and possible errors, it may be assigned to a variable name once and for all. In Fig. 6 a simple attenuator network, Fig. 7, with input and output impedance 50Ω and an attenuation factor of 5, is assigned to the variable ‘atten’. Using this variable in *Nodal*’s *NoiseParameters* function provides the results listed in Table 2.

Parameters listed are Fmin, the minimum noise figure, NFmin, the minimum noise figure in decibels, Rn the network resistance, Yopt the optimum source admittance, and Gammaopt the optimum source conductance.

One of the advantages of *Mathematica* is that it allows three-dimensional plots. This makes it possible to visualise the effects of two parameters simultaneously. Figure 8 shows a decibel plot of the noise figure of the attenuator against source resistance and source impedance. The minimum noise figure is found when source resistance is 50Ω and source impedance is zero.

**Pole-zero analysis**

Pole-zero analysis is available only in *Spice3*, and certain high-level Spice implementations. At present, of the simulators I am looking at, only the full version of *IsSpice* has this feature. The command statement for the band-pass filter of Fig. 9 is,

```
PZ 0 1 0 2 VOL PZ
```

The numerals specify input and output nodes respectively, VOL indicates that the input is a voltage — use CUR for a current — and PZ calls for both poles and zeros to be calculated. For poles only use POL, or for zeros only, use ZER.

*Nodal* provides a routine for visualising the poles and zeros of a transfer function. In Fig. 10, the circuit of Fig. 9 is described by the netlist net. In this example, components are not given specific values but symbolic names: r1, c1 and h1. The ability of *Mathematica* and *Nodal* to work with symbols as well as, or instead of, numeric values is one of their strengths.

The network is analysed, using the ‘NodalAnalyse’ function, to find the transfer function, which is the ratio V2/V1. The ‘Simplify’ function simplifies the result of the analysis and it is displayed as,

\[
\frac{r1 + h1 x s + c1 x h1 x s^2}{s^2 + q x \omega_0 + \omega_0^2}
\]

This formula can be used for calculating the transfer function, given values of r1, c1 and h1.

Analysis continues by eliminating the component symbols, using well-known relationships, replace h1/c1 with 1/\(\omega_0^2\) and r1 with \(\omega_0^2 h1/\omega_0\), where \(\omega_0\) is the resonant frequency and q is the quality factor of the filter. After simplifying, the transfer function is,

\[
\frac{q x \omega_0}{s^2 + q x \omega_0 + \omega_0^2}
\]

Simplification is required after certain calculations because *Mathematica* does not always reduce an expression to its simplest possible form. In the example above, it omits to cancel out \(h1\) throughout the expression when ‘Simplify’ is not used. Simplify tells it to try harder.

To find the zeros, look for values of the variables to make the expression equal to zero. Values that make it equal to zero are values which make the numerator equal to zero. Zeros can usually be found by inspecting the expression. Quality factor and \(\omega_0\) can not be zero, but the expression evaluates to zero.
SuperFILTER synthesizes Active, Passive and Digital FIR/IIR filters and ports to SpiceAge for Windows™ for a complete analysis.

SuperFILTER Version 3 for Windows provides the following features.

1. Choice of specifying parameters for desired response includes gain & phase coordinates, graphical (mouse tracing response), poles and zeros in S and Z planes and Laplace transfer function coordinates.
2. No order limits of cascaded filters - applies to digital, active and passive types.
3. Types available include Butterworth, Chebyshev, Elliptic, Bessel, Realpole, Gaussian, Linear phase, Inverse Chebyshev, Digital Hilbert FIR, Differentiator, Raised cosine, Squared root raised cosine of LPF, HPF, BPF, APF, Notch filters.
4. Minimum specification of suitable op amps for achieving active filter performance.
6. Analysis of effect of register characteristics on digital filters and D to A converters.
7. Analysis of inductor losses for passive filters.
9. Supports behavioural modelling within SpiceAge for Windows synthesizing more than 150 topologies.
10. Graphic display of the realized versus the ideal filter with best fit options taken from a comprehensive (and user controllable) library of preferred component values.

"This is a stunning program that will save and save again."

For further details and demonstration disk, contact Those Engineers Ltd, 31 Birkbeck Road, LONDON NW7 4BP.

Tel 0181-906 0155, FAX 0181-906 0969, CompuServe 100550, 2455.
PORTABLE X-RAY MACHINE PLANS Easy to construct plans on a simple and cheap way to build a home X-ray machine. Ideal for experimental purposes. Not a toy or for mended. Ref: ERFX1.

TELEKINETIC ENCHANCED PLANS A unique plan for you to create a telekinetic world of your own by creating objects with no known apparent means or cause. Uses electrical and mechanical connections, no special gimmicks. Ideal for those of you who are interested in magic shows, party demonstrations or serious research & development. ERFX1

GRAVITY GENERATOR PLANS This plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. No magical effects, simple and practically usable. ERFX1

WORLD'S SMALLEST TESLA COIL LIGHTING PLANS Produces up to 750,000 volts of dc, experimental unit which is yet to be fully developed. ERFX1

COPPER VAPOUR LASER PLANS Produces 100mW of visible green light. High, comprehensibility and spectral quality similar to that of helium cadmium laser. ERFX1

VOICEMAIL PLANNERS Medium solid state device turns speech sound into indecipherable noise that cannot be understood by any means except the user. Use on your telephone system to prevent third party listening and bugging. Ref: FNS9.£/set

NEGEV IN Israel. £10/set. Ref F/CVL1.

CRAWLING INSECT ROASTER PLANS Harmless high voltage alternating current is passed through 1000V solenoid to cause insects to levitate. £3/set. Ref F/R12.

LASER BOUNCE LISTENER SYSTEM PLANS Allows you to steal a bomb from a room monitor. The ultimate in home/offce security and safety! simple electrical phenomena that produces an anti-gravity effect. No magical effects, simple and practically usable. £15/set. Ref F/EH2.

LASER LIGHT SHOW PLANS Do it yourself plans show three colours in a single beam, with a laser. £4/set. Ref F/TKE1.

BUG DETECTOR PLANS Is that someone getting the goods on you? £7 Ref F/TELEGRAB.

LADYbug PLANS Little lady bug to demonstrate a simple electrical phenomena that produces an anti-gravity effect. No magical effects, simple and practically usable. £15/set. Ref F/EH2.

CUBIC NO. 148 ON REPLY CARD

PLANS FOR A HOME X-RAY MACHINE:

- Plans on a simple and cheap way to build a home X-ray machine!
- A unique plan for you to create a telekinetic world of your own by creating objects with no known apparent means or cause.
- A plan that demonstrates a simple electrical phenomena that produces an anti-gravity effect.
- A medium solid state device that turns speech sound into indecipherable noise.
- A copper vapour laser plan.
- A voicemail planner.
- Plans for a world's smallest Tesla coil lighting.
- Plans for a copper vapour laser.
- Plans for a copper vapour laser.
- Plans for a laser bounce listener system.
- Plans for a laser light show.
- Plans for a bug detector.

MINI FM TRANSMITTER KIT

- A kit that transmits radio frequencies and transmits messages. £7 Ref F/TELEGRAB.

MICROFONE PLANS

- Plans for a microphone that can detect the presence of bugs.

MOBILE PHONE Bugging System PLANS

- Kits that allow you to eavesdrop on mobile phones.

PHONE BUG DETECTOR KIT

- A kit that warns you if someone is eavesdropping on your line.

LIQUID LEVEL DETECTOR KIT

- A kit that detects the presence of liquid levels.

CAR ALARM KIT

- A kit that works on voltage drop and vibration.


PORTABLE ALARM KIT

- A kit that uses mercury switches to continue an alarm. £3 ref EF34.


FLYING PARROTS

- Easily assembled kit that builds a parrot that flies when rubbed together! £3.99 a pair Ref EF29.

VENUS FLYTRAP KIT

- Grow your own carnivorous plant with this kit. £4 each Ref EF1.

UNIVERSAL PC POWER SUPPLY KIT

- A kit that is compatible with all PC boards, complete with flyleads and DC power plug. price for two is £29.99 ref AUG3P4.

PORTABLE 100,000VDC OUTPUT GENERATORS

- Operates on 9-12v, many possible experiments. £10 Ref F/NVMT/72.

HUMIDITY METER KIT

- Builds into a precision LCD humidity meter, 35cm design, nice display and all components included. £9.99 PC/TMR KIT

Four channel output controlled by your PC, will switch high current mains with relays (Supplied). Are supplied for use in industry, offices, factories or schools. £9.99 ref F/TELEGRAB.

MAGNETIC MARBLEs

- They have been around for a number of years, but now that they can be made better they are an excellent security and law enforcement, research and development, etc. £15.99 Ref F/EH2.

FACIAL RECOGNITION SYSTEM KIT

- A kit that uses facial recognition to identify individuals. £179.99 Ref F/TELEGRAB.

ELECTRONIC KINEMATIC MACHINE PLANS

- Plans for a simple and cheap way to build a home X-ray machine!
- A unique plan for you to create a telekinetic world of your own by creating objects with no known apparent means or cause.
- A plan that demonstrates a simple electrical phenomena that produces an anti-gravity effect.
- A medium solid state device that turns speech sound into indecipherable noise.
- A copper vapour laser plan.
- Plans for a copper vapour laser.
- Plans for a laser bounce listener system.
- Plans for a laser light show.
- Plans for a bug detector.

MINI FM TRANSMITTER KIT

- A kit that transmits radio frequencies and transmits messages. £7 Ref F/TELEGRAB.

MICROFONE PLANS

- Plans for a microphone that can detect the presence of bugs.

MOBILE PHONE Bugging System PLANS

- Kits that allow you to eavesdrop on mobile phones.

PHONE BUG DETECTOR KIT

- A kit that warns you if someone is eavesdropping on your line.

LIQUID LEVEL DETECTOR KIT

- A kit that detects the presence of liquid levels.

CAR ALARM KIT

- A kit that works on voltage drop and vibration.


PORTABLE ALARM KIT

- A kit that uses mercury switches to continue an alarm. £3 ref EF34.


FLYING PARROTS

- Easily assembled kit that builds a parrot that flies when rubbed together! £3.99 a pair Ref EF29.

VENUS FLYTRAP KIT

- Grow your own carnivorous plant with this kit. £4 each Ref EF1.

UNIVERSAL PC POWER SUPPLY KIT

- A kit that is compatible with all PC boards, complete with flyleads and DC power plug. price for two is £29.99 ref AUG3P4.

PORTABLE 100,000VDC OUTPUT GENERATORS

- Operates on 9-12v, many possible experiments. £10 Ref F/NVMT/72.

HUMIDITY METER KIT

- Builds into a precision LCD humidity meter, 35cm design, nice display and all components included. £9.99 PC/TMR KIT

Four channel output controlled by your PC, will switch high current mains with relays (Supplied). Are supplied for use in industry, offices, factories or schools. £9.99 ref F/TELEGRAB.

MAGNETIC MARBLEs

- They have been around for a number of years, but now that they can be made better they are an excellent security and law enforcement, research and development, etc. £15.99 Ref F/EH2.

FACIAL RECOGNITION SYSTEM KIT

- A kit that uses facial recognition to identify individuals. £179.99 Ref F/TELEGRAB.

ELECTRONIC KINEMATIC MACHINE PLANS

- Plans for a simple and cheap way to build a home X-ray machine!
- A unique plan for you to create a telekinetic world of your own by creating objects with no known apparent means or cause.
- A plan that demonstrates a simple electrical phenomena that produces an anti-gravity effect.
- A medium solid state device that turns speech sound into indecipherable noise.
- A copper vapour laser plan.
- Plans for a copper vapour laser.
- Plans for a laser bounce listener system.
- Plans for a laser light show.
- Plans for a bug detector.

MINI FM TRANSMITTER KIT

- A kit that transmits radio frequencies and transmits messages. £7 Ref F/TELEGRAB.

MICROFONE PLANS

- Plans for a microphone that can detect the presence of bugs.

MOBILE PHONE Bugging System PLANS

- Kits that allow you to eavesdrop on mobile phones.

PHONE BUG DETECTOR KIT

- A kit that warns you if someone is eavesdropping on your line.

LIQUID LEVEL DETECTOR KIT

- A kit that detects the presence of liquid levels.

CAR ALARM KIT

- A kit that works on voltage drop and vibration.


PORTABLE ALARM KIT

- A kit that uses mercury switches to continue an alarm. £3 ref EF34.


FLYING PARROTS

- Easily assembled kit that builds a parrot that flies when rubbed together! £3.99 a pair Ref EF29.

VENUS FLYTRAP KIT

- Grow your own carnivorous plant with this kit. £4 each Ref EF1.

UNIVERSAL PC POWER SUPPLY KIT

- A kit that is compatible with all PC boards, complete with flyleads and DC power plug. price for two is £29.99 ref AUG3P4.

PORTABLE 100,000VDC OUTPUT GENERATORS

- Operates on 9-12v, many possible experiments. £10 Ref F/NVMT/72.
SURVEILLANCE TELESCOPE Superb Russian zoom telescope with 75 to 1200 mm focal length, includes fitted carry bag, £169.95 ex VAT.

RADIATION DETECTOR SYSTEM Designed to be wall mounted and connected into PC, ideal for remote monitoring, whole building coverage, £320.95 exc VAT.

WOLVERHAMPTON BRANCH NOW OPEN AT WORCESTER STATION TEL: 01922 220397

MINI MICRO FANS 12V 1.5w sale price £2 REF SA5.

JEWELLERY, BEADs, BEADS, BEADS Etc. Enthusiasts welcome, our stock includes unusual and unusual. Visit the shop, is open 7 days a week, less than 1 hour’s use £199.95 ex VAT.

CCTV CAMERA MODULES 46TVLM30, 30mm, 12v 1000 TV lines. Includes lens and basic bracket. £79.95 exc VAT.

2.2m 25mm objective module with a 3.6mm F2 lens, CCIR, 512x492 pixel, 13 deg angle of view, focusing range 1.5m to infinity. 2 AA batteries. Producing thin red beam ideal for lasing. £13.95 exc VAT.

LIQUID CRYSTAL DISPLAYS Bargain prices, 16 character 2 line, 65x14mm £2.99 exc VAT.

PLASMA SCREENS 222x310mm, no data hence E4.99 ref BAR63. A separate infra red light is available at £30 ref E PE53.

COIN OPERATED TIMER KIT Complete with coinslot and connected into a PC, ideal for remote monitoring, whole building coverage, £6.99 exc VAT.

ELECTRONICS WORLD+WIRELESS WORLD

FOR SALE

1093
ARTICLES WANTED

WE WANT TO BUY!!

IN VIEW OF THE EXTREMELY 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 0181-445-2713/0749
FAX 0181-445-5702

WANTED


TELFORD ELECTRONICS
Phone: 01952 605451
Fax: 01952 677978

ELECTRONICS VALVES & SEMICONDUCTORS

Phone for a most courteous quotation

We are one of the largest stockists of valves etc., in the U.K.

COLOMOR ELECTRONICS LTD
170 Goldhawk Road, London W12 8HJ England.
Tel: 0181 743 0899
Fax: 0181 749 3934

STATIC INVERTORS

Ferranti type P.1.55E AC type 24/28 V DC 1P rated 165 watt cont sine wave, or 225 watt 10 Min. with connect & mt hardware £22.00 each inclusive.

A.H. SUPPLIES
Unit 12, Bankside Works
Damall Road, Sheffield S9 5HA
Tel: 0114 244 4278

ARTICLES FOR SALE

WIRELESS WORLD and television magazines. 1976 to date. For list write to S. Jacovides, 20 Cheverton Road, London N19 3AY. Tel: 0171-272 7139.

FOR SALE. Marconi 2018 synthesised AM/FM Si Gen £600. Philips oscilloscope PM 3065 100 Mhz D.T.B. £400. Lab closing down, can fax list of equipment available. Call 01252 871048.


WANTED: Suit case radio sets, “Spy-Set”, Crypto equipment for museum. Rac Otterstad, P.O. Box 73, LIDAN, N-1113, Oslo, Norway.

ADVERTISERS PLEASE NOTE

For all your future enquiries on advertising rates

Please contact
Malcolm Wells on

Tel: 0181-652 3620
Fax: 0181-652 8956
I DON'T BELIEVE IT!
This new 264 page Guide to SMDs now includes 64 pages of SM Connector Systems from AMP, JAE, Molex, Hirose, Osxly, Cinch and Sumitomo and mainly from stock as well. Not only that but it's bulging with new SMDs from over 30 franchises which now include Panasonic. What an incredibly useful publication.
I had better ring 01530 510333 for my copy before they run out!

NEW CATALOGUE
The new 1996 National Instruments Instrumentation Reference and Catalogue is available now. Discover how to develop integrated systems for test and measurement and industrial automation. Includes details of over 500 software and hardware products for PCs and workstations. Includes valuable tutorials on data acquisition and instrument control.
NATIONAL INSTRUMENTS
Tel: 01635 523545

NEW Feedback T&M catalogue
The latest edition of the Feedback Test & Measurement catalogue is now available. Over 60 pages packed with more than 800 products divided into over 20 sections. The catalogue is indexed for both product and manufacturer and is fully illustrated. Whether you are looking for an individual product, a complete workstations, or a solution to a particular Test & Measurement need the NEW Feedback catalogue will solve your problems, send for a copy NOW!
At last! The complete PC-Based PLD Training System

THE PAL TRAINER

Until now, introducing students and engineers to the world of Programmable Logic Devices has been fraught with problems. Not only has the necessary hardware to be laboriously assembled in bits and pieces, but suitable software and - equally important - supporting documentation has been, if anything, harder to source.

With the launch of THE PAL TRAINER system from Flight Electronics International, the entire problem has been neatly solved in one comprehensive hardware/software/documentation package...

...providing everything that the engineer and student needs for a thorough introduction to PLD's at a very realistic price.

COMPLETE & COMPREHENSIVE

One of the main advantages of THE PAL TRAINER is its completeness. The board and accessory kit consists of:

- The MPLDT-10 main unit - a sturdy metal-cased PCB containing both a GAL programmer and a test unit. There is also a separate demo area for use with the demonstration section of the manual.
- A PCPET interface card, which plugs into a free PC expansion slot, and connects to the main unit via a supplied API-37 cable. This allows rapid programming of the PLD, and greater flexibility than a serial link can deliver.
- A 360kb system diskette containing the board driver files.
- Various connection lines and block jumpers.
- The PALASM software package, whose separate manual also contains a number of example programs.

SIMPLE, FAST, FRIENDLY

The design parameters of THE PAL TRAINER were that it should:

- run on IBM XT, AT or compatibles - with no need for ANY other hardware.
- provide a complete training course, from initial logic design, to PC simulation, device programming & testing.
- be enjoyable, readily-understandable, but fully applicable to 'real-world' situations.
- include a top programming language - in this case AMD's PALASM Version 4, widely regarded as the PLD standard. Version 4, incidentally, can be linked to other schematic packages such as OrCad.

LIKE TO SEE THE PAL TRAINER IN ACTION?

Nothing beats an actual hands-on experience of the system's completeness, ease of use, and flexibility. Just call 01703 227721 and order today! - We operate a "no strings" 30 days 'no risk' refund.

USING THE SYSTEM

The two main parts of the PAL TRAINER are the programmer and the applications sections. Using the programmer section, up to 3 GAL devices are placed in ZIF sockets, and programmed from the PC using the supplied software. This lets you choose a particular PAL to emulate, loads a JEDEC file into memory (either generated from the PAL TRAINER's own software or any other appropriate software package), downloads the JEDEC file to the GAL, and even lets you 'view' the GAL once it has been programmed.

Flight House
Aucocart Street
Southampton
S014 1WP U.K.
Telephone: 01703 227721
Facsimile: 01703 330039
Email: Sales@flight.demon.co.uk

Flight ELECTRONICS INTERNATIONAL LIMITED

Flight also make
- ELECTRONIC & MICROPROCESSOR TRAINING EQUIPMENT
- TEST & MEASUREMENT EQUIPMENT
- 4 FREE COLOUR BROCHURES AVAILABLE - CALL TODAY!
If you have never lost a file, never ran out of disk space or love re-installing software, don’t read any further.

Backer® is a high performance back-up system designed specifically for the home user. For less than the price of most PC games, you can store up to 1.5Gbytes of data on a single VHS video tape, the equivalent of 3 CD-ROMs. Backer® utilises your existing video recorder to transfer data from your hard disk at up to 9Mbytes per minute, faster than many of the significantly more expensive tape streamers.

- Free up extra disk space by archiving less frequently used files
- Protect important files by keeping back-up copies
- Transfer data between PCs, copy hundreds of Megabytes quickly and easily
- Runs under Windows® in the background, allowing you to continue working with other applications
- Uses low cost standard video tapes
- Comprises of an expansion card and easy-to-use software
- State of the art sophisticated error correction ensures reliable operation
- Back-up selected files or the whole hard disk

Order now by ringing 01606 44244 quoting your Access or Visa number or by sending your cheque or postal order for £37.45 (£34.95 inc. VAT + P&P £2.50) to Danmere Technologies Ltd., Darland House, 44 Winnington Hill, Northwich, Cheshire CW8 1AU.

Distributor enquiries welcome.

Danmere Technologies Ltd., Darland House, 44 Winnington Hill, Northwich, Cheshire CW8 1AU.