ELECTRONICS WORLD

OCTOBER 1993 £1.95

RF DESIGN
Working with transmission lines

REVIEW
Smarter look to graphics?

APPLICATIONS
On-board current measurement

ANALOGUE DESIGN
Wideband current mode amplifiers

COMPUTING
Bandpass filter on a micro processor

SCIENCE
Cold fusion warming up?

SPECTRALLY CHALLENGED:
THE TOP TEN AUDIO POWER CHIPS PUT TO THE TEST
The PC82 Universal Programmer and Tester is a PC-based development tool designed to program and test more than 1500 ICs. The latest version of the PC82 is based on the experience gained after a 7 year production run of over 100,000 units.

The PC82 is the US version of the Sunshine Expro 60, and therefore can be offered at a very competitive price for a product of such high quality. The PC82 has undergone extensive testing and inspection by various major IC manufacturers and has won their professional approval and support. Many do in fact use the PC82 for their own use!

The PC82 can program E/EPROM, Serial PROM, BPROM, MPU, DSP, PLD, EPLD, PEEL, GAL, FPL, MACH, MAX, and many more. It comes with a 40 pin DIP socket capable of programming devices with 8 to 40 pins. Adding special adaptors, the PC82 can program devices up to 84 pins in DIP, PLCC, LCC, QFP, SOP and PGA packages.

The unit can also test digital ICs such as the TTL 74/54 series, CMOS 40/45 series, DRAM (even SIMM/SIP modules) and SRAM. The PC82 can even check and identify unmarked devices. Customers can write their own test vectors to program non standard devices. Furthermore it can perform functional vector testing of PLDs using the JEDEC standard test vectors created by PLD compilers such as PALASM, OPALjr, ABLE, CUPL etc. or by the user.

The PC82's hardware circuits are composed of 40 set pin-driver circuits each with TTL I/O control, D/A voltage output control, ground control, noise filter circuit control, and OSC crystal frequency control. The PC82 shares all the PC's resources such as CPU, memory, I/O hard disk, keyboard, display and power supply.

A dedicated plug in card with rugged connecting cable ensures fast transfer of data to the programmer without tying up a standard parallel or serial port. Will work in all PC compatibles from PC XT to 486.

The pull-down menus of the software makes the PC82 one of the easiest and most user-friendly programmers available. A full library of file conversion utilities is supplied as standard.

The frequent software updates provided by Sunshine enables the customer to immediately program newly released ICs. It even supports EPROMs to 16Mbit.

Over 20 engineers are employed by Sunshine to develop new software and hardware for the PC82. Not many competitors can boast of similar support!

Citadel, a 32 year old company are the UK agents and service centre for the Sunshine range of programmers, testers and in circuit emulators and have a team of engineers trained to give local support in Europe.

NOW SUPPLIED WITH SPECIAL VALUE ADDED SOFTWARE (worth over £300 if bought seperately):

- MICROTEC disassemblers for Z8, 8085, 8048, 8051, 6809 & 68HC11.
- NATIONAL SEMICONDUCTOR OPALjr PAL/PLD development software.
- BATCH SOFTWARE for production programming.
- Software supplied to write own test vectors for custom ICs and ASICs etc.
- Protection circuitry to protect against wrong insertion of devices.
- Ground control circuitry using relay switching.
- One model covers the widest range of devices, at the lowest cost.
- No need to tie up a slow parallel port.
- Two year free software update.
- Speed optimised range of programming algorithms.

Our stocked range of own manufactured and imported Sunshine products include:

- Super fast EPROM Erasers.
- 1, 4 & 8 gang EPROM 8Mbit production programmers.
- Battery operated portable EPROM programmers.
- "In circuit" Emulators.
- Handy pocket IC testers.

ORDERING INFORMATION

PC82 complete with interface card, cable, software and manual only £395

Please add £7 carriage (by overnight courier) for UK orders, £20 for export orders, and VAT where applicable.

ACCESS, MASTERCARD, VISA or CWO. Official orders are welcome from Government bodies & local authorities.

Free demo disk with device list available.

NOW ONLY £395
CONTENTS

FEATURES

SPECTRALLY CHALLENGED:
THE TOP 10 AUDIO
POWER CHIPS .......................... 804
Ben Duncan analyses distortion
performance and harmonic spectra in the
10 most popular audio power ICs. In a
unique guide, he names the good, the
bad – and the ugly.

SLIDING INTO A SOFTWARE SPECIALITY ............. 814
Drawing together various graphs and plots from different
sources into a coherent slide presentation is notoriously
difficult. Allen Brown finds Stanford Graphics makes it
easy.

DISTORTION IN POWER AMPLIFIERS: THE
VOLTAGE AMPLIFIER ...................... 818
The typical circuit that provides most of the voltage gain
and all the voltage drive to the output stage of an audio
amplifier seems likely to contribute a significant distortion
component. But Douglas Self shows how detailed analysis
contradicts this.

VOICE LINK OVER
SPREAD SPECTRUM RADIO ............... 826
James Vincent looks at the detailed circuitry used for a
fully functional experimental voice link.

REWITING THE RULE BOOK WITH CURRENT
MODE AMPLIFIERS .......................... 843
Current feedback amplifiers open up new designs for wide
bandwidth circuits while retaining similarities with
conventional amplifiers. Bashir Al-Hashimi uses
commercially available current mode devices to design
high performance, wideband amplifiers.

BAND PASS FILTER ON A MICROPROCESSOR ... 865
A hybrid comb FIR filter/second order IIR filter has useful
benefits. Allen Brown shows how to implement the hybrid
on a general purpose microprocessor.

CLAWING BACK RESPECTABILITY
FOR COLD FUSION? ......................... 869
Is there life after Fleischmann and Pons? Andy Wright
reports on a revival.

REGULARS

COMMENT ....................................................... 795
A communications revolution

UPDATE ................................................. 796
Time runs out for digital tv breakthrough, Video scramble
for pot of gold, Flat screen leads Matsushita's push, Europe
snubs US global plans, Resources pooled to make solid
state discs, BT moves on System X replacement, TFT cell
scores 3V goal

RESEARCH NOTES ............................... 801
Blue laser burns into storage record book, Top people are
always in a spin, Space service will tackle Hubble’s
wobbles, Geniuses are made not created, Diamonds
without pressure.

USING RF TRANSISTORS .......................... 834
How does a figure in a data sheet relate to performance in
a real circuit? Motorola RF transistor application experts
Norm Dye and Helge Granberg explain how to interpret
manufacturers’ data sheets.

LETTERS ................................................. 847
Breaking Windows, Clunky versus cost, Sounding out the
critics, Power to protect, Authors wanted, Drawing error,
A question of theory.

CIRCUIT IDEAS ................................. 850
Transconductance squarer, No-loss tuned circuit, Cheap
mosfet audio power, FSK receiver has auto decision-
threshold control, Electrocardiograph simulator.

APPLICATIONS ................................. 860
Are 4Mbit drams a drop-in upgrade? Battery life meter
from Chinatown? Op-amp transmits baseband video over
1500m, Versatile fast-charge chip has only three pins,
Using the PCB as a current shunt.

DESIGN BRIEF ................................. 872
Ian Hickman delves into the true effects of matched and
unmatched loads to map the movement of energy in a
transmission line.

In next month’s issue: Digital television. In 1991 a MAC future
for TV broadcasting seemed certain. Two years on it is now digital
television which will bring 100s of channels into the living room
of the next century. We present both the systems and the silicon.
Also next month, the start a new series on using programmable
logic.

NOVEMBER ISSUE IS ON SALE OCTOBER 28

October 1993 ELECTRONICS WORLD + WIRELESS WORLD 793
INSTRUMENTS TO BUY
FROM SAJE ELECTRONICS TEL: (0223) 425440 FAX: (0223) 424711

Prices include VAT and Postage

MULTIMETERS - The 180 series of multimeters provide advanced features and are supplied complete with probes, battery and rubber holsters. 181: 3.5 digit LCD, ACV, DV, ACA, DCA, resistance, continuity buzzer, diode test, hold, basic accuracy 0.5%. 185: As 183 plus bar graph, temp. -40°C to 1370°C, capacitance (1pF to 400uF), frequency (1Hz to 200kHz), max/min, ent%, compare, basic accuracy 0.1%. 187: As 185 plus Auto ranging. 285: As 185 but digit true rms, basic accuracy 0.05%.

EPROM PROGRAMMER/EMULATOR - The SP1000 is a full featured stand-alone high speed eprom programmer/ emulator with extended power via a PC remote link. Most eproms up to 1M bit (expandable to 4M Bit) can be programmed, empty, checked, listed, edited, verified or emulated.

COUNTERS - The SC series are high performance microprocessor based frequency counters. With advanced features, SC40: 5Hz to 400MHz, hand hold, battery powered. 8 digit LCD, sensitivity typically 10mV, hold, min, max, ave, diff, variable gate-and filter. SC130: as SC40 but 5Hz to 1.2GHz, SC230: Bench version of SC130, backlit LCD, PS232 as standard.

RF GENERATORS - SG4160B, 100kHz to 150MHz (450MHz with harmonics) in/2x modulation. SG4162AD: As SG4161B but on-board frequency counter.

OSCILLOSCOPES - A professional range of high quality oscilloscopes. CS4025: 20MHz dual trace, full featured (inc. probes), CS3170: 100MHz dual trace, cursor readout (inc. probes). CO1305: 5MHz single trace.

FUNCTION GENERATOR - MX2020: 200kHz to 2MHz sweep function generator with frequency readout, output waveforms include sine, square, triangle, skewed sine, pulse and TTL. LV & HQ sweep, DC offset and symmetry. FS2020B: 0.5Hz to 500Hz function generator providing sine, square and triangle waveforms.

POWER SUPPLIES - The PS series of low cost bench power supplies offer single or dual output with output protection. PS303: single DC power supply, 0-30V 3A. PS303D: dual tracking DC power supply 0-30V 3A. PS2243: DC power supply, 0-24V 3A.

MULTI INSTRUMENT - The MX9000, suitable for a broad range of applications, combines four instruments including: 1. Triple output power supply with LCD-reading, 0-30V 5A, 0-15V 1A, 5V 2A, with meter overcurrent protection. 2. An 8 digit LED, 1Hz-100MHz frequency counter with gating rates of 0.1Hz, 1Hz, 10Hz, 100Hz providing resolution to 0.1Hz plus attenuation input and data hold. 3. A 0.05Hz to 21kHz full featured swept/function generator producing sine, square, triangle, skewed sine, pulse and a TTL output for sin & log sweeps. Outputs of 0.1% and 0.01% impedance are standard features. 4. Oscilloscope with 3.5 digit LCD multimeter reading DCV, DCA, ACA, resistance and relative measurement with data hold functions.

LCR METER - The MIC4070D LCD digital LCR meter provides capacitance, inductance, resistance and dissipation measurement. Capacitance ranges are from 0.1pF to 2000uF plus dissipation. Inductance ranges from 0.1uH to 2000H plus a digital readout of dissipation. Resistance ranges from 1mΩ to 20MΩ. Housed in rugged ABS case with integral stand complete with battery and probes.

CLAMP METER - The clamp meter provides digital readout and the following ranges; ACA to 600A, ADV to 750V, DCV to 1000V. Resistance to 2kΩ. Peak detector holds the max rms value. Audio continuity for short circuits.

CREDIT CARD ORDERS BY PHONE/FAX

To order any of the above items please send this form with your cheque/credit card details to: SAJE Electronics, 117 Llewellyn Road, Cambridge, CB4 2QW. Please send me the following instruments:

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>183</td>
<td>£46.41</td>
</tr>
<tr>
<td>185</td>
<td>£87.54</td>
</tr>
<tr>
<td>187</td>
<td>£116.91</td>
</tr>
<tr>
<td>285</td>
<td>£128.86</td>
</tr>
<tr>
<td>SC40</td>
<td>£194.56</td>
</tr>
<tr>
<td>SC180</td>
<td>£126.88</td>
</tr>
<tr>
<td>SC230</td>
<td>£175.00</td>
</tr>
<tr>
<td>PS303</td>
<td>£154.65</td>
</tr>
<tr>
<td>PS303D</td>
<td>£283.86</td>
</tr>
<tr>
<td>PS2243</td>
<td>£119.26</td>
</tr>
<tr>
<td>MIC-4070D</td>
<td>£123.38</td>
</tr>
<tr>
<td>MIC-2060PA</td>
<td>£65.80</td>
</tr>
<tr>
<td>SP1000</td>
<td>£351.33</td>
</tr>
<tr>
<td>SG4162AD</td>
<td>£262.50</td>
</tr>
<tr>
<td>SG4160B</td>
<td>£150.87</td>
</tr>
</tbody>
</table>

Name: ____________________________
Address: __________________________
Telephone: __________________________

Please Allow 28 Days Delivery

NB: All prices quoted above include VAT.

I enclose a cheque to the value of £__________ OR please debit my credit card no. ________ expiry date ________

the sum of £__________

Name: ____________________________
Address: __________________________
Telephone: __________________________

Please Allow 28 Days Delivery

794
A communications revolution

The world is about to change irrevocably. At face value, the UK now has, or will have, an extra 14 satellite TV channels controlled by News International and its associates. Whatever one may say about the quality of programming, this new group will broaden viewer choice. What we are really seeing is the start of a revolution.

For those of us who have grown up with three or four channels of terrestrial television, it is hard to conceive how we could comfortably deal with 20 or 30 channels. New digital compression technology promises to increase this viewer choice by an order of magnitude within ten years.

With hundreds of channels to choose from, individual programming will become highly specialised. The most appropriate analogy seems to be with the world of publishing. If one considers the four existing terrestrial channels as daily newspapers, then the new satellite services will become specialist magazines. Not inferior substitutes for something which already exists but a new communications medium for a specialist audience. If you want to find your particular leisure activity – for instance sailing and windsurfing – on the box whenever you want it, then the new TV explosion will almost certainly offer it to you.

But the communications revolution means more than that. Satellite video channels can transmit a large amount of data very quickly to the viewer's or user's home. When high local density storage (video recorder?) and some computing power is available at the receiving end, then many things become possible. Entertainment programmes, electronic newspapers and magazines may be downloaded off-peak for later viewing or reading – a son of multimedia interactive video service. And since this magazine, your daily newspaper and most of the other things you read and watch are already originated electronically, this is only a very small step from the world today. The existing telephone network will allow the viewer and reader to place their specific programme requirements with the local TV control centre.

The concept of panoramic choice is difficult to grasp; the concept of global broadcasting seems equally so. We conventionally think that our programme material should originate, in the main, from our own country. Satellite broadcasting represents true internationalism by its nature and foreign doesn’t always mean inferior. Ted Turner's CNN News Service is highly regarded the world over, mostly exceeding anything which our own national networks can provide in the field of global current affairs. High quality international leisure and education services will also become available outpacing our own national networks in both scope and resource. No matter what we may think about such an idea at present, we will eventually accept and use them.

Global communications have so far acted as an humanising influence; brutal regimes can no longer hide their activities from the world's television screens. But communication without borders carries significant risk: those who would control global networks wield immense power unfettered by individual nations or electorates. This makes me uneasy. One could conceive of a new kind of tyranny where communications moguls might practice blatant propaganda or, even worse, subtle persuasion against governments and people. Broadcast technologists are now able to deliver this power to their unanswerable masters.

We must ensure that we address the moral, ethical and democratic issues of the communications revolution.

Frank Ogden.
UPDATE

Time runs out for digital tv breakthrough

There is hardly any time left to stop tv broadcasters, electronics manufacturers and viewers in the next century looking back on 1993 as the year in which the ITC lost the UK a unique opportunity to lead Europe into a digital future.

History has left Britain in a unique position. It has a pair of frequencies in the middle of the UHF tv broadcasting band that are not used for broadcasting and can be used to kick start Britain into the digital tv age.

Unfortunately the already ageing Broadcasting Act 1990 obliges the Independent Television Commission to try to earn money for the treasury by selling off these frequencies for a fifth tv service, to be called Channel 5. This will use the same analogue technology as is used for today’s four tv channels. It will provide one new programme channel for around 70% of the population. Analogue Ch 5 will also cause interference to many millions of VCRs, satellite receivers and video games that use the frequencies to connect with a tv set.

Research work recently carried out by the BBC suggests that if the same two frequencies were used with digital technology, they could provide 97% of the population with eight new channels and less risk of interference.

If granted, the licence for analogue Ch 5 will run for 10 years – though it cannot be granted until 1994 at the earliest so the analogue route blocks the digital option until well into the next century. It is hard to find anyone, except those who hope to make quick money out of it, who favours analogue Ch 5. In the long term the digital option will generate far more revenue for the treasury. But it has yet to see the wisdom of waiting a couple of years for the technology to be ready for consumer use.

In late June the ITC published a consultation document on the broad issue of digital television. Although heavy reading, the document gives the clear message that digital tv technology makes far more efficient use of available frequency spectrum.

When the ITC published the document, Peter Rogers, the ITC’s deputy chief executive, refused to discuss the issue of allocating the Ch 5 frequencies for digital tv. He said that the ITC had separated the issues of digital tv and Ch 5, and would be publishing a second document, specifically dealing with Ch 5, in a few weeks time.

The ITC published its Ch 5 document in mid-July and by the ITC’s own admission the content was deliberately neutral. It simply listed holding the Ch 5 frequencies free for digital tv as one of three options. The ITC says it believes it has discharged its duties.

A lost digital multi-channel opportunity will cause few tears to be shed by the Ch 3 and Ch 4 stations, who are already losing advertising to the satellite stations.

The ITC has invited anyone interested in Ch 5 to comment on the two documents* published so far, by October 15. But without wider explanation of the issues, it is a safe prediction that many of those who should be interested in commenting will not realise it until they are years too late. The Broadcasting Act may bar the ITC from taking sides, and blocking analogue Ch 5. But it does not bar it from ensuring that the mass media understand the issues and inform the public of their right to comment.

If the ITC does grant a licence for analogue Ch 5 then it must stand accused by future generations of failing to ensure that the public had the best possible chance to understand what the UK stood to lose.

Barry Fox

*Copies of both documents are still available from the ITC at 33 Foley Street, London W1P 7LB.

The joint European x-ray telescope, called Jet-X, has completed its vibration and decompression tests at British Aerospace Space Systems in Stevenage. The picture shows the 551 kg telescope being prepared for the decompression tests. These were carried out in a 3.5m diameter by 6.4m autoclave evacuated from 2 to 1 bar in 80s. Video film recorded no distortion of the structure or movement of the thermal insulation. The satellite is due for launch in 1995 by the Russian Proton rocket. Its four-day orbit will be highly elliptical with a perigee of 1000km and an apogee of 200,000km.

796 ELECTRONICS WORLD + WIRELESS WORLD October 1993
BT moves on System X replacement

BT has named AT&T and Alcatel, the world's largest telephone equipment manufacturers, as its first suppliers for the digital telephone exchange technology that will replace System X exchanges at the turn of the century.

The decision not to support any development of the broadband switch technology known as ATM (asynchronous transfer mode) in Britain by ignoring a bid from GPT and Siemens is likely to come as a major blow to hundreds of engineers at GPT.

GPT is already struggling to adapt its switching business in anticipation of a run down of System X exchange orders from BT now that its UK network is largely complete. In 1991 GPT, the UK's largest telecommunications manufacturer, shed more than 1000 workers from its Liverpool switching site.

The disappointment will be increased because it was thought that the company's technical partnership with its German parent Siemens had secured its future by developing new technologies like ATM and the SDH transmission system.

Earlier this year GPT/Siemens was named as one of BT's two SDH suppliers and also won orders for broadband computer network technology known as MANs. But the failure to be named as a main ATM supplier is a blow to GPT, which supplied virtually all of BT's existing digital telephone exchanges. Siemens has already secured ATM orders in Germany and the US.

The AT&T ATM switches will be used in BT's national telephone network while Alcatel's will support BT's participation in the European ATM trial. BT will also introduce ATM switches into the SuperJanet academic network in 1994.

Richard Wilson, Electronics Weekly.

Pirates ride the waves

The annual report of the Radiocommunications Agency, since 1990 an Executive Agency of the DTI, tells that radio piracy is on the increase again. In the year 1990/91, the RA prosecuted 145 people for radio piracy. The Broadcasting Act 1990 then came into force and gave the RA new powers to target people who finance pirate stations and advertise on them, as well as those who broadcast. This deterred some operators and the RA prosecuted only 67 in 1991/92. But now they are broadcasting again. In the year 1992/93 the RA made 536 raids, and secured 68 convictions.

Video scramble for pot of gold

When Rupert Murdoch talked recently of his "global vision" and plans to develop a common standard for digital TV transmission and the delivery of video pictures by telephone line, he is really talking about the pot of gold to be earned from scrambling pictures.

The electronics industry has already developed the digital compression technology that makes transmission and delivery possible, and in a remarkable demonstration of world wide cooperation the industry has almost finished five years of work on setting a common standard. But nobody has yet been able to agree on the encryption system to be used to ensure that only those viewers who pay to watch are able to watch.

News Datacom, a small security company owned by Rupert Murdoch's News International, has already developed an encryption system. If Murdoch can get the world to adopt this, NI will earn vast royalties through the next century.

When Rupert Murdoch began broadcasting his Sky service from Luxembourg's Astra satellite in February 1989, he chose the existing analogue Pal TV system, and broadcast clear - without scrambling. A year later Sky started to scramble some transmissions, to earn money from subscriptions.

Broadcasters had previously judged it impossible to scramble analogue Pal, with sufficient security to prevent piracy and without degrading the picture when unscrambled.

Thomson Consumer Electronics of France developed an old idea from Westinghouse in the US, which involved chopping up the lines of the picture before transmission and putting them together again in a receiver decoder. Professor Adi Shamir of the Weizmann Institute of Science in Israel had already been working on ciphers for NI's News Datacom. Using smart card technology, TCE and NDC jointly developed Videocrypt for Sky. The system uses digital encryption to control the analogue line chopping.

Murdoch has snubbed TCE and signed a deal with inventors of the "microbrains". These are NDC, NTL (formerly the Independent Broadcasting Authority's research laboratory), and US telecommunications company Comstream. A separate deal ties in British Telecom and its cellular phone network Cellnet.

The deal is nicely timed. The moving picture experts group of the ISO and IEC recently sealed a first standard, MPEG-1, for handling digital tv pictures at low data rate (1.5Mbits/s) and the telecoms industry is already looking at ways of sending MPEG-1 data streams down telephone lines. The group is on the point of finalising its second standard, MPEG-2, for broadcasting digital tv at higher data rates (usually 4 or 8Mbit/s) from terrestrial or satellite transmitters.

Although Murdoch has dropped TCE, News Datacom had worked with TCE on a digital version of Videocrypt for use with DirecTV, the new digital satellite tv service planned by aerospace company Hughes in the US. Because the previous deals between NDC and TCE were specific to projects,
Resources pooled to make solid state discs

America's third largest disc-drive maker Quantum is teaming up with Silicon Storage Technology (SST), a Silicon Valley flash chip designer, to produce solid state memory discs.

The companies have signed an agreement where Quantum will gain exclusive rights to use SST's flash chips in PCMCIA memory cards with IDE and AT interfaces. It is projected that 12 million portable computers will have PCMCIA compatible slots by 1996.

James Prasad, a product manager at Quantum, said there are several reasons why Quantum has chosen SST's technology.

First, it only requires a single power supply of 5V for programming and reading. This contrasts with the chips made by Intel, the world's largest flash supplier, which need two power supplies. This, says Prasad, means that Quantum flash devices will dissipate little power.

Secondly, the sector erase size on the SST chip is fully compatible with the AT bus used in most PCs.

Finally, the SST flash chips have a much thicker oxide layer than Intel's chips (40nm as opposed to 10nm), which makes them easier to make and results in a smaller die size. The flash drives should be available in the second half of next year.

TFT cell scores 3V goal

Mitsubishi has used its thin film transistor (TFT) static ram cell, first developed for a 4Mbit part, to build a 1Mbit device.

The result is a chip that operates from a 3V supply while consuming just 0.05µA on standby. Power consumption rises to 16mA for the chip when active.

The device is organised as 128K x 8bit and samples will be available later this year. A fourth polysilicon layer forms the TFT yielding soft error counts of 0.03 on cycle times of 300ns.

New opportunities for environmentally sound electronics: small scale electricity generation projects such as the Caernes Bay wind farm in Wales are providing new opportunities for development in process control engineering. This wind farm uses rented equipment from Livingstone Hire as part of the high voltage safety commissioning procedure.
ITEMS BORROWED FROM AN GOVERNMENT SUPPLIERS, PRICE IS EX WORKS, S.A.E. FOR ENQUIRIES, PHONE FOR APPOINTMENT OR FOR DEMONSTRATION OF ANY ITEM. AVAILABLE AT PRICE OR PRICE CHANGE. WE ARE CARB, EXTRA ITEMS MARKED TESTED HERE 30 DAY MARKET. WANTED: TEST EQUIP. - WIRES & PLUGS. - CONNECTORS - TRANSMISSION & RECEIVING EQUIP. ETC.

Johns Radio, Whitehall Works, 8 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No. (0274) 584007. Fax 651160.

October 1993

ELECTRONICS WORLD+WIRELESS WORLD
EASY FAST & POWERFUL
CAD SOFTWARE THAT GIVES YOU THE EDGE

ISIS - SCHEMATIC CAPTURE

Easy to use yet extremely powerful schematic entry system with all the features you need to create input for ARES or other CAD software. Now available in a super-fast 32 bit version capable of handling huge designs even on A0-sized sheets.

- Graphical User Interface gives exceptional ease of use - two mouse clicks will place & route a wire.
- Automatic wire routing, dot placement, label generation.
- 2D drawing capability with symbol library.
- Comprehensive device libraries.
- Heterogeneous devices (e.g. relay and coil) allowed in different places on the schematic.
- Special support for connector pins - put each pin just where you want it.
- Output to printers, plotters, Postscript.
- Export designs to DTP and WP packages.
- Netlist formats for most popular PCB & simulation software.
- Bill of Materials and Electrical Rules Check reports.
- Multi-sheet and hierarchical design support.
- Automatic annotation/packaging.
- ASCII data import database facility.

from £275

ARIES - PCB DESIGN

Advanced netlist based PCB layout software newly updated to version 2.5. Major new features include SMT library, real time snap (for those tricky SMT spacings), thermal relief power planes and enhanced autorouting.

- Graphical User Interface.
- Real time snap.
- Auto track necking.
- Curved, 45/90 or any angle tracks.
- Extensive through hole and SMT package libraries as standard.
- 2D drawing capability with symbol library.
- Connectivity highlight.
- Output to printers, plotters, Postscript, Gerber and NC drill.
- Gerber View facility.
- Graphics export for DTP etc.
- Advanced netlist management with forward design modification.
- Component renumber and back-annotate to ISIS.
- Full physical and electrical design rule checks.
- Autorouter handles single, double or multi-layer boards.
- Power plane generator with reliefs.
- Strategy & DRC information loadable from ISIS.
- Gerber import utility available.

from £275

ISIS ILLUSTRATOR

Schematic capture for MS Windows 3.1 - produces high quality schematics like you see in the magazines with your choice of line thicknesses, fill styles, fonts, colours etc. Once entered, drawings can be copied to most Windows software through the clipboard.

New version 2 includes netlisting, bill of materials, hierarchy, and much more. An ideal front end for Windows Simulation and PCB design.

new low prices from

£99

CADPAK - BUDGET PRICE CAD

Two programs - ISIS SUPERSKETCH and PCB II - for the price of one.

CADPAK has everything you need to produce circuit diagrams and PCBs on your PC and is exceptionally easy to use.

superb value at only

£79

Call us today on 0274 542868 or fax 0274 481078 for a demo pack. Combination, multi-copy and educational discounts available. Prices exc P&P and VAT.

14 Marriner's Drive, Bradford, BD9 4JT.

CIRCLE NO. 126 ON REPLY CARD

ELECTRONICS WORLD+WIRELESS WORLD October 1993
Blue laser burns itself into storage record books

Scientists have demonstrated a blue laser optical recording system that can write and read data at what they claim is a world record density of 2.5 gigabits per square inch on a removable magneto-optic disk. That’s the equivalent of 6.5 gigabytes on a double-sided 5.25-inch optical disk.

Researchers have long known that blue light, because of its shorter wavelength, is potentially capable of writing more data on a given disk area. It is simply that blue light can be focused on to a smaller spot than infra-red: 0.411 micron, as compared to 0.81 micron, about a quarter of the area. But while the theory is straightforward, the practical problems are immense. What researchers at IBM’s Almaden Research Centre in California have shown is that the high storage density predicted for blue light systems can now be achieved under realistic conditions.

For their latest demonstration, the IBM team wrote a pattern of data bits on a rotating glass disk coated with a film of magneto-optic material optimised for blue light. They then read back the pattern at a realistic rate of 2Mbyte/s and were able to distinguish the signal from the background noise as accurately as in current commercial products.

In rewritable magneto-optic recording, a mark is made when a short, high-intensity laser pulse very quickly heats a small spot of the magneto-optic coating in the presence of a magnetic field. Within a few milliseconds after the laser pulse, the material cools, locking in the magnetic orientation, which in turn affects the polarisation of any light that subsequently passes through it.

To read the data, a low intensity laser illuminates the track. A detector and its associated electronics then reads the changes in polarisation and converts them into data pulses. Erasure is achieved by re-heating the area with the high intensity laser while the magnetic field is reversed.

IBM’s team generates its blue light by passing the output of an infra-red gallium arsenide diode laser through a specially designed frequency doubler. Careful feedback controls enable this process to operate efficiently at the power levels required. The blue laser technology has been licensed to Coherent Inc who will initially be targeting industrial, medical and printing applications.

Top people are always in a spin

EW + WW can now reveal the secret to staying at the top of the pile. To succeed in the stock market, politics, courtship or the media, you have to behave just a little unpredictably. At least that is the conclusion of a study by two researchers at the University of Illinois in Urbana.

Computer simulations by physics professors Alfred Hubler and David Pines show that the best strategy in any kind of chaotic situation is to be neither completely orderly nor totally unpredictable. According to Hubler: “a competitor who imposes a weakly chaotic dynamic on a chaotic environment stays leader for the longest.”

Using mathematical terms to define variables such as a competitor’s unpredictability and changes in the environment, the researchers charted the results of several hypothetical long-term interactions. Their simulations suggested that the most productive arrangement for two competitors is to exist in a leader-follower relationship. The arrangement avoids conflict, whether in the home, in the workplace or between nations.

Hubler and Pines’ conclusion is hardly surprising. But what is interesting is the finding that such stable relationships last longest when a small degree of unpredictability is introduced by one or both participants. If a person, or organisation, behaves too predictably, a competitor can figure out a pattern and attempt to short-circuit it, in turn, destabilising the relationship.
The logical advice to companies, therefore, is to avoid making your corporate strategy too transparent or unchanging.

On the other hand, says Hubler: "if behaviour is too chaotic, unpredictable and non-reproducible, it may alarm competitors who were formerly content."

Such formerly happy competitors may then energise all their efforts in a powerful, but dangerous over-reaction. It's the sort of thing that leads to price battles, stock market collapses and ultimately, wars.

According to the computer simulation, a small degree of unpredictability is desirable for two reasons. Not only does it stabilise your position at the top, it also offers the tools to respond more quickly to changes in the economic or political climate.

Unfortunately, after the telescope was launched in 1990, its pointing capability was affected by jitter caused by expansion and contraction of the solar arrays every 90 minutes as the craft passed in and out of sunlight. Temperature variations of 200°C caused the tips of the panels to bend out of true by up to 30cm.

The problem was solved provisionally by anticipating the temperature changes and issuing commands for the telescope to change its direction to counter the changes caused by the flexing solar panels. But this extremely cumbersome procedure occupies a large amount of on-board processing power.

Effects of the flexing have been made worse by the fact that the expansion and contraction is jerky. The new panels, with fewer moving parts, are being carefully designed to minimise the problem. Each support boom is covered with an aluminium layer supported by 900 plastic discs forming an accordion-like structure. The structure will reduce thermal gradients by a factor of 20 while, at the tip of the arrays, a complex system for countering expansion has been replaced by one of frictionless springs. The deployment drum will also be immobilised by an electrical brake.

If all this seems a bit over the top, it is important to realise the degree of stability necessary. The telescope's precision pointing system demands that residual torque from the solar cells must not exceed 0.002Nm - equivalent to the weight of half a paper-clip held at arm's length!

As well as ridding Hubble of its wobble, the astronauts will be fitting an optical device to correct the aberration of the primary mirror. Space testing and servicing of the device will make use of the faint object camera (foc). The foc, one of the main contributions from ESA, the European Space Agency, is one of several light sensors on the telescope, and consists of a powerful image intensifier able to detect stars of magnitude 29. That is five billion times too low to be seen by the naked eye and is roughly equivalent to a candle on the moon. In conjunction with the telescope optics, the foc is sensitive enough to distinguish between a pair of coins at a distance of 200km. At the moment, one of its two detectors is showing signs of deterioration and will also need to be fully re-tested.

Final testing at British Aerospace of the roll-out solar array for the ESA/NASA Hubble space telescope. The first servicing mission is scheduled for December.
Geniuses are made not created

At a time when British industry is desperately trying to seek out (and retain) its brightest talent, it is illuminating to ask - as psychologists at Florida State University have - exactly what are the ingredients of talent or giftedness.

Florida's Anders Ericsson, professor of psychology, may have an answer. He has been studying world-class experts in music, chess, sport and the arts to learn what talent really means. It seems that all we need to emulate feats - such as the amazing ability to recite $\pi$ to 32,000 digits - is practice.

Reassuringly, he is discovering that experts may not be any smarter than the rest of us. Indeed, to judge from Ericsson's findings, giftedness has as much more to do with environment than with whatever "clever" genes we inherit. The common factor that emerges when top people are studied is not their IQ but their dedication. As Ericsson casually observes with there are no "naturally gifted" people. Brilliance in these areas can start your PhD thesis at 18 months of age.

Unfortunately, there may be a certain age after which you must give up trying to become a megastar - in the artistic professions at least. A common feature of many famous musicians and sportspersons is that they started practising consistently from a very early age. Genius at the Mozartian level appears to be largely a matter of motivation.

Ericsson cites the example of students who were put through a rigorous training programme to help them memorise numbers. After a week of practising an hour a day, a typical college student could recite the value of $\pi$ to about 12 or 13 digits. After two years' practice, he or she could manage about 80. Ericsson is now continuing his research into the ability of the 35-year old psychology graduate and his 32,000 digit $\pi$ - taking about three hours to recite: he's hoping to reach 100,000.

Genius, says Ericsson, is not born but becomes gifted in this - or indeed other areas - seems to be largely a matter of motivation. Ericsson doesn't imply that everyone can become a genius. There are undoubtedly genetic differences that make some people more likely to succeed than others. But the assumption that talent is largely in the genes is not supported by the evidence.

The key difference between ordinary people and highly talented people is the extent to which they are motivated to practise, and it is not just the quantity of practice, but its quality. Endless repetition will not create talent: the sort of practice that makes for genius is well organised and aimed at a specific goal. Truly talented people, says Ericsson, regard properly directed practice as so essential that they come almost to enjoy what other people find an unrewarding grind. They are also motivated to seek out other experts who will direct their practice effectively. As yet no-one knows why some people have the necessary motivation to become geniuses and others, with equal intelligence, don't. Pushy parents, I'd guess.

Diamonds without pressure

Chemists at Pennsylvania State University have devised what they say is the first method for making diamond from a soluble, solid-phase non-diamond material. The process works at normal atmospheric pressure and at relatively low temperatures.

Natural diamonds are created under conditions of extremely high temperatures and pressures deep inside the Earth, and most existing industrial processes employ similarly energy-intensive approaches. The Penn State chemists, led by Patricia Bianconi, have adopted a less aggressive and therefore potentially cheaper technique. They have developed a polymer, called polyphenylcarbyne, which looks like brown sugar and has a natural tendency to turn into diamond when heated because some of its atoms are already in a diamond-like configuration. The polymer is also the first proto-diamond material that can be dissolved in solvents. It opens up the possibility of being able to coat objects with the polymer solution and then, by heating, to cover the object with a protective coat of wear-resistant artificial diamond.

Bianconi speculates that such artificial diamond could have widespread applications in the electronics industry. Not only does it have the highest melting point of any known material, it also has a very high thermal conductivity. She says that it might be possible to draw diamond components directly onto a chip by coating it with the polymer solution and then directing localised heat at it by means of a laser beam. Bianconi and her team are now refining the chemistry to reduce the amount of impurity, especially graphite.

Penn State protodiamond polymer after processing (40 x). Black areas are microscopic diamond coated with graphite; transparent areas are crystalline diamond.

Research Notes is written by John Wilson of the BBC World Service.
Ben Duncan analyses distortion performance and harmonic spectra of the UK’s ten most popular audio power ICs. In a unique performance guide, he names the good, the bad – and the ugly

SPECTRALLY CHALLENGED:
The top 10 audio power chips

Electronic components have faced little of this. The open-ended application of component parts appears to make comparative review (beyond checking published specifications) next to impossible. But IC power op-amps are different in that they are made and used mainly for just one task – driving audio into loudspeakers.

They are used in professional audio for talkback and headphone monitoring; in low budget audio, and by one maker as a power amp driver stage. Similarly, comms, and wherever a few tenths to tens of watts are needed, from a few Hz to 20kHz, are also likely applications.

In use, the small signal stages must be protected from positive feedback induced by asymmetric, Class A-B currents in the adjacent output section and from thermal distortion caused by widely fluctuating Class A-B junction temperatures. So design with low distortion and RF/LF stability is quite a challenge, but today there are over 100 IC power amplifiers to choose from, several dating back twenty years. A large number are Japanese and most of these are not readily available outside the orient. The remaining main players are Nat Semi in the US, and Philips and SGS-Thomson (representing Europe).

For practical testing, these companies’ 50 or so devices have been whittled down to the most useful ten best sellers in the UK (Table 1).
Table 1. Power op-amps under test.

<table>
<thead>
<tr>
<th>Model</th>
<th>Maker</th>
<th>Nominal Po</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM380</td>
<td>Nat Semi</td>
<td>3W, 3% THD</td>
</tr>
<tr>
<td>LM383 T</td>
<td>Nat Semi</td>
<td>17W, 10% THD</td>
</tr>
<tr>
<td>LM386 N4</td>
<td>Nat Semi</td>
<td>0.3W, 3% THD</td>
</tr>
<tr>
<td>LM1875</td>
<td>Nat Semi</td>
<td>33W, 1% THD</td>
</tr>
<tr>
<td>TBA820 M</td>
<td>SGS-Thom</td>
<td>1.6W, 10% THD</td>
</tr>
<tr>
<td>TDA1514</td>
<td>Philips</td>
<td>50W, 0.1% THD</td>
</tr>
<tr>
<td>TDA2030</td>
<td>SGS-Thom</td>
<td>16W, 0.5% THD</td>
</tr>
<tr>
<td>TDA2040</td>
<td>SGS-Thom</td>
<td>36W, 10% THD</td>
</tr>
<tr>
<td>TDA2822</td>
<td>Philips</td>
<td>12W, 10% THD</td>
</tr>
<tr>
<td>TDA2611</td>
<td>Philips</td>
<td>1W, 10% THD</td>
</tr>
</tbody>
</table>

These 10 power op-amps were chosen as being presently the largest selling models in the UK, from European & US makers. Maximum power outputs are maker's specification into lowest rated load at highest rated supply, or closest tabulated rating. They cannot be directly compared, as the loads and %THD reference points differ: for example, power ratings at 10% THD will be higher than those taken (more properly) at 0.1% THD.

Power capabilities range from hundreds of milliwatts (TBA820M) up to tens of watts (TDA1514).

Testing standards
The devices being tested vary greatly, and bold decisions were needed to make the processing reasonably straightforward while giving meaningful results. To begin with - and unlike most IC op-amps - over half the group of power ICs is devoid of a standard package or pinouts. The four units in the Pentawatt package are the exception. With consistent pinout, and dual polarity supplies and inputs, the Pentawatt is a universal receptacle for amplifiers configured as op-amps.

Most of the remaining ICs are not pure op-amps (note the requirement for a DC blocking capacitor on the LM383's -ve input, for example, signifying internal input biasing). But they all employ mainly direct-coupled stages with overall NFB. The LM380, 386 and TDA2611, 2822 have fixed gains to save on parts count, ranging from +26 to +39dB. This is too much gain for use at common line levels, but allows most transducers to be connected without intermediate preamplification - a particularly useful facet in ultra compact, low budget equipment. On the other hand, it prevents testing at a uniform gain.

Gain can be adjusted on all the remaining devices, and - with the exception of the TBA820 - it is set by an external, shunt feedback.
Fig. 5 to 10. The dynamic THD and transfer plots on this page show a variety of pathologies. All plots are at 5kHz.

In Fig. 8, the distortion is barely out of the noise floor (at -31dBu input drive) before it begins to rise again, into a very soggy asymmetric clip, rather like a single ended valve amplifier. The transfer functions for all the others bend as clip is entered. The almost flat distortion curves in Figs. 6, 9 and 10 are characteristic of crossover distortion.

In Fig. 5, distortion (and noise) are commendably low for signals 20dB below clip, but %THD rises at a steady rate thereafter.

Fig. 5. TDA2040

Fig. 6. TDA2611 A

Fig. 7. LM380

Fig. 8. TBA820 M

Fig. 9. LM386 N4

Fig. 10. TDA2822 M
divider. The LM383 (Fig. 23) employs unusually low resistor values here to enhance PSRR. Instead of fixing the gains of the flexible devices at one arbitrary level, gain is allowed to follow the maker's evaluation circuit, excepting the LM383 and LM1875, which are set at 20dB.

The conditions are reasonable in that all the devices have gains which are close to those most used in practice, considering the ICs' span of power ratings. For example, the higher power devices are less liable to be used in portable battery-powered systems, and rather more likely to be driven at line level, requiring less gain.

All devices are operated in the non-inverting mode as this is the sole option for the non-op-amp types (Fig. 22), excepting the TDA1514. As the lowest gain is +20dB, common mode distortion will be expected to be a minor feature.

Most of the lower power ICs work on single rails, while the higher output models employ dual supplies. Maximum supply voltages vary from ±30V (TDA1514) down to ±15V (TDA2822 M). The test supply is fixed at the lowest device's maximum: +15V for single rail devices and ±15V for dual rail devices. Under these conditions, the loop gain of the devices having significantly higher maximum voltages will be depressed about 10 to 15%. This affects %THD above 5kHz, but only marginally against the background of loop gain unit-to-unit tolerance of 30 to 50%, and the gain differences already discussed.

Test circuits
Looking at the test circuitry in more detail, on all the single rail circuits, the output DC blocking capacitor is standardised at 100uF. Some circuits specify – and most received – an RF filter capacitor at their inputs. On several ICs, it is mandatory, despite being driven by just 1.5m of screened cable from a 250 source. Some units need a DC blocking capacitor at their inputs to preserve their biasing.

Figs. 11 to 21 show harmonic spectra and noise. Harmonic levels are slightly changed when testing proceeds from switch on, as opposed to being pre-warmed by quiescent current. If further changes were evident over logarithmic time intervals, the audiophile's claim that equipment sonics change over a long period of 'warm up' would be potentially validated, subject to further psychoacoustic translation. And while the broad pattern of the harmonics were only slightly changed with temperature, this might amount to a disproportionate audible change.

---

Ben Duncan Research PA -1514AMP1(d6) vs FREO(Hz) 19 JUN93 14,06:28

-5000 -6000 -7000 -8000 -9000 -10000 -11000 -12000 -13000 -14000 -15000

1.00k 2.00k 3.00k 4.00k 5.00k 6.00k 7.00k 8.00k 900k 10.0k

Fig. 11. TDA1514

Ben Duncan Research PA -2030 AMP(lf) vs FREQU(Hz) 19 JUN93 14:15:25

-6000 -7000 -8000 -9000 -10000 -11000 -12000 -13000 -14000 -15000

1.00k 2.00k 3.00k 4.00k 5.00k 600k 7.00k 8.00k 900k 10.0k

Fig. 12. TDA2030

Ben Duncan Research PA -LM383 AMP(lf) vs FREQU(Hz) 19 JUN93 14:15:25

-6000 -7000 -8000 -9000 -10000 -11000 -12000 -13000 -14000 -15000

1.00k 2.00k 3.00k 4.00k 5.00k 600k 7.00k 8.00k 900k 10.0k

Fig. 13. LM383

Ben Duncan Research PA -1875 AMP(lf) vs FREQU(Hz) 19 JUN93 14:15:25

-6000 -7000 -8000 -9000 -10000 -11000 -12000 -13000 -14000 -15000

1.00k 2.00k 3.00k 4.00k 5.00k 600k 7.00k 8.00k 900k 10.0k

Fig. 14. LM1875

---

October 1993 ELECTRONICS WORLD + WIRELESS WORLD 807
Figs. 15 to 20. In this group the TDA2040 is a good example of monotonically reducing harmonics, with the exception of the 10th and 11th. This kind of structure is more pleasing to the ear, and more like the harmonics in euphoric musical sounds than the humped pattern of the LM380 in Fig. 17. At over twenty years, LM380 is the oldest device in the tests, and the only DIL unit having provision for copper heatsinking "wings" to be soldered to 6 of its pins. But the even more ugly, roller-coaster harmonic pattern of a much newer device like the LM386 (Fig. 19) shows that audio quality evolution cannot be counted upon.
The TDA2611's stability margin is such that the Audio Precision analyser's mildly reactive loading had to be isolated with 1k. The TDA1514 works well despite its modest supply decoupling. Past experience led me to increase the supply decoupling on other units beyond the maker's recommendations.

The 470µF rail decoupling capacitors are all Low-Z at HF types. Power is taken from a regulated supply with a reasonably low source impedance, below 10mΩ (including leads & connections), from below 100Hz to above 10kHz. In practice, many battery and low budget mains supplies will be considerably higher.

The circuits are built on Veroboard explicitly made for analogue prototyping and solely available from RS (433-911). As each node has five holes, inter-track capacitance is limited to a few pF. RF stability and low THD are assured by noding all the main grounds to a common point, and by running solder along power, output and ground tracks to keep resistance down. Hook-up is with 1/0.6mm solid core wire with a maximum length of 50mm.

Test procedure
All testing is performed into an 8Ω load, with about 1nF of load capacitance. As a preliminary to spectral testing, each DUT (device under test) is checked by first performing a bandwidth sweep. Several have secondary (HF) crossover distortion, slew limiting and/or RF oscillation above 20kHz. Results of the tests led to some of the fixes described above.

Next, %THD is plotted dynamically, against level. The DUT is driven from 15 or 20dB below clip, up to and beyond clip, at a spot frequency of 5kHz. The characteristic of a
high-performance, clean device with high
NF is a "lazy V" or sideways "L" shape. The
noise floor at first drops linearly to reveal
the real %THD, and the THD then rises abruptly,
beyond clip. Looking at the results in Figs. 1-
10, the TDA1514 and LM1875 come closest
to this. The same Figs also plot the transfer
function, in watts, with a log scale so that
the power can be related to a given %THD and
drive level.

On Fig. 1, for example, 0.1% at A on the
THD graph corresponds to point B (draw a
straight vertical line above), which is around
11W. Looking down shows that input drive is
around -7.5dBu. The AP's %THD residue is
typically below 0.0007% up to clip, much
lower than even the best DUTs.

As in previous tests, the devices' harmoni-
cic spectra are then plotted, using the Audio
Precision dual domain test set's DSP facility,
set at 48kHz sample rate to provide a tight,
3Hz bandwidth. All the units had spectra
(Figs. 11-20 ) much higher than the AP
residue (Fig. 21) and their own noise, so there
is none of the uncertainty that plagues mea-
suring the better op-amps. Processing is speed-
up by averaging just 16 samples for cer-
tainty, and all testing was done with DUTs
placed in a steel shielding tray. The results of
Figs. 1-10 were used to set the test level at
between 1 and 2dB below clip – the latter
defined clearly in most cases by the point
where the %THD graph turns irrevocably
upwards.

All the devices heated up when tested, and
whereas external heatsink temperatures would
be lower with program instead of a sine-wave,
and with a real loudspeaker as a load, peak
junction temperatures could be much the
same. Some tests were run immediately at
switch on, and while several showed greater
power on output, %THD and spectral results
were only marginally better, if different at all,
particularly with the 8pin DIL devices, which
have small junctions and high thermal resis-
tance.

From best to worst
Ranking devices by absolute level of their
spectra (Table 2), it is fitting that Philips' TDA1514
appears as the top performer, as it's trumpeted as a "high performance Hi-Fi amplifier", as well as being the newest in
the group (1991). But that two of the oldest
(circa 1975-8) devices came next best shows that evolution in audio quality is not to be
relied upon. If the harmonic pattern is taken to
be more critical to the ears than the absolute
levels of spectra, then the clear leaders are
TDA1514 and TBA2822M, with their even-
order dominance. On this basis, asymmetric
clipping and even the 820's primitive, single-
ended output stages are beneficial!

Next most likely to be preferable on sonic
grounds are the units with monotonically
descending spectra (TDA2030, 2040, 2611 and
LM383). Soft clipping may contribute to good
sonics, where the amplifier's swing is forced
(by design, battery technology and budget
constraints) to be inadequate. When this is the
case, the LM386, TBA2822, TDA2822 and to a
lesser extent the LM2040 are expected to sound
least painful in overdrive. Much hearing
damage is caused by compression or signal
clipping, not high SPLs per se, so it is hoped
that designers of equipment driving headsets
ear speakers (particularly domestic replay
equipment likely to be used by children) are
being made notes. Ideally, audio designers will
all be studying Douglas Self's treatise (series
running in this issue) on fundamental bipolar
amplifier distortion pathologies too.

Looking now at Fig. 10, the TDA2822M is
strictly unacceptable as an audio device, on the
grounds that THD consistently above 0.1%
from a device with overall feedback is bound
to be fatiguing and irritating. It could prove
fatal (or at least needlessly stressful) if used to
drive an air traffic controller's or pilot's head-
set, for example.

Finally, how do ICs compare to real power
amplifiers? Well compared to the profession-
al PA amplifiers measured so far, the top five
ICs are returning similar absolute levels,
though with different spectra. The remaining
five are probably not much different to most
tight budget commercial amplifiers.

References
1. Ben Duncan, AMP-02 state of the art
preamplifier, Part 5, p.37-39, Hi-Fi News, May
'90.
2. Martin Giles (Ed), Audio/Radio Handbook,
Nat Semi, 1980, section 4 "Power amplifiers".
3. Ben Duncan, How clean is your audio op-
amp ?, EW + WW, Jan '93.
4. Ben Duncan, Evaluating Audio op-amps,
Pts. 2 & 3, Studio Sound, Aug-Oct '90.

Acknowledgement
The author would like to acknowledge the
assistance given by Audio Synthesis and
Macro Marketing.
AMAZING PC BASE SALE

WE HAVE ACQUIRED A SELECTION OF HIGH QUALITY AMSTRAD PC BASE UNITS AT MEGA DISCOUNT PRICES. LOOK WHAT YOU CAN BUY FROM US TODAY!

UNTESTED AMSTRAD PC BASE UNITS COMPLETE WITH MOTHER -BOARD, VIDEO CONTROLLER, DISK CNTRLR, & 5.25" DRIVE(S), (jectoryboard. Mouse. PSU & DOS not supplied)

AMSTRAD 1512SD £19.00 REF: EW/AM19P
AMSTRAD 1512DD £22.50 REF: EW/AM22P
AMSTRAD 1640SD £22.50 REF: EW/AM22P
AMSTRAD 1640DD £30.00 REF: EW/AM30P

NEW or REFURBISHED PC BASES COMPLETE WITH KEYBOARD, MOUSE, and 5.25" DRIVE.

RUNS UNDER MS-DOS VER 3 (DOS not supplied)

AMSTRAD 1512SD (512k memory Single 3.5" disk drive) £69.00 REF: EW/AM69P
AMSTRAD 1512DD (512k memory Two 3.5" disk drive) £79.00 REF: EW/AM79P
AMSTRAD 1640SD (640k memory one 3.5" drive modem) £49.00 REF: EW/AM49P
AMSTRAD 1640DD (640k memory two 3.5" drive modem) £59.00 REF: EW/AM59P

AMAZING COMPUTER BARGAINS

IBM COMPATIBLE LAPTOPS FROM ONLY £99.00 (plus VAT)

LIMITED OFFER - HURRY WHILE STOCKS LAST

AMAZING SALE OF BT ANSWERPHONES

AS NEW, FULLY GUARANTEED BT PRODUCT AS LESS THAN HALF THE ORIGINAL RETAIL PRICE!!!

RESPONSE 200 AND 400 MODELS

Each Response Unit is supplied with a Micro cassette, PSU and User Details. The following features are found on the 400 Model and the 200 has almost as many features:

- Micro Cassette
- Call Screening
- Call Count
- Answer only
- Last No redial
- On hook dialing
- BT Network Services
- Mute Facility
- LCD Display

RESPONSE 200 £35.99 (plus VAT) REF: EW/35P
RESPONSE 400 £49.99 (plus VAT) REF: EW/49P

10 WATT SOLAR CELL

(3" x 1") 14.5v/700mA
Now available by mail order

Coated with exceptionally efficient amorphous silicon these glass solar cells have an almost timeless lifespan and will not suffer with discoloration. There are possibly hundreds of uses for these cells, a few of which could be: for Car Battery Charging, for use on Boats or on Caravans, in fact anywhere a portable 12V supply is required. Several of our overseas Mediterranean customers with homes in remote hilly sites, use these solar cells as a daytime power source to backup generators. The solar cells can be connected in series or parallel to give higher voltages or larger current capacity.

PRICED at only

£33.95 (plus VAT)

PLUS an additional £2.00 special packaging charge

PORTABLE RADIATION DETECTOR

SPECIAL OFFER

£49.99 (plus VAT)

NEVER OFFERED BEFORE.............. We can now supply a unique hand held personal portable Gamma and X-Ray detector. This Radiation detector contains two Geiger Tubes has a 4 digit LCD display with a piezo speaker, giving an audio visual indication. The radiation detector detects high energy electromagnetic quanta with an energy from30k eV to over 1.2M eV and a measuring rate 5-9999 U/r (sampling rate 255) to 10-99990 N/H (sampling rate 2555) or Source of radiation could be Granite Kerbstones old Luminous Watch dials or even a Jewellery shop where mineral ore is sold to rock collectors. A piece of uranium Ore would be ideal......

Only £49.99 Each Ref: EW/50P

BULL ELECTRICAL

250 PORTLAND ROAD HOVE SUSSEX BN3 4OT

MAIL ORDER TERMS: CASH PO OR CHEQUE WITH ORDER PLUS £3.00 POST PLUS VAT.

PLEASE ALLOW 7-10 DAYS FOR DELIVERY

TELEPHONE ORDERS WELCOME.

TEL: 0273 203990

FAX: 0273 329377

CIRCLE NO. 128 ON REPLY CARD
BARGAINS GALORE

**Magnetic Solenoids**
- Various types and sizes available.
- Ideal for controlling machinery or appliances.
- Prices starting from £1.

**Solar Panels**
- Various wattages available, from 10W to 100W.
- Ideal for off-grid power generation.
- Prices starting from £15.

**Solar Cells**
- Small and large solar cells available.
- Suitable for charging small electronics.
- Prices starting from £1.

**Lighting Fixtures**
- LED strips, bulb replacements, and fixtures available.
- Energy-efficient and long-lasting.
- Prices starting from £5.

** Batteries**
- Li-ion, Ni-MH, and lead-acid batteries available.
- Suitable for various applications.
- Prices starting from £1.

**Motors**
- Various types and sizes available, including shaded pole, DC, and stepper motors.
- Suitable for DIY projects or replacement.
- Prices starting from £5.

**Relays**
- Various types and sizes available, including DPDT, SPDT, and 3PDT relays.
- Suitable for controlling power.
- Prices starting from £1.

**Si Lamps**
- Various sizes and types available, including red, green, and white.
- Suitable for signal or warning purposes.
- Prices starting from £1.

**Miscellaneous**
- Various other components and accessories available.
- Suitable for a wide range of applications.
- Prices starting from £1.
HIS Hewlett-Packard oscilloscope combines the feel and display of a top line analogue instrument with the precision and programmability of digital electronics.

This DSO is easy to use because it was designed by electronics engineers for electronics engineers.

Electronics World is looking for freelance authors who can bring applied electronics design alive for other electronics professionals through their writing. We want to commission articles on circuit design using the wealth of modern components now available to electronics engineers. Possible areas of interest could be RF, microwave, audio, video, consumer electronics, data acquisition, signal processing and computer peripherals.

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

The author of the best script received over the period June 1, 1993 to May 30, 1994 will receive an HP54600A oscilloscope in addition to the normal author’s fee.

The judging panel will be drawn from Electronics World and Hewlett-Packard.

For further details about our quest for the best call or write to:
Frank Ogden, Editor, ELECTRONICS WORLD, Quadrant House, The Quadrant, Suron
SW2 5AS. Tel 081-652 3128
One of the key aspects of any good presentation is confidence. For that, a coherent and lucid aural presentation of the facts supported by well produced visual aids is essential – gone are the days when an engineer could present information simply by using half a dozen transparencies and a few felt tip pens.

Fortunately presentation software – such as Stanford Graphics for Windows from 3-D Visions of California – is making the task of generating quality visual aid material now relatively easy.

Stanford Graphics is an alternative to the well known Harvard Graphics, and allows the user to create a set of slides with a consistent format, irrespective of source. The slides may be included in documents or used for audio visual purposes (or both). Images can be imported from other sources (including TIF and PCX formats) and so slides can incorporate graphs, images and text. Using the slide sorter enables slides to be displayed as an array for final checking.

The finished product could be a set of 35mm colour transparencies for projectors (several companies will now convert EPS image files into 35mm) and a set of accompanying handouts, including the slide contents, which can be produced from a laser printer. When generating text slides the user has access to the Style Master which allows the creation of several templates which are used to standardise the presentation format.

Graphing
Prime feature of Stanford Graphics is its large array of graphing formats, grouped into the four categories of business, statistical, technical and custom. A “gallery” enables the user to have a quick look at each option by browsing through the possible designs. Each group offers an impressive range of designs, including 3-D options: some are well known (bar and column graphs); others not so. For example, apparently the Spider plot allows a number of system parameters to be rated on an equal scale, enabling a user to track any parameter moving outside an acceptance envelope. Among the useful business options is the Gantt chart, frequently used to plan projects (unfortunately it still does not predict slippages!).

Statistical options include histograms, scatter plots, star plots and error-bar plots, all useful for plotting very basic statistical information. But anyone needing to perform any serious statistics would probably turn to a statistical package such as SPSS or StatGraphics. These already have an impressive range of graphical representations and since they run under Windows, it is highly unlikely that an engineer or statistician would deliberately choose Stanford Graphics for statistical processing. But the technical graphing options are very useful and include polar plot, shadow-contour, Smith chart and a surface plot.

Importing data
Importing data from spreadsheets such as Microsoft Excel or Lotus 1-2-3 presents no problem. But if other sources are
used, data must be in an ascii file format with a minimum of two arrays (X and Y). Unfortunately, a sequence of data (Y co-ordinates) can not be plotted directly from a data acquisition card or data file, as X co-ordinate values must be supplied. The limitation can be irritating as all data files must be pre-processed to add the scaled X array data.

Imported data is loaded into a spreadsheet-like table, which can be edited, and the spreadsheet associated with each graph can be accessed at any time by clicking on the appropriate icon. As with spreadsheet programs, editing options allow data cells to be manipulated, including a paste function which enables a mathematical function to be applied to a cell or a range of cells (the user’s guide is not very informative on this feature, and its use is confusing and needs to be cleared up on a future version). Overall, playing around with the spreadsheet facility makes it clear that technical data should be fully prepared in another package prior to importing it for plotting.

On the graphs themselves, reasonable control is exercised over labelling, axis definition and orientation of the plots, all performed through typical Windows dialogue boxes. Through format and graph menus, labelling size, orientation, font and positioning can all be specified, and axis scales can be changed to reflect logarithmic requirements, either dBs or linear. Even the 3-D pie charts can be scaled logarithmically – giving true meaning to “lies and statistics”.

Analysis
Data, once imported and graphed, can be analysed using curve fitting (regression analysis), interpolations, statistics and an FFT.

USER’S GUIDE
Documentation is a detailed and well laid out – though hefty – soft-bound guide. Much of it is taken up with the standard interface features of Windows, while the all-important “getting started” section provides an adequate overview of features.

To help the new user, the package powers up to a “quick start” menu, guiding access to standard features. The tutorial included is well thought out, and the resulting impression of this carefully planned introduction to the package is a very favourable one for the first time user.
Curve fitting choices are quite reasonable including one for surface fitting which carries out a regression process on a surface plot. Another attractive feature is the graphics equaliser, allowing coefficients to be adjusted after regression modelling analysis has been carried out on a plot. The result is the original curve plus the error difference curve, generated by the coefficient adjustments. It’s a sort of “what if?” analyser, though the pictorial graphics equaliser icon only seems to appear in a super-VGA graphics mode.

Speed limitation
For generating presentation slides, hand-outs and professionally drawn graphs for importing into desk top publishing packages, Stanford Graphics scores highly. Its bewildering array of graphing options leaves the user spoilt for choice. But there are a few problems, and the main criticism of the package, apart from its inability to plot a single array of data, is speed. Under certain conditions, plotting rate on a 33MHz 486-PC with 8Mbyte ram can be painfully slow – spectral plots for example. Redrawing when the mouse button is released is also irritating and time consuming and “Out of memory” messages keep appearing, even when there may be 3Mbyte of unused ram left.

Running on a 16MHz 386-PC does not bear thinking about and, though possible, should be avoided. To run this package efficiently needs a fast PC and a fair amount of memory. But once equipped, Stanford Graphics is easy to work with and very effective for producing presentation information.
Subscribe to the magazine that experienced electronics professionals never miss

Whatever your interest in the world of television electronics, there’s a wealth of news, advice and hard information for you in TELEVISION.

TELEVISION offers you a definitive guide to today’s TV electronics business, keeping you up-to-date with new developments in TV, video and satellite – whilst furnishing you with ‘hands-on’ advice and information on the latest equipment.

EVERY MONTH – EVERYTHING YOU NEED TO KNOW
Once you are a subscriber to TELEVISION you’ll enjoy a great information advantage. You’ll be ahead of all of the latest product developments – you’ll receive inside information on important techniques and time-saving work methods – and, importantly, you’ll have access to the most comprehensive marketplace for components and services in the UK.

Quite simply TELEVISION is the ‘bible’ of the television electronics industry – if you want to keep up with the competition, you can’t afford to be without it.

SUBSCRIBING IS SIMPLE
Complete the coupon and return it to us at TELEVISION, Reed Business Publishing, FREEPOST, 9th Floor, Quadrant House, The Quadrant, SUTTON, Surrey SM2 5BR

Please send me TELEVISION
☐ One Year at a cost of £26
☐ Two Years at a cost of £49 SAVE £3
☐ Three Years at a cost of £70 SAVE £8

Name
Job Title
Company
Address
Postcode
Telephone No.
Fax No.

4 WAYS TO PAY
1 ☐ I enclose a cheque for £_____ made payable to Reed Business Publishing

2 Please charge my:
☐ Access ☐ Visa
☐ Diners Club ☐ American Express
Expiry Date

3 Please invoice me/my company
Order No.

4 Or alternatively just ring our credit card hot-line on 0622 721666 and quote reference RJ3

Are you registered for VAT, Yes ☐ No ☐
If yes, please supply your registration Number

Please send a VAT receipt ☐

Signature Date

Prices apply to UK, Isle of Man, and Channel Islands only.
The typical circuit which provides most of the voltage gain and all the voltage drive to the output stage of an audio amplifier seems likely to contribute a significant distortion component. Detailed analysis contradicts this. Good design can reduce its contribution to below the noise floor. By Douglas Self.

3: the voltage-amplifier stage

The voltage-amplifier stage (or VAS) has often been regarded as the most critical part of a power-amplifier, since it not only provides all the voltage gain but also must deliver the full output voltage swing. This is in contrast to the input stage which may give substantial transconductance gain, but the output is in the form of a current. But as is common in audio design, all is not quite as it appears. A well-designed voltage amplifier stage will contribute relatively little to the overall distortion total of an amplifier, and if even the simplest steps are taken to linearise it further, its contribution sinks out of sight.

As a starting point, Fig. 1 shows the distortion plot of a model amplifier with a Class-A output, (+15V rails, +16dBu out.) The model is as described in previous articles. No special precautions have been taken to linearise the input stage or the VAS and output stage distortion is negligible. It can be seen that the distortion is below the noise floor at low frequencies, the distortion slowly rising from about 1kHz is coming from the voltage amplifier stage. At higher frequencies, where the VAS 6dB/octave rise becomes combined with the 12 or 18dB/octave rise of input stage distortion, we can see the accelerating distortion slope typical of many amplifier designs.

The main reason why the voltage amplifier stage generates relatively little distortion is because at LF, global feedback linearises the whole amplifier, while at HF the voltage amplifier stage is linearised by local negative feedback through $C_{dfn}$.

Fig. 1: THD plot for model amp showing distortion below noise floor at low frequency, and increasing from 2kHz to 20kHz. The ultimate roll-off is due to the 80kHz measurement bandwidth.
Examining the mechanism

Isolating the voltage amplifier stage distortion for study requires the input pair to be specially linearised, or else its steeply rising distortion characteristic will swamp the VAS contribution. This is most easily done by degenerating the input stage which also reduces the open-loop gain. The reduced feedback factor mercilessly exposes voltage amplifier stage non-linearity. This is shown in Fig. 2, where the 6dB/octave slope suggests origination in the VAS, and increases with frequency solely because the compensation is rolling-off the global feedback factor.

Confirming that this distortion is due solely to the voltage amplifier stage requires varying VAS linearity experimentally while leaving other circuit parameters unchanged. Fig. 3 shows achieves this by varying the VAS neg-

---

**Fig. 2:** The change in HF distortion resulting from varying the negative rail in the VAS test circuit. The voltage amplifier stage distortion is only revealed by degenerating the input stage with 100Ω resistors.

**Fig. 3:** Voltage amplifier stage distortion test circuit. Although the input pair mirror moves up and down with the VAS emitter, the only significant parameter being varied is the available voltage swing at the collector.

**Fig. 4:** Six variations on a voltage amplifier stage: a. conventional current source VAS b. conventional bootstrapped VAS c. increase in local NFB by adding emitter follower d. increase in local NFB by cascoding e. one method of buffering VAS collector from output stage f. alternative buffering arrangement uses bootstrapping resistor.

---

October 1993 ELECTRONICS WORLD + WIRELESS WORLD
AUDIO

active rail voltage; this varies the proportion of its characteristic over which the voltage amplifier stage swings, and thus only alters the effective VAS linearity, as the important input stage conditions remain unchanged. The current-mirror must go up and down with the VAS emitter for correct operation, and so the $V_{re}$ of the input devices also varies, but this has a significant effect as can be proved by the unchanged behaviour on inserting cascode stages in the input transistor collectors.

The typical topology as shown in Fig. 4a is a classical common emitter voltage amplifier stage with a current-drive input into the base. The small-signal characteristics, which set open-loop gain and so on, can be usefully simulated by the spice model shown of Fig. 5, of a VAS reduced to its conceptual essentials. $G$ is a current source whose value is controlled by the voltage-difference between $R_{in}$ and $R_{2}$, and represents the differential transconductance input stage. $F$ represents the voltage amplifier stage transistor, and is a current source yielding a current of beta times that current in $G$. The value of beta, representing current-gain, models the relationship between VAS collector current and base current.

Stage distortion

total voltage gain clearly depends linearly on beta, which in real transistors may vary widely. Working on the trusty engineering principle that what cannot be controlled must be made irrelevant, local shunt NFB through $C_{dov}$ sets the crucial HF gain that controls Nyquist stability. The LF gain below the dominant pole frequency $P_1$ remains variable (and therefore so does $P_1$) but is ultimately of little importance; if there is an adequate NFB factor for overall linearisation at HF then there are unlikely to be problems at LF where gain is highest. As for the input stage, the linearity of the voltage amplifier stage is not greatly affected by transistor type, given a reasonably high beta value.

Stage distortion voltage amplifier stage distortion arises from a curved transfer characteristic of the common-emitter amplifier, a small portion of an exponential. This characteristic generates predominantly second-harmonic distortion, which, in a closed-loop amplifier, will increase at 6dB/octave with frequency. Distortion does not get worse for more powerful amplifiers as the stage traverses a constant proportion of its characteristic as the supply-rails are increased. This is not true of the input stage: increasing output swing increases the demands on the transconductance amp as the current to drive $C_{dov}$ increases. The increased $V_{re}$ of the input devices does not measurably affect their linearity.

It seems ironic that VAS distortion only becomes clearly visible when the input pair is excessively degenerated - a pious intention to 'linearise before applying feedback' can make the closed loop distortion worse by reducing the open loop gain and hence the NFB factor available to linearise the VAS. In a real (non-model) amplifier with a distortive output stage, the deterioration will be worse.

The local open-loop gain of the VAS (that existing inside the local feedback loop closed by $C_{dov}$) should be high, so that the voltage amplifier stage can be linearised. This precludes a simple resistive load. Increasing the value of $R_{l}$ will decrease the collector current of the transistor reducing its transconductance. This reduces voltage gain to the starting value. One way to ensure sufficient gain is to use an active load. Either bootstrapping or a current source will do this effectively, though the current source is perhaps more dependable and is the usual choice for hi-fi or professional amplifiers.

The bootstrap promises more output swing as the collector of $R_{l}$ can soar above the positive rail. This suits applications such as automotive poweramps that must make the best possible use of a restricted supply voltage.

These two active-load techniques also ensure enough current to drive the upper half of the output stage in a positive direction right up to the supply rail. If the collector load were a simple resistor, this capability would certainly be lacking.

Checking the effectiveness of these measures is straightforward. The collector impedance may be determined by shunting the collector node to ground with decreasing resistance until the open loop gain falls by 6dB indicating that the collector impedance is equal to the current value of the test resistor. The popular current source version is shown in Fig. 4a. This works well, though the collector impedance is limited by the effective

Fig. 5: Conceptual spice model of differential input stage (G) and VAS (F). The current in F is beta times the current in G.

Fig. 6: Showing the reduction of VAS distortion possible by cascoding. The results from adding an emitter follower to the voltage amplifier stage, as an alternative method of increasing local voltage amplifier stage feedback, are very similar.

<table>
<thead>
<tr>
<th>AUDIO PRECISION APLASTIC THD+N(%) vs FREQ(Hz)</th>
<th>29 APR 93 18:37:06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input pair degeneration resistors = 100</td>
<td></td>
</tr>
<tr>
<td>A No cascode</td>
<td></td>
</tr>
<tr>
<td>B Cascode</td>
<td></td>
</tr>
<tr>
<td>C Cascade, Normal HP pair without degeneration</td>
<td></td>
</tr>
</tbody>
</table>

Noise floor

0.005

0.010

0.015

0.020

20

40

60

80

100

120

140

160

180

200

220

240

260

280

300

320

340

360

380

400

420

440

460

480

500

520

540

560

580

600

620

640

660

680

700

720

740

760

780

800

820
output resistance $R_o$ of the voltage amplifier stage and the current source transistors which is another way of saying that the improvement is limited by Early effect.

It is often stated that this topology provides current-drive to the output stage; this is only partly true. It is important to realise that once the local NFB loop has been closed by adding $C_{dom}$, the impedance at the VAS output falls at 6dB/octave for frequencies above $f_1$. The impedance is only a few kΩ at 10kHz, and this hardly qualifies as current-drive at all.

Bootstrapping (Fig. 4b) works in most respects as well as a current source load, for all its old-fashioned flavour. The method has been criticised for prolonging recovery from clipping. I have no evidence to offer on this myself, but I can state that a subtle drawback definitely exists: LF open loop gain is dependent on amplifier output loading. The effectiveness of bootstrapping depends crucially on the output stage gain being unity or very close to it. However the presence of the output transistor emitter resistors means that there will be a load-dependent gain loss in the output stage significantly altering the amount by which the VAS collector impedance is increased. Hence the LF feedback factor is dynamically altered by the impedance characteristics of the loudspeaker load and the spectral distribution of the source material.

This has significance if the load is a quality speaker with impedance modulus down to two ohms, in which case the gain loss is serious. If anyone needs a new audio-impairment mechanism to fret about, then I offer this one in the confident belief that its effects, while measurable, are not of audible significance.

The standing dc current also varies with rail voltage. Since accurate setting and maintaining of quiescent current is difficult enough, an extra source of possible variation is decidedly unwelcome.

A less well known but more dependable form of bootstrapping is available if the amplifier incorporates a unity gain buffer between the VAS collector and the output stage as shown in Fig. 4f, where $R_o$ is the collector load, defining the VAS collector current by establishing the $V_{be}$ of the buffer transistor across itself. This is constant, and $R_o$ is therefore bootstrapped and appears to the VAS collector as a constant current source.

In this sort of topology a voltage amplifier stage current of 3mA is quite sufficient, compared with the 6mA standing current in the buffer stage. The voltage amplifier stage would in fact work well with collector currents down to 1mA, but this tends to compromise linearity at the high-frequency, high-voltage corner of the operating envelope, as the VAS collector current is the only source for driving current into $C_{dom}$.

**Voltage stage enhancements.**

Fig. 2, which shows only VAS distortion, clearly indicates the need for further improvement over that given inherently by the presence of $C_{dom}$ if an amplifier is to avoid distortion. While the virtuous approach might be an attempt to straighten the curved voltage amplifier stage characteristic, in practice the simplest method is to increase the amount of local negative feedback through this capacitance. Equation 1 in the first article shows that the LF gain (ie the gain before $C_{dom}$ is connected) is the product of input stage transconductance, $Tr_4$ beta and the collector impedance $R_o$. The last two factors represent the VAS gain and therefore the amount of local NFB can be augmented by increasing either. Note
that so long as the value of \( C_{\text{dom}} \) remains the same, the global feedback factor at HF is unchanged and so stability is not affected.

The effective beta of the stage can be substantially increased by replacing the VAS transistor with a Darlington, Fig. 4c. Adding an extra stage to a feedback amplifier always requires thought because, if significant additional phase-shift is introduced, the global loop stability may suffer. In this case the new stage is inside the Miller loop and so there is little likelihood of trouble. The function of such an emitter follower is sometimes described as ‘buffering the input stage from the VAS’ but its true function is linearisation by enhancement of local NFB.

Alternatively the stage collector impedance may be increased for higher local gain. This could be done with a cascode configuration (Fig. 4d) but the technique is only useful when driving a linear impedance rather than a Class-B output stage with its non-linear input impedance.

Assuming for the moment that this problem is dealt with, either by use of a Class-A output or by VAS-buffering, the drop in distortion is dramatic as is the beta-enhancement method. The gain increase is ultimately limited by Early effect in the cascode and current source transistors, and more seriously by the loading effect of the next stage. But it is of the order of 10 times and gives a useful improvement.

This is shown by curves A, B in Fig. 6 where the input stage of a model amplifier has been over-degenerated with 100Ω emitter resistors to bring out the voltage amplifier stage distortion more clearly.

Note that the slope of the distortion increase is 6dB/octave. Curve C shows the result when a standard undegenerated input pair is combined with the cascoded VAS; the distortion is submerged in the noise floor for most of the audio band, being well below 0.0008%.

This justifies my assertion that input stage and VAS distortion need not be a problem; we have all but eliminated distortions 1 and 2 from the list of seven given in the first article.

A cascode transistor also allows the use of a high-beta transistor for the voltage amplifier stage; these typically have a limited \( V_{\text{ce(sat)}} \), which cannot withstand the high rail voltages of a high-power amplifier. There is a small loss of available voltage swing, but only about 300mV, which is usually tolerable. Experiment shows that there is nothing to be gained by cascoding the current source collector load.

A cascode topology is often used to improve frequency response by isolating the upper collector from the \( C_{\text{vn}} \) of the lower transistor. In this case the frequency response is deliberately defined by a well defined passive component.

It is hard to say which technique is preferable; the emitter follower circuit is slightly simpler than the cascode version, which requires extra bias components, but the cost difference is minimal. When wresting with these kind of financial decisions it is as well to remember that the cost of a small-signal transistor is often less than a fiftieth of that of an output device, and the entire small-signal section of an amplifier usually represents less than 1% of the total cost, when heavy metal such as the mains transformer and heatsinks are included.

Benefits of voltage drive

The fundamentals of linear voltage amplifier stage operation require that the collector impedance is high, and not subject to external perturbations. Thus a Class-B output stage, with large input impedance variations around the crossover point, is the worst possible load. The ‘standard’ amplifier configuration stands in a cruel way to treat a VAS since current variations cause extra distortion.

The VAS buffer is most useful when LF distortion is already low, as it removes Distortion 4, which is - or should be - only visible when grosser non-linearities have been seen to. Two equally effective ways of buffering are shown in Figs 4e and 4f.

There are other potential benefits to VAS buffering. The effect of beta mismatches in the output stage halves is minimised. Voltage drive also promises the highest, \( f_{t} \) from the output devices, and therefore potentially greater stability, though I have no data of my own to offer on this point. It is right and proper to feel trepidation about inserting another stage in an amplifier with global feedback, but since this is an emitter follower its phaseshift is minimal and it works well in practice.

A VAS buffer put the right way up can implement a form of dc coupled bootstrapping that is electrically very similar to providing the voltage amplifier stage with a separate current-source.

The use of a buffer is essential if a VAS cascade is to do some good. Fig. 7 shows before/after distortion for a full-scale power amplifier with cascode VAS driving 100W into 8Ω.

Balanced voltage amplifier stage

When linearising an amplifier before adding negative feedback one of the few specific recommendations made is usually the use of a balanced voltage amplifier stage - sometimes combined with a double input stage consisting of two differential amplifiers, one complementary to the other. The latter seems to have little to recommend it, as you cannot balance a stage that is already balanced, but a balanced (and, by implication, more linear) voltage amplifier stage has its attractions. However, as explained above, the distortion contribution from a properly-designed VAS is negligible under most circumstances, and therefore there seems to be little to be gained.

Two possible versions are shown in Fig. 8:

(a) simply loading down the collector. This is a cruel way to treat a VAS since current variations cause extra distortion.

(b) local NFB with a resistor in parallel with \( C_{\text{dom}} \). This looks crude, but actually works very well.

open-loop gain more open loop gain than the standard, but this naturally requires an increase in \( C_{\text{dom}} \) if the same stability margins are to be maintained. In a model amplifier, any improvement in linearity can be wholly explained by this \( O/I \) gain increase, so this seems (not unexpectedly) an unpromising approach. Also, as John Lindsay Hood has pointed out, the standing current through the bias generator is ill-defined compared with the usual current source VAS. Similarly the balance of the input pair is likely to be poor compared with the current-mirror version. Two signal paths from the input stage to the VAS output must have the same bandwidth; if they do not then a pole-zero doublet is generated in the open-loop gain characteristic that will markedly increase settling-time.
Finally an upgradeable PCB CAD system to suit any budget ...

BoardCapture - Schematic Capture
- Direct netlist link to BoardMaker2
- Forward annotation with part values
- Full underlay 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
- Block annotation from BoardMaker2

PHASE LOCKED SIGNAL SOURCES
TYPE 8034 Frequency as specified in the range 20-250MHz. Output 10mW. £194

TYPE 9036 Frequency as specified in the range 250-1000MHz. Output 10mW. £291

TYPE 9038 Frequency as specified in the range 1-2GHz. Output 10mW. £350

TYPE 9282 FM facility. Frequency as specified in the range 1-2GHz. Output 10mW. £350

LOW NOISE GASFET PREAMPLIFIERS
Two-stage Gasfet preamplifiers. High Q filters. Masthead or local use.

TYPE 9006 Frequency 5-250MHz. B/W up to 40% of CF. NF 0.6dB. Gain 10-40dB variable. £105

PHASE LOCKED LOOP FREQUENCY CONVERTERS
TYPE 9315 Down converter. Input frequencies 20MHz to 1GHz. B/W up to 100MHz. NF 0.7dB. Gain 40dB variable. £650

TYPE 9115 Up/Down converter. Input & output frequencies 20MHz to 1GHz. B/W up to 100MHz. NF 0.7dB. Gain 40dB variable. £650

WIDEBAND LINEAR POWER AMPLIFIERS
TYPE 8246 1 watt output. 100kHz-150MHz. 13dB gain. £192

TYPE 8247 4 watts output. 150MHz. 13dB gain. £215

TYPE 9614 10 watts output. 20-200MHz. 13dB gain. £215

TELEVISION TRANSMISSION EQUIPMENT
TYPE 9036 1 watt output. 10MHz-1GHz. Gain 20dB. £350

TELEVISION TRANSMITTERS AND TRANSPOSERS
TYPE 9253 5 watts output. 820-900MHz. £353

BoardMaker1 - Entry level
- PCB and schematic drafting
- Easy and intuitive to use
- Surface mount support
- 60, 45 and curved track corners
- Ground plane fill
- Copper highlight and clearance checking

BoardMaker2 - Advanced level
- All the features of BoardMaker1 plus
  - 100% netlist support - OrCad, Schematics, Tangos, CadStar
  - Full Design Rule Checking - mechanical & electrical
  - Top down modification from the schematic
  - Component remeasurement with back annotation
  - Report generator - Database ASCII, BOM

BoardRouter - Gridless autoplanner
- Simultaneous muli-layer routing
- BMD and analogue support
- Full interrupt, resume, pan and zoom while routing

NEW
- Thermal power plane support with full DRC

Call for info or full evaluation kit
Tsien (UK) Limited
Tel: (0354) 695959
Fax: (0354) 695957

CIRCLE NO. 100 ON REPLY CARD

Phases exclude p&p charges and VAT

RESEARCH COMMUNICATIONS LTD
Unit 1, Aerodrome Industrial Complex, Aerodrome Road, Hawkinge, Folkestone, Kent CT18 7AG
Tel: 0303 893631 Fax: 0303 893838

CIRCLE NO. 101 ON REPLY CARD
after a transient. This seems likely to apply to all balanced voltage amplifier stage configurations. The second type is attributed by Borbely to Lender. Fig. 8 shows one version, with quasi-balancing due to the VAS transistor, via both base and emitter. This configuration does not give good balance of the input pair since it depends on the tolerances of $R_2, R_f$, the $V_n$ of the voltage amplifier stage, and so on. Borbely has advocated using two complementary versions of this giving a third type, but this would not seem to overcome the objections and the increase in complexity is significant.

All balanced voltage amplifier stages seem to be open to the objection that the vital balance of the input pair is not guaranteed, and that the current through the bias generator is not well-defined. However one advantage would seem to be the potential for sourcing and sinking large currents into $C_{vin}$ which might improve the ultimate slew-rate and HF linearity of a very fast amplifier.

Open loop bandwidth.

Acute marketing men will appreciate that reducing the LF open loop gain, leaving HF gain unchanged, must move the PI frequency upwards, as shown in Fig. 9. Open loop gain held constant up to 2kHz appears so much better than open loop bandwidth restricted to 20Hz. These two statements could describe near identical amplifiers, except that the first has plenty of open loop gain at LF while the second has even more. Both amplifiers have the same feedback factor at HF, where the amount available has a direct effect on distortion performance, and could easily have the same slew rate. Nonetheless the second amplifier somehow reads as sluggish and indolent, even when the truth of the matter is known.

Reducing low frequency open loop gain may be of interest to commercial practitioners but it also has its place in the dogma of the subjectivist. Consider it this way: firstly there is no engineering justification for it and, secondly, reducing the NFB factor will reveal more of the output stage distortion. NFB is the only weapon available to deal with this second item so blunting its edge seems ill-advised. It is of course simple to reduce open loop gain by degenerating the input pair, but this diminishes it at HF as well as LF. To alter it at LF only requires engineering changes at the VAS. Fig. 10 shows two ways. 10a reduces gain by reducing the value of the collector impedance, having previously raised it with the use of a current source collector load. This is no way to treat a gain stage: loading resistors low enough to have a significant effect cause unwanted current variations in the VAS as well as shunting its high collector impedance, and serious LF distortion appears. While this sort of practice has been advocated in E&W in the past, it seems to have nothing to recommend it. 10b also reduces overall open loop gain by adding a frequency insensitive component to the local shunt feedback around the voltage amplifier stage. The value of $R_{NFB}$ is too high to load the collector significantly and therefore the full gain is available for local feedback at LF, even before $C_{vin}$ comes into action. Fig. 11 shows the effect on the open loop gain of a model amplifier for several values of $R_{NFB}$; this plot is in the format described in the first part of this series where error voltage is plotted rather than gain so the curve appears upside down compared with the usual presentation. Note that the dominant pole frequency is increased from 800Hz to above 20kHz by using a 220kΩ value for $R_{NFB}$; however the gain at higher frequencies is unaffected and so is the stability. Although the amount of feedback available at 1kHz has been decreased by nearly 20dB, the distortion at +16dBu output is only increased from below 0.001% to 0.0013%. Most of the reading is due to noise. In contrast, reducing the open loop gain by just 10dB through loading the VAS collector to ground requires a load of 4.7kΩ which, under the same conditions, yields distortion of more than 0.01%.

It might seem that the stage which provides all the voltage gain and swing in an amplifier is a prime suspect for generating the major part of its non linearity. In actual fact, this is unlikely to be true, particularly with a cascode VAS/current source collector load buffered from the output stage. Number 2 in the distortion list can usually be forgotten.

Next month: the power output stages.

References
M & B RADIO (LEEDS)

THE NORTH'S LEADING USED TEST/EQUIPMENT DEALER

OSCILOSCOPES

TEKTRONIX 3/A 50MHZ GPIB

TEKTRONIX 2/A 50/125MHZ

TEKTRONIX 475 200/2000MHZ DUAL-CHANNEL DIGITAL STORAGE

TEKTRONIX 434 400/4000MHZ DIGITAL STORAGE

TEKTRONIX 236/0 400/4000MHZ PORTABLE

TEKTRONIX 235/0/5 200/2000MHZ PORTABLE

TEKTRONIX 231/0 100/1000MHZ PORTABLE

TEKTRONIX SC504/TM503/DM501 PORTABLE 80MHZ

TEKTRONIX 475 200MHZ DUAL-TRACE WITH PROBES

TEKTRONIX 244SA 150MHZ

and many more

8051...

68000...

68HC11

68000...

68HC11

and many more

COMPILERS CROSS-ASSEMBLES SIMULATORS

Call for data sheets

Tel: 081-441 3890
Fax: 081-441 1843

Z8 Z80 Super 8
8051, H8, Z-80
68HC11, 68800

from only £49

and many more

COMPILERS CROSS-ASSEMBLES SIMULATORS

Call for data sheets

Tel: 081-441 3890
Fax: 081-441 1843

CIRCLE NO. 102 ON REPLY CARD

October 1993 ELECTRONICS WORLD+WIRELESS WORLD

£25

CIRCLE NO. 104 ON REPLY CARD
2: detailed circuitry

Spread spectrum radio is now used extensively for both military and civilian communications. James Vincent describes the circuitry for a fully functional experimental voice link.

\[\text{Pseudo-random codes can be categorised as being linear or non-linear codes.} \]

Linear codes are generated using linear operations (which for binary pseudo-random codes is solely modulo-2 addition or subtraction). This essentially means only ex-OR gates are used in the shift register feedback path. A pseudo-random generator which does not use such techniques is termed non-linear.

The most commonly used group of pseudo-random sequences used in spread spectrum are the maximal linear code sequences (sometimes called M-sequences or pn - pseudo-noise - codes). Maximal codes are the longest codes that a shift register of specified length can produce and have mathematical properties well suited to spread spectrum communications.

A maximal shift register pseudo-random generator consists of a shift register with selected outputs being exclusive-ORed and fed back into the shift register input. The circuit goes through a number of states (determined by the bits in the shift register at each clock pulse) before it repeats itself after a set number of clock pulses. The maximum number of states for a shift register of length \(m\) is \(2^m\), ie for a 7-stage shift register \(2^7 = 128\) states. However the all-zero state is not allowable as the pseudo-random generator would lock-up as ex-ORing two logic 0 results in yet another logic 0 at the input. Therefore a maximal length pseudo-random code generator can produce a pseudo-random sequence \(2^m-1\) bits long before repeating itself.

To obtain a maximal sequence, the correct shift register outputs (tap points) must be found. These could be found by experimentation but this would be very time consuming! However tables of feedback connections are available.

A 7-stage (ie seven flip-flop) shift register can produce a maximal code of length \(2^7-1 = 127\) bits (known as chips in spread spectrum terminology) long. The feedback tap points may be taken from the following stages:

\[[7,1][7,3][7,3,2,1][7,4,3,2][7,6,4,2][7,6,3,1][7,6,5,2][7,6,5,4,2,1] \text{and} [7,5,4,3,2,1]\]
RF ENGINEERING

127 chip maximal length pseudorandom code generator

As the simplest circuit implementation is often desired, the first option of tapping the
seventh and first stages is selected
To avoid the all-zero lock up problem, inverting stages are inserted before the shift
register input and at the output of the shift reg-
ister. When the shift register is switched on, a
reset pulse is initiated. This pulse initiates all
shift register outputs to logic 0. This would
normally lock up the pseudo-random sequence
generator. However the input inverter injects a
logic 1 so that the maximal sequence can com-
mence. The output inverter ensures that max-
imal code output is inverted negating the
effect of the anti-lock-up inverter at the input.
The maximal code is also available at the out-
put (A) of the modulo-2 adder, but the second
inverter output is normally used to permit
direct drive of the DBM in a direct sequence
system

Receiver functional description

The 435MHz direct sequence (ds) signal is
first amplified by a low noise amplifier followed
by a helical filter and further amplification
by a low noise amplifier block (MAN-LN) and a MAR8. The da signal is mixed with
a 7dBm 365MHz local oscillator in a down-
converter. The ds signal now centred on an
intermediate frequency of 70MHz is amplified
(MAR8) and bandpass filtered (P1F-70),
before being resistively split into three identi-
cal signal paths. In each signal path (late, on
time or early) the 70MHz signal is amplified
by a further MAR6 amplifier. A DBM config-
ured as a biphase shift keyer is driven by an
early, on time or late pn code. The DBM is

Direct sequence digital voice transmitter-exciter. The 435MHz 7dBm carrier feeding the balanced diode ring
modulator comes from an external oscillator (not shown).

Power amplifier and driver circuit for direct sequence transmitter.
The delay locked loop

After initial acquisition, the spread spectrum receiver must maintain synchronisation by tracking changes in the transmitter's pn code clock. The circuitry required is known as a tracking loop as it tracks the transmitter's code clock frequency variations. Without a tracking loop synchronisation will be lost as the transmitter and receiver pn code clocks drift apart.

In a delay locked loop two identical pseudo-random or pn despreading codes are delayed with respect to each other. Each pn code is used in separate correlators (early and late) to despread (correlate) the received direct sequence signal. The result of correlation between an incoming direct sequence signal and the receiver pn code is a triangular function two chips (code bits) wide. Assuming synchronisation two correlated signals (each with a triangular correlation waveform) are produced with their correlation peaks separated by the delay between the early and late receiver pn codes. If the two correlation signals are summed in a difference amplifier and filtered, then a composite correlation function is produced. This composite correlation function has a linear region between its maximum and minimum values. If this composite correlation function is used to control the receiver's code clock frequency (for example by driving a voltage controlled oscillator) then the receiver will track the transmitter's code clock at a point halfway between the maximum and minimum values of the composite correlation function.

An optimum solution is to have a third on-time (punctual) pn sequence correlator channel for signal recovery, with early and late correlators simply providing tracking to keep the on-time channel in the middle of the correlation window. Such an approach provides an optimally correlated (despread) output signal for subsequent data demodulation.

The composite correlation function and correlator waveforms in the 1/2 chip delay locked loop.

The 1/2 chip delay locked loop system. An analogue difference signal derived from the relative correlation levels of advanced and retarded PN code controls a high stability VXCO such that code synchronisation is maintained.

Block diagram – double conversion receiver for digital voice direct sequence spread spectrum reception.
buffered by 50Ω pads and driven by an AC logic buffer as with the DBM used as a BPSK modulator in the transmitter.

Assuming synchronism the despread output is injected into a NE605 low power FM IF integrated circuit. The second local oscillator at 64MHz in conjunction with the on-chip mixer downconverts the despread signal (which contains the data in a BPSK format) to 6MHz. The NE605 further amplifies the 6MHz signal and provides filtering using 6MHz ceramic filters originally designed for television sound strips.

A RSSI (received signal strength indicator) is available from each NE605 with a 90dB range logarithmic output. The RSSI outputs from the early and late channels go to the delay locked loop circuit. The despread data output from the on time (punctual) channel is further amplified by a MAR8 amplifier before being frequency doubled in a Mini Circuits RK3 doubler. As previously discussed the despread data signal has a biphase shift keyed (BPSK) format. The BPSK frequency spectra is similar to that of a double sideband suppressed carrier and as for DSBSC, carrier recovery is required to demodulate the signal. It can be shown mathematically\(^3\) that by squaring or doubling a BPSK signal a twice frequency carrier is obtained. After passing the doubled signal through a 12MHz crystal used as an exceptionally narrow bandpass filter, the signal is applied to a synchronous oscillator. This versatile circuit (see section The Synchronous Oscillator) free runs at 6MHz and on application of the 12MHz signal synchronously locks to half of the input frequency, effectively regenerating the 6MHz carrier reference. This locked 6MHz output is buffered and amplified to produce a logic level 0, +5V output, which together with the signal output from the on-time (punctual) NE605 IC is injected into a DBM configured as a phase detector. The voltage output of the phase detector is amplified, level shifted and
70MHz IF despreading circuit. The output from the upper and lower blocks provides data for the synchronisation function. The output from the middle block is eventually decoded to audio.
using a voltage comparator converted into standard logic levels.

The output from this squaring loop BPSK demodulator does not recover the original data polarity as the original phase of the signal is lost in the doubling process. This is why the data was diphase encoded at the transmitter so that the correct data polarity could be recovered at the receiver.

An edge detector configured from an exclusive-OR gates produces a negative pulse for both positive and negative edges of the comparator's diphase data stream output. The edge detector output triggers monostable A, one half of a dual monostable. (Note: all monostables are non-retriggerable). Monostable A is set to produce a positive output pulse with a duration of 75% of the diphase bit cell period. The Q output of monostable A triggers monostable B which produces a positive output pulse of duration 25% of the diphase bit cell period.

In turn the negative going edge of monostable B output triggers monostable C which produces a positive output pulse of duration 50% of the diphase bit cell period. D-type flip-flop D1 is clocked by the /Q output of monostable C and flip-flop D2 by the Q output.

The positive edges of the Q and /Q outputs of monostable C occur before and after any mid-bit transition. Thus when D1 and D2 are clocked, their outputs will be different if the diphase encoded bit represents a one, or the same if the diphase encoded bit represent a
The synchronous oscillator

The synchronous oscillator is an elegant but little known circuit which can be used to advantage where a phase-locked loop (PLL) would normally be employed. The SO is a free-running oscillator which oscillates at a frequency determined by its LC tank with no signal applied to its input.

When a signal is applied within the SO's acquisition bandwidth the oscillator synchronises and tracks the input signal. The SO output amplitude is constant when locked to and tracking an input signal. A decrease in the input carrier-to-noise ratio reduces the SO's tracking bandwidth to maintain a constant signal-to-noise ratio at the SO's output. This characteristic allows a SO to acquire and track very noisy signals.

The SO can also act as a frequency multiplier or divider. In the direct sequence receiver, the SO locks to a noisy 12MHz signal and provides a stable 6MHz output. This function could be achieved using a PLL but the SO has many advantages5,6 and, as it is based on only two transistors, is much simpler to implement.

A simplified explanation of operation is that the upper transistor acts as a Class C oscillator. The upper transistor only conducts for a very brief period of time; when the upper transistor conducts, there is a voltage across the lower transistor biasing it allowing it to conduct. At this time the input signal can then be injected to synchronise the oscillator. During the rest of the oscillator cycle input noise is unable to enter the oscillator as the lower transistor is reverse biased. This arrangement produces coherent amplification which is why the SO can extract signals from very low signal-to-noise inputs.

Zero. If $D_1$ and $D_2$ outputs are exclusive OR-ed then the instantaneous NRZ data is obtained. The clock is recovered at the Q output only. A decrease in the input carrier-to-noise ratio reduces the SO's tracking bandwidth to maintain a constant signal-to-noise ratio at the SO's output. This characteristic allows the SO to acquire and track very noisy signals.

The SO can also act as a frequency multiplier or divider. In the direct sequence receiver, the SO locks to a noisy 12MHz signal and provides a stable 6MHz output. This function could be achieved using a PLL but the SO has many advantages5,6 and, as it is based on only two transistors, is much simpler to implement.

A simplified explanation of operation is that the upper transistor acts as a Class C oscillator. The upper transistor only conducts for a very brief period of time; when the upper transistor conducts, there is a voltage across the lower transistor biasing it allowing it to conduct. At this time the input signal can then be injected to synchronise the oscillator. During the rest of the oscillator cycle input noise is unable to enter the oscillator as the lower transistor is reverse biased. This arrangement produces coherent amplification which is why the SO can extract signals from very low signal-to-noise inputs.

The delay lock loop and code generation circuitry permits code correlation, synchronisation and tracking. The difference amplifier has its inverting and non-inverting inputs respectively connected to the early and late channel RSSI outputs. The difference amplifier is followed by a summing amplifier used to adjust the quiescent frequency of the voltage controlled crystal oscillator and a low pass filter. The output of the inverter drives the control input of the voltage controlled oscillator. The VCXO consists of a high stability AT cut crystal in a discrete transistor based oscillator with varicap frequency control. The oscillator's low voltage output is amplified by approximately 10,000 with a linear biased HC logic gate. This hard limits the buffer's output to standard logic levels. The VCXO provides a highly stable, repeatable output which has a 2kHz tuning range centred on 8MHz for a tuning voltage of 0 to 6V.

The VCXO output is divided by two to produce a 4MHz clock. This clock signal drives the 127 chip maximal pn generator. The output of this pn generator is re-clocked through a shift register by the original 8MHz clock. By extracting the three outputs from neighbouring outputs three identical pn codes are available (early, on-time and late) but with a half clock cycle difference between them. Thus the early code is one clock cycle (or "chip" in spread spectrum terminology) ahead of the late code. Each pn code generator output drives the relevant correlator (de-spreader). See section Delay Locked Loop.

In operation the VCXO is offset to a slight-higher frequency than the crystal clock in the transmitter, effectively producing a sliding correlator. Assuming that the receiver is in range and unsynchronised, the receiver code will slide past the transmitter code. At one point in time the two codes will match. This will result in correlation and the direct sequence signal will be despread. The early channel will be despread before the late channel and the early RSSI value will be considerably higher than the late uncorrelated channel. This difference signal after filtering steers the VCXO output towards the frequency of the transmitter clock. When the receiver and transmitter clocks and pn codes are synchronised the RSSI outputs from the early and late channels will be identical and the difference amplifier output will be zero. Should the receiver clock be retarded greater energy will be in the late channel than the early channel, and the VCXO will be driven by the difference amplifier to increase its frequency. If the receiver clock is advanced greater energy will be in the early channel than the late channel and the VCXO will be driven by the difference amplifier to decrease its frequency. Thus the delay locked loop will maintain synchronism once the sliding correlator has caused the receiver to lock. The frequency offset is selected such that it will cause rapid synchronisation but remain within the capture range of the loop.

Construction and Testing

The direct sequence transmitter and receiver were constructed on a combination of Veroboard and double-sided printed circuit boards. The radio-frequency circuits were built on the double-sided pcb's, with the usual RF design techniques employed. The photographs of the completed transmitter- exciter and receiver shows the combination of construction techniques used.(See August EW+WW).

The system is designed around easily obtainable components and all inductors and filters are selected from either the Toko or Mini-Circuits range to avoid the difficulties of winding coils.

The set-up of the receiver requires a functioning exciter as a source of a direct sequence signal, hence the exciter is adjusted first. This involves setting the master 4MHz crystal oscillator with the aid of a frequency counter. Now the receiver can be directly connected (with a suitable attenuator in-line to prevent overload) to the exciter output. Initially the 6MHz second local oscillator should be adjusted on frequency. The VCXO's frequency is set using the centre frequency adjust potentiometer, to be slightly higher or lower than twice the measured frequency of the transmitter's master clock.

The resonant circuit of the synchronous oscillator (SO) has to be adjusted until it free-runs at 6MHz. It is important to ensure that the SO oscillates at 6MHz (ie not a harmonic) and the input level potentiometer is set to the minimum input level which permits reliable operation.

The gain and comparator reference point potentiometers should be adjusted such that the phase detector recovers the diphase data stream with HC logic compatible levels.

The VCXO frequency is slowly adjusted until the sliding correlator and delay locked loop lock to and track the transmitter. If a spectrum analyser is available, a narrowband despread BPSK data signal will be detected at the input to the PIF-70 filter. A dual channel oscilloscope can be used to monitor and compare the transmitter and receiver (punctual) pn codes. If the receiver has synchronised then the two pn codes will line up and the receiver code will be seen to track the transmitter's code. If all is correctly adjusted then the synchronous oscillator will regenerate the 6MHz carrier with the data recovery circuit and delta-modulator i.c. recovering the audio. Various waveforms are shown on the circuit diagram to aid trouble shooting.

After this initial procedure the power and...
pre-amplifiers can be added for free-space checks (provided radio regulations permit). Some minor adjustments particularly of the VCXO frequency may be required to ensure reliable acquisition and locking. If the VCXO frequency offset is too great then the receiver will initially acquire the signal, but will be unable to track it. A degree of trial and error may be necessary at a receiver clock offset which provides rapid synchronisation and reliable tracking performance. The prototype took less than two seconds from power-up to synchronise and would remain in lock provided the signal was not lost.

The Radiocommunications Agency (the UK radio regulatory authority) granted special authority to the author to experiment with spread spectrum techniques on the 70cm band under his amateur radio service licence. At present the UK amateur radio licence does not permit the use of spread spectrum modulation. It is hoped that in the future the standard UK licence will permit spread spectrum modes of operation as is allowed in the USA by the Federal Communications Commission.

The design and circuitry presented in this article is held in copyright by James A Vincent, 1993.

References

Bibliography

TUF1, RK3 and MAR series devices are manufactured by Mini-Circuits (from Cirkit in the UK and Dole Electronics, Camberley) FX609J from Consumer Microcircuits, Witham, Essex. Crystals are available from OIQ Ltd, Crowleke, Somerset. RFFM2 DBM comes from Walmore Electronics, London.
USING RF TRANSISTORS

1: Making rf data sheets make sense

How does a figure in a data sheet relate to performance in a real circuit? In an extract from their book Radio frequency transistors: principles and practical applications, Norm Dye and Helge Granberg explain how to interpret manufacturers' data sheets.

Data sheets are often the sole guide to a product’s capability and characteristics. Circuit designers, unable to talk directly with the factory, must rely on the data sheet for device information. So it is vital that user and manufacturer of rf products speak a common language. The problem is that what the semiconductor manufacturer is saying about an rf device is not always fully appreciated by the circuit designer.

DC specifications

Rf transistors are characterised by two types of parameters: dc and functional.

By definition, “dc” specs consist, of breakdown voltages, leakage currents, $h_{FE}$ (dc beta), and capacitances. Functional specs cover gain, ruggedness, noise figure, $Z_{in}$ and $Z_{out}$, $S$-parameters, distortion, etc.

Thermal characteristics do not fall cleanly into either category since thermal resistance and power dissipation can be either dc or ac. So thermal resistance is best treated as a special specification.

Table 1 is from a typical rf power data sheet showing dc and functional specs. A critical part of selecting a transistor is choosing one that has breakdown voltages compatible with the supply voltage of an intended application. The design engineer must select a transistor that, on the one hand, has breakdown voltages which will not be exceeded by the dc and rf voltages appearing across the various junctions of the transistor; and on the other, has breakdown voltages permitting the “gain at frequency” objectives to be met by the transistor.

Mobile radios normally operate from a 12V source and portable radios use a lower voltage, typically 6 to 9V. Avionics applications are commonly 28V, while base station and other ground applications such as medical electronics generally take advantage of the superior performance characteristics of high voltage devices, operating with 24-50V supplies.

In making a transistor, breakdown voltages are largely determined by material resistivity and junction depths (Fig. 1), so breakdown voltages are intimately entwined with functional performance characteristics. Most product portfolios in the rf power transistor industry have families of transistors designed for use at specified supply voltages such as 7.5V, 12.5 volts, 28, and 50V.

Leakage currents (defined as reverse biased junction currents occurring prior to avalanche breakdown) are likely to be more varied in their specification – and also more informative.

Many transistors do not have leakage currents specified because they can result in excessive, and frequently unnecessary, wafer/die yield losses. Leakage currents arise as a result of material defects, mask imperfections, and/or undesired impurities entering wafer processing. Some sources of leakage currents are potential reliability problems: most are not. Leakage currents can be material-related such as stacking faults and dislocations, or can be “pipes” created by mask defects and/or processing inadequacies. These sources result in leakage currents that are constant with time. If initially acceptable for a particular application, they will remain so, and do not pose long term reliability problems.

But channels induced by mobile ionic contaminants in the oxide (primarily sodium) cause leakage currents that tend to change with time and can lead to increases that render the device useless for a specific application. Distinguishing sources of leakage current can be difficult, which is one reason devices for application in military environments require HTRB (high temperature reverse bias) and burn-in testing. But even for commercial applications – particularly where battery drain is critical or where bias considerations dictate limitations – a leakage current limit should be included in any complete device specification.

Dc parameters such as $h_{FE}$ and $C_{Osb}$ (output capacitance) need little comment. Typically, for rf devices, $h_{FE}$ is relatively unimportant for unbiased power transistors because the functional parameter of gain at the desired fre-
quency of operation is specified. Note, though, that dc beta is related to ac beta (Fig. 2). Functional gain will track dc beta particularly at lower rf frequencies. An hFE specification is needed for transistors requiring bias, which includes most small signal devices normally operated in a linear (class A) mode. Generally rf device manufacturers do not like to have tight limits placed on hFE, primarily because:

- There is a lack of correlation with rf performance;
- Difficulty in controlling wafer processing;
- Other device manufacturing constraints dictated by functional performance specs which preclude tight limits for hFE.

A good rule of thumb for hFE is to set a maximum-to-minimum ratio of no less than 3 and not more than 4, with minimum hFE value determined by an acceptable margin in functional gain. Output capacitance is an excellent measure of comparison of device size (base area) provided most of the output capacitance is created by the base-collector junction and not parasitic capacitance arising from bond pads and other top metal of the die. Remember that junction capacitance will vary with voltage (Fig. 3) while parasitic capacitance will not. Also, in comparing devices, the voltage at which a given capacitance is specified should be noted, as no industry standard exists. The preferred voltage at Motorola is the transistor Va. rating, ie 12.5V for 12.5V transistors and 28V for 28 volt transistors.

Ratings and thermal characteristics

Maximum ratings (Table 2) tend to be the most frequently misunderstood group of device specifications. Ratings for maximum junction voltages are straightforward, and simply reflect the minimum values set forth in the dc specs for breakdown voltages. If a device meets the specified minimum breakdown voltages, then voltages less than this will not cause junctions to reach reverse bias breakdown and the potentially destructive current levels.

The value of BVCEO is sometimes misinterpreted. Its value can approach or even equal the supply voltage rating of the transistor, and the question naturally arises as to how such a low voltage can be used in practical applications. First, BVCEO is the breakdown voltage of the collector-base junction, plus the forward drop across the base-emitter junction with the base open. It is never encountered in amplifiers where the base is at or near the potential of the emitter. That is, most amplifiers have the base shorted or use a low value of resistance such that the breakdown voltage of interest approaches BVCE.

Second, BVCEO involves the current gain of the transistor and increases as frequency increases. So the value of BVCEO at rf frequencies is always greater than the value at dc.

Maximum rating for power dissipation (Pd) is closely associated with thermal resistance (θjc). In reality, maximum Pd is a fictitious number because it assumes that case temperature is maintained at 25°C. But, providing everyone arrives at the value in a similar manner, the rating of maximum Pd is also a useful comparative.

Even so, several reasons dictate a conservative value be placed on θjc. Thermal resistance increases with temperature, and die temperature Tj is not a worst case number. Also, by using a conservative value of θjc, a realistic value is determined for maximum Pd. Generally, Motorola's practice is to publish θjc numbers approximately 25% higher than that determined.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BVCEO</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>Vdc</td>
</tr>
<tr>
<td>BVCE</td>
<td>36</td>
<td>-</td>
<td>-</td>
<td>Vdc</td>
</tr>
<tr>
<td>ICES</td>
<td>4.0</td>
<td>-</td>
<td>10</td>
<td>mA/°C</td>
</tr>
<tr>
<td>hFE</td>
<td>20</td>
<td>70</td>
<td>150</td>
<td>-</td>
</tr>
</tbody>
</table>

Functional tests:

Common-emitter amplifier power gain

\[
\frac{V_{OC}}{I_{CS}} = 12.5 \text{V dc, } P_{out} = 45\text{W, } I_C = 20\text{mA dc. } V_{BB} = 0\text{V.} \]

Collector efficiency

\[
\eta = \frac{P_{out}}{P_{in}} \text{ where } P_{in} = 13 \text{Watts} \]

Load mismatch stress

\[
\text{No degradation in output power} \]

Series equivalent output impedance

\[
Z_{out} = 1.4 + 4.0 \text{ ohms} \]

Table 1. Typical dc and functional specifications from an rf power data sheet.

Notes:

1. Pin = 150% of drive requirement for 45W output. @ 12.5V.

\[
\text{Mismatch stress factor} = \frac{V_{out}}{V_{in}} \text{ the electrical criterion established to verify the device resistance to load mismatch failure. The mismatch stress test is accomplished in the standard test fixture terminated in a 20:1 minimum load mismatch at all phase angles.} \]

![Curvature and resistivity determine breakdown voltage.](image)

October 1993 ELECTRONICS WORLD + WIRELESS WORLD
Handling ability of the wires or the die. But considerations in an rf transistor concern the current ratios. The only valid maximum current limitation of the part. Many lower frequency parts have relatively gross top metal on the transistor die — ie wide metal runners — and the “weak current link” in the part is the current handling capability of the emitter wires (for common-emitter parts). Current handling ability of wire is well known, so maximum current rating may be limited by the number, size and material used for emitter wires.

Maximum collector current \(I_c\) is probably die-limited because of high current densities resulting from very small current carrying conductors. These densities can lead to metal migration and premature failure. It is up to the transistor manufacturer to specify an \(I_{\text{max}}\) based on whichever of the two limitations, die or wire, is paramount. Circuit design engineers should consult semiconductor manufacturers for additional information if \(I_{\text{max}}\) is of any concern.

Storage temperature is another maximum rating that is frequently not given the attention it deserves. A range of \(-55^\circ\text{C}\) to \(200^\circ\text{C}\) has become more or less standard. For the single-metal, hermetic-packaged type of device, 200°C creates no reliability problems. But a lower high-temperature limitation exists for plastic encapsulated or epoxy-sealed devices which should not be subjected to >150°C to prevent deterioration of the plastic material.

### Power transistor characteristics

Selection of a power transistor usually depends on frequency of operation, output power, desired gain, voltage of operation and preferred package configuration consistent with circuit construction techniques. By necessity, functional characteristics of an rf power transistor are tied to a specific test circuit. Without specifying a circuit, the functional parameters of gain, reflected power, efficiency and even ruggedness, hold little meaning. Furthermore, most test circuits used by rf transistor manufacturers (even those used to characterise devices) are designed mechanically to allow for easy insertion and removal of the device under test (DUT). This mechanical restriction sometimes limits achievable device performance, explaining why performance by users frequently exceeds that indicated in data sheet curves.

Conversely, a circuit used to characterise a device is usually narrow band and tunable, resulting in higher gain than attainable in a broadband circuit. Unless otherwise stated, characterisation data such as \(P_{\text{out}}\) vs frequency can be assumed to be generated on a point-by-point basis by tuning a narrow band circuit across a band of frequencies. As such it represents what can be achieved at a specific frequency of interest provided the circuit presents...

---

**Fig. 2.** Dc beta is related to ac beta.

**Fig. 3.** Junction capacitance varies with voltage.

---

Table 2. Maximum power ratings of a typical rf power transistor, the Motorola MRF650.
Ruggedness
RF power transistors give considerable weight to ruggedness. Ruggedness is the characteristic of a transistor to withstand extreme mismatch conditions in operation — causing large amounts of output power to be "dumped back" into the transistor — without altering performance capability or reliability.

Many circuit environments, particularly portable and mobile radios, have limited control over the impedance presented to the power amplifier by an antenna (at least for some duration of time). In portables, the antenna may be placed against a metal surface; in mobiles, perhaps the antenna is broken off or inadvertently disconnected from the radio. RF power transistors must be able to survive such load mismatches without effect on subsequent operation. One realistic possibility for mobile radio transistors, though not a normal situation, is where an RF power device "sees" a worst case load mismatch (an open circuit, any phase angle) along with maximum \( V_{ce} \) and greater than normal input drive — all at the same time.

So the ultimate test for ruggedness is to subject a transistor to a \( P_{out} \) (rf) 50% above that necessary to create rated \( P_{out} \); increase \( V_{ce} \) by about 25% (12.5V to 16V for mobile transistors); and then set the load reflection coefficient at a unity while its phase angle is varied through all possible values from 0-360°.

Ruggedness specifications come in many forms. Older devices (and even some newer ones) simply have no ruggedness specifica-
RF ENGINEERING

detectable, with 5% or less normally considered an acceptable limit.

More advanced device specifications for rf power transistors use this criteria to determine success or failure in ruggedness testing.

Matching circuit
A circuit designer must know the input/output characteristics of the rf power transistor(s) selected, to design a circuit that matches the transistor over the frequency band of operation. Data sheets provide this information in the form of large signal impedance parameters, \( Z_{in} \) and \( Z_{out} \) (commonly referred to as \( Z_{oL} \)). Normally, these are stated as a function of frequency and are plotted on a Smith chart and/or given in tabular form.

\( Z_{in} \) and \( Z_{out} \) apply only for a specified set of operating conditions, – power output, voltage and frequency – and are determined in a similar way: place the DUT in a tunable circuit and tune both input and output circuit elements to achieve maximum gain for the desired set of operating conditions. At maximum gain, DUT impedances will be the conjugate of the input and output network impedances. So terminate the input and output ports of the test circuit, remove the device and measure \( Z \) looking from the device – first, toward the input to obtain the conjugate of \( Z_{in} \) and, second, toward the output to obtain \( Z_{oL} \).

the output load required to achieve maximum \( P_o \).

A network analyser is used to determine the complex reflection coefficient of the circuit using, typically, the edge of the package as a plane of reference.

Once \( Z_{in} \) and \( Z_{oL} \) of the transistor are known as a function of frequency, cad can be used to design \( L \) and \( C \) matching networks for a particular application.

The complete impedance measuring process is somewhat time-consuming since it must be repeated for each frequency of interest: note that the frequency range permitted for characterisation is that over which the circuit will tune. For other frequencies, additional test circuits must be designed and constructed, explaining why it is sometimes difficult to get a semiconductor manufacturer to supply impedance data for special conditions of operation such as different frequencies, different power levels or different operating voltages.

---

LOW COST RANGER1 PCB DESIGN FROM SEE TRAX

- Circuit Schematic
- Circuit Capture
- PCB Design
- Host Of Outputs

All-In-One Design System

\( \£100 \)

Fully Integrated Auto Router

\( \£50 \)

Ask Us About Trade-In Deals

Call Now For Demo Disk on 0705 591037

Seeetrax CAE • Hinton Daubny House
Broadway Lane • Lovedean • Hants • PO8 0SG
Tel: 0705 591037 • Fax: 0705 599036

What The Press Said About RANGER1

For most small users, Seeetrax Ranger1 provides a sophisticated system at an affordable price. It is better than EasyPC or Tsien’s Boardmaker since it provides a lot more automation and takes the design all the way from schematic to PCB. Other packages separate designs for both, that is, no schematic capture. It is more expensive but the ability to draw in the circuit diagram and quickly turn it into a board design easily makes up for this.

Source JUNE 1991
Practical Electronics

Pay by Visa or Access

CIRCLE NO. 121 ON REPLY CARD

838 ELECTRONICS WORLD+ WIRELESS WORLD October 1993
PROMulator

ROM Emulator

Fast Flexible

from only £99

✓ Emulates up to 4
1 Mbit EPROMs
via one standard
printer port

✓ Emulates 24, 28, 32,
40 and 42 pin devices

✓ Downloads 27256
in 3 seconds

✓ Other models available
up to 8 Megabits and
with bi-directional
communications

✓ Accepts Intel Hex,
Motorola S-Records
and Binary files

CALL FOR
FULL DATA SHEET

Tel: 081-441 3890
Fax: 081-441 1843

SMART
COMMUNICATIONS

CIRCLE NO. 105 ON REPLY CARD

FIBRE-OPTICS EDUCATOR

Versatile training
equipment for
education and
industry.

FIBRE-OPTICS POWER METER

dBm and µW
scale; battery life
500 hours.

FIBRE-OPTICS MONITOR

For continuity
testing and voice
comms.

For further details contact:
ELLMAX ELECTRONICS LTD.,
Unit 29, Leyton Business Centre,
Elloe Road, Leyton, London, E10 7BT.
Telephone: (081) 539 0136
Fax: (081) 539 7746

ELEMMAX
ELECTRONICS

CIRCLE NO. 106 ON REPLY CARD

October 1993 ELECTRONICS WORLD+WIRELESS WORLD
in grasping electrical and electronics theory. This book has been written to help such students to understand the mathematical principles underlying their subject so that they can go on with confidence to tackle problems in practical circuits. Paperback 256 pages. 
Price £14.95 0 7506 0924 9

**CIRCUIT MANUALS**

*Ray Marston*

A series of books dealing with their subjects in an easy-to-read and non-mathematical manner, presenting the reader with many practical applications and circuits. They are specifically written, for the design engineer, technician and the experimenter, as well as the electronics student and amateur. All the titles are written by Ray Marston, a freelance electronics design engineer and international writer.

*Op-amp Circuits Manual*  
Paperback 224 pages  
Price £18.95 0 434 912077

*Audio IC Circuits Manual*  
Paperback 168 pages  
Price £13.95 0 434 912107

*CMOS Circuits Manual*  
Paperback 192 pages  
Price £13.95 0 434 912123

*Electronic Alarm Circuits Manual*  
Paperback 144 pages  
Price £13.95 0 7506 00640

*Timer/Generator Circuits Manual*  
Paperback 224 pages  
Price £13.95 0 434 912913

*Diode, Transistor and FET Circuits Manual*  
Paperback 240 pages  
Price £13.95 0 7506 02287

*Instrumentation and Test Gear Circuits Manual*  
*Ray Marston*

Modern instrumentation and test gear circuits of value to the industrial, commercial, or amateur electronic engineer or designer make up this book. Almost 500 outstandingly useful and carefully selected practical circuits are in here. This is one book you must have if you want access to practical working circuits ranging from simple attenuators and bridges to complex digital panel meters, waveform generators, and scope trace doublers. Paperback 400 pages.  
Price £16.95 0 7506 0758 0

**Logic Designers Handbook**

*Andrew Parr*

Easy to read, but none the less thorough, this book on digital circuits is for use by students and engineers and provides an accessible source of data on devices in the TTL and CMOS families. It's a 'Designers Handbook' that will live on the designer's bench rather than on the bookshelf. The basic theory is explained and then supported with specific practical examples. Paperback 448 pages.  
Price £25.00 0 7506 0535 9

**Digital Audio and Compact Disc Technology**

*Luc Baert, Luc Theunissen & Guido Vergult*

Essential reading for audio engineers, students and hi-fi enthusiasts. A clear and easy-to-follow introduction and includes a technical description of DAT (digital audio tape). Contents includes principles of digital signal processing, sampling, quantization, A/D conversion systems, codes for digital magnetic recording, principles of error correction, the compact disc, CD encoding, opto-electronics and the optical block, servo circuits in CD players, signal processing, digital audio recording systems, PCM, Video 8, R-DAT and S-DAT. Paperback 240 pages. 
Price £16.95 0 7506 0614 2

**NEWNES POCKET BOOKS**

A series of handy, inexpensive, pocket sized books to be kept by your side and used every day. Their size makes them an ideal 'travelling' companion as well.

*Newnes Electronics Engineer's Pocket Book*  
Keith Brindley  
Hardback 319 pages  
Price £12.95 0 7506 0937 0

*Newnes Electronics Assembly Pocket Book*  
Keith Brindley  
Hardback 304 pages  
Price £10.95 0 7506 0222 8

*Newnes Television and Video Engineer's Pocket Book*  
Eugene Trundle  
Hardback 334 pages  
Price £12.95 0 7506 0677 0

*Newnes Circuit Calculations Pocket Book*  
T Davies  
Hardback 300 pages  
Price £10.95 0 7506 0195 7

**Newnes Guide to Satellite TV**

*D J Stephenson*

A practical guide, without excessive theory of mathematics, to the installation and servicing of satellite TV receiving equipment for those professionally employed in the aerial rigging/TV trades. Hardback 256 pages.  
Price £17.95 0 7506 0215 5

**Newnes Practical RF Handbook**

*Ian Hickman*

Pressure on the RF spectrum has never been greater and it's people with knowledge and skills of RF design who are now in demand in the electronics industry to design, produce, maintain and use equipment capable of working in this crowded environment. This practical introduction to modern RF circuit design will equip you with the necessary RF knowledge and skills to enable you to compete effectively in the industry. Paperback 320 pages. 
Price £16.95 0 7506 0871 4

**Troubleshooting Analog Circuits**

*R A Pease*

Bob Pease is one of the legends of analog design. Over the years, he's developed techniques and methods to expedite the often-difficult tasks of debugging and...
**Price £14.95**  0 7506 16326

Digital Logic Design  
**Brian Holdsworth**  
As one of the most successful and well established electronics textbooks on digital logic design, this book reflects recent developments in the digital fields. The book also covers new functional logic symbols and logic design using MSI and programmable logic arrays. 
Paperback 448 pages.  
**Price £19.50**  0 7506 0501 4

The Circuit Designers Companion  
**T Williams**  
This compendium of practical wisdom concerning the real-world aspects of electronic circuit design is invaluable for linear and digital designers alike. Hardback 320 pages.  
**Price £29.00**  0 7506 1142 1

Return to: Lorraine Spindler, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS  
Please supply the following titles:

<table>
<thead>
<tr>
<th>Qty Title</th>
<th>ISBN</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programmable Logic Handbook</td>
<td>07506 0808 0</td>
<td>19.95</td>
</tr>
<tr>
<td>Understanding Electrical &amp; Elec Maths</td>
<td>07506 0924 9</td>
<td>14.95</td>
</tr>
<tr>
<td>Op-amp Circuits Manual</td>
<td>0434 912077</td>
<td>13.95</td>
</tr>
<tr>
<td>Audio IC Circuits Manual</td>
<td>0434 912107</td>
<td>13.95</td>
</tr>
<tr>
<td>CMOS Circuit Manual</td>
<td>0434 912123</td>
<td>13.95</td>
</tr>
<tr>
<td>Electronic Alarm Circuits Manual</td>
<td>07506 0064 0</td>
<td>13.95</td>
</tr>
<tr>
<td>Power Control Circuits Manual</td>
<td>07506 0690 6</td>
<td>13.95</td>
</tr>
<tr>
<td>Diode, Transistor &amp; FET Circuits Manual</td>
<td>07506 0228 7</td>
<td>13.95</td>
</tr>
<tr>
<td>Instrumentation &amp; Test Gear Circuits Manual</td>
<td>07506 0758 0</td>
<td>16.95</td>
</tr>
<tr>
<td>Digital Designers Handbook</td>
<td>07506 0535 9</td>
<td>25.00</td>
</tr>
<tr>
<td>Digital Audio and Compact Disc</td>
<td>07506 0614 2</td>
<td>16.95</td>
</tr>
<tr>
<td>Newnes Electronics Pkt Bk</td>
<td>07506 0937 0</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Elec Assemby Pkt Bk</td>
<td>07506 0222 8</td>
<td>10.95</td>
</tr>
<tr>
<td>Newnes TV and Video Eng Pkt Bk</td>
<td>07506 0677 0</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Circuit Calculations Pkt Bk</td>
<td>07506 0427 1</td>
<td>10.95</td>
</tr>
<tr>
<td>Newnes Data Communications Pkt Bk</td>
<td>07506 0308 9</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Telecommunications Pkt Bk</td>
<td>07506 0307 0</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Z80 Pkt Bk</td>
<td>07506 0308 9</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes 80800 Pkt Bk</td>
<td>07506 0309 7</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Electrical Pkt Bk</td>
<td>07506 05318</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Electric Circuits Packet Bk</td>
<td>07506 0112 9</td>
<td>12.95</td>
</tr>
<tr>
<td>Newnes Guide to Satellite TV</td>
<td>07506 0215 5</td>
<td>17.95</td>
</tr>
<tr>
<td>Newnes Practical RF Handbook</td>
<td>07506 0871 4</td>
<td>16.95</td>
</tr>
<tr>
<td>Troubleshooting Analog Circuits</td>
<td>07506 16326</td>
<td>14.95</td>
</tr>
<tr>
<td>PC-Based Instrumentation and Control</td>
<td>07506 1631 8</td>
<td>14.95</td>
</tr>
<tr>
<td>Electronic Circuits Handbook</td>
<td>07506 0758 0</td>
<td>24.95</td>
</tr>
<tr>
<td>Communication Services via Satellite</td>
<td>07506 0437 9</td>
<td>25.00</td>
</tr>
<tr>
<td>Digital Logic Design</td>
<td>07506 05014</td>
<td>19.50</td>
</tr>
</tbody>
</table>

Add VAT at local rate  
NB ZERO RATE FOR UK & EIRE  
**TOTAL**

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

Remittance enclosed

Cheques should be made payable to Reed Book Services Ltd.  
Please debit my credit card as follows:

<table>
<thead>
<tr>
<th>Access/Master</th>
<th>Barclay/Visa</th>
<th>Amex</th>
<th>Diners</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME (Please print)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORGANISATION</td>
<td>STREET</td>
<td>COUNTRY</td>
<td>TOWN</td>
</tr>
<tr>
<td>STREET</td>
<td>POST CODE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DATE</td>
<td><em>TELEPHONE NUMBER</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIGNATURE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAT RATES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6% Belgium, 25% Denmark, 5.5% France, 7% Germany, 4% Greece, 4% Italy, 3% Luxembourg, 6% Netherlands, 5% Portugal, 3% Spain. FOR COMPANIES REGISTERED FOR VAT, PLEASE SUPPLY YOUR REGISTRATION NUMBER BELOW (customers outside the EEC should leave this part blank)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAT NO.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| If in the UK please allow 28 days for delivery. All prices are correct at time of going to press but may be subject to change.  
Please delete as appropriate. I do/do not wish to receive further details about books, journals and information services|

Return to: Lorraine Spindler, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS  
Registered in England 151537
**SYSTEM 200 DEVECE PROGRAMMER**

**SYSTEM:** Programs 24,28,32 pin EPROMS, EEPROMS, FLASH & Emulators as standard, quickly, reliably and at low cost. Expandable to cover virtually any programmable part including serial E5, PALS, GALs, EPLD's and microcontrollers from all manufacturers.

**DESIGN:** Not a plug in card but connecting to the PC serial or parallel port; it comes complete with powerful yet easy to control software, cable and manual.

**SUPPORT:** UK design, manufacture and support. 10 day dispatch, 12 month warranty. 10 day money back guarantee.

---

**Prodution/A.C.E.**

**HUGE SAVINGS**

**SPECIAL OFFER - SCOOP PRICE**

**TERATRON**

**SHARP**

**SANSUI**

**SIDEWIRE**

**SUNOCO**

**SANYO**

**SAC**

**SAMPO**

**SANDEN**

**SANTA CRUZ**

**SAMBHUM STRAIGHT**

**SANKEN**

**SANKEN**

**SANDEN**

**SANYO**

**SANDEN**

**SANYO**

**SANDEN**

**SANYO**

---

**TELETRONIX**

**Monitor.** LCMI 245, 240V Printer. As New. HP5350 11 20GHz Counter Output 240V 2.5A, Input 204-276V 48-63Hz

**CLAUDE LYONS**

**LVC 250 Line Voltage Conditioner.**

**Camera 8 Monitor.** Bourch 8 Lomb Stereozoom 4

**Hughes 2460-11 TAB Bonder.** Excellent Condition.

**NEW 1990**

**HUGHES 2460-11 TAB Bonder.** Excellent Condition.

**Good Condition**

**Attainable Finger Conveyor.**

**SOLDERABILITY TESTER**

**CEMCO Fluxer with variable control, Air Knife, Adjustable angle.**

**HOLLIS ASTRA 16" Dual Wave Solder Machine.** Foam, Rota Dip RDA Dip Solder Pot with Solder,

---

**POWER SUPPLIES**

**AC Input 204-276v - output 240v e 6% at 2.5A**

**Portable Safety Isolating Transformer 500VA Input 8 AP100**

**EPROM PROGRAMMERS**

**Universal Editing GP P600**

**EPROM ERASER UV III Timing Period 5-50 min**

---

**SIGNAL SOURCES**

**SPECTRUM**

**TEKTRONIX 576 Curve Tracer, with Calibrated counter, Gated Counter Measurements, Several Powerful Features Including Auto Aet-up, MS35, Full Programmability and Flexing.**

**Measurements 5 MHz, Digital Output 16 bits**

---

**WANTED** — If you have manufacturing equipment to sell, give us a call. We can turn your under-utilised assets into cash.

---

**ASK FOR FREE INFORMATION PACK**

---

**SYSTEM: 200 DEVECE PROGRAMMER**

**Low cost data acquisition for IBM PCs & compatibles**

All our products are easy to install - they connect directly to either the printer or serial port and require no power supply. They are supplied with easy to use software which collects data for either display or print-out.

---

**ADC-10**

---

**ADC-11**

---

**ADC-16**

---

---

**PICTO TECHNOLOGY LTD**

---

---

---

**ELECTRONICS WORLD+ WIRELESS WORLD**

October 1993
Rewriting the rules with current mode amplifiers

Current mode amplifiers open up new designs for wide bandwidth circuits while retaining similarities with conventional operational amplifiers. Bashir Al-Hashimi uses commercially available devices in design examples of high performance, wideband amplifiers.

Circuits working at video frequencies used to depend largely on discrete or hybrid designs. But now, better fabrication techniques coupled with novel circuit design have given rise to a new family of integrated circuit amplifiers based on the current feedback approach (CFA).

Performance of these monolithic amplifiers matches or surpasses their hybrid counterparts at a fraction of the cost.

To minimise deviation from the standard approach, CFA manufacturers are designing their products to be used directly in textbook op-amp configurations — in spite of their significantly different internal design from conventional op-amps. So obtaining optimum performance with the various commercially available CFAs, has meant a new set of design rules has been formulated. It is these rules for design of wideband amplifiers that will be considered, using the EL2030 8-pin device from Elantec.

As an illustration, we will look at the requirement for a HDTV system amplifier. The HDTV amplifier needs a gain of 2 to provide matching to its termination, and uses the standard non-inverting op-amp configuration where the gain is \(1 + \frac{RF}{R1}\). Voltage feedback amplifiers (VFAs) allow an almost arbitrary choice of feedback — provided the ratio of RF to R1 is correct.

This is the first, and possibly most important, difference between CFAs and VFAs. With CFAs, the feedback resistor sets the amplifier bandwidth and the frequency response shape, as well as defining the gain of the circuit. RF and R1 must not be arbitrary.

### Table 1 Typical list of commercially available CFAs.

<table>
<thead>
<tr>
<th>Company</th>
<th>Part no</th>
<th>3dB bw (MHz)</th>
<th>SR (V/µs)</th>
<th>ST (ns)</th>
<th>Op current (mA)</th>
<th>Quiescent current (mA)</th>
<th>Diff gain and phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elantec</td>
<td>EL2030</td>
<td>120</td>
<td>2000</td>
<td>40 to 0.25%</td>
<td>65</td>
<td>15</td>
<td>0.01%, 0.01</td>
</tr>
<tr>
<td>Harris</td>
<td>HA5020</td>
<td>100</td>
<td>800</td>
<td>45 to 1%</td>
<td>60</td>
<td>7.5</td>
<td>0.02%, 0.03</td>
</tr>
<tr>
<td>Linear Tech</td>
<td>LT1223</td>
<td>100</td>
<td>1000</td>
<td>75 to 0.1%</td>
<td>50</td>
<td>6</td>
<td>0.02%, 0.12</td>
</tr>
<tr>
<td>Comlinear</td>
<td>CLC410</td>
<td>200</td>
<td>2500</td>
<td>12 to 0.05%</td>
<td>70</td>
<td>16</td>
<td>0.01%, 0.01</td>
</tr>
<tr>
<td>Analogue Dev</td>
<td>AD811</td>
<td>140</td>
<td>2500</td>
<td>50 to 0.1%</td>
<td>100</td>
<td>15</td>
<td>0.01%, 0.01</td>
</tr>
<tr>
<td>Burr-Brown</td>
<td>OPA803</td>
<td>100</td>
<td>1000</td>
<td>50 to 0.1%</td>
<td>150</td>
<td>20</td>
<td>0.03%, 0.02</td>
</tr>
<tr>
<td>Nat Semi</td>
<td>LM6181</td>
<td>100</td>
<td>2000</td>
<td>50 to 0.1%</td>
<td>100</td>
<td>8</td>
<td>0.5%, 0.4</td>
</tr>
</tbody>
</table>

### Table 2 Typical specification of a HDTV amplifier.

<table>
<thead>
<tr>
<th>Design parameter specification</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>DC to 30MHz</td>
</tr>
<tr>
<td>Gain flatness</td>
<td>&lt;0.1dB</td>
</tr>
<tr>
<td>Group delay ripple</td>
<td>&lt;2ns</td>
</tr>
<tr>
<td>I/O signal level output</td>
<td>1V (p-p) into 75Ω</td>
</tr>
</tbody>
</table>

### Fig. 1. The EL2030 8-pin device from Elantec used to test out the new design rules.

### Fig. 2. The HDTV amplifier has a gain of 2 to match its termination and uses the standard non-inverting op-amp configuration where the gain is \(1 + \frac{RF}{R1}\).
**Design rules to tackle disadvantages**

Compared to VFAs, CFAs have several advantages and disadvantages. Advantages are:
- Bandwidth largely independent of the closed loop gain;
- Superior AC performance, including high slew rate and low settling time;
- Linear phase response.

Disadvantages include:
- Feedback resistor must be optimised
- Unstable with capacitive feedback
- Supply voltage affects performance.

But by following certain design rules, CFAs can be used much more effectively, with disadvantages largely overcome:
- Choose the feedback resistor to set the amplifier bandwidth and the shape of the frequency response;
- Choose the other resistor ($R_I$) to set the amplifier gain;
- Do not use capacitive networks in the feedback path, since this drives the amplifier into oscillation;
- Use maximum allowable supply voltage since this allows CFAs to achieve optimum performance;
- Always terminate the amplifier input and output;
- Use RF layout techniques (see box).

**Frequency response of the HDTV amplifier**

The frequency response of the HDTV amplifier at three different values of $R_F$ (560Ω, 820Ω and 1kΩ) shows that $R_I$ for correct gain — shows that $R_F$ (Fig. 3) affects the amplifier bandwidth and the frequency response peaks. $R_I$ has no effect on bandwidth and frequency response, only affecting the gain.$R_F$ has no effect on bandwidth and frequency response, only affecting the gain. But it becomes clear that optimum bandwidth and maximal flat frequency response at a gain of $+2$ is obtained when $R_F = 820Ω$, the measured -3dB bandwidth being approximately 110MHz. Higher values of $R_F$ decrease the bandwidth: lower values increase bandwidth at the expense of peaking in the amplifier frequency response. The minimum value for a given CFA — below which the CFA becomes unstable — is usually given in its data sheet. For example, lowering $R_F$ in the HDTV amplifier below 400Ω causes the amplifier to oscillate. So, to change the amplifier gain, $R_I$ should be varied not $R_F$.

Good signal fidelity will depend on a video amplifier exhibiting linear phase shift or a flat group-delay response. Examining the phase response of the amplifier for the previously used three different values of $R_F$ (Fig. 4), we can see good phase linearity at high frequencies and the phase shift increases as the bandwidth decreases (or $R_F$ increases). Another difference between CFAs and VFAs is the effect of power supply. For example, lowering the supply voltage of the HDTV amplifier from ±15V to ±7V reduces amplifier bandwidth from approximately 110MHz to 96MHz.

**Fig. 5. Lowering the supply voltage of the HDTV amplifier from ±15V to ±7V reduces amplifier bandwidth from approximately 110MHz to 96MHz.**

**Fig. 6. Requirements for gain flatness...**

**Fig. 7...and group delay are both met.**
The bandwidth and frequency-response peaking, while $R_f$ sets the gain. $R_i$ also determines the input impedance of the amplifier, so a maximum input impedance is possible for a given amplifier gain. For example, take a 75Ω input impedance amplifier with a gain of -4.

We know that the EL2030 requires $R_f = 820\Omega$ to achieve maximally flat frequency response and optimum bandwidth. This gives $R_i = 205\Omega$.

Clearly there is a no problem in simultaneously achieving the required amplifier input resistance and the gain because a shunt resistor ($R_f$) can be added (Fig. 9). Amplifier gain is still (-$R_f/R_i$), and the value of $R_x$ is given by:

$$R_x = (R_f/R_i)(R_i - R_o)$$

where $R_o$ is the required amplifier input resistance.

Referring back to the example, if $R_o = 75\Omega$, $R_f = 820\Omega$ and $R_f = 205\Omega$ (to achieve a gain of -4), this gives $R_x = 118\Omega$. Care needs to be taken when using CFAs in applications requiring low impedances and relatively high gains.

If in the previous case the gain required was -30, $R_i$ would be $27\Omega$ which would provide too low an impedance, and a buffer would be necessary.

Common practice in voltage feedback inverting amplifiers is to connect the non inverting input to ground through a resistor of value equal to $R_f/R_i$, giving bias current cancellation. Unlike a voltage feedback amplifier, a current feedback amplifier does not have two high impedance inputs.

The non-inverting input is a high impedance, of the order of 1MΩ, while the inverting input is a low impedance, around 30Ω. It means that the two CFA bias currents are unrelated and no attempt need be made to minimise them through the impedance matching of the inverting and non inverting inputs. In CFA-based inverting amplifier circuits, the non-inverting input should be connected directly to ground or through a small resistor (<30Ω) to ensure stability.

**Buffer amplifier design**

A common application of CFAs is in buffer amplifiers driving high speed flash A-to-D converters. These amplifiers must have wide bandwidth, fast settling time, low output impedance and the ability to drive large and variable capacitive loads.

Current feedback amplifiers meet all these requirements (Table 1), but to realise the full capabilities of an A-to-D converter, bandwidth of the driver amplifier should be at least three times the Nyquist frequency (half the sampling frequency), minimising gain and phase aberrations. Also, the driver amplifier should be able to settle within one-half LSB of the correct value within the sampling period. For example, the driver amplifier must settle to 0.2% within 10ns, for use with an 8-bit 100MHz flash A-to-D converter.

In voltage feedback buffer amplifiers, the output may be connected directly to the invert-

---

**Board layout and passive components**

As with any high frequency device, care must be taken in board layout to maximise performance of current feedback amplifiers. Key points include:

- Use a large ground plane to assure that low impedance ground is available throughout the layout.
- Do not extend the ground plane under nodes which are sensitive to stray capacitance, in particular the inverting amplifier input. Make short and wide connection tracks to minimise losses.
- Bypass power supplies very close to the amplifier pins. For best results, bypass the power supplies with 1 to 10μF tantalum capacitors in parallel with 100nF ceramic capacitors. The power supplies should be well stabilised.
- Use surface mount passive components since they have the lowest inductance and capacitance.
- Avoid use of IC sockets.

---

**Fig. 8.** Ratio of the feedback resistor to input resistor determines the CFA voltage gain.

**Fig. 9.** There is no problem in simultaneously achieving the amplifier input resistance and the gain because a shunt resistor can be added.

**Fig. 10.** In CFA-based buffers the output must be connected to the inverting amplifier input through the recommended feedback resistor.

**Fig. 11a.** Modifying the circuit to a gain of +1 causes frequency response peaking due to stray capacitance to ground from the inverting input. 11b. Adding 2pF results in a further 2dB peaking, implying that 2pF of equivalent strays originally existed. 11c. Changing RF to 960Ω provides a flat response.

**Fig. 12.** Pulse response of the buffer amplifier shows excessive overshoot. (Top trace input, bottom trace output).

**Fig. 13.** To reduce overshoot, insert a series resistor between the amplifier output and the load.
From the previous results outlined for a gain of +2, the optimum feedback resistor $R_F$ is $820\Omega$. Modifying the circuit to a gain of +1 by removing $R_1$, causes frequency response peaking to take place (Fig. 11a), due to stray capacitance to ground from the inverting input.

When gain is employed, $R_1$ shunts the effects of strays, and adding a capacitor to simulate larger strays gives the results in Fig. 11b. Here adding 2pF results in a further 2dB peaking, implying that 2pF of equivalent strays originally existed. Changing $R_F$ to 960Ω provides a flat response (Fig 11e).

An important feature of CFAs is that once $R_1$ is chosen correctly, the –3dB bandwidth of the amplifier is approximately 116MHz with a gain of +1, and 110MHz with a gain of +2. Gain-bandwidth limitation of VFC's is not followed by CFA's.

Input impedance of flash A-to-D converters is highly capacitive, so that a typical 8-bit, 20MHz video flash converter will have an impedance of 25pF/100kHz.

Pulse response of the buffer amplifier driving directly a 24pF/100kHz load (Fig. 12) shows excessive overshoot, and increasing the load capacitor further results in the amplifier becoming more unstable. One way of reducing the overshoot and boosting the buffer-capability to drive higher capacitive loads, is to insert a small series ($R_1$) resistor between the amplifier output and the load (Fig. 13). The result is a much improved performance (Fig. 14), when $R_1 = 47\Omega$. Value of resistor $R_1$ depends on the value of the load capacitor and should be determined from manufacturer data.

The drawback to this method is a reduction in amplifier bandwidth.

Reference
2. Ogden, F. "Current Alternative to Operational Amplifiers, FW + WW, August 1992
Clunky versus cost

Breaking Windows

With the profusion of Windows software being marketed and reviewed in the computer press, I'm struck by the paradox that so few people that actually like and use it. Everyone seems to have their tale of woe regarding installation followed by the realisation that the cost in computer memory and disk space appears to be too great in comparison to any benefits gained. Although computer magazines offer plenty of technical criticism of Windows, I don’t ever recall seeing the need for its very existence being called into question. The truth of the matter we have to an ideal Windows’ hungry demand for high performance machines is the driving force behind the computer sales market today. And the personal computer magazines that depend on the industry’s advertising budgets are hardly likely to bite the hand that feeds them.If the trend is for software producers to concentrate their efforts only on Windows compatible versions, I suppose all of us will eventually be forced into buying expensive upgrades to maintain compatibility. It seems a pity that the steady improvements in PC price and performance should be soaked up by such a cumbersome and gimmicky operating system rather than more powerful applications. In the meantime is there anyone else out there prepared to stand up and say “I’m sorry I don’t do Windows".

John Carrey
Malvern

Sounding out the critics

I was pleased to see Drs Blake-Coleman and Yorke report on their investigation into fancy speaker cables (EW + WW, May). Their results seem to be pretty much in accord with what Davis, Greiner and others have been trying to tell us for years. In fact, I was personally involved in a similar test recently that produced pretty much the same result. I am pleased that the good doctors have publicly put their weight behind a more informed approach to hi-fi interconnections. I also read with keen interest Ben Duncan’s article on op-amp distortion. “How clean is your audio op-amp?” (EW + WW, January). It was a thought provoking piece, more for the explanation of the exercise than the actual data. I was a little amused, however, that Duncan has been unable to uncover any harmonics generated by resistors. Resistors are about the most linear circuit components around. I think his time might be more productively spent investigating the non-linear behaviour of electrolytic capacitors! There are also many other factors, such as circuit layout, more important to distortion than resistor non-linearity. I disagree with Duncan’s idea that the “Cause of the difference is... relatively unimportant”. Before we can accept his hypothesis as anything more than conjecture, it is essential that we establish any genuinely audible effects and to ascribe them accurately to differences in the circuit. For example, it is pointless to measure differences in distortion if listeners respond only to a change in mains noise. As far as Chris Daly’s remarks go (EW + WW, April), I think he has the wrong end of the stick. One does not need a hot soldering iron nor any practical application to recognise a poor argument. My criticism of Duncan’s is that he proves nothing much. Since there is no scientific evidence that the effects are audible Duncan has furnished us with no more than hypothesis. Unsubstantiated anecdotes are not proof. It is often the lack of theoretical and experimental rigour that renders claims from the golden eared or subjectivist club invalid.

Andy Millar
Whiston, Devon

Power to protect

On reading R Gough's letter (EW + WW, August), I was struck by several points. I study with a group of people that doesn’t know that the human body is tuned to a cosmic keyboard, but there you are; there’s just no telling some people. However, I was most perturbed to read that certain music sounds can stimulate the pancreas, pineal glands and so on. Clearly there are unexpected dangers in listening to music or indeed any other sound; unlooked-for stimulation of the pancreas is likely to send us into insulin coma while nudging the pineal is going to cause sudden uncontrollable attacks of jet-lag, or possibly mass hibernation. The hazards are obvious, and I think that Mr Gough has a clear duty to specify which frequencies have these hitherto unsuspected effects, so that we audio engineers can guard the public against them with suitable banks of filters. Seriously though, what is this kind of wretched nonsense doing in EW + WW? I would, as Meechan, wish to be catty, surely the "we've out-thought Einstein" contingent are enough of a cross to bear.

Douglas Self
London
As editor, I have a duty to allow heretical discussion and presentation of controversial views. This is not just a result of some woolly liberalism, but the shameless desire to give entertainment to other readers - FO.

Malvern

LETTERS
LETTERS

listener, as well as their state of health and fatigue, and whether they have had any stimulants or depressants (such as coffee, tea, alcohol, cigarettes, and so on) within hours before any auditioning. Lipshitz and Vanderkooy even suggest that this noise material often has greater effect on the sound than the performance of the reproduction equipment.

Based on the evidence that Duncan has published it is unlikely that the new harmonic structure is due to harmonics from the mains. If it were caused by mains we would see many more spectral lines at multiples of 50Hz, not just the 1kHz spacing that we do see. I think Duncan would probably agree with me there.

It is interesting then that Daly claims "that the near total absence of mains noise (hum)" when Duncan's results show no effect on mains noise. Daly shows that the reverse biased capacitor causes an increase in even harmonic distortion. Daly on the other hand says only that he "noticed no sonic degradation". One cannot say that Daly's claims support Duncan's results, since Daly's experience with this modification is quite at odds with what Duncan seems to be saying. If anything Daly's claim that he "noticed no sonic degradation" tends to suggest that these levels of distortion are inaudible.

However, I am perplexed by a philosophy that seems to be telling me that some distortion is acceptable because it makes the music more euphonious (to some people), but at the same time tone controls should not be allowed because they introduce distortion, even though they reduce sonic aberrations and make the music more euphonious when properly used. Such an illogical and inconsistent philosophy is not likely to maintain much credibility.

Authors wanted

There are a number of subjects and ideas that I have not seen in print that could provide the base for some interesting articles. For example information on surface acoustic wave resonators; they come in one and two port configurations. One manufacturer of these, Siemens, is fully booked through 1994. I would like to see a list of other possible suppliers.

Incidentally did you know that resonator oscillators hold the record for noise floor/spectral purity, they give a better figure than the best crystal oscillators. It is not only Q that matters, saws can operate at much higher power.

A review of university departments would be interesting for prospective students and people with research money. Who is an expert at what and where?

Good technical information means finding out what is not on the manufacturer's data sheet. This is possible if its made in the UK and almost impossible from elsewhere. Few distributors are interested in providing technical information on products from their suppliers that are outside the range they stock.

What MPs have a technical background? To whom are we to write if we wish to complain about the sale of the UK's last truly world class electronics capability - STC Submarine Cables.

Submarine fibre optic cables are preferred by telecommunications companies worldwide for satellite for commercial and user convenience. The competitors AITT and Alcatel are regarded in their own countries as critically strategic. They are directly supported and control would never pass outside their national boundary.

Inertial sensors could only be afforded by the military. As an inertial platform for a submarine could set one back £0.5m. Accelerometers are available to the automotive industry for a few pounds. Angular rate sensors (the equivalent of a rate gyro) are required to sense car turning for computer control of steering geometry, suspension rotation, steering wheel spin (the Magimix effect), and to interpolate between GPS fixes.

Who makes these low cost sensors, what specification parameters are important, and what other applications could ride on low cost automotive devices?

The department of the government chemist is really useful in letting interested parties communicate in the field of chemical sensors; this should be a model for the rest of the DTI which in most things is truly appalling.

Douglas Dwyer
Okehampton, Devon

If any readers are interested in taking up some of the above ideas for articles, may I remind them of the authors' award scheme that we run. Turn to page 813 to find out more - Editor.

A question of theory

Surely measures Catt, Elmdendorf, and Goldberg (EW+W, August) have missed the point. It is rare indeed for a scientific theory or formula to be proved correct or even incorrect, as the continuing big-bang versus steady-state controversy illustrates.

All one can generally say is that the predictions of one tend to fit the evidence better than those of others. The other reason for preferring a theory is simplicity. Generally a very large number of possible theories will fit the observations; to pick the simplest one has itself proved to be a useful principle.

The Michelson-Morley experiment indicated the aether to be stationary with respect to the Earth, a circumstance untenable in the prevailing philosophy. Another possibility not considered by Goldberg or anyone at the time is that the aether is viscous, and stationary wherever it is measured - rather like air, which tends to attach itself to moving bodies. Of course this makes nonsense of the constancy of the velocity of light, and can be dismissed lightly; its only value as an explanation would be if it fitted reality better than current theories.

We sometimes forget that our theories - and indeed basic concepts like particle and wave - are only convenient fictions to describe complex behaviour. I could go on, but since challenges seem to be in fashion, I challenge Elmdendorf to indicate first with respect to what is the Earth's rotation to be measured, and secondly, if he finds our weather systems unconvincing, what conceivable type of evidence he would accept as absolute proof that it does?

AM New Bristol

Drawing error

Unfortunately there is an error in the redrawing of the circuit diagram in my article "Audio induction technology for the deaf" (EW + WW, September).

The universal preamp should have shown separate jacks sockets to different points in the circuit for the dynamic (M) and electret (E) microphone inputs, the former being open circuit and the latter being short circuit when unused.

Phil Dennis
University of Sydney, Australia

5. Ibid, p484.
If you have followed our series on the use of the C programming language, then you will recognise its value to the practising engineer.

But, rather than turning up old issues of the journal to check your design for a digital filter, why not have all the articles collected together in one book, Interfacing with C?

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

To complement the published series, Howard Hutchings has written additional chapters on D-to-A and A-to-D conversion, waveform synthesis and audio special effects, including echo and reverberation. An appendix provides a "getting started" introduction to the running of the many programs scattered throughout the book.

This is a practical guide to real-time programming, the programs provided having been tested and proved. It is a distillation of the teaching of computer-assisted engineering at Humberside Polytechnic, at which Dr Hutchings is a senior lecturer.

Source code listings for the programs described in the book are available on disk.
**CIRCUIT IDEAS**

**THIS MONTH’S £100 CIRCUIT IDEA**

**FSK receiver has auto decision-threshold control**

This low-cost, low-power PLL receiver for FSK binary-coded data automatically sets the best decision-threshold level for recovering the data. Ideally, $V_{th}$ should be midway between $V_h$ and $V_l$, the upper and lower peak voltages of the demodulated signal, which are not usually stable due to the effects of drifts and gain inequalities. Signal from the LM568 demodulator passes to comparators $IC_{2a,2b}$, which work in conjunction with current source $Tr_{2,3}$ and sink $Tr_{4,5}$ as positive and negative peak detectors, tracking variations of the peak voltages. Their outputs are combined and averaged by $f_1$, $f_2$ to put $V_{th}$ half way, this voltage going to the output comparators, which also accept the input from the demodulator. Current generators improve the dynamic range of the peak detectors.

With a 100mV carrier at 110kHz, the local oscillator at $2f_c$, and frequency deviation between 500Hz and 5kHz, drift was simulated by adding a 0.1Hz signal to the 300b/s digital modulation. When $V_h - V_l$ is between 100mV and 600mV and $V_{th}$ 1-3V, data is always recovered with negligible jitter.

**G Stochino**
Ericsson Fatme Spa
Rome
Italy

Simple method of adapting data-recovery decision-level threshold to take account of noise, drift and gain variations in the amplifiers and demodulator.
Cheap mosfet audio power

To provide very good performance using cheap mosfet output devices, this circuit uses an op-amp driving a conventional source follower output stage. Transistor $T_1$ sets the quiescent current, the two LEDs dropping a fixed 3.2V; a single zener would be just as suitable. There is a small drift, but since quiescent current is not critical, there is no correction. Since the output stage voltage gain is less than unity, the op-amp should be chosen to have enough internal frequency compensation to avoid instability; it should also have a high slewing rate and reasonable current drive. Capacitor $C_2$ reduces gain at higher frequencies. Power output depends on supply voltage; at ±22V, power is 15W into 8Ω.

Andrew Southgate
Sutton, Cambridgeshire

No-loss tuned circuit

The circuit shown is (ideally) a loss-free parallel tuned circuit, for use as part of a band-pass filter or as a reasonably accurate square wave oscillator if the dotted resistor is in place, although a diode limiter across one of the capacitors may be needed in the oscillator form. With component values normalised to unity, the dotted resistor would be typically 50. Frequency control is also unity, $R$ being the top half to give

$$\omega = \sqrt{\frac{R}{1-R}}$$

Varying the control gives a fairly straight line over around two octaves, accurate enough for use in a simple spectrum analyser.

McKenny W Egerton Jr
Owneys Mills, Maryland, USA

Transconductance squarer

An op-amp and a dual fet combine to give output $i_{out}$ when $v_1 > 0$.

National Semiconductor's 2N5452 n-channel dual fet has good matching between the two devices and low output conductance. Normally, the voltage between the fet gates and the non-inverting op-amp input is constant at $V_{GS}$, the pinch-off voltage of the two transistors. $V_{GS}$ is $(v_1^* + V_D)$ and $i_{out}$ is proportional to $v_1^2$.

The coefficient $k$ is adjustable by means of the 5kΩ input variable, the two diodes and the 4.7kΩ resistor ensuring that $i_{out}$ does not exceed $I_{DS}$ and allowing negative feedback should $v_1^*$ become greater than $I_{DS}$. Output voltage must lie within the 5-15V range. Including an absolute-value detector at the input produces a true squarer: either polarity of input gives the same output. With a $\mu$A741, the circuit works at several kilohertz.

Alexandru Ciubotaru
University of Texas at Arlington
Texas, USA
CIRCUIT IDEAS

Zero-crossing detector

At every zero crossing, this circuit produces a 150µs pulse, centred on the crossing, the output being optically isolated from mains input.

Diodes D1..4 rectify the input current, which is limited by R1..2 to around 1.3mA; power dissipation is minimal, so virtually any kind of resistor will suffice. Output from the rectifier powers the quad Nand IC1, zener D6 limiting the voltage to about 12V.

Since input to IC1 is normally high, output from the three parallel gates is high, except for the period around each zero crossing, when input to IC1 is low and so is the output, which turns the led and output transistor on. Resistor R6 avoids trouble caused by stray coupling at the transistor base. Capacitor C1 takes about 100ms to charge at switch-on.

A. J. Find
Taunton, Somerset

Electrocardiograph simulator

This simple ECG simulator has been useful for some years in teaching and equipment test and development.

IC1 forms an astable flip-flop at 20Hz to drive the clock input of the decade counter IC2, which produces sequential highs on its Q0..9 outputs. The voltage at the common point of the output resistors is determined by the potentiometer action of one on resistor chosen to form the required pulse shape.

When Q0 goes high, it inhibits the IC1.e.6

Electrocardiograph simulator, variable from 30 to 160 pulses per minute, pulse shape being synthesised by sequential outputs from decade counter and resistor bank.

Alberto R. Marino
Madrid
Spain

Simple zero-crossing detector produces an isolated pulse, used by the author to synchronise a sawtooth generator.
Electronic Designs Right First Time?

See us on Stand P29 EDS Wembley 5-7 Oct

Affordable Electronics CAD

<table>
<thead>
<tr>
<th>CAD Type</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>EASY-PC: Low cost PCB and Schematic-CAD</td>
<td>£98.00</td>
</tr>
<tr>
<td>EASY-PC Professional: Schematic Capture and PCB CAD. Links to ANALYSER III and PULSAR.</td>
<td>£195.00</td>
</tr>
<tr>
<td>PULSAR: Low cost Digital Circuit Simulator - 1500 gate capacity</td>
<td>£98.00</td>
</tr>
<tr>
<td>PULSAR Professional: Digital Circuit Simulator - 50,000 gate capacity</td>
<td>£195.00</td>
</tr>
<tr>
<td>ANALYSER III: Low cost Linear Analogue Circuit Simulator ~ 130 nodes</td>
<td>£98.00</td>
</tr>
<tr>
<td>ANALYSER III Professional: Linear Analogue Circuit Simulator ~ 750 nodes</td>
<td>£195.00</td>
</tr>
<tr>
<td>Z-MATCH II: Smith Chart Program for R.F. Engineers</td>
<td>£98.00</td>
</tr>
</tbody>
</table>

No penalty upgrade policy. Prices exclude P&P and VAT.

Number One Systems Ltd.
Ref: WW, Harding Way, St. Ives, Huntingdon, Cambs. PE17 4WR, UK.

For Full Information Please Write, Phone or Fax.
Tel: 0480 461778
Fax: 0480 494042

CIRCLE NO. 113 ON REPLY CARD

CVC

Chelmer Valve Company

Worldwide supplier with 30 year’s experience

- Electron tubes: Transmitting, Industrial, Microwave, Audio, Receiving, Display, etc, etc.
- For Maintenance, Spares or Production.
- Semiconductors: Transistors, Thyristors, Diodes, RF, Power I/C’s, etc.
- We have one of the largest stocks in the U.K.

★ TRY US! ★

FAX, PHONE, POST OR TELEX YOUR REQUIREMENTS
130 NEW LONDON ROAD, CHIELSFORD, ESSEX CM2 0RG, ENGLAND
Telephone: (0245) 353296/266865
Telex: 991990 CEEVEE G Fax: (0245) 490064

CIRCLE NO. 114 ON REPLY CARD

CIRCLE NO. 115 ON REPLY CARD

October 1993 ELECTRONICS WORLD + WIRELESS WORLD
**Bench Power Supplies from DiaWA Industry Co**

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF2180</td>
<td>Digital Error Detector</td>
<td>£200</td>
</tr>
<tr>
<td>TF2180A</td>
<td>AM/FM Signal Generator 10 MHz</td>
<td>£2432A 560 MHz Digital Frequency Meter</td>
</tr>
<tr>
<td>TF2181</td>
<td>IT 1247 20-300 MHz Oscillator</td>
<td>£200</td>
</tr>
<tr>
<td>TF2182</td>
<td>IT GTA 9A Milliwatt Power Meter</td>
<td>£200</td>
</tr>
<tr>
<td>TF2183</td>
<td>Marconi 3964A Instrumentation Recorder (as new)</td>
<td>£200</td>
</tr>
<tr>
<td>TF2184</td>
<td>3763A Error Detector</td>
<td>£200</td>
</tr>
<tr>
<td>TF2185</td>
<td>3762A Data Generator</td>
<td>£200</td>
</tr>
<tr>
<td>TF2186</td>
<td>3705A (Differential Phase Detector)</td>
<td>£200</td>
</tr>
<tr>
<td>TF2187</td>
<td>3702A IF/Baseband Receiver fitted with 3710A IF/Baseband Transmitter</td>
<td>£200</td>
</tr>
<tr>
<td>TF2188</td>
<td>3405A Broadband Sampling Voltmeter</td>
<td>£200</td>
</tr>
<tr>
<td>TF2189</td>
<td>3400A RMS Voltmeter</td>
<td>£200</td>
</tr>
<tr>
<td>TF2190</td>
<td>3300A Function Generator with 3306A Sweep Plug-In</td>
<td>£200</td>
</tr>
<tr>
<td>TF2191</td>
<td>9084 Synthesized Signal Generator</td>
<td>£200</td>
</tr>
<tr>
<td>TF2192</td>
<td>9341 IC Databridge</td>
<td>£200</td>
</tr>
<tr>
<td>TF2193</td>
<td>9300 RMS Voltmeters</td>
<td>£200</td>
</tr>
<tr>
<td>TF2194</td>
<td>9083 2 Tone Signal Source</td>
<td>£200</td>
</tr>
<tr>
<td>TF2195</td>
<td>9081 Synthesized Signal Generator - 5201MHz</td>
<td>£200</td>
</tr>
<tr>
<td>TF2196</td>
<td>3100 Synthesizer 40-130 MHz</td>
<td>£200</td>
</tr>
<tr>
<td>TF2197</td>
<td>RACAL DANA Philips 3261 - 120 MHz Dual Channel</td>
<td>£250</td>
</tr>
<tr>
<td>TF2198</td>
<td>Philips 3226 - 15 MHz Dual Channel</td>
<td>£250</td>
</tr>
<tr>
<td>TF2199</td>
<td>Philips 3217 - 50 MHz Dual Channel</td>
<td>£250</td>
</tr>
<tr>
<td>TF2200</td>
<td>Philips 3211 - 151 MHz Dual Channel</td>
<td>£250</td>
</tr>
<tr>
<td>TF2201</td>
<td>Gould 3020 - Digital Storage Oscilloscope</td>
<td>£250</td>
</tr>
<tr>
<td>TF2202</td>
<td>Tektronix 453 - 100 MHz Dual Channel</td>
<td>£250</td>
</tr>
<tr>
<td>TF2203</td>
<td>TEKTRONIX 466 100 MHz Storage</td>
<td>£250</td>
</tr>
<tr>
<td>TF2204</td>
<td>TEKTRONIX 468 100 MHz Digital Storage Dual Trace</td>
<td>£250</td>
</tr>
<tr>
<td>TF2205</td>
<td>TEKTRONIX 475 - 200 MHz Dual Trace</td>
<td>£250</td>
</tr>
</tbody>
</table>

**Compact and lightweight**

**Cost efficient**

**Rapid delivery**

SOUTH MIDLANDS COMMUNICATIONS LIMITED
S M House, School Close, Chandlers Ford Ind Est, Eastleigh, Hampshire, SO5 3BY
Tel: (0703) 255111 Fax: (0703) 263507

---

**Radio Modem**

- MPT1329 licence exempt.
- Range up to 20 km in free space or 1 km in buildings.
- Half duplex asynchronous transmission at 4800/9600 bits/sec.
- Serial interface with baud rates of 1200, 2400, 4800 and 9600.
- 4K of buffer memory.
- Predictor/corrector error checking.
- Automatic repeater mode to extend range.
- Station addressable.
- Analogue and digital interfaces.
- Low power battery operation.

Warwick Industrial Electronics Ltd
The Manor
Aston Flamville
Leicestershire
Tel: 0455 233616

---

**Telnet**

- One of the largest stockists and distributors of electronic valves, tubes and semiconductors in this country

Over 5 million items in stock covering more than 6,000 different types, including CRT's camera tubes, diodes, ignitrons, image intensifiers, IC's, klystrons, magnetrons, microwave devices, opto electronics, photomultipliers, receiving tubes, rectifiers, tetrodes, thyratrons, transistors, transmitting tubes, triodes, vidicons.

All from major UK & USA manufacturers.

Where still available.

Obsolete items a speciality. Quotations by return.

Telephone/telex or fax despatch within 24 hours on stock items. Accounts to approved customers. Mail order service available.

LANGREX SUPPLIES LTD
1 Mayo Road, Croydon, Surrey CR0 2QP
Tel: 081-684 1166
Telex: 946708
Fax: 081-684 3056
NEW PRODUCTS CLASSIFIED

ACTIVE

Asics
Mixed-signal asics. Fujitsu has a new family of mixed-signal, standard-cell asics in 1.2 and 0.8micron cmos, which includes two layers of polycrystalline and three metal layers for the integration of analogue and fast, dense logic. Fujitsu Microelectronics Ltd, 0262 76100.

A-to-D & D-to-A converters
12-bit, 2MHz ADC. Datel’s ADS-132/883 analogue-to-digital converter, qualified to MIL-STD-883, is a high-speed A-to-D combined with a fast sample-and-hold amplifier in a small 35-pin TDIIP package. It has its own reference, three-state outputs, digital correction circuitry and internal clock. Total harmonic distortion is ~0.08%. Datel (UK) Ltd, 0256 890444.

Discrete active devices
13.5GHz transistor. The industry’s highest gain/bandwidth product of 13.5GHz is achieved by Hitachi’s 25SC050, which also offers a noise factor of 1.1dB at 900MHz, 5V and 5mA. At a bandwidth of 20GHz, forward transfer gain at around 900MHz is 11.7dB. The device is in a miniature SM resin moulded MPAK-4 package. Hitachi Europe Ltd, 0282 585000.

SM rectifier diodes. 1W surface-mounting rectifier diodes by Temic-Thelefunken are available in the 5V-1000V range in standard, fast and ultrafast variants. IIT Multicomponents, 0753 824212.

UHF msetel. SGMM2014M is a GaAs dual-gate msetel by Sony, intended for UHF low-noise amplifiers, mixers and oscillators. Noise figure is 1.5dB at 900MHz and gain is 18dB; cross modulation is low and there is a gate-protection diode built in. The device is packaged in a standard four-pad SOT-143. Sony Semiconductor Europe, 0794 466660.

Linear integrated circuits
VHF linear amplifier. RF2103 is a medium-power linear amplifier for digital or spread-spectrum transmitters. The amplifier is operating in the 800-1000MHz region, or as an exciter for higher powers. The IC is self-contained, with a power-down facility, and produces 800mW CW or 400mW average for two-tone input, at 6.3V DC or 3V (135mW CW). Gain is 25-30dB. Anglia Microwaves Ltd, 0277 630000.

Current-feedback op-amp. Burr-Brown OP263 has a large-signal bandwidth of 350MHz at 2.8V pk-pk and >170mA output. Gain can be as high as 4mA. An external feedback resistor sets open-loop gain for best frequency response and constant bandwidth with varying gain. Slew rate is 210V/us. Burr-Brown International Ltd, 0923 238937.

Power-factor controllers. MC34262/33262 are power-factor controller ICs meant for use as preconverters in electronic ballasts and in off-line power converters. They include start-up timer, single-quadrant multiplier for near-unity power factor, zero-current detector, transconductance error amplifier, trimmed bangdago reference and output for power mosfets. There is a full range of protective measures.

Motorola Ltd, 0098 614614.

Logic building blocks
Modems. Hitachi has released three new single-chip modem ICs, HD819003/04/10, based on the earlier 81900. They conform to CCITT V.29, V.27ter and V.21ch2 standards. They are simple, low-power and include memory, DTMF generation, protocol conversion and alarm. A new single-chip modem IC, HD819002, is based on the earlier 81900. They conform to CCITT V.29, V.27ter and V.21ch2 standards. They are simple, low-power and include memory, DTMF generation, protocol conversion and alarm. HD4074639 has

Memory chips
64Kb eeprom. AMT’s 24C65 is claimed to be the world’s first 64Kb device and is the first in a new series of smart serial eeproms. Bus rate is 400kHz, there is a 64byte data-input cache and up to eight devices can be on the same bus to give 512Kb. A 4bit block of one million cycle erase/write memory is provided, as is a 64K block with a 10,000-cycle memory. Arizona Microchip Technology, 0234 222352.

Microprocessors and controllers
Floating-point accelerator. An arithmetic co-processor board using the risc machine’s floating-point accelerator chip is meant for use with the Archmedes A540 and A5000 and the R260 Unix station. The FPA10 interfaces with the ARM family of CPUs, implementing often-used instructions on chip and a software-ship combination for the rest. The chip fits a socket on the A5000 motherboard and the A540 and A5000 card to increase floating-point performance by about 50 times, doubling throughput and extends precision calculation to 14 and 18 decimal places respectively. Acom Computers Ltd, 0223 245200.

Microcontroller. An eight-bit risc microcontroller by Arizona, the PIC16C64 contains 1K by 14b of eeprom program memory, 64byte of eeprom data memory and 36 by 8b of

Telecoms controllers. HD4048360 are low-power telecommunication system controllers operating from voltages down to 2.7V, several power-saving standby and stop modes being provided, as well as a 32kHz "sub-active" clock. The two devices have 8K and 16K by 10 bits of ram respectively and 1152 by 4 bits of ram. The HD4047639 has 16K of one-time-programmable memory, and all three have DTMF generator, timers, serial interfaces, a voltage comparator and input capture. Hitachi Europe Ltd, 0268 585000.
general-purpose ram. Supply is 2-6V and the sleep mode current is 400mA.

There are four hardware interrupts, including wake-up on keystore and the instruction set has 35 single-word instructions to give a single-cycle execution rate of 400ns. Arizona Microchip Technology, 0268 850303.

Frugal micro. TMP86803C by Toshiba is a microprocessor based on the 68HC002 microprocessor core, but with two types of power-down and a clock generator. In power-down, either the clock alone is left running to support external circuits or the whole thing is turned off, in which case current drain is 0.1mA. The 8-pin POPP package has all the address bus pins on one side and all the data pins on the other. Toshiba Electronics (UK) Ltd, 0276 694600.

Mixed-signal ICs.
PC sound synthesiser. Yamaha's YMF278 sound synthesiser generates both PCM and FM sound through a single device. PCM comes from a 12 or 16bit. Output is in stereo. Polar sampling rate, the data word being 8, generated simultaneously at 44.1kHz compatible with the YMF278 sound source LSI. Twenty-four tones may be generated simultaneously at 44 1kHz sampling rate, the data word being 8, 12 or 16bit. Output is in stereo. Polar plc, 0205 377070.

Voice for moderns. Rockwell's RC06V24ACW cmos modem chipset allows a PC to act as a comms station for data, fax and voice storage and playback from one telephone line. It conforms to the TR25.2 standard and Rockwell has a development program (VAPI) for Windows and dos which provides a driver. VAPI stores data on disk and has intelligent call discrimination to sort out the use of the single line. RCSI Microsystems Ltd, 081-979 2204.

Optical devices
Bright led. Toshiba TLQ4165 by Toshiba is an exceptionally bright led, intended in the main for use as high-mounted car stop lights, where it offers size and placing advantage over the more usual Incandescent bulb, measuring only 5mm diameter. Intensity is 8000cd at 6500K over 30deg angle, with a forward current of 20mA. Toshiba Electronics (UK) Ltd, 0276 684900.

Programmable logic arrays
5ns ecmos plal. Claimed by AMD to be the fastest electrically erasable 20-pin programmable logic device currently being sold. Maximum clock speed is 142.8MHz and the device uses less power than bipolar 5ns ICs, also offering the facility of frequent and fast reprogramming. PALCE16VH-5 has pull-up resistors on inputs and i/o and is a plug-in replacement for the PAL16R8 and most of the PAL10R8 series. Advanced Micro Devices UK Ltd, 0483 740440.

Power semiconductors
95% efficiency regulator. Linear's LTC1147 is an 8 pin step-down switcher exhibiting 95% efficiency at an output current of 20mA-2A, with a stand-by current of 160µA (quiescent 20µA). It comes in fixed 3.3V and 5V versions, accepting 4-16V at the inputs. An external mosfet is required at up to 250kHz. Burst mode stand-by power is 2mW with 40mA input. Linear Technology (UK) Ltd, 0932 765868.

2A, 5V switcher. MAX726 is a step-down switching regulator, accepting 8V-40V (60V in the 726HV) and producing 2.5V-40V. It is a buck regulator and can be arranged as an inverter, a negative boost converter or a flyback converter with input down to 5V. Power switch, 100kHz oscillator and control circuitry are built in. Maxim Integrated Products Ltd, 0734 845255.

Transistor suppressor. Semtech's transient voltage suppression diode array handles 300W peak pulse power per line, has data, signal and DC supply line protection, and is obtainable in unidirectional or bidirectional forms. Reverse stand-off voltage is 5-24V, leakage current 1µA or 100µA and capacitance 63-550µF. Semtech Ltd, 0592 673720.

Motor control. Siliconix's S29901 provides low-to-high-voltage interfacing to the S29911 and S29914 high-side drivers, with built-in protection for high-voltage motor control. S29901 low-side driver includes the bootstrap diode, protection circuitry, fault indication, cmos-compatible input and a pump oscillator. A 1µA quiescent current reduces drain on the bootstrap capacitor. Siliconix, 0344 485757.

Power mos arrays. Under the name POWER+ ARRAYS, Texas offers up to seven power transistors on one chip. In various packages, TPC2301/200/2301/207 contain from two to seven devices. Those with up to three transistors are 7.5A, 60V devices, while the seven-device package (TPC2701) contains 0.5A types. Texas Instruments, 0234 222325.

Passive components
Encapsulated transformers. For switched-mode power supplies, Microspire has introduced the MPMP series of transformers and MPLP inductors, both of which offer high power in a small size; 40W from 3400 cubic millimetres, up to a point which is as little as 5mm above the board and, since the core material touches the board, it acts as a heat sink, so that the units withstand 150°C. Microspire UK Ltd, 0227 740368.

Tantalum chips. Ultra-miniature tantalum-chip capacitors in NEC's SVS range measure 2 by 1.2 by 1.25mm, but come in values from 0.33µF to 2.2µF at voltages from 2.5V to 16V DC. Leakage current is 0.5µA maximum with a dissipation factor of 0.1. The existing R series covers the 0.047-330µF range up to 250V DC. NEC Electronics (UK) Ltd, 0908 691133.

Electrolytics. Nichicon's Muse electrolytic capacitors come in nine varieties, all of them intended for audio use. Range of values is 0.1-22,000µF at 4.100V DC. The ranges vary various levels of use: K2, for example, is meant for high-quality audio. E8 is non-polarised, FA is for mid-to-top quality work and KV is a 6mm long chip type. Nichicon (Europe) Ltd, 0276 685393.

Lithium batteries. High-performance manganese dioxide lithium backup batteries in button form for 3V operation are available from P Caro. Six sizes from 25mA to 500mA provide continuous current of 2mA to 20mA, P Caro & Associates Ltd, 021 742 1328.

Current limiters. Surge-Gard current-limiting devices from Rhopoint handle steady-state current from 0.3A to 30A and are meant for use in bridge power supplies to limit the inrush current for up to two seconds, whereupon their resistance decreases so that voltage drop is negligible. Several models are available from Rhopoint Components, 0883 717988.

Chip capacitors. Solid tantalum chip capacitors in the Matsuo Tanchip 267 range are resin moulded and designed for surface mounting, being as small as 3.2 by 1.6mm and precisely sized. Capacitance range is 0.1uf-100µF at 4-35V, or up to 220µF in a larger case. Operating

NEW PRODUCTS CLASSIFIED
Please quote "Electronics World + Wireless World" when seeking further information
Connectors and cabling

Edge connector. Methods have an edge connector with a 0.05in pitch and 0.3in off-board height. Between 20 and 122 beryllium-copper pins are mounted on a 0.05 by 0.1in grid in a heat-resistant polyphenylene sulphide body. ITT MULTicomponents, 0753 110412.

Filtered BNCs. Noise problems in coax. transmission lines are reduced by Oxley's BNC connector with built-in filtering. The cable outer is not connected to chassis, avoiding ground loops, integral multilayer ceramic capacitors providing AC coupling, so that noise currents on the screen can be decoupled to ground. VSWR is better than 1.3:1 over 0-4GHz and, with 10nF between cable screen and equipment shield, attenuation is over 30dB. Oxley Developments Co. Ltd, 0256 52621.

Euro V35 connector. St Cross now stocks the Belgian CDM range of products, including the CDM-V.35 connector designed for the V.35 CCITT interface, which incorporates a strain relief and RFI/EMI shielding. St Cross now stocks the Belgian CDM range of products, including the CDM-V.35 connector designed for the V.35 CCITT interface, which incorporates a strain relief and RFI/EMI shielding. St Cross now stocks the Belgian CDM range of products, including the CDM-V.35 connector designed for the V.35 CCITT interface, which incorporates a strain relief and RFI/EMI shielding.

Displays

Panel meters. Digitron's new 440 series panel indicators work with a variety of sensors, for which the indicators provide a 12-24V supply.

Displays

Panel meters. Digitron's new 440 series panel indicators work with a variety of sensors, for which the indicators provide a 12-24V supply.

Instruments

Subminiature DVM. Datel's DMS-20PC is a 3.5-dgt digital voltmeter that occupies around 0.5 cubic inch. Thirty-six models cover the range ±2-200V, with 1000µA inputs, autozero and autopolarity. Display is by 0.37in leds and the units are surface-mounted or panel-mounted.

Instrumentation

Subminiature DVM. Datel's DMS-20PC is a 3.5-dgt digital voltmeter that occupies around 0.5 cubic inch. Thirty-six models cover the range ±2-200V, with 1000µA inputs, autozero and autopolarity. Display is by 0.37in leds and the units are surface-mounted or panel-mounted.

Filters

UHF filters. Toko UHF dielectric filters are now available in surface-mount packages. They are meant chiefly for RF front-end filtering in cellular and cordless telephones and GPS, with centre frequencies in the 800-1700MHz range and ±12.5MHz bandwidth. Insertion loss of the two and three-pole types is 2dB, passband ripple less than 1dB and VSWR 2:1. Cirkit Distribution Ltd, 0992 444111.

Satellite filters. Four new satellite filters from Mattley are meant for use in SNG video upconverter equipment and professional satellite receivers. Centre frequency is 70MHz and the filters conform to Eutelsat amplitude and group delay shaping characteristics for both full and half transponder use. Mattley Electronics, 0782 577588.

Hardware

Air packing. Air Box is a double-walled plastic bag for transporting delicate components. When the package is inflated, the inner bag contracts and is surrounded by air under pressure, the whole then being put into a carton. The contents can be seen before opening. The Post Office recognises the Air Box for sending blood products. The bag can be inflatd by mouth or by air line. Air Bag Packaging Ltd, 0789 297000.

RF shielding material. Available in a variety of forms, EMI shielding material from RS is made from copper-coated non-woven nylon fabric, in self-adhesive and non-adhesive varieties. There is a 25mm door-seal tape in gasket form, laminated to a PVC foam strip. All types attenuate by 50dB in the 1MHz-10GHz range and have a typical surface conductivity of 0.0442 per square. RS Components Ltd, 0536 201234.

Test gear. New instruments in the 1993 power-supply handbook covers a wide range of over 80dB. Livingston Hire Ltd, 0992 444111.

Reflection coefficient. Marconi now has the 6210, an add-on to the 6220 series microwave test set family of instruments, which is designed to provide precision reflection analysis on microwave and RF systems and components in the 250MHz-2.6GHz range. Time-domain analysis is also offered by way of a simplifying user interface. Display formats include phase, polar, real, imaginary and Smith chart, in addition to normal Cartesian return loss and VSWR. Accuracy is such that return loss measurement of 20dB is accurate to within 0.5dB. Marconi Instruments Ltd, 0727 59292.


PSU handbook. Computer Products' 1993 power-supply handbook covers AC/DC supplies and DC/DC converters. It also has a technical section on recent advances in design, with a multilingual glossary of terms. There is an offer of free technical handbooks on safety and EMC and

Please quote "Electronics World + Wireless World" when seeking further information.
thermal management. Computer Products, 0494 883113.

Audio amplifiers. Philips Semiconductors offers the Audio Amplifier Cook Book, which lists audio power devices from 150mW to 50W and contains over 100 pages of application notes, including PCB design. Gothic Crellion Ltd, 0734 788878.

DSP. The DSP Catalogue gives details of what LSI claims to be the world's most comprehensive range of digital signal processing and data acquisition boards and software support, including products for VMEbus, PCbus and Bus. There are also specifications of all the leading DSP chips currently available, including the TI TMS320C40 and Motorola's DSP56002. Loughborough Sound Images Ltd, 0509 231843.

Radio communications products

Microwave link. Designed for secure, point-to-point Ethernet and voice, Diplink 60 from Wadsworth can be installed in less than a day and offers communication between sites up to 1km apart. Beam width is 2deg for invulnerability to movement. Two versions operate at 2Mb/s and 10Mb/s and frequency is 60GHz, at which the equipment is said to be completely safe; an operating licence is supplied with the units. Wadsworth Electronics Ltd, 081-941 4716.

Transducers and sensors

Gas sensors. The Capteur G series of semiconductor selective toxic gas sensors measure ammonia and hydrogen sulphide concentration in the 0-100ppb and 10ppm up to 100%ppm ranges. Unusually, the sensors exhibit a resistance increase in the presence of the target gases, with negligible interference from methane and other toxic gases. Contained in one cubic centimetre, they can be PCB-mounted or in flame-proof enclosures. Circuit diagrams or ready-built interface boards are offered. Capteur Sensors & Analysers, 0235 821323.

Gas sensor modules. Only a 5V reference is required by Nippon Ceramic gas sensor modules to convert gas concentration into a voltage output. An output indicator completes the instrument, which measures air cleanliness of 100-3000ppm hydrogen or carbon monoxide. A chart recorder and up to 100 channels for each copy of the data logger. A graphics program allows custom displays to be designed and another enables RS232 interfacing. The package can be linked to Windows spreadsheets, word processors or database software. Windmill Software Ltd, 061 883 2782.

Development and evaluation

Embedded computer development. Arcrom's Fastcycle-88 is a multi-tasking STBus processor board with the SourceVIEW PC-based debug environment. It works with Borland C or Pascal compilers, the combination optimising Borland's Turbo Debug to produce code for embedded systems. Arcrom Control Systems Ltd, 0223 411200.

Fuzzy logic toolkit. The Togai Infralogic Fuzzy Logic toolkit enables system development for a range of microcontrollers such as the 8051. 68HC11 and 805166. Resulting fuzzy rule base can then be integrated with C code, which can also form part of the rule base, whose output is a defuzzified variable for use in the application. A simulator proves the system, which is then compiled to C code for the processor. A free demo version is available. Hitex (UK) Ltd, 0203 692006.

CAN development. Hitex has a range of development tools for the Controller Area Network protocol, in software and hardware. The range includes the Keil C51 Assembler compiler, Keil RTX51/CAN operating system for the 8051, a Pentium microcomputer card, Hipps51 source-level debugger and the Hitex Telatest 51 emulator. Hitex (UK) Ltd, 0203 692066.

Computer peripherals

Shielded VME bus. Elco's VME bus system provides shielding and data protection and is available in up to eight-layer form for use in many known bus application. Press-fit, multilayer back panels make for optimum capacity and cross talk to adjacent pins is 350mVSS. Ceramic capacitors between slots reduce LF disturbances. Elco Europe Ltd, 0938 664514.

Software

Antenna calculation. A set of programs called RF Tools assists in the production of critical base antenna calculations and tailoring to special requirements. EXPLOT allows precise calculation of beamwidth coverage; PATPLOT displays digitised base antenna patterns; and ANTIPLOT develops patterns for side-mounted base antennas. The programs come on three 5.25in disks, but can be down-loaded free from the company's bulletin board, of which the modem format is 300-1200/2400/9600-N81; telephone Motorola Specialists Co., (US) 0101 216 349-8400.

RF amplifier plotting program. Motorola's Plotting Utility Program disk enables the plotting of RF-amplifier characteristics on Smith chart or polar plots. It will plot input and output stability circles, transition frequency against log frequency and maximum gain in dB against log frequency. Needs an IBM-type PC with a 5.25in, 1.2M drive, a VGA display and dos. The program disk is free. Motorola Inc., (USA) 602 994 6561.
40 serial & 1 parallel ports
4.7 Mhz speed
MS-DOS 4.01
October 1993

with built in power supply! Ideal as exterior drives! £499.00 (F)

5.25" EXTRA SPECIAL BRAND NEW Mitsubishi MF50113
3.5" Mitsubishi MF355C-D. 1.4 Meg. Non laptop

and are fully tested, aligned and shipped to you with a 90 day
(unless stated) are removed from often brand new equipment

leaves the good old ST506 interface standing. In mint condition
standard SMD interface. Ultra hi speed transfer and access time

1.2 meg 5-1/4" floppy
640k RAM expandable with standard SIMMs

_ _

- ELECTRONICS -

1991 Winter Issue of Display News now available - send large SAE - POCKED with bargain:

The TELEBOX consists of an attractive fully cased mains
tuner - - ELECTRONICS -

and RGB video outputs are located on the rear panel for direct

HYPERBAND as used by most cable TV operators. Composite

- ELECTRONICS -

All goods supplied subject to our standard Conditions of Sale and unless otherwise stated guaranteed for 90 days. All guarantees on a return to base

LOW COST PC SPECIALISTS - ALL EXPANDABLE - ALL PC COMPATIBLE

THE ORIGINAL SURPLUS WONDERLAND!

Surplus always

- ELECTRONICS -

October '93 ELECTRONICS WORLD+WIRES WORLD
APPLICATIONS

Are 4Mbit drams a drop-in upgrade?

One megabit drams with pin designations to jdec and eiae standards were designed with upgradability in mind. This applies to both small-outline J-lead and dip package formats. In theory, any PCB layout for a standard 1Mbit chip will work equally well with a 4Mbit upgrade without needing any modification, assuming only 1Mbit needs to be addressed of course.

Standardisation fulfills two needs. Firstly, upgradability is simplified. The only circuit modification needed to address a 4Mbit chip as opposed to a 1Mbit device is to connect an extra multiplexed address line (for the additional two bits) to a previously unused pad. Secondly, standardisation ensures that equipment designs performing adequately with 1Mbit chips will not be forced into redesign or obsolescence when the unit price of a 4Mbit ram chip falls below that of its 1Mbit predecessor.

Electrically however, compatibility is not 100% in all applications. Motorola application note AN1124 discusses possible incompatibilities with refresh and power-up sequences. Both incompatibilities exist because the 4Mbit dram has a different test-mode entry sequence from its predecessor. Because 4Mbit drams have 1024 rows as opposed to 512 for a 1Mbit device, refreshing takes twice as long. Refresh versus operating time is however the same, as the table shows. In common with many contemporary dynamic rams, both 1Mbit and 4Mbit industry-standard parts can be refreshed in a number of ways.

A potential incompatibility between the two device sizes can occur when CAS-before-RAS refresh is used. For a 1Mbit dynamic ram, the state of the write input is irrelevant during a CAS-before-RAS refresh. With 4Mbit devices however, the negated write input must be disabled, i.e. high, to prevent the device from entering test mode. Test mode on a 1Mbit memory is entered in an entirely different manner.

During power up, both 1 and 4Mbit drams need a 200ms pause followed by eight RAS cycles to guarantee proper operation. To prevent a 4Mbit ram from erroneously entering test mode however, these RAS cycles should be either RAS-only or CAS-before-RAS types.

Motorola Ltd, European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP. Telephone 0628 585000.

---

Battery life meter from Chinatown?

In the film Chinatown, Jack Nicholson placed a cheap analogue watch under a parked car's tyre so that he could return at his leisure to find out precisely what time the car departed.

This trick allegedly provided the inspiration for the circuit shown here. The design shown is intended to provide an accurate reading of battery life. Unlike its ancestor however, this new idea provides a read out of battery life. Unlike its ancestor, battery life is hardly affected by the car departing.

To set the "battery-expired" point, a potentiometer is adjusted to the threshold marked on the diagram. Next, the ten-turn potentiometer is adjusted to the threshold where the clock starts operating.

To commission the circuit, the note advises, "remove the power supply, set the clock to 12:00, connect the test circuit and go home". Presumably, connect the test circuit means connect the equipment that the battery normally supplies to the battery's positive and negative terminals.

There is no mention of connecting the same battery or cell to the input terminals shown on the diagram but it is difficult to see how the circuit would operate otherwise.

Among other circuits discussed in Maxim's Engineering Journal Volume 11 are a third-order high-pass filter incorporating a synthetic inductor and two circuits for converting 3V supplies to 5V. There is also a pulse stretcher for capturing pulses down to 1.5ns that, unlike most flip-flop alternatives, will respond to amplitudes down to 100mV.

The bulletin's in-depth article discusses new transconductance amplifiers, culminating in the op-amp circuit.

---

The bulletin's in-depth article discusses possible incompatibilities with refresh and power-up sequences. Both incompatibilities exist because the 4Mbit dram has a different test-mode entry sequence from its predecessor. Because 4Mbit drams have 1024 rows as opposed to 512 for a 1Mbit device, refreshing takes twice as long. Refresh versus operating time is however the same, as the table shows. In common with many contemporary dynamic rams, both 1Mbit and 4Mbit industry-standard parts can be refreshed in a number of ways.

A potential incompatibility between the two device sizes can occur when CAS-before-RAS refresh is used. For a 1Mbit dynamic ram, the state of the write input is irrelevant during a CAS-before-RAS refresh. With 4Mbit devices however, the negated write input must be disabled, i.e. high, to prevent the device from entering test mode. Test mode on a 1Mbit memory is entered in an entirely different manner.

During power up, both 1 and 4Mbit drams need a 200ms pause followed by eight RAS cycles to guarantee proper operation. To prevent a 4Mbit ram from erroneously entering test mode however, these RAS cycles should be either RAS-only or CAS-before-RAS types.

Motorola Ltd, European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP. Telephone 0628 585000.

---

Battery life meter from Chinatown?

In the film Chinatown, Jack Nicholson placed a cheap analogue watch under a parked car's tyre so that he could return at his leisure to find out precisely what time the car departed.

This trick allegedly provided the inspiration for the circuit shown here. The design shown is intended to provide an accurate reading of battery life. Unlike its ancestor however, this new idea provides a read out of battery life. Unlike its ancestor, battery life is hardly affected by the car departing.

To set the "battery-expired" point, a potentiometer is adjusted to the threshold marked on the diagram. Next, the ten-turn potentiometer is adjusted to the threshold where the clock starts operating.

To commission the circuit, the note advises, "remove the power supply, set the clock to 12:00, connect the test circuit and go home". Presumably, connect the test circuit means connect the equipment that the battery normally supplies to the battery's positive and negative terminals.

There is no mention of connecting the same battery or cell to the input terminals shown on the diagram but it is difficult to see how the circuit would operate otherwise.

Among other circuits discussed in Maxim's Engineering Journal Volume 11 are a third-order high-pass filter incorporating a synthetic inductor and two circuits for converting 3V supplies to 5V. There is also a pulse stretcher for capturing pulses down to 1.5ns that, unlike most flip-flop alternatives, will respond to amplitudes down to 100mV.

The bulletin's in-depth article discusses new transconductance amplifiers, culminating in the op-amp circuit.
Op-amp transmits baseband video over 1500m

Although very easy to implement, the high-speed link shown in Fig. 2 achieves exceptional performance. Using new high-performance transconductance op-amps, it provides an interface for transmitting baseband video via a twisted pair over distances up to 1.5km.

Twisted-pair cable is cheaper and more compact than its coaxial counterpart. On the other hand, twisted pair links involve transformers and have limited bandwidth. Without sacrificing the noise immunity of transformer-based twisted-pair transmission systems, this circuit signals down to DC without coupling transformers.

Operating with around 150m of 22 gauge (American) twisted pair intended for burglar-alarm wiring, the circuit attenuates a baseband video 3.58MHz colour burst by about 6dB, Fig. 3. In many cases this will not matter. If it does, overall brightness resulting from ohmic losses is adjusted via $R_1$ and bandwidth can be extended by trimming $C_1$. Figure 4 compares a waveform resulting from $R_1$ and $C_1$ being in their nominal settings.

According to the note, stranded and unstranded twisted pairs exhibit similar bandwidths. Unshielded pairs with low dielectric constant polyethylene or polypropylene insulation offer the highest bandwidth. Gauge of the twisted pair becomes increasingly important as distance increases due to ohmic losses in the cable.

At the driver end, each cable is terminated by 50Ω to ground. Mismatches can degrade video quality but amplifier stability is unaffected since the MAX435 has no feedback.

Versatile fast-charger chip has only three pins

A single three-terminal IC, whose functional diagram is shown here, is capable of fast charging lithium, NiCd, NiMH or lead-acid batteries without any additional components. Called the DS1300, this IC holds its charging parameters digitally in user programmable non-volatile memory. As a result, it can be set up to produce charging characteristics for a wide variety of cell types and sizes.

Primarily designed with portable equipment in mind, the DS1300 handles standard or trickle charging of batteries up to 3.7V, given a 5V input. With a 6V input, maximum battery voltage capability rises to 4.7V.

Throughout the charging cycle, output current can be directly related to battery voltage. With simple chargers, output current falls as battery voltage rises. Most batteries however can handle the same current at all stages in their charge cycle so the gradual decrease in current wastes time.

With the DS1300, output current versus battery voltage is programmable. The device can be programmed to provide constant-current charging until the battery voltage reaches a certain threshold. Alternatively it can be programmed to provide any charge current at any of 32 discrete battery voltages in roughly 37mV steps.

Being TO220 packaged, the device has only three pins— one connecting supply input, one feeding the battery and one providing a ground connection. For programming, the pins are fed with a special access sequence which initiates single-wire communications.

Once initiated for programming, the device can be fed with parameters including power supply range, charge-current load line and trickle-charge rate. An optionally selectable timer provides charge termination after a programmed period. There are also five fully preprogrammed options catering for triple NiCd packs charging at 20 to 100mA.

Dallas Semiconductor, Unit 26, West Midlands Freeport, Birmingham B26 3QD. Telephone 021 782 2959.

Maxim Integrated Products, 21C Horseshoe Park, Pangbourne, Reading RG8 7JW. Telephone 0734 845255.

Figure 2. Video and data transmission via coaxial cabling is expensive relative to twisted-pair alternatives. This simple transmitter and receiver communicates signals over a twisted-pair link up to 1.5km without the bandwidth restrictions of transformer coupling.

Maxim Integrated Products, 21C Horseshoe Park, Pangbourne, Reading RG8 7JW. Telephone 0734 845255.
Using PCB as a current shunt

To keep power losses to a minimum, current-sensing shunts for mosfets passing tens of amps need to drop as little voltage as possible. Purpose designed power mosfet current sensors like the LTC1154/5/6 can detect voltage drops of less than 100mV.

For a mosfet passing ten amps, the resistance needed to develop 100mV is just 0.01Ω. In this example, dissipation is 1W. Resistors with such a low value and capable of dissipating more than a watt can be difficult to obtain, particularly in surface-mount format.

For applications where the accuracy of a special current shunt is unnecessary, Application Note 53 from Linear Technology suggests using a printed circuit board track to provide the necessary voltage drop.

Copper used for PCBs is often expressed in ounces of copper per square foot. The thickness of 1oz copper-clad board is approximately 0.00343cm. Resistivity of pure copper is 1.822μΩ-cm so the 'sheet' resistance of a 0.00343cm thick layer of copper is around 530Ω/square. This means that a density of 50A per 25mm width of copper is approximately 0.010. In this example, dissipation is 1W.

Copper has a rather high positive temperature coefficient of around 0.39%/C. As a result, shunt resistance rises with increasing temperature. In some applications this may be a disadvantage but in others, it will be desirable to reduce the current limit as circuit board temperature rises.

Applications

Using PCB as a current shunt

From Fig. 1, you can see that four connections are made, as is common with power shunts. Two large terminals connect the supply to the power mosfet drain and two sensing terminals provide the voltage drop. The distance between the two sensing terminals is important.

If a long stretch of PCB is unavailable, the resistor can be folded. In this case, the corner resistors should be counted as 0.6 squares since current concentrates at the inside corner, Fig. 2.

Copper has a rather high positive temperature coefficient of around 0.39%/C. As a result, shunt resistance rises with increasing temperature. In some applications this may be a disadvantage but in others, it will be desirable to reduce the current limit as circuit board temperature rises.

Linear Technology, 111 Windmill Road, Sunbury-on-Thames, Middlesex, TW16 7EF. Telephone 0932 765688.

Fig. 1. Resistors with values below 0.1Ω are difficult to find, particularly in surface mount form with power ratings above a few hundred milliwatts. Circuit-board tracks form ideal power shunt resistors where accuracy and power dissipation are not too critical.

Fig. 2. Where board area available for a PCB track low-value resistor is limited, a serpentine layout may offer an alternative. Compared with the straight-line resistor layout, overall length needs to be increased since adjacent corner squares exhibit 0.6 the resistance of their linearly spread counterparts.

Fig. 3. While providing ideas for mosfet switching, these circuits illustrate designs where low-value resistors formed from copper on a PCB could be useful.

a) Here, a low-value resistor senses current to make sure that the mosfet is kept within its safe operating area.

b) Protection circuit for a mosfet switch handling a resistive load. A 10μs delay built into the drain sense circuitry eliminates false triggering due to power supply or load transients.

c) When switching an inductive load, the only additional component needed is a diode to divert stored energy to ground.

d) Capacitive loads need more complex circuitry to cope with the charging and discharging.
e) Inrush current when a lamp turns on can be up to 20 times the rated operating current. In this circuit, the current limit is raised at turn on.

f) To reduce the amount of time that the power mosfet is in short-circuit condition, the delay resistor can be bypassed with a speed-up diode.

g) Simply connecting a resistor protects against reverse battery connection by limiting current.

h) Adding power supply filtering to the IC feed ensures that the 3.5V needed for correct operation remains in the event of a momentary regulator overload.

i) Quad switch designed for a laptop computer. One sensing circuit controls all four outputs, although each may be switched independently.

j) Complete power management system for battery operated equipment. By using an LT1431 reference as the heart of a regulator, a costly switching converter is avoided.
This reference book is divided into five parts: techniques, physical phenomena, materials and components; electronic design and applications. The sixth edition was updated throughout to take into account changes in standards and materials as well as advances in techniques, and was expanded to include new chapters on surface mount technology, hardware and software design techniques, semi-custom electronics and data communications.

Fraidoon Mazda has worked in the electronics and telecommunications industry for over twenty years, and is currently Product and Operations Manager, Generic Network Management, with Northern Telecom. He is the author of six technical books (translated into four languages) and the editor of the Communications Engineers Reference Book published by Butterworth-Heinemann.

Contents:
- Techniques
- Trigonometric functions and general formulae;
- Electric circuit theory; Statistics. Physical Phenomena
- Quantities and units; Electricity; Light; Radiation; The ionosphere and troposphere. Materials and components
- Resistive materials and components; Dielectric materials and components; Magnetic materials; Inductors and transformers; Relays;
- Piezoelectric materials and components; Connectors; Printed circuits; Power sources; Discrete semiconductor devices; Optical digital integrated circuits; Linear integrated circuits; Semiconductor memories; Microprocessors; Application-specific integrated circuits; Electron microscopy;
- Digital design; Software engineering; Digital systems analysis; Control systems; Antennas and arrays; Noise management in electronic hardware; Noise and communication; Computer aided design; Television and sound broadcasting. Applications
- Communication satellites; Point-to-point communication; Fibre-optic communication; The integrated services digital network (ISDN); Local area networks; Radar systems; Computers and their application; Videotape recording; Office communications; Medical electronics.

1006 pages PAPERBACK ISBN 07506 0809 9 £42.50 (inc post & packaging)

Please return to: Lorraine Spindler, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

* Now available to Electronics World & Wireless World readers in paperback.
* Expert coverage of all aspects of electronics
* Over 50 contributors
* For electronic engineers, technicians and students

Please supply me — copies of the ELECTRONIC ENGINEERS REFERENCE BOOK (ISBN 07506 0809 9) @ £42.50 (INC POST & PACKAGING)

Add VAT at local rate
NB ZERO RATE FOR UK & EIRE TOTAL

Business purchase: Please send me the books listed on the accompanying invoice within 30 days. I will attach my business card/letterhead and have signed the form below.

Guarantee: If you are not completely satisfied, books may be returned within 30 days in a resaleable condition for a full refund.

Remittance enclosed £

Cheques should be made payable to Reed Book Services Ltd.

Please debit my credit card as follows:
Access/Master
Amex
Barclay/Visa
Diners
Credit Card No. Exp date
NAME (Please print) ORGANISATION
STREET TOWN
COUNTY POST CODE COUNTRY
DATE TELEPHONE NUMBER
SIGNATURE
T3000

VAT RATES
6% Belgium, 25% Denmark, 5.5% France, 7% Germany, 4% Greece, 4% Italy, 3% Luxembourg, 6% Netherlands, 5% Portugal, 3% Spain. FOR COMPANIES REGISTERED FOR VAT, PLEASE SUPPLY YOUR REGISTRATION NUMBER BELOW (customers outside the EEC should leave this part blank)

VAT NO.

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

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

Credit card orders accepted by phone. Call 081 652 3614.
Implementing a band pass filter on a microprocessor

A hybrid comb FIR filter/second order IIR filter has useful benefits. Allen Brown shows how to implement the hybrid on a general purpose microprocessor.

Digital filters have become regular building blocks in the design of digital based systems. Remarkable roll-off and ease of design and implementation has led to their widespread use. Like their analogue counterparts, they are available in various forms and can suffer from the same problems - pass band ripple and ringing.

Fixed gain digital filters broadly fall into two camps, the finite impulse response (FIR) and infinite impulse response (IIR) filters.

An FIR filter is dependent on the current and the previous input samples: the IIR filter is not only dependent on the current and previous input samples but also on previous output samples. So it is recursive and can suffer from instability problems due to the feedback of output to input. FIR filters on the other hand are unconditionally stable (no feedback) but require more computation (more taps) to achieve the same performance as equivalent IIR filters.

The ideal would be to have the benefits of an IIR filter without the problem of potential instability, achievable by constructing a hybrid of a comb FIR filter and a second order IIR filter.

Under certain conditions this hybrid digital filter can be implemented on a general purpose microprocessor. Normally that is not an option since digital filters require intensive multiplications that cannot be performed efficiently on microprocessors. But the problem can be overcome by eliminating multiplications through ensuring that the digital filter only requires the numerical additions at which microprocessors excel.

A comb filter (Fig. 1) has an input sample...
A comb filter has an input sample sequence \( x(n) \) and an output sequence \( y(n) \) with \( m \) intermediate storage locations for the \( m \) previous input samples. An attraction of the comb filter is its non-recursive nature, in that there are no feedback components which can lead to instability in a filter's operation.

Actual output of the comb filter is the difference in the newest input \( x(n) \) and the oldest \( x(n - m) \) expressed as,

\[
y(n) = x(n) - x(n - m) \quad (1)
\]

Now the behaviour of the filter must be considered in the Z domain, and for this the Z-transform needs to be invoked. Two properties of the Z-transform will be used,

\[
Z\{x_1(n) + x_2(n)\} = Z\{x_1(n)\} + Z\{x_2(n)\} \quad (2)
\]

\[
Z\{x(n - m)\} = z^{-m}Z\{x(n)\} \quad (3)
\]

When the Z-transform is applied to Eq. 1, then

\[
Z\{y(n)\} = Y(z) \quad \text{and} \quad Z\{x(n - m)\} = z^{-m}X(z)
\]

which leaves,

\[
Y(z) = X(z) - z^{-m}X(z) \quad (4)
\]

where \( X(z) \) is the Z-transform of \( x(n) \) and \( Y(z) \) is the Z-transform of \( y(n) \). Eq. 4 can be written as

\[
Y(z) = X(z)[1 - z^{-m}] \quad (5)
\]

The transfer function \( H(z) \) for the comb filter can be defined

\[
H(z) = \frac{Y(z)}{X(z)} = 1 - z^{-m} \quad (6)
\]

Dividing the right hand side by \( z^m \) this equation becomes

\[
H(z) = \frac{z^m - 1}{z^m} \quad (7)
\]

But what are the conditions needed to ensure that \( H(z) = 0 \)? when the right hand side is zero. For this to happen

\[
z^m = 1 \quad (8)
\]

When \( H(z) \) is zero it means that when a signal, whose frequency matches the value of \( z \) is fed into the filter, there is no output from the filter. In the Z plane, all the activity revolves around the unit circle, a circle with a radius of one unit (Fig. 2).

The east point of the circle represents 0Hz and the west point represents the maximum frequency which can be realised in a digital system, and that is half the sampling frequency.

Moving anti-clockwise along the perimeter from east to west is the positive frequency direction: moving east to west clockwise is the negative frequency direction. (In DSP, negative frequencies are just as real as positive ones.) The points at which the transfer function is zero are displayed as small zeros on the unit circle. These are frequencies where there is no output from the filter.

Taking a closer look at Eq. 8 shows that every time Eq. 8 is true then a zero will appear in the comb filter (a zero in the unit circle). From this equation there will be \( m \) zeros in the unit circle (each delay element in Fig. 1 will give rise to a zero in the unit circle). Remembering that \( z \) is a complex number with real and imaginary components, then \( z \) may be expressed as,

\[
z^m = e^{im\theta} = \cos(m\theta) + jsin(m\theta) \quad (9)
\]

For \( z^m \) to be a real, then the imaginary component in this equation must be zero. For this to occur then \( m\theta = 2n\pi \), since \( \sin(2n\pi) = 0 \).

Our comb filter will therefore have \( m \) zeros, equally distributed on the perimeter of the unit circle. So for example if there were four zeros (\( m = 4 \) ), then

\[
x^4 - 1 = (z^2 + 1)(z^2 - 1) = (z + j)(z - j)(z + 1)(z - 1) \quad (10)
\]

The first zero at the south point (\( z = j \), \( -\pi/4 \))Hz), the second zero at the north point (\( z = j, +\pi/4 \) Hz), the third zero at the west point (\( z = 1, -\pi/2 \) Hz) and the forth point at east point (\( z = 1, 0 \) Hz). These are shown on the unit circle in Fig. 2. As the number of delay elements increases in the comb filter, more zeros appear on the unit circle, all equally spaced and closer together. To see what the transfer function of the comb filter looks like in real terms, use the complex conjugate:

\[
H(z) H^*(z) = (z^4 - 1)(z^{-4} - 1) = 2 - (z^4 + z^{-4}) \quad (11)
\]

Since \( z^4 = \frac{e^{4\theta}}{2} \cos(4\theta) = \frac{e^{4\theta} + e^{-4\theta}}{2} \), then

\[
H(\theta)^2 = 2(1 - \cos(4\theta))
\]

A plot of \( H(\theta) \) is shown in Fig. 3, showing...
The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,

\[
H(z) = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1} = \frac{z^2}{z^2 - 2 \cos(\alpha) - 1}
\]  

(13)

The filter will have a second order zero at the origin, but we are now interested in the behaviour of the poles which are on the perimeter of the unit circle. The condition for the filter to remain stable is that its poles must remain within the unit circle. This filter is on the margin of stability, if it is subjected to an impulse it will be excited into an oscillating condition. Now look at the case when $\alpha = 60^\circ$ then $2\cos(\alpha) = 1$, the above equation will therefore become,
NEW

THE DEFINITIVE 'OFF-AIR' FREQUENCY STANDARD

Only £195 + VAT carriage extra

- Provides 100kHz, 1MHz & 10MHz
- Uses 4-bit enabling equipment that relies on quartz crystals, TCXOs, VCXOs, oven crystals
- Please look to PPI 47/107/P several issues controlled and available to NPL
- For MODIFIED step phase lockers ACOV (quartz controlled) and available to OF - Philips plus up to NPL
- British designed and British manufactured
- Now with Nine Wrist Options, output 1 volt into 50Q

ACTION 25P SYNCHRONISING PULSE GEN & 50Q
ENCODER

RADOMETER INFRARED DISTANCE 20x20 500Q
RADOMETER VHF-METER TUL 10MHz
DAVIES 1000 SOUND LEVEL METER 90-120dB
DAVIES MODELLING I&M DETECTOR
HIATTU 55-550 DIGITAL STORAGE
SOUDOR 650 S2 SINGLE TRACE
TEKTRONIX 2105 4-1/2 TRACE, REL, T/S
TEKTRONIX 4205A 4-1/2 TRACE, REL, T/S
TELECONTROLL TSC SINGLE TRACE 50MHz
HP 5860 V-V DISPLAYS

ECG MONITOR SEMICON WITH SEM4001 £75
CARDIAC MONITOR SEMICON WITH SEM4001 £90
HP GMU 5000 REMOTE ELECTROCARDIOGRAPH
HP 500DH REMOTE PAPER RECORDE £100
HP 550H FLUORESCENCE RECORDE £150
HP 58440 32-34 MIDSPAN ATTENUATOR
RADIOMETER AFM2 MOD. METER 7MHz-1GHz
RADIOMETER BKF6 DISTRIBUTION METER 20Hz-20KHz

£375 ea 2695/pr CARDIAC RECORDERS LTD MINIGRAPH TYPE 123 ENCORDER

ACRON 402P SYNCHRONISING PULSE GEN & 605PECG MONITOR SEM430 WITH SEM42012

- Now with Sine Wave Option, output 1 volt into 50Q hybrid, PPM9 microprocessor and PPM8 IEC/DIN -50/+6dB Limiter 3
- Stereo Disc Amplifier 4 *Peak Deviation Meter *PPM5 10 Outlet Distribution Amplifier 4 *Stereo Variable Emphasis
- Stabilizers and Fixed Shift Circuit Boards for howl reduction
- Advanced Active Aerial 1kHz-30MHz *PPM10 In -vision PPM at 90% modulation -44dB, 0.6% (originally 20dB, 10%)
- AM system achieves exceptionally low distortion: THD, 200Hz-6kHz and all the original microprocessor features are retained. The new improvements.
- The receiver is available in free standing or rack mounting form
- Transmitted modulation envelope on an oscilloscope *Mains safety improvements.
- Rechargeable memory and clock back-up *Balanced Audio line gather: from international short wave stations.
- Provides all mode FRG8800 communications receiver and made over 30 modifications to provide a receiver for rebroadcast purposes or checking transmitter performance as well as being suited to communications use and news gathering from international short wave stations.
- The modifications include four additional circuit boards providing *Rechargeable memory and clock back-up *Balanced Audio line output *Reduced AM distortion *Buffered IF output for monitoring transmitted modulation envelope on an oscilloscope *Mains safety improvements.
- The receiver is available in free standing or rack mounting form and all the original microprocessor features are retained. The new AM system achieves exceptionally low distortion: THD, 200Hz-6kHz at 95% modulation -44dB, 0.6% (originally 20dB, 10%).
- *Advanced Active Aerial 4kHz-30MHz *PM10 In-sion PPM and chart recorder *Twin Twin PPM Rack and Box Units
- Stabilizers and Fixed Shift Circuit Boards for howl reduction *10 Outlet Distribution Amplifier *Stereo Variable Emphasis
- Limiter 3 *Stereo Disc Amplifier 4 *Peak Deviation Meter *PPM hybrid, PPM9 microprocessor and PPM8 IEC/DIN -50/+6dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275597. Fax: 276477

LECTRONICS WORLD+WIRELESS WORLD
October 1993
Is there life in cold fusion after Fleischmann and Pons? Andy Wright reports on a growing scientific community that says yes.

Cold fusion looked dead. Fleischmann and Pons were discredited, the public had lost interest, and within a year work published on the subject had been cut to a trickle. Science magazines were jostling to write obituaries.

But now the technology seems to have come back to life, with scientists from Europe, the US and Japan revealing evidence showing that perhaps the two professors were on the right track.

Following the Fleischmann and Pons debacle (see box) cold fusion was starved of funds, with work occasionally carried on in researchers' spare time, and sometimes lacking the scientific rigour demanded by such a controversial topic. But at the Third International Conference on Cold Fusion3, heretics with substantial academic credentials were presenting credible results indicating both the generation of excess heat and nuclear products.

Excess heat
M C H McKubre's group at the Stanford Research Institute in California is funded by the Electric Power Research Institute. Using sealed and pressurised electrochemical cells, they observed excess power between 2 and 50% of the power they put in – with occasional bursts of 350 to 500% of power-in. The excess only occurred when the palladium cathode was highly loaded with deuterium – specifically when \( x \) is greater than approximately 0.9 in the beta phase of the palladium-deuterium system \( \text{PdD}_x \). Other factors are also implicated, but these have not been characterised in detail.

At face value, there seems little room for error. Some 17 electrochemical variables were carefully controlled and the reaction parameters recorded on-line. Great care went into the cell design and electrochemical aspects of the loading process gained close attention. In particular, deuterium loading was carefully monitored \( \text{in situ} \) for the duration of the test so the team could be sure that this was indeed a key condition for excess heat.

McKubre's team is not alone in reporting excess heat. In similar experiments, a group from Osaka University in Japan has recorded 70% excess heat from a cell with a palladium plate cathode. Other experiments using the same method (by E Celani of INFN Laboratory, Frascati, Italy) have also generated 25% excess power.

So, from the Los Alamos National Laboratory in New Mexico, through IMRA in Japan to IMRA SA, France, scientists are independently gaining tantalising glimpses of the effects first noted by Pons and Fleischmann.

Apparently, high deuterium/palladium loading ratios are necessary to create excess enthalpy. But it is also clear that this is not the only significant variable – and still the results are not repeatable on demand.

Fusion physics
Several nuclear fusion reactions have been proposed as cold fusion candidates.

- Deuteron-deuteron fusion
  \[ \text{d} + \text{d} \rightarrow \text{He} + \text{p} + \text{n} \]
  \[ \rightarrow (1.01 \text{MeV}) + (3.02 \text{MeV}) \]

- Deuteron-triton reactions may account for the emission of \( \text{He} \), through the mechanism
  \[ \text{d} + \text{t} \rightarrow \text{n} + 4\text{He} \]

As illustrated in the graph, such fusion has a higher cross-section than \( \text{d} + \text{d} \).

October 1993 ELECTRONICS WORLD + WIRELESS WORLD 869
Furthermore, an explanation involving nuclear reactions requires other corroborative evidence.

**Nuclear products**

Direct observation of nuclear products at ordinary temperatures is more convincing evidence for fusion. Soon after the Pons-Fleischmann bombshell, fusion-generated neutrons were indeed observed in electrolytic cells, though the validity of these observations remains in doubt.

Nevertheless the work has continued. A collaboration between Provo Canyon Laboratory, Utah and the University of Tokyo has recorded small steady emissions of neutrons in an underground laboratory. In Osaka and Rome teams have reported neutron emissions in electrochemical experiments, coinciding with apparent excess heat production. In the Italian experiments, neutrons came in bursts.

Another group, working at NTT Basic Research Laboratories, Tokyo, claims to have identified He-4 coming from deuterated palladium. Early-on in the investigation, large neutron bursts were seen simultaneously with explosive release of gas, with plastic bending of the sample and production of excess heat. Later, ultra-high resolution mass spectrometry indicated the presence of He-4 during evolution of excess heat.

Similarly M F Miles and B F Bush of China Lake, California, have repeatedly correlated He-4 signals with excess heat in electrochemical reactions, though they have not so far been able to make the excess heat production repeatable.

J O'M Bockris of Texas A & M University has reported production of "massive quantities" of tritium at a palladium electrode, accompanied by He-4 production. Thermal expulsion and mass spectrometry by N Hoffman of Rockwell International Corporation confirmed that He-4 was present in nine out of ten specimens—in quantities corresponding to two or three hundred times the background. No helium was present prior to tritium production, implying that the element was synthesised by fusion.

**Pro-cold fusion data suppressed**

Several explanations have been put forward to explain cold fusion. For example, substituting a charged radioactive particle called a muon, particles that could only come from fusion reactions. Most failed, or at least produced cryptic effects.

Some of the most painstaking research was carried out at AEA Harwell under Professor Williams. In three months, seven-days-a-week investigation at a cost some £320,000, the Harwell team found that observations attributed to cold fusion could be artefacts arising from several possible errors. Among defects identified were inadequate controls; imprecise material characterisation; insufficiently thorough calorimeter calibration; problems in distinguishing neutron counts from the background; and well-known spurious effects with $^{19}$F$_2$ and $^3$He proportional counters.

The AEA work was perhaps the turning-point for cold fusion research. While producing an essentially negative result, it also set a tough standard for researchers to follow, concluding: "Claims of observations of cold fusion ought now to meet similar standards of data analysis and materials characterisation, so that a proper assessment can be made."

---

**Cold fusion explosion**

The scientific community was shocked in March 1989, when Professors Pons and Fleischmann announced they had discovered nuclear fusion at ordinary temperatures. Their evidence was production of excess heat during heavy water electrolysis experiments, using a palladium cathode and platinum anode in a simple calorimeter. The only way excess heat could have been produced, it was claimed, was via nuclear reactions between deuterons (heavy hydrogen nuclei).

The reactions just shouldn't happen. After all conventional wisdom is that fusion can only happen at very high temperatures—millions of K—such as the nuclear reactions that fuel the stars. Such energies are needed to bring the nuclei close enough together for fusion. For it to occur in condensed matter, at room temperature, some novel mechanisms must be at work, perhaps as a result of the non-equilibrium conditions.

Spurred on by the possibility of low-cost inexhaustible energy, scientists tried to repeat the experiments, concentrating on verifying the energy-balance calculations and attempting to find nuclear isotopes or

---

Top: AEA Harwell's sixteen 50cc 'Fleischman' cells undergoing excess heat studies. Some of these are control cells. The experiment would normally be covered with an insulated lid.

**Right:** Experimental cold fusion cell structure co-located with neutron and gamma detectors.
200 times heavier than the electron in a hydrogen molecular ion, increases the probability of fusion by around eighty orders of magnitude.

A similar distortion of the wave function between nuclei could arise when deuterons are loaded into a metal lattice, particularly under the special conditions that might occur during electrolysis.

But this amounts to little more than speculation until it is backed by real scientific results.

The lack of reproducibility is not in itself surprising as electrochemical reactions are by their very nature highly sensitive to the state of the surfaces involved. In addition, cold fusion is a notoriously difficult field involving several highly specialised scientific disciplines spanning nuclear physics, materials science, electro-chemistry and instrumentation technology. Nevertheless, it is surprising that none of the pro-cold-fusion data gathered has earned publication in a respectable, refereed scientific journal - arguably publishing data at conferences of fellow enthusiasts does not add to the body of scientific evidence.

So can the latest research pass the scrutiny of the orthodox scientific community? Increased funding, especially from Japan, may produce results. But the fact that so much effort has yielded so few conclusions, gives little room for optimism. The case for cold nuclear fusion remains unproved through lack of reliable witnesses. Unfortunately, on the current evidence it seems unlikely to even reach court.

Inconclusive search: Dr Derek Craston examines data logging equipment used in the calorimetric measurements on 24 cold fusion cells. Despite closely matching the original conditions which were said to have produced excess heat, AEA Harwell’s researchers were unable to duplicate the results.

References
RF REFLECTIONS

Ian Hickman delves into the true effects of matched and unmatched loads, to map the movement of energy in a transmission line.

The maximum power theorem says that a practical power source will deliver the maximum power of which it is capable to a load, when that load is matched – that is, has the same value of resistance as the source's internal resistance. Its corollary is that the internal dissipation in the source is then equal to that in the load $R_L$, giving an overall system efficiency of 50%. This applies at dc, or at ac if reactive components are absent – and even if they are present given certain conditions.

To keep the sums simple, a 1Ω source delivering 1W to a matched load is assumed, except where otherwise stated. But for other value loads, the internal dissipation in the source can be anything from zero to four times that delivered to a matched load.

In practical situations where high system efficiency is desired, eg a flash-lamp or a 500MW turbo-alternator, the load resistance will be much higher than the internal resistance of the source, so that most of the energy finishes up where it is wanted, in the load.

In Fig. 1b the 1Ω source is connected to a transmission line with a 1Ω characteristic impedance, terminated with either a short- or an open-circuit. Either way, 100% of the incident energy is reflected. But the internal dissipation in the source is anything but 2W (1W as with a matched load plus 1W supplied to the line but entirely reflected back by the load).

I had come across this conundrum years before and concluded that what was reflected was basically voltage (and current), and that the question of power had to be deferred until we saw how the reflected voltage combined with the incident voltage at the output terminals of the source.

But this is a wrong conclusion. Looking back into the output terminals of the source you see a matched source, yes: but because of the presence of the ideal voltage generator, a matched load, no.

This difference becomes clearer if we consider what happens in more detail (Fig. 2a), when the source is connected to a loss-free coaxial transmission line 200,000km long.

Velocity of propagation in the line is two thirds that of the speed of light – commonly the case with coax – and on closing switch $S_1$ at time $t = 0$ seconds, the source sees a matched load and delivers 1W to it. After 1s the source has supplied 1J (1watt second) to the line, and its internal dissipation is 1W. At $t = 1s$, the 1V wavefront reaches the load, which we will assume to be an open circuit, but cannot continue any further. Therefore the 1A current in the line must somehow fall to zero at this point, the current being reflected back towards the source.

To cause the current to flow back again against the incident wavefront, the voltage at the open circuit end of the line must rise 2V – the current is reflected in antiphase and the voltage in phase. The 2V step propagates back along the line, arriving at the source at $t = 2s$. Line voltage now equals the source emf so there is zero voltage across the internal source resistance $R_S$ and no current flows in it. The source has effectively disconnected itself at $t = 2s$ exactly, so we can open $S_1$ at $t = 2s$ or any subsequent time without making the slightest difference to the 2J of energy stored in the line.

But if instead of opening $S_1$ at $t = 2s$, we had instead replaced the 2V generator by a short circuit, the source would now look like a matched load and would dissipate 1W during the next 2s, until at $t = 4s$, all the energy reflected from the load would be dissipated in the "source".

Radar transmitter designers uses a line charged up to kilovolts in just this way to feed a short square high power dc pulse to a magnetron.

Avoiding contradictions

It is tempting to think that at $t = 2s$, and thereafter, there is no current in the line and all the energy is stored in the line's capacitance. But this leads to a contradiction, only
avoided by an apparently slightly absurd hypothesis. Namely that there really is a current of IA flowing left to right and another flowing, on the same line at the same time, from right to left, like a train going round the long thin loop of London’s Circle Line - a train so long that its head is hitched up to its tail. This is just a case of a pulse of 1V amplitude and 2s duration circulating in the line and there is no reason why it should not. Consider the case of a 1V pulse of 1s duration, Fig. 3a. Here, the switch connects the line to source for just one second from \( t = 0 \) to \( t = 1 \). Figure 3b shows the state of affairs at various subsequent times.

After the source is disconnected, the pulse bounces back and forth along the loss-free line for ever, the voltage being 1V at \( t = 1, 2, 3... \) seconds, but 2V on half of the line and zero on the other half at 1.5, 2.5, 3.5s.

If total capacitance of the line is \( C \) Farads, then at 1, 2 seconds etc, if the energy were all stored in the line’s capacitance it would total \( \frac{1}{2} C \times 1^2 \) or (numerically) \( C/2 \) joules: at 1.5, 2.5 seconds when the energy is all stored in one half of the line, it would total \( \frac{1}{2} (C/2)^2 \) or \( C/2 \) joules - twice as much! The conclusion can only be that the energy is stored jointly in the line’s capacitance and inductance, which presupposes that current is flowing in the line.

**Sinewave signal**

If the signal supplied to the 1Ω open circuit line were not a dc pulse of whatever duration, but a sinewave, the situation at the open circuit is just the same. Voltage is reflected in-phase and the current in antiphase (Fig. 5). Vectors further down the line (ie to the right in the case of the incident wave and to the left in the case of the reflected) are shown lagging – displaced clockwise – since they will not catch up until a little later. The incident \( v \) and \( i \) vectors are unit vectors, 1V and 1A. It can be seen that at \( \lambda/8 \), the impedance seen looking towards the open circuit is a capacitive reactance equal to \( Z_0 \), or \(-j\lambda\Omega\) in this case. Drawing the diagram for the short circuit case gives \( +j\lambda\Omega \), illustrating the well known fact that

\[
Z_0 = \sqrt{Z_{oc} Z_{se}}
\]

The voltage and current both vary from zero to twice the incident value, at different points along the line, giving a standing wave ratio of infinity to 1. This would apply only on the right half of the 200,000km line at \( t = 1.5s \), if an rf source were connected to the line for just \( 1s \), the rest of the line being devoid of energy travelling in either direction.

As in the dc case, a 2s pulse would fill the line twice over, the standing waves demonstrating that energy was indeed travelling both ways all the time. Hanging a very high input impedance buffer amplifier on one end of the line, would make available – almost indefinitely – a sample of the rf, giving a signal which was greatly "stretched" in time.

Receiving a radar pulse and retransmitting it at low level in such a stretched form is the basis of one type of counter-measure used in electronic warfare. The fact that a line of (about) 200,000km provides a delay of \( 1s \) (ie the signal travels at about two thirds the speed of light) comes about as follows:

\[
Z_0 = \sqrt{\frac{L}{C}}
\]

(see box) where \( L \) and \( C \) are the inductance and capacitance of any length of line.
Increasing the diameter of the inner until it nearly fills the outer would reduce the inductance: the length of the magnetic flux paths would be increased and the cross sectional area available to carry the flux reduced – both effects increasing the reluctance of the magnetic circuit, reducing the total flux caused by the current. But capacitance would be increased, offsetting any gain.

Conversely, moves such as increasing the diameter of the outer could only reduce the capacitance at the expense of increasing the inductance. A fortune awaits the inventor who can half both L and C simultaneously, as the velocity in such a cable would exceed that in free space. Values of L and C per metre in free space are the lowest that can ever be achieved, giving \( v = c \) (the velocity of light) and \( Z_0 = 377\Omega \).

Given that \( Z_0 = 377\Omega \) and \( \beta = 1/c = 3.33\text{ns/m} \), we can find out just what they are, since:

\[
Z_0 \times \beta = \sqrt{LC} \times \sqrt{LC} = L = 377 \times 3.33 \times 10^{-9} = 1256\text{nH/m}
\]

and

\[
\beta / Z_0 = \sqrt{LC} / \sqrt{LC} = C = 3.33 \times 10^{-9} / 377 = 8.85\text{pF/m}.
\]

The value of 8.85pF/m for C is easy to visualise: it is the capacitance of two metal plates each of area \( A = 1\text{m}^2 \) separated by distance \( d = 1\text{m} \) (ignoring fringing). Since \( C = \varepsilon_0 \varepsilon A d \) – and the relative permittivity \( \varepsilon \) for air is unity – then 8.85pF/m is numerically equal to \( \varepsilon_0 \), the value of the permeability of free space \( \mu_0 \).

So \( \beta = \sqrt{\varepsilon_0 \mu_0} \) and \( c = 1/(\sqrt{\varepsilon_0 \mu_0}) \).

That the internal dissipation in the source is apparently
not 2W, when the load reflects 100% of the incident energy, is true of both a Thevenin generator (Fig. 1a) and a Norton generator (Fig. 6a) - at dc. But it is not necessarily so at ac.

When a 1Ω Thevenin generator tries to deliver 1W to a purely reactive load which, at the frequency in question, has a reactance of 1Ω, the internal dissipation is indeed 2W, Fig. 6b. The same is true for the Norton generator. But it would be elegant to find a generator which always dissipated 2W internally. The clue to such an arrangement is the fact that on short-circuit a Thevenin generator dissipates 4W internally while a Norton dissipates zero, and vice versa on open-circuit. Take two 1Ω loads, one receiving 0.5W from a matched Thevenin generator and the other receiving 0.5W from a matched Norton generator, connect them in parallel and the result will be 1W delivered to a 1Ω load from a source, dissipating 2W internally on either short- or open-circuit (Fig. 7a).

2W is also dissipated internally when trying to deliver 1W into any purely reactive load (Fig. 7b). The situation can be a little confusing to envisage without resorting to formal mesh analysis. But the vector diagram is easily derived if the Thevenin and Norton sections are provided with separate jΩ loads, which are subsequently paralleled. Furthermore, for any impedance load with any phase angle, the sources in the two generators always supply a total of 2W between them - any power not finishing up in the load being dissipated internally. I leave algebra to prove this to you.

Compared to a 1Ω 1W Norton generator, the Norton section of the "Hickman type 1" generator (Fig. 7a) has a 1A constant current generator instead of a 2A one, and a 2Ω shunt resistor in place of a 1Ω one. By contrast, in

For a loss free line where \( R = G = 0 \), \( \gamma \) simplifies to \( \beta \), the j in the exponential indicating that it refers to the sine wave's phase, not its exponentially decreasing amplitude. So, if \( R = G = 0 \), then:

\[
\beta = j\omega L \quad \gamma = -\omega^2 LC
\]

and \( |\beta| = j\omega \sqrt{LC} \) at 1 radian/s.

The phase constant is proportional to frequency and has units of radians per unit distance along the line - radians per metre if \( L \) and \( C \) are the inductance and capacitance per metre of the line.

The difference between \( \theta \) and \( \beta \) must be borne in mind. \( \theta \) refers to the continually changing phase of the signal at a fixed point on the line - \( \theta = \alpha t \) where the instantaneous voltage \( V = V_{\text{max}} \sin(\alpha t) \) - the latter to the phase at one point on the line relative to another at the same instant. The Figure shows a sine wave of frequency Hz (f cycles per second) entering a transmission line, the voltage at the input being \( +V_{\text{max}} \) at time \( t = 0 \), which makes it in fact a cosine wave. To see what happens, put a spot of red paint on the waveform at the input at \( t = 0 \), point A in the figure. Then at \( t = 1/f \) later, the next peak B is just entering the line while the spot of red paint is distance \( d \) down the line. Distance \( d \) between successive peaks on the line is the wavelength \( \lambda \) on the line, in the case of coax typically two thirds of the free space wavelength. The phase of the signal at the point on the line where the red spot is now (at \( t = 1/f \)) is lagging that at the input by 2\( \pi \) radians - it won't have caught up until \( t = 2f \), by which time the red spot will be a further distance \( d = \lambda f \) down the line. After 1s, the red spot will have travelled a distance \( \lambda \) down the line, so the velocity \( v \) of the wave is \( \lambda f \text{ m/s} \).

\[ \beta = 1\alpha \sqrt{LC} \]

\( L \) and \( C \) are values for 1 metre of line) has units of radians/metre. Dividing by \( \alpha \) gives the result independent of frequency and has units of (rad/m)/(rad/s) = s/m.

\[ \beta = \sqrt{(LC)} \] has units of seconds delay per metre for the particular cable in question, and the reciprocal of this has units of metres per second, giving \( v = \alpha \beta \) directly.

That excellent if ancient textbook, The Handbook of Line Communications, calls \( v \) the phase or wave velocity, adding darkly, without further explanation, that "the group velocity (ie, the velocity at which energy is transferred along the line) is \( d\alpha/d\beta \)."

In the present case of a transmission line, where \( \beta \) is directly proportional to \( v \) and the ratio is constant so the wave and group velocities are the same and are independent of frequency.
Fig. 7a. Showing the derivation of a Hickman type I generator. This source supplies a total of 2W, dissipating it all internally with either a short- or open-circuit load.

7b. It also dissipates 2W internally with a purely reactive load. In fact, for any load impedance and angle, it always sources 2W, dissipating internally any power rejected by the load.

7c. The Hickman generator type II behaves in exactly the same way.

the Thevenin section, only the series source resistor changes, from 1Ω to 2Ω. From a philosophical point of view there seems an odd lack of symmetry. But this is due to the fact that — in the short circuit case — currents in parallel add, whereas — in the open circuit case — voltages in parallel do not.

Symmetry is restored by taking into account the dual, the Hickman type II generator (Fig. 7c). Here it is a case of voltages in series add, but currents in series do not.

I have not seen this type of generator mentioned in any text book, but almost certainly someone else has invented it already, in which case doubtless a well-informed reader will kindly write in to the Editor, quoting chapter and verse, and the name by which it should rightly be known.

References

FREE TO SUBSCRIBERS
Electronics World offers you the chance to advertise
ABSOLUTELY FREE OF CHARGE!

Simply write your ad in the form below, using one word per box, up to a maximum of twenty words (remember to include your telephone number as one word). You must include your latest mailing label with your form, as this free offer applies to private subscribers only. Your ad will be placed in the first available issue.

This offer applies to private sales of electrical and electronic equipment only. Trade advertisers should call Pat Bunce on 081-652 8339

All adverts will be placed as soon as possible. However, we are unable to guarantee insertion dates. We regret that we are unable to enter into correspondence with readers using this service, we also reserve the right to reject adverts which do not fulfil the terms of this offer.

Please send your completed forms to:
Free Classified Offer: Electronics World, 11th Floor, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS
<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL USED EPROMS ERED AND BLANK CHECKED</td>
<td>£5</td>
</tr>
<tr>
<td>KS82C55-250 SAMSUNG 89/901100 AVAILABLE</td>
<td>£5</td>
</tr>
<tr>
<td>6845 CRT NEW 4164-15</td>
<td>£1</td>
</tr>
<tr>
<td>27C64-25 used/wiped</td>
<td>£1.50</td>
</tr>
<tr>
<td>2817A-20 (2K x8) EEPROM ex eqpt.</td>
<td>£5</td>
</tr>
<tr>
<td>COMPUTER ICS</td>
<td></td>
</tr>
<tr>
<td>TEXTOOL ZIF SOCKETS</td>
<td>£1.60</td>
</tr>
<tr>
<td>TIP 141/2 £1 ea</td>
<td></td>
</tr>
<tr>
<td>BC107 BCY70 PREFORMED LEADS</td>
<td></td>
</tr>
<tr>
<td>2N2907A</td>
<td></td>
</tr>
<tr>
<td>10M245 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
<tr>
<td>I7M6256 18M432 25M000 28M4694 31M4696</td>
<td></td>
</tr>
<tr>
<td>CRYSTALS</td>
<td>£2.20</td>
</tr>
<tr>
<td>18M432000 19M0500 20M0500 38M10000 56M6092</td>
<td></td>
</tr>
<tr>
<td>10M240 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
<tr>
<td>CRYSTALS</td>
<td>£2.20</td>
</tr>
<tr>
<td>18M432000 19M0500 20M0500 38M10000 56M6092</td>
<td></td>
</tr>
<tr>
<td>10M240 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
<tr>
<td>CRYSTALS</td>
<td>£2.20</td>
</tr>
<tr>
<td>18M432000 19M0500 20M0500 38M10000 56M6092</td>
<td></td>
</tr>
<tr>
<td>10M240 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
<tr>
<td>CRYSTALS</td>
<td>£2.20</td>
</tr>
<tr>
<td>18M432000 19M0500 20M0500 38M10000 56M6092</td>
<td></td>
</tr>
<tr>
<td>10M240 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
<tr>
<td>CRYSTALS</td>
<td>£2.20</td>
</tr>
<tr>
<td>18M432000 19M0500 20M0500 38M10000 56M6092</td>
<td></td>
</tr>
<tr>
<td>10M240 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
<tr>
<td>CRYSTALS</td>
<td>£2.20</td>
</tr>
<tr>
<td>18M432000 19M0500 20M0500 38M10000 56M6092</td>
<td></td>
</tr>
<tr>
<td>10M240 10M70000 11M000 12M000 13M000</td>
<td></td>
</tr>
<tr>
<td>13M270 14M000 5M000 5M0688 6M0000 6M400</td>
<td></td>
</tr>
<tr>
<td>8M000 8M488 9M8304 10M240 4M0256 10M368</td>
<td></td>
</tr>
</tbody>
</table>
Cooke International
Supplier of Quality Used Test Instruments

October Sales Offers

**SPECTRUM ANALYSER**
H.P. 141T Display with 8553B and 8552B Plug-ins. Freq 1KHz-110MHz £1200
Tektronix 7603 O’scope R/O Main Frame with 7L5 Spectrum Analyser Plug-in. Freq 20Hz-5MHz with L2 Module 75 ohm complete £2500
H.P. 8649B Signal Generator AM/FM/Pulse 500kHz-512MHz £950
H.P. 8620C Sweep/Oscillator with 86260A Module. Freq 12.4-18GHz £1500

**Tektronix 7603 O’scope R/O Main Frame with 7L5 Spectrum Analyser Plug-in. Freq 20Hz-5MHz with L2 Module 75 ohm complete £2500**

**H.P. 214B Pulse Generator 10Hz-10MHz 100V output £1400**

**H.P. 8640B Signal Generator AM/FM/Pulse 500KHz-512MHz £950**

**H.P. 86241A R.F. Module 3.2-6.5GHz £400**

**H.P. 86290A R.F. Module 2-18GHz £1750**

**H.P. 86242A R.F. Module 5.9-9.0GHz £400**

**H.P. 432A R.F. Power Meter plus Lead and 478A Thermister Mount £175**

**H.P. 3455A Digital Voltmeter 61/2 digit Autorange £375**

**H.P. 8405A Vector Voltmeter 0.5-1024MHz £600**

**Marconi TF2164 P.S.U. 0.30v 4 amp max variable £35**

**Farnell 60/50 stabilised P.S.U. 60v 50 amps £400**

All Prices Exclude VAT and Carriage

---

**PURCHASE FOR CASH**
**SURPLUS - OBSOLETE - REDUNDANT**
EXCESS Stocks of electronic, electrical components/accessories, part processed and/or finished products. Please submit preliminary information or lists for immediate response to:

K.B. COMPONENTS
21 Playle Chase, Gr. Totham, Maldon, Essex CM9 8UT
Telephone: 0621 893204 Facsimile: 0621 893180

---

**AMAZING 486-66 OFFER**
LOCAL BUS GRAPHICS ACCELERATOR, 800 KB RAM, 20MB HARD DRIVE, 3.52 LF 144 FDD, 102 KEY UK KEYBOARD, 12 MONTHS WARRANTY £1099+VAT

Graeme Duncan
COMPUTERS LTD
0444 244498

---

**ADVERTISERS PLEASE NOTE**
For all your future enquiries on advertising rates, please contact Pat Bunce on:
Tel: 081-652 8339 Fax: 081-652 8931
WANTED

High-end Test Equipment, only brand names as Hewlett-Packard, Tektronix, Rhode & Schwarz, Marconi etc. Top prices paid.
Please send or fax your offer to:

RBT ELEKTRONIK
Albert Apelier Weg 8, 2858 Schiffdorf, West Germany
TEL: 01497 73 04
FAX: 01497 73 09

WANTED

Receivers, Transmitters, Test Equipment, Component, Cable and Electronic, Scrap. Boxes, PCB's, Plugs and Sockets, Computers, Edge Connectors.

TOP PRICES PAID FOR ALL TYPES OF ELECTRONICS EQUIPMENT

A.R. Skelley, Electronics, Stockholders,
2 Normans Lane, Rabley Heath, Welwyn,
Herts AL5 9YD. Telephone: 0438 812 193.
Mobile: 0500 214302. Fax: 0438 812 387

ARTICLES FOR SALE

Tektronix, Rhode & Schwarz, Marconi

High -end Test Equipment, only brand

2 Normans Lane, Rabley Heath, Welwyn,
Alter Apeler Weg 5, 2858 Schiffdorf,
A2426EC158M8162 Mul
4CX350A Eimac, used but fully tested
(also Magnetrons, Klystrons, 4CX250/350)

Mobile: 0860 214302. Fax: 0438 812 387

E810F
EIBOF
Klystrons
E810L
GY501
DET23
DET22EL84
DA42 EL81 Mul
CX1140
CV7180
CV6087
CV4024
CV4014
CV2355
CV188I
CV488EF73
inquire.EF39
Please
listed below.ECC88
CT TYPES: ManyECC83PD500
CCS1
C1166
C1149-1
VALVES
D 13.61 I GH
CME1431W
09.110011£61.50DG7-36£12.00CRE1400
1396P
3JP1
CATHODE RAY TUBES
Many other types in stock. Please enquire re any type not listed.

Orders from government departments, overseas etc. most welcome.
Special prices for wholesale quantities.

Minimum order charge of £50 VAT

WANTED

Testing to special quality - Military/CV, low microphony etc available on request

PROFESSIONAL TEST & MEASUREMENT EQUIPMENT

WANTED

and Electronic, Scrap. Boxes,
PCB's, Plugs and Sockets,
Sinclair,
ELECTRONICS EQUIPMENT

WANTED

West Germany

and Electronic, Scrap. Boxes,
PCB's, Plugs and Sockets,
Sinclair,
ELECTRONICS EQUIPMENT

WANTED

TELEPHONE: 081-422 3593 or fax us on 081-423 4009

STEWART OF READING

110 WYKEHAM ROAD,
READING, RG6 1PL.
TELEPHONE: 0734 288041
FAX: 0734 251696.

TOP PRICES PAID FOR ALL TYPES OF SURPLUS TEST EQUIPMENT, COMPUTER EQUIPMENT, COMPONENTS. etc.

ANY QUANTITY

October 1993 ELECTRONICS WORLD+ WIRELESS WORLD 879
SPECTRUM ANALYSERS

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF2910</td>
<td>Non-linear distortion (video) analyser</td>
<td>840</td>
</tr>
<tr>
<td>TF2304</td>
<td>Automatic modulation meter</td>
<td>840</td>
</tr>
<tr>
<td>OA2805A</td>
<td>PCM regenerator test set</td>
<td>840</td>
</tr>
<tr>
<td>8938</td>
<td>Audio power meter</td>
<td>840</td>
</tr>
<tr>
<td>6912</td>
<td>Power sensor 30kHz-4.2GHz for above series</td>
<td>840</td>
</tr>
<tr>
<td>6960/6910</td>
<td>Digital RF power meter 10MHz-20GHz GPIB</td>
<td>840</td>
</tr>
<tr>
<td>67008</td>
<td>Sweep oscillator 8-12.4GHz &amp; 12.4-18GHz</td>
<td>840</td>
</tr>
<tr>
<td>6600A</td>
<td>Sweep generator 26.5-40GHz</td>
<td>840</td>
</tr>
<tr>
<td>6460/6423</td>
<td>Power meter 10MHz-12.4GHz 0.3mW-3W</td>
<td>840</td>
</tr>
<tr>
<td>6460/6420</td>
<td>Power meter 10MHz-12.4GHz 0.3µW-10mW</td>
<td>840</td>
</tr>
<tr>
<td>6140</td>
<td>GPIB adapter</td>
<td>840</td>
</tr>
<tr>
<td>6059A</td>
<td>Signal source 12-18GHz</td>
<td>840</td>
</tr>
<tr>
<td>2956</td>
<td>NMT cellular adapter, latest issue software</td>
<td>840</td>
</tr>
<tr>
<td>2955A/2960</td>
<td>Mobile radio test set with cellular adapter options 30 0 50</td>
<td>840</td>
</tr>
<tr>
<td>2828A/2829</td>
<td>Digital simulator/analyser</td>
<td>840</td>
</tr>
<tr>
<td>2955A/2960 (TACS BAND III opts)</td>
<td>Mobile radio test set</td>
<td>840</td>
</tr>
<tr>
<td>2017</td>
<td>Signal generator counter installed in GPIB-main frame TM5006</td>
<td>840</td>
</tr>
<tr>
<td>TEKTRONIX 496P</td>
<td>As above with tracking generator TR503 &amp; frequency</td>
<td>840</td>
</tr>
<tr>
<td>MARCONI INSTRUMENTS</td>
<td></td>
<td>840</td>
</tr>
<tr>
<td>SPECTRUM ANALYSERS</td>
<td></td>
<td>840</td>
</tr>
<tr>
<td>MANY MORE FULLY RE-FURBISHED, FULLY GUARANTEED TEST INSTRUMENTS AVAILABLE FROM STOCK. PLEASE ASK FOR OUR CURRENT LISTING. WE CAN FAX LISTS &amp; SHIP GOODS WORLDWIDE. HIGH-END EQUIPMENT ALWAYS PREFERRED FOR STOCK. &quot;CALL US NOW&quot;</td>
<td></td>
<td>840</td>
</tr>
</tbody>
</table>

INDEX TO ADVERTISERS

<table>
<thead>
<tr>
<th>Page</th>
<th>PAGE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Distribution (UK) Ltd</td>
<td>IPK Broadcast Systems</td>
<td>Pico Technology Ltd</td>
</tr>
<tr>
<td>Bull Electrical</td>
<td>Johns Radio</td>
<td>Raile Electronics</td>
</tr>
<tr>
<td>Citadel Products Ltd</td>
<td>JFG Electronics</td>
<td>Research Communications</td>
</tr>
<tr>
<td>Chelmer Valve</td>
<td>Kare Electronics</td>
<td>SAJE Electronics</td>
</tr>
<tr>
<td>Dataman Programmers Ltd</td>
<td>Keytronics</td>
<td>Seetrax Ltd</td>
</tr>
<tr>
<td>Display Electronics Ltd</td>
<td>Labcentre</td>
<td>Smart</td>
</tr>
<tr>
<td>Electrovalue Ltd</td>
<td>Langrex Supplies Ltd</td>
<td>SMC Ltd</td>
</tr>
<tr>
<td>Ellmax Electronics Ltd</td>
<td>M &amp; B Electrical</td>
<td>Stewart of Reading</td>
</tr>
<tr>
<td>Flash Designs</td>
<td>Supplies Ltd</td>
<td>Surrey Electronics Ltd</td>
</tr>
<tr>
<td>G H Systems Ltd</td>
<td>M &amp; B Radio (Leeds)</td>
<td>Telnet</td>
</tr>
<tr>
<td>Halcyon Electronics Ltd</td>
<td>Number One Systems</td>
<td>Tsien Ltd</td>
</tr>
<tr>
<td>Ice Technology Ltd</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OVERSEAS ADVERTISMENT AGENTS

France and Belgium: Pierre Mussian, 18-20 Place de la Madeleine, Paris 75008.
United States of America: Joy Fermer, Reed Business Ltd, 205 East 42nd Street, New York, NY 10017 - Telephone (212) 867 2000 - Telex 23627.

THE BEST LOW COST PROGRAMMERS
DESIGNED & MANUFACTURED IN THE UK

SPEEDMASTER 1000
SPEEDMASTER 1000E
UNIVERSAL PROGRAMMER
- Superfast PC based programmer
- Programmes: EPROMS UP TO 8M BIT, FLASH EPROMS, EEPROMS, BPROMS, NVRAMs, MICROs (8748/51), PALs, GALs, EPLDs, PEELs, MACHs, MAPLs, MAX
- Plugs directly into parallel port
- 1000E Version has ROM/RAM emulator built in: 128k (1 Mbit) standard, optional 512K (4 Mbit)

MICROMASTER 1000
MICROMASTER 1000E
UNIVERSAL PROGRAMMER
- Programmes: EPROMS UP TO 8M BIT, FLASH EPROMS, EEPROMS, BPROMS, NVRAMs, PALs, GALs, EPLDs, PEELs, MACHs, MAPLs, MAX etc
- PLUS over 80 different Micros including 8748/51, 68HC705, 68HC711, PICs, Z86, TMS320, TMS370 etc DIPs WITHOUT ADAPTORS OR PERSONALITY MODULES!
- Package adaptors available.
- 1000E Version has ROM/RAM emulator built in: 128K (1 Mbit) standard, optional 512K (4 Mbit)

SPEEDMASTER 8000
GANG/SET PROGRAMMER
- 8 way, PC or stand alone
- Super-fast programming times, manufacturer recommended algorithms
- 32 pin devices as standard
- Support for 8748, 51, TMS370, PIC Micros and 40 pins

WHY BUY AN INFERIOR IMPORTED PROGRAMMER WHEN YOU CAN HAVE A MANUFACTURER APPROVED UNIVERSAL PROGRAMMER/EMULATOR DIRECT FROM ICE TECHNOLOGY!

We offer the best range of low-cost programmers available, now including our unique UNIVERSAL PROGRAMMERS WITH BUILT IN EMULATORS

Unrivalled device support, for example the Micromaster 1000 programmes PICS, Z86, 87C705, 68HC705, TMS370, 77C82 ETC WITHOUT ADAPTORS, as well as the full range of Eproms, PLDs etc supported by all our universal programmers.

Approved by National Semiconductor for their full range of PALs, GALs, and MAPLs - other programmers claiming approval are often only approved for EPROMS - a much less exacting specification!

All our programmers and programme/emulators work off the standard parallel port with any IBM compatible PC, even laptops

Unbeaten programming times: Programme a 27256 in just 5 SECONDS including download and verify.

Easy upgrade path between Models.

FOR MORE DETAILS, DEVICE LIST AND DEMO DISK CALL NOW ON
TEL +44 (0)226 767404 FAX +44 (0)226 370434
ICE TECHNOLOGY LTD, UNIT 4, PENISTONE COURT, STATION BUILDINGS, PENISTONE, S. YORKS, S30 6HG, UK.
The legendary S4 - the smallest, most powerful personal programmer you can buy - and only £495!

Plus V.A.T.

From engine management to Antarctic survey teams, you can find S4s the world over, up and running where the competition is left far behind. S4 gets the job done in every situation you might expect - and quite a few you wouldn't!

**Capabilities**

A 32 pin ZIF socket programs a huge library of EPROMs, EEPROMs and FLASH devices. Dataman S4 programs devices up to 6Mbits and the unique, loadable Library means that new parts can be added quickly without extra cost! Serial EPROMs, 40 pin EPROMs and micro-controllers are all supported with optional modules.

**S4 Emulation**

With Dataman S4's powerful emulation system you see your code running before committing yourself to an EPROM. Simply download your code to S4, press 'EMULATE', and your target system runs, in real time, as if an EPROM was plugged in.

**Internal Processor**

Dataman S4 has its own internal processor and memory, but can also be operated remotely from your PC at speeds up to 115,200 baud. S4 is supplied with a floppy disk containing custom terminal software and a pop-up TSR communications utility.

**Ready to Use**

Dataman S4 is shipped ready to use, complete with a mains charger, emulation lead, write lead, personal organiser/instruction manual, MS-DOS communications software, spare Library ROM - and a 3 year guarantee.

Dataman Programmers Ltd

Credit Card Hotline:
(0300) 320719

for same day dispatch

Dataman Programmers Ltd

Credit Card Hotline:
(0300) 320719