THEORY
The meaning of square law in fets

PC ENGINEERING
A case for CASE tools?

APPLICATIONS
Using an 850MHz op-amp, Lowest noise audio

RF ENGINEERING
Tailoring the IF passband

DESIGN
Micro-controlled programmable power supply

AUDIO
End to amplifier distortion?

BUSMAN'S GUIDE TO I²C
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.

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 £295

THE WORLDS No.1 BEST SELLING UNIVERSAL PROGRAMMING AND TESTING SYSTEM.

* More sold worldwide than any other of its type.
* UK users include BT, IBM, MOD, THORN EMI, MOTOROLA, SANYO, RACAL
* High quality Textool or Yamaichi zero insertion force sockets.
* Rugged screened cabling.
* High speed PC interface card designed for use with all PC models from XT to 486.
* Over 1500 different devices (including more than 100 MPU's) supported.
* Tests and or identifies a wide range of logic devices.

* 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.

CITADEL PRODUCTS LTD
DEPT. WW, 50 HIGH ST., EDGWARE, MIDDX. HA8 7EP.

Phone now on: 081 951 1848/9
A nasty case of slipped disks

Please allow me to share with you a personal dream. All desktop computer operating systems rely on hard disks, which in a world of solid-state electronics, are anachronistic. The majority of computer failures derive from mechanical components. Replacing mechanics with electronics results in faster, more reliable products. I contend that what the desktop computing world needs is not Chicago, Windows NT, Apple's and Acorn's but machines which integrate all aspects of their operation into electronics. Of course, this is not an original thought. Every high street tech shop is alive with things called PDAs - personal digital assistants. These are miniature computer devices which combine all sorts of features which nobody has asked for with a data entry system which nobody wants to use. But they do have technical merit. They contain their operating systems in silicon and are thus probably reliable while their absence of motors reduces power consumption to the point where they can do more than boot themselves up before the battery goes flat. I would like to see a desktop computer, full sized keyboard and a built-in solid state operating system. And, of course, the applications software to run on it. This remains a dream because solid-state storage devices with sufficient capacity do not exist... yet.

Here is the reality. Microsoft and other vendors of computer operating systems have misplaced objectives. First, a few facts. Microsoft has spent more than £100 million developing Windows NT, a true 32-bit operating system designed to subvert the Unix world. As such it provides all sorts of security mechanisms for networked computer applications. However, it occupies no less than 70Mb of disk space and is noticeably slower in use than the already sluggish and restrictive Windows 3.1. On the plus side, it breaks away from the Intel monopoly by being eventually available for PowerPC and other microprocessor architectures. This allows application software to become independent of machine and microprocessor type. Indeed, since IBM opened its doors to merchant chip sales, I would only buy a PC with IBM Inside, preferably the 100MHz Blue Lightning which knocks spots off Intel's Pentium. But that is another story.

Secondly, semiconductor companies think too conventionally. The largest flash eeprom chips, currently some 16Mbit/chip, are guaranteed 100 per cent functional which makes large memory arrays built from them expensive. The concept of wafer scale integration is some 25 years old but derives little interest. In the same way that bad disk exchange - floppy disk. I insist that, if WSI were that easy, it would have been done years ago. Also, a viable computer system requires a low cost data exchange - floppy disk. I insist that, if semiconductor companies directed as much of their effort into memory system function - a founder of Abacus Computers - insists - a founder of Abacus Computers - insists - a founder of Abacus Computers - insists - a founder of Abacus Computers - insists - a founder of Abacus Computers - insists, the ability to buy silicon memory arrays with their own individual chips. My consultant Derek Rowe - a founder of Abacus Computers - insists that if WSI were that easy, it would have been done years ago. Also, a viable computer system requires a low cost data exchange - floppy disk. I insist that, if semiconductor companies directed as much of their effort into memory system function as they put into process technology, WSI could be reality. I also say "smart card". It seems incredible that the computer industry, alone shows virtually no technological progress while making so much money out of inappropriate engineered products. Frank Ogden.
Welcome to the world of DSP.

“A Simple Approach to Digital Signal Processing” is Texas Instruments’ new publication for anyone who needs to know about DSP but who doesn’t have the first idea what it’s all about.

Ideal for students and mature engineers who want to get into the world of DSP, this book gives a very readable introduction to high-y technical subjects such as sampling, filters, frequency transforms, data compression and design decisions.

Unlike other DSP publications, the book is light on complicated mathematics and heavy on diagrams, examples and clear explanations. It also includes a typical development cycle for engineers who need to design and build a DSP system.

Order your copy now and open up a new world of DSP designs. Just mail the coupon below with your cheque to:

Texas Instruments, Black Horse Road, London SE8 5NH, Fax 81 694 0099, Tel. 81 691 9000

This is my order for A Simple Approach to Digital Signal Processing. My cheque for £____ is enclosed.

RF MODULES UP TO 2GHz

GASFET LNAs 5MHz-2GHz
Two-stage. High Q filters. Masthead or local use.
TYPE 9006 Freq. 5-250MHz. B/W up to 40% of CF. Gain 10-40dB variable. 50 ohms. NF 0.6dB ........................................... £105
TYPE 9004 Freq. 250-1000MHz. B/W up to 10% of CF. NF 0.6dB. Gain 25dB, 50 ohms .................................................... £135
TYPE 9004 Freq. 1-2GHz. B/W up to 10% of CF. NF 0.4dB. Gain 20dB, 50 ohms ............................................................. £165
TYPE 9035 Transient protected mains power supply for above amplifiers ................................................................. £56
TYPE 9010 Masthead weatherproof unit for above amplifiers ....................................................................................... £16

PHASE LOCK FREQUENCY CONVERTERS
TYPE 9315 Down converter. Up frequencies 250MHz-2GHz. Clip frequencies 20MHz-1GHz. B/W up to 10MHz. NF 0.7dB. Gain 30dB variable ........................................ £350
TYPE 9316 Up/down converter. Up & clip frequencies 20MHz-2GHz. B/W up to 100MHz. NF 0.7dB. Gain 40dB variable ................................................................. £550
TYPE 9115A Up/down converter. Up & clip frequencies 20MHz-1GHz. B/W up to 100MHz. NF 0.7dB. Gain 60dB variable. Clip up to 10mW + 10dBm AGC. ................................ £650

VOLTAGE TUNABLE DOWN CONVERTER
TYPE 9317 T/l with tune 30% of CF specified in the range 300MHz-2GHz. Clip 70MHz, NF 0.6dB. Gain 60dB. Clip up to 10mW + 10dBm AGC. ........................................ £950

PHASE LOCK SIGNAL SOURCES 20-2000MHz
TYPE 8034 Freq. as specified in the range 20-250MHz. Clip 10mW .......................................................... £194
TYPE 9036 Freq. as specified in the range 250-1000MHz. Clip 10mW ......................................................... £291
TYPE 9038 Freq. as specified in the range 1-2GHz. Clip 10mW .............................................................. £350
TYPE 9282 FM up to 2.75kHz max. Freq. as specified in the range 30-2000MHz. Clip 10mW ........................................ £378

WIDEBAND AMPLIFIERS
TYPE 9301 100KHz-500MHz. NF 20dB at 500MHz. Gain 30dB. Output 12.5dBm, 18mW, 50 ohms ........................................ £165
TYPE 9302 10MHz-1GHz. NF 20dB at 500MHz. Gain 30dB. Output 12.5dBm, 18mW, 50 ohms ........................................ £165
TYPE 9008 Gasfet. 1MHz-2GHz. NF 2.5dB at 1GHz. Gain 20dB. Output 18dBm, 65mW, 50 ohms ........................................ £165
TYPE 9009 Gasfet. 1MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 100mW, 50 ohms ........................................ £165

WIDEBAND LINEAR POWER AMPLIFIERS
TYPE 9246 1 watt output. 100KHz-175MHz. 13dB gain. £192
TYPE 9036 1 watt output. 10MHz-1GHz. 15dB gain. £312
TYPE 9247 4 watt output. 1-50MHz. 13dB gain. £215
TYPE 9051 4 watt output. 10MHz-1GHz. 15dB gain. £215
TYPE 9176 4 watts output. 1-50MHz. 26dB gain. £345
TYPE 9177 4 watts output. 20-200MHz. 26dB gain. £345
TYPE 9178 10 watts output. 1-50MHz. 26dB gain. £304
TYPE 9179 10 watts output. 20-200MHz. 13dB gain. £304
TYPE 9173 20 watts output. 1-50MHz. 13dB gain. £395
TYPE 9174 20 watts output. 20-160MHz. 10dB gain. £395
TYPE 9271 40 watts output. 1-50MHz. 26dB gain. £748
TYPE 9272 40 watts output. 20-160MHz. 10dB gain. £748
TYPE 9660 60 watts output. 25-75MHz. 10dB gain. £898

UHF LINEAR POWER AMPLIFIERS
Tuned to your specified frequency in the range 250-750 MHz
TYPE 9123 500W input, 5 watts output ........................................ £350
TYPE 9124 2-3 watts output, 5 watts output .................................. £510
TYPE 9126 6 watts input, 50 watts output .................................. £1495

Prices 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
FEATURES

BUSMAN'S GUIDE TO I2C....................................24
When system flexibility is more important than access speed, I2C bus provides the ideal choice. Originally designed for communication around a PCB, it is now used as a communication channel between equipment. Design consultant Mike Button reveals why this simple two-wire interface has become so popular.

MICRO CONTROLLED POWER SUPPLY..................12
As well as making output easier to set and read accurately, adding a microprocessor to a power supply increases flexibility. Matthew Rahman and Robin Thick present a fully programmable design based on a Z80, with program code available on disk.

MARCONI'S 200kW TRANSATLANTIC TRANSMITTER...........29
In 1916, Marconi built a massive wireless station for transatlantic traffic representing the world's most powerful spark transmitter. By recreating some of the essential technology, George Pickworth sheds new light on a spark transmitting system with a power conversion efficiency comparable to thermionic tube transmitters.

DISTORTION IN POWER AMPLIFIERS......................41
Douglas Sel1 continues his quest for perfect audio reproduction, discussing an often overlooked aspect of power amplifier design – physical layout.

WORKING WITH PROGRAMMABLE LOGIC...............49
Discrete logic blocks are a hallmark of an old-fashioned design. Don't give people the chance to laugh at yours... Move to generic and gate array logic with Geoff Bostock.

USING RF TRANSISTORS..................................76
Class and bias are important topics in RF amplifier design. Norm Dye and Helge Granberg investigate the relative merits of common base and common emitter configurations for both bipolar and fets.

MAKING A DIFFERENCE TO SQUARE-LAW FETS...........82
According to Michael Williams, the familiar difference between two squares concept could be a route to the perfect fet amplifier, whether for radio or audio applications.

REGULARS

COMMENT.......................................................3
A nasty case of slipped disks.

UPDATE.......................................................4
Will synchronous drains be quick enough? Silicon Valley in space, HDTV debate, Buckyballs for semiconductor film?, Bit reversal speeds up computing 500 times, Plasma promotes clean soldering.

RESEARCH NOTES........................................9

PC ENGINEERING........................................21
Being costly, computer aided software engineering tools have traditionally been the domain of the big user. John Anderson looks at a new package that has a price tag within the reach of small businesses.

DESIGN BRIEF.............................................34
Synchronously tuned IF stages. Ian Hickman describes shaping IF response for instruments and pulse/data receivers; the passband characteristic has a significant effect on its settling time. Settle your IF strip fast...

LETTERS.....................................................46
Sun spots and power lines, Audio cable mythology. Listening versus hearing, EM radiation – killer or cure?

APPLICATIONS.............................................58
Combined notch and low-pass filter. Low noise mic preamplifier with phantom power, Bidirectional coaxial driving. Efficient DC converter, Magnetic current sensor.

CIRCUIT IDEAS...........................................65
Cascode oscillator, Battery backup, 1GHz prescaler, Remote motor control. DC modulator, ESR tester.

NEW PRODUCTS.........................................71
Round up of active, passive and computer components including literature.

In next month's EW+WW: Special bass issue.
Bass reproduction tends to be the single most significant factor in determining the perceived performance of an audio system. Five separate luminaries look for the ultimate in bass reproduction technology. We consider the theory, the practice, the materials, the size, the electronics, the arrangement and the room. A heavyweight investigation for heavyweight bass reproduction.

JANUARY ISSUE IS ON SALE DECEMBER 30
Synchronous drams: better mass memory technology?

A recent announcement by NEC that it is ready to begin production of 16Mbit synchronous drams places the technology on the starting blocks. But it is clear there is little – almost minimal – demand for the devices currently and that future demand will depend on whether it is a practical and cost effective solution for high speed system design.

Conversely under synchronous control of the system clock, the addresses are latched in the dram until the device is ready to deliver the data after a preprogrammed number of clock cycles. During this time the processor can perform other functions.

The synchronous dram has two internally interleaved banks and the row address strobe will need only a single pulse signal while hidden precharge and a programmable burst sequence provide the high bandwidth.

The row address is strobed in on the rising edge of the system clock activating a row or word line. A column address in then latched in after three clock cycles (30ns minimum). A byte of data appears on the outputs after three more cycles are taken to decode the address and deliver data to the output buffers – just six cycles in total.

Synchronous dram can reduce access time further by pipelining addresses. The input latch stores the next address while the dram is processing the previous one.

Burst mode is similar to the old nibble mode in which four bits of sequential data are provided in rapid succession without having to provide new address information. In the synchronous dram however, as much as an entire page, typically 1024-bits, can be provided after the first 60ns access at the rate of one byte every 10ns. This burst mode can also be combined with a wrap feature to give access to strings of data stored both before and after the initial bit location. It will be useful for cache line filling where data tends to have spatial locality properties. The wrap feature has a programmable length of 1, 2, 4 or 8 bytes or a full page.

A further benefit of the interleaving is that active rows in separate banks can emulate a cache; the row is held active and reselected simply by supplying a new column address.

There are many other features such as clock enable/disable which will suspend the device, in its current state and put it into a low power standby mode. Self refresh is also included.

Jedec published the specification for synchronous dram in October. To date the only bus interface contained in the specification is low voltage LVTTL.

According to Desi Rhoden, one of the subcommittee chairmen on the JC42.3 committee which is overseeing the development of synchronous dram, the LVTTL interface is good for 100MHz, but no higher. The committee is therefore looking at other interfaces including GTL, CTT and ECL to raise performance to 200 to 250MHz.

"GTL is under investigation and is not yet proven to work in a system at any reasonable frequency," said Rhoden. "I expect some modifications will be needed. ECL and CTT are also high power alternatives and that doesn't really track well with what we are trying to do. GTL is also actually high power because of all the terminations needed in a system."

All of these interface standards have limited voltage swing in common. Our overall goal is to limit the amount of charge flowing between buffers. So a 4V swing would seem a logical objective. We may have to go for a compromise between all the alternatives to get the kind of performance we want."

Rhoden admits though that 200MHz dram performance is unlikely to be demanded by systems designers for at least two years – pretty much when the current generation of synchronous drams is expected to be in volume production.

The ultimate success of synchronous dram will Depend on whether it can effectively replace a second level cache, which currently relies on expensive sram, and on there being little or no price premium for the chips.

According to some industry experts, how successful synchronous dram is at replacing caches cannot be judged at present because most major systems houses are keeping their conclusions to themselves.

The price issue is more easily judged. Anne West, NEC UK's assistant product manager for memory, says the current price of an ordinary 16Mbit dram is about £50. A 16Mbit synchronous dram will be at least double that initially, "she said. Only market demand will drop that price".

**Simon Parry, Electronics Weekly**
Space for Silicon Valley

If NASA has its way, there will be two Silicon Valleys – one in California and the other in space.

In January of next year, the Space Shuttle will launch the Wake Shield Facility – the first commercial production facility designed to produce near-perfect gallium arsenide wafers while circling the Earth in low orbit.

The space-grown wafers will result in integrated circuits which can run eight times faster than circuits made from silicon and three times faster than gallium arsenide chips made on earth, according to University of Houston researchers.

Conceived by the Space Vacuum Epitaxy Center at the University of Houston and by Space Industries in League City, Texas, the Wake Shield Facility will use molecular beam epitaxy to produce near perfect crystal wafers of gallium arsenide. The gallium arsenide wafers are made by laying down ultrathin layers of molecules in a vacuum.

During the flight, the Wake Shield Facility, a 12ft stainless steel disc, will travel at close to 17,000 miles an hour, pushing the thin atmosphere out of its way and leaving in its wake a vacuum more than 10,000 times purer than the best vacuum chambers on earth.

Because the vacuum created in space is so pure, the crystals will not be contaminated by unwanted atoms, which slow down conduction of electronic signals.

If all goes well in January, NASA is planning to use the Wake Shield Facility to make other thin crystalline films for lasers and superfast computer circuits.

Warning on digital TV

Everyone should move as fast as possible to establish digital terrestrial television services, with simulcasting of existing TV channels in digital and analogue forms starting as early as 1997, and it should also move as soon as possible to an all-digital world. So says a report published last week by city firm Coopers and Lybrand. Co-author Dermot Nolan said existing terrestrial broadcasters are likely to go under if they miss the digital boat.

Picture firms up for digital HDTV

There is still a considerable amount of HDTV research in the pipeline if the recent conference in Ottawa is anything to go by. But a number of the remaining problems stem from the sometimes diverse interests of the broadcast, cable, satellite and computer industries.

For example, to placate the latter, square pixels have been included in the latest North American CIE specification even though the corners will become rounded in the display medium.

The digital TV system is now defined as a four layer model: the picture or image layer; the compression layer; the transport layer; and the transmission layer.

The picture layer defines a strategy that is perhaps future proof, providing for 24, 30 and 60 frames a second with progressive scanning. The long term aim of 1050 lines has been upgraded to 1080 lines with 1920 samples per line.

The compression layer is defined around the MPEG-2 standard, at least as far as the video signal is concerned. It has been decided that Dolby AC-3 at 384Kbit/s suits the North American environment better than the European Musican system. But the final specification may include both as alternative sound systems.

The transport layer relates to the protocol of packetisation, prioritisation and universal headers in the bitstream and is accepted as pure MPEG-2.

And the transmission layer is to be based on quadrature amplitude modulation or vestigial sideband, rejecting the European coded orthogonal frequency division multiplex system.

It was reported at the conference that the MPEG-4 committee is close to producing a draft report dealing with the future needs for audio-visual processing, addressing the applications and operational environment for very low (a few 10s of kHz) bit rate coding.

The introduction of HDTV will mean simulcasting from existing transmission sites and many masts won’t be able to take the extra weight. It poses a particular problem in the US where a substantial number of the 1600 or so US transmitters operate in the vhf band. Because their masts are ageing, it is doubtful if they can meet current construction standards because of the heavier vhf arrays. A similar situation may arise in Europe.

As well as nuts and bolts issues, a significant number of papers dealt with ultra high definition TV – pictures made up from more than 2000 lines and pictures in 3D.

One hardware, German company Digital TV systems showed its ISP500 image sequence processor using up to 16Mbyte of ram. It can store several minutes of real time video images in any format, including high definition versions, under software control.

Geoff Lewis

Diamonds and bucky balls feature in new films

Two newly developed carbon-based films, one diamond and one fullerene C_{60}, are being explored by researchers at Bell Labs for use in microelectronics.

The films have radically different properties. As is well known, diamond is extremely hard with excellent thermal properties. Fullerene C_{60} on the other hand has unique properties that could trigger "thousands of new uses" according to AT&T.

Thin-film diamond, shown in the top photo, makes a highly efficient heat sink for high-power semiconductor lasers such as those used for long distance communications via optical fibres. Derived from soot, fullerene C_{60} has recently been found to be photoresistive and sensitive to ultraviolet light. There may be uses for it in semiconductor manufacture. Earlier research showed that C_{60}, shown in the bottom photograph, becomes superconducting when compounded with potassium or rubidium.
**Significant bits first speeds up digital filters**

Digital signal processing system designers are doing their arithmetic the wrong way round, jokes Professor John McCanny of Belfast University. To prove his point, engineers there have designed an IIR (infinite impulse response) filter chip which is about 500 times faster than a comparable implementation on a programmable DSP.

Samples of the chip were recently delivered to Professor McCanny's team. Manufactured by GEC-Plessey using its CLA70000 series gate array, the IIR chip has a 30MHz clock speed and has five modes, giving filters up to 16th order, and operates on 16bit two's complement data. GPS is considering making the chip one of its standard signal processing products.

The crux of the IIR filter, however, is that the latency is only two clock cycles despite the extensive pipelining employed in the chip's architecture and is independent of word length. The reason is an arithmetic scheme used in the chip's architecture which calculates the most significant bits (MSBs) first - unlike traditional approaches which start at the least significant bit (LSB).

Professor McCanny says MSB-first arithmetic offers significant performance benefits and these are most apparent in high speed systems that require some form of pipelining. "If MSB-first arithmetic is used in a pipeline then, crucially, you do not have to wait until the end of the pipeline to begin using the result," he said. "This is how you can reduce the latency of feedback loops.

The outcome is that for signal processing operations that are recursive in nature (hence which require a feedback loop) the sampling rate can be lower to attain a chosen performance, or the silicon can operate at much higher sampling rates than would otherwise have been possible.

The breakthrough at Belfast University was to realise that MSB-first arithmetic - made possible by use of a signed binary number representation - could be implemented on conventional 'carry-save' arithmetic circuits widely used in digital signal processing systems. Carry-save arithmetic is inherently redundant making it an ideal fit to an MSB first scheme. Also, these circuits need only conventional binary numbers and, hence, would not require special conversion circuitry.

The IIR chip comprises two biquad filter sections (since any order IIR filter can be built from cascaded biquad sections) with each section integrating four multiply-accumulate (MAC) blocks and a shifter circuit. Carry-save and MSB-first arithmetic is used inside the MACs.

The MAC blocks generate the most significant bits of the result after just two clock cycles which can be fed back immediately and used in another computation. For this reason the chip can process two separate data streams allowing two independent fourth order IIR filters to be implemented. Both of them can operate at a sampling rate of 15MHz (corresponding to a clock speed of 30MHz).

Professor McCanny says that the success of the IIR filter chip has proved the concept but there are other benefits to be gained from MSB-first arithmetic. "Signal processing operations usually have some truncation or rounding process after a calculation in which the LSBs are thrown away," he said. "So why start at the LSBs? It would be quicker and less computationally intensive if the MSBs were done first. The arithmetic can also be successfully extended to other mathematical functions such as division and square root extraction. In a processor the multiply operation is typically much faster than division or square root operations," said Professor McCanny.

"But, if you think about it, a square root calculation is inherently most significant digit first. Using our technique we can perform division and square root calculations in times comparable to a multiply operation."

However, Professor McCanny thinks the efficiency of the technique is perhaps its biggest advantage. The filter chip contains 30,000 gates and can perform up to 300 million multiplications and additions per second. That is 10,000 per gate which is impressively high." -- Simon Parry

---

**Plasma leaves soldering out in the cold**

Cold plasma technology can be used to remove organic contaminations from pcbs, eliminating fluxing and post cleaning in production.

The process leaves pcbs clean, dry and solder ready says German firm Grasmann. To work, a vacuum chamber with a pressure of 1000Pa is needed, incorporating a high frequency generator that ionises oxygen and passive tetratluoromethane (CF₄) gas.

This plasma cloud oxidises organic compounds on the solder surfaces leaving them ready for wave soldering. Even small voids are penetrated so that through holes are correctly conditioned.

Low temperatures from 30 to 100°C may be used since the free wavelength of the elemental parts is very high.

This treatment can be used on any components and has no visible effect on plastics surfaces; ram chips are already prepared in plasma for printing.

And the treated solder surface degrades very slowly so that fast transfer between plasma treatment and soldering process is not essential.

Grasmann has developed a two-stage production machine available in the UK from Parkheath of Cardiff. It comprises a plasma preparation unit and a soldering module. The plasma unit can be used separately with an existing inert atmosphere soldering line.

Tests on the process include metallographic analysis, REM photographs, x-ray analysis, temperature cycle, shear, and wetting angle.

The firm describes beta test results as "excellent" saying they resulted in "yields of perfect pcbs as high as could be achieved by conventional methods".

The major benefit though is savings in materials and machine cleaning time, which the firm claims gives a projected payback period of two years.
BULLE'S BULLETIN BOARD

MASSEIVE WAREHOUSE CLEARANCE
FANTASTIC £20.00 REDUCTION

REFURBISHED PC BASE UNITS
COMPLETE WITH KEYBOARD
FROM ONLY £29.00

AMSTRAD 1512 BASE UNITS
GUARANTEED PERFECT WORKING ORDER.

A LOW COST INTRODUCTION TO THE HOME COMPUTER MARKET.

AMSTRAD 1512D
1512 BASE UNIT, 5.25" Floppy Drive and Keyboard. All you need is a Monitor and Power Supply. WAS £49.00 NOW ONLY £29.00 REF: MAG2Z

AMSTRAD 1512D
1512 BASE UNIT AND KEYBOARD AND TWO 5.25" Floppy Drives ALL YOU NEED IS A MONITOR AND POWER SUPPLY. NOW ONLY £39.00 REF: MAG2P1

SOLAR POWER PANELS
3Ft X 1Ft 10Watt Glass Panels
14.5v/700mA
NOW AVAILABLE BY MAIL ORDER
£33.95

PACKAGE AVAILABLE FOR SPECIAL OFFER ORDER ON SPECIFICATION

CIRCULAR NO. 104 ON REPLY CARD

COMMODORE MICRODRIVE SYSTEM
no store device for C64's 4 times faster than disc drives. 10 times faster than hard disk! Complete with unit and US keyboard. £9.95 REF: MAG230

STREET SELLERS you have a quite a few of the above units which are returns as they are quite comprehensive units. They could be used for other projects etc. Let us know how many you need at just 50p a unit (minimum 10)

HEADPHONES 16 ohm These are ex Virgin Atlantic. You may have others at lower prices.

PROXIMITY SENSORS These are small PCB's with what looks like a loudspeaker and sensor LED on one end and lots of components on the other. £3 REF: MAG240

PIR DETECTORS These are very small PCB's with a led and a sensor. £1 each REF: MAG240

OPTICAL CALLER BLUETOOTH cradles look like split wire. Not a very good quality unit. £1 per set REF: MAG240

PIR DETECTORS Made by famous UK alarm manufacturers these are top spec. Long range external units. 12v operation. Light sensor on case and sounder. Price is £15 each REF: MAG240

WINDLIP SELF POWERED RADIO AM/FM radio complete with charger and solar panel for £49.00 REF: MAG2P1

WINDLIP RADIO TRANSMITTER housed in standard working 13A adapter!! (23x23x23mm) and 200w at £20 REF MAG2OP3 (23x23x23mm)

UK SUPPLIERS LASER 2MW helium neon tube Brand new fad spec 30minutes. £15 REF: MAG50

FPO PRINTER ASSEMBLY Made by Amstrad they are ready to plug into a payphone. The units we have generally have the locks supplied to detective agencies etc. 9v battery req'd. £14 REF: MAG6P2

*MINATURE RADIO TRANSMITTER Selling like hot cakes, over a range of up to 200m for garden use or as an educational toy. £3 each REF MAG BP1 2 x P33 ref1 £3.50 REF: MAG30

COMPOSITE VIDEO KIT. Converts composite video into RGB colour and composite output! (works with any TV) complete with power supply and fully cased. Price is just £20 REF: MAG2P4 Also some customer returned units available at £10 each REF: MAG10

PPC MODULE CARDS. These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 REF: MAG9P1

100 WATT MOSFET PAIR Same spec as 2SK343 and 2SB508. £15 each REF: MAG3P2

SUPER SIZE HEATSINK Superb quality aluminium heatsink. 225x150x35mm. 15 fins enable high heat dissipation. No holes! £8 REF: MAG15P4

PIR DETECTOR Made by famous UK alarm manufacturers these are top spec. Long range internal units. 12v operation. Light sensor on case and sounder. Price is £15 each REF: MAG240

THREE WIRE COIN BOX STRIPPER Originally made as some form of energy harvesting project, £3 per unit REF: MAG3P8

SURFACE MOUNT STRIPPER Originally made as some form of energy harvesting project, £3 per unit REF: MAG3P8

EMS TRANSMITTER Back in stock! £4 each REF: MAG4P4

BIRDS MANS CABLES These are 2 core standard black mains cables fitted with a 3 pin plug on one end. £1 each REF: MAG2P1

REMOTE CONTROL PCB These are receiver boards for garage door opening systems. You may have another unit! £4 each REF: MAG4P5

MONO VGA MONITOR Made by Amstrad. refurbished £40 REF: MAG240

CMOS 1244 COLOUR MONITOR Made to work with CPC464 home computer. Standard RGB input so will work with other machines. Refurbished £49.00 REF: MAG2P1

MIKE S HUND TONE DIALLERS Ideal for the control of the garage door opening systems. You may have another use? £4 each REF: MAG3P2

POLICE GRADE HAND HELD TONE DIALLERS Ideal for the control of the garage door opening systems. You may have another use? £4 each REF: MAG3P2

MAGNETIC AGITATORS Consisting of a cased mains motor with a lead. The motor has two magnets fitted to a rotor that spins round inside a loop of wire which is also 2 core insulated and covered magnets supplied complete with any special thing you may have a use for £2 each REF: MAG3P2

POLICE GRADE HAND HELD TONE DIALLERS Ideal for the control of the garage door opening systems. You may have another use? £4 each REF: MAG3P2

SUPER SIZE HEATSINK Superb quality aluminium heatsink. 250x150x35mm. 15 fins enable high heat dissipation. No holes! £9.99 REF: MAG7P1

RELAY CAR POWER CABLES [2 core standard black 2 metre mains power supply and fully cased. Price is £27 REF. MAG27

LOW COST WALKIE TALKIES Pair of battery operated units 2.5km range. £12 per pair REF: MAG8P5

LOW CUTOFF WIRE WALLIES pair of battery operated units with a range of about 200m for garden use or as an educational toy. £3 each pair REF MAG BP1 2 x P33 ref1 £3.50 REF: MAG30

THE ENTIRE RANGE of PC CASES NOW AVAILABLE BY MAIL ORDER
FROM ONLY £29.00

AMSTRAD 1512B
250 PORTLAND ROAD Hove Sussex

MAIL ORDER TERMS: CASH PO OR CHEQUE WITH ORDER PLUS £3.00 POST PLUS VAT.
PLEASE ALLOW 7 - 10 DAYS FOR DELIVERY
TELEPHONE ORDER SERVICE WELCOME
TEL. 0727 128600
FAX. 0727 127777

SOME OF OUR PRODUCTS MAY BE UNAVAILABLE IN THE UK

BULL ELECTRICAL

1994 CATALOGUE OUT NOW

CIRCLE NO. 104 ON REPLY CARD

£49.99

A Hands held personal Gamma and X Ray detector. This unit contains two Geiger Tubes, has a 4 digit LCD display with a Piezo speaker, giving an audio visual indication. The unit detects high energy electromagnetic waves with an energetic output of 30kv e and a measuring range of 5.9999 UV/hr or 10.9999 Nir/h. Supplied complete with handbook. REF: MAG50

January 1994 ELECTRONICS WORLD + WIRELESS WORLD 7
"... there is no doubt that running under Windows puts it ahead of the field and makes it a visually attractive package." Electronics World + Wireless World July 1993

High Quality PCB and Schematic Design for Windows 3/3.1 and DOS

- Supports over 150 printers/plotters including 9 or 24 pin dot-matrix, DeskJet, LaserJet, Postscript, and HPGL. Professional Edition imports GERBER files, and exports GERBER and NC-DRILL files.
- Up to 200,000 pads/track nodes depending on memory. Simple auto-router and schematic capture tools with SPICE compatible net-list output.
- Low cost DOS version (reduced features) also available. Ring for full details!

"Quickroute provides a comprehensive and effective introduction to PCB design which is a pleasure to use" Radio Communication May 1993.

Quickroute is available for Windows 3/3.1 in Professional (£99.00) and Standard (£59.00) editions, and for DOS with reduced features (£39.00). All prices inclusive. Add £5 P+P outside UK.

POWERware, Dept EW, 14 Ley Lane, Marple Bridge, Stockport, SK6 5DD, UK.

Ring us on 061 449 7101 or write, for a full information pack.

Quickroute is available for Windows 3/3.1 in Professional (£99.00) and Standard (£59.00) editions, and for DOS with reduced features (£39.00). All prices inclusive. Add £5 P+P outside UK.

CIRCLE NO. 105 ON REPLY CARD

Electronic Designs Right First Time?

Schematic Design and Capture
Create your schematics quickly and efficiently using EASY-PC Professional. Areas of the circuit can be highlighted on screen and simulated automatically using PULSAR, ANALYSER III and Z-MATCH our simulation and design programs.

Digital and Analogue Simulation
Modify the configuration and change component values until the required performance is achieved.

PCB Design
The design, complete with connectivity, can then be translated into the PCB. The connectivity and design rules can be checked automatically to ensure that the PCB matches the schematic.

Affordable Electronics CAD
EASY-PC: Low cost PCB and Schematic CAD £98.00
EASY-PC Professional: Schematic Capture and PCB CAD. Links to ANALYSER III and PULSAR. £195.00
PULSAR: Low cost Digital Circuit Simulator ~ 1500 gate capacity. £98.00
PULSAR Professional: Digital Circuit Simulator ~ 50,000 gate capacity. £195.00
ANALYSER III: Low cost Linear Analogue Circuit Simulator ~ 130 nodes £98.00
ANALYSER III Professional: Linear Analogue Circuit Simulator ~ 750 nodes £195.00
Z-MATCH for Windows: Smith Chart Program for R.F. Engineers £245.00

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. 106 ON REPLY CARD

CIRCLE NO. 106 ON REPLY CARD
Macho behaviour that could unlock the universe

Three separate groups of astronomers say they have tracked down the mysterious dark matter that is believed to permeate the universe.

Cosmological theory has long suggested that there is much more to space than meets the eye - at least 90% more. So far this dark matter has remained elusive, with evidence for it coming largely from its effect on the universe we can see.

For the cosmos to behave as it does, scientists believe there must be something exerting a pronounced gravitational effect, a phenomenon that dominates the movements of the stars and something that will ultimately determine the fate of the universe.

Charles Alcock, Head of astrophysics at the Lawrence Livermore Laboratory in California, says that current measurements of the mass of our own Galaxy exceed the mass of what we can directly observe by a factor of between 10 and 20. So where is all this "missing mass"?

The first (and obvious) conclusion is that it can not exist in the form of stars or gas clouds, because if it did, it would not be dark. Nor can it exist as dust clouds, because it would periodically eclipse other, more luminous, objects. Cosmologists have therefore proposed the existence of several forms of exotic matter, such as axions, extensive neutrinos and wimps - weakly interacting massive particles.

There is no real evidence that any such particles actually exist. So attention has turned to the search for more conventional forms of dark matter, objects such as planets and defunct stars. Real evidence for the existence of such objects in a halo around our galaxy has led astronomers to coin the memorable acronym for non-radiating things around the galaxy: machos - massive compact halo objects.

Back in 1986, Princeton Astronomer Bohdan Paczynski (with colleagues at the University of Warsaw and the Carnegie Institute in Washington) suggested machos might be detected by an effect called microlensing.

The idea is simple, and depends on a fact recognised earlier this century by Einstein, namely that a gravitational field can act as a sort of converging lens on light from a distant source. Astronomers have already discovered examples of what purport to be two identical stars, but which are actually a single star whose rays are bent along two different paths by the gravity of an intervening galaxy.

Paczynski reasoned that a macho would have a similar but less pronounced effect. Being small, it would not split the image of a distant star completely, but it might modulate its intensity considerably as it passed between that star and Earth. Teams from Australia, France and the USA have all now simultaneously announced the discovery of what appears to be the first observations of microlensing. The groups found their evidence for dark matter from computer analyses of overlapping sky images.

Paczynski's group published its findings in the quarterly journal Acta Astronomica: the US/Australian and French groups gave details at scientific conferences in Italy, followed by publication in Nature (Vol 365, No 6447). The fact that only a few microlensing events have been observed is not surprising, considering the precise alignment necessary. Paczynski calculates that the odds of any star being microlensed is about one in a million - even if 90% of the Universe consists of such stuff.

Ken Freeman of the Australian team at Mt Stromlo observatory says that, for each team to have found a single event strongly suggests that the halo around the galaxy is made up very largely of this kind of object, probably a dim star known as an M-dwarf.

Organic leds offer bright prospects

Organic materials are set to make further inroads into electronic devices, following the announcement of a massive increase in the efficiency of polymer leds.

Polymer leds were first created by a Cambridge group in 1990 using PPV poly (p-phenylene vinylene) sandwiched between electrodes with a forward bias of 14V. This arrangement emitted yellow/green light with an internal efficiency of 0.014%. The system worked, but only just. For every 10,000 electrons injected into the material, only one caused the emission of a photon. Since then, the Cambridge team, from the University Chemical Laboratory and the Cavendish Laboratory, have made a leap forward.

Using ingenious techniques they have raised the efficiency of their polymer light-emitting diodes to 4%, higher than for many inorganic leds.

First step in this search for greater efficiency lay in confining the singlet exciton generated in the polymer when opposite charges meet. In a led, these singlet excitons should ideally decay by emission of a photon. But what they often do is migrate to a quenching site where they decay without emitting any radiation.

Last year the Cambridge scientists published details of a co-polymer system designed to confine the singlet state and prevent non-radiative decay. Efficiency rose to 0.3% and it was possible by clever chemical processing to produce two colour emission (J Am Chem Soc, 1993, Nov 31). Further improvements came about by tackling the fact that, for most semiconducting polymers, holes are much more easily injected than electrons.

Addition of a special electron-transporting layer was one ingenious way by which the team lifted the efficiency figure to 1%. What the Cambridge group have now done is to balance charge injection by chemically increasing the electronegativity of the polymer.

But the most recent development (Nature, Vol 365, No 6447) shows how cooperation between chemists and physicists can bring breakthroughs. Chemists Stephen Moratti and Andrew Holmes used what is called a Knoevenagel condensation to prepare co-polymers with cyano groups substituted along a PPV backbone. Physicists Neil Greenham, Dostal Bradley and Richard Friend then designed a bi-layer device using this material, in conjunction with PPV and stable aluminium electrodes, to produce working leds.

The team attributes the 4% efficiency of the latest devices to the significant charge confinement at the interface between the PPV and the cyano-substituted material.
Could a Magic Flute make you smarter?

Developing a taste for classical music could improve your intelligence... at least for a short while. But don't listen while you work, according to the Center for the Neurobiology of Learning and Memory at the University of California, Irvine, or you could overload your neurones.

The conclusions are the results of studying the IQs of 36 college students before and after they had listened to a variety of audio tapes.

Those who listened to a Mozart piece experienced a temporary IQ boost compared to those who had heard either a relaxation tape or nothing at all. Researcher Frances Rauscher, who led the study (Nature, Vol 365, No 6447) says that the results were conclusive beyond any doubt.

Tests were designed to measure one particular aspect of intelligence - spatial ability - and a typical example would be to imagine how a piece of paper with complex folds would look when unfolded.

All 36 students completed the exercise several times, following a period of silence, after listening to a relaxation tape or after listening to a recording of Mozart's Sonata in D major for two pianos (K448).

The IQ improvements were so marked that Rauscher estimates the odds of it happening by chance are only two in a thousand.

Lots of unanswered questions remain. The team still does not know how long the effect lasts. All that can be said is that it is less than 25 minutes.

Why Mozart boosts IQ is also a mystery. The only hypothesis is that the neuronal firing patterns of the brain in both music and in abstract reasoning skills are similar. So if those firing patterns are simulated by listening to music, then they will be more ready to perform the sort of skills needed for spatial tasks.

Rauscher believes that Mozart is particularly good because the music has a complex structure and is therefore more effective in exercising the relevant parts of the brain. She is now about to undertake experiments to demonstrate another hypothesis: that dull, thumping, repetitive music dulls the reasoning powers.

Eventually the Californian research team plans to carry out studies to find out if a person's taste in music affects the results, and whether musicians differ from non-musicians.

One thing is already abundantly clear; you cannot boost your performance at any task requiring abstract thought if you listen to music at the same time. The reason is quite simply that the nerve pathways become overloaded trying to perform two similar functions in parallel.

So the next time someone claims their irritating tzz-t-t-tazz personal stereo is helping them concentrate - you can now offer at least two good reasons why it won't.
Life found – but is it intelligent?

Of the 60-odd planets, comets, asteroids and moons encountered by our spacecraft, no mission has ever sent back unequivocal evidence of life. But would we recognise ET life, even if it were there?

This was a question tackled by a team of scientists led by Carl Sagan, Director of the Laboratory of Planetary Sciences at Cornell University. The team decided to turn the usual search for life upside down – and look for it on Earth. They did this with the help of an interplanetary probe that swooped in from space and visited the Earth three years ago.

Fiction? Not at all! The probe in question was Galileo, a spacecraft launched primarily to explore Jupiter. To reach the giant planet, Galileo had to head away from earth, then swoop back, using the Earth’s gravitational attraction as a sort of slingshot to gain extra momentum before heading off to the giant planet. It was on this return path that Sagan and his colleagues decided to put its equipment to the test by studying our own planet. They agreed, for the purposes of this study, that life on Earth would be a “hypothesis of last resort”.

Galileo analysed reflected light from the Earth to determine the nature of the atmosphere and the surface chemistry. Sagan says: “We saw the continents of the Earth tainted with a strange pigment that absorbs light in a very special way, just beyond the red end of the spectrum.” The team had discovered chlorophyll, the green pigment in plants.

They also discovered oxygen in the atmosphere, something that would be hard to explain except for the existence of some sort of life processes.

Where Galileo failed to find any trace of life was when it looked for evidence of artificial structures. In the course of examining 4% of the Earth’s surface at a resolution of 1km, nothing was found at all – a cautionary lesson for those who expect to find huge artificial structures on alien planets. But Galileo scored a resounding triumph when it searched the Earth in the radio spectrum.

Scanning the hf region, the probe discovered hundreds of signals with forms of modulation that could not have been generated by any known natural system. These signals, say the scientists, must have been coming from the Earth’s surface because their escape was blocked by ionised layers (the ionosphere) in a way that was dependent on the presence or absence of sunlight.

Reluctantly, the team concludes from the Galileo observations that there must be some sort of intelligent life on Earth. A trivial exercise? Not at all. The real lesson is that if we want unequivocal evidence of life elsewhere in the cosmos, we might as well forget photography and chemistry and concentrate on good old short wave radio!

Making less of a meal of image analysis

In theory a computer can solve any problem given enough processing power. But looking at all the options and choosing the best is a sledge-hammer approach. In the real world, computing power costs money and researchers are for ever striving to develop more efficient software.

At Rochester University in New York, graduate Ray Rimey has been looking at new ways for computer vision systems to analyse images. In the past, researchers involved with artificial intelligence have often overlooked the fact that robots need to be selective in where they put their attention. Ray’s work is devoted to structuring which methods the computer should adopt and in what order.

“A computer only has so much processing power,” says Rimey, “If it needs to solve a problem in a given amount of time, it needs to prioritise. A doctor analysing a patient could run endless tests costing thousands of dollars but it could take so long that the patient could die. Instead, a doctor uses prior knowledge to decide on tests needed to maximise useful information and minimise diagnosis time,” adds Rimey.

Analysing different kinds of place settings for a dining table proved to be a perfect test.

Rimey taught his robot to collect visual clues and sequentially gain confidence in its answer. It could tell, for example, whether the setting is formal or informal and whether it was breakfast, lunch, dinner or desert. The method extends to judging whether the table is messy, how many guests there are, and whether they have begun eating.

The focus of the research is on teaching a processing system how to scan a scene and home in on the most important information. As well as helping set the table, this work is expected to be useful in applications including medical diagnostics and satellite image analysis.

Rimey taught the robot its analysis tricks through extensive programming using decision theory and mathematical constructs known as Bayes Nets. His computer vision system is due to be described in a forthcoming issue of International Journal of Computer Vision.

Honeywell is said to be interested in using Ray’s ideas to analyse infrared images from roving vehicles. Colleagues of his are also interested in tracking moving objects such as trains and cows. Others are investigating decisions involving both observing and interacting with moving objects, namely herding mechanical sheep. We will be following that one closely.

Dinner service – according to researchers at Rochester in New York, place settings are an excellent test of a robot’s analytical capabilities.

Research Notes is written by John Wilson of the BBC World Service.
Microprocessor controlled power supply

Adding a microprocessor brings new meaning to the word power in power supply. This cost-effective design from Matthew Rahman and Robin Thick features a user friendly interface.

This design is for those of you who are fed up with tweaking a potentiometer every time you want to set the voltage on your power supply. As described, the system provides microprocessor control for two positive and two negative output supply lines. By breaking the design down into modules however, any combination of output rails can be created.

The design is economical yet comparable to commercial supplies costing many hundreds of pounds. It originally formed part of a project that we undertook as part of our training as air traffic engineers with the Civil Aviation Authority and is fully tested.

Specifications
When implemented in full, the design allows keypad entry of two independent positive and negative voltage outputs, each programmable to a resolution of 100mV from 0V to 25V. All outputs can deliver nominally about 1.2A across the whole voltage range. Below 18V current capability rises to 1.5A.

Each output can be monitored if need be. By feeding the monitoring information back to the microprocessor, software correction can be applied to the outputs to stop the voltage drifting. This feature also forms part of a digital voltmeter function included in the software.

A standard liquid-crystal display module displays all operations and other information. It is possible to use a larger display without modifying the design, but the software held in ROM may need to be modified.

Other features when the full design is used with our software include audible feedback for the keypad, output voltage tracking and program memories to store all your settings. Single stepping of the voltage from the keypad in either 100mV or 1V steps is also possible.

System overview
At the heart of the design is a Z80 microprocessor with 8Kbyte ROM and 2Kbyte RAM. Figure 1 is a basic block diagram of the microprocessor control unit showing that each voltage output can be independently controlled via a digital to analogue converter, or DAC.

Sampled input voltage is in fact multiplexed and can be any one of the output voltages selected by an analogue switch controlled by the processor. This has the advantage of reducing costs by requiring only one analogue switch controlled by the processor. The liquid crystal display is a 2-line-by-20-character module. We recommend a backlit type but a standard reflective type could easily be used.

Figure 2 shows a block diagram of two of the four voltage regulators used in this design. Channels 1 and 3 are positive outputs while channels 2 and 4 are negative, each with current limited outputs. These circuits will be discussed later.

Microprocessor unit
Figure 3 shows the circuit diagram of the main microprocessor unit and its related control circuits. The circuit is fairly standard and operates as follows.

Clocking of the Z80 CPU. IC1, at 2MHz is performed by the crystal oscillator circuit based on IC2. This frequency is divided down using a ripple counter, IC3, to provide a 125kHz clock for the analogue-to-digital converter. Note that it may be necessary to tweak the variable capacitor C7 to obtain the correct pulse shape for the Z80.

On power-up, the reset line on pin 26 of IC1 is pulsed low by means of C1 and R6. All
unused control pins are taken to the positive supply via 10kΩ resistors. The clock pin is also pulled up via R4 to ensure that the minimum 4.4V is present for a high pulse.

Address and data lines are connected conventionally to the 8K ROM, IC2, and 2K static RAM, IC3. Addresses for these and other devices are decoded by IC7. This IC is a 3-to-8 line decoder dividing the 64K address space into 8Kbyte block outputs, used to select external devices when addressed. The RAM devices are decoded by /C7. This IC is a 3-to-8 line decoder dividing the 64K address space into 8Kbyte block outputs, used to select external devices when addressed. The RAM only occupies 2K of address space and has not been fully decoded for ease of design. As a result, the RAM is shadowed throughout the second 8K block. This is not a problem since nothing else occupies any of that block.

A select line for I/O devices, such as digital to analogue converters, and a line for the LCD are also provided by IC7. A complete memory map of the system is shown under the software explanation later. The RAM is battery backed. It holds data about the system and stores several user settings which need to be retained when the unit is switched off.

To prevent data being corrupted when the main power is not present, Circuit IC8 is powered by the +Vbb supply.

Finally, a free-running 555 timer, IC6, is used to generate a pulse for the processor’s interrupt line, INT. It runs at approximately 12Hz with a very small duty cycle to prevent still being low when the processor completes the interrupt service routine.

Details about the software used are presented further into the article.

**Data input/output**

Figure 4 shows the input/output address decoder for the processor. Decoder IC9 is only

---

### DESIGN

**Fig. 2. Two of the four programmable-voltage regulators.** Channels 1 and 3 are positive, channels 2 and 4 negative, each with current limiting.

**Fig. 3. Main Z80 microprocessor unit with related control circuits.** Address decoding and bussing are straightforward. The 555 timer provides interrupts at 12Hz while the divider produces the signal for clocking the data converter.

**Non-volatile memory option**

For designers wanting to simplify RAM back-up, Xicor manufactures static RAMs with Novstor—a technology that automatically saves the contents of RAM to its own internal EEPROM on power-down and recall them back on power-up. Quoted data-retention time for these parts is a minimum of 100 years and 10^4 write cycle to the EEPROM can be performed. Because they are quite new on the market we have yet to use them in this application, but we don't envisage any problems with them. With these devices, the control gates of IC8 and the battery back-up supply can be eliminated. The Xicor 20C17 could be used as a replacement for the 2764 in our design.
enabled when the I/O select line from the first address decoder IC7 and the memory request line MREQ from the CPU are both active (low). It will then take the address lines A0, A1, and A2 at its inputs and make one of its eight outputs low, selecting the device connected to that output. The I/O devices are therefore mapped to addresses 400016 to 400716.

Input and output devices used in this design are digital to analogue converters, analogue to digital converters and a keypad.

Figure 4 also shows the digital-to-analogue converters, IC14,17, used to generate the control voltage for each of the four regulators circuits. The resistor on each dac, $R_{12}$, is required to load the internal reference voltage and capacitors $C_{2,3}$ decouple the reference. Output from each dac is in between 0V and 2.55V depending on the binary value in its data inputs (0 to 255).

The dacs used here do not have internal data latches so the job of latching the data from the processor is performed by $74L$S373 octal latches, IC10,13, between the data bus and each dac. When the Z80 wants to write data to a dac, its corresponding latch is selected by the address decoder which clocks in the data from the data bus and holds it until changed again by the Z80. The nor-gate IC18 on the clock input pin 11 of each latch ensures that data is changed only when write line WR is low, i.e. when the processor is actually writing.

It is quite feasible to replace these converters with other types, maybe ones that include latches or are more accurate, so long as the addressing is the same.

Lcd module

This design has the added flexibility of using a dot-matrix liquid crystal display, rather than the standard 7-segment led types found on commercial units. With this, the status of all four outputs can be monitored simultaneously and menus can be used when setting up the system. It is also more user-friendly when entering commands on the power supply's keypad.

Our design uses the Hitachi LM032L LCD module, a 2-line-by-20-character display which can be bought for less than £20. Connection of this to the processor is shown in Fig. 5.

You are not restricted to using this particular module, and you may want to use a larger 4-line display or any other Hitachi or Densitron display that has a HD44780 controller IC. We recommend that if you use our software, then the LM032L type or its backlit equivalent should be chosen.

Circuit IC19 acts as an inverter to provide an active high ENABLE line.

Keypad scanning

Rather than use a dedicated keypad scanning chip, we decided that a simple scanning circuit could be used under control from the microprocessor.

Figure 6 shows that the circuit uses just one octal latch IC20 and one octal buffer, IC19. The processor writes data to the keypad latch and reads the result of any key presses by enabling the buffer to transfer data to the data bus. Details of how the software does this will be explained later.

In addition, the latch will control a 'KEYPAD ENTRY' led and a piezo sounder. Buffer IC19 also accepts the BUSY signal from the analogue to digital converter, discussed later.

Layout for the keypad switch matrix can be seen in Fig. 7, with the keypad's legend for each key also shown. The keypad used in our original design was a Maplin 20-way membrane type. Pin connections shown in brackets in Fig. 7 correspond to this particular keypad.
Output voltage regulation

Final output from the power supply is a regulated, current limited supply from 0 to 25V, providing up to 1.5A.

Figure 8 shows the circuit for one positive and one negative output. The positive regulator works as follows. The positive 34V rail from the mains transformer is regulated by a standard monolithic regulator, IC2, programmed to provide 28V. This is a smooth, noise free output and gives protection against overload from the next stage. Devices Tr1, 2 and IC2, form the final output regulator.

Op-amp IC2, takes the control voltage from the dac and amplifies it by 10 to produce an output of 0 to 25V. Transistor Tr1 current amplifies this voltage using the supply from IC2, while Tr2 and R28 form a fold-back current limiting circuit at approximately 1.5A. Feedback is provided by R29 and RV,.

The negative regulator works in a similar way, except that the control voltage is inverted to a negative value by IC2, before being amplified by IC2, Note also that IC2, uses a positive supply of +5V in addition to its -28V supply. The -28V regulator takes its power amplified by /C2,b. Note also that /C2,b uses a feedback circuit of the regulator, which should be multi-turn for improved precision. Should then be adjusted to give this voltage at the output. The same should be done for 5V.

When 15V is entered very little tweaking should be necessary, and the output should be accurate across the range 0 to 25V with an error of 200mV or so. When setting up the outputs, the correction option should be switched off if using our software.

Capacitors C1, and C12 are used for suppressing digital noise from the microprocessor. We found that these were best placed directly entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage generated by the microprocessor unit.

The output that you are trying to set up should be programmed to give a voltage of 25V, by entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage at the output. The same should be done for 5V.

When 15V is entered very little tweaking should be necessary, and the output should be accurate across the range 0 to 25V with an error of 200mV or so. When setting up the outputs, the correction option should be switched off if using our software.

Analogue to digital converter

The analogue to digital converter circuit, Fig. 9, is included so that each output can be monitored by the microprocessor unit. The output that you are trying to set up should be programmed to give a voltage of 25V, by entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage at the output. The same should be done for 5V.

When 15V is entered very little tweaking should be necessary, and the output should be accurate across the range 0 to 25V with an error of 200mV or so. When setting up the outputs, the correction option should be switched off if using our software.

Capacitors C1, and C12 are used for suppressing digital noise from the microprocessor. We found that these were best placed directly entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage generated by the microprocessor unit. The output that you are trying to set up should be programmed to give a voltage of 25V, by entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage at the output. The same should be done for 5V.

When 15V is entered very little tweaking should be necessary, and the output should be accurate across the range 0 to 25V with an error of 200mV or so. When setting up the outputs, the correction option should be switched off if using our software.

Capacitors C1, and C12 are used for suppressing digital noise from the microprocessor. We found that these were best placed directly entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage generated by the microprocessor unit. The output that you are trying to set up should be programmed to give a voltage of 25V, by entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage at the output. The same should be done for 5V.

When 15V is entered very little tweaking should be necessary, and the output should be accurate across the range 0 to 25V with an error of 200mV or so. When setting up the outputs, the correction option should be switched off if using our software.

Capacitors C1, and C12 are used for suppressing digital noise from the microprocessor. We found that these were best placed directly entering it on the keypad. The variable resistor, which should be multi-turn for improved precision, should then be adjusted to give this voltage generated by the microprocessor unit.
Fig. 9. Each of the power supply's four outputs is sampled by an input of this four-channel a-to-d converter. Samples read by the processor can be used for compensating for output voltage variations and for providing a digital voltmeter display.

Fig. 10. Power supply for the system's internal circuits includes battery back-up for the RAM and a 12V rail for fan driving. The POWER_STATE line gates to the RAM's write input to provide write protection.

Fig. 11. Mains isolation and rectification. The toroidal transformer we used was conservatively rated. If a smaller one is used, it should be capable of providing at least 4A per winding.

inted and, if required, corrected for small errors. This allows the inclusion of a digital voltmeter function so that the true output voltages can be shown on the display.

First of all, each output voltage is tapped off and attenuated by a resistor network to give a tenth of its value. Current actually drawn from this tap-off is so minimal that it is perfectly feasible to use a resistor divider.

Variable resistors RV4,7 should be adjusted so that one-tenth of the channel output voltage appears at the input of the analogue switch. This ensures that the conversion will be fairly accurate. Using multi-turn pots improves the precision at which the voltages can be set-up.

Negative voltages are inverted by IC25 to give a positive voltage. Each sample of voltage is decoupled by C15,18 to remove any digital noise. The signals are then fed to analogue switch IC26. Via latch IC28, the microprocessor selects the channel to be converted by the ADC. IC32. The latch also drives the ERROR LED.

The microprocessor tells the ADC when to
Microprocessor controlled power supply - features

- User-friendly interface
- Keypad programming of each output
- Switchable audio feedback for keypad
- Settings remembered from when the unit was last used
- Nine memories for storing different voltage configurations
- Single key stepping of voltage in 100mV or 1V increments
- Tracking of positive and negative channels - user-selectable
- Automatic error correction for outputs - user-selectable
- Digital voltmeter optional display
- Options all menu-driven

start converting and monitors the BUSY line, via IC4. In this way it knows when the ADC has finished converting before reading the sampled data. A 125kHz sample clock is used, derived from the system clock, making a conversion period of approximately 75μs.

In the ZN449 data sheet, it states that the chip needs a negative supply for the talk current of the fast comparator. This is a very low current of about 150μA maximum and can be derived by connecting pin 5 to a -5V supply via an 821S2 resistor. Rather than generate this supply by connecting pin 5 to a -5V supply, an LM317 voltage regulator is used, with R4, to derive -5V from the mains -34V supply. Potentiometer R1/8 should be adjusted for -5V without it being connected to the ADC and R4 to prevent any large voltages appearing at pin 5 of the chip.

Improving the accuracy of conversion can be done by using the pin-for-pin compatible ZN448 or ZN447 ADCs instead of a ZN449 but these tend to be more expensive.

Internal circuit supplies

Nearly all of the internal control circuits run from a single +5V supply, apart from the ADC which has been dealt with above. A battery back-up supply is also required for the RAM, Figure 10 is the circuit for the internal supplies.

First of all, the main +34V has to be reduced to a +5V supply using a toroidal transformer with two 25V windings delivering up to 6.6A each. A smaller transformer will suffice, but it must be able to deliver at least 4A per winding. The 1000μF capacitors are recommended for a smooth supply when drawing large currents.

NiCd type which will probably preserve the data in the RAM for many months without the unit being switched on. While the unit is on, the battery is charged via D1 and R5.

Figure 11 is the mains input and ±34V supply circuit. For stepping down the mains, we used a transformer with two 25V windings delivering up to 6.6A each. A smaller transformer will suffice, but it must be able to deliver at least 4A per winding. The 1000μF capacitors are recommended for a smooth supply when drawing large currents.

Software

A disk is available from EW&W containing all of the software required for a complete system that is even better than commercial systems we have seen. The complete ROM dump is 4Kbyte and contains the features shown in the panel.

In Fig. 12, you can see a diagram outlining the power supply's memory map. The first 8K of address space is taken up by the ROM while the next 8K is occupied by the RAM. Only 2K of which is used). Input/output devices take up the next 8Kbyte but as you can see from Fig. 12, only eight addresses are used. This leaves plenty of room for expansion. The liquid crystal display occupies four addresses from 600016. Remaining address space is free.

Keypad and display

Scanning of the keypad is performed by software, with a bit pattern being sent to the keypad row latch. This pattern is a walking one so that only one row is active at any time. After a row is made active, the program reads the column register to see if any ones appear in the byte that it reads. If not, then the next row is made active until they are all done.

If any of the column bits does contain a one then a key has been pressed in that row. In this case the column bit is rotated so that it can detect in which column the key was pressed. Rotating the bits this way means that the first bit it comes to, it accepts, avoiding any ambiguity if more than one key is pressed.

Now that the program knows the row and the column in which the key was pressed, it can convert this into a key scan code, say between 1 and 20. This can be done by multiplying the column number (0 to 4) by 4 and then adding the row number, assuming a 20-way keypad is used.

This operation is laid out in the flow chart Fig. 13. Suggested layout for the keypad was shown earlier in Fig. 7. Functions of each key is explained in Table 1, along with its key number.

Programming the LCD is pretty straightforward, but we recommend that the data sheet is to hand so that you have access to all of the commands available. The LCD module used here has four addresses, Table 2.

To send a command to the display, you just write a command byte to address 600016. A list of some of the commands, along with their command byte is given in Table 3.

Flow diagrams are shown in Fig. 14 for the processes of writing a character to the display, (a), and sending a command to the display, (b). Our software includes many subroutines for the display functions, taking all of the hard work out of dealing with cursor positions, displaying strings etc.

LED/beeper driving

Both LEDs and beeper are programmed via existing latches. Address and bit numbers of each device are as follows

<table>
<thead>
<tr>
<th>LED/beeper</th>
<th>Addr</th>
<th>Bit</th>
<th>Used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piezo beeper</td>
<td>Addr</td>
<td>4</td>
<td>Used for audio feedback and warnings</td>
</tr>
<tr>
<td>Entry led</td>
<td>Addr</td>
<td>5</td>
<td>Visual feedback for keypad</td>
</tr>
<tr>
<td>Error led</td>
<td>Addr</td>
<td>3</td>
<td>When the system encounters an error</td>
</tr>
</tbody>
</table>

Fig. 12. Outline of the power supply’s memory map. The top 32K is entirely free for expansion. Only eight addresses are used for I/O devices. Many more could be added in this area with a little extra address decoding.
Table 1. Assigning these functions to the power supply's keypad makes for an ergonomical design.

<table>
<thead>
<tr>
<th>Label</th>
<th>Function</th>
<th>Key scan No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command entries...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[CAN]</td>
<td>Cancel current operation</td>
<td>1</td>
</tr>
<tr>
<td>[ENT]</td>
<td>Enter or accept command or entry</td>
<td>5</td>
</tr>
<tr>
<td>[ST]</td>
<td>Store present voltage and tracking settings</td>
<td>6</td>
</tr>
<tr>
<td>[RE]</td>
<td>Recall one of the nine memories</td>
<td>2</td>
</tr>
<tr>
<td>[&lt;&gt;T]</td>
<td>Toggle tracked and independent output modes for channels 1&amp;3 or 2&amp;4, which ever was last selected</td>
<td>7</td>
</tr>
<tr>
<td>[FUNC]</td>
<td>Go into FUNCTION mode. Pressing one of the nine number keys will short cut into a function. Pressing [FUNC] again brings up the function menu.</td>
<td>3</td>
</tr>
<tr>
<td>[UP]</td>
<td>Increments currently selected output by 1V or 100mV, whichever is chosen</td>
<td>8</td>
</tr>
<tr>
<td>[DOWN]</td>
<td>Decrements currently selected output</td>
<td>4</td>
</tr>
<tr>
<td>[CH]</td>
<td>Select another Channel to program. Followed by channel number, 1-4</td>
<td>20</td>
</tr>
<tr>
<td>Numeric entries...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[.]</td>
<td>Decimal point</td>
<td>12</td>
</tr>
<tr>
<td>[0]</td>
<td>Zero</td>
<td>16</td>
</tr>
<tr>
<td>[1]</td>
<td>One</td>
<td>17</td>
</tr>
<tr>
<td>[2]</td>
<td>Two</td>
<td>13</td>
</tr>
<tr>
<td>[4]</td>
<td>Four</td>
<td>18</td>
</tr>
<tr>
<td>[5]</td>
<td>Five</td>
<td>14</td>
</tr>
<tr>
<td>[6]</td>
<td>Six</td>
<td>10</td>
</tr>
<tr>
<td>[7]</td>
<td>Seven</td>
<td>19</td>
</tr>
<tr>
<td>[8]</td>
<td>Eight</td>
<td>15</td>
</tr>
<tr>
<td>[9]</td>
<td>Nine</td>
<td>11</td>
</tr>
</tbody>
</table>

Fig. 13. Key presses are converted to a code between 1 and 20 by 280 software. This is done by multiplying the column number (0 to 4) by four and then adding the row number. Rows are scanned, columns are read. If a key press is detected, column bits are read by rotating to avoid ambiguities.

Table 2. Programming the LCD used for the microprocessor controlled power supply is straighforward. The display has these four addresses.

<table>
<thead>
<tr>
<th>Address</th>
<th>Description</th>
<th>Read/Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>600016</td>
<td>Send command to display controller</td>
<td>Write</td>
</tr>
<tr>
<td>600116</td>
<td>Check if the display is ready or busy</td>
<td>Read</td>
</tr>
<tr>
<td>600216</td>
<td>Send character to display ram</td>
<td>Write</td>
</tr>
<tr>
<td>600316</td>
<td>Read data from display ram</td>
<td>Read</td>
</tr>
</tbody>
</table>

Fig. 14. Writing a character to the display. For sending a command to the display, the routine is identical except that ascii code 600016 is used instead of 600216.
The first things that should be done when the unit is powered up are to initialise any variables and registers and set up the processor’s stack and interrupts. A flow chart for general initialisation is shown in Fig. 15. Initially, the dacs are reset to prevent spurious voltages from appearing at the outputs on power-up. In our software, the outputs are then restored to their previous state before the unit was switched off.

**Figure 16** shows the process involved in entering a voltage for a particular channel. Routines are needed to decode keypad entries and error-check the entries, ensuring no illegal values are entered. This entry would then be converted to BCD for storage and conversion to ascii is required to echo entries to the LCD. Finally, the entered voltage has to be converted to an eight-bit binary number ready for writing to the appropriate dac address location.

**Figure 17** shows the process of sampling a voltage via the analogue to digital converter. First, the analogue switch should be programmed to select the correct input. It may be a good idea to introduce a short delay, of say, a few milliseconds, to allow the voltage to settle. Conversion can then be started by writing any byte to the ADC. The status of the ADC can be monitored by reading bit seven of address 400516. When it is set, data is available for reading at address 400616. This byte is set, data is available for reading at address 400616.

By using the above functions, a more simple and/or digital voltmeter display. Each of the four output channels is routed via an analogue switch to a single analogue-to-digital converter. 

**System initialization**

Comprehensive software on disk

A disk containing software and supplementary information can be obtained by sending a cheque or postal order for £10 plus vat to EW&WW’s editorial offices at the address in the front of the magazine. Included on this disk is the hex dump in various formats — ascii, Motorola, etc. — for downloading into an eprom programmer. There is also a user manual that can be printed out, in various word processor formats and ascii, together with details of how you can obtain a preprogrammed rom. In addition, an assembly listing is included so that you can modify the program. The assembly listing is fully annotated, and is built up from a library of subroutines. This helps the programmer enhance the software easily as all entry and exit conditions are given for most subroutines. The program includes many arithmetic, i/o and display subroutines.

| Table 3. Command codes for display operations. To send a command to the display, you simply write a command byte to address 600016. |
| Clear display and home cursor | 011616 |
| Home cursor | 021616 |
| Set next display data ram address (first line) | 801616+column |
| Set next display data ram address (second line) | C01616+column |
| Cursor off | 0C1616 |
| Display blank (memory retained) | 0A1616, 0B1616 |
| Display on | 0D1616 |

These are just a few options. There are many more relating to storing your own characters, changing the cursor type, shifting data etc and these will be found in the manufacturer’s data.
Proteus software is for PC 386 compatibles and runs under MS DOS. Prices start from £475 ex VAT; full system costs £1495. Call for information about our budget, educational & Windows products. All manufacturers' trademarks acknowledged.

CIRCLE NO. 108 ON REPLY CARD
A suitable CASE for development?

For high-end applications, designing software via effective but expensive computer-aided engineering tools is becoming standard practice. John Anderson looks at Select Yourdon – a new CASE tool within the reach of small businesses.

Most of the software I review is intended to help design hardware. This month’s review discusses a software design tool generically referred to as a computer aided software engineering, or CASE, tool. The term computer aided software engineering describes a range of tools aimed at formally describing and documenting computer software before – and during – its production.

Installation and manual
Called Select Yourdon, the package comes as a single disc together with a 250 page paperback manual. Installation follows the usual windows set-up routine, with the license identification being entered the first time the software is called up.

On running Yourdon I sometimes experienced Windows exception errors, but selecting the ‘ignore’ box started the software. The software was reinstalled to determine whether there had been an error at that stage but to no avail.

Tutorial
The tutorial represents a large section of the manual amounting to over 150 pages. With a volume of material like this, you would expect that the manual would cover the fundamentals of CASE and the ideas behind formal software control methodology. However this is far from the case.

Much of the tutorial is taken up with describing the obvious – how to click on a windows bar, how to insert an object (click on insert) etc. So if you need some background material on this subject don’t expect to learn the technique from the Select Yourdon documentation. On the other hand, there are some good examples in the tutorial, and working through these should give a good idea of how the system operates.

As you would expect, full Windows-style help is available on screen.

Diagrams
Select Yourdon uses two types of diagram – one type for contexts and one for data flow. Context diagrams show how the information flows between the system being specified and the external entities. Data flow diagrams are the primary tool for depicting the functional requirements of the system being analysed. They partition these requirements into processes interconnected by data flows. In a CASE tool, it is this formal decomposition of complex programs into clear routes of data flow that enables formal control over software development and maintenance.

Diagrams are generated by selecting specific data entities from the menu, and then adding the flows between them. The diagrams can be arranged on the screen, and on page, by selecting an item and dragging it with the mouse. Flow lines move accordingly.

Unfortunately, the drawing outlines and the text fonts are not always scaled together properly. This can result in an unpleasant display with the text completely out of proportion to the boxes which should contain it.

Case background
CASE is an embodiment of structured programming methods. It has been developed over the past twenty years in response to the need for better control over software...
Amending software written with a CASE tool is simple. Add modules or other constructs – then specify the flows between them.

projects where reliability is critical - in military, life support or aerospace applications for example.

Edward Yourdon developed the original ideas in the 1970s. He has been so influential in the subject that his name is now synonymous with structured analysis and design.

In the early 1980s two workers, namely Ward and Mellor, developed additional features within the Yourdon framework. These involved control information for data flow diagrams and the use of state transition diagrams to specify dynamic behaviour. These extensions make the Yourdon method applicable to documentation of real time event and multi-tasking systems.

Conclusion

Select Yourdon is a CASE tool for software systems with its roots in the control of large software projects. Its functionality and price however are targeted at more mundane microcontroller systems.

The Windows GUI environment is ideally suited to this type of product. Although the display sometimes looks untidy, the ability to switch quickly between between diagrams and layers is an important part of maintaining the diagrams.

With the Ministry of Defence demanding the use of CASE tools for its real time systems, and pressure from quality systems and life support applications for formal software documentation, Select Yourdon is assured part of a growing market. There are competitive products priced at an order of magnitude more than Select Yourdon. If you need to use formal software control methods with minimal outlay, then this package is well worth considering.

Further reading

Modern Structured Analysis by Edward Yourdon, Prentice Hall.

SYSTEM REQUIREMENTS

Windows 3.1 under MS Dos 5.0
Config.sys must have FILES=40
80386 or 80486 processor
VGA 640x480, 16 colours
3 Mbyte of ram
3 Mbyte hard disc space
Mouse
Windows supported printer

SUPPLIER DETAILS

Manufactured by Select Software Tools, Select Yourdon is available in the UK via Computer Solutions Ltd, 1A New Haw Road, Addlestone, Surrey KT15 2BZ. Tel. 0932 829460. Its price is £495.
Your best design could win you this £2500 H-P Oscilloscope

This Hewlett-Packard oscilloscope combines the feel and display of a tcp 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.

A Hewlett-Packard HP54600A 100MHz digital storage scope could be yours when you write for Electronics World + Wireless World, the journal that design engineers pay to read.

For further details about our quest for the best call or write to:
Frank Ogden, Editor, ELECTRONICS WORLD
Quadrant House, The Quadrant, Sutton
SM2 5AS Tel 081-652 3128
The I²C approach to distributed processing allows the designer to include every kind of processing and signal conditioning function on a simple two-wire bus. This proprietary Philips concept is so flexible and accommodating that other semiconductor companies have adopted it and added to the function range. Design consultant Mike Button* reveals the secrets of its success.

**BUSMAN'S GUIDE TO I²C**

The low cost of microprocessor devices makes it common sense to provide future compatibility in all but the most trivial of designs. Consequently the majority of electrical and electronic circuits employ the ubiquitous microprocessor to implement logical functions. With the advent of the microcontroller with on-chip prom or eprom in the 70’s, single chip solutions are now a norm.

Control functions, often involving human reaction times, are the norm in the majority of systems. The high speed data transfer rate of an 8-bit parallel data bus is likely to be unnecessary and expensive. A simple, two-wire serial interface often provides enough performance for a surprising range of applications.

The Inter-Integrated Circuit Bus, written I²C for short and pronounced "I squared C", was invented and patented by Signetics and Philips and has become a de facto standard in chip to chip and board to board communication. Due to Philips' involvement in audio, television and telecoms, a legion of I²C bus devices is now available. Other semiconductor manufacturers are also making devices for the bus.

The range includes 8-bit data converters, adc/dac, audio frequency generators, clock timers, ram, eprom, led/lcd display drivers and a range of audio, radio and television control circuits. Several microcontrollers have on-chip hardware to ease programming and relieve the processor of software overheads. The PCB8XC552 and PCB8XC652 are of particular note.

The ability to add more master devices at any time puts great power at the finger tips of a system designer. When the microcontroller software becomes overloaded additional microcontrollers can be added. Alternatively external test equipment can contain a master and slaves to exercise, test and report on system functionality. In control functions where response time in the order of 1ms is acceptable, the I²C bus provides a convenient adaptable and low cost solution.

**Definitions**
The I²C bus is a bi-directional two wire serial bus having a defined protocol which allows data transfer between compatible integrated circuits. The number of devices that can be added and controlled is limited by the bus frequency and the maximum addressing size. 

*TDR Ltd.
attached to the bus is limited only by the bus capacitance. The bus is so designed that the addition or removal of a device will not affect the working of any devices still on the bus. Philips defines the bus as multi-master, multi-slave working.

The standard-mode of operation can handle data and clock signals at baud rates up to 100kHz. Fast-mode devices are now being made available that will work at 400kHz. The low speed mode is used when microprocessors need to poll the bus in software. A 10-bit address mode was recently introduced to provide more independent slave addresses. All modes of operation conform to the same protocol and provide enhancements for use in special cases.

The I²C bus uses two leads plus a common (earth) return. The SCL lead carries the clock pulses, the SDA lead carries the data information. Commencement of a data transfer is indicated by a START condition [S]. The end of transfer is indicated by a STOP condition [P].

Data is transferred in a 9-bit word, comprising of eight data bits plus an acknowledge bit. The acknowledge signal, ACK, is sent after every data byte to indicate that data transfer may continue. The NACK (not ACK) signal indicates that no further data transfer is possible and a STOP or repeated START condition should be sent. The device that generates the START and STOP conditions and provides clock pulses is called a MASTER. Devices that respond to a MASTER are called SLAVES.

All SLAVES devices are provided with a unique SLAVE ADDRESS. A MASTER, wishing to transfer data to or from a SLAVE must, prior to data transfer, generate the address appropriate to the required SLAVE. A SLAVE on recognising its own address will generate an ACK signal.

The device that sends data is called a TRANSMITTER. Conversely, the device that accepts data is called a RECEIVER. Except for the condition when a SLAVE acknowledges its own address, it is the RECEIVER that generates the ACK signal.

Thus an I²C bus device can be any one of four types dependent on its function during data transfer. The majority of devices produced for the bus are slave devices and can be either transmitters or receivers dependent on function or mode of operation. The master function is normally provided from a microprocessor with an I²C bus controller chip (PCD8584) or a microcontroller with on-chip I²C bus hardware.

Hypothetical complex microcontroller system

The I²C bus provides a two-wire communications channel for both commands and data for all elements of the system. It replaces a multiple line address/data bus with consequent savings in PCB complexity and area. It was designed as a simple communications channel between individual ICs but is increasingly used as a local network between systems, providing they are not speed sensitive.

System inputs may include: converted analogue to digital signals from transducers such as temperature sensors, analogue joysticks, etc. and logical signals from level switches, key contacts, etc.

Transducer outputs may include: converted digital to analogue signals to drive motors, current loops, etc. digital signals to switch relays or lamps and drivers for led or led displays. Special functions such as television receiver channel selection or teletext reception and display may also be included.

Electrical properties

The electrical connections to the I²C bus rely on open collector wired and-logic gating. Both the SDA and SCL leads have the same electrical configuration.

Figure 1 shows a typical bus connection for one of the wires (SCL or SDA). If all the device transmitters (devices 1..n) are at logic-high the bus wire will be pulled high to VCC (normally but not necessarily +5V) via the bus pull-up resistor. All of the device receivers will see this high state on the bus as a logic-high signal. If any of the device transmitters go to logic-low the bus wire will be pulled to ground potential and all of the device receivers, including the receiver of the device

Electrical and logic circuit of the SDA & SCL leads. The wired-and connection allows each device to simultaneously monitor the bus while transmitting data. When a device transmits a logic-high it expects to see a logic-high on its input, if a logic low is received then another device is using the bus.
Data transfer under I²C

Start and stop conditions shows the relationship of the start, repeated start and stop conditions on the SDA lead with reference to the SCL Lead. The repeated start condition is used when a master needs to retain control of the bus during a combined write/read transfer, for example, when accessing a memory device.

Addressing a slave receiver. Shows waveform to write to slave address A0. (Eeprom PCF8582). Note that the SDA lead is low (write) during the 8th SCL clock pulse. The ACK signal, during the 9th SCL clock pulse is generated by the slave.

Arbitration. When a master sends a start condition it must check the bus for arbitration. The waveform shows two masters starting at the same time. The first master to send a logic-low on the SDA lead when the other master sends a logic-high wins the arbitration. In the waveform above master 1 is attempting to address slave 1011 010 and master 2 addresses slave 1011 001. Master 1 loses arbitration on clock pulse 6 and releases the bus. (Leaves the SDA lead high).

SDA & SCL lead DC requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard Mode</th>
<th>Fast Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low level input voltage</td>
<td>$V_{IL}$</td>
<td>0.3$V_{DD}$</td>
</tr>
<tr>
<td>High level input voltage</td>
<td>$V_{IH}$</td>
<td>0.7$V_{DD}$</td>
</tr>
<tr>
<td>Low level output voltage at 3mA sink current</td>
<td>$V_{OL}$</td>
<td>0</td>
</tr>
<tr>
<td>Input capacitance, each lead</td>
<td>$C_{i}$</td>
<td>10 pF</td>
</tr>
</tbody>
</table>

I²C bus line length limitations

Because of the non active pull-up feature of the wired-and bus, the capacitance on each of the bus wires restrict both the number of devices connected and the working distance. This capacitance comprises of the total input capacitance of the connected devices and the bus wire leakage capacitance. The minimum value of the pull-up resistor is defined by the maximum low level sink current of the devices. It may also be necessary to provide a resistor in series with each device to provide input protection against voltage spikes on the bus.

Data sheets for all of the Philips devices give information on how to calculate the pull-up and series resistor values for a given bus. To obtain maximum distance the pull-up resistor should be a minimum value, without series resistor. With a 5V system and 3mA maximum sink current the minimum value of the pull-up is 1.7kΩ (5.1V/3mA).
## SDA and SCL lead timing requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Standard Mode</th>
<th>Fast Mode</th>
<th>Philips Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCL clock frequency</td>
<td>fCL</td>
<td>0</td>
<td>400</td>
<td>fSD</td>
</tr>
<tr>
<td>Low period of SCL clock</td>
<td>fLC</td>
<td>4.7</td>
<td>1.3</td>
<td>fLLOW</td>
</tr>
<tr>
<td>High period of SCL clock</td>
<td>fHC</td>
<td>4.0</td>
<td>0.6</td>
<td>fHIGH</td>
</tr>
<tr>
<td>Bus free time between stop &amp; start condition</td>
<td>fBUF</td>
<td>4.7</td>
<td>1.3</td>
<td>fBUF</td>
</tr>
<tr>
<td>Time SCL must be high before start or repeated start</td>
<td>fAS</td>
<td>4.7</td>
<td>0.6</td>
<td>fAD.STA</td>
</tr>
<tr>
<td>Hold time SCL must be high after start or repeated start</td>
<td>fBS</td>
<td>4.0</td>
<td>0.6</td>
<td>fAD.STA</td>
</tr>
<tr>
<td>Time SDA must be stable before rising edge of SCL</td>
<td>fSC</td>
<td>300</td>
<td>300</td>
<td>fAD.DAT</td>
</tr>
<tr>
<td>Time SDA must be stable after falling edge of SCL</td>
<td>fSC</td>
<td>300</td>
<td>100</td>
<td>fAD.DAT</td>
</tr>
<tr>
<td>Time SDA must be low after a rising edge on SCL prior to a stop (rising edge on SDA)</td>
<td>fSP</td>
<td>4.0</td>
<td>0.6</td>
<td>fUS.STO</td>
</tr>
<tr>
<td>Rise time of both SDA and SCL signals</td>
<td>tR</td>
<td>0</td>
<td>1000</td>
<td>tR</td>
</tr>
<tr>
<td>Fall time of both SDA and SCL signals</td>
<td>tF</td>
<td>0</td>
<td>300</td>
<td>tF</td>
</tr>
<tr>
<td>Capacitance load for each line</td>
<td>CP</td>
<td>0</td>
<td>400</td>
<td>Cb</td>
</tr>
</tbody>
</table>

![Conventional I2C devices handle clock signals and bit rates to 100kHz but fast mode devices are now appearing that are capable of working at 400kHz. These timings cover both fast and slow modes.](image)

Defined as a falling edge on the SDA lead when SCL is high. A stop condition is defined as a rising edge on SDA when the SCL is high. It follows that to avoid false start and stop conditions being generated during data transfer, the state of the SDA lead must be stable while the SCL lead is high.

The generation of a start condition indicates to all other devices that the bus is busy until a stop condition is generated. Masters wait for this stop condition before attempting to send a start. All slaves, on detecting a start, will reset their hardware and prepare to receive the slave address. A slave recognising its own address will generate an ACK signal.

The ACK signal is a logic-low signal during the ninth clock pulse. The NACK signal is, therefore, a logic-high. The generation of a non-existent slave device address automatically generates a NACK because the bus is inherently in the high state.

It is possible that two masters could simultaneously generate a start followed by a slave address. For this reason all masters must always check the SDA lead for arbitration. As two or more masters could attempt to address the same slave, the check for arbitration must continue for the whole of the data transfer.

(Until the stop condition is generated.)

### Slave addressing

All slave devices are designed with a unique address which, when recognised and accepted, sets the slave in data transfer mode. There are two modes of addressing, both using the same protocol. The “standard” seven bit address is used by most of the devices available at present. The ten bit address mode will be provided on some future devices.

To address a slave device, a master will generate a start followed by a nine bit word. This word comprises seven data bits (ADDRESS), a read/write (W) bit and an acknowledge (ACK) bit. The read/write bit determines the data direction. A logic-high (read) sets the slave as a transmitter, a logic-low (write) makes the slave a receiver.

If an addressed slave device is capable of responding to the master it will generate an ACK signal (a low level on the SDA lead during the ninth clock pulse) and set its internal hardware or software for the data transfer. Any slave not addressed will ignore any further action on the bus until another start condition is generated.

The seven bit address has several reserved codes used for special purposes.

### Slave address byte

| Allocation | 6543 210 W |
| General call | 0000 000 0 |
| Start byte | 0000 001 0 |
| CBUS | 0000 001 X |
| Reserved | 0000 1XX X |
| 10 bit addressing | 1111 0XX X |
| Reserved | 1111 XXX X |

X = any state

### Data transfer

All currently available devices perform data transfer in a 9-bit word comprising eight data bits plus a ninth ACK bit. An astute reader will observe that the I2C bus protocol does not necessarily require an eight bit format for addressing and data transfer. Provided that a master is capable of generating the clock pulses and the slave is configured to receive them, then the word format can by any number of bits. Early bus formats, particularly systems using the 8048 type microcontroller, were open and allowed the user to choose the word length.

Transmitters send data on the SDA lead, receivers read data from the SDA lead and generate the ACK signal. Masters generate clock pulses on the SCL lead and control the bus by generating start and stop conditions. A data transfer can be of any number of data words. The transfer is terminated when a (repeated) start or a stop condition is sent by the master. The bus is considered to be busy during the period between an initial start condition and a stop condition. A receiver can indicate that the transfer is over by sending a NACK signal but it is the responsibility of the master to send a stop.

### General calls

The slave address 0000 0000 (a write to slave address 00) is reserved for a general call to devices that require “broadcast” information. The second byte of the transfer will indicate what type of information is being transmitted. General calls are used to globally set slaves to a defined state or to send global configuration data. A full discussion is beyond the scope of this article. Interested readers should obtain the relevant Philips data sheets.

### Other modes

#### Low speed mode

This mode is an extension of the bus protocol to allow relatively slow slave devices to respond to a “normal” master using an optional lower clock rate, preceded by a longer start procedure. The start procedure is as follows:

- A standard start condition
- A start-byte 0000 0001. (This is equivalent to “read address 0”)
- A repeated START condition

The start-word is seven clock pulses long...
Putting in an extra feature

We had a requirement to add an auxiliary keypad to one of our existing designs. This product used a PCB80C552 microcontroller with I2C bus software drivers already installed (clock timer and a led display). Expecting future enhancements and modifications we arranged the original circuit layout such that all spare '552 port leads were made accessible on suitable connecting points.

The PCF8574, a remote 8-bit i/o expander, has the necessary functions. It is an 8-bit quasi-bidirectional port similar in function to the 8051 microcontroller ports. It has an interrupt facility which is activated when the input to one or more of the port leads changes state. The interrupt signal is cleared when a bus read or write is sent to the device. There are two versions of the PCF8574; one version has an allocated slave address 0100 XXX, the other (PCF8574A) 0111 XXX.

The PCF8574 was mounted on a small daughter board attached to the hex keypad. The eight wires from the keypad were connected to the device ports. The 5V supply, ground, SCL, SDA and interrupt leads were wired to a suitable connector. Hardware links set the address to 0100 000. In the idle (waiting for a key depression) state the PCF8574 port bits 4-7 are set to binary 0000, which applies a ground potential to the four row pins on the keyboard. Bits 0-3 are set to binary 1111. When a key is pressed one of the column pins (bits 0-3) is pulled to ground via the key connection. This change of input causes the internal logic in the PCF8574 to apply a ground potential on the "int" pin 13 which is detected by the microcontroller. The software then performed the following I2C bus transfer.

S start; P stop sent or R repeated start; A ack; W read/write 1=read, 0=write

The only one stop condition is sent. The repeated start feature was used to prevent other masters from interfering, and thus delaying, the bus transfer. When the key is released the PCF8574 will detect another change on its inputs and present a further signal on the "int" pin. The software must delaying, the bus transfer. When the key is released the PCF8574 will detect another change on its inputs and present a further signal on the "int" pin. The software must delay before performing another read or write to the device to clear this signal. The interrupt signal is cleared when a bus read or write is sent to the device. There are two versions of the PCF8574; one version has an allocated slave address 0100 XXX, the other (PCF8574A) 0111 XXX.

Putting in an extra feature

All of the bits (K) in the received data bits 0-3 will be logic-high except for the bit(s) corresponding to the pressed keys. Note that only one stop condition is sent. The repeated start feature was used to prevent other masters from interfering, and thus delaying, the bus transfer. When the key is released the PCF8574 will detect another change on its inputs and present a further signal on the "int" pin. The software must now perform another read or write to the device to clear this signal.

The initial concern whether the bus would be fast enough to detect and process the key depressions was soon dispelled by a calculation. With a baud rate of 100kHz and nine bits required for each data byte and with a total of 18 bytes, the maximum time to scan the keyboard was 9*18/100=1.6ms. This time was less than the contact bounce period of the keyboard. Appropriate software delay routines were needed to insure that valid readings were obtained.

S start; P stop sent or R repeated start; A ack; W read/write 1=read, 0=write

The initial concern was that the bus would be fast enough to detect and process the key depressions. This was soon dispelled by a calculation. With a baud rate of 100kHz and nine bits required for each data byte and with a total of 18 bytes, the maximum time to scan the keyboard was 9*18/100=1.6ms. This time was less than the contact bounce period of the keys and appropriate software delay routines were needed to insure that valid readings were obtained.

This product used a PCB80C552 microcontroller with I2C bus software drivers already installed (clock timer and a led display). Expecting future enhancements and modifications we arranged the original circuit layout such that all spare '552 port leads were made accessible on suitable connecting points.

The PCF8574, a remote 8-bit i/o expander, has the necessary functions. It is an 8-bit quasi-bidirectional port similar in function to the 8051 microcontroller ports. It has an interrupt facility which is activated when the input to one or more of the port leads changes state. The interrupt signal is cleared when a bus read or write is sent to the device. There are two versions of the PCF8574; one version has an allocated slave address 0100 XXX, the other (PCF8574A) 0111 XXX.

The PCF8574 was mounted on a small daughter board attached to the hex keypad. The eight wires from the keypad were connected to the device ports. The 5V supply, ground, SCL, SDA and interrupt leads were wired to a suitable connector. Hardware links set the address to 0100 000. In the idle (waiting for a key depression) state the PCF8574 port bits 4-7 are set to binary 0000, which applies a ground potential to the four row pins on the keyboard. Bits 0-3 are set to binary 1111. When a key is pressed one of the column pins (bits 0-3) is pulled to ground via the key connection. This change of input causes the internal logic in the PCF8574 to apply a ground potential on the "int" pin 13 which is detected by the microcontroller. The software then performed the following I2C bus transfer.

S start; P stop sent or R repeated start; A ack; W read/write 1=read, 0=write

The only one stop condition is sent. The repeated start feature was used to prevent other masters from interfering, and thus delaying, the bus transfer. When the key is released the PCF8574 will detect another change on its inputs and present a further signal on the "int" pin. The software must delay before performing another read or write to the device to clear this signal. The interrupt signal is cleared when a bus read or write is sent to the device. There are two versions of the PCF8574; one version has an allocated slave address 0100 XXX, the other (PCF8574A) 0111 XXX.

Putting in an extra feature

All of the bits (K) in the received data bits 0-3 will be logic-high except for the bit(s) corresponding to the pressed keys. Note that only one stop condition is sent. The repeated start feature was used to prevent other masters from interfering, and thus delaying, the bus transfer. When the key is released the PCF8574 will detect another change on its inputs and present a further signal on the "int" pin. The software must now perform another read or write to the device to clear this signal.

The initial concern whether the bus would be fast enough to detect and process the key depressions was soon dispelled by a calculation. With a baud rate of 100kHz and nine bits required for each data byte and with a total of 18 bytes, the maximum time to scan the keyboard was 9*18/100=1.6ms. This time was less than the contact bounce period of the keys and appropriate software delay routines were needed to insure that valid readings were obtained.
Marconi's 200kW transatlantic transmitter

Enigma surrounds Marconi's massive 200kW wireless station, built nearly eighty years ago. George Pickworth pieces together the technology behind the world's most powerful spark transmitter.

Marconi's 200kW timed-spark continuous-wave transmitter was the ultimate spark-type transmitter. It was installed at Marconi's Caernarvon transatlantic 'super' station in Wales and came into service in 1916 to handle North Atlantic traffic. This was after the original synchronous-spark, wave-train transmitter was taken over by the military in 1914 for long range strategic signalling.

The timed-spark transmitter worked US stations at New Brunswick, Tuckerton, Marion and the Central Radio Station at Long Island. In 1919 it transmitted the first signals directly to Australia. Wavelength was given as 14km, which is approximately 21.5kHz.

To take advantage of the Earth/ionosphere waveguide effect, all transoceanic 'super' stations operated frequencies less than about 50kHz. However, the lowest useable frequency, typically 20kHz, was set by physical constraints imposed by antenna structures; even the largest practical structures were very inefficient at 20kHz.

Because all transoceanic stations were confined to a 30kHz bandwidth, a high level of selectivity became vital to reduce mutual interference as the numbers of stations progressively increased. The only way of attaining this was with continuous wave systems. With these, oscillations progressively built up in the receiver tuner by virtue of resonance; this was known as syntony — a term invented by Lodge.

Remarkably, Marconi's 1906 Clifden transatlantic super-station in Ireland, which originally radiated continuous waves, was a quenched-arc type. It had a plain triple disc discharger that was inherently self-cooling, and the draft created by the rotating discs dispersed ionized gases, Fig. 1.

On the other hand, Poulsen, with his quenched-arc system incorporated 'rod' type electrodes, comparable with an arc lamp. These required elaborate water cooling and a strong magnetic field to drive ionized gases from the arc-gap.

The Clifden transmitter was powered by a DC generator which charged 6000 lead acid accumulators. However, the Clifden discharger was modified by attaching transverse electrodes to the main disc, similar to the 1916 synchronous discharger. These electrodes, described in the November issue, radiated wave trains; the official explanation was so that signals could be received by Marconi's magnetic detector which responded only to wave trains. There is some evidence that the magnetic detector will demodulate AM signals but I have not been able to confirm it.

Options

Originally, the Caernarvon transmitter was a 200kW synchronous spark type radiating wave trains. It only allowed a very limited degree of syntony since there were too few waves in each train. These declined too quickly for resonance to be effective. In 1916 however, it was replaced with a continuous wave transmitter to increase receiver selectivity.

As early as 1906, Fessenden and Goldschmidt adopted RF alternator-type continuous wave transmitters for their north Atlantic service. Poulsen adopted the quenched-arc continuous wave system for his Hawaii/San Francisco link. Marconi's approach on the other hand was to indirectly produce continuous waves. He used spark systems to generate wave trains in rapid succession so that in effect they overlapped in phase. This led to the development of the Caernarvon timed-spark discharger.

Although the waves were continuous, they undulated in amplitude. Provided they remained in phase, this in itself did not significantly affect syntony. Indeed the undula-
This article is about generating continuous waves. Modulated the transmission with a tone. Rate was out of the question. However, at the rate that they overlapped in phase required extraordi-
nary technical expertise. But timing the wave trains—hence the term limed’—so to 50kHz transoceanic frequencies. But timing.

Overlapping wave trains
My experiments have shown the number of significant waves in a train to be around 25. When creating continuous waves by progressively reducing the period between trains they eventually overlap. Repetition rate must therefore be at least 1/25th of the transmission frequency, but undulation is unacceptable at this rate. The Caernarvon transmitter generated waves that overlapped every 13.5 waves.

A repetition rate equal to the 25th sub-multiple presented no particular problem at the 20 to 50kHz transoceanic frequencies. But timing the wave trains—hence the term ‘timed’—so that they overlapped in phase required extraordi-
mary technical expertise. However, at the 500kHz and 1MHz maritime frequencies used with mechanical dischargers this repetition rate was out of the question.

Trains overlapped. Operation seems to have narrowed, Fig. 2.

I am unsure how the device actually worked; indeed Tesla himself does not make this clear. A possible explanation is that the internal resistance of the battery limited the capacitor charge rate. During discharge, current is drawn from the capacitor faster than it is replaced, so potential falls. Then, as the hub continues to rotate, the discharge is quenched. In this way, the capacitor is charged and dischared synchronously with alignment of pairs of electrodes. At a critical rotation speed, this corresponds to the resonant frequency of the circuit.

The ‘flywheel’ effect of the tuned circuit converted charging and discharging into con-
trusive sine waves. Operation can therefore be compared to the quenched-arc system. The effect of the capacitor-type microphone was to de-tune the circuit so that power output corresponded to sound pressure waves.

In later versions, Tesla used a pair of toothed wheels rotating at very high, but at slightly differing speeds, in opposite directions. This was reported to give up to 10,000 discharges a second. For an even greater discharge rate, Tesla added a jet of mercury intercepted by projections on a disc rotating at extremely high speed, but this was a low power device intended as an oscillator for use.

Fessenden’s experiments
In 1900, during early radio telephone experiments prior to adopting radio frequency alternat-
ers, Fessenden built a system whose main elements were a battery, a vibrating-reed type interrupter and a transformer. The interrupter was tuned to 10kHz, in series with the aperi-
odic primary winding of the hf transformer. In turn, the transformer’s secondary winding was tuned to the interrupter frequency. This was the first transmitter to use a vibrating reed to set transmitter frequency. Fig. 4.

My replication of Fessenden’s experiments showed that the method worked well when the vibrator was tuned to a low sub-multiple of the resonant frequency. Here, the oscillation trains overlapped. Operation seems to have been by each DC pulse shocking the tuned cir-

cuit into oscillation.

Before thermionic valve type oscillators, there were many ingenious spark systems. Despite these, rf alternators were the only devices capable of producing continuous waves pure enough for practical radio tele-

The ‘flywheel’ effect of the tuned circuit converted charging and discharging into con-
trusive sine waves. Operation can therefore be compared to the quenched-arc system. The effect of the capacitor-type microphone was to de-tune the circuit so that power output corresponded to sound pressure waves.

In later versions, Tesla used a pair of toothed wheels rotating at very high, but at slightly differing speeds, in opposite directions. This was reported to give up to 10,000 discharges a second. For an even greater discharge rate, Tesla added a jet of mercury intercepted by projections on a disc rotating at extremely high speed, but this was a low power device intended as an oscillator for use.

Fessenden’s experiments
In 1900, during early radio telephone experiments prior to adopting radio frequency alter-
ners, Fessenden built a system whose main elements were a battery, a vibrating-reed type interrupter and a transformer. The interrupter was tuned to 10kHz, in series with the aperi-
odic primary winding of the hf transformer. In turn, the transformer’s secondary winding was tuned to the interrupter frequency. This was the first transmitter to use a vibrating reed to set transmitter frequency. Fig. 4.

My replication of Fessenden’s experiments showed that the method worked well when the vibrator was tuned to a low sub-multiple of the resonant frequency. Here, the oscillation trains overlapped. Operation seems to have been by each DC pulse shocking the tuned cir-

cuit into oscillation.

Before thermionic valve type oscillators, there were many ingenious spark systems. Despite these, rf alternators were the only devices capable of producing continuous waves pure enough for practical radio tele-

The ‘flywheel’ effect of the tuned circuit converted charging and discharging into con-
trusive sine waves. Operation can therefore be compared to the quenched-arc system. The effect of the capacitor-type microphone was to de-tune the circuit so that power output corresponded to sound pressure waves.

In later versions, Tesla used a pair of toothed wheels rotating at very high, but at slightly differing speeds, in opposite directions. This was reported to give up to 10,000 discharges a second. For an even greater discharge rate, Tesla added a jet of mercury intercepted by projections on a disc rotating at extremely high speed, but this was a low power device intended as an oscillator for use.

Fessenden’s experiments
In 1900, during early radio telephone experiments prior to adopting radio frequency alternat-
ers, Fessenden built a system whose main elements were a battery, a vibrating-reed type interrupter and a transformer. The interrupter was tuned to 10kHz, in series with the aperi-
odic primary winding of the hf transformer. In turn, the transformer’s secondary winding was tuned to the interrupter frequency. This was the first transmitter to use a vibrating reed to set transmitter frequency. Fig. 4.

My replication of Fessenden’s experiments showed that the method worked well when the vibrator was tuned to a low sub-multiple of the resonant frequency. Here, the oscillation trains overlapped. Operation seems to have been by each DC pulse shocking the tuned cir-

cuit into oscillation.

Before thermionic valve type oscillators, there were many ingenious spark systems. Despite these, rf alternators were the only devices capable of producing continuous waves pure enough for practical radio tele-

The ‘flywheel’ effect of the tuned circuit converted charging and discharging into con-
trusive sine waves. Operation can therefore be compared to the quenched-arc system. The effect of the capacitor-type microphone was to de-tune the circuit so that power output corresponded to sound pressure waves.

In later versions, Tesla used a pair of toothed wheels rotating at very high, but at slightly differing speeds, in opposite directions. This was reported to give up to 10,000 discharges a second. For an even greater discharge rate, Tesla added a jet of mercury intercepted by projections on a disc rotating at extremely high speed, but this was a low power device intended as an oscillator for use.

Fessenden’s experiments
In 1900, during early radio telephone experiments prior to adopting radio frequency alternat-
ers, Fessenden built a system whose main elements were a battery, a vibrating-reed type interrupter and a transformer. The interrupter was tuned to 10kHz, in series with the aperi-
odic primary winding of the hf transformer. In turn, the transformer’s secondary winding was tuned to the interrupter frequency. This was the first transmitter to use a vibrating reed to set transmitter frequency. Fig. 4.

My replication of Fessenden’s experiments showed that the method worked well when the vibrator was tuned to a low sub-multiple of the resonant frequency. Here, the oscillation trains overlapped. Operation seems to have been by each DC pulse shocking the tuned cir-

cuit into oscillation.

Before thermionic valve type oscillators, there were many ingenious spark systems. Despite these, rf alternators were the only devices capable of producing continuous waves pure enough for practical radio tele-

The ‘flywheel’ effect of the tuned circuit converted charging and discharging into con-
trusive sine waves. Operation can therefore be compared to the quenched-arc system. The effect of the capacitor-type microphone was to de-tune the circuit so that power output corresponded to sound pressure waves.

In later versions, Tesla used a pair of toothed wheels rotating at very high, but at slightly differing speeds, in opposite directions. This was reported to give up to 10,000 discharges a second. For an even greater discharge rate, Tesla added a jet of mercury intercepted by projections on a disc rotating at extremely high speed, but this was a low power device intended as an oscillator for use.
Phonies. Using rf alternators, Fessenden radiated his voice from his Brant Rock station in the USA. As early as 1906, these broadcasts were reported to be heard by operators at his station in Scotland.

However, Marconi still rejected alternators, probably because they were still in their infancy and ran at very high speed. Frequency raisers which allowed alternators to run at lower speed had yet to be developed; so had the inductor type alternator, which eliminated windings on the rotor and thereby the major problem with rotor windings flying out of their slots.

Early spark cw

The Marconi company had considerable expertise in the manufacture of spark apparatus. Having progressed so far with arc/spark systems, particularly for maritime use, it is understandable that Marconi should have pursued this path.

Early attempts to produce continuous waves with spark systems were based on tuning the interrupter of an induction-coil type spark-transmitter to a sub-multiple of the oscillator frequency. Fig. 5. However, while tuning the vibrator to a sub-multiple presented no special problem, contact bounce made precise timing extremely difficult and almost impossible to maintain at frequencies above a few kilohertz.

Moreover, the vibrating reed was essentially a low power device. In my 7kHz reproduction, fine tuning to bring the wave trains into phase was by adjusting the oscillator frequency. Figs 6(a,b), I found using shock excitation simpler however.

Morrietti's system

Morrietti's 'hydrothermic' discharger, used for experimental radio telephony between Rome and Tripoli around 1910, consisted of a pair of copper discs set horizontally, one above the other. The lower disc had a tiny hole drilled through the centre. Through this hole, acidulated water was steadily pumped so as to form a jet that impinged on the upper disc, Fig. 3.

Current immediately vapourised the jet. This interrupted the circuit which was then re-established - to be interrupted again to create current pulses. Operation was therefore automatic and required no moving parts. Each pulse shock excited the secondary circuit at a submultiple of its resonant frequency. In this way, oscillations persisting in the secondary circuit were continually reinforced to produce slightly undulating continuous waves.

Morrietti's device drew power from a 500V DC generator via a variable resistor. This component was presumably intended to synchronize the discharges and bring them in phase with oscillations in the antenna circuit.

Marconi's timed discharger

Marconi's 1913 experimental consisted of a bank of four rotary dischargers. Each comprised four radial electrodes rotating between a pair of fixed electrodes and driven by a common shaft extending from the drive motor. Individual primary circuits, one per discharger, were inductively coupled to a common secondary circuit. The device was powered by a DC generator, Fig. 7.

Discharge commenced while the gaps were still narrowing. Further narrowing as the electrodes rotated reduced resistance across the gaps. Amplitude of the oscillations declined and energy was transferred to the secondary circuit. Then the gaps widened and the draught created by the rotating electrodes dispersed ionized gases, thus quenching the discharge and returning the gaps to a high resistance state.

Assuming operation in quenched-arc mode, the quenching effect caused by the rotating electrodes would limitation the number of oscillations in each train to 15 or fewer, insufficient to overlap. As a result, wave trains in the primary circuit could have operated in quenched-arc mode and transferred energy to the secondary by induction. Alternatively, current pulses through the primary circuit could have shock excited the secondary circuit into oscillation. It was most probably a combination of both these modes. Whichever, discharges occurred consecutively, giving a total of 16 discharges per revolution.

Assuming operation in quenched-arc mode, the quenching effect caused by the rotating electrodes would limit the number of oscillations in each train to 15 or fewer, insufficient to overlap. As a result, wave trains in the primary circuit were discrete. Provided they were in phase with oscillations in the secondary circuit, they would be reinforced to create continuous oscillations with undulations corresponding to their reinforcement points. Fig. 8. Reinforcement of oscillations in the secondary circuit would be exactly the same with shock excitation of the secondary circuit.

Consider for example a frequency of 10kHz reinforced every 13th oscillation. This creates 'the reinforcement frequency', 10/13 which is 769.21Hz. As each revolution produces 16 reinforcements, it needs to run at 769.2/16, or
300kW motor

Three phase primary were insufficient to potentials were high, spark-gaps were fairly electrodes had large surface area. Because the device had an inherent drawback.

5kHz. Moreover, 50rev/s (3000rev/min) which limited operating drive speed was unlikely to have exceeded the secondary circuit. However, maximum speed would have to be adjusted to keep wave trains in phase with oscillations persisting in the secondary circuit. However, maximum drive speed was unlikely to have exceeded 50rev/s (3000rev/min) which limited operating frequency to the order of 15kHz. Moreover, the device had an inherent drawback.

In order to handle considerable power, the electrodes had large surface area. Because potentials were high, spark-gaps were fairly wide. Changes in atmospheric pressure, humidity and presence of ionized gases significantly altered the dielectric strength of air. Therefore, the point at which discharge occurred, varied and this upset timing.

**Caernarvon 200kW timed discharger**

Unfortunately very little information on the operation of the 200kW Caernarvon timed-spark transmitter has been published. Some information regarding the timer even seems to be misleading. This is understandable as there was great commercial rivalry between expenents of alternator and quenched arc systems. Nonetheless, by gleaning information from various sources, and by making a few assumptions, I believe that the following notes truly explain the operation of this remarkable transmitter. Fig. 9.

In essence, operation was similar to the experimental timed discharger, but the Caernarvon timed-spark discharger employed two pairs of discharge assemblies. Each of these consisted of a tuned primary circuit, a power discharger and a timing discharger. The timer had a common drive shaft arranged so that discharges occurred in sequence, but in alternate assemblies, as the shaft rotated. Both primary circuits were inductively coupled to the common secondary circuit.

The power dischargers were plain triple-disc types, i.e. with one main disc and two side discs. Discharge was from side disc to main disc to side disc. Independent electric motors rotated the main and side discs. This assisted cooling and created a draught that dispersed ionized gases. Drive speed was not critical and it seems as if they rotated at a relatively low speed, in the order of a few hundred rev/min.

The remarkable feature of these systems was that the distance between the main disc and the side discs was so wide that a discharge could not ordinarily occur at the energising potential of 5kV DC. However, set close to the side discs were a pair of ionizing electrodes.

**Timing discharger**

Both timing dischargers were connected to a common drive shaft and driving motor so that both timing dischargers rotated synchronously. Each discharger had a number of radial electrodes, probably 16, but because timing current was low, the timing electrodes had small face areas. Also, because the potential was relatively low, gap-width was narrow. This allowed close mechanical tolerances which minimised timing errors caused by changes in the dielectric strength of air. When the electrodes of the timing discharger were aligned, gap-width was less than a millimetre.

At each alignment the timer capacitor, charged to 5kV, discharged across the gap and through the primary of an induction-type coil. This induced a very high potential in its secondary winding which in turn caused a spark across the ionizing electrodes which created a conductive path for the main discharge. As a result, the timer can be likened to an automotive capacitor discharge ignition system. Because the power discharger electrodes were in the form of discs, discharge could occur at any time so timing could be precisely controlled.

The 5kV DC 300kW generator delivered 50A charging current to the primary circuit capacitors. This could be generated with dynamos without undue arcing across the commutator segments. Because of the ionizing spark, the power discharge occurred at this relatively low potential of 5kV; moreover, the wide spark gap caused the discharge to be quenched immediately the ionizing spark ceased. Keying was by interrupting the charging current to the timer capacitor as this circuit took only 300mA. Incidentally, although...
January 1994 ELECTRONICS WORLD + WIRELESS WORLD

installed in a brick-silence cabin, the noise caused considerable stress among operators.

**Operation**

My original experiments suggest that the time duration of the timing-spark, and consequently the main discharge was probably in the order of 250µs. On this assumption, at 21.42kHz, or 47µs, each train in the primary circuit probably consisted of about five oscillations. Subsequent research suggested that the primary circuit was effectively untuned and discharge was virtually a DC pulse which shocked excited the secondary circuit into oscillation. But as I have already explained, the operating mode does not affect timing.

The reason for the half cycle was probably caused considerable stress among operators.

**Alternators**

In 1921, it was decided that in order to increase keying speed and take advantage of improvements in receiver selectivity, it was necessary to replace the timed-spark transmitter with one that produced continuous waves of constant amplitude. Thermionic valve transmitters could meet this criterion, especially if improvements in receiver selectivity, it was necessary to replace the timed-spark transmitter with one that produced continuous waves of constant amplitude. Thermionic valve transmitters could meet this criterion, especially if the keying speed was limited to about 100 words a minute. Antenna current was 280A and efficiency from generator to antenna was given as 66½.

Although requiring careful adjustment and maintenance, the timed-spark transmitter was reliable. It proved so successful that the manufacture of a duplicate machine was put in hand immediately it came into service, but this was delayed because of difficulty in obtaining materials during the war. It does however seem to have been prone to radiating harmonics. In the meantime, a Poulsen quenched arc was installed as a reserve, but this was incapable of delivering antenna current of more than 170A and could not be worked for long periods without giving trouble.

**Further reading**

---

**LOW COST RANGER1 PCB DESIGN FROM SEETRAX**

- 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

Seetrax CAE • Hinton Daubnay House

Broadway Lane • Lovedean • Hants • PO8 0SG

Tel: 0705 591037 • Fax: 0705 599036

---

**What The Press Said About RANGER1**

For most small users, Seetrax 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. 109 ON REPLY CARD
Tuning in IF stages

Ian Hickman sheds light on synchronously tuned IF stages – the design route to the best-shaped IF response for RF instrumentation and pulse/data receivers.

Most of the selectivity in a single superheterodyne receiver is obtained in one of two sections. These are the intermediate frequency stages, IFs, following the mixer, or in those following the second or third mixer in a multiple superheterodyne design.

A professional HF communications receiver covering typically 1.6 to 30MHz may consist of just a few half-octave filters. Designs with an open-ended front-end, apart from a 30MHz low-pass filter, have even appeared. However with ever heavier use of the HF bands, proper front-end tuning is now reappearing.

Whatever the receiver, HF, MW AM, VHF FM or TV, the requirement is the same – to pass with equal amplitude the whole of the band of frequencies occupied by the wanted signal while rejecting all else. This leads to a brick-wall filter design with a flat top and very steep skirts.

For a few specialised receivers, a flat IF filter passband with steep skirts is not desirable. Two examples are radar receivers and spectrum analysers. In both cases, the IF strip is designed to pass pulses. In radar the pulses are reflections of transmitted pulses from a target while in analysers they are the energy of a signal as it is swept through the IF passband by the analyser’s tuning sweep.

Of course, selectivity is still required. In the case of the radar receiver selectivity is needed to minimize the noise bandwidth so that only the return-pulse energy is passed. In the case of the spectrum analyser selectivity provides resolving power. A small signal, little removed in frequency from a large one, needs to be seen without it being lost in the skirt of the IF filter’s response to the large signal.

According to Zverev a Gaussian filter shape is optimum for pulse response, but he goes on to say that a true Gaussian response is not practicable. The group delay of such a filter would be infinite, so you would wait for ever for a signal applied at the input to come out the other end. So he goes on to give designs that approximate a Gaussian response down to 6 or 12dB.

Modern spectrum analysers often claim a Gaussian response, though how accurate it is is another matter. Certainly earlier analysers made do with synchronously tuned IF strips. These are easy to design, build and adjust and are satisfactory for many applications. Further, as far as dynamic response goes, they have the advantage of being free from overshoot, however many stages are cascaded. It is these filters that form the subject of this design brief.

In a synchronously tuned IF strip, all the tuned circuits are usually identical not only in centre frequency but also in Q. This simplifying assumption is made here.

Figure 1 outlines a stage which is typical of the strip, together with its equivalent circuit. At an IF between 30 and 40MHz say, the high output impedance provided by a grounded base driver stage and the comparatively high input impedance of a subsequent emitter-follower buffer stage may result in
over-heavy damping of the tuned circuit in Figure 1. As a result, the connection to the tuned circuit might be tapped down the coil.

Whatever the working $Q$, the stage gain exactly on tune is given approximately by $\frac{R_0}{R_1}$. Parameter $R_0$ is the transconductance of the driving stage while $R_1$ is the operating dynamic resistance of the tuned circuit. Resistance $R_0$ is equal to $Q_0L$ in parallel with the shunt resistive components of the driving and load impedances, ignoring any regeneration.

Selectivity can be increased by tapping the connection further down the coil. This brings the tuned circuit nearer to its unloaded $Q$ and reduces gain. Conversely increased gain can only be bought at the expense of reduced selectivity.

A good compromise is a working $Q$ of half the unloaded $Q$. There is little more selectivity to be had but gain is much reduced. Demanding any more gain results in a disproportionate sacrifice in selectivity. If input impedance of the following stage is virtually infinite, the driving stage can be matched to the tuned circuit. This corresponds to the half-unloaded $Q$ condition. Conversely, if the driving impedance is so high as to be an ideal current source, the following stage can be so matched. But in no way is it possible to match both simultaneously.

How the gain varies at frequencies other than the resonant frequency $f_r$ is discussed in the panel. Armed with the results in the panel, the performance of a synchronously tuned IF strip can be calculated. Figure 2(a) shows the response of a single tuned circuit. It can also represent the response of several synchronously tuned identical circuits, since as Hot Carrier noted, you can "just add the dBs".

From the formula in the panel, you can calculate the 6dB and 60dB bandwidths and hence the 60dB to 6dB shape factor. For a brick-wall filter in a communications receiver this might be well under 3:1. For a spectrum analyser however, using either a Gaussian or a synchronously-tuned filter, it may be typically between 10:1 and 20:1.

To calculate the 60dB to 6dB shape factor for an IF strip with four synchronously tuned stages, Fig. 2(b), simply evaluate the 1.5dB to 15dB shape factor for a single tuned circuit. I have done this for several shape factors and numbers of stages, Fig. 3. If the working $Q$ of the tuned circuits was very high, the 60dB to 6dB shape factor of the $N=2$ IF strip of Ref. 2 would be 31.7:1.

Also shown in Fig. 3 is the 6dB to 1dB shape factor, which it turns out actually improves with the number of stages. The passband becomes squarer with an increasing number of stages - something I had not previously realised. The improvement is not dramatic. There is little change beyond three stages. But it is nonetheless useful.

Note the assumption that $X_C - X_L$ (or vice versa) is still small compared to $2\pi f_0 L$, or, equally, to the reactance of the capacitor at resonance. For a single tuned circuit, this means that the calculated detuning to $A=60$dB is only accurate if $QL$ is very much greater than 10000. This is an impossible specification for a discrete LC circuit but not so for a crystal. Even a very mediocre crystal has a $Q$ of 10,000 and some 100,000 or more.

Crystals are used in the more selective filters in a spectrum analyser to permit better resolution of closely spaced signals. This is especially important in an instrument having an on-screen logarithmic display of 60dB or more. In a simple instrument with a linear

---

**DESIGN BRIEF**

![Fig. 2. Response curve for a single tuned circuit can also represent an IF strip with several identical stages (a). At (b) is a pole zero diagram of a synchronously tuned IF strip compared with that of a stagger tuned strip.](image)

**Fig. 3. Pole versus shape-factor ratios for synchronously tuned IF strips with different numbers of stages.**

![Fig. 4. Equivalent circuit of a quartz crystal, and the variation of its impedance in the vicinity of series resonance, including parallel resonance. Diagram (b) shows how, ignoring $C_s$, series resonance can provide a very narrow passband when working between source and load impedances comparable with its equivalent series resistance.](image)
Fig. 5. Response of filter of Fig. 4 (b) taking into account $C_0$ is shown in the graph. Middle circuit illustrates obtaining a symmetrical response and high out-of-band attenuation by out-phasing the signal via $C_0$. Capacitance $C_0$, the trimmer and the centre tapped tank circuit form a balanced bridge, suppressing the effect of $C_0$. Main circuit (c) is as used in an early HP852A spectrum analyser to obtain resolution bandwidths of 1, 3 and 10kHz using a single crystal. Two such synchronously tuned stages were employed in cascade to obtain a satisfactory shape factor.

Fig. 6. Circuit diagram of an experimental crystal filter stage (a) using a 35.3MHz crystal with 5mm electrodes. In (b), main (centre) and spurious responses of (a) are shown at 50kHz/div horizontal, 10dB/div vertical, and analyser bandwidth of 10kHz. Actual filter responses are only a few hundred hertz wide. Much wider analyser bandwidth was selected for clarity. Curve (c) is as (b) but for a crystal with 3mm electrodes. Note that spurious responses come in different places.
The tuned circuit

In the tuned circuit shown, drive is inductively coupled via a single closely coupled turn. This effectively generates a small voltage from a near zero source impedance generator in series with the inductor. The arrangement is actually a series resonant circuit. However for values of $Q$ high enough to be useful, say twenty or greater, the performance is virtually the same as the current-fed parallel circuit of Fig. 1.

This is illustrated in the diagram below, which shows the situation at a frequency slightly above $f$. Here the reactance of the inductor is somewhat greater than that of the capacitor. The usual assumption that the capacitor is loss free, and the $Q$ determined solely by the inductor, has been made. It is also assumed that $Q$ is large so that $\omega l >> r$, the coil's series $r$ loss resistance.

At $f$, i.e., on tune, $\theta$ is zero and circulating current $i$ is $i_0$. Output voltage across the capacitor $V_C$ is $i_0$, where $\omega C$ is the capacitor's reactance at $f$, namely $1/2\pi f C$. If, for example, frequency rises by 1%, then so does the reactance of the inductor. Reactance of the capacitor on the other hand falls by 1% - almost exactly. This result is due to the Binomial Theorem. The difference between $x_C-x_L$, shown in the second diagram below, has risen from zero to 2% of the reactance of either at resonance.

The third side of the triangle $z$ is the impedance in which $i$ now flows. If the value of the series resonance is taken to be unity, the off-tune value is $r/\omega C \sin \theta$. So if $\theta = 45^\circ$, $x_C-x_L$ would be 2% of $Q$, namely equal to $r$. Thus $\theta$ would be $45^\circ$ and $1/(\omega C \sin \theta) = 0.707$, i.e. 3-dB. This is the fall in the value of $i$, but since $x_L$ has only fallen by 1% it is also approximately the fall in $V_C$. Cosine $\theta$ is the approximate per unit response of the circuit, i.e. the output relative to an assumed on-tune output of unity. $\sin \theta = (x_C-x_L)/r$ which works out to be $Q \sin \theta_0 - x_C/r_0$ or approximately, courtesy of the Binomial Theorem again, $2Q^2$, where $\delta$ is the 'per unit' detuning; for 5% off tune $\delta$ is 0.05.

Armed with these approximate results, finding the detuning corresponding to a given relative attenuation is easy. For example, for 6dB down, first convert the attenuation to 'per unit' value, i.e., -6dB is equivalent to 0.5. Now take the inverse cosine, in this case $60^\circ$, and this value equals $2Q$. So any tuned circuit for which our approximations are valid is 6dB down at $\theta = 1.732Q$, e.g., at $\delta$ is 0.0173 (1.73% off tune) if $Q$ is 50.

The following works out to the 'per unit' or fractional detuning $\delta$ for any attenuation $AdB$ down, for any number of stages $N$ the selectivity of each being given by $Q$, on a calculator.

\[
\text{ENTER } N \text{ Kinl ENTER A divide } \text{routed } = \text{divide } 20 = 10^x \times \text{ inv cos tan } \text{divided } 2 \times \text{ divide } Q = \text{ (answer)}
\]

\[\text{Inductively coupled tuned circuit and its equivalent in series-excited form. Associated vector diagrams are also shown.}\]
provides the narrowest bandwidth. Between high source and load resistances it provides the widest bandwidth.

When using crystals to implement narrow-band synchronously-tuned filters, there are other problems to cope with, in addition to $C_r$. For instance, at frequencies somewhat above $f_0$ a crystal usually has one or more subsidiary resonances or "spurious responses". This is illustrated in Figs 6(a) and (b). The spectrum analyser used had no built in tracking generator; a signal generator was swept slowly back and forth across the band. Actual filter responses are very narrow, a much wider analyser resolution bandwidth being selected for clarity.

Since at least two such stages would usually be necessary to obtain the required shape factor, the second stage would use a crystal with the same $f_0$, but where the spurious resonances fell at different frequencies. While that in Fig. 6(b) has 5mm electrodes, the crystal in Fig. 6(c) has 3mm electrodes (from McKnigt Fordahl, Hythe). Note that the two halves of the centre-tapped second tank-circuit, Fig. 6(a), should ideally be very tightly coupled, especially if output is being taken from another tap on the coil.

Alternatively, the coil could be replaced by a centre-tapped resistor, the two ends connecting to an op-amp whose common-mode rejection is maintained up to radio frequencies. Example of such ICs are the LT1193 from Linear Technology and the MAX436 from Maxim. Both these devices have gain-defining arrangements independent of the inverting and non-inverting inputs. This makes both inputs high impedance nodes. The filter section itself, being entirely passive, could be used in reverse, i.e. the balanced end could be the input.

Using the filter in reverse provides yet another opportunity to replace the centre-tapped tank circuit with an IC, as shown in Fig. 7. This circuit uses a Burr-Brown OPA2662 dual transconductance amplifier. A small trimmer from pin 14 to ground was necessary to maximise the stop-band rejection by adjusting the balanced outputs for exact anti-phase. When using crystals in synchronously tuned IF strips, the final hurdle to overcome is the selection tolerance on $f_0$. The tighter the tolerance the higher the cost. As a result, the final adjustment is made with the aid of a series trimmer, shown in Figure 5(c) as $C_7$. A fixed capacitor is used in this position as in the other crystal filter stage. The crystals are thus operated slightly above series resonance, where their inductive reactance resonates with the series capacitor or trimmer.

References
Are you up to date with the latest in circuit simulation?

Development on SpiceAge for Windows since its introduction in 1991 has been moving at a pace. SpiceAge 2 for Windows arrived in the autumn of last year. SpiceAge 3 for Windows is available for Christmas 1993.

V3 provides digital simulation an order of magnitude faster than before. It has a 32 channel logic analyser display, input signal bus grouping plus more digital models, but unlike logic simulators, you can of course see the analogue effects of capacitive loads, pull-ups, diodes etc. Analogue developments include bundling of the Zetex SPICE library and a brand new opamp model.

Existing SpiceAge for Windows owners will be notified of these developments by post. Owners of the Original SPICE-AGE, BITSPICE, LOGANOU and NODALOU should contact us for upgrade details. If you are new to SpiceAge for Windows, please phone us for a demonstration kit. Those Engineers Ltd, 31 Birkbeck Road, LONDON NW7 4BP. Tel: 081-906 0155, Fax: 081-906 0969.

CIRCLE NO. 112 ON REPLY CARD
Dual port serial communications for your PC

The PC 47, 48 and 49AT boards each provide two independent serial ports for any PC/XT/AT(ISA) computer. RS232, RS422 and RS485 standards are supported and all combinations are possible with this range of low power boards.

9 pin D connectors are provided for the RS422 and 485 ports. RS232 can be connected via 9 or 25 way D connectors and charge pump circuitry ensures signal levels in excess of 7V are transmitted. Interrupt and base addresses are independently selectable for each port, full, half duplex and multistop communications are fully supported and all boards use the industry standard 82C450, UART.

Designed and manufactured by Amplicon Liveline each board is supplied with a comprehensive technical manual and interrupt driven device driver software is available.

Write in number 1

750kHz professional data acquisition with Windows support

PC226 from Amplicon Liveline provides 16 true differential 12 bit analog inputs each with dynamically programmable gain. PC226 has sample rates up to 400kHz multichannel and 750kHz single channel, programmable scanning hardware, flexible triggers and a 2048 sample FIFO to ease programming in high speed applications.

PC 226 is supplied with menu driven software for DOS and Windows. LabTech Notebook drivers and comprehensive well documented libraries for most popular high level languages.

Optional software support for Microsoft Windows includes a complete Dynamic Link Library (DLL) and two icon driven packages, Signal Centre for signal capture and analysis and TRACS for process monitoring, visualisation and control.

Write in number 2

48 lines TTL I/O with 16bit counter timers

PC 14AT available from Amplicon Liveline is a high quality general purpose interface board for PC/XT/AT(ISA) computers.

The board has 48 lines of TTL compatible digital I/O provided as six 8 bit ports four of which can be programmed to be all inputs or all outputs and two which can be split to be 4 inputs and 4 outputs if required. There are also three 16bit-counter timers which can be used to generate and measure pulses at up to 5MHz.

An on board 4MHz crystal oscillator is also included on PC 14AT along with LEDs showing the status of a selection of the I/O ports, these can be used as programming and debugging aids.

PC 14AT is suitable for a wide variety of interface, monitoring and control applications and an LP (low power) version PC 14LP is available for installation in laptop computers, both boards have flexible base address and interrupt support.

Write in number 3

For up to the minute information on over 1,000 high quality, high specification electronic products, make sure you’ve got the latest AMPLICON catalogue.

It’s not just first class equipment that makes AMPLICON your first choice- we provide outstanding service too: like telesales engineers for pre and post sales support. Easy to manage corporate accounts. Excellent documentation...

To order your free catalogue, simply phone the winning line today.
Some of the most common sources of distortion in audio power amplifiers relate to the electrical and physical layout of the circuit, an area overlooked by many designers. In his continuing search for the perfect audio amplifier Douglas Self explains the mechanisms.

Distortion in power amplifiers

6: the remaining distortions

The previous two parts of this series considered closely the distortion produced by amplifier output stages: a basically conventional but well designed Class-B amplifier with proper precautions taken against the various sources of nonlinearity can produce insignificant levels of distortion. That which is generated is mainly due to the difficulty of reducing high order crossover nonlinearities with negative feedback that has declining effectiveness with frequency. For 8Ω loads this is the major source of distortion. For convenience, I have chosen to call such a device a blameless amplifier.

Distortion 3: quiescent current control

An optimised amplifier requires minimisation of output stage gain irregularities around the crossover point by holding the quiescent current \( I_q \) at its optimal value. Increasing \( I_q \) to move into Class-AB makes the distortion worse, not better, as \( g_m \) doubling artifacts are generated.

The initial setting of quiescent current is simple. Given a distortion analyser to get a good view of the residual; keeping that setting under varying operating conditions is a much greater problem because \( I_q \) depends on small voltages established across low value resistors by power devices with thermally dependant \( V_{be} \) drops.

How accurately does quiescent current need to be maintained? I wish I could be more specific on this. Some informal experiments with Blameless CFP type outputs at 1kHz indicate that crossover artefacts on THD residual seem to stay at roughly the same level, partly submerged in the noise, over an \( I_q \) range of about 20mA. Results may well be different for emitter follower type outputs.

This may seem a wide enough target, but given that junction temperature of power devices may vary over a 100°C range, this is not so. Some kinds of amplifier (eg current dumping types) manage to evade the problem altogether, but in general the solution is thermal compensation: the output stage bias voltage is set by a temperature sensor (usually a \( V_{be} \) multiplier transistor) coupled as closely as possible to the power devices.

There are inherent inaccuracies and thermal lags in this sort of arrangement leading to programme dependency of \( I_q \). A sudden period of high power dissipation will begin with the bias current increasing above optimum, as the junctions will heat up very quickly. Eventually the thermal mass of the heatsink will respond, and the \( V_{be} \) voltage will be reduced. When the power dissipation falls again, the bias voltage will not be too low to match the cooling junctions and the amplifier will be under biased, producing crossover spikes that may persist for some minutes. This is well illustrated in an important paper by Sato.

Emitter follower outputs

The major drawback of emitter follower output stages is thermal stabilisation. This can cause production problems in initial setting up since any drift of quiescent current will be very slow as a lot of metal must warm up. For EF outputs, the bias generator must attempt to establish an output bias voltage that is a summation of four driver and output \( V_{be} \)'s. These do not vary in the same way. It seems at first a bit of a mystery how the EF stage, which still seems to be the most popular output topology, works as well as it does. The probable answer is Fig. 1, which shows how driver dissipation (averaged over a complete cycle) varies with peak output level for the three kinds of EF output, and for the CFP configuration. The Spice simulations used to generate this graph used a triangle waveform to give a slightly closer approximation to the peak-average ratio of real waveforms. The rails were ±50V, and the load 8Ω.

It is clear that the driver dissipation for the EF types is relatively constant with power output, while the CFP driver dissipation, although generally lower, varies strongly. This is a con-
sequence of the different operation of these two kinds of output. In general, the drivers of an EF output remain conducting to some degree for most or all of a cycle, although the output devices are certainly off half the time. In the CFP, however, the drivers turn off almost in synchrony with the outputs, dissipating an amount of power that varies much more with output. This implies that EF drivers will work at roughly the same temperature, and can be neglected in arranging thermal compensation; the temperature dependent element is usually attached to the heatsink to compensate for the junction temperature of the output devices alone. The Type I EF output keeps its drivers at the most constant temperature.

The above does not apply to integrated Darlington outputs, with drivers and assorted emitter resistors combined in one ill-conceived package where the driver sections are directly heated by the output junctions. This works directly against quiescent stability. The drawback with most thermal compensation schemes is the slow response of the heatsink mass to thermal transients. The obvious solution is to find some way of getting the sensor closer to one of the output junctions. If TO3 devices are used, then the flange on which the actual transistor is mounted is as close as one can get without a hacksaw. This is however clamped to the heatsink, and almost inaccessible, though it might be possible to hold a sensor under one of the mounting bolts. A simpler solution is to mount the sensor on the top of the TO3 can. This is probably not as accurate an estimate of junction temperature as the flange would give, but measurement shows the top gets much hotter much faster than the heatsink mass, so while it may appear unconventional, it is probably the best sensor position for an EF output stage.

Fig. 2 shows the results of an experiment designed to test this. A TO3 device was mounted on a thick aluminium L-section thermal coupler in turn clamped to a heatsink; this construction represents many typical designs. Dissipation equivalent to 100W/8Ω was suddenly initiated, and the temperature of the various parts monitored with thermocouples. The graph clearly shows that the top of the TO3 responds much faster, and with a larger temperature change, though after the first two minutes the temperatures are all increasing at the same rate. The whole assembly took more than an hour to asymptote to thermal equilibrium.

The CFP output

In the CFP configuration, the output devices are inside a local feedback loop, and play no significant part in setting $I_q$, which is affected only by thermal changes in the drivers’ $V_{ce}$. Such stages are virtually immune to thermal runaway; I have found that assaulting the output devices with a powerful heat gun induces only insignificant $I_q$ changes. Thermal compensation is mechanically simpler as the $V_{ce}$ multiplier transistor is simply mounted on one of the driver heatsinks, where it aspires to mimic the driver junction temperature. It is now practical to make the bias transistor of the same type as the drivers, which should give the best matching of $V_{be}$ multipliers, where $V_{be}$ is buffered.

Because driver heatsinks are much smaller than the main heatsink, the thermal compensation time constant is now measured in tens of seconds rather than tens of minutes, and should give much shorter periods of non optimal quiescent current than the EF output topology.

Distortion 4: nonlinear loading of the voltage amplifier stage by the nonlinear impedance of the output stage.

This distortion mechanism was examined in Part 3 from the point of view of the voltage amplifier stage. Essentially, since the VAS provides all the voltage gain, its collector impedance tends to be made high. This renders it vulnerable to nonlinear loading unless it is buffered.

Making a linear VAS is most easily done by applying a healthy amount of local negative feedback via the dominant pole Miller capacitor, and if VAS distortion needs further reduction, then the open loop gain of the VAS stage must be raised to increase local feedback. The direct connection of a Class-B output can make this difficult for, if the gain increase is attempted by cascoding with intent to raise the impedance at the VAS collector, the output stage loading will render this almost
completely ineffective. The use of a VAS buffer eliminates this effect.

As explained previously, the collector impedance, while high at LF compared with other circuit nodes, falls with frequency as soon as $C_{bias}$ starts to take effect, and so the fourth distortion mechanism is usually only visible at LF. It is also masked by the increase in output stage distortion above dominant pole frequency $P_1$ as the amount of global NFB reduces.

The fall in VAS impedance with frequency is demonstrated in Fig. 3, obtained from the Spice conceptual model outlined previously, with real life values. The LF impedance is basically that of the VAS collector resistance, but halves with each octave once $P_1$ is reached. By 3kHz it is down to 1kΩ and still falling. Nevertheless, it can remain high enough for the input impedance of a Class-B output stage to significantly degrade linearity, the actual effect being shown in Fig. 4.

An alternative to cascading for VAS linearity is to add an emitter follower within the VAS local feedback loop, increasing the local NFB factor by raising effective beta. This point is easy to overlook, and attempts to improve amplifier linearity by labouring on the signal, then distortion will degrade badly. A common route for interaction is via decoupling grounds shared with input or feedback networks, and a completely separate decoupler ground usually effects a total cure. The fall in VAS impedance with frequency starts to take effect, and so the LC filter 100kHz to 100mHz is demonstrated in Fig. 3, obtained from the Spice conceptual model outlined previously, with real life values. The LF impedance is basically that of the VAS collector resistance, but halves with each octave once $P_1$ is reached. By 3kHz it is down to 1kΩ and still falling. Nevertheless, it can remain high enough for the input impedance of a Class-B output stage to significantly degrade linearity, the actual effect being shown in Fig. 4.

An alternative to cascading for VAS linearity is to add an emitter follower within the VAS local feedback loop, increasing the local NFB factor by raising effective beta rather than the collector impedance. Preliminary tests show that as well as providing good VAS linearity, it establishes a lower impedance across the audio band. It should be more resistant to this type of distortion than the cascode version.

Figure 5 confirms that the input impedance of a conventional EF Type I output stage is anything but linear; the data is derived from a Spice output stage simulation with optimal $h_{ie}$. Even with an undemanding 8Ω load, the impedance varies by 10:1 over the output voltage swing. Interestingly, the Type II EF output (using a shared drive emitter resistance) has a 50% higher impedance around crossover, but the variation ratio is rather greater. CFP output stages have a more complex variation that includes a precipitous drop to less than 20kΩ around the crossover point. With all types under biasing produces additional sharp impedance changes at crossover.

**Distortion 5: supply ground loops**

Virtually all amplifiers include some form of rail decoupling apart from the main reservoir capacitors; this is usually required to improve HF stability. The standard decoupling arrangements include small to medium sized electrolytics (say 10 - 10000µF) connected between each rail and ground, and an inevitable consequence is that voltage variations on the rails cause current to flow into the ground connection chosen. This is just one mechanism that defines the power supply rejection ratio (PSRR) of an amplifier, but it is one that can do serious damage to linearity. If we assume a simple unregulated power supply, (and there are excellent reasons for using such a supply) then these rails have a significant AC impedance and superimposed voltage will be due to amplifier load currents as well as 100Hz ripple. In Class-B, these supply rail currents are halfwave rectified sine pulses with strong harmonic content, and if they contaminate the signal, then distortion will degrade badly. A common route for interaction is via decoupling grounds shared with input or feedback networks, and a completely separate decoupler ground usually effects a total cure. This point is easy to overlook, and attempts to improve amplifier linearity by labouring on the input pair, VAS, etc., are doomed to failure unless this distortion mechanism is eliminated first.

As a rule it is simply necessary to take the decoupling ground separately back to the ground star point, as shown in Fig. 6. Note that the star point A is defined on a short spar from the heavy connection joining the reservoirs; trying to use B as the star point will introduce ripple due to the large reservoir charging current pulses passing through it.

Figure 7 shows the effect on an otherwise optimised amplifier delivering 60W/8Ω, with 220µF rail decoupling capacitors. At 1kHz distortion has increased by more than ten times, which is quite bad enough. However, at 20Hz the THD has increased at least 100 fold, turning a very good amplifier into a profoundly mediocre one with a single misconceived connection.

If the residual on the supply rails is examined, the ripple amplitude will usually be found to exceed the pulses due to Class-B signal current, and so some of the "distortion" on the upper curve of the plot is actually due to
ripple injection. This is hinted at by the phase crevasse at 100Hz, where ripple partly cancelled the signal at the instant of measurement. Below 100Hz the curve rises as greater demands are made on the reservoirs, the signal voltage on the rails increases, and so more distorted current is forced into the ground system.

Generally, if an amplifier is made free from ripple injection under drive conditions, shown by a THD residual without ripple components, there will be no distortion from the supply rails and the complications and inefficiency of high current rail regulators are unnecessary.

There has been much discussion of PSRR induced distortion in EW+WW recently, led by Ben Duncan and Greg Ball. I part company with Ben Duncan on this issue where he assumes that a power amplifier is likely to have 25dB PSRR, making expensive high power DC regulators the only answer. He agrees that this sort of PSRR is highly unlikely with the relatively conventional amplifier topologies I have been considering.

Greg Ball also initially assumes that a power amp has the same PSRR characteristics as an op-amp, ie falling steadily at 6dB/octave. There is absolutely no need for this to be so, given a little RC decoupling, and Ball states at the end of his article that "a more elegant solution... is to depend on a high PSRR in the amplifier proper."

**Power supply rejection**

For low noise and distortion, all the obvious methods of rail injection must be attended to as a matter of routine. I therefore give here some guidelines that I have found effective with unregulated supplies:

- The input pair must have a tail current source. A tail made of two resistors decoupled mid way is simply not adequate.
- This tail source will probably be biased by a pair of diodes or a led fed from a resistor to ground. This resistor should be split and the midpoint decoupled with an electrolytic of about 10µF to the appropriate rail.
- If a cascode transistor is used in the VAS, then its base will need to be biased about 1.2V above whichever rail the VAS emitter sits on; if this is implemented with a pair of diodes then further decoupling seems unnecessary.
- Having taken care of the above, the PSRR will now be limited by injection from the neg-
ative rail by a mechanism that is not yet fully clear. RC decoupling can however reduce this to negligible levels.

This is not the whole story on power rail rejection, but it does provide a starting point.

Distortion 6: induced output current coupling

This distortion mechanism, like the previous case, stems directly from the Class-B nature of the output stage. Assuming a sine input, the output hopefully carries a good sine waveform, but the supply rail currents are halfwave rectified sine pulses, which are quite capable of inductive crosstalk into sensitive parts of the circuit.

This can be very damaging to the distortion performance, as Fig. 8 shows.

The distortion signal may intrude into the input circuitry, the feedback path, or even the cables to the output terminals. The result is a kind of sawtooth on the distortion residual that is very distinctive, an extra distortion component which rises at 6dB/octave with frequency. This effect appears to have been first publicised by Cherry, in a paper that deserves further attention, as point C-D. The authors are repeatedly told that too much feedback can affect slew rate. Possibly true, though the greater danger is that an excess amplifier may produce transient feedback instability.

However, there is another and more subtle danger. Class-B output stages are a hotbed of crosstalk with this approach in a stereo amplifier, but it does seem to deal most effectively with the induced distortion problem.

Distortion 7: nonlinearity from incorrect NFB connection point

Negative feedback is a powerful technique and must be used with care. Designers are repeatedly told that too much feedback can affect the crossover. Possibly true, though the greater danger is that an excess amplifier may produce transient feedback instability.

However, there is another and more subtle danger. Class-B output stages are a hotbed of high amplitude halfwave rectified currents, and if the feedback takeoff point is even slightly asymmetric, these will contaminate the feedback signal making it an inaccurate representation of the output voltage. This will manifest itself as distortion, Fig. 10.

At the current levels in question, all wires and PCB tracks must be treated as resistances, and it follows that point C is not at the same potential as point D when TR conducts. If feedback is taken from D, then a clean signal will be established here, but the signal at output point C will have a half wave rectified sinewave added to it, due to the resistance C-D. The output will be distorted but the feedback loop will do nothing about it as it does not know about the error.

Figure 11 shows the practical result for an amplifier driving 100W into 8Ω, with the extra distortion shadowing the original curve as it rises with frequency. Resistive path C-D that did the damage was a mere 6mm length of heavy gauge wirewound resistor lead.

Elimination of this distortion is easy, once you know the danger. Connecting the feedback arm C-D is not advisable as it will not be a mathematical point, but will have a physical extent inside which the current distribution is unknown. Point E on the output line is much better, as the half wave currents do not flow through this arm of the circuit.

Reference:
6. Duncan, B, Private communication, Oct 93.
Making ripples

I was very interested to see AM Wilkes' article "Simulating capacitor ripple" (EW + WW, September 1993), since I have analysed the behaviour of this circuit. Wilkes' paper makes the same assumption as most textbooks, that the transformer acts as a perfect voltage source, and that the ripple voltage is the same as the load voltage. This assumption is not valid in reality, and the ripple voltage is not affected by the current drawn from it. One consequence of this assumption is that the peak voltage on the capacitor will always equal the T_V1 of the supply. In reality, the output voltage is subject to Ohm's Law due to the finite resistance of the secondary and primary windings. When the rectifier diodes are conducting, the transformer sees the capacitor effectively as a short circuit, and its own resistance is the predominant factor in limiting the charging current.

The effective voltage in the circuit equals the difference between the instantaneous induced voltage in the secondary and the voltage on the capacitor. An immediate effect of this is to reduce the ripple voltage, since the peak voltage on the capacitor is reduced. For example, suppose the load is such that the average voltage on the capacitor equals the rms of the transformer output. If the transformer was a perfect voltage source, the ripple voltage would be at least T_V1 - V_cap. In reality, reasonable capacitor values can give a much smaller ripple voltage than this.

To give an example, I have just measured the dc resistance of the secondary of a nominal 10V, 1.2A transformer. It is about 0.4Ω. Supposing the smoothing capacitor has 10V across it when peak voltage of 14.1V occurs, then a charging current of 10.3A will be flowing (ignoring diode drops), and the voltage seen by the capacitor will be 10V, with V_cap depending on the capacitor value. This analysis is simplified since it ignores other current-limiting factors, such as the dc resistance of the transformer primary and the current drawn by the load.

John Harper
Valence, France

Lightning response

I found the report of a link between lightning and cosmic radiation (Research Notes, EW + WW, November 1993) established by Moscow and Los Alamos researchers rather exciting because it suggests that conditions close to terrestrial power lines may also enhance sky radiation and help explain the observations I reported in a previous article (EW + WW, November 1992). Since the article appeared, a single joint test with the NRPB in mid-1993 on a 400kV line carrying 800A per phase showed a raw current increase of about 4% close to the line, which was not regarded as significant because it could have been due to local geology.

More recently, tests by the Swedish Radiation Research Institute using more sophisticated equipment produced rate curves rather resembling the plots in the November 1992 article. The problem is that relevant solar particle emission has fallen by about 70% since my original field work in 1990 and 1991, close to the peak of solar cycle 22, so exact replication of my original observations will have to wait for the peak of cycle 23 in about five years. In the meantime, research into the theoretical and practical implication of my observations may help to explain the growing body of epidemiological evidence that people living close to power lines may suffer some ill effects.

Research should also concentrate on detecting an 11-year cycle for human disease. Such a cycle would suggest that solar ionising radiation at levels well below those considered hazardous leads to power line focusing of natural radiation that may pose real dangers for those with a genetic susceptibility.

Anthony Hopwood
Upton-on-Sewern, Worcester

Valve mystery

Older readers of your magazine will remember with nostalgia valves manufactured with trade names such as Cossor, Ferranti, Mullard, Marconi, Muzda, Osram and Tungsram. There were also many lesser-known companies who made or distributed valves during the 1920s and 1930s. Among these were Hivac, Lissen, Octron and 363. I would be pleased to hear from readers who have any knowledge of these companies' valve manufacturing or distributing activities, particularly Lissen whose valve making was included in mystery.

Keith Thrower
Old Cedar, 12 Wychatts
Caversham, Reading RG4 7DA

Sad subjectivism

I was interested to read Jerry Mead's defence of subjectivist listening tests (EW + WW, November 1993) but sad to see that his procedures apparently have no chance of deciding whether one amplifier is better than another. The trouble is that his manifesto nowhere mentions double-blind A/B testing, or indeed any kind of A/B comparison at all. As far as I can discover, he simply listens to one amplifier, relying on his claimed ability to retain mental performance maps for several days between amplifier versions.

Such a procedure would be absolutely unacceptable even in a first-year psychology project, as decades of experience in psychoacoustics and related fields have shown beyond any possible quibble that experimenter expectancy renders the results valueless.

The fact that no audible differences are likely to exist unless the circuitry is seriously misconceived sets the final seal of sterility on the whole proceedings. It is a well-worn debating technique to call for an open mind when discussing these matters, though I can see no hint that Mead has considered the possibility that he might himself be wrong or misled.

Surely, to sail into an allegedly scientific investigation with an open mind as to whether or not to measure things properly is not a triumph for tolerance, but a complete misunderstanding of what constitutes the scientific method. Taking this philosophy to its logical conclusions debars us from any progress, as it becomes impossible to determine between truth and falsity.

Mead is absolutely correct when he says the mere fact that something cannot be measured or quantified does not mean it doesn't exist. However, if after 20 years of talking about it you still can't measure, or even demonstrate, what you claim to be studying, most of us would regard this as a rather suspicious circumstance.

He also appears to overlook the two classic proofs that mysterious subjective nuances have no existence — the Haflerl and Baxtedall demonstrations. I have yet to meet a subjectivist who was able to argue his way past either of them.

Since no equally positive demonstration of the non-existence of auras has made its existence — I could argue that subjectivism is actually in rather worse shape than ufology.

I was glad to see the Mead-Duncan team take level matching seriously — until on a closer look I saw that it was just channel balance that was being so effectively policed. Level matching between the A and

Complex cables defy physics

The behaviour of an audio signal in a cable is far more complex than a simple first year textbook explanation of Ohm's Law, which Drs Blake-Coleman and Young assume (EW + WW, May 1993).

The flow of ac electricity in a conductor is not uniform over the cross sectional area. Also the metal on the surface of a conductor is likely to be different from that at the centre due to oxidation. An oxidised metal is more likely to have semiconducting properties than the same conductor properties of the metal at the centre of the conductor.

There is no perfect insulator and insulating materials exhibit power loss and dielectric absorption, which can be easily measured.

The most significant influence on sound quality is the conductor used. Although copper is the most common metal used, other metals offer better sound, in particular silver. Silver plated copper offers a high quality performance where pure silver is too expensive.

Insulation will affect sound quality due to dielectric absorption. PTFE not only has the best sound quality as an insulator, but also the lowest measured dielectric absorption compared to other insulating materials. A PTFE insulated cable will give a more focused sound, like a pair of binoculars adjusted to give a sharper visual focus.

Conductor size affects sound quality. Even on high impedance connections preamp and power amp, increasing the cross sectional area of conductor increases bass frequencies. Also some large diameter solid core cables attenuate treble frequencies.

Other factors claimed to influence sound quality include heat treatment, larger crystal size and purity of metal. Cables also sound better when the screen is removed, or when a shorter length of the same cable is used.

The engineering of a cable to reproduce music in the form of rapidly changing dynamically variable electrical voltage is a complex art that needs the scientific application of knowledge and skill to achieve success.

Graham Nalty Derby
Mr Nalty should have declared an interest — he sells exotic audio cables. Editor
the B of an A/B comparison has long been known to be critical – the oldest trick in the book is to make amplifier A sound repeatedly better by making it 1dB or so louder – the listener usually perceiving this as an improvement in clarity rather than amplitude. Of course, if you don’t do A/B comparisons then this trick is harder to pull off.

I refuse to believe in the existence of a seasickness capacitor until further proof is forthcoming. I simply can’t believe that a capacitor in any position in an audio amplifier could induce anything resembling motion sickness.

How about showing us the circuit diagrams unless there are any, on this cassette? The only audio-related uncerainty I usually experience is that which wells up when the umpteenth time I am told: “I have evidence that backs up my views, but I am going to keep it secret.”

I note Mead is curious about the mechanisms of hearing. Fortunately, there exists a huge body of knowledge on the subject of psychophysiology and psychoacoustics and it is the human brain doing the work, and understanding that may well be the ultimate challenge that faces us.

What is known in considerable detail is the low-level functioning of the ear, with particular reference to what is perceptible and what is not. Really it is not on to claim that perceived amplifier performance is shrouded in mystery.

**Douglas Self**

**Forest Gate, London**


**Doctor WHO**

Douglas Self (Letters, EW + WW, October) should search a little wider before he condemns earlier writers on adverse and beneficial effects of exposure to ELF, RF and microwave fields.

The World Health Organisation has just published in its environmental health series, “Electromagnetic fields 300Hz - 300GHz”. It details hundreds of references from scientific, medical and physics authors on the effects on humans, animals and cell lines in vivo and in vitro.

He should also pause to muse that the WHO published in 1989 a text called “Non-ionising radiation protection”. This is divided into sections on ELF, RF, UV, sonic, ELF and so on.

Is it likely that it would publish these books unless there are perceived hazards soundly based in research? Fructose and ulcer healing studies are reported from many sources worldwide. Indeed, St. Thomas’ and Bart’s hospitals are working on these lines.

It is especially interesting that many studies indicate that there are windows of frequency and amplitude which can, and do, affect immunocompetence (via free radical mechanisms at cellular level), bone healing, wound healing and subclinical endocrinodysrhythmias.

As a very wise military signals officer told me “all radiation is radiation”. Too much UV from the sun can trigger malignant melanoma, too much RF from furnaces can lead to glass blowers cataract (unless protective measures are taken), and too much exposure to microwaves (WHO 1993) can trigger thermal and uthermal effects, including brain damage of varying degree.

---

**Dr Allen** in *Journal of Radiological Protection 1991* describes reactive near fields, which he says “can affect people and objects”, as against radiating near and far fields.

In June the International Bioelectromagnetics Society met in the USA. There were 700 attendees with 486 papers and posters: 250 were from the US, 50 from China, 20 from most European countries, and five from Yugoslavia and seven from the UK. In November Euro held a conference in Bad Neumheim called “Biological effects of magnetic fields” (Verband Deutscher Elektrotechniker). Radio Electronics in the US in September 1986 carried a six page article on the effects of RF energy on the body and detailed many experiments carried out on healing, production of aggression, hallucinations and so on.

Lastly, Elizabeth Davies’ paper “The healing face of electromagnetic fields” (EW + WW, April 1993) calls for research into the signal/tissue response. A timely invitation as the WHO calls for urgent multidisciplinary epidemiological research into the effects of fields on the human body.

Anne C Arnold Silk

Great Missenden, Bucks
1992 Winter Issue of Display News now available - send large SAE - PACKED with bargains

LOW COST PC SPECIALISTS - 100% COMPATIBLE
8086 XT - PC99
286 AT - PC286
386 AT - PC386

- 2.86M RAM - expandable
- Factory built-in PSU
- 4.7 Mhz speed
- 360k 5-1/4" floppy
- 2 serial & 1 parallel ports
- MS-DOS 4.01
- In good used condition.

Only £249.00

- 640k RAM expandable
- With standard SIMMS
- 12 Mhz Lanchester speed
- 20 meg hard disk
- 2 serial & 1 parallel ports
- MS-DOS 4.01
- In good used condition.

Only £249.00

- 2 megar expanded by slots
- 20 Mhz with 32k cache
- 40 meg hard disk
- 2 serial & 1 parallel ports
- MS-DOS 4.01
- In good used condition.

Only £249.00

- 14" Philips MT5-9603 VGA
- With 16 colors and 1280 x 1024 pixels
- MS-DOS 4.01
- In good used condition.

Only £425.00

- Fujitsu M3041 600 LPM band printer
- connection to most makes of monitor. For complete compatibility virtually all television frequencies VHF and UHF including the colour television or video channels. TELEBOX MB covers virtually all television receivers (TELEBOX MB). Push button controls provide diagnostic information on the video output. On board Superbly made UK manufacture. EPROMs contain the custom operating system on which we are sure that with a bit of experimentation and ingenuity many useful applications will be found for this board! It is supplied complete with a connector panel which brings at the I/O to 17 and BNC type connectors - all you have to do is provide the PC and compats. 640 x 350 resolution. With Text switch with monochrome high resolution mode), Ar- chimedes etc. In good used condition (possible minor screen burns) 90 day guarantee. 15" 14" x 12" Only.

- Philips PC973 similar (not identical) to above for EGA/GA and compats. 640 x 350 resolution. With Text switch for EGA/GA with or given screen expansion to 12 x 12 x 12 x 12 and 15" x 12" x 12" x 12". KME 10" high definition colour monitors. Not to 0.2" dot pitch for super clarity and modern styling. Operates from any 120v 60 hz 40w AC power source. VGA, digital/analog, switch selectable. Sound volume and controls are there. As a special "Flex" switch for word processing, graphics, business spreadsheets and the like. Compatible with IBM PCs, Apple, BBC etc. Measures only 13.5" x 12" x 12" and 15" x 12" x 12" x 12". Only £75.00.

- BBC Model B type computer on a board. A major purchase allows us to offer you the PROFESSIONAL version of the BBC computer at a parts only price. Used as a front and graphic systems. Which on large networks the architecture of the BBC board has so many similarities to the BBC model B that we are sure that with a bit of experimentation and ingenuity many useful applications will be found for this board! It is supplied complete with a connector panel which brings at the I/O to 17 and BNC type connectors - all you have to do is provide the PC and compats. 640 x 350 resolution. With Text switch with monochrome high resolution mode), BBC, Archimedes etc. In good used condition (possible minor screen burns) 90 day guarantee. 15" 14" x 12" Only.

- Philips PC973 similar (not identical) to above for EGA/GA and compats. 640 x 350 resolution. With Text switch for EGA/GA with or given screen expansion to 12 x 12 x 12 x 12 and 15" x 12" x 12" x 12". KME 10" high definition colour monitors. Not to 0.2" dot pitch for super clarity and modern styling. Operates from any 120v 60 hz 40w AC power source. VGA, digital/analog, switch selectable. Sound volume and controls are there. As a special "Flex" switch for word processing, graphics, business spreadsheets and the like. Compatible with IBM PCs, Apple, BBC etc. Measures only 13.5" x 12" x 12" and 15" x 12" x 12" x 12". Only £75.00.

- 14" Philips Model MT5-9603 VGA multi-synchronous with resolution of 1280 x 768 0.16 pitch, "Test" switch for word processing etc. Overseas switch included. Ideal for the PC 386 or PC-286 with VGA card added. Also suitable for the PC-286 with the monochrome high resolution model), Archimedes etc. In good used condition (possible minor screen burns) 90 day guarantee. 15" x 14" x 12" Only.

- Philips PC973 similar (not identical) to above for EGA/GA and compats. 640 x 350 resolution. With Text switch for EGA/GA with or given screen expansion to 12 x 12 x 12 x 12 and 15" x 12" x 12" x 12". KME 10" high definition colour monitors. Not to 0.2" dot pitch for super clarity and modern styling. Operates from any 120v 60 hz 40w AC power source. VGA, digital/analog, switch selectable. Sound volume and controls are there. As a special "Flex" switch for word processing, graphics, business spreadsheets and the like. Compatible with IBM PCs, Apple, BBC etc. Measures only 13.5" x 12" x 12" and 15" x 12" x 12" x 12". Only £75.00.
Working with programmable logic

3: generic and gate array logic

The first two articles of this series considered methods of designing logic to fit into combinational and registered PLDs. In this final part, Geoff Bostock looks at generic logic and field programmable gate arrays.

A common element among standard logic PLDs is their fixed architecture. For example, a PAL16R6 has eight fixed inputs, two bidirectional I/O pins, and six registered outputs; a PLS173 has twelve fixed inputs and ten I/O pins.

In the mid-1980s, Lattice Semiconductor unveiled a device whose architecture itself could be programmed. It was designed to be capable of emulating any of the standard combinatorial or registered PALS and, as a further innovation, it was fabricated with CMOS technology.

This device, the GAL16V8 and its 24-pin counterpart the GAL20V8, featured a programmable macrocell whose design is shown in Fig. 1.

The basis of gals (generic array logic) is the introduction of programmable multiplexers into the output structure. The basic device features four multiplexers: for output enable, register bypass, feedback, and the eighth product term.

The output enable can be driven in four ways. It may be always enabled as in an output pin of a simple I/O family pal, or it may be always disabled as in an input pin from the same range. In PAL16L8s, it is derived from a dedicated product term, while in registered PALS there is a common enable from pin 11 (or pin 13 in the 24-pin family).

The 'eighth product term' is used as the output enable in the PAL16L8, but as a pure logic term in all other PALS. Register bypass allows both combinatorial and registered outputs to be derived from the same output macrcell. The feedback multiplexer has four possible signal sources. It must come from the output flip-flop in registered PALS, from the output pin in bidirectional I/Os, and be disabled in fixed outputs.

The fourth source is an adjacent output pin. In the PAL16L8, pins 12 and 19 are fixed outputs while pins 13 to 18 are I/Os; in the PAL12L6 family (apart from 10L8 and 10H8) pins 12 and 19 are fixed inputs, and the middle pins may be either fixed input or output according to the device type. Also, pin 1 is the clock input in registered PALS but a logic input in combinational PALS.

The feedback from the top macrcell to the and-array must come from pin 1 in a combinational pal but from pin 19 in a PAL16R6 or PAL16R4 (where it is an I/O pin).

Likewise, the feedback from the second macrcell...
Complex PLDs, of which gals are an early example, rely on multiplexers to provide output function programmability. Gals, in particular, are able to emulate nearly all of the standard pals by routing the output, feedback and enable signals through the output macrocell.

In the PAL12L6 emulation, the 'adjacent stage' lines route the pin 1 input to the pin 19 feedback multiplexer, and pin 19 to pin 18 feedback; pin 18 becomes a direct output.

The PAL16L8 also routes pin 1 to pin 19 feedback but pin 19 is also a direct output with no feedback. Pin 18 is an output with feedback. Both pins use the output multiplexer register by-pass path and the 'eighth product term' in the enable multiplexer.

PAL16L8s have a mixture of combinatorial and registered outputs. Pin 19 is combinatorial so the register by-pass output, direct pin feedback and 'eighth product term' enable are selected. The registered pins, such as pin 16, use registered output, feedback from the flip-flop and common enable.

Fortunately, in practice these selections are performed automatically by the software built into most programmers, which set the correct bits for the macrocell multiplexers. Gal design software will also set the select bits if architectures which do not correspond to standard Pals are chosen.

...comes from pin 18 in a PAL16L8 or PAL16L4, but pin 19 in any other combinatorial pal in which pin 19 is an input.

The feedback and output multiplexing for the top two macrocells is shown in Fig. 2 for emulations of pals 12L6, 16L8 and 16L6.

The other feature of the gal macrocell is the programmable polarity output. This makes it possible to emulate active-high as well as active-low pals.

Although gals can emulate nearly all standard pals, their architectural possibilities are not limited to these alone. For example, it is possible to use a gal as a pal with three registered and five combinatorial outputs, and to mix these as active-high and active-low, as desired.

There are a few restrictions though; for example, pins 12 and 19 cannot be used as inputs in some modes because of the way in which the multiplexer program cells set the feedback multiplexer.

We have not described the operation of the multiplexer program cells because this is all taken care of by the device programmer or the design software. Device programmers which can program gals have the emulations built into them so that the correct architecture fuses are set when the pal being emulated is selected. Assemblers for gals also set the appropriate bits for the chosen architecture even if this is not a pal emulation.

While Lattice were bringing out the GAL16V8 and GAL20V8, AMD introduced the PAL22V10. This device also features output macrocells which can be set as combinational i/o or registered outputs, although their design differs slightly from the Lattice circuit. This is because the 22V10 is not aimed at replacing standard pals, although it can emulate the PAL20L10 family, but it is a more complex device altogether.

The most powerful feature of the 22V10 is the variable number of and-terms in the and-array. As Fig. 3 shows, the lowest number of and-terms in any output is eight (pins 14 and 23) and increases to sixteen for pins 18 and 19. This goes some way to overcoming the transition term restrictions which can be found when trying to use pals for state machines.

There is also a separate and-term for the output enable in each output pin. Separate and-terms are also provided for synchronous preset and asynchronous reset across the whole device. These features are also helpful in state machines for setting the device to a known state for test or start-up.

Low power logic
The gals were designed as cmos PLDs, and the PAL22V10 is also available in cmos from several manufacturers. Their data sheets indicate that they still consume tens of milliamps of supply current, about half as much as the equivalent bipolar PLDs which they may replace. While this is still a useful saving, it is not much help to designers...
of portable or battery-powered equipment.

The reason is to be found in the structure of the internal logic. A standard CMOS gate, as in Fig. 4, consists of a parallel transistor structure topped by a serial transistor structure, one half being p-channel the other n-channel. In this NOR gate, if all inputs are low the top conducts but none of the bottom n-channel transistors are turned on. If an input goes high it switches off its p-channel transistor in the top half, thereby preventing conduction, but turns on its n-channel transistor, pulling the output low. The net result is that no direct current flows in the gate, only charging current when the output changes sense.

A typical and-term in a PLD has 32 or more inputs, but it is not feasible to construct a CMOS gate with 32 transistors in series because of the threshold voltage of the individual transistors in the chain, and the voltage drop across the channel resistance when current is taken from the chain. Instead, each and-term has to be powered by a current source which is always supplying some current to the multiple input gate. The main power saving comes from building the peripheral components, such as input and output buffers and flip-flops from true CMOS.

Some PLDs are available with stand-by current of a few microamps. The way in which this achieved is shown in Fig. 5. The logic arrays are powered via a switchable current source; while there is no activity at the inputs the current is switched off, so there is virtually no current taken by the device. The activity detector at the inputs switches the current source on for a sufficient time to allow the logic array to react to the new inputs. The resulting output is latched at the device outputs so that it remains in place when the array current source switches off again. Zero-power versions of many PLDs are now available such as the GAL16V8Z, GAL20V8Z, PAL22V10Z and PLC18V8Z, a more universal version of the GAL16V8Z.

Asynchronous registered PLDs
All the registered PLDs described so far have a single clock signal input. This ensures that all the flip-flops in the output register are clocked simultaneously, a necessary condition in a state machine.

There are many instances of simultaneous clocking being unnecessary or not possible. Examples are multiple state machines and random logic.

It is quite conceivable that two or more state machines can be fitted into a single PLD: the only restriction is that the total number of inputs and outputs does not exceed the resources available. It is not necessarily the case that each machine will use the same clock, although they often will. If they do not, the PLDs described so far will not be suitable.

There is no reason why random logic cannot involve flip-flops as well as combinatorial devices. One example...
of a standard logic function which does not use simultaneous clocking is a ripple counter.

In this case, the output from one flip-flop is the clock input for the next.

Figure 6 illustrates a simple random logic circuit involving flip-flops; it detects whether the rising edge of the data input occurs before or after the falling clock edge. The output could be used to synchronise the data with the clock, by feeding it back to a voltage controlled oscillator.

The equations for this circuit use the following format:

\[ Q_1 := D \]
\[ Q_1.CLK = CLK1 \]
\[ Q_2 := D \]
\[ Q_2.CLK = Q_1 \land \neg CLK1 \]

the \( CLK \) extension denoting that this is the clock input to the flip-flop whose output is \( Q_1 \) or \( Q_2 \) respectively.

The \( PAL2ORA10 \) is a common asynchronous pal; a macrocell from this pal is shown in Fig. 7. Each macrocell has eight and-terms, four of these are logic terms, the other four drive the output enable, clock, set and reset. The clock input can be any logical combination of the input and output signals, provided that it can be described in a single and-term. In the above example, the clock input is drawn as \( \neg (Q_1 + \neg CLK) \) but can be transformed to \( \neg Q_1 \land \neg CLK \) to fit into one and-term.

The set and reset behave as usual for a flip-flop, except for the usually forbidden combination of set and reset both high. This condition in the \( PAL2ORA10 \) bypasses the flip-flop and converts the output into a combinatorial i/o.

Many other PLDs are now made with an asynchronous option. A common way of implementing this is to use a double multiplexer, as in Fig. 8. One multiplexer feeds the clock, the other drives the output enable. The clock multiplexer has inputs from an and-term and the common clock, the output enable multiplexer is driven by the same and-term and either a common output enable or an ‘always enabled’ input. The multiplexer select bit is arranged so that the and-term is available to either clock or output enable.

**Buried register PLDs**

Although some FPLSs have buried registers, these are designed into the part and the designer has no choice in the proportion of flip-flops which are internal, and those which are outputs.

Another failing of some PLDs is the waste of resources when an output flip-flop is by-passed to provide a combinatorial i/o. Some of the more advanced PLDs overcome both of these shortcomings by allowing by-passed flip-flops to be used as internal components, but with no direct access to the outside world.

One of the most versatile programmable logic devices in the 20 to 28 pin range, is the \( PLC42VA12 \). This is an FPLS which can emulate the \( PLS179, PAL22V10 \) or \( PAL2ORA10 \). Figure 9 shows the output stage of the device. There are separate and-terms for the ten clock inputs and ten output enable signals, as well as the set and reset lines and direct load facility, which is found on the \( PLS179 \).

Each output has three or-terms and two feedback lines to the and-array. If the flip-flop is bypassed, so that the output becomes a combinatorial i/o pin, the feedback from the flip-flop is still available.

A by-passed flip-flop becomes a buried flip-flop, so this resource need not be wasted.

When designing for the \( PLC42VA12 \) with Snap, which is the Philips PLD software, all nodes in the design can be defined irrespective of whether they are internal or external. All flip-flop outputs are treated equally, whether they are by-passed or fed to output pins.

It is only at the time when nodes are assigned to pins that the software will allocate logical nodes to physical elements within the PLD.

Many PLD compilers require the designer to define buried nodes at the start of the design.

The circuit of Fig. 10a can be used as an indication of the complexity of design which may be incorporated into the \( PLC42VA12 \). Eight internal flip-flops are used to form a two digit decade counter whose outputs feed a quadruple...
two-bit multiplexer. The multiplexer output drives a seven segment decoder which is output from the device. Selection of the multiplexer is by a two bit state machine which also provides digit select outputs. Different clocks are used for the counter and the digit select. This circuit uses only three inputs and nine outputs leaving three i/o and seven inputs unused. As we shall see, the counters need nine terms each, the decoder/multiplexer uses 32 terms while the digit select takes just two terms. There are, therefore, twelve and-terms spare for using with the leftover inputs and i/o.

The design may be split into four sections.

Let us first examine the decade counters: their state diagram is shown in Fig. 10b. The most efficient way of building counters is, usually, with toggle flip-flops, so we will follow this approach. To find the minimum solution we can draw out the Karnaugh maps for each counter bit; this is done in Fig. 10c.

A toggle must be entered on every occasion when a bit changes from 1 to 0 or from 0 to 1, remembering that above 9 (1001b) the counter must jump direct to 0 (0000b). The numbers 10 to 15 have been included in case the counter could get stuck. If they were not included, the counter should find itself in one of these states, perhaps above 9 (1001b) the counter must jump direct to 0 (0000b).

Changes from 1 to 0 or from 0 to 1, remembering that this is done in Fig. 10c.

From the Karnaugh maps we can write the following equations:

\[ B_3.T = CE \& (B_3 \& B_2) \]

\[ B_2.T = CE \& (B_3 \& B_2) \]

\[ B_1.T = CE \& (B_3 \& B_1) \]

\[ B_0.T = CE \& (B_1 \& B_0) \]

although there are eleven terms, two of them are duplicated, \( B_3 \& B_2 \) and \( B_3 \& B_1 \), so a single and-term is used for each making nine terms needed in all. The MSB counter, \( A_3 \) to \( A_0 \), will use the same equations except that it only toggles when the LSB is nine; the term \( B_3 \& B_2 \& B_1 \& B_0 \) must, therefore, be on with every term giving:

\[ A_3.T = CE \& B_3 \& B_2 \& B_1 \& B_0 \& A_3 \& B_2 \& B_1 \& B_0 \& \ldots \]

We must also define the clock to be used; this is done as follows:

\[ B_3.C.LK = CLK \]

\[ B_2.C.LK = CLK \]

\[ B_1.C.LK = CLK \]

\[ B_0.C.LK = CLK \]

These definitions do not use up any and-terms.

The third section we can define is the multiplexer/decoder.

The seven segment decoder is a straightforward combinatorial design.

Segment ‘a’, for example, is used in every number except ‘1’ and ‘4’; the basic equation for segment ‘a’ is therefore:

\[ SEG_a = B_3 \& B_2 \& B_1 \& B_0 \]

\[ SEG_a = B_3 \& B_2 \& B_1 \& B_0 \]

In order to select the MSB or LSB this basic function must be gated with the appropriate select function. We can define these as \( D_1 \& !D_0 \) for the MSB and \( !D_1 \& D_0 \) for the LSB. The full equation becomes:

\[ SEG_a = D_1 \& D_0 \& !B_3 \& B_2 \& B_1 \& B_0 \]

\[ SEG_a = D_1 \& D_0 \& !B_3 \& B_2 \& B_1 \& B_0 \]

\[ SEG_a = D_1 \& D_0 \& !A_3 \& A_2 \& A_1 \& A_0 \]

\[ SEG_a = D_1 \& D_0 \& !A_3 \& A_2 \& A_1 \& A_0 \]

\[ SEG_a = D_1 \& D_0 \& !A_3 \& A_2 \& A_1 \& A_0 \]

Similar equations may be derived for the other segments; in all, 32 terms are needed for the whole decode.

The state diagram for the final section is shown in Fig. 10d. The basic function is a toggle between \( D_1 \& !D_0 \) and \( !D_1 \& D_0 \), but we must also include the illegal states \( D_1 \& D_0 \) and \( !D_1 \& !D_0 \). The transitions are unconditional so we can easily derive the equations as:

\[ D_1.J = D_0.D_1.K = !D_0 \]

\[ D_0.J = !D_0 \]

\[ D_0.K = D_0 \]

\[ D_1.C.LK = DCLK \]

\[ D_0.C.LK = DCLK \]

These use just two and-terms as the two \( D_0 \) and the two
10 terms each use just one and-term which is used twice in the OR-array.

While this design has been aimed at the PLC42VA12, there are other PLDs with similar capabilities. Among these is the GAL6001; this device has input flip-flops but no direct load facility. It uses D-type flip-flops with a clock enable input allowing J-K flip-flop emulation.

It also has an eight bit wide dedicated buried register making it more powerful in some applications than the PLC42VA12.

Other complex PLDs exhibiting buried registers include the PALCE29M16 and PALCE29MA16 from AMD, CY7C330 and CY7C331 from Cypress, 5AC312 from Intel, ATV750 from Atmel and XL7C800 from Exel. All these use pal architecture (i.e. fixed or-array) except the XL7C800, which has a nor-nor structure in a single array.

This is equivalent to an and-or structure because:

\[ \neg(A \land B) \land \neg(C \land D) = \neg(A \lor B) \land \neg(C \lor D) \]

by de Morgan’s Laws.

LSI PLDs

So far we have described PLDs with up to 28 pins but, in the last few years, technology has moved on to the point where PLDs are being made with over one hundred pins and the capability to replace a dozen or more 16V8s.

LSI has followed three basic paths, the simplest of which is a multi-pal approach. The main families are the AMD Mach and Altera Max; the chief difference between them is the way in which the pal blocks are interconnected.

Large pal type devices engender problems with propagation delay introduced by the and-array. Each programmable cell adds capacitance to the array and, for example, in an 84 pin device, there could be about 160 inputs to the and-array if all the inputs and I/O were directly connected to the array. This compares with just 32 array inputs in a GAL16V8 making the structure significantly slower than a basic gal.

In the Mach family, the device inputs are fed to a switch array which allocates them to the pal blocks, with a maximum of 22 or 26 into each block. The actual size of each pal block varies according the actual device, but they are of the form 22V12, 26V16 etc.

Each fixed-or term is fed by only four and-terms but a logic allocator combines up to four or-terms into each output. Thus, the and-terms associated with I/O used as inputs need not be wasted. Half the devices in the basic Mach family have macrocells which are all routed to I/O pins, while the rest have half the macrocells buried.

Figure 11 is the block diagram of the Mach220, a middle size device with 68 pins and buried registers.

Each macrocell has three and-terms, plus an exclusive-or for J-K emulation, but, unlike the machs, none of the I/O macrocells can be buried if the pin is used as an input. The signal routing is handled by the programmable interconnect array (pia), which has all the I/O and macrocell feedbacks available.

As with Machs, each lab is fed those signals which it requires; unlike Machs, all direct inputs and local lab feedbacks are always available to each lab. The block diagram of a 68 pin Max, the EPM5128, is shown in Fig. 12. Both families have similar logic capability with the slight edge going to the Max family. This advantage is bought by having a higher connectivity into each lab.

The result is a slightly slower device, and one with variable delays.

Because all Mach signals pass through the switch array they all have virtually the same delay time; in the Max
The traditional way to mop up large quantities of logic elements has been with masked asics, particularly gate arrays. PLD design files can even be used as data input for many asic design packages. FPGAs are the PLD answer to masked asics. The floor plan of a typical FPGA is shown in Fig. 13a; the similarity to a gate array is self evident. The same four principal components exist in both structures.

Logic signals enter and leave the FPGA via i/o cells, which offer the usual features, such as tri-state, cmos/TTL interfacing, edge speed selection, and so on. The logic functions are defined in internal logic blocks. These are often more complex than masked gate array logic cells. Two examples are shown in Figures 13b and 13c. The Xilinx cell is the more complex, and includes configuration bits to define the logic paths through the macrocell. The Actel macrocell is smaller and, apart from the flip-flop bypass, has a fixed architecture. Connections between macrocells are made by horizontal and vertical routing lines in channels between the macrocells. Fuses or, in the case of Xilinx, ram cells at crossing points define the interconnections, and the logic paths in and out of the macrocells and i/o cells.

Design path is very similar to a masked asic, with logic capture, simulation, place and route, and timing simulation as the main steps. The advantage of FPGAs is that turn-round is very much quicker, and the minimum quantity is very much lower.
way in which they are programmed. Xilinx arrays use ram cells to define both interconnections and logic block configuration. The program data is usually stored in an adjacent eprom which is automatically downloaded into the array on power up, because the ram cells lose their data when switched off. This additional board space can be a disadvantage, but product development can be much simplified, and it might be possible to use the same circuit board for more than one function.

The Actel FPGAs do not need their cells configuring, because they are a much simpler design. Array connections are made with an 'anti-fuse'; this consists of a thin dielectric layer sandwiched between polysilicon and the silicon surface. The programming pulse ruptures the dielectric and alloys the two silicon layers together. The connections in this case are therefore hard wired and the device cannot be reprogrammed.

Designing FPGAs involves more steps than pal structure devices.

The basic logic design is the same but, once the desired function is defined, it must be broken into modules which fit the architecture of the FPGA logic blocks. The modules must be allocated to blocks and then connections routed between them. These are the same place and route steps which are needed to define masked gate arrays.

Once the design is placed in the array, timing simulation is necessary for the delay of internal signals will be affected by the lengths of tracks they use. From this point of view it may be more difficult to achieve instant success than with a pal structure, but the final result should give more efficient use of silicon, and therefore a cheaper solution.

The third class of LSI is based on an FPLS structure; two examples are the MAPL (multiple array programmable logic) from National Semiconductor and PML (programmable macro logic) from Philips.

MAPL is a large FPLS with additional gal outputs on larger devices.

The chief innovation is the use of page mode power-up, so that only a small portion of the array is consuming power at any one time.

As well as a 'next state' output from each transition, there is a 'next page' which powers up the page containing possible jumps from the next state. This allows the array to achieve high speed without an excessive power consumption.

PML, in Fig. 14, uses a single foldback array of nand-gates for logic implementation. This uses the equivalence:

\[ ! ((A \cdot B) \cdot (C \cdot D)) = (A \cdot B) \cdot (C \cdot D) \]

which can be deduced from de Morgan's Laws.

In PML, the logic core is surrounded by macro logic elements with inputs and outputs to the NAND array. Device inputs and outputs are also connected to the logic core so that the macro elements can be used either internally or as output functions.

The PML array, for example, has 29 dedicated inputs, 16 of which have by-passable flip-flops; there are 24 bi-directional i/o lines including 16 by-passable registered outputs.

Internally there are 20 J-K flip-flops with a separate clock array, and a logic core of 96 nand-gates.

This structure is freer than pal-type LSI, although this particular device has not quite the power of 68PLCC Mach or Max parts in terms of gate and flip-flop count. Neither does it match FPGAs for potential logic complexity. There is no reason why, with denser internal logic, this structure

**Fig. 14. PML structure.**
Multi-Device Programmer

- Fast Programming - Intelligent Algorithms
- Connects directly to printer port
- On line "HELP" System
- Easy to use menu driven software
- Supports a wide range of devices

All without adapters

including:

- EPROMs and Flash (28F and 29F)
- PLDs GALs PALs
- 8748 and 8551 families including 87C751
- Additional modules include:
  - Serial EPROMs (59C.. and 24C..)

New parts added all the time

Contact SMART Communications for our full range of programmers including stand-alone programmers, gang programmers and our comprehensive universal device programmer

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

CIRCLE NO. 117 ON REPLY CARD

**OSCILLOSCOPES**

- HEWLETT PACKARD 4245A - 40 MHz 7000V Twenty Bit Averaging
- HEWLETT PACKARD 4246A - 40 MHz 7000V
- HEWLETT PACKARD 4247A - 80 MHz 7000V
- HEWLETT PACKARD 4248A - 100 MHz Dual Channel
- HEWLETT PACKARD 4249A - 120 MHz

**SPECTRUM ANALYSERS**

- RACAL-DANA 5033A SPECTRUM ANALYSER
- RACAL-DANA 5034A SPECTRUM ANALYSER
- RACAL-DANA 5035A SPECTRUM ANALYSER
- RACAL-DANA 5036A SPECTRUM ANALYSER

**MISCELLANEOUS**

- PHILIPS 5167 - FUNCTION GENERATOR
- MULTICORE SOLDERABILITY TESTER
- GALLENIC EMP 300+ SERIES THERMOSTAT/CYCLE TIMER
- FARNELL R51030-36 ELECTRONIC LOAD
- DATRON 1071A - AUTOCAL MULTI FUNCTIONAL AVO
- RACAL-DANA 9084 SYNTHESISED SIGNAL GENERATOR
- MARCONI 2631 CHANNEL ACCESS SWITCH
- KEITHLY 197 AUTO D.M.M WITH IEEE 488 GPC INTERFACE
- HEWLETT PACKARD 3486A DIGITAL VOLTMETER

**COMMENTS**

Please check availability before ordering.

Please CALL for your FREE copy of our latest Catalogue.
O.E.M. Dealer & Educational Enquiries Welcome.
Switched capacitor filter combines notch and low-pass functions

It is increasingly common to reserve a very narrow band of the audio spectrum for data, control or coding information. Provided that very sharp band stop and pass filtering is used for insertion and recovery, adding the information sacrifices very little in audio quality.

GEC Plessey has produced a switched-capacitor device in CMOS ASIC technology called the MA6882. As Application Note 137 describes, the device combines both sharp notch and low-pass filter functions.

For the low-pass filter section, the -3dB point is fixed at the clock frequency divided by 1470. Clocking at 5MHz for example will cause cut-off at 3.4kHz. The notch filter however can be placed at four jumper-selectable points, at divisions of the clock frequency of 1870, 2493, 3740 or 7480.

Further suggested applications for the notch information are wow and flutter correction, AGC, noise reduction and sound effects.

GEC Plessey Semiconductors, Cheney Manor, Swindon, Wiltshire SN2 2QW. Tel. 0793 518000.
Low-noise microphone preamplifier exhibits less than 1nV/√Hz noise

Instrumentation amplifier configurations are useful as microphone preamplifiers. Besides allowing gain to be set via one resistor, they remove the need for a transformer while keeping common-mode rejection high.

This low-noise circuit from Analog Devices note AN242 features a phantom power option with input protection and is gain adjustable via one resistor, RG.

Input-referred noise is less than 1nV/√Hz over a gain range of 2 to 2000 while common-mode rejection capability is 90dB or more. For gains to 200, the THD plus noise figure is well below 0.01% at all frequencies to 20kHz.

Phantom power involves inserting a DC voltage, typically between 10 and 48V, on the preamplifier input. This voltage is needed to power capacitive microphones. In its steady state the phantom voltage presents no problems. At power up or down, or when the microphone is plugged or unplugged however, protection is needed to avoid damaging the preamplifier inputs.

Given a phantom voltage of 48V, the input capacitors can discharge several amps into the amplifier inputs.

In this circuit, protection is provided by two zener diode pairs and resistors for limiting peak current. The IN752 diodes are 400mW types, equivalent to a European 5.6V BZX79, and limit peak transients to 10V or below.

Further details in the note cover the op-amp, circuit design, performance and the importance of selecting the right components. There is also a discussion of how to further reduce the circuit’s RF sensitivity.

Analog Devices, Station Avenue, Walton-on-Thames, Surrey KT12 1PF. Telephone 0932 232222.

Over a gain range of 2 to 2000, this transformerless microphone preamplifier exhibits input referred noise of less than 1nV/√Hz. Switching phantom power can cause very large current surges which would normally destroy the instrumentation amplifier input. This circuit is fully protected.
Bidirectional drive for coaxial cable

For voice-band signals, designing a single-cable bidirectional link is quite simple. Similar links for megahertz bandwidth however involve high-speed amplifiers and well-controlled impedance matching.

Programmable wideband transconductance amplifiers can provide such a wideband bidirectional coaxial interface, as illustrated in this diagram from Maxim’s twelfth Engineering Journal.

Functionally, the circuit is similar to ones used in telephone interfaces and offers the same benefit—it saves the cost of a return cable. Components shown are for a 50Ω system but with appropriate modifications, the circuit is equally suited to 75Ω video and other impedance levels.

Identical circuits terminate each end of the cable. As well as performing signal reception, each return amplifier (the top two) also cancels all signals originating at its end of the link.

On either side, input signals drive both the inverting input of their receiver and the non-inverting input of their transmitter. In this way, the signal passes through the transmitter unchanged but is inverted in the receiver, which results in its cancellation.

To achieve the cancellation, the amplifier transconductances must be set for unity gain throughout. Several factors can degrade the cancellation. First, phase shift in the line driver prevents the return amplifier from subtracting identical signals.

Secondly, any transconductance mismatch in the amplifiers causes the signals to have different amplitudes, which again disturbs the output nulling. Finally, any impedance mismatch along the cable causes reflections. The non-adaptive circuits shown cannot distinguish between such echoes and the desired incoming signal.

Signal cancellation depends on the tolerances of termination resistors R1,5,6,10. Their degree of mismatch with the cable impedance is also important. Similarly, the transconductance for each amplifier is affected by resistors R2,3,8,9. Transconductance, g_m, is 8/R. The ‘8’ is a property of the IC and guaranteed to be within ±2.5%.

Outputs test traces are shown. Those at the top show both outputs when one end of the link is driven with a 1MHz signal, the other with 2MHz. Both generators are 50Ω impedance.

On the lower pair of traces, one input is driven while the other is terminated with 50Ω. On the receive side, the receiver outputs the full signal as required, top trace. The receiver on the transmit side however should show none of the transmitted signal. The small residual signal shown in the lowermost trace results from 30dB cancellation in the low megahertz range, which will be acceptable for most applications. To achieve it, resistors need to be matched to 1%.

Maxim, 21C Horseshoe Park, Pangbourne, Reading RG8 7JW. Tel. 0734 845255.

In a high-speed bidirectional link, one of the main problems is getting the receiver at the transmitting end to ignore the transmitted signal. If 1% resistors are used, the circuit shown can cancel to about 30dB (lowest trace).

Two transconductance amplifiers form a high-frequency coaxial cable interface similar to the hybrid-circuit interface found in telephones.
Step-down converter remains efficient at low currents

At currents of around an amp and an input of 12V, this step-down converter is 93% efficient. Many switching converters are highly efficient at a specific output current near their maximum but this design remains efficient as current falls. Although efficiency is highest at low input voltages, the circuit operates from supplies up to 48V.

Designed for use in battery and low power applications, the LTC1149-5 is a synchronous switching step-down controller capable of operating in 'burst mode'. As Linear Technology's Power Solutions 1993 brochure explains, it is this mode that allows the device to maintain efficiency with low output currents.

At very low battery voltages the IC produces a 100% duty cycle, i.e. the circuit stops switching and passes current directly to the output. The only losses are those in the mosfet, inductor and sense resistor. When battery input voltage falls to a predefined level, this switching converter stops switching so the only losses are those in the mosfet, inductor and sense resistor.

In normal mode, the two mosfets switch synchronously. Constant off-time control maintains constant ripple current in the inductor, easing the design in applications needing a wide input voltage range. Current mode control ensures good line and load regulation. This circuit provides 5V at 2A load current with ±5% regulation over load and line variations. Although efficiency is maximum at low input voltages, it stays above 80% for load currents down to 20mA under most conditions. In shut-down mode, current consumption falls to less than 42µA.

A 3.3V version of the IC is available, namely the LTC1149-3.3. There are over forty more circuits in Power Solutions 1993.

Linear Technology Corporation, Coliseum Business Centre, Riverside Way, Camberley, Surrey GU15 3YL. Tel. 0276 677676.

New solution to current sensing

By sensing current via the magnetic field it produces, a new type of transducer from Zetex combines the features of low measurement voltage drop and galvanic isolation.

As this circuit from the KMC10 data sheet implies, the shunt is isolated from the sensor to 2kV. In systems where only one power supply is available, this reduces grounding problems and removes the need for a separate supply. Additionally, the magnetic circuit is sensitive. As a result the shunt resistance is small and causes little effect when inserted in the circuit being measured. Maximum current handled by the KMC10 is 10A while resistance of its shunt is 0.7mΩ. Offset trimming is provided in the application circuit to compensate for the sensing bridge’s maximum offset of ±2mV.

The bridge makes use of the magnetostrictive effect of thin-film permalloy and operates up to 100kHz. Temperature limits of the device are -65°C and 120°C.

Zetex, Fields New Road, Chadderton, Oldham OL9 8NP. Tel. 061 627 4963.

Measuring current by sensing magnetic field strength in a series shunt can offer low voltage drop combined with galvanic isolation. This circuit incorporates a specially designed current sensing IC from Zetex.

January 1994 ELECTRONICS WORLD + WIRELESS WORLD
Low cost data acquisition for IBM PCs & compatibles

All our products are easy to install. They either plug into a serial port or are stand-alone units. They are supplied with easy to use software designed for either display or print-out.

**ADC-10**
- 8-bit resolution
- One channel
- 20-512K samples per second
- Oscilloscope/Voltmeter software
- 9-V input range
- Connects to printer port

**ADC-11**
- 16-bit resolution + sign
- 11-channel
- 5-16K samples per second
- Data logger software
- 0-255 input range
- Connects to printer port

**ADC-16**
- 18-16-bit resolution + sign
- 8 or 4 differential inputs
- 216 or 500-bit samples per second
- 21/2 input range
- Data logger software
- Connects to serial port

**£49**

PICO TECHNOLOGY LTD
Broadway House, 149-151 St Neots Road, Hardwick, Cambridge CB3 7QJ

**£75**

**£99**

**KESTREL ELECTRONIC COMPONENTS LTD**

- All items guaranteed to manufacturers’ spec.
- Many other items available.

‘Exclusive of V.A.T. and post and package’

1+ 100+ 1+ 100+

**EPROMS**
- 2764-250 2.56 2.20 62256ALP-10 3.30 2.60
- 2764-150 2.56 2.20 6264ALP-10 1.95 1.48
- 2712A-200 2.40 2.10 6116ALP-10 1.10 0.80
- 27256-250 2.30 2.10 628128ALP-10 12.00 10.00
- 27C512-250 2.30 2.30 HD63821P 1.95 1.50
- 27C512-150 3.30 2.55 6522P 2.40 1.80
- 27C100-510 5.80 4.20 65C02P 2.90 2.50
- 27C200-150 9.00 7.50 65C212P 2.90 2.50
- 68B50P 1.40 0.85 65C22P 2.75 2.40
- 68749H 4.40 3.75 280A CPU 1.30 0.92
- MM58274CN 7.00 3.95 280A P10 0.95 0.75
- 80C31-12meg 2.60 2.10 280A CTC 0.90 0.70
- 75176P 1.90 0.95 280A DART 2.20 1.30

**STATIC RAMS**
- 2764-250 2.56 2.20 62256ALP-10 3.30 2.60
- 2764-150 2.56 2.20 6264ALP-10 1.95 1.48
- 2712A-200 2.40 2.10 6116ALP-10 1.10 0.80
- 27256-250 2.30 2.10 628128ALP-10 12.00 10.00
- 27C512-250 2.30 2.30 HD63821P 1.95 1.50
- 27C512-150 3.30 2.55 6522P 2.40 1.80
- 27C100-510 5.80 4.20 65C02P 2.90 2.50
- 27C200-150 9.00 7.50 65C212P 2.90 2.50
- 68B50P 1.40 0.85 65C22P 2.75 2.40
- 68749H 4.40 3.75 280A CPU 1.30 0.92
- MM58274CN 7.00 3.95 280A P10 0.95 0.75
- 80C31-12meg 2.60 2.10 280A CTC 0.90 0.70
- 75176P 1.90 0.95 280A DART 2.20 1.30

74LS, 74HC, 74HCT Series available

Phone for full price list

All memory prices are fluctuating daily, please phone to confirm prices.

178 Brighton Road, Purley, Surrey CR8 4HA
Tel: 081-668 7522. Fax: 081-668 4190.
**Custom metalwork — good & quick!**

Plus a wide range of rack-mounting cases etc. from stock.

Send for our new Product Catalogue.

---

**SYSTEM: 200 DEVICE PROGRAMMER**

Program's 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial E2, PALS, GALS, EPROM'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. Same day dispatch, 12 month warranty. 10 day money back guarantee.

---

**M & B RADIO (LEEDS)**

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

---

**SYSTEM: 200 DEVICE PROGRAMMER**

Program's 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial E2, PALS, GALS, EPROM'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. Same day dispatch, 12 month warranty. 10 day money back guarantee.

---

**M & B RADIO (LEEDS)**

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

---

**SYSTEM: 200 DEVICE PROGRAMMER**

Program's 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial E2, PALS, GALS, EPROM'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. Same day dispatch, 12 month warranty. 10 day money back guarantee.

---

**M & B RADIO (LEEDS)**

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

---

**SYSTEM: 200 DEVICE PROGRAMMER**

Program's 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial E2, PALS, GALS, EPROM'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. Same day dispatch, 12 month warranty. 10 day money back guarantee.

---

**M & B RADIO (LEEDS)**

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

---

**SYSTEM: 200 DEVICE PROGRAMMER**

Program's 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial E2, PALS, GALS, EPROM'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. Same day dispatch, 12 month warranty. 10 day money back guarantee.

Analog Module includes:
- Complete control over all component values
- Ideal and real-world models for active components
- Resistors, capacitors, inductors, transformers, relays, diodes, Zener diodes, LEDs, BJTs, opamps, bulbs, fuses, JFETs, and MOSFETs
- Manual, time-delay, voltage-controlled and current-controlled switches
- Independent, voltage-controlled and current-controlled sources
- Multimeter
- Function generator (1 Hz to 1 GHz)
- Dual-trace oscilloscope (1 Hz to 1 GHz)
- Logic plotter (1 mHz to 10 GHz)
- SPICE simulation of transient and steady-state response

Digital Module includes:
- Fast simulation of ideal components
- AND, OR, XOR, NOT, NAND and NOR gates
- RS, JK and D flipflops
- LED probes, halfadders, switches and seven-segment displays
- Word generator (16 eight-bit words)
- Logic analyzer (eight-channel)
- Logic converter (converts among gates, truth table and Boolean representations)

Complement Your Test Bench

Here's why Electronics Workbench belongs on your test bench: Wires route themselves. Connections are always perfect. And the simulated components and test instruments work just like the real thing. The instruments are indestructible and the parts bin holds an unlimited supply of each component. The result: thousands of electronics professionals and hobbyists save precious time and money. **Over 90% would recommend it to their friends and colleagues.** Electronics Workbench: the ideal, affordable tool to design and verify your analog and digital circuits before you breadboard.

And now the best is even better - Electronics Workbench Version 3.0 is here. It simulates more and bigger circuits, and sets the standard for ease of use. Guaranteed!

**NEW** Features in Version 3
- New components include JFETs, MOSFETs, voltage-controlled and current-controlled sources and manual, time-delay, voltage-controlled and current-controlled switches
- Real-world models for opamps, BJTs, JFETs, MOSFETs and diodes - over 100 models available
- MS-DOS version now supports up to 16 MB of RAM for simulation of bigger circuits
- New Microsoft® Windows® version available
- Technical support now also available on CompuServe

Just £199!

Electronics Workbench
The electronics lab in a computer™

Call: (0827) 66212

ROBINSON MARSHALL (EUROPE) LTD.
17 Middle Entry, Tamworth, Staffs, England B79 7NJ
Fax: (0827) 58533

* 30 day money-back guarantee.
* Shipping charges: 15% of 3D. All prices are plus VAT.
* All trademarks are the property of their respective owners.

CIRCLE NO. 126 ON REPLY CARD
Cascode oscillator

This is a simple oscillator, but is very reliable and exhibits many of the features of a near-perfect circuit. It uses a two-terminal coil with no taps, self starts and draws only 1mA at 12V, the drive being inherently Class D. Output impedance is small and output swing large. Over the supply-voltage range of 2-24V, frequency stability and waveform purity are exceptional. Taking the gate input to 0V starts the oscillator at the same point in the cycle and the earthy end of R4 has a similar, but reversed effect. Tuned circuit $L_1C_2$ determines frequency – 160kHz in the case shown – and the time constant $R_1C_2$ must be longer than the period.

I J Hyland
Glazertron Ltd
Rochester
Kent

Battery backup

This provides 12V DC to an alarm clock when the mains-derived supply fails, the 12V coming from four 1.2V cells in a boost converter. The circuit is simply connected in parallel with the existing DC supply, which maintains charge on the cells through R. If the mains supply fails, the BC327 circuitry detects the drop and turns on the 1MHz multivibrator of gates 1 and 2, which triggers the monostable of gates 3 and 4, the output pulse of which is variable in width. The pulse, G, drives the converter mosfet, a low-voltage, low-R_{DS(on) type such as the BUZ10. Diode D is an ultra-fast device (an MUR110 was used) and inductor L is five turns of doubled 0.2mm diameter enamelled-copper wire on a ferrite bead, inductance being 20µH. It must not enter saturation.

With a 100kΩ load, 3V from the cells gives 12V output, this increasing to 5V for loads of 1kΩ or less down to a practical limit of a 220Ω load (around 50mA).

Dominique Bergogne
Saint Etienne
France
1 GHz frequency divider

To extend the frequency range of a 10 MHz counter frequency meter to 1 GHz, the input frequency must be divided by 100, to give a convenient reading. The frequency divider used in PLL tuners, shown as IC1 in the circuit diagram, divides by 64, so that a further division of 25/16 remains to be carried out.

IC3a,b are a dual binary counter, which would normally count to 256, but which is reset at a count of 25 by the feedback A, D and E outputs via AND gates IC3a,b, as shown in the timing diagram. Outputs B, C and A are further used by IC4 and IC5 to allow 16 input pulses to proceed to the output during this time, so that the division ratio is 25/16.

W. Dijkstra
Waalre
The Netherlands

Wide-band 64 divider, followed by 25/16 divider, gives division by 100 to extend measuring range of lower-frequency counter frequency meter.

Remote motor control

Using only the two DC power-supply leads, this circuit switches the motors in a remote unit such as a television camera over a distance up to 100 m or more with a different control signal. An LM3914 bar-graph IC in dot mode forms the core of the system, its input being the “raw” power supply itself, varied in steps at the remote control point.

Since the power line varies, a voltage regulator restores the correct level to the control circuitry, the type depending on the motors. Eight op-amps in two LM324 quads, boosted by transistor pairs if necessary, select motors and direction. Op-amp IC4a amplifies the IC3 reference voltage and reapplies it to the internal resistor chain after adjustment to about 7 V by RV1. This output is also used as adjustable offset to IC4b.

Resistors R28,29 apply line changes to the input op-amp. Figure 2 shows the selector circuit, in which a switched resistor chain varies the output of a regulator from 13 V to 15 V.

To set up, adjust RV1 so that pin 12 of the bar graph is selected with 15 V applied to the input (a LED array on the bar graph output assists here). Then, with 13 V applied, adjust RV2 to select pin 1, repeating the process if necessary.

For greater distances than around 100 m, a 4-20 mA current loop could be used, R28 being removed.

Ken Bedwell
Rees Instruments Ltd
Godalming
Surrey

Shown top-right, Fig. 1. Bar-graph IC controls motors in response to remote signals carried on power lines.

Shown right, Fig. 2. Remote selector circuit for distances up to around 100 m; for greater distances, a current loop would be better.
Simple DC modulator

In addition to its requirement for only a single switch, this modulator does not isolate the input. As the feedback loop of the op-amp in Fig.1 is varied by \( v_{\text{mod}} \), its gain changes and is given by \( \frac{R_2 + R_4 + R_2R_4/R_3}{R_1} \). The output is not, however, symmetrical about zero.

In Fig.2, the op-amp forms either an inverting amplifier or a voltage follower, depending on \( v_{\text{mod}} \) to give an output about zero.

\[ \text{N I Lavrentiev} \\
\text{Schiulkovo} \\
\text{Moscow Region} \]

Electrolytic ESR tester

In sensitive circuitry, for example in a feedback loop, it is often necessary to know the equivalent series resistance of an electrolytic capacitor. This circuit measures ESR quickly and simply, assuming access to a digital storage oscilloscope.

Operation is simple: press the push-button switch and view the DSO trace. Calculate ESR from \( \text{ESR} = \frac{v_1}{v_2} - 1 \) in ohms, the two voltages being those indicated in Fig. 2.

Replacement of the pushbutton switch with a logic switched mosfet would eliminate switch bounce effects. It would also allow operation at higher voltages for greater signal output. The channel resistance and self capacitance of the device need to be taken into account however.

\[ \text{A M Wilkes} \\
\text{Glasgow} \]

Faulty circuit

There was an unfortunate printing error in my circuit idea (EW+WW, November 1993). Propagation delay decreases and not increases as \( V_{\text{cc}} \) is increased. This is fundamental to understanding the whole design.

\[ \text{Laurence Richardson} \\
\text{Horsham, Surrey} \]
**BELIEFS AND THE GOVERNMENT PAVING THE WAY FOR PUBLIC INTEREST**

**MARKET TRENDS AND THE FUTURE OF ELECTRONICS**

**SPECIAL REPORT: ELECTRONICS, THE NEW FRONTIER**

**NEW PRODUCTS AND TECHNOLOGIES**

**ELECTRONIC COMPONENTS AND ACCESSORIES**

**INDUSTRY INSIGHTS AND TRENDS**

**INNOVATIVE SOLUTIONS AND ADVANCES**

**FURTHER INFORMATION AND RESOURCES**
**MOTORS – BATTERY 1-12V**

- **MINI Scope tube face size 2"x2 1/2", electrostatic 3v heater**
  
- **Ref. 10P104**

- **4 3v dc (2a) psu with filtering & voltmeter regulation, £4.5, Order Ref. 19P3**

- **5v dc 150mA, £1.5, Order Ref. 21P3**

- **6v700mA, £1.5, Order Ref. 104**

- **6v dc 200mA output in 13a case, £2.2, Order Ref. 29P12**

- **6-12v dc for models with switch to vary voltage and remove polarity, £2, Order Ref. 29P3**

- **9v dc 150mA, £1, Order Ref. 762**

- **9v dc 21A by Sinclair, £3.5, Order Ref. 31P5**

- **9v dc 100mA, £1, Order Ref. 733**

- **12v dc 200mA output in 13 case, £2, Order Ref. 29P14**

- **12v 500mA on 13 case, £2.5, Order Ref. 25P4**

- **12v 1A filtered & regulated on power rails & plastic sounder, unboxed, £3, Order Ref. 39P80**

- **Amstrad 13 5v at 1.8A at 2S or at 2A, £6, Order Ref. 6P23**

- **24v dc at 200mA twice for stereo amplifiers, £2, Order Ref. 29P4**

- **9.5v ac 600mA made for BT, £1.5, Order Ref. 1.5P7**

- **15v 500mA ac on 13a base, £2, Order Ref. 29P12**

- **Ac out 9.9v ±10% 1.5A ±15% ac, £1, Order Ref. 751**

- **10v power supply unit 20W, charges 12v battery, output cuts off output should voltage fall below pre-set, £6, Order Ref. 15P65**

- **Solar microvision psu, £5, Order Ref. 51P48**

**LASERS & LASER BITS**

- **2W laser, helium neon by Phillips, full spec. £30, Order Ref. 30P1**

- **Power supply for this kit in form with case is £15, Order Ref. 15P16, or in larger case to house tube as well, £18, Order Ref. 18P16**

- **The larger unit, made up, tested and ready to use complete with laser tube, £69, Order Ref. 69P1**

**SOME POPULAR BARGAINS**

- **LCD 3" DIGITAL PANEL, this is a multi range voltmeter/ammeter suitable for the 4-20mA converter chip 17D6 which provide 5 ranges each of volts and amps. Supplied with full data sheet. Special snap price of £12, Order Ref. 12P19**

- **12-6v DC PULSE GENERATOR TRANSFORMER, normal 230v primary and conventional opening with connection, £1, Order Ref. 938**

- **MINITRANS, a very modern and compact new. Standard replace- ment or why not have an extra one? £20, Order Ref. 20P28**

- **THEY COULD SAVE YOU EXPENSIVE BATTERIES, an in car unit for operating 6v radio, cassette player, etc from car lighter socket. £2, Order Ref. 29P18**

- **MEDICINE CUPRUS PATENTED. It could be used to warm when any cupboard door is opened, built and neatly canalised requires only a battery, £3, Order Ref. 13P5**

- **FULLY ENCLOSED VACUUM TRANSFORMER, on a 2m core leading with a 13A plug. Secondary rated at 6A. Arranged on a built in isolating push on tags, £3, Order Ref. 31P29, Dito but BA, £4, Order Ref. 4P99**

- **DON'T LET IT OVERFLOW, it be bath, sink, cellar, damp or any other thing that could flood. This device will tell you when the water has risen to the pre-set level. Adjustably over quite a useful range, neatly canalised for wall mounting, ready to work when battery fitted, £3, Order Ref. 31P55**

- **MULTI DIGITAL TESTER MG3800, single switching covers 30 ranges including 20A ac and dc, 10 Ohm input impedance, 31/2 LCD display, Complete with lead. Currently advertised by many dealers at nearly £45, our price only £25, Order Ref. 25P14**

- **ANALOGUE TESTER, input impedance 2K ohms per volt. It has 14 ranges, ac volts 0-50k to 500v, dc current 500 micro amp, 250 milliam, resistance 0-1meg-ohm, decibels 20, 10, 0, 0-1, 10, 100, 1000, 31/2 LCD display. Overall size 30x63x25mm. Complete with test leads, price £7.50, Order Ref. 7.5P84**

- **LCD CLOCK MODULE, 1.5v battery operated, fits nicely into our 50p project box. Order Ref. 876, Only £2, Order Ref. 876**

- **SATELLITE COMPONENT BOARD, amongst hundreds of other parts, this has 15 IC's all plug in so don't need des- solating. Cost well over £100, yours for £4, Order Ref 4P97**

- **ANSIEHARD MODEL, KB5, this is a most comprehensive keyboard, having over 100 keys including, of course, full numerical and qwerty. Brand new, still in manufacturer's packing, £5, Order Ref. 5P202**

- **SOLAR PANEL BARGAIN, gives 3v 0.15A, £2, Order Ref 3P204**

- **ULTRA SONIC TRANSDUCERS, 2 metal cased units, one transmits, one receives, Built to operate around 40kHz, £1.50 the pair, Order Ref. 1.5P64**

- **INSULATION TESTER WITH MULTIMETER, internally generates voltages which enables you to read insulation directly in megohms. The multimeter has 4 ranges ac/dc volts, 3 ranges dc milliamperes, 3 ranges resistance and 5 amps. These instruments are ex BT but in very good condition, tested working. Complete for only £7.50, with leads, carrying case £2 extra, Order Ref. 7.5P54**

- **MAINS ISOLATION TRANSFORMER, stops you getting to earth shocks, 250v in and 230v out. 150W upright mounting, 9v 500mA, 24v 2.1A, 110v 2A, 230v 1A. £5, Order Ref. 25P6**

- **MINI MONO AMP on pcb. Size 4x2 with front panel holding volume control and with spare hole for switch or tone control. Output is 4W into 4 ohm speaker using 12v or 18W into 8 ohm using 9v. Brand new and perfect, only £1 each, Order Ref. 49P5**

- **EXPERIMENTING WITH VALVES, don't spend a fortune on a mains transformer, we can supply one with standard mains input and 250-0-250v at 75mA and 6.3v at 3A. £5, Order Ref. 31P56**

- **5-1MA FULL VISION PANEL, 24v square, scaled 0-100 but scale easily modified for re-writing, £1, Order Ref. 756**

- **PCB DRILLS, 12 assorted sizes between 75 and 1.5mm, £1 the kit, Order Ref. 128**

- **12v AXIAL FAN, for only £1, ideal for equipment cooling, brand new, made by West German company. Plug in, virtually everlasting. Supplied complete with diagram of transistor driver, £1, Order Ref. 918**

- **PC OPERA SYMMETRICAL TRANSDUCER, this prototype was documented and including software. MS-DOS 3.20, with 5" disk, £5, Order Ref. 5P2076; MS-DOS 3.32 with 3 1/2" disk, £5, Order Ref. 6P208, or with 5" disk, £5, Order Ref. 5P2088. MS-DOS 4.01 with 3 1/2" disk, £10, Order Ref. 10P99**

- **45A DOUBLE POLE MAINS SWITCH, mounted on a 65x45mm, diameter 40mm, nickel-plated, in polished chrome. Brand new, still in box, £6.50, Order Ref. 6.5P11**

- **LASERS & LASER BITS**

- **Variable transformer technology, loads 150mA, £5, Order Ref. 31P5**

- **Dorset Wavelength detector, £10, Order Ref. 6P93**

- **3kW tangential heater, £8, Order Ref. 29P3**

- **Water-proof heating wrap, 500cm long by 15cm wide, £3.50, Order Ref. 8.5P3**

The above prices include VAT but please add £3 towards our packing and carriage if your order is under £50. Send cheque or postal orders or phone & quote credit card number.
NEW PRODUCTS CLASSIFIED

ACTIVE
A-to-D & D-to-A converters

30Msamples/s A-to-D. Two-step analogue-to-digital converter from Signal Processing Technologies, the SPT1175, produces 8-bit words at conversion rates up to 30Msamples/s. Signal-to-noise ratio is 45dB for 3.58MHz input at 20Msamples and differential gain and phase are 1% and 0.7° respectively; large-signal bandwidth 12MHz and input capacitance less than 15pF. Differential non-linearity is ±0.6LSB and there are no missing codes over the entire operating range. Ambar Cascom Ltd, 0296 434141.

Small, 12-bit A-to-D, LTC1257 from Linear is a complete 12-bit, voltage-output, single-supply digital-to-analogue converter in a surface-mounting SO-8 package, with output buffer amplifier, 2.048V reference and three-wire serial interface. Differential non-linearity error is 0.5LSB. Power supply needed is 4.7-15.75V, current being 150μA at 5V. Linear Technology (UK) Ltd, 0276 677766.

3.3V, 10-bit A-to-D. TI's new family of A-to-D converters have 10-bit resolution, 2μs conversion time, on-chip, microprocessor-controlled sample and hold and a serial interface supporting the Serial Peripheral Interface and Microwire. The single-input TLV1549 is contained in an 8-pin dip or SO and the 11-input TLV1543 in a 20-pin dip or wide-body SO. Texas Instruments, 0234 223252.

Discrete active devices

Disk-drive Schottky. Dual Schottky barrier diode from Allegro is meant chiefly for use in hard-disk drives. The A8920S1, exhibits a 440mV forward drop at 150mA, a 500mV maximum forward current and 20V reverse voltage and reverse recovery time at 100mA of 32ns. A multi-chip version, the TDA6003, has three pairs of diodes in a 16-lead SOIC package. Allegro Microsystems Ltd, 0932 253355.

Fast diodes. Silicon epitaxial planar diodes in ITT's new range provide extremely fast switching. BAS16J1 handles 100Vpk reverse, 150mA average rectified current and 500mA surge forward at 25°C. Dual common-cathode diodes, BAZ70 and BAV99, and the BAW86 common-anode type offer 70Vpk reverse and 250mA continuous forward. Power dissipation is 350mW. ITT Semiconductors, 0932 336116.

Smart fets. IRSF30J10 SmartFET transistors by International Rectifier feature over-current shutdown, gate drain clamp and gate-source clamp for ESD protection. There is also over-temperature protection which is latched, as is the over-current circuit. Polar Electronics Ltd, 0525 377093.

Fast rectifiers. Super fast rectifier diodes from Semtech have reverse voltages from 2.5kV to 10kV, recovery time of 50ns and forward currents of 100mA/1A. Reverse current is 0.2μA/1μA. Type numbers are: FFXX, 2FFXX, 5FFXX and 10FFXX. Semtech Ltd, 0592 773520.

Power mosfet. Siliconix's S9396DY Low Foot power mosfet is meant for use in disk drives and portable computers, delivering 5A with a rated on-resistance of 50mΩ. It is a dual in-channel device and replaces two typical SM or TO-220 devices. Voltage rating is 30V. Siliconix/TEMIC Marketing, 0344 485757.

Digital signal processor

32-bit DSPs. TI announces its first low-power 32-bit digital signal processor. The 33MHz performance achieved by the 5V TMS320C31 is now available in the 3.3V version, the TMS320LC31, with no increase in price. Two power-down modes are provided to either reduce the instruction rate or shut down an inactive device while retaining memory contents. A new version of the 5V device runs at 50MHz op's. Texas Instruments Ltd, 0234 223252.

Linear integrated circuits

Photodiode amplifier. A low-cost photodiode amplifier from Centronic, the CA-100, measures currents from 200pA to 2mA, giving an output of 2V at an accuracy of 1% FSD on all eight ranges. It can be operated in optical-power mode, in which the calibration adjust control sets the amplifier to a known optical power to give direct reading of optical power on the LC display. Lectors are available as extras. Centronic Ltd, 0689 842121.

Phase control. GEC Plessey's TDA2088 bipolar IC is for current feedback phase control of motor-speed controllers; it is also usable in open-loop mode. Power comes from an AC or DC supply, the IC incorporating a 5V regulator for internal functions and to power external circuits. Output tric drive is 100mA maximum. GEC Creation Ltd, 0734 788678.

Cheap 900MHz chipset. Five chips from Motorola, MRF72C001/2/2/4/2/6, form a 900MHz chipset for personal communication. Costing $13.57 in low volumes, the set is designed for use end for CT-2 cordless telephones, but is also suitable for GSM, ISM and 915MHz cordless. The chipset consists of a down-converter LNA/mixer, transmit mixer, GaAs antenna switch, driver and ramp and a two-stage power amplifier. Motorola Inc., USA, 602 994 6561.

TV signal encoders. TDA48501 and TDA8505 television signal encoders by Philips convert RGB or YUV video input to standard composite video, 8501 for Pal or NTSC and 8505 for Secam. Both types produce separate luminance and chrominance for equipment such as VHS-C recorders. A minimum of external components is needed: a luminance delay line, a few CAs and a crystal for the 8501. TDA8501 needs no alignment and TDA8505 only one operation. Philips Semiconductors, (Europe)+31 40722091.

ICE stereo decoder. TDA1592 is a development of Philips's existing TDA1591 stereo decoder/noise blanker for high-performance car radio. It features 50mV muting offset to give RDS switching without clicks, an S/N ratio of 62dB, input overdrive of 6dB and automatic FM/AM high-cut control for weak signal conditions. An analogue voltage from the level detector allows smooth stereo/mono changeover with signal level. Philips Semiconductors, (Europe)+31 40722091.

Microprocessors and controllers

Microprocessors. New versions of Hitachi's H8/500 microcontrollers in 8.0μm cmos offer a choice of higher speed or low voltage operation and different packages. H8/535 and -536 have 32K or 62K of rom or eeprom and 2K of on-chip ram, the "S" versions operating at up to 16MHz at 5V to give a minimum instruction time of 125μs. 16 by 16-bit multiplications take up 1.4μs and 32/16-bit division 1.63μs. Several timers are provided, as is a 10-bit A-to-D converter.

New packaging is the Thin QFP, which is only 1.2mm thick. Hitachi Europe Ltd, 0628 585000.

Low-power microprocessor. Motorola's PowerPC 603 is a low-power design intended for use in notebook and laptop computers, running all the popular operating systems including OS/2, MS-Dos via emulation, standard variations of Unix and pen-based systems. Its superscalar architecture allows three instructions per clock cycle at frequencies up to 60MHz. Motorola Ltd, 0209 305252.

64-bit risc processor, A low-power, low-cost, 64-bit risc processor, the VR4220 by NEC, achieves an 80MHz...
NEW PRODUCTS CLASSIFIED
Please quote "Electronics World + Wireless World" when seeking further information.

clock speed, derived from a 40MHz external clock, and operates on 3.3V at 1.5V (0.4W standby). Functions include calibration adjustment, floating calculation unit and a cache memory for 16KB of instructions and 8KB of data. Packages are a 179-pin PGA or a 208-pin QFP. NEC Electronics (UK) Ltd, 0908 691133.

Fuzzy co-processor. The VY96C570 is a 12-bit, high-performance fuzzy co-processor capable of carrying out full fuzzy rule evaluation 20-30 times faster than software-only methods, being capable of more than 850 000 rule evaluations per second at 20MHz. Its integral rule base eliminates the need for external rule-base memory in most cases. VLSI Technology Ltd, 0908 667595.

Mixed-signal ICS.
Data retiming. Analog's AD905 is a 155Mb/s PLL for data retiming in which the clock-recovery technique eliminates incompatibility between types A and B regenerators, overcoming the jitter tolerance limitations of type B circuits. The IC exploits the 1 RMS jitter of an external crystal oscillator and has an independent phase-control feedback path to track data with jitter. Analog Devices Ltd, 0932 253323.

Telecomm switch. CP Clare's TS series is a combined hookswitch and ring detector in an 8-pin dip. Using an optically-isolated mosfet relay for hookswitch, dial pulse or loop start switching, with a bidirectional opto-coupler for ring current or drop current detection. Switches handle voltages up to 400V ac, AC or DC, and currents to 170mA. Switching speed is 3ms, CP Clare Corporation, 0460 41771.

Audio decoder. Complete audio decompression system in one IC, the CS42590 by Crystal, contains everything needed to receive and process compressed audio and convert it to stereo analogue output; the built-in digital signal processor supporting a range of decomposition standards. Signal-to-noise ratio is up to 90dB and THD less than 0.01%. A digital output derived from the decompressed audio conforms to the Sony-Philips Digital Interface Format or the AES/EBU format. Crystal Semiconductor, (US) (512)445-7222.

Real-time MPEG encoders. Details of C-Cube's VideoRISC Compression Architecture (VCA), the first architecture specifically designed to compress and decompress digital video in real-time, have been announced. VCA supports fast encoding and decoding for a variety of international standards, including MPEG, JPEG and H.261. First in the range are the CLM4600 broadcast MPEG 2 video encoder and the CLM4500 consumer MPEG 1 version. Kudos Thame Ltd, 0734 351010.

Oscillators

Programmable logic arrays
2500-gate device. With 282 registers and 2500 usable gates, Altera's EPCS825 is the newest member of the FLEXE/000 family of programmable logic devices, which Altera claims gives better performance at lower cost than field-programmable arrays. The device is in a 0.8mm static random process in 3.3V and 5V versions. Altera, 0626 486811.

Air-cooled coils. Canton air-water cooling in coil in an internal diameter from 1.5mm to 10mm as standard, using wire diameters from 0.315mm to 2mm in lengths up to 25mm. They are supplied with tinned or untinned leads and for through-hole or surface mounting. Products Ltd, 0433 621555.

Power semiconductors
8A IGBT. Harris claims its HGTDBPSG1 to be the world's first p-channel, enhancement-mode, insulated-gate bipolar transistor. Main features are 8A collector current and 500V breakdown. The use of a p-channel device in conjunction with n-channel types greatly simplifies the design of circuitry such as half bridges. Harris Semiconductor (UK), 0276 666866.

Voltage-controlled oscillators. Voltage regulators in SOT223 and E-line packages from Zetex come in five voltages from 3.3V to 10V and give a 20mA output. Voltage dissipation is 2W for the SM package or 0.6W for the E-line type. Voltage constancy is around 10mV under both line and load variation and quiescent current is held down to 400mA. Zetex plc, 061- 627 5105.

Passive components
'Mallerc' capacitors Panasonic claims its Series EL Gold double-layer capacitors to be the world's smallest, having values in the 0.1F-2F range and measuring 6.8mm in diameter by 1.4mm. Rated working voltage is 2.5V from -25 to 70 C and life is 100 000 charge-discharge cycles. The company also claims the world's largest capacitor — the power range, with a value of 1500F. Panasonic Industrial Europe, 0344 853927.

Display
Touch screen controller. The SMT-1 miniaturised, surface-mounted touch screen controller by MicroTouch can be mounted on the back or at the bottom of a CRT and is designed for external retrofitting. It needs only one supply voltage between 5 and 16V at 70mA, obtainable from the monitor. MicroTouch Systems Ltd, 0844 260123.

Fluorescent panel. NEC's chip-in -glass fluorescent display panels have only 22 lead terminals instead of the 198 used in conventional types. The module has an in-built microcomputer, character generator, power supplies and -res. Serial receive data rate is 9600 baud. NEC Electronics (UK) Ltd, 0908 691133.

Hardware
Wavesoldering fluids. Soldering fluids from Fry's use nitrogen to produce an oxygen-free soldering path, so that extremely low-activity fluxes can be used to leave a minimum of residue. 1174, 1175 and 1220 fluids leave even less than conventional low-solids fluxes and no cleaning is needed, giving good results in oxygen concentrations up to 500ppm. Fry's Metals Ltd, 081-665 6666.

Instrumentation
Miniature controller, CAL's model 3200 controller is contained in a 1.32 DIN unit and 'auto-tunes' itself to configure it for a range of process variables. Inputs can come from most thermocouples, PT100 or from five linear process ranges, the 4-digit led display presenting one-digit units, degrees of temperature or engineering units. CAL Controls Ltd, 0462 486161.

Cable data analyser. Halcyon is billed as the world's first parallel cable data analyser, which analyses a data stream at very high speed, byte-by-byte and bit-by-bit, correcting it before driving the printer. Its effectiveness is such that its maker, End Design, says it will handle 50kbyte/s or over a half a kilometre of cable. The unit is plugged into a cable run just before the printer, where it obtains its 2mA of supply current from the PC and printer. End Design Ltd, 0372 458086.

Low-cost H-P T&M. Hewlett-Packard has four new instruments in its low-
cost range. Benchlink software allows the import of test data to a PC.

**HP3410A** is a direct digital sampled function generator, producing standard or arbitrary waveforms to 12-bit resolution and with linear/log sweep. HP34610A is a 500MHz oscilloscope with very accurate measurement and 1ns/division sweep rate. And the 35W HP3620A triple-output power supply provides 0-6V at 1-2.5A and 0 to ±20V at 0.5A. Hewlett-Packard Ltd, 0344 362967.

**EMC kit.** Mrtron's EMC laboratory kit allows all electromagnetic compatibility and radio-frequency interference tests required by current and future EC legislation. The kit costs around £12 000 and covers both conducted and radiated emissions to CISPR over the 9kHz-1GHz frequency range. A PC-based software program produces a representation on screen of results and a hard-copy report. Mrtron Instruments Ltd. 0494 459200.

20MHz function generators. Three programmable function generators by Thurlby Thandar cover the 2MHz-20MHz frequency range to an accuracy within 0.1%. Model 8020 generates sine, triangle and symmetrical square waves, symmetrical pulses and DC, also including eight log/in sweep modes. VCO, gating and triggering pulses. 8027 offers the same, but with six controllable pulse and two ramp modes. 8022 provides all that plus AM and carrier control. Thurlby Thandar Instruments, 0400 412451.

**Multimeter with PC interface.** Thurlby Thandar's 5108 benchtop digital multimeter is a 5½-digit auto/manual ranging instrument which connects directly to the serial port of a PC, which controls function, range and configuration, reading results individually or in blocks. Up to 32 instruments can be controlled in this way, using the RS232 interface in addressable mode. The meter will perform linear scaling with offset, percentage deviation, limits comparison, min/max storage and data logging. Thurlby Thandar Instruments, 0400 412451.

**Interfaces**

Card readers. New versions of MR Sensors's magnetic card readers incorporate serial outputs and come in RS232, RS422 or RS485 versions. Since all is contained within the reader housing, no external interface is needed. Magnetic-resistive techniques make for increased reliability and further features include selectable baud rate, handshake and parity and high/low level coercivity compatibility. MR Sensors Ltd. 0222 520222.

**Talking modem.** Mutek designs and makes the DiSPatch digital signal processor-based modem, a technique that, being software-based, allows simple addition of features by means of a rom exchange. It also enables the use of voice synthesis. The unit meets V42, V42bis, V32bis and G3 fax specifications and the relevant lower-speed function with sync. and async. input. Mutek Data Communications Ltd. 0223 696502.

**PCMCIA interface kit.** To connect laptop PCs to GPIB instruments. National Instruments has introduced an IEEE488 interface for the PCMCIA bus, including the PCMCIA-GPIB plug-in board. NI's NI-488-210 card and Windows software and a GPIB-terminated 2m cable. National Instruments UK. 0635 522545.

**Literature**

**Test & measurement catalogue.** Fluke's 1994 catalogue is now available, covering a range of test and measurement equipment from basic multimeters to data acquisition systems. This is the first Fluke catalogue since the firm's acquisition of the Philips T&M operation. It is obtained free. Fluke (UK) Ltd, 0223 240511.

Cambion guide. Interconnection Products has produced a guide to its wide range of Cambion electromechanical and magnetic product, which includes lists of product literature and quality approvals. Interconnection Products Ltd. 0433 621555.

**Materials**

Conductive paints. Enco has introduced a method of spray masking for the spraying of conductive paint, spraying being necessary for the paint to keep its properties. Instead of labour-intensive masking tape or precision hard masks, Enco's masks are CNC machined plastic inserts, economic up to 600 units per day, and the method is said to be one-third as expensive as hard tooling. Enco Industries Ltd., 05057 5151.

**Power supplies**

DC-to-DC converters. Ericsson announces the PKE-MacroDens series of 3-7W DC-to-DC converters usable as SM or through-hole components for automatic insertion. Isolation is 1.5kV and the devices may be paralleled. They are provided with output voltage adjustment and low-input turn-off for battery protection, outputs are from 2V/3W to 12V/7W, Ericsson Components AB, 0793 498300.

40W DC-DC converter. Ericsson's PKE series of low-pressure DC-to-DC power modules now includes the PKE 4431 Pi, which measures 76mm square and 10.7mm high, while providing 40W in three outputs: 5V and ±12V. Input voltage range is 38-72V DC and efficiency is around 85%. There is under-voltage lockout and remote on/off switching. Ericsson Components AB, 0793 498300.

**Radio communications products**

Feedforward amplifiers. RF amplifiers from Pacific Amplifier are now available here in a range of bandwidth, high-power amplifiers covering 0.1-2000MHz. Examples are a 500W design working at VHF for medical use and a 150-1200MHz, 50W type working in Class A with a flatness of ±1dB over the band. A 47dB gain and harmonics of less than ±20dB. A recent model is microprocessor-controlled at 850MHz and -60dBc intermodulation at 80W, Anglia Microwave Ltd., 0277 630000.

18GHz dividers/combiners. Two-way, triple, phase-power dividers in octave and multi-octave bandwidths to 18GHz are announced by KDI Electronics. The V2 and D030 series use a ceramic pad as the internal passive element, handling 1W CW and 1kW peak powers. Isolation is 20dB and connectors...
GPS IC set. GEC Plessey's three-piece chipset for GPS consists of the GP1010 front end, the GP1020 correlator and a DW5230 saw filter, which works with both the GPS Coarse/Acquisition code or Glonass signal. GP1010 is a silicon device in the company's 15GHz bipolar process, converting the L-band spread-spectrum signal to two-bit digital data for correlation in GP1020. This is a six-channel, 1μm cmos gate array, using code from six satellites to calculate three-dimensional position to within 100m. GEC Plessey Semiconductors, 0793 518510.

GPS receiver. Rockwell's NavCard is a Global Positioning System receiver on a PCMCIA Type II card, with an average power consumption of 750mW. An integrated, removable antenna is provided, with external antenna kits available. The card provides a time-to-first-fix of 20-30 seconds and dynamic tracking, even in foliage and an urban environment and in the presence of vibration and shock. Rockwell International, 010 33 90 03 31.

Scanning telemetry. Designed solely for telemetry and thereby avoiding problems associated with voice radios adapted to telemetry, Wood & Douglas's MPT1411 ScanLine consists of a duplex base station, semi-duplex outstation and a monitor, providing scanning telemetry to public utilities. Outstations operate in semi-duplex, with receive and transmit separated by 5.5MHz, one version operating at 10W and the second at 500mW. Switching time is better than 10ms. Wood & Douglas Ltd, 0734 81444.

Switches and relays

HV relays. FR has a new series of high-voltage relays that handle stand-off voltages up to 10kV DC (7kV AC), with over 15kV DC isolation between coil and contacts. First model is in Form A and will shortly be followed by a Form B and a flying-lead version. FR Electronics, 0202 897969.

Optical relays. Having four relays in one sili package, Matsushita's AQX photoMOS device can be used as either four independent relays, each with its own input and normally open output or as one single input for four independent outputs. Each output carries up to 80mA at 400V AC or DC, with negligible output offset. Isolation is 1500V. Matsushita Automation Controls, 0908 231555.

Immisible microswitch. Matsushita's new microswitch conforms to IP67 for waterproofing and to IP65 against dust. An ultrasonic swaging process seals the rubber seal round the mechanism and the terminals are sealed by potting the base in epoxy resin. Capability is 3A at 300V AC, or 1mA at 24V DC. Pin plunger, hinge lever or roller lever types are available and the smallest switch measures 12.8mm by 6mm by 6.5mm. Matsushita Automation Controls, 0908 231555.

Transducers and sensors

Pressure transducer. The Sensit P-152 pressure transducer is compatible with wet and corrosive substances by virtue of its construction, in which the bridge is fused into the rear face of an alumina diamphigrm, which in turn is assembled into a brass housing carrying a male thread pressure port. Spans are in the 10-40bar range, with a two-span overload without calibration. Burst pressure tolerance is four times span. Errors from all causes lie within 1% and are typically below 0.15%. Eurosensor, 071-405 6000.

Audio signaliser. Producing a sound level of 75dBa at two feet, the Mallory Sonalert II measures only 23mm in diameter and 9mm in height. It operates at 3-20V DC, drawing 1-12mA, and produces a 3.4kHz signal. It is surface-mounted and an octagonal version is made for use with insertion equipment. Highland Electronics Ltd, 044 236000.

Software

LabWindows/CVI. National has the new LabWindows/CVI, which is software running under Windows for developing virtual instruments using the C programming language. It expands on LabWindows for dos, which uses C and Basic. LabWindows/CVI is a 32-bit, multiplatform environment including all tools for C-compatible test, measurement and control applications on a PC or as X-Windows systems for Unix SPARCstations. Dos-based LabWindows applications run in /CVI. National Instruments UK, 0635 523645.

Windows neural network. A new version of the NeuDesk Windows-based neural-network PC package is a low-cost means of evaluating the networks by means of an intuitive GUI with the option of embedding programs so created in other Windows applications. Version 2.1 handles larger problems to greater accuracy and two optional algorithms optimise networks for classes of problem such as forecasting and classifying data. Neural Computer Sciences, 0703 667775.

Computer board level products

PC A-to-D. Made by Amplex Liveline, the PC264AT is a 16-channel, 12-bit analogue-to-digital converter add-on board for PCs that has a crystal oscillator to drive the 16-bit counter timers, offering a DMA capability of 50kHz throughput. Conversion time of the successive-approximation device is 10µs and it can operate in unipolar mode with full scale of 3V-10V, or in bipolar mode from ±1.5V to ±10V. Demo software is written in QuickBasic. Microsoft C, Turbo C and Turbo Pascal. Amplex Liveline Ltd, (Free)0800 523545.

12MHz DDS. The model DD35 PC 12MHz direct digital synthesiser on a PC card provides 5pm accuracy, 10ppm/year stability and good spectral purity while generating sine and TUT/cmos clock signals simultaneously from 2Hz to 12MHz in 2Hz steps. Phase noise is less than -90dBc at 1kHz offset from carrier. Spurious signals are below -45dBc and harmonics below -40dBc. The card comes with a C program running under dos. Novatech Instruments Inc., (US) 206 328 6902.

MPEG decoder card. Polar offer a PC card performing real-time MPEG decoding for video-by-wire and conferencing systems, claimed by the company to be the first in the field. It gives full audio and video decoding at resolutions of 720 by 376 at 25Hz or 720 by 480 at 30Hz. Decompressed video can be seen in a screen window, depending on system configuration. Polar Electronics Ltd, 0259 377093.

Image acquisition. VideoWizard is a low-cost image acquisition system for Windows that includes the VLL, miniature Peach camera, tripod, mono framegrabber card and PhotoFinish software. The camera takes power from the PC. The six image formats include TIFF, PCX and BMP. Total cost is £285. VLSI Vision Ltd, 031-539 7111.

Development and evaluation

Windows FPGA design. Data I/O's Synamo is a Windows-based FPGA design system to ease the transition from PLDs to FPGAs and to allow FPGA designers to work with complex architectures. It allows the creation, simulation and verification of designs, independently of architecture, so that the best architecture for a given application may be selected. Since it runs under Windows, users can move between applications through a standard interface. Data I/O Ltd, 0734 440011.

Return of the Stag. Stag ended production of the SE100T eprom eraser recently and stopped advertising it two years ago, but continuing demand has forced the company to restart manufacture. The UV instrument erases up to 104 24-pin devices at a time, a 60-minute timer and full safety interlocks being provided. Stag Programmers Ltd, 0702 332148.

Software

LabWindows/CVI. National has the new LabWindows/CVI, which is software running under Windows for developing virtual instruments using the C programming language. It expands on LabWindows for dos, which uses C and Basic. LabWindows/CVI is a 32-bit, multiplatform environment including all tools for C-compatible test, measurement and control applications on a PC or as X-Windows systems for Unix SPARCstations. Dos-based LabWindows applications run in /CVI. National Instruments UK, 0635 523645.

Windows neural network. A new version of the NeuDesk Windows-based neural-network PC package is a low-cost means of evaluating the networks by means of an intuitive GUI with the option of embedding programs so created in other Windows applications. Version 2.1 handles larger problems to greater accuracy and two optional algorithms optimise networks for classes of problem such as forecasting and classifying data. Neural Computer Sciences, 0703 667775.

PC STEbus board. Arcom has the SCIM-X STEbus board for embedded software applications, using a 466SLX CPU with over 10MBbyte of ram and flash eprom. It integrates the hardware of three STEbus modules. There is ample expansion facility, including enough ram to run systems such as Unix, and the display can take several forms, the drive being a plug-in module. Software can be developed on-board, since it is PC-compatible, and software is provided to blow the result into rom-disk or ram-disk for use in hostile conditions. Arcom Control Systems Ltd, 0223 411200.
New low-priced Desolder Bits from Antex

Removing larger components from PCB boards can be a problem in rework and repair shops. The new Antex range of 10 SMT Desolder Bits have been produced to fit components from SO18 through to PLCC 68.

They will fit most Antex Temperature Controlled Irons and complement the existing range of smaller DST Desolder Bits.

All Bits are available singly or in sets together with a Bench Rest for Irons fitted with the New Bits plus an attachment for Antex Soldering Stations is also available from leading Electronic Distributors.

Antex (Electronics) Ltd.
2 Westbridge Industrial Estate, Tavistock, Devon PL21 8DE
Tel: (0822) 613565 Fax: (0822) 617598

CIRCLE NO. 129 ON REPLY CARD

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.

10 OUTLET DISTRIBUTION AMPLIFIER 4

A compact mains powered unit with one balanced input and ten AC and DC isolated floating line outputs.

- Exemplary RF breakthrough specifications giving trouble-free operation in close proximity to radio telephones and links.
- Excellent figures for noise THD, static and dynamic IMD.
- Any desired number of outlets may be provided at microphone level to suit certain video and audio recorders used at press conferences.

- Meets IEC65-2, BS415 safety.

*Advanced Active Aerial 4kHz-30MHz *PPM10 in-vision PPM and chart recorder *Twin PPM Rack and Box Units *Stabilizers and Fixed Shift Circuit Boards for how reduction *Broadcast Monitor Receiver 150kHz-30MHz *Stereo Variable Emphasis Limiter 3 *Stereo Disc Amplifier *Peak Deviation Meter *PPM5 hybrid. PPM5 microprocessor and PPM8 IEC/DIN ~50+5dB drives and movements *Broadcast Stereo Coders

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Telephone: 0483 275997. Fax: 276477.
How do you choose the right device configuration? In an extract from their book Radio frequency transistors: principles and practical applications, Norm Dye and Helge Granberg supply the answers, show the importance of class and explain about bias for linear applications.

Common emitter and common source circuit configurations are some of the most widely used because of their stability, good linearity and high power gain up to uhf. They are also the only configurations where input and output are out of phase, enhancing their stability — except for the half $f_0$ mode and at frequencies where the feedback capacitance delays are close to 180°.

But if the common emitter or source inductance is increased, the power gain will drop due to the negative feedback generated by the reactance. So for proper operation the common element inductance must be kept as low as physically possible.

Gain is inversely proportional to the frequency and increases approximately 5dB per octave until the $\beta$ cut-off is reached. At this point it may be as high as 30-40dB.

A common emitter circuit (Fig. 1) can be directly adapted to mosfets, but in that case since $I_B = 0$, $I_D = I_E$. Lumped-constant matching elements are practical in narrow band circuits up to vhf. But at over 300-400MHz, microstrip techniques — or a combination of microstrip and transformer impedance matching techniques — are normally used.

For broadband performance, the initially-higher device impedance levels make impedance matching easier to implement to a 50Q interface with a push-pull configuration. In multi-stage systems the interstage impedance matching is usually carried out at lower than 50Q levels, and in some instances very little impedance transformation is required. The result may be better broadband performance than with 50Q interfaces between each stage, but it does not have the advantage that each stage can be individually tested in a standard 50Q set-up.

Up to vhf and low uhf, input impedance of a mosfet is high compared to that of a bjt but at higher frequencies they reach similar values, and the matching procedures become almost identical.

In practice, virtually all multi-octave amplifier designs independent of frequency spectrum and device type are push-pull. Another advantage is that the power levels of two devices are automatically combined for higher power output levels. So electrically-small individual devices can be used for a given power output.

RF power transistors housed in push-pull headers have been available since the mid-1970s. But it was the development of high frequency fets that really made the push-pull package so popular. Now fets and bjts are both available in push-pull headers, most as the "Gemini" type where two individual and independent transistors are mounted on a common flange next to each other. Gemini packages are manufactured in several physical sizes, the largest being able to dissipate up to 500-600W. A big attraction of the push-pull transistor — whether in a single push-pull header or in a Gemini package — is the close electrical proximity of the two dice. Device performance of a push-pull circuit is greatly enhanced as a result, where the important factor is a low emitter-to-emitter (source-to-source) inductance and not the emitter-to-ground inductance.

In all Gemini housed devices, the emitter (or source) is connected to the mounting flange — the electrical dc ground.

No significant difference in efficiency is apparent between amplifiers using either fets or bjts. The higher saturation voltage of fets probably make them less efficient but this may be true only at low operating voltages (12V and lower).

At higher frequencies, device output capacitance has a much larger effect on efficiency, though part of it can be tuned out in narrow band circuits.

Common base and common gate

At uhf and microwave frequencies, common base circuits with bjts are widely used because their $\alpha$ cut-off is higher than the $\beta$ cut-off. Higher power gains are possible than with the common emitter configuration.

If base-to-ground inductance is added, power gain of a common base amplifier increases where positive feedback is generated. Add more inductance and the gain will increase to a point of instability, finally leading to steady oscillation — usually at a frequency where the matching networks resonate. All common base transistors have some positive feedback, generated by the inductances of the base bonding wires and the internal part of the base lead. But this inductance is generally low enough not to generate sufficient positive feedback to create instability.

As in the common emitter circuit, a common base transistor's gain is inversely proportional to its frequency of operation. The
slope is also the same, approximately 5dB/octave, but only up to the α cut-off. Below α cut-off, the gain flattens out to 12-15dB and remains at that level down to dc.

Input power need not be fed through in a common base amplifier circuit, so the power output is actual and not \( P_{\text{in}} + P_{\text{out}} \) as in a common emitter amplifier. The effect is that device ruggedness (ability to withstand load mismatching) is probably improved through reduced dissipation.

In a common base circuit (Fig. 2), the total current flows through the emitter, so the input matching network, or an emitter dc return choke, must be able to carry \( I_{\text{in}} + I_{\text{C}} \). The normal output capacitance \( C_{\text{ob}} \) and feedback capacitance \( C_{\text{fb}} \) are reversed. Fortunately, except at low bias voltages where \( C_{\text{ob}} \) can be several times higher than \( C_{\text{de}} \), their values are about equal.

Under normal drive conditions there should be little difference in output capacitance or impedance between common emitter and common base circuits. But the highly non-linear \( C_{\text{ob}} \) reportedly creates increased tendencies for the well known half \( f_0 \) phenomenon.

**Common gate and base**

Mosfets, operated as a common gate amplifi-
er, create a totally different situation. Their feedback capacitance \( C_{\text{gs}} \) has a value many times lower than the output capacitance \( C_{\text{ds}} \).

When these are reversed, the actual feedback capacitance goes high with respect to the input and output capacitances, creating an unstable condition.

Even if the common gate inductance can be minimised, stability may not be achievable. The input inductance is lower than in a common source circuit because of the high value of feedback capacitance enhanced by the Miller effect.

Stable single-frequency or narrow-band circuits with fractional octave bandwidths are possible using the common base configuration. But wide-band circuits are difficult to design if internal matching is required.

Neutralisation can improve stability in some cases, though it is not easy to implement except in push-pull designs. In high power circuits, biasing to a linear mode is difficult as an opposite polarity supply is required at the base-to-ground resistance can be used to generate a self bias.

Push-pull common base circuits are not normally seen at higher power levels, at high uhf or higher frequencies. One reason may be that the 180° phase shift is difficult to achieve and hold except for very narrow bandwidths.

But push-pull common base circuits are widely employed at power levels up to 0.5-1W in applications such as cable tv amplifiers, where an un-bypassed common base resistance can be used for self biasing to a linear mode of operation.

For each configuration — common emitter and common base — push-pull offers the same advantages, the most important of which is the non-critical base or emitter common mode inductance.

Power gain and stability of the push-pull circuit depends to a large extent on base-to-base inductance. Mosfets must always be biased to a level close to or greater than the gate threshold voltage to overcome \( V_{\text{gs(b)}} \) with rf input drive (excluding class D and other switch-mode systems). The bias source must be able to carry the full drain current: at a gate threshold voltage of 4-5V this would amount to considerable dissipation. But with bjt's the voltage is only 0.6-0.7V and so much more tolerable.

Common gate mosfet circuits are most useful in relatively low power applications, in circuits where neutralisation can be easily realised and their high range age (power gain/gate voltage) is an advantage.

Disadvantages of the common base amplifier circuit include the need for two dc power supplies for classes A, AB and B; poor linearity due to regeneration; low input impedance; no possibility to implement negative feedback (except in push-pull), and high susceptibility to half \( f_0 \) instability.

**Common collector**

Common collector, emitter follower circuits (Fig. 3) are widely used for high input and low output impedance levels.

As in a common base configuration, there is no phase reversal between input and output. The emitter follower has a voltage gain of less than unity, and amplification is obtained from the current gain through impedance transformation. Output impedance is directly related to the input impedance divided by current gain \( (\alpha \times I_{\text{in}}) \). Conversely, input impedance equals the output load multiplied by \( \alpha I_{\text{in}} \).

The circuit is less suitable for rf power amplifiers than the two other configurations since variations in load impedance are directly reflected back to the input. So its widest use is as a broadband buffer amplifier, driving low impedance or capacitive loads.

In fact, the circuit offers one of the best drivers for capacitive loads — especially in a complementary configuration providing active “pull-up” and “pull-down” in the output. Applications include crt video drivers and mosfet gate drivers in class D/E amplifier systems.

**Common drain**

In bipolar circuits, the emitter follower is represented by a common drain or source follower circuit configuration. As before, input impedance is high and output impedance low. Compared to common source and common gate circuits, input capacitance, drain-to-gate, is low — considerably lower for the fet (because of absence of the forward biased collector-base diode junction) than for a bipolar of comparable electrical size. A source follower also has a voltage gain of less than unity, and since it is not a current amplifier, discussion of current gain is not appropriate.

But amplification takes place through impedance transformation as is the case in a bipolar circuit.

Extremely high input impedance, more variable with frequency than in common source and common gate circuits, means heavy resistive loading at the gate must be used for any broadband application. Negative feedback is not needed, nor is it easy to implement due to equal phase of the input and output.

For these reasons, common source circuits exhibit exceptional stability. But excessive stray inductances in the circuit lay-out can lead to low frequency oscillations.

Unlike the emitter follower, variations in load impedance are not reflected to the input, making the source follower suitable for rf power amplifier applications — at least up to vhf.

Push-pull broadband circuits for 2-50MHz have been designed for 200-300W power levels, having inherent good linearity, stability and gain flatness without levelling networks. High power linear amplifiers are probably the most suitable application for this mode of operation. The agc range is comparable to that in common source, but a higher voltage swing is required.

One problem to watch for is that during high voltage operation, gate rupture voltage can easily be exceeded, since during the negative half cycle of the input signal the gate voltage can approach the level of \( V_{DS} \).

**Biasing to linear operation**

All solid-state devices and vacuum tubes intended for linear operation must have a certain amount of "forward bias" dc idle current to place their operating points in the linear region of the transfer curve (Fig. 4).

Perfect linearity means that power output follows the power input in a linear fashion: a \( P_{\text{in}} \) of 1W produces a \( P_{\text{out}} \) of 10W, 2W results in a \( P_{\text{out}} \) of 20W etc.

It can also mean that the power gain must be constant from almost zero to the maximum \( P_{\text{out}} \) level. This can also be expressed as gain compression in dB, or as the third order intercept point as widely used in low power and catv applications.

In large signal voice communication, linearity is usually measured as intermodulation
Performance of an amplifier depends on how it is biased.

<table>
<thead>
<tr>
<th>Class</th>
<th>Configuration</th>
<th>Efficiency %</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>all</td>
<td>50</td>
<td>depending on angle of conduction</td>
</tr>
<tr>
<td>B</td>
<td>all</td>
<td>78.5</td>
<td>depending on angle of conduction</td>
</tr>
<tr>
<td>AB</td>
<td>all non-saturating</td>
<td>85-90</td>
<td>assumes infinite switching speed</td>
</tr>
<tr>
<td>C</td>
<td>all</td>
<td>100</td>
<td>assumes no overlap for the output</td>
</tr>
<tr>
<td>D</td>
<td>all</td>
<td>100</td>
<td>rf currents and voltages</td>
</tr>
</tbody>
</table>

Table 1. Maximum theoretical efficiencies for basic classes of amplifier operation.

Class questions

A logical question would be: “Can class A characterised transistors be used as class C amplifiers?”. The obvious answer is yes. Similarly class C characterised transistors can be used in class A amplifiers – provided certain conditions are met. The condition involves a “derating” of the class C transistor to a lower power level, with the amount of derating depending on the class of operation.

If a class C transistor is used in a truly linear class A amplifier, it should be derated by a factor of four. So if it can deliver, say, 60W class C, it should not be used class A at level greater than 15W.

Class AB use requires a safe derating factor of three.

Two factors make these deratings necessary for use in a more linear mode.

First, linear classes of operation require bias. Not uncommonly, a Class AB high power transistor will be biased at several amperes of current, resulting in a large amount of power dissipated in the device.

Second, efficiency of the more-linear forms of amplification decreases as linearity increases. So for the same amount of output power, the power dissipated in the transistor will increase. Dissipated power raises the die temperature of a device, for a given heat sink temperature, and for silicon devices this should not exceed 200°C.
Distortion (IMD) using two test frequencies (tones) spaced 1kHz apart as a standard.

Testing amplifying devices for linearity in television, requires two or three test frequencies to be employed (depending on the specifications) with their spacings in the MHz range.

Three test frequencies (triple beat) are common with low power devices and are standard in CATV device testing, where distortion levels are very low. A wider spectrum can be analysed as a result, which better simulates multichannel systems.

Distortion expressed as IMD — because it is easier to relate to actual numbers — is the method by which linearity is initially measured, and can be converted to third order intercept. The test frequencies are viewed on a spectrum analyser screen and the distortion products (third, fifth, seventh order, etc.) appear on each side of the test tones. Their amplitudes can be read directly and are expressed either in dB below one of the tones (MIL STD) or below the peak power (EIA standard). Numerous ways can be used to generate the test tones.

Conversion to third order intercept can be done by
\[
IP^3 = P_{out} + IMD/2
\]
where \( IP^3 \) is third order intercept point, \( P_{out} \) is power output (one tone, dBm), IMD is third order intermodulation distortion below one tone (dB).

Reversing the equation gives IMD = 2(IP^3 - P_{out}). For example, if an amplifier has an IP^3 of +20dBm and the PD = +5dBm/tone, the third order IMD is 2(20-(+5)) which is 30dB below one of the +5dBm tones.

Either the power input or the power output can be used for the power reference. In circuits having an insertion loss, such as mixers, the \( PD \) is generally used as a reference. \( P_{out} \) is preferred in circuits with power gain due to a smaller factor of possible error.

Bipolar devices require a constant voltage source, whereas mosfets can be biased with simple resistor divider networks. But both become more complex where temperature stability is required.

In addition, enhancement-mode mosfets always need some gate bias voltage to overcome the gate threshold. Exceptions are mosfets operated in class D or in other switch-mode classes.

Apart from those applications already discussed that call for amplifier linearity, examples include all amplitude-modulated systems for communications and broadcast, nuclear magnetic resonance, magnetic resonance imaging, digital cellular telephone, and signal sources for instrumentation.

One of the requirements for transistor linearity is the flatness of \( f_t \) (gain-bandwidth product) vs \( I_c \) (collector current). Variation in collector current results in a change of \( f_t \), and so a variation in power gain.

The low \( f_t \) area (Fig. 5) is not very critical and produces only cross-over distortion, which in most cases can be reduced by increasing the bias idle current. If the "knee" from zero current to maximum \( f_t \) is sharp, a smaller amount of bias or idle current is required.

Mosfets will produce a similar \( f_t \) vs Ic curve, except that their low current knee is not as sharp as that of a bjt, explaining their need for higher bias idle currents.

The input signal can drive the transistor to peak current levels significantly above the bias current. So the slope of the \( f_t \) curve, from the bias current level to the maximum current caused by the input signal, determines the transistor’s linearity performance at high current. Some reduction with increasing current is tolerable without noticeable non-linearities, Fig. 5. Excessive downward sloping however would cause early saturation of the amplifier and flat topping of the output modulation peaks.

Finally, measurements of \( f_t \) vs \( I_c \) are usually carried out under pulse conditions, which excludes thermal effects. Thus the \( f_t \) vs \( I_c \) curve shows less sloping down than will be experienced in actual use of the transistor.

Norm Dye is Motorola's product planning manager in the Semiconductor Products Sector, and Helge Granberg is Member of Technical Staff, Radio Frequency Power Group (Semiconductor Products) at Motorola. Their rf transistors book includes practical examples from the frequency spectrum from 2MHz to microwaves, with special emphasis on the UHF frequencies.

RF Transistors: Principles and Practical Applications is available by postal application to room L333 EW+WW, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS. Cheques made payable to Reed Books Services. Credit card orders accepted by phone (081 652 3614). 288pp HARDBACK 07506 9059 3 Cost £19.95 + Postage £2.50
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 £13.95 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 0229 7

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 need 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 488 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 B, 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 Brintle
Hardback 319 pages
Price £12.95 0 7506 0937 0

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

Newnes Television and Video Engineer's Pocket Book
Eugene Trundle
Hardback 384 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

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
Credit card orders accepted by phone 081 652 3614

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

Please supply the following titles:

<table>
<thead>
<tr>
<th>Qty</th>
<th>Title</th>
<th>ISBN</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Programmable Logic Handbook</td>
<td>07506 0808 0..</td>
<td>19.95</td>
</tr>
<tr>
<td></td>
<td>Understanding Electrical &amp; Elec Maths</td>
<td>07506 0924 9..</td>
<td>14.95</td>
</tr>
<tr>
<td></td>
<td>Op-amp Circuits Manual</td>
<td>0434 912077</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>Audio IC Circuits Manual</td>
<td>0434 912078</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>CMOS Circuit Manual</td>
<td>0434 912121</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>Electronic Alarm Circuits Manual</td>
<td>07506 0064 0..</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>Power Control Circuits Manual</td>
<td>07506 06908</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>Timer/Generator Circuits Manual</td>
<td>0434 91291</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>Dsoul, Transistor &amp; FET Circuits Manual</td>
<td>07506 02257</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td>Instrumentation &amp; Test Gear Circuits Man</td>
<td>07506 0578 0..</td>
<td>16.95</td>
</tr>
<tr>
<td></td>
<td>Logic Designers Handbook</td>
<td>07506 0535 9..</td>
<td>25.00</td>
</tr>
<tr>
<td></td>
<td>Digital Audio and Compact Disc</td>
<td>07506 0614 2..</td>
<td>16.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Ele Engineers Pkt Bk</td>
<td>0 7506 0937 0..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Ele Assembly Pk Bk</td>
<td>07506 0222 8..</td>
<td>10.95</td>
</tr>
<tr>
<td></td>
<td>Newnes TV and Video 5ng Pkt Bk</td>
<td>07506 0677 0..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Circuit Calculations Pkt Bk</td>
<td>07506 0427 1..</td>
<td>10.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Data Communications Pkt Bk</td>
<td>07506 0108 9..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Telecommunications Pkt Bk</td>
<td>07506 0107 0..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes B80 Pkt Bk</td>
<td>07506 0108 9..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes 68000 Pkt Bk</td>
<td>07506 0309 7..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Electrical Pk Bk</td>
<td>07506 05138</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Electrical Pocket Pkt Bk</td>
<td>07506 0132 9..</td>
<td>12.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Guide to Satellite TV</td>
<td>07506 0215 5..</td>
<td>17.95</td>
</tr>
<tr>
<td></td>
<td>Newnes Practical RF Handbook</td>
<td>07506 0871 4..</td>
<td>16.95</td>
</tr>
<tr>
<td></td>
<td>Troubleshooting Analog Circuits</td>
<td>07506 16326</td>
<td>14.95</td>
</tr>
<tr>
<td></td>
<td>PC-Based Instrumentation and Control</td>
<td>07506 0218 8..</td>
<td>14.95</td>
</tr>
<tr>
<td></td>
<td>Electronic Circuits Handbook</td>
<td>07506 0437 9..</td>
<td>25.00</td>
</tr>
</tbody>
</table>

PLEASE ADD £2.50 FOR POSTAGE.

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

TOTAL

Business purchase: Please send me the books listed with the 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 10 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 Barclay/Visa Amex Diners

Credit Card No. Exp date

NAME (Please print)

ORGANISATION

STREET

TOWN

COUNTY POST CODE COUNTRY

DATE TELEPHONE NUMBER

SIGNATURE

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 not wish to receive further details about books, journals and information services.

Reed Business Publishing - Registered Office - Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS
Registered in England 151517
Making a linear difference to square law fets

Michael Williams shows how the familiar "difference of two squares" could produce a linear output from a pair of fets, forming the basis for a perfect linear amplifier.

Plot a graph of output volts versus input volts for an amplifier and the result will be a straight line through the origin - up to certain limits anyway. The implication is that the various devices in the amplifier must also have linear characteristics. Certainly some - resistors and capacitors for example - can be very linear and were once thought inherently perfect. Thermionic valve characteristics can also be pretty linear. But fets have a square law characteristic. My contention is that by using the familiar "difference of two squares" (D2S), a linear output could be produced. The law seems to offer the prospect of a perfect linear amplifier from devices with a perfect square law.

I have always been surprised to find that though books quote the square law formula - even give mathematical proofs of it - nobody actually offers any hard evidence for it. Graphs might be drawn, but only to illustrate the formula, which seems to be untested.

Finding matched pairs

While lecturing at the (then) Middlesex Polytechnic, I decided to test some devices, so set up a laboratory experiment for first year BEng electronics students. Their task was stated roughly as follows:

"The FET is said to follow the law

\[ I_d = \frac{1}{2} V_d \]  

where \( I_d \) is the drain current through the fet, \( V \) is the input gate voltage and \( V_p \) (the "pinch-off voltage") is a value of \( V \) which just cuts off the current. Investigate how valid this is for your fet."

A graph of this form, Fig. 1, has an output current of \( I_d \) when input \( V \) is zero, falling smoothly to zero as \( V \) approaches \( V_p \) - negative for our students' fets - but the principles apply to all types.

Year after year, the exercise revealed that some fets had a characteristic very close to the square law over the whole range between pinch-off and zero bias: but many did not. Of these, most had a square law for higher currents, but the pinch-off region extended to the left more than expected from extrapolation from the upper part of the graph. Some graphs were well behaved at low currents, but then mysteriously reached a limit as they got near the vertical axis.

In addition to these deviations from the square law, fets are very variable devices - even two square law characteristics may be perfect but different. To find matched pairs of fets with perfect square law characteristics, implies mass testing and recording. So for many years I set the design of a square law tester as a project for all second-year BEng students. They found it extremely difficult. It took at least six weeks of team effort before anyone could even say roughly what the problem was. Working solutions were rare. Design is a lot harder than people think, especially of a new kind of device.

Effort repaid?

Is all the trouble worth the effort? To answer that, let us look at the way the two characteristics combine, and then at applications.
D2S at a glance

Write out a row of consecutive digits, and square the row. Then repeat this row of squares but displace it to one side by any amount. The differences between the latter rows form a linear sequence.

For example:

<table>
<thead>
<tr>
<th>-6</th>
<th>-5</th>
<th>-4</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>+4</th>
<th>+5</th>
<th>+6</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>25</td>
<td>16</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>16</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td>25</td>
<td>16</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>16</td>
<td>25</td>
<td>36</td>
<td>49</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>-1</td>
<td>-3</td>
<td>-5</td>
<td>-7</td>
<td>-9</td>
<td>-11</td>
<td>-13</td>
</tr>
</tbody>
</table>

Results can be displayed graphically - just plot squares against the original numbers - and it does not have to be limited to integers. It works for all displacements. Just take the difference of offset identical square-law graphs - and a linear graph results.

Take a simple circuit (Fig. 2) of a matched pair of fets with a positive bias $V_1$, on their (joined) sources, and equal and opposite signals fed to their two gates. Push-pull triodes are hardly a novelty, but there is something new in this approach.

Bias $V_1$ pushes the transfer characteristic $I_2(V_1)$ sideways (Fig. 3). Note that $V_1$ is the gate potential (ie pd from ground), whereas the resultant input to the fet is the potential difference between the gate and the positively biased source. (We could have used negative gate bias instead of positive source bias.)

This displaced characteristic can be written algebraically as:

$$I_2 = \left(\frac{d^2V_1}{dV_0^2}\right)(V_0 - (V_p + V_b))^2$$

Amplification is proportional to the slope at the working point $(V_1)$, ie to the mutual conductance, $g_m$ and

$$g_m = \frac{dI_2}{dV_2} = \frac{(2dV_2^2) |V_2 - (V_p + V_b)|}{dV_1}$$

This varies with bias and also with signal $V_j$, so $V_j$ has to be kept very small if $g_m$ is not to change with signal change.

The characteristic $I_2(V_2)$ of the second fet is the same as the first, $I_2(V_1)$. But, to display the two currents and their differences together, they must all be plotted against $V_2$, so plotting $I_2$ against $V_2$ instead of against $V_1$, just reverses the characteristic left to right (Fig. 4). Since the difference curve is straight, the two non-linear devices have combined to make a linear one - at least, in the range where both fets are on. This range is for values of input $V_1$ in the range $2V_b$, or $2(V_p + V_b)$, whichever is the smaller. The largest range is found with the bias set half way to pinch-off, when the full characteristics can be used.

Algebraically, the second characteristic is

$$I_2 = \left(\frac{d^2V_2}{dV_0^2}\right)[-V_2 - (V_p + V_b)^2]$$

By subtraction, the difference graph has the equation

$$I_1 - I_2 = -(4dV_1^2)(V_1 - (V_p + V_b))$$

a straight line through the origin. Redefining mutual conductance as $g_m = \frac{dI_1 - dI_2}{dV_1}$, then

$$g_m = -(4dV_2^2)(V_1 - V_p)$$

The first bracketed term is simply a constant. The second is constant for any fixed value of bias $V_2$, but the bias can be varied. Remember that $V_p$ is negative, whereas the (variable) source bias $V_b$ is positive.

As the bias $V_b$ goes from zero to $V_b$, $g_m$ varies from $-4dV_2^2$ to zero. But it never varies with the strength of the signal. So, even for large inputs, as long as the signal is kept in the range, amplification is distortionless.

The behaviour is in complete contrast to that of the old "variable mu" circuit, where only tiny segments of the curved characteristic can be considered even quasi-linear.

If the bias is set at $V_b/2$ for the largest symmetrical swing, then $g_m = 2dV_2^2/V_b$, the value for a single fet at zero bias.

Figure 5 shows a set of linear characteristics calculated for a D2S pair with a pinch-off voltage of $-4V$ as the bias varies between pinch-off and zero. The slopes of the characteristics vary by a factor of seven, as the bias...
goes from -3.5V to -0.5V, and the minimum input range shown is ±0.5V.

Generally, with characteristics described by polynomials, sinusoidal input gives a distorted output, which can be described as linear plus added harmonics. Normally, push-pull reduces some of the harmonics; in the special case of a square-law, it cancels them completely.

Another useful feature is that with Class A mid bias, the standing current is not the usual half of the maximum – as it is in linear devices such as thermionic valves. Instead, it is only a quarter of the maximum current, giving less power loss in the quiescent state (perhaps it should have a special title, such as Curvilinear Class A).

The usual push-pull arrangement in small-signal stages, the “long-tailed pair”, involves an unbiased resistor between the common source and ground. The effect is simultaneous equal but opposite current (rather than voltage) swings in the two fets, and so does not produce the distortionless result for all swings.

In principle, two fets can be paired to obey square laws which are not identical. Output current differences can be matched by use of different transformer tappings or different loads. The input voltage swing to one fet can be attenuated to balance differences in pinch-off voltage. It may not seem like a strategy for mass production, but will probably appeal to the amateur “tweaker”.

Applications of D2S.

The most obvious application of the D2S pair is in audio power output stages. People must be doing this without realising what is happening, though few makers of amplifiers have probably consciously selected their output fet pair for square law characteristics. More likely is that devices are selected for best linearity – if at all. A recent article1 shows curves for power fets following a square law at low current but a linear law at high current. With fets like these, biasing in the middle of the square law region should give a totally linear difference curve over the whole range, because just as one fet goes off the other goes linear.

In small signal amplifications, a D2S pair might provide a current need to a bipolar transistior which is linear in current amplification.

For audio work, the variable gain might be useful in volume expansion or compression, while a mid-biased D2S pair would be useful in radio frequency amplifiers which amplify signals from many stations at once, as it would give no intermodulation of signals for peak inputs up to Vp/2.

Similarly, there are obvious uses in oscillators. All oscillators need some gain control or their outputs would go on rising for ever. In the simplest transistor oscillators, gain control is provided by saturation of the transistor – which then has a very distorted current waveform. The hope is always that the resonant circuit will clean up the output waveform.

An oscillator could use D2S to provide distortionless variable gain to keep the loop gain verging on unity. The effect would be to remove distortion in the oscillator.

Occasionally it should be possible to use just one fet twice over! In chopper amplifiers for dc amplification, an input direct voltage passes through a reversing switch, giving a symmetrical voltage square wave to the input electrode. With a square law fet amplifier stage, the output should be an asymmetrical square wave, whose pk-pk value is proportional to the input voltage.

To summarise, there seems little doubt that matched fets can offer truly linear amplification in push-pull circuits. This linearity can be expected for all bias settings, though the allowable input swing depends on bias. Varying the bias varies mutual conductance, allowing distortionless automatic gain control. The only drawback to the approach is that fets tend to vary widely, and practical testing and selection of matched pairs with suitable characteristics remains a problem.

Reference.

Cooke International
SUPPLIER OF QUALITY USED 
TEST INSTRUMENTS 
ANALYSERS, BRIDGES, CALIBRATORS, 
VOLTMETERS, GENERATORS, OSCILLOSCOPES, 
POWER METERS, ETC. ALWAYS AVAILABLE
SPECIALIST REPAIR WORK & CALIBRATION 
UNDERTAKEN
ORIGINAL SERVICE MANUALS FOR SALE 
COPY SERVICE ALSO AVAILABLE
EXPORT, TRADE AND U.K. ENQUIRIES WELCOME,
SEND LARGE "A3" S.A.E. FOR LISTS OF EQUIPMENT 
AND MANUALS.
ALL PRICES EXCLUDE VAT AND CARRIAGE
DISCOUNT FOR BULK ORDERS
SHIPPING ARRANGED
OPEN MONDAY-FRIDAY 9AM-5PM
Cooke International
ELECTRONIC TEST & MEASURING INSTRUMENTS
Unit Four, Fordingbridge Site, Main Road, Barnham, 
Bognor Regis, West Sussex, PO22 0EB
Tel: (+44) 0243 545111/2 
Fax: (+44) 0243 342457
HIGH END TEST & COMMUNICATIONS 
EQUIPMENT PURCHASED
AMAZING 486-66 OFFER
LONG AT. 80% GRAPHICS ACCELERATOR
IBM BASS, 2MB MEM: CACHING HARD DRIVE:
251-1440, 20 IN 16 IN COLUMN: 
E10999+V AT
94-95 (see. 28-33 SYSTEMS
FOR VERBAL INQUIRIES CONTACT
Graeme Duncan
COMPUTERS LTD
0444 244498
FREE CLASSIFIED
FOR SALE Original thinking disciplined 
development & prototype 
engineer. Sensing & process control int
location M.J. Nicholas 0127 452206.
G.R. 1697-A Transfer function and 
immittance bridge £200 (inc valves KT88
EL34 kitons C.Ts 0135 865112. Mr 
Mansef, 48 Bowling Green. Thetham 
RG13 3DA.
FOR SALE 2 Claude Lyons AC voltage 
stabiliser series TS output 240V 5% V 16A
3.9 KVA complete with handbook any 
offers. Tel 0181 940 7866.
WE WANT TO BUY !!
IN VIEW OF THE EXREMELY 
RAPID CHANGE TAKING PLACE 
IN THE ELECTRONICS 
INDUSTRY, LARGE QUANTITIES 
OF COMPONENTS BECOME 
REDUNDANT. WE ARE CASH 
PURCHASERS OF SUCH 
MATERIALS AND WOULD 
APPRECIATE A TELEPHONE 
CALL OR A LIST IF AVAILABLE. 
WE PAY TOP PRICES AND 
collect. 
R.HENSON LTD. 
21 Lodge Lane, N.Finchley, 
London N12 8JG. 
5 Mins, from Tally Ho Corner. 
TELEPHONE 081-445-2713/0749 
FAX 081-445-5702.
ARTICLES FOR SALE

VALVES AND C.R.T.s
(also Magnetrons, Klystrons, 4CX250/350)
Minimum order charge of £50 + VAT

One million valves in stock. Obsolete types a speciality! Fax or phone for quote.
Special prices for wholesale quantities.
Orders from government departments, overseas etc. most welcome.
Many other types in stock. Please enquire re any type not listed.

CATHODE RAY TUBES: 400 different types in stock.
Please ensure if your requirements are not listed below.

ARTICLES FOR SALE

For all your future enquiries on advertising rates, please contact Pat Bunce on:
Tel: 081-652 8339
Fax: 081-652 8931

PLACE ORDER FORM

CLASSIFIED ADVERTISEMENT ORDER FORM

<table>
<thead>
<tr>
<th>Size</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

Place a lineage advertisement in next month’s issue and it will cost, for a single insertion, only £2.10 per word.

Special rates:
6 insertions £2.10 per word/issue (Advertisement can appear every month or every other month only).

WHY NOT PLACE A BOXED ADVERTISEMENT TO GIVE MAXIMUM IMPACT? →

EXTRAS:
Spot Colour ...................................... 20%
Box number service ........................................ £22.00

EXAMPLE SIZE
3cm x 1 column
For 1 insertion cost is: £45.00

Lineage advertisements under £50 have to be pre-paid by credit card or cheque.

ALL RATES QUOTED ARE EXCLUSIVE OF VAT:
All major credit cards accepted
Please debit my ........................................ card a total of £

Expiry Date: ........................................

Please ensure that address given is where your credit card statement goes to.

NAME ..................................................
ADDRESS ...........................................

TEL NO ........................................... SIGNATURE

All advertisements must be received five weeks prior to publication date.
All cancellations must be received by eight weeks prior to publication date. After that no advertisement can be cancelled.
Please send to Electronics World & Wireless World, Classified, 11th Floor, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Tel: Pat Bunce on 081-652 6339.
The system 2000 is an ideal programmer for the production environment. Fast programming results in high throughput and rigorous verification leads to improved quality control. Single key functions and checks against misoperation facilitates its use by unskilled staff.

**MQP ELECTRONICS LTD.**
Tel: 0666 825146
Fax: 0666 825141

OLSON ELECTRONICS LIMITED is a leading manufacturer in the field of mains distribution panels of every shape and size to suit a variety of needs. For use in Broadcasting, Computing, Data Communications, Defence, Education, Finance, Health etc. All panels are manufactured to BS5733, BRITISH AMERICAN, FRENCH, GERMAN CEE22/IEC and many other sockets. Most countries cater for.

All panels are available ex-stock and can be bought direct from OLSON.

**Olson Electronics Limited**
Tel: 081 885 2834
Fax: 081 885

**FREE VXI BROCHURE**
The National Instruments VXI brochure describes the company's embedded PC and GPIB controllers, MXIBus interface kits for multiple platforms, and NI-VXI, LabWindows, and LabVIEW software for developing and controlling VXI instrumentation systems.

**NATIONAL INSTRUMENTS**
Tel: 0800 289877

**IR Group, Europe's leading supplier of used instrumentation, has published the latest update of models available.** With a range from power supplies to network analysers, most items are available on short delivery and come with a 12 month parts and labour warranty. For a detailed quotation call 0753 670000.

**CIRKIT have just published the 2nd Edition of the Toko RF Catalogue, featuring details of Tokos' extensive range of RF coils, inductors, filters and comm ICs.** The 128 page catalogue includes many new products such as: Surface mount high current inductors, surface mount multilayer inductors, helical filters at 2.5GHz and a new section of push button and tact switches.

**Stag Programmers Limited**
Martinfield Welwyn Garden City, Herfordshire, AL7 1JT UK
Tel: (0707) 332148
Fax: (0707) 371503

**ELECTRONICS UPDATE** is Electronics Weekly's section for advertisers to market their product information. From catalogues to newsletters, Data Update is designed to present your product information in a clear and attractive manner, whilst our colour coded enquiry numbers help readers to obtain the information they need fast.

CIRCLE NO. 147 ON REPLY CARD

**ELECTRONIC UPDATE is** Electronic World and Wireless World's section for advertisers to market their product information. From catalogues to newsletters, Data Update is designed to present your product information in a clear and attractive manner while our "CIRCLE NUMBERS" help readers to obtain the information they need fast.

HIGH SPEED EPROM & FLASH Programming from your PC
- Programs EPROMs to 4 Mbits/32-pins
- Superfast 8, 16 & 32-bit programming
- Approved algorithms
- Menu driven software included
- Sophisticated editor functions
- Easy file management
- FREE demo disk available

Stag Programmers Limited
Martinfield Welwyn Garden City, Herfordshire, AL7 1JU
Tel: (0707) 332148
Fax: (0707) 371503

CIRCLE NO. 149 ON REPLY CARD
ADVANTECH TR-3111 3.5GHz portable analyser
HP3580A 770MHz single channel analyser
HP3580A dual-channel 770MHz analyser
HP3582A 2.2GHz single channel analyser
HP53135B 130GHz analyser
HP53136B 210GHz analyser
HP53137B 340GHz analyser (with ext mixers)
HP53138B 570GHz analyser (with ext mixers to 110GHz HP)
MARCONI E7000 110MHz
MARCONI E7011 1000MHz (and extendable to 1400MHz)
TEKTRONIX T1111 1GHz portable analyser

TEST EQUIPMENT

BRIJUL E1A2R 2611 vibration meter set £2900
BRIJUL E1A2R 2610 vibration meter £2800
BRIJUL E1A2R 77070130 level recorder £2900
BRIJUL E1A2R 161 vibration meter £800
BRIJUL E1A2R 30090130 level recorder £800
BRIJUL E1A2R 5161 vibration meter £800
AVO R200S 62/10 vibration meter & window test £850
AVO R500S 62/10 digital tachometer £750
MARCONI E7025 10mhz to 6GHz analyser £1250
MARCONI E7025 6GHz to 21GHz analyser £1250
FLUKE 16100 calibration £500
KEITHLEY 1972 programmable DC £490

MUCH MORE. FULLY REFURBISHED. FULLY GUARANTEED TEST EQUIPMENT AVAILABLE FROM STOCK. PLEASE REQUEST OUR CURRENT LUTTONS. WE CAN FAX LISTS & SHIP GOODS WORLDWIDE. HIGH END EQUIPMENT ALWAYS WANTED FOR STOCK. ALL LISTS NOW AVAILABLE.

INDEX TO ADVERTISERS

Amplicon Liveline 40
Antex 75
Bull Electrical 7
Citadel Products Ltd 8
Dataman Programmers Ltd 48
Display Electronics Ltd 75
Electrovalue Ltd 39
Field Electric 57
Halecyon Electronics Ltd 69
Integrated Measurement 62
Johns Radio 63
JP6 Electronics 62
Kiloch 20
Kestral Electronics 84
Labcentre 62
Langrex 84
Logicom 62

CIRCLE NO. 134 ON REPLY CARD

ELECTRONICS WORLD + WIRELESS WORLD January 1994
FROM CONCEPT TO ARTWORK IN 1 DAY

Your design ideas are quickly captured using the ULTicap schematic design Tool. ULTicap uses REAL-TIME checks to prevent logic errors. Schematic editing is painless; simply click your start and end points and ULTicap automatically wires them for you. ULTicap’s auto snap to pin and auto junction features ensure your netlist is complete, thereby relieving you of tedious netlist checking.

ULTishell, the integrated user interface, makes sure all your design information is transferred correctly from ULTicap to ULTiboard. Good manual placement tools are vital to the progress of your design. Therefore ULTiboard gives you a powerful suite of REAL-TIME functions such as, FORCE VECTORS, RATS NEST RECONNECT and DENSITY HISTOGRAMS. Pin and gate swapping allows you to further optimise your layout.

Now you can quickly route your critical tracks. ULTiboard’s REAL-TIME DESIGN RULE CHECK will not allow you to make illegal connections or violate your design rules. ULTiboard’s powerful TRACE SHOVE and REROUTE-WHILE-MOVE algorithms guarantee that any manual track editing is flawless. Blind and buried vias and surface mount designs are fully supported.

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

ULTiboard’s autorouter allows you to control which parts of your board are autorouted, either selected nets, or a component, or a window of the board, or the whole board. ULTiboard’s intelligent router uses copper sharing techniques to minimise route lengths. Automatic via minimisation reduces the number of vias to decrease production costs. The autorouter will handle up to 32 layers, as well as single sided routing.

ULTiboard’s backannotation automatically updates your ULTicap schematic with any pin and gate swaps or component renumbering. Finally, your design is postprocessed to generate pen/photo plots, dot matrix/laser or postscript prints and custom drill files.

ULTiboard PCB Design/ULTicap Schematic Design Systems are available in low-cost DOS versions, fully compatible with and upgradable to the 16 and 32 bit DOS-extended and UNIX versions, featuring unlimited design capacity.

NEW
ULTiboard/ULTicap evaluation system:
• all features of the bigger versions
• full set of manuals
• design capacity 350 pins.
Price incl. S & H, excl. VAT: £75
Purchase price 100% credited when upgrading to a bigger version. Also suitable for study & hobby

ULTimate Technology UK Ltd.  2 Bacchus House, Calleva Park, Aldermaston Berkshire RG7 4QW  Fax: 0734 - 815323  Phone: 0734 - 812030

CIRCLE NO. 100 ON REPLY CARD

ULTIcap + ULTiboard = MAXIMUM PRODUCTIVITY

The European quality alternative
The smallest, most powerful personal programmer you can buy!

Owning the world's best selling portable programmer/emulator is just a phone call away. From engine management to Antarctic survey teams, the powerful and versatile S4 goes where others get left behind.

A 32 pin ZIF socket programs a huge library of EPROMs, EEPROMs and FLASH devices up to 8Mbit. And our unique user loadable Library means that new parts can be added quickly, and at no cost. All software upgrades are free and available for 24hr download from our high speed bulletin boards.

Emulation
See your code running before committing yourself to an EPROM. With S4's powerful and easy-to-use internal emulation system, download your code to S4, press 'EMULATE', and your target system runs in real time as if an EPROM was plugged into the socket. Use S4's 'EDIT' command to make minor alterations to your code and see the changes happen immediately - just one reason why S4 is used by the world's car manufacturers to develop advanced engine management systems in real time! With S4 emulation there's no need for trailing cables or external power sources; earth loop problems are a thing of the past. S4 even emulates RAM.

Remote Control
As well as being totally stand alone and self contained, S4 can be operated remotely via its serial port at speeds up to 115,200 Baud. We supply you with a FREE disk containing custom terminal software and a pop-up TSR communications utility.

The Company
If you are looking for a supplier with longevity and stability, then you'll be pleased to learn that Dataman has been designing and selling innovative programmers world-wide for over 15 years. As well as having sales and support offices in both the UK and the USA, we supply the world demand for our products via a network of approved dealers stretching from Norway to Australia.

Availability
S4 is always in stock. Phone through your credit card details to ensure next working day delivery. Full 30 day no-risk refund.

Dataman has been designing and selling innovative programmers world-wide for over 15 years. As well as having sales and support offices in both the UK and the USA, we supply the world demand for our products via a network of approved dealers stretching from Norway to Australia.

The Package
S4 comes fully charged and configured for immediate use. You get a mains charger, emulation lead, write lead, personal organiser instruction manual, MS-DOS communications software, spare Library ROM and a 3 year guarantee. Optional modules available for serial EPROMs, 40 pin EPROMs and microcontrollers.

Size: 186 x 111 x 46mm
Weight: 315g

Dataman Programmers Ltd
Credit card hotline: 0300 320719
for same-day dispatch

Station Road, Maiden Newton, Dorset DT2 0AE, UK. Telephone: 0300 320719; Fax: 0100 321012; Telex: 418442; BBS: 0300 321095 24hr; Modem: V32bis/16.8K HST
22 Lake Beauty Drive, Suite 101, Orlando, FL 32806, U.S.A. Telephone: (407) 649-3335; Fax: (407) 649-3310; BBS: (407) 649-3159 24hr; Modem: V32bis/16.8K HST
CIRCLE NO. 101 ON REPLY CARD