Free extract from PICBasic experimenters' book

ELECTRONICS WORLD

DECEMBER 2000 £2.65

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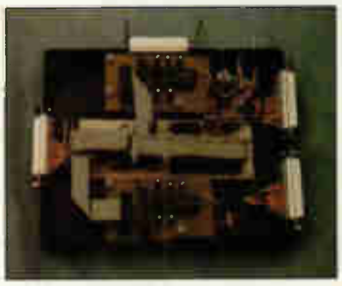
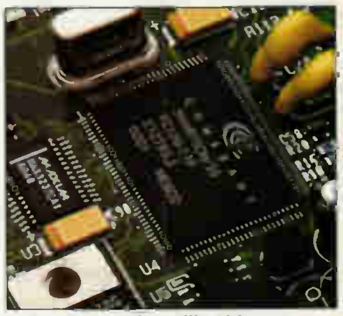
Cover art Mark Swallow



There's a wealth of PC add-ons with RS232 interfacing, but few computers have more than one spare COM port. This box, detailed on page 943, routes one port into four under software control.



Advanced modems like this one are part of the reason why old-fashioned copper, as a means of connecting telephones, is showing no sign of being rendered obsolete. Read the whole story on page 918.

New book for those of you wanting to experiment with microcontroller programming without the tears of learning assembler – see page 926.

January issue on sale 7 December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Due diligence and culpable incompetence

At the close of the latest newsletter from the Bletchley Park Trust – the organisation that's doing a marvellous job conserving and developing our World War II code-breaking centre – is the tag line, "The Bletchley Park website is now a secure site."

It's doubly appropriate too, not merely because the security of its highly confidential activities was maintained a secret until recent times. Today the website – at www.bletchleypark.org.uk – accepts credit card orders for the many books and video tapes its sells on cryptographic subjects and its customers expect their transactions to be handled with total security.

No doubt they are, but how does the customer know? Equally importantly, how does the organisation offering electronic commerce services know? On the basis of recent happenings, they don't and this is the scandal.

Undertakings that handle the money of others have a duty of care and trust. And this duty applies regardless of the channels by which the money passes. Firms inviting customers to do business with them electronically are expected to exercise due diligence to ensure that the mechanisms they provide are fit for purpose. But what do we find?

- A man logging on to Powergen's website to pay his bill came across unencrypted credit card details, home address and payment records for himself and 7000 other customers.
- The online bank Egg was subject to a serious attempted fraud that required little technical skill.
- A miscreant accessed the customer files of supermarket giant Safeway and sent an amusing but highly damaging e-mail to its entire customer base.
- Woolworths had to shut down its online store after customers' details and another user spotted credit card numbers.
- On Barclays Bank site, any customers' details could be viewed – even after they had logged out. This was the third blunder in two weeks.
- The Halifax Building Society was forced to delay the opening of its on-line bank, Intelligent Finance, because of security concerns.
- A survey commissioned for Internet shopping site Zoom.co.uk revealed that one in four UK Internet users who buy goods online were still concerned about security – that's 25 per cent of those disposed towards electronic shopping; by implication 100 per cent of the rest of the population would not risk it.

Although lamentable, this last episode was the only event to confer any real credit. Woolworths paid customers compensation after the event. Powergen first denied insecurity, then accused its customer of being a hacker, while Barclays failed to apologise immediately to the customer who exposed its security flaws. None of this inspires confidence.

Excuses of 'one-off incidents' hold little water either. When confidential data can be accessed as simply as hitting the browser's back key (Barclays) or deleting the trailing section of a URL, it's patently clear that no 'due diligence' has been exercised in bug-testing these systems.

In the frantic rush to be first-to-market, traditional testing has been forsaken. Ironically, in the same week as Powergen had its 'one-off incident', security consultancy NTA Monitor revealed that 80 per cent of companies did not test the security of their sites.

With the number of Europeans banking on the Internet set to triple in the next three years – according to a report published by investment bank JP Morgan – banks and other exponents of e-commerce will have to do better. Both the Consumers' Association and the National Association of Bank Customers have stated that Internet banks must take responsibility for fraud and draw up clear policies for handling security breaches.

Currently, policies vary and in some cases, customers themselves are liable for losses incurred. Only the Halifax has proactively stated that it would guarantee any losses incurred to customers who not acted with criminal gain in mind.

This comes at a time when unless they improve their security procedures, online banking operations are likely to become a major target for organised crime. Indeed, according to security testing firm NTI Monitor eastern European criminals may already be targeting operations in the UK.

Two software designers from Kazakhstan recently demanded $200 000 in exchange for the database of financial tycoon Michael Bloomberg. And a number of other high-profile frauds involving electronic banking have been traced to countries of the former Soviet Union.

Legal remedies are far less effective than prevention and as Winn Schwartau, CEO of Security Experts and founder of Infowar.com, observes, "We want to prevent breaches, not study them later. Fear of police prosecution doesn't stop the enlightened criminal when he knows full well that the odds of being caught are almost zero."

And legal remedies lose effectiveness when incidents cross international borders and in any case, computer fraud, unlike murder or robbery, is still not universally recognised as crime. Laws to fight it are typically found only in industrialised nations that depend on computers.

This will not stop new shopping and banking sites from opening online but to secure their customers' confidence they will have to demonstrate far higher standards of security. To continue as at present would be culpable incompetence. ■

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UPDATE

Fourth generation mobile phones already under consideration

Fourth generation mobile phone technology is already under consideration despite the fact they will not be a commercial reality for at least ten years.

Ericsson is one company already starting work because as vice president of research, Hakan Eriksson, points out the technology has so far followed a ten year cycle of development.

According to Eriksson, data rates of up to 100Mbit/s could be possible from 4G systems depending on where you are sited in relation to a basestation.

"If you're close you have a high bit rate, it could maybe come up in the order of 20 to 100Mbit/s," said Eriksson. "If you're far out you could maybe have what we have today with W-CDMA at 384kbit/s. It would be the largest span in possible bit rates."

The system might incorporate new technology but this is not a pre-requisite, said Eriksson as he expects it to combine existing technologies such as GSM, W-CDMA, satellite and Bluetooth.

Eriksson also believes the basestation concept will have to be redefined. Instead of basestations being situated at least 3km apart there will be a very dense network of what he calls "radioheads."

To get round the problem of low data rates when the user is far away from a basestation the company is also looking at a way in which other terminals connected to the network can be used to relay the data. "What you need is a higher degree of connectivity," said Eriksson.

Melanie Reynolds

New materials studied for nanometre MOS gates

Silicon dioxide will fail to satisfy the needs of CMOS in the next few years, as somewhere between 2 and 1nm it is too thin and leaks current.

New materials are needed and some of these come from the hidden depths of the chemistry set.

Lucent's Bell Labs is looking at zirconium and silicon doped aluminates. Used with a TiN gate, these materials can withstand standard, i.e. high-temperature, CMOS processing.

With an equivalent oxide thickness (EOT) of 1.2nm, Lucent achieves leakage below 50mA/cm2.

EOT is used to compare gate insulators. It is the thickness of SiO_2 needed to get the same transistor transconductance as the insulator being compared.

The University of Texas has been looking at ZrO_2 and zirconium silicate – $Zr_{27}Si_{10}O_{63}$. At equivalent thicknesses of 0.89 and 0.96nm respectively, it is getting leakages of 20 and 23mA/cm^2. The university used a TiN barrier between insulator and polysilicon gate to prevent destructive interaction during 950°C anneal.

The same university also showed that HfO_2 can be used with n-type polysilicon gates with no barrier layer, achieving a leakage of 0.23mA/cm2 at 1.04nm EOT. Further work has produced working P and NMOS devices with an EOT of 0.8nm. These use a TaN gate and the combination is said to show promise for 70nm (compared with today's 1.3µm)processes.

Together with other US universities, Texas is also working on molybdenum as a gate metal for hard-to-make ZrO_2 PMOS devices. Samsung has taken a look at Al_2O_3 and may have found a way to make use of it as a gate insulator. It is said to have leakage three orders of magnitude better than SiO_2.

Over in Japan, Toshiba has shown that Ta_2O_5 is suitable for use in sub-50nm damascene metal gate MOSFETS and has been doing fundamental research into materials including ZrO_2.

Finally, a German team has really plundered the dark recesses of the periodic table and come up with praseodymium oxide. At an EOT of 1.4nm it has measured leakage currents of 5 x 10^{-9}A/cm2. This is around 10^4 better than HfO_2 and ZrO_2 films. The team claims that breakdown voltage for such a gate would be 6V, corresponding to an incredible field strength of 43MV/cm.

Nanocrystals for non-volatile memory

Nanocrystals storing electric charge might be the future of non-volatile memory, according to Lucent Technologies. At the International Electron Devices Meeting (IEDM) in December, Lucent is to present details of its nanocrystal memory. A layer of crystals replaces the polysilicon floating gate used in flash memory.

Surrey launches new microsatellite

Surrey Satellite Technology has successfully fired another of its microsatellites into space.

This one, Tiungsat-1, was launched on board a Dnepr launch vehicle from the Baikonur Cosmodrome in Kazakhstan.

Team work... Malaysian scientists and technicians have shadowed Surrey staff for a year to find out how to run a microsatellite. The picture shows the team with the Tiungsat-1 satellite.

The launch on board Dnepr is significant in that it is the second commercial use of the demilitarised SS18 intercontinental ballistic missile. The first was for the launch of Surrey's Uosat-12 minisatellite in April 1999 when Surrey was the sole payload for the Dnepr rocket.

Tiungsat-1was built for Malaysian firm Astronautic Technology, and was activated on its first transit over Malaysia seven hours after launch from a ground station installed by Surrey in Kuala Lumpur.

The 50kg Tiungsat-1 microsatellite will provide 80m resolution multispectral Earth imaging, 1.2km meteorological Earth imaging, digital store-and-forward communications and a cosmic-ray energy deposition experiment.

Among the benefits that Tiungsat-1 will provide for Malaysia is information on Earth resources, land use and environmental haze pollution and weather patterns, including hurricane warnings.

This is Surrey's third launch this year, making a total of 19 satellites in 19 years.

LEDs under consideration for traffic control

Light-emitting diode technology is being considered for use in traffic-control applications by the Intelligent Transport Systems industry.

UK suppliers, users and evaluators discussed the possibilities for the technology at a recent meeting of the Intelligent Transport Society (UK) Enforcement Interest Group. Although LED technology offers advantages, there are problems to be overcome before it can be deployed.

"Optical units utilising LED technology offer the potential for reduced energy consumption and reduced maintenance costs," said Trevor Ellis, the Group's chairman, "but new approaches to monitoring LED failures have to be developed for legal and safety reasons."

Meanwhile, the M25 Controlled Motorway Scheme is to be extended following the award of a four year contract by the Highways Agency to consulting group Mouchel.

The contract will see automatic control of the motorway extended from 22km to a 30km stretch.

Work will include development of a system that includes second-generation camera enforcement equipment and new controlled motorway indicators.

Wristwatch transmits distress calls for 48 hours

Swiss watchmaker Breitling is selling a wristwatch equipped with a transmitter to broadcast on the international distress frequency in an aeronautical emergency.

Called the Breitling Emergency, it is intended to enable downed pilots to be located on land or at sea.

When activated by unscrewing a protective cap and pulling out an antenna, the Emergency broadcasts at 121.5MHz. The signal lasts for 48 hours and could be picked up 160km away by a search aircraft flying at 6000m, said the company.

Initially, the watch will be available for sale only to licensed pilots and a fine is payable for misuse.

Price is $3500 in titanium or $48000 in gold and diamonds.

Obsolescence problem gets Government cash

The government is putting up money to tackle component obsolescence - the problem increasingly hitting makers of long-life electronic equipment.

"Electronic component obsolescence is now one of the biggest threats to the future of many sectors of industry," said Sir Richard Evans, chairman of BAe. "Unless we start managing obsolescence from the beginning of a new production cycle to the end of equipment life, military and commercial aerospace, nuclear, medical, transportation, petrochemical and other areas will face critical problems as essential electronic components disappear from the market."

Sir Richard was speaking at the opening of the National Obsolescence Centre (NOC), jointly funded by the DTI and the Defence Evaluation & Research Agency (DERA).

DERA already maintains a database of components for third party organisations.

It constantly checks component production status with manufacturers. It also notifies users if a component becomes obsolete or is approaching obsolescence, in other words, the manufacture has said it would stop production.

Currently DERA only offers the service to military customers and prime contractors. With the introduction of NOC, this service will be opened up to commercial clients.

"Users will lodge lists of components with NOC," said Mike Housley, DERA director of NOC. "We will update the status of the components on a regular basis, probably once a week."

The service will be Web-based with customers having secure access to status information.

NOC, using DERA engineering resources, will also be offering to find alternatives for obsolete components.

Also involved in NOC is the Component Obsolescence Group (COG), an industry body made up of component users and producers that aims to provide information to members through regular meetings.

Steve Bush, *Electronics Weekly*

**See www.nocweb.org and www.cog.org.uk.
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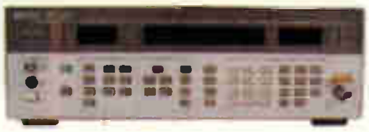

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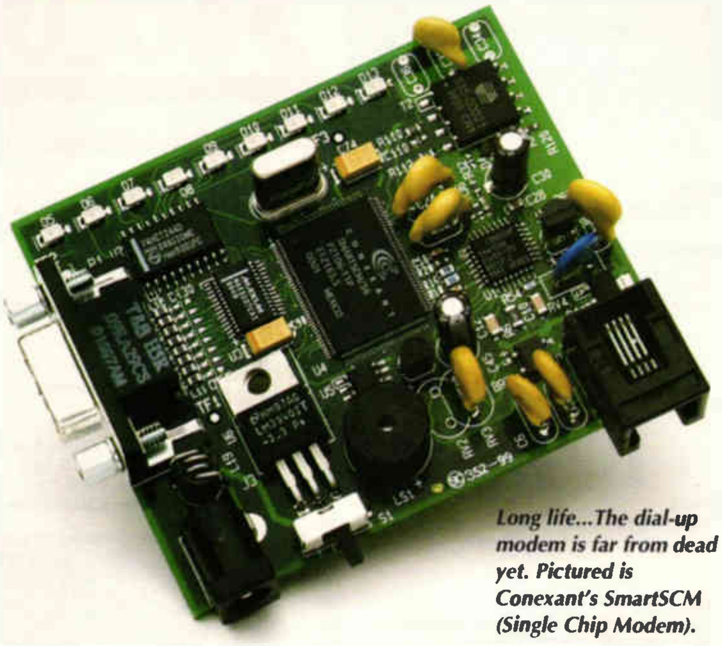
Long live copper



Long life...The dial-up modem is far from dead yet. Pictured is Conexant's SmartSCM (Single Chip Modem).

Optical fibre and radio spectrum may be trendy communications technologies but most people still rely on good old copper. Melanie Reynolds reports on whether the comms industry will abandon copper.

Anyone could be forgiven for thinking that the radio spectrum and optical fibre are the only transmission mediums worth using for transmitting communications traffic given the amount of buzz they currently generate.

But while these technologies may be talk of the town in the telecoms world, generating huge amounts of comment and column inches, it would do us well not to forget that the majority of people still rely on that old faithful technology – the trusty copper wire.

"While you read an awful lot about wireless technology and other forms of access, copper is far from dead," says Charles Louisson, access applications marketing director at Lucent Technologies Microelectronics Group. "With the unbundling of local loops happening in most of the European countries there is going to be tremendous competition [to gain access to the copper networks]."

Indeed the United Kingdom is a classic example of this with companies clamouring to fit their equipment in the exchanges while BT seemingly clings avidly onto its exclusive access to them. There must be money to be made here considering the huge row which the process of opening up the networks to competition has created.

Companies want to be able to use the copper network to provide high speed ADSL (asymmetric digital subscriber loop) services in competition to BT, but there is still money to be made using the copper network in its current incarnation.

"Everybody talks about DSL and broadband services and while these are definitely coming," comments Louisson, "in the near term consumer equipment manufacturers are looking for something that can be used in any home, ideally anywhere in the world so they can build just one flavour of their product. PSTN modem is really what offers that to them."

Louisson says there has been a tremendous surge in enthusiasm over the last couple of years for fitting modems into equipment. Part of this surge can be put down to the rise of interactive digital TV.

"We believe the TV is becoming an alternative method, at least in some sectors of the market, for Internet access," states Louisson. "So much of the media today contains links to Internet sources we believe it will become the pervasive way of accessing the Internet."

Which means good news for the traditional dial up modem for the Internet connection part,which in turn is good news for companies like Lucent and Conexant who supply the silicon.

This is especially true as new standards like V.92 emerge which are intended to close the performance gap between modems on standard copper wire and ADSL. Making the best of what is already there seems the way to go because the fact is that despite all the talk there are going to be some areas that ADSL simply will not reach for economic reasons.

"I don't think it's the case you'll see copper diminish in any way. I think you'll see an increase in other types of technology but copper is still going to be around it," says Nick Burd, director of DSL products for Conexant's Personal Computer Division. "The fact that copper is in the ground already is a fairly compelling reason for its re-use in as many forms as you can possibly find."

Copper cables are here to stay and it seems there is still plenty of life left in the old technology.

Modem rates at a glance

- **Dial-ups over telephone lines**
  V.90 - 33.6kbit/s from user
  V.92 - 48kbit/s from user
  56k - 56kbit/s from user
- **Data compression**
  V44 &V42 - boost dial-up speed by 50 per cent and more
- **ADSL modems over telephone lines**
  G.lite - 384kbit/s from user & 1.5Mbit/s to user
  DMT full rate - 384kbit/s from user & up to 8Mbit/s to user
- **Cable modems over coaxial cable TV networks**
  DOCSIS standard-compliant - 10Mbit/s from user & 36Mbit/s to user.

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HP New Colour Spectrum Analysers LAST FEW ONLY
HP141T+ 8552B IF + 8553B RF -1KHZ -110Mc/s - £500.
HP141T+ 8552B IF + 8554B RF -100KHZ -1250M - £600.
HP141T+ 8552B IF + 8556A RF - 20Hz-300KHz - £400.
HP141T+ 8552B IF + 8555A 10 MC/S-18GHzS - £1000.
HP8443A Tracking Gen Counter 100KHz-110Mc/s - £200
HP8445B Tracking Preselector DC to 18GHz - £250.
HP8444A Tracking Generator • 5-1300Mc/s - £450.
HP8444A OPT 059 Tracking Gen • 5-1500Mc/s - £650.
HP35601A Spectrum Anz Interface - £300.
HP4953A Protocol Anz - £400.
HP8970A Noise Figure Meter + 346B Noise Head - £3k.
HP8755A+B+C Scalar Network Anz PI - £250 + MF 180C - Heads 11664 Extra - £150 each.
HP3709B Constellation ANZ £1,000.
HP11715A AM-FM Test Source - £350.
FARNELL TVS70MKII PU 0-70V 10 amps - £150.
MARCONI 6500 Network Scaler Anz - £500. Heads available to 40GHz many types in stock.
Mixers are available forANZs to 60GHz.
HP6131C Digital Voltage Source + -100V½ Amp.
HP5316A Universal Counter A+B.
Marconi TF2374 Zero Loss Probe - £200.
Racal/Dana 2101 Microwave Counter - 10Hz-20GHz - with book as new £2k.
Racal/Dana 1250-1261 Universal Switch Controller + 200Mc/s PI Cards and other types.
Racal/Dana 9303 True RMS Levelmeter + Head - £450.
TEKA6902A also A6902B Isolator - £300-£400.
TEK CT-5 High Current Transformer Probe - £250.
HP Frequency comb generator type 8406 - £400.
HP Sweep Oscillators type 8690 A+B + plug-ins from 20Mc/s to 18GHz also 18-40GHz.
HP Network Analyser type 8407A + 8412A + 8601A - 100Kc/s - 110Mc/s - £500 - £1000.
HP 8410-A-B-C Network Analyser 110Mc/s to 12 GHz or 18 GHz - plus most other units and displays used in this set-up - 8411a-8412-8413-8414-8418-8740-8741-8742-8743-8746-8650. From £1k.
Racal/Dana 9301A-9302 RF millivoltmeter - 1.5-2GHz - qty in stock £250-£400.
Racal/Dana Modulation Meter Type 9009-9008 - 8Mc/s - 1.5GHz - £150/£250 - 9009A £350.
Marconi RCL Bridge type TF2700 - £150.
Marconi Microwave 6600A 1 sweep osc., mainframe with 6650PI - 18-26.5 GHz or 6651 PI - 26.5-40GHz-£750 or PI only £600, MF only £250.
Gould J3B test oscillator + manual - £150.
Marconi 6155A Signal Source-1 to 2GHz - LED - £400.
Barr & Stroud Variable filter EF3 0.1Hz-100Kc/s + high pass + low pass - £150, other makes in stock.
Racal/Dana 9300 RMS voltmeter - £250.
HP 8750A storage normalizer - £400 with lead + S.A. or N, A
Marconi mod meters type TF2304 - £250 - TF2305 - £1,000.
Racal/Dana counters-9904-9906-9916-9915-9916-9917-9921-50Mc/s-3GHz - £100 - £450 - all fitted with FX standards.
HP180TR. HP181T, HP182T mainframes £300 - £500.
HP432A-435A or B-436A-power meters + powerheads to 60GHz - £150 - £1750 - spare heads available.
HP3586A or C selective level meter - £500.
HP86222A+B Sweep PI -01-2.4GHz + ATT £1000-£1250.
HP86290A+B Sweep PI-2 - 18GHz - £1000 - £1250.
HP8620C Mainframe - £250. IEEE £350.
HP8165A Programmable signal source - 1MHZ - 50Mc/s - £1k
HP3455/3456A Digital voltmeter - £400.
HP5370A Universal time interval counter - £1k
HP5335A Universal counter - 200Mc/s-£1000.
HP3552A Transmission test set - £350.
TEKTRONIX 577 Curve tracer + adaptors - £900.
TEKTRONIX 1502/1503 TDR cable test set - £400.
HP8699B Sweep PI YIG oscillator .01 - 4GHz - £300. 8690B MF-£250. Both £500.
Dummy Loads & Power att up to 2.5 kilowatts FX up to 18GHz - microwave parts new and ex equipt - relays - attenuators - switches - waveguides - Yigs - SMA - APC7 plugs - adaptors etc. qty. in stock.
B&K Items in stock - ask for list.
Power Supplies Heavy duty + bench in stock - Farnell - HP - Weir - Thurlby - Racal etc. Ask for list. Large quantity in stock, all types to 400 amp - 100Kv.
HP8405A Vector voltmeter - late colour - £400.
HP8508A Vector voltmeter - £2500.
HP8505A Network Anz 500KHz-1.3GHz - £1000.
HP8505A + 8502A or 8503A test sets- £1200 - £1500.
HP8505A + 8502A or 8503A + 8501A normalizer - £1750-£2000.
Phillips 3217 50Mc/s oscilloscopes - £150-£250.
Wavetek-Schlumberger 4031 Radio communication test set

LIGHT AND OPTICAL EQUIPMENT

Anritsu ML93A & Optical Lead Power Meter - £250.
Anritsu ML93B & Optical Lead Power Meter - £350.
Power Sensors for above MA96A - MA98A - MA913A - Battery Pack MZ95A.
Anritsu MW97A Pulse Echo Tester.
PI available - MH914C 1.3 - MH915B 1.3 - MH913B 0.85 - MH925A 1.3 - MH929A 1.55 - MH925A 1.3GI - MH914C 1.3SM - £500 + one P.I.
Anritsu MW98A Time Domain Reflector.
PI available - MH914C 1.3 - MH915B 1.3 - MH913B 0.85 - MH925A 1.3 - MH929A 1.55 - MH925A 1.3GI - MH914C 1.3SM - £500 + one P.I.
Anritsu MZ100A E/O Converter.
+ MG912B (LD 1.35) Light Source + MG92B (LD 0.85)
Light Source £350.
Anritsu MZ118A O/E Converter.
+MH922A 0.8 O/E unit + MH923 A1.3 O/E unit £350.
Anritsu ML96B Power Meter & Charger £450.
Anritsu MN95B Variable Att. 1300 £100.
Photo Dyne 1950 XR Continuous Att. 1300 - 1500 £100.
Photo Dyne 1800 FA. Att £100.
Cossor-Raytheon 108L Optical Cable Fault Locator 0-1000M 0-10kM £200.
TEK P6701 Optical Converter 700 MC/S-850 £250.
TEK OF150 Fibre Optic TDR - £750.
HP81512A Head 150MC/S 950-1700 £250.
HP84801A Fibre Power Sensor 600-1200 £250.

HP8158B ATT OPT 002+011 1300-1550 £300.
HP81519A RX DC-400MC/S 550-950 £250.
STC OFR10 Reflectometer - £250.
STC OFSK15 Machine jointing + eye magnifier - £250.

COMMUNICATION EQUIPMENT

Anritsu ME453L RX Microwave ANZ - £350.
Anritsu ME453L TX Microwave ANZ - £350.
Anritsu MH370A Jitter Mod Oscillator - £350.
Anritsu MG642A Pulse Patt Gen. £350.
System MS02A Timer & Digital Printer - £500.
Complete MS65A Error Detector.
Anritsu ML612A Sel Level Meter - £400.
Anritsu ML244A Sel Level Meter - £300.
W&G PCM3 Auto Measuring Set - £300.
W&G SPM14 Sel Level Meter - £300.
W&G SPM15 Sel Level Meter - £350.
W&G PS19 Level Gen - £500.
W&G DA20+DA1 Data ANZ £400.
W&G PMG3 Transmission Measuring Set - £300.
W&G PSS16 Generator - £700.
W&G PS14 Level Generator - £350.
W&G EPM-1 Plus Head Milliwatt Power Meter - £450.
W&G DLM3 Phase Jitter & Noise - £350
W&G DLM4 Data Line Test Set - £400.
W&G PS10 & PM10 Level Gen. - £250.

MISCELLANEOUS ITEMS

HP 3852A Data Acquisition Control Unit + 44721A 16ch input £1,200.
HP 4261 LCR meter - £650.
HP 4274 FX LCR meter - £1,000.
HP 4951A Protocol ANZ - £500.
HP 3488A Switch Control Unit + PI Boards - £500.
HP 75000 VXI Bus Controllers + E1326B-DVM - quantity.
HP 83220A GSM DCS/PCS 1805-1990MC/S converter for use with 8922A - £2,000.
HP 1630-1631-1650 Logic ANZ's in stock.
HP 8754A Network ANZ 4-1300MC/S + 8502A + cables - £1,800.
HP 8754A Network ANZ H26 4-2600MC/S + 8502A + Cables £2,000.
HP 8350A Sweeper MF + 83540A PI 2-8.4GHZ + 83545A PI 5.9-12.4GHZ PI at 3 - £3,500.
HP MICROWAVE TWT AMPLIFIER 489A 1-2GHZ 30DB - £400.
HP PREAMPLIFIER 8447A 0.1-400MC/S - £200. Dual - £300.
HP PREAMPLIFIER 8447D 0.01-1.3GHZ - £400.
HP POWER AMPLIFIER 8447E 0.01-1.3GHZ - £400.
HP PRE + POWER AMPLIFIER 8447F 0.01-1.3GHZ - £500.
HP 3574 Gain-Phase Meter 1HZ-13MC/S OPT 001 Dual - £400.
MARCONI 2305 Modulation Meter-50KHZ 2.3GHZ - £1,000.
MARCONI 2610 True RMS Meter - £450.
MARCONI 893B AF Power Meter (with S ped filter) - £250-£350.
MARCONI 6950-6960B Power Meters + Heads - £400-£900.
MARCONI SIGNAL SOURCES-6055-6056-6057-6058-6059 - FX Range 4-18GHZ - £250-£400.
RACAL 1792 COMMUNICATION RX - £500 early - £1,000 - late model with band sharing and byte test.
RACAL 1772 COMMUNICATION RX - £400-£600.
PLESSEY PR2250 A-G-H COMMUNICATION RX - £500-£900.
TEK MODULE MAINFRAMES - TM501-502-503-504-506-5003-5006.
TEK PI 5010-M1 - Prog Multi Interface - £250. FG Prog 20MC/S Function Gen - £400 - S1 Prog Scanner - £150 - DM Prog DMM - £400.
TEK 7000 OSCILLOSCOPE MAINFRAMES - 7603-7623-7633-7834-7854-7904-7904A-7104 - £150-£1,000.
TEK 7000 PI's - 7A11-7A12-7A13-7A18-7A19-7A22-7A24-7A26-7A29-7A42-7B10-7B15-7B53A-7B80-7B85-7B92A-7D15-7D20.
TEK 7000 - 7S11-7S12-7S14-7M11-S1-S2-S3A-S4-S5-S6-S51-S52-S53-S54.
HP POWER SUPPLIES - 6321A-6624A-6624A-6632A-6652A.
Qtys available. Also 6000 types £POA.

RADIO COMMUNICATION TEST SETS

BULK PURCHASE ONLY FROM JOHNS RADIO
HP 8920A RF Communication Test Sets - Opts available 001-3-4-5-11-13-14-H13-K13. £1,500-£1,750.
HP8920A with opt 002 Spectrum anz plus tracking generator plus opts 001-3-4-5-11-12-014 available in part includes syn sig generator - digital oscilloscope distortion meter - mod meter - RF power meter etc. £2,500

SPECIAL OFFERS

MOTOROLA R2600A plus RLN4260A RF Test Set - £1,500.
MARCONI 2955 RF Test Sets-1000MC/S - £1,000 each.
MARCONI 2958 RF Test Sets-1000MC/S - £1,000 each.
MARCONI 2960 RF Test Sets-1000MC/S - £1,250 each.
MARCONI 2955A RF Test Sets-1000MC/S - £1,500 each.
MARCONI 2960A RF Test Sets-1000MC/S - £1,500 each.
ANRITSU MS555A2 Radio Comm Anz-1000M/Cs - £750 each.
MARCONI 2019A SYNTHESIZED SIGNAL GENERATORS - 80KC/S-1040MC/S - AM-FM - £400 inc. instruction book - tested.
MARCONI 2022E SYNTHESIZED SIGNAL GENERATOR - 10KC/S-1.01GHZ AM-FM - £500 inc. instruction book - tested.
R&S APN 62 LF Sig Gen 0.1Hz - 260KHz c/w book - £250.

WE KEEP IN STOCK HP and other makes of RF Frequency doublers which when fitted to the RF output socket of a S/Generator doubles the output frequency EG.50-1300MC/S to 50-2600MC/S price from £250 - £450 each.

SPECTRUM ANALYZERS

HP 3580A 5HZ-50KHZ - £750.
HP 3582A Dual 0.2HZ-25.5KHZ - £1,500.
HP 3585A 20HZ-40MC/S - £3,500.
HP 3588A 10HZ-150MC/S - £7,500.
HP 8568A 100HZ-1.5GHZ - £3,500.
HP 8568B 100HZ-1.5GHZ - £4,500.
HP 8590B 9KC/S-1.8GHZ - £4,500.
HP 8569B 10MC/S (0.01-22GHZ) - £3,500.
HP 3581A Signal Analyzer 15HZ-50KHZ - £400.

TEK491 10MC/S-12.4GHZ + 12.4-40GHZ - £500.
TEK492 50KHZ-21GHZ OPT 2 - £2,500.
TEK492P 50KHZ-21GHZ OPT 1-2-3 - £3,500.
TEK492AP 50KHZ-21GHZ OPT 1-2-3 - £4,000.
TEK492BP 50KHZ-21GHZ - £5,000-£6,000.
TEK495 100KHZ-1.8GHZ - £2,000.
HP 8557A 0.01MC/S-350MC/S - £500 + MF180T or 180C - £150 - 182T - £500.
HP 8558B 0.01-1500MC/S - £800 - MF180T or 180C - £150 - 182T - £500.
HP 8559A 0.01-21GHZ - £1,000 - MF180T or 180C - £150 - 182T - £500.
HP 8901A AM FM Modulation ANZ Meter - £800.
HP 8901B AM FM Modulation ANZ Meter - £1,750.
HP 8903A Audio Analyzer - £1,000.
HP 8903B Audio Analyzer - £1,500.
MARCONI 2370 SPECTRUM ANALYZERS - HIGH QUALITY - DIGITAL STORAGE - 30HZ-110MC/S Large qty to clear as received from Gov - all sold as is from pile complete or add £100 for basic testing and adjustment - callers preferred - pick your own from over sixty units - discount on qtys of five.
A EARLY MODEL GREY - horizontal alloy cooling fins - £200.
B LATE MODEL GREY - vertical alloy cooling fins - £300.
C LATE MODEL BROWN - as above (few only) - £500.

OSCILLOSCOPES

TEK 465-465B 100MC/S + 2 probes - £250-£300.
TEK 466 100MC/S storage + 2 probes - £200.
TEK 475-475A 200MC/S-250MC/S + 2 probes - £300-£350.
TEK 2213-2213A-2215-2215A-2224-2225-2235-2236-2245-60-100MC/S - £250-£400.
TEK 2445 4ch 150MC/S + 2 probes - £450.
TEK 2445A 4ch 150MC/S + 2 probes - £600.
TEK 2445B 4ch 150MC/S + 2 probes - £750.
TEK 468 D.S.O. 100MC/S + 2 probes - £500.
TEK 485 350MC/S + 2 probes - £550.
TEK 2465 4ch-300MC/S - £1,100.
TEK 2465A 4ch-350MC/S - £1,250.
TEK 2465ACT 4ch-350MC/S - £1,350.
TEK D.S.O. 2230 - 100MC/S + 2 probes - £1,000.
TEK D.S.O. 2430 - 150MC/S + 2 probes - £1,250.
TEK D.S.O. 2430A - 150MC/S + 2 probes - £1,750.
TEK D.S.O. 2440 - 300MC/S + 2 probes - £2,000.
TEK TAS 475-485 - 100MC/S-20MC/S-4 ch + 2 probes - £900-£1.1K.
HP 1740A - 100MC/S + 2 probes - £250.
HP 1741A - 100MC/S storage + 2 probes - £200.
HP 1720A - 1722A - 1725A - 275MC/S + 2 probes - £300-£400.
HP1744A - 100MC/S storage - large screen - £250.
HP1745A - 1746A - 100MC/S - large screen - £350.
HP54100A - 1GHz digitizing - £500.
HP54200A - 50MC/S digitizing - £500.
HP54501A - 100MC/S digitizing - £600.
HP54100D - 1GHZ digitizing - £1,000.

MICROWAVE COUNTERS - ALL LED READOUT

EIP 351D Autohet 20Hz-18GHz - £750.
EIP 371 Micro Source Locking - 20Hz-18GHz - £850.
EIP 451 Microwave Pulse Counter - 300MC/S-18GHz - £700.
EIP 545 Microwave Frequency Counter - 10Hz-18GHz - £1K.
EIP 548A Microwave Frequency Counter - 10HZ-26.5GHz - £1.5k.
EIP 575 Microwave Source Locking - 10Hz-18GHz - £1.2K.
EIP 588 Microwave Pulse Counter - 300MC/S-26.5GHz - £1.4K.
SD 6054B Micro Counter 20HZ-24GHZ - SMA Socket - £800.
SD 6054B Micro Counter 20HZ-18GHZ - N Socket - £700.
SD 6054D Micro Counter 800MC/S-18GHz - £600.
SD 6246A Micro Counter 20Hz-26GHz - £1.2K.
SD 6244A Micro Counter 20Hz-4.5GHz - £400.
HP5352B Micro Counter OPT 010-005-46GHz - new in box - £5k.
HP5340A Micro Counter 10HZ-18GHz - Nixey - £500.
HP5342A Micro Counter 10HZ-18-24GHz - £800-£1K - OPTS 001-002-003-005-011 available.
HP5342A + 5344S Source Synchronizer - £1.5K.
HP5345A 500MC/S 11 Digit LED Readout - £400.
HP5345A + 5354A Plugin - 4GHz - £700.
HP5345A + 5355A Plugin with 5356A 18GHz Head - £1K.
HP5385A 1GHz 5386A-5386A 3GHz Counter - £1K-£2K.
Racal/Dana Counter 1991-160MC/S - £200.
Racal/Dana Counter 1992-1.3GHz - £600.
Racal/Dana Counter 9921-3GHz - £350.

SIGNAL GENERATORS

HP8640A - AM-FM 0.5-512-1024MC/S - £200-£400.
HP8640B - Phase locked - AM-FM-0.5-512-1024MC/S - £500-£1.2K. Opts 1-2-3 available.
HP8654A - B AM-FM 10MC/S-520MC/S - £300.
HP8656A SYN AM-FM 0.1-990MC/S - £900.
HP8656B SYN AM-FM 0.1-990MC/S - £1.5K.
HP8657A SYN AM-FM 0.1-1040MC/S - £2K.
HP8657B SYN AM-FM 0.1-2060MC/S - £3K.
HP8660C SYN AM-FM-PM-0.01-1300MC/S-2600MC/S - £2K.
HP8660D SYN AM-FM-PM-0.01-1300MC/S-2600MC/S - £3K.
HP8673D SYN AM-FM-PM-0.01-26.5 GHz - £12K.
HP3312A Function Generator AM-FM 13MC/S-Dual - £300.
HP3314A Function Generator AM-FM-VCO-20MC/S - £600.
HP3325A SYN Function Generator 21MC/S - £800.
HP3325B SYN Function Generator 21MC/S - £2K.
HP8673-B SYN AM-FM-PH 2-26.5 GHz - £6.5K.
HP3326A SYN 2CH Function Generator 13MC/S-IEEE - £1.4K.
HP3336A-B-C SYN Func/Level Gen 21MC/S - £400-£300-£500.
Racal/Dana 9081 SYN S/G AM-FM PH-5-520MC/S - £300.
Racal/Dana 9082 SYN S/G AM-FM-PH-1.5-520MC/S - £400.
Racal/Dana 9084 SYN S/G AM-FM-PH-.001-104MC/S - £300.
Racal/Dana 9087 SYN S/G AM-FM-PH-.001-1300MC/S - £1K.
Marconi TF2008 AM-FM-Sweep 10KC/S-510MC/S - £200 Fully Tested to £300, as new + book + probe kit in wooden box.
Marconi TF2015 AM-FM-10-520MC/S - £100.
Marconi TF2016A AM-FM 10KC/S-120MC/S - £100.
Marconi TF2171/3 Digital Synchronizer for 2015/2016A - £50.
Marconi TF2018A AM-FM SYN 80KC/S-520MC/S - £500.
Marconi TF2019A AM-FM SYN 80KC/S-1040MC/S - £650-£1K.
Marconi TF2022E AM-FM SYN 10KC/S-1.01GHZ - £1K-£1.2K.
R & S SMPD AM-FM-PH 5KHz-2720MC/S - £3K.
Anritsu MG3601A SYN AM-FM 0.1-1040MC/S - £1.2K.

ITEMS BOUGHT FROM HM GOVERNMENT BEING SURPLUS. PRICE IS EX WORKS. SAE FOR ENQUIRIES. PHONE FOR APPOINTMENT OR FOR DEMONSTRATION OF ANY ITEMS, AVAILABILITY OR PRICE CHANGE. VAT AND CARRIAGE EXTRA. ITEMS MARKED TESTED HAVE 30 DAY WARRANTY. WANTED: TEST EQUIPMENT-VALVES-PLUGS AND SOCKETS-SYNCROS-TRANSMITTING AND RECEIVING EQUIPMENT ETC.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel: (01274) 684007. Fax: 651160

CIRCLE NO. 108 ON REPLY CARD

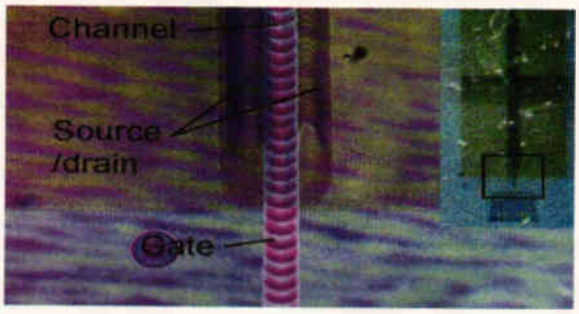
Flexible polymer substrates carry circuits

At IDEM, the International Electron Devices Meeting, in December, a team from Pennsylvania State University will describe organic circuits made on flexible polymer substrates.Penn State's active material is pentacene, a material also used by Bell Labs to create organic devices.

Along with nickel for gate electrodes and palladium for the source and drain, the pentacene is deposited on 75μm thick polyethylene naphthalate.

The maximum temperature used during device processing is 110°C. Manufacturing at lower temperatures on plastic material could reduce the cost of making devices.

Flexible friend... US researchers have fabricated pentacene-based transistors on a flexible polymer substrate. Circuits include inverters, oscillators and differential amplifiers.



Print power... The picture shows an ink-jet printed polymer TFT. The channel length is 5μm giving on-off ratios above 105. Electron mobilities are around 0.02cm2/Vs, adequate for many applications. The inset (top right) shows the printed source, drain and gate electrode.

Multiple circuits have been fabricated including inverters, ring oscillators, frequency dividers, differential amplifiers and various test structures.

A ring oscillator has a propagation delay of less than 40μs per stage.

Electron mobility is said to be 1cm2/Vs, while the transistor's on-off ratio is greater than 107.

These specs are equal to that of organic devices on rigid substrates, the researchers claim.

Meanwhile Cambridge is the source of two papers in the organic electronics and displays session at IEDM.

While ink-jet printing has been applied to polymer displays, Cambridge University has used the technique to print transistors.

One of the major achievements is accurately aligning the gate with the drain and source after the gate insulation has been laid down.

Using a piezoelectric ink-jet print head from Seiko Epson, the team managed to print a channel 5μm in length (the distance between the drain and source). Reducing the amount of photolithography will significantly cut the cost of manufacturing devices.

Finally, Cambridge Display Technology (CDT) will give an overview of the state of the art in polymer light-emitting diodes and a full colour active matric display will be shown.

3G phones need 100 000Mips

Processors addressing the 3rd generation (3G) mobile phone market need to be capable of 100 000Mips performance, according to Colin Macnab, CEO of Silicon Valley company Morphics. This performance figure compares with current GSM-class mobile phones which need only 100Mips.

According to Macnab, Morphics' own reconfigurable microprocessor technology can deliver 100 000Mips at a Mops per milliwatt ratio.

The Morphics processor achieves over 100Mops per mW, said Macnab, compared to the 6Mops/mW ratio of competitors. "FPGAs are five times worse in terms of energy efficiency," claimed Ravi Subraiman, v-p of systems engineering at Morphics.

Morphics says that its first product - a reconfigurable processor in the Tops (Terabit operations per second) performance bracket will be available in the first quarter of 2001. It will be a signal processor for 3G basestations. The company's second product – a signal processor IP core for 3G handsets – is scheduled for Q4 2001.

Macnab, an ex-Plessey Semiconductors engineer who has also worked at Linear Technology and Analog Devices, is currently looking around for licensees of the technology.

Macnab believes that Morphics has "a strong and defensible patent position" on the technology with 67 patent applications filed and two granted. **David Manners**

Fuel cells promising for mobile phones

Motorola Labs has taken another step towards a working fuel cell for mobile phones with the demonstration of a prototype micro fuel pump.

The pump uses multi-layer ceramic technology for processing and delivering fuel and air to the fuel cell membrane-electrode assembly (MEA). This fuel delivery system can, said Motorola, be built into a miniature fuel cell.

Direct methanol fuel cells are proposed as alternatives to rechargeable batteries in mobile phones with the user inserting a small fuel cartridge into the phone instead of recharging it.

"Eventually, these fuel cells could enable what people just dream of today – a lightweight energy source that would safely power a cellular phone for a month,"said Jerry Hallmark, manager of Motorola Labs' Energy Technology Group.

Front-end design tools run under Linux

Synopsys has rolled out a complete set of its front-end design tools running on the Linux operating system.

Products include the firm's flagship synthesis tools such as Design Compiler, along with static verification, test pattern generation and tools for FPGA design.

The move will push other EDA firms to port products, the firm says. "You can expect a flood of Linux announcements after this," said Karen Bartleson, director of interoperability at Synopsys.

"People like the price/performance benefits along with lower cost hardware. Linux is a very stable OS and this is important to EDA."

For example, many tools can run overnight in large chip designs, requiring computers that do not crash.

Missing from the Linux line-up are the firm's physical synthesis and layout tools, and Epic analysis tools. ■

TiePieScope HS801 PORTABLE MOST

ABRITARY WAVEFORM GENERATOR-
STORAGE OSCILLOSCOPE-
SPECTRUM ANALYZER-
MULTIMETER-
TRANSIENT RECORDER-

Reliability

- The HS801: the first 100 Mega samples per second measuring instrument that consists of a MOST (Multimeter, Oscilloscope, Spectrum analyzer and Transient recorder) and an AWG (abritary waveform generator). This new MOST portable and compact measuring instrument can solve almost every measurement problem. With the integrated AWG you can generate every signal you want.

- The versatile software has a user-defined toolbar with which over 50 instrument settings quick and easy can be accessed. An intelligent auto setup allows the inexperienced user to perform measurements immediately. Through the use of a setting file, the user has the possibility to save an instrument setup and recall it at a later moment. The setup time of the instrument is hereby reduced to a minimum.

- When a quick indication of the input signal is required, a simple click on the auto setup button will immediately give a good overview of the signal. The auto setup function ensures a proper setup of the time base, the trigger levels and the input sensitivities.

- The sophisticated cursor read outs have 21 possible read outs. Besides the usual read outs, like voltage and time, also quantities like rise time and frequency are displayed.

- Measured signals and instrument settings can be saved on disk.This enables the creation of a library of measured signals. Text balloons can be added to a signal, for special comments. The (colour) print outs can be supplied with three common text lines (e.g. company info) en three lines with measurement specific information.

- The HS801 has an 8 bit resolution and a maximum sampling speed of 100 MHz. The input range is 0.1 volt full scale to 80 volt full scale. The record length is 32K/64K samples. The AWG has a 10 bit resolution and a sample speed of 25 MHz.The HS801 is connected to the parallel printer port of a computer.

- The minimum system requirement is a PC with a 486 processor and 8 Mbyte RAM available. The software runs in Windows 3.xx / 95 / 98 or Windows NT and DOS 3.3 or higher.

- TiePie engineering (UK), 28 Stephenson Road, Industrial Estate, St. Ives, Cambridgeshire, PE17 4WJ, UK
Tel: 01480-460028; Fax: 01480-460340

TiePie engineering (NL),
Koperslagersstraat 37, 8601 WL SNEEK
The Netherlands
Tel: +31 515 415 416; Fax +31 515 418 819

Web: http://www.tiepie.nl

Remote control the easy way

If you want to add remote control to your next design, there's no need to start from the ground up. Les Johnson shows how easy it is to produce your own infrared decoder that responds to a wide range of low-cost commercial remote-control hand-sets. And if you thought that you would never get to grips with programming a microcontroller, there may be something here for you too...

Infrared remote-control decoding is considered something of a black art. However, this article will show you that it is quite straightforward in principle, and how easy it is to implement it on a PIC microcontroller.

Infrared remote control has been around for so long now that we tend to take it for granted. Yet, it is a marvel of modern technology that allows a whole variety of devices to be activated with the touch of a button.

Remote control handsets are produced in such abundance now that they can be bought for a few pounds, which makes them viable items for experimentation.

There are dedicated chips available that will decode the signals from a particular handset. However, with the flexibility and cost effectiveness of the PIC range of microcontrollers, you can develop a decoding subroutine for inserting into your own programs, or for use as a stand-alone infrared to RS232 converter.

Manufacturers' infrared protocols

Regrettably, remotes do not come in a single flavour. Each manufacturer uses a different set of protocols. The three main ones are RC80, which is used by Panasonic, RC5, which was designed by Philips and has become one of the more popular types, and then there's the Sony protocol.

Called SIRC, Sony's protocol is hugely popular. Conveniently, it is also one of the easiest to decode. As a result, I will focus on this alternative and endeavour to illustrate how to decode the signals from a Sony remote control handset using the ever-popular PIC16F84 microcontroller.

Infrared-to-TTL converter

In a bid to eliminate ambient light sources – both natural and man made – from interfering with the data stream transmitted by the handset, modulated light is used. This modulation is centred around different frequencies depending on the manufacturer. It varies from 32kHz to 40kHz. In the case of Sony handsets, the modulation is centred at 40kHz.

What you need first is a device that can receive the modulated infrared light and convert it into a TTL signal that the PIC can handle. There's a number of these devices available, each having a specific centre frequency that they're more sensitive too.

For this explanation, I chose the IS1U60 from Sharp. It has a centre frequency of 38kHz, which is close enough to 40kHz so as not to matter.

Figure 1, shows the internal block diagram of one of these devices. Although the receiver/demodulator looks simple, it is a lot more than just a re-packaged infrared photodiode. It filters and amplifies and it demodulates the infrared signal. Then it provides a nice clean TTL output by means of a final comparator stage.

The demodulator chip also has built-in automatic gain control, or AGC, which helps stop overloading; if the handset is held too close. Using one of these devices is a great deal cheaper – and easier – than building your own discrete version.

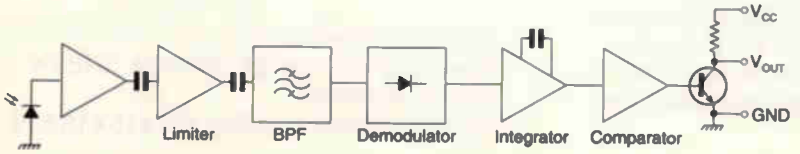


Fig. 1. Before the modulated infrared signal from the remote-control handset can be decoded, it first needs to be demodulated. One way of doing this is using an IS1U60 decoder chip from Sharp. Although this chip is designed for use with a 38kHz carrier, it works fine with the 40kHz carrier from Sony-type remote-control hand-sets.

Table 1. Sony's SIRC protocol defines the type of equipment in the device code sent from the handset.

Command	Device
1	Television receiver
2	VCR 1
3	VCR 2
4	Laser-disc player
5	Surround sound unit
6	Cassette deck/tuner
7	CD player
8	Equaliser

Table 2. Button codes for a TV set are defined as follows in Sony's SIRC protocol.

Command	Function	Command	Function
0-9	Numerals 0-9	24	Contrast +
16	Channel +	25	Contrast –
17	Channel –	26	Colour +
18	Volume +	27	Colour –
19	Volume –	30	Brightness +
20	Mute	31	Brightness –
21	Power	38	Balance left
22	Reset	39	Balance right
23	Audio mode	47	Power off

Most infrared sensors have an active-low output. This means that the decoder – in this case the PIC controller – is presented with a logic 0 when an infrared signal is detected. With no signal present, a maximum current of 4.8mA is consumed, 2.8mA being typical. In addition, the recommended voltage is 4.7V to 5.3V.

Sony's infrared control protocol

SIRC – an acronym for 'serial infra-red control' – uses a form of pulse-width modulation (PWM) to build up a 12-bit serial data stream, known as a packet. This is the most common protocol, but 15-bit and 20-bit versions are also available.

A pulse with a duration of 2.4ms is sent first as a header. This allows the internal AGC to adjust. It also allows the receiver to check if a valid packet is being received. A logic 1 bit is represented by a pulse duration of 1.2ms, while a logic 0 bit has a duration of 0.6ms. A delay of 0.6ms is inserted between every pulse.

The string of pulses builds up the 12-bit packet. This packet incorporates a 5-bit device code. This code has 2^5, i.e. 32, different permutations and is used to represents a TV, video, hi-fi, etc., **Table 1**. There's also a 7-bit button code, which represents the actual button pressed on the remote, **Table 2**.

Each packet is transmitted starting with the most-significant bit, or MSB. First the device code is sent, then the button code, **Fig. 2**.

After the packet is sent, a delay is implemented, which brings the whole transmitted signal to a length of 45ms. This is repeated for as long as a button is pressed.

Assembler versus BASIC

Knowing the principles behind infrared communications is one thing. Actually writing software based on the information is another.

For many, programming microcontrollers tends to conjure up the nightmare of writing programs in assembly language. But things have moved on. There are many high level language implementations for use with the PIC, such as C, Pascal, and BASIC. My personal preference is BASIC, or rather PicBASIC Pro.

In general, BASIC has received a lot of bad press since its conception in the middle part of the seventies. It is considered clumsy and inflexible, yet nothing could be further from the truth. Thanks to microEngineering lab's PicBASIC and PicBASIC Pro compilers, and Leading Edge Technologies' PicBASIC compiler range, this language has been brought into the 21st century.

Thanks also, in part, to BASIC's shallow learning curve, software designs that used to take weeks can now be realised in a just few hours.

So as to not seem too biased towards either language, I will present the software for this article in both assembler and PicBASIC Pro. This will allow you to make your own mind up.

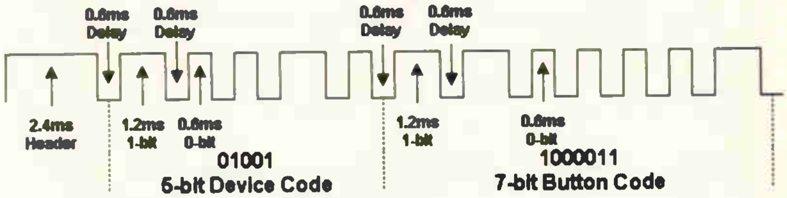


Fig. 2. When you press a button on the Sony hand set, a 12-bit data packet is transmitted, comprising 5 bits that represent the equipment type and a further 7 bits representing the command requested.

I will also endeavour to illustrate the pros and cons (no pun intended) of both languages by not using optimised assembler routines. This means that both the BASIC and the assembler versions will follow the same structuring, which will enable a fairer appraisal of them.

It is not my intention to teach you how to program a PIC micro, so, throughout this article, it is assumed that you already have some knowledge of either assembler or PicBASIC Pro. I will also assume that you have a means of programming the PIC16F84.

For more information concerning the PicBASIC range of compilers, as well as an assortment of programmers, visit Crownhill Associates' dedicated web site at www.picbasic.co.uk. For information concerning assembler programming, visit Microchip's web site at www.microchip.com.

Decoding circuitry

Figure 3 is intended to help explain the principles behind infrared decoding. This PIC-based circuit incorporates two light-emitting diodes, one green, the other, red. The software is arranged so that pressing the channel-up button on a TV remote lights the green LED while channel-down will illuminate the red one.

As well as illuminating the LEDs, two bytes are transmitted serially, via asynchronous RS232, from Port A,3 through a 1kΩ current limiting resistor, R_2. The serial data contains the device code as well as the button code and is transmitted at inverted 9600 baud (N-8-1).

You could attach this device to the PC's serial input for remotely influencing some software running on the PC for example. Or you could attach it to a BASIC Stamp for use in robotics applications.

The circuit layout is not too critical and could easily be built on stripboard. However, decoupling capacitor C_5 should be placed as close to the IR sensor as possible, and C_2 should also be located close to the PIC.

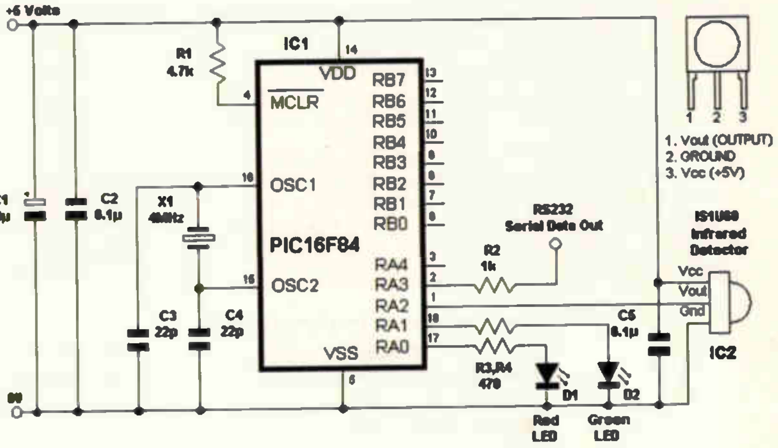


Fig. 3. With this demonstration circuit and the right software in the PIC, you can turn the LEDs on remotely using a Sony handset. With a little imagination and a few software alterations though, this becomes a versatile yet very low cost wireless remote control circuit.

Listing 1. Determining a port's direction in assembly language.

```
Bsf STATUS,5                ;Point to TRIS reg
Movlw b'00000100'           ;Set PortA,2 as IN
Movwf PortA                 ;Configure the Port
Bcf STATUS,5                ;Back to Page0
```

Listing 2. Assembler subroutine for pulse measurement.

```
; Measure duration of high-to-low pulse on PortA,2
; And leave the result in P_VAL.
; An 11µs resolution is achieved with a 4MHz crystal
Pulsin  Clrwdt              ;Walk the dog
        Clrf    Cntr        ;Clear variables used,
        Clrf    P_Val       ;prior to subroutine
Trans   Btfss   PortA,2     ;Wait for 1 to 0 transit
        Goto    Edge        ;Edge found!
        Incfsz  P_Val       ;Else inc. P-VAL until >255
        Goto    Trans
        Incfsz  Cntr        ;Loop until 255
        Goto    Trans
        Return
Edge    Clrf    P_Val       ;1 to 0 transit occurred
Ege_lp  Btfsc   PortA,2     ;Count how long it's logic 0
        Return
        Clrwdt              ;Walk the dog
        Nop                 ;Timing loop
        Nop
        Nop
        Nop
        Nop
        Incfsz  P_Val       ;Inc. P_VAL until >255
        Goto    Edge_LP
        Return
```

Listing 3. Assembler, 12-bit packet construction.

```
'Receive a signal from a Sony remote control,
'If no header then IR_DEV, IR_BUT will hold 255
IRIN    Clrwdt                  ;Walk the dog
        Call     Pulsin         ;Measure the header
;Verify good header, if not valid then exit
;** If PVAL <200 then return with IR_DEV=255 **
        Movlw    200
        Subwf    P_VAL,W
        Btfsc    STATUS,C
        Goto     Next1
        Movlw    255
        Movwf    IR_Dev
        Return
;** If PVAL > 250 then return with IR_DEV=255 **
Next1   Movlw    250
        Subwf    P_VAL,W
        Btfss    STATUS,C
        Goto     PK_Strt
        Movlw    255
        Movwf    IR_Dev
        Return
;Build up packet by pulling in all 12-bits
PK_Strt Movlw 12                ;Create a loop for 12-bits
        Movwf    Bitcnt
S_again Call     Pulsin         ;Get the bit duration
        Movlw    80             ;If >=80 then it's a 1
        Subwf    P_VAL,w
        Btfsc    STATUS,C
        Goto     One
        Bcf      Packet+1,4     ;Clear the bit
        Goto     Cont
One     Bsf      Packet+1,4     ;Set the bit
Cont    Rrf      Packet+1,F     ;Rotate bit into place
        Rrf      Packet,F
        Decfsz   Bitcnt         ;Are 12-bits done yet?
        Goto     S_again        ;No! then loop again
```

Getting down to the coding

The actual infrared decoding software is presented in the form of a subroutine, named IRIN, to make it easy to incorporate it into your own programs. The subroutine and subsequent main program loop may be split into several software tasks. These are outlined over the page.

Task 1. Configure Port A as both inputs and outputs.

Task 2. Devise a method of measuring the high to low pulse length received from the active low IR sensor.

Task 3. Implement task 2 to detect the header and bit pulses and then construct the 12-bit packet.

Task 4. Split the packet into two separate bytes containing the 7-bit button and 5-bit device codes.

Task 5. Devise a method of transmitting inverted serial RS232 data.

Task 6. Construct a main program loop that calls the decoder subroutine and illuminates the correct LED, as well as using task 5 for transmitting both, the device and button codes, serially.

Implementing Task 1

Our first coding task, that of configuring the port's direction, is the easiest. Assembler code for this is shown in **Listing 1**. This code configures bits 0, 1 and 3 of Port A as outputs, for attaching the LEDs and the serial output. Bit-2 is made an input for the attachment of the infrared sensor.

The same thing written in PicBASIC Pro is,

```
TrisA = %00000100
```

Note, that it is not necessary to do this in PicBASIC. The commands that deal with external influences automatically set the required pins as inputs or outputs.

Task 2

A means of measuring the pulse durations that signify a header, as well as the separate ones and zeros that go to make up the packet, is needed. An assembler version of a routine to do this is shown in **Listing 2**.

The high-to-low pulse duration is measured at bit 2 of Port A and the 8-bit value is returned in the variable P_VAL. Because we're using an 8-bit (0...255) variable, it's impossible to return a value of 2400 for a pulse length of 2400 microseconds. Therefore, the routine has a resolution of around 11µs when used in conjunction with a 4MHz crystal.

An 11µs resolution was chosen as opposed to 10µs, because not all remote handsets stick stringently to the recommended pulse widths. Therefore, a header pulse could be more than 2.55ms in length, which would push it beyond a byte's storage capacity, i.e. greater than 255.

Values returned in P_VAL for a given pulse length are,,

Header pulse	2400µs returns 220
One-bit pulse	1200µs returns 110
Zero-bit pulse	600µs returns 55

To do the same task in PicBASIC Pro, requires just one command,

```
Pulsin PortA.2 , 0 , (8 or 16-bit Variable)
```

When used in association with a 4MHz crystal, the compiler's PULSIN command has a resolution of 10µs. Also, if a 16-bit variable is used to hold the result then a duration of 0-65535µs may be measured, where as, if an 8-bit variable is used this is reduced to 0-255µs.

You can use this property to your advantage by detecting the 2400µs header pulse with a 16-bit variable, and the individual 600µs or 1200µs bit pulses with an 8-bit variable. This eliminates any problems arising from a header pulse that is longer than 2.55ms. The values returned from the PULSIN command are as follows,

Header pulse	2400µs returns 240
One-bit pulse	1200µs returns 120
Zero-bit pulse	600µs returns 60

The middle parameter of the PULSIN command, 0 or 1, determines whether a high-to-low or low-to-high pulse is to be measured. Where a zero is concerned, a high-to-low type is measured.

Task 3

Now we come to one of the two main body parts that build up the subroutine IRIN. In this routine, bit information received from the IR sensor is gathered, and the 12-bit packet is constructed from it.

Listing 3 is the assembler version of this. The first thing the routine does is to try and detect a 2.4ms header pulse using the PULSIN subroutine, Task 1.

The result, held in P_VAL, is examined to see whether it's between the values of 200 and 250. If it does not lie between these values, then the subroutine is abandoned with IR_DEV and IR_BUT holding a value of 255, which signifies an invalid header.

If a valid header *is* detected, then a loop of 12 is set up. Within this loop, the individual bits are measured using the subroutine, PULSIN. Depending on the result returned in P_VAL, the individual bits of the 16-bit variable PACKET are set or cleared. This is achieved by splitting the difference between a one-bit (110), and a zero-bit (55).

If the result is greater than or equal to 80 then it must be a one-bit that's been received. If it's less than 80 then it must be a zero-bit. The PicBASIC Pro version of the same routine is shown in **Listing 4**. This has exactly the same function as the assembler version, but because of the different values returned from the PULSIN command, the comparisons for a header and bit pulses are slightly different.

Resulting 12-bit packets for both types of routine are held in the variable PACKET ready for splitting into separate codes.

Task 4

For the resulting 12-bit packet to be of any practical use, it must be split into the 5-bit device code and the 7-bit button code. This is achieved by a series of rotations then masking.

The assembler version of this is shown in **Listing 5**. Within the variable PACKET, the button code is located, starting at bit-0. This is extracted by ANDing PACKET with 127, or 01111111_2 in binary, and the result is placed into IR_BUT.

To extract the device code, seven right rotations are performed, which effectively moves the button code out of the way and places the device code starting at bit-0 of PACKET. Again, this is extracted by ANDing, but this time with 31, or 00011111_2, and placed into IR_DEV.

The PicBASIC Pro's version of the same routine takes only two lines of code,

```
'Split the 7-bit Button code and 5-bit DEVICE code
IR_But=Packet & %01111111
'Mask the 7 BUTTON bits
IR_Dev=(Packet >>7) & %00011111
'Move down and mask, the 5 DEVICE bits
```

Task 5

Our finished decoder could simply bring the eight Port B pins high for a given button pressed on the handset. A more desirable result would be to transmit both the button and the device codes serially. Therefore, our fifth task is a subroutine that does just that.

Listing 6 shows the assembler version of an asynchronous RS232 transmitter operating at inverted 9600 baud from bit 3 of Port A. The byte to transmit is first loaded into the W register then a call is made to Sout.

As it stands, the bit rate is set at 9600. To change it, alter the value placed into DLCTR, the higher the value, the lower the baud rate. For instance, a value of 44 will lower it to 4800 baud, while 88 will produce 1200 baud.

To do the same task in PicBASIC Pro, again takes only one command,

```
Serout PortA.3 , N9600 , [ Variable ]
```

Continued on page 985...

Listing 4. PicBASIC Pro code for 12-bit Packet construction.

```
'Receive a signal from a Sony remote control,
'and return with the 7-bit BUTTON code in the variable
'IR_BUT and the 5-bit DEVICE code in the variable IR_DEV.
'If header no header then IR_DEV, IR_BUT will hold 255
IRIN: IR_Dev=255:IR_But=255         'Preset return variables
      Pulsin PortA.2,0,Header       'Measure header length.
      If Header < 200 then Return   'Verify a good header
      If Header > 270 then Return   'If not valid then exit
'Receive the 12 data bits and convert them into a packet
      For Bitcnt=0 to 11            'Create a loop of 12
      Pulsin PortA.2,0,P_Val        'Receive the IR bit pulse
      If P_Val >= 90 then           'If it's >=90 then we've
                                    'received a 1
      Packet.0[Bitcnt]=1            'So set appropriate bit
      Else                          'Else
      Packet.0[Bitcnt]=0            'Clear appropriate bit
      Endif
      Next                          'Close the loop
```

Listing 5. Device-code splitter in assembler.

```
; Split the 7-bit BUTTON code, and the 5-bit DEVICE
code
Movf    Packet,W; Mask the 7-bit BUTTON code
        Andlw    B'01111111'
        Movwf    IR_But
; ** Shift PACKET and PACKET+1, right, 7 times **
        Rrf      Packet+1,F
        Rrf      Packet,F
        Rrf      Packet+1,F
        Rrf      Packet,F
        Rrf      Packet+1,F
        Rrf      Packet,F
        Rrf      Packet+1,F
        Rrf      Packet,F
        Rrf      Packet+1,F
        Rrf      Packet,F
        Rrf      Packet+1,F
        Rrf      Packet,F
        Rrf      Packet+1,F
        Rrf      Packet,F
        Movf     Packet,W     ;Mask the 5-bit DEVICE code
        Andlw    B'00011111'
        Movwf    IR_Dev
        Return
```

Listing 6. Assembly language for the serial output subroutine.

```
;Transmit the byte held in W at inverted 9600 baud (8-N-1)
;From PortA,3
Sout    Movwf   Tr_Byte      ;Load TR_BYTE with W reg
        Movlw   08
        Movwf   Bit_Cntr     ;Create a loop of 8
        Bsf     PortA,3      ;Send the start bit
        Call    Bit_Dly      ;Delay one bit time
Xmtlp   Rrf     Tr_Byte      ;Rotate Right, moves data bits
                             ;into Carry, starting bit 0.
        Btfsc   Status,0     ;Is it a One-bit?
        Bcf     PortA,3      ;Yes, so send A One
        Btfss   Status,0     ;Is it a Zero-bit?
        Bsf     PortA,3      ;Yes, so send A Zero
        Call    Bit_Dly      ;Delay one bit time
        Decfsz  Bit_Cntr     ;Have we reached 8-bits yet?
        Goto    Xmtlp        ;No, so loop again
        Bcf     PortA,3      ;Yes, so send the stop bit
        Call    Bit_Dly      ;Delay one bit time
        Return
;** Delay 1-bit time subroutine**
Bit_Dly Movlw   22           ;Set Baud to 9600
        Movwf   Dlctr
Slp     Clrwdt               ;Walk the dog (1µs)
        Decfsz  Dlctr
        Goto Slp
        Return
```

Experimenting

with the PICBasic Pro compiler

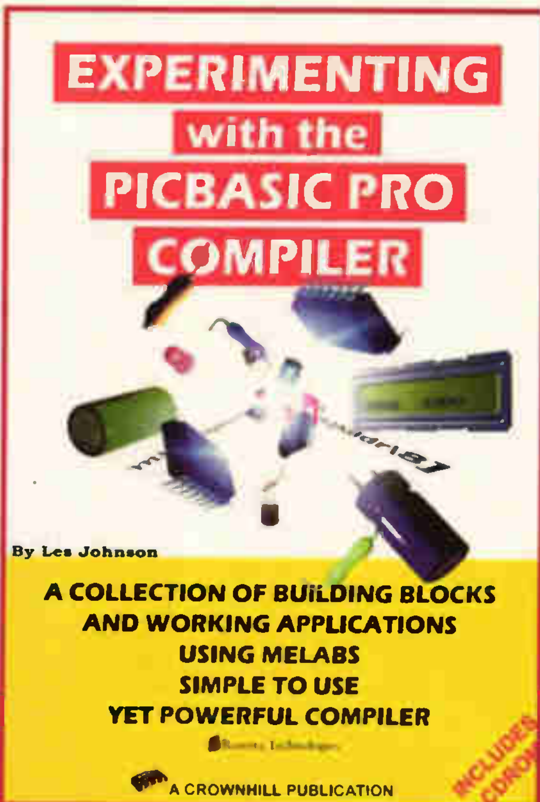
Pleased with the sample chapter? Then buy the full book with CDROM now for only £24.95 excluding shipping.

You no longer need to be a nerd to write your own professional microcontroller applications. PICBasic Pro is a viable alternative to assembly language regardless of whether your PIC-based application is part of high-end professional system or a kitchen table prototype.

The idea that Basic is a beginners language is a myth, as many PICBasic Pro developers will testify. See for yourself in Les Johnson's new book,'Experimenting with the PICBASIC Pro Compiler' – a free chapter from which you should have found on the cover of this issue*

The work comprises over 150 pages detailing,

- Display controller experiments
- Keypad interfacing
- Serial eeproms
- A-to-D & D-to-A conversion
- Remote control
- Temperature measurement
- Robotics
- Audio control devices
- Programming techniques



The full PICBASIC Pro instruction set and PDF format manual are available for download form www.picbasic.co.uk.
Order PICBasic Pro on line, and save money on bundled packages.

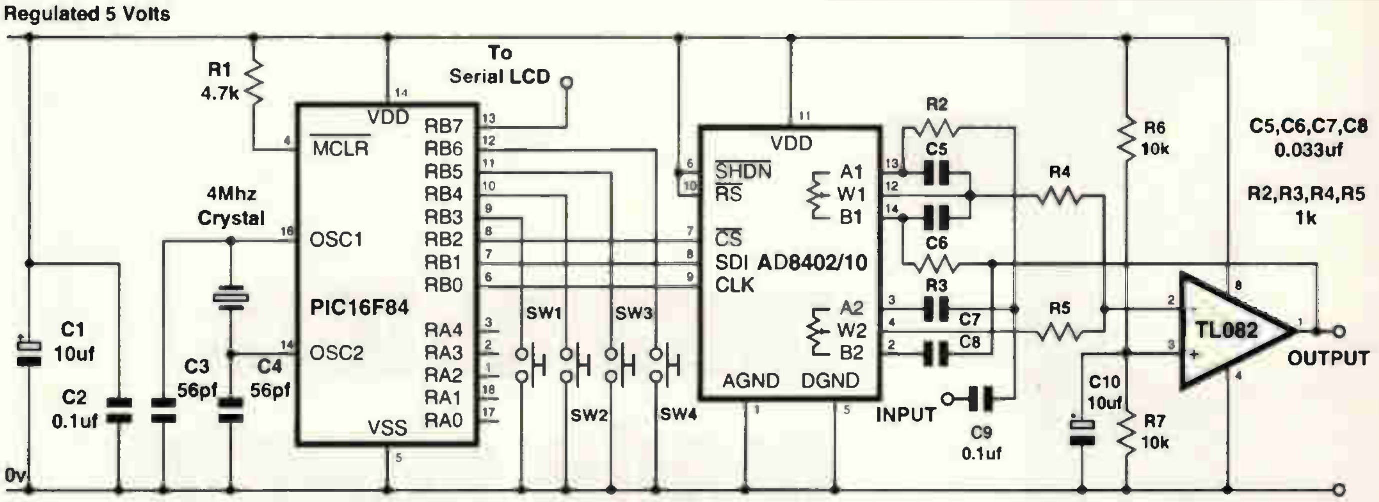
What is PicBasic?

The PicBasic Pro Compiler is the easiest way for you to program the fast and powerful Microchip Technology PICmicro microcontrollers. PicBasic Pro converts your BASIC programs into files that can be programmed directly into a PICmicro MCU.

The Compiler features: Basic Stamp II commands, direct and library routine access to pins on PORTA, C, D, E, as well as PORTB, arrays, real IF...THEN...ELSE and interrupt processing in BASIC.

The PicBasic Pro Compiler gives you direct access to all of the PICmicro registers – I/O ports, a-to-d converters, hardware serial ports, etc.– easily and in Basic. It automatically takes care of the page boundaries and RAM banks. It even includes built-in commands to control intelligent LCD modules.

For more information, visit,
www.picbasic.co.uk
and,
www.crownhill.co.uk



Digitally-adjustable bass and treble control. Read all about it in the book. You'll find the source code for this and many other designs on the CDROM that comes with the book.

Instruction set compatibility

The PicBasic Pro Compiler instruction set is upward compatible with the BASIC Stamp II and Pro uses BS2 syntax. Programs can be compiled and programmed directly into a PICmicro, eliminating the need for a BASIC Stamp module.

These programs execute much faster and are generally smaller than their Stamp equivalents. They may also be protected so no one can copy your code.

The PicBasic Pro Compiler is a DOS command line application (it also works in Windows) and runs on PC compatibles. It can create programs for the PIC12C67x, PIC12CE67x, PIC14C000, PIC16C55x, 6xx, 7xx, 84, 92x, PIC16CE62x, PIC16F62x, 8x, 87x, PIC17Cxxx and PIC18Cxxx microcontrollers. It also works with most PICmicro programmers, including Crownhill's EPIC Plus Pocket PICmicro Programmer. A printed manual and sample programs are included to get you started.

Simulation options

The PicBasic Pro Compiler can also be used inside Microchip's MPLAB IDE. This allows programs to be edited and simulated within Windows. More information is on the MPLAB page.

Version 2.3 of the PicBasic Pro Compiler adds support for the 16-bit core PIC18Cxxx microcontrollers. If you are a current PicBasic Pro owner and would like the latest version, please see the upgrade page on the web site for upgrade information.

To order the book, send £24.95 plus £5.50 for shipping (overseas readers £8.50) to Crownhill Associates Limited, 32, Broad Street, Ely, Cambs, CB7 4AH. Tel: 01353 666709, fax: 01353 666710, e-mail sales@crownhill.co.uk

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S-parameters made simple

Les Green believes that RF designers who are not familiar with S-parameters are missing out on a wealth of information. Here he sets out to explain them in relatively simple terms.

Leslie Green CEng MIEE

S-parameters are not particularly complicated to use or to understand, but like any mathematical or engineering subject, if you don't have somebody to ask about them they can be difficult to pick up from books and articles alone.

So why do you need to know about S-parameters? Well, if you have never been specifically taught about S-parameters, then you are missing out on lots of articles related to RF engineering. Given that S-parameters originated in 1920, there is a lot of technical information in existence that makes use of them, and this is currently inaccessible to you.

Part of the problem with learning from application notes and articles is that they often have mistakes in them. If you don't understand S-parameters, it is impossible to differentiate between a good, accurate article and an article containing basic errors.

I would estimate that it takes at least ten times longer to understand a small subject area when some of the sources of your information are wrong. One purpose of this article then, is to help you to spot errors in papers, books and application notes within this subject area.

At the same time, the article will give you the basic knowledge that you need. Armed with this knowledge, you may be able to go back to these other sources with renewed zest.

What is an S-parameter?

S-parameter is a contraction of 'scattering parameter'. In English the word 'scatter' has as one of its definitions, 'separate and drive off in different directions'. The word 'parameter' means a constant for a particular system, which will vary from one system to another.

For example, a rubber ball will have a certain 'bounciness'. This bounce-factor would be a parameter for the ball and you might want to select one with a very high bounce-factor.

Thus, so far we have that S-parameters are constants for a particular component, that relate to its tendency to pass, reflect or amplify a signal. Clearly, the subject we are talking about is closely related to transmission lines, amplifiers, signal generators and attenuators.

S-parameters only apply to the sinusoidal response at a particular frequency, or over a range of frequencies. This is known as the frequency domain, where domain means a region of thought or activity.

In general, it is difficult to calculate what the exact response of a system will be in the time domain (pulse response) when you only know the frequency domain response.

I'll start with a very simple system, in very simple terms. A load has a complex impedance Z_L, which in general changes with frequency. You could measure this impedance with some sort of meter and plot a graph of how the impedance changes with frequency. Other people could now use this data to see how the load would perform in their system.

If the system that the load is to be connected to is a transmission line then things change. You would now have to characterise the load according to frequency *and* the length of the transmission line. This is not very convenient.

It is preferable to characterise the load in terms of its relationship to the transmission line. In this way only one set of measurements is necessary.

Such a system has been worked out and consists of quoting the reflection coefficient of a load. If the load is measured at the end of a length of lossless transmission line then the magnitude of the measured reflection coefficient will be the same, regardless of the length of the line.

A transmission line is considered to have a forward travelling wave going down the line towards the load. At the load some fraction of this *incident* signal is reflected, according to the reflection coefficient of the load. This reflected signal then heads back up the line towards the sending end, **Fig. 1**.

As you move along the transmission line, away from the load, the incident and reflected signals change in phase by opposite amounts. This is because the signals are travelling in opposite directions. On the phasor diagram, therefore, the incident and reflected voltage phasors rotate in *opposite* directions.

It is easy to see then, that at some points on a long line the two phasors will be pointing in the same direction. At some other specific points the phasors will be pointing in opposite directions.

The reflection coefficient is represented by a capital Greek letter gamma, Γ, where it is understood that Γ is a complex number. If you want just the magnitude of the reflection coefficient then you either write |Γ|, or use the symbol ρ, which is the Greek letter rho.

If you have an incident voltage V_i, and a reflection coefficient of Γ, then the reflected voltage is simply given by

$$V_r = V_i \times \Gamma$$

This is the definition of the reflection coefficient in fact. When the incident and reflected phasors point in the same direction, you get a maximum signal whose amplitude is,

$$V_i \times (1 + |\Gamma|)$$

When the phasors point in opposite direction a minimum signal occurs whose amplitude is,

$$V_i \times (1 - |\Gamma|)$$

What has been described here is a standing-wave pattern on the transmission line. If you were to get a high-impedance RF voltmeter and put your probes onto the transmission line at various points as you moved away from the load, you would find points where the RMS signal was large and others where it was small. The signal would vary continuously between these maximum and minimum signal points.

The standing wave of voltage would have a ratio of maximum to minimum values of:

$$\frac{V_i(1+|\Gamma|)}{V_i(1-|\Gamma|)} = \frac{(1+|\Gamma|)}{(1-|\Gamma|)}$$

This ratio is simply known as the voltage standing wave ratio, VSWR.

You can therefore specify the load in terms of the VSWR it will give on a transmission line, rather than its reflection coefficient. However, you will note that giving the reflection coefficient magnitude and phase imparts more detail about the load than merely giving the VSWR. The VSWR does not contain the phase information.

Having worked through this introductory material, you should now be now in a position to meet the first S-parameter. For a simple load, the reflection coefficient is exactly equal to the parameter S_{11}. In fact whenever you see an S-parameter where the two subscripts are the same, you know that you are looking at a reflection coefficient when all the other ports are perfectly terminated in the characteristic impedance of the system, Z_0.

I have written that very carefully and in full. People often use the term 'matched' very loosely and this causes confusion. If you want the maximum power transfer you use a conjugate match. If you want minimum reflected signal you use a Z_0 match.

There are also other conditions of network terminations that can be referred to as matching which are 'obvious' from the context, provided you are already an expert in the field of course! In this article I will explicitly refer to Z_0-matching and conjugate matching as appropriate.

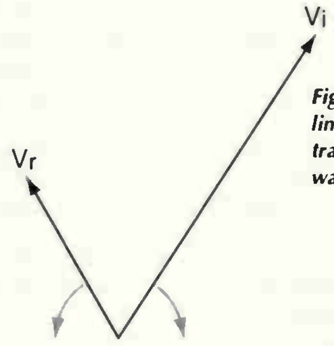


Fig. 1. A transmission line has a forward-travelling incident wave and a reflection.

Complex numbers made simple – part 1

In electrical engineering, we are used to dealing with sinusoidal AC signals. Everyone in the business knows about resistance and reactance. This is the most elementary presentation of impedance; there is a resistive part that dissipates power and there is a reactive part that doesn't.

The reactive part comes in two types; there is inductive reactance, which increases with frequency, and there is capacitive reactance, which decreases with frequency.

In mathematical terms,

$$X_L = 2\pi f \times L$$

and,

$$X_C = \frac{1}{2\pi f \times C}$$

In a series combination of a resistor and an inductor, you can't just add the resistance and the reactance together because the current in the inductor is 90° out of phase with the voltage across it. The total impedance is evaluated by the use of a phasor diagram.

In mathematical terms, you can use a simple notation and say that for a series *LR* circuit,

$$Z = R + j \times X_L$$

Here '*j*' represents the 90° phase shift. For inductance, +*j* is used. For capacitance, –*j* is used because the phase shift in a capacitor is opposite to that in an inductor.

Since *j* represents 90° phase shift, *j*×*j* is 180° phase shift, which means it is now heading back in the opposite direction. Thus *j*×*j* is equal to –1 and you have the mathematical idea that,

$$j = \sqrt{-1}$$

At school, you may have used *i* instead of *j*; electrical engineers prefer *j*, as *i* is reserved for current.

Remember: this mathematical method *only* applies to sinusoidal signals.

Two-port nets

The two-port network is the most common type of device you will encounter. It simply means that there are two entry points to the device. A load would be an example of a one-port device and an in-line attenuator would be an example of a two-port device.

Figure 2 is a simple diagram of this two-port network. It has two sets of terminals, labelled port 1 and port 2. You might expect them to be labelled as 'input' and 'output' and there are two specific reasons why this is not done.

In the first place, a device such as an attenuator or a filter may have no preferred direction; in this case the use of the terms input and output would be arbitrary.

In the second place, there may be multiple i/o ports and the signals will in general be passing in both directions simultaneously. Huh? If you remember the transmission line case, there were forward and reverse travelling signals in the same conductor at the same time.

Fig. 2. The most common type of network has two ports and neither is strictly an input or an output.

In general you want to look at the system in terms of simultaneous forward and reverse travelling signals. The maths has to sort out which is the dominant direction at any time.

Hopefully the haze is beginning to clear and some of the things you have read about are starting to make sense. If you see S_{33} you know that you are dealing with a network that has at least three ports. If all the other ports are Z_0-matched then the reflection coefficient seen at port 3 will be simply S_{33}. That isn't very hard is it?

Two ports, four S-parameters

There are four S-parameters for a two-port network. There are the two input reflection coefficient terms and there are transfer terms in each direction. When an incident voltage arrives at a port, some is reflected and some continues.

In a lossless device such as a connector, the amount that is transmitted is necessarily less than that which arrived, since some power has been reflected. In an active network such as an amplifier, it is critically important that there is more gain in one direction than in the other. Both of these situations are handled by the mathematics embedded in the S-parameter equations.

In these equations, incident voltages are heading into the network. In other words, both ports are considered as inputs. The reflected voltages are heading away from the ports,

$$V_{ref1} = S_{11}V_{inc1} + S_{12}V_{inc2}$$
$$V_{ref2} = S_{21}V_{inc1} + S_{22}V_{inc2}$$

Interpreting these equations, the signal coming out of port 1 is the (complex) sum of the reflected part of the signal going in at port 1 and the signal transmitted from port 2. Thus S_{12} is the transmission factor from port 2 to port 1.

The subscript notation looks backwards in this case, but is necessary in order to make the parameters fit conveniently into a matrix.

Note that S-parameters are complex numbers in general. But they may reduce to ordinary numbers at low frequencies, due to the phase shift becoming essentially zero.

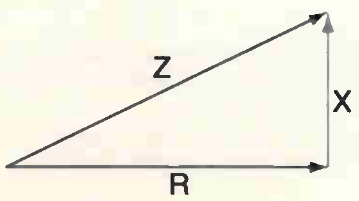
It is instructive to start off with a simple signal flow graph showing a generator connected to a load. The result is an equation for the incident voltage on the load. Of course the

Complex numbers made simple – part 2

We have represented an impedance by the formula $Z=R+jX$ and in general, any series or parallel impedance can be represented by this form. Obviously the sign of the reactive part could also be negative, but the equation is still of the same form. The R is the resistive part of the impedance, which is also known as the in-phase part or the real part. The jX is the resistive part, which is also known as the quadrature part or the imaginary part.

A number that has both real and imaginary parts is known as a complex number. This doesn't mean it is complicated; it just has two parts. Throughout this article, complex is used to mean a number having both real and imaginary parts.

The magnitude, size or modulus of the impedance is easily seen from the phasor diagram,



and is represented mathematically by a pair of bars around the value.

$$|Z| = \sqrt{R_2 + X_2} \quad \text{(good old Pythagoras)}$$

The angle between the Z direction and the R direction is the angle or argument of Z, abbreviated to arg(Z) or written as $\angle Z$. If you remember your trigonometry, it should be clear that,

$$\tan(\angle Z) = \frac{X}{R}$$

the tangent of the angle being 'opposite over adjacent' and that,

$$\angle Z = \tan^{-1}\left(\frac{X}{R}\right)$$

i.e. the angle Z is the angle whose tangent is X/R.

This is a tricky notation. It reads as 'tan to the –1' and means the inverse tangent, ie 'the angle whose tangent is.' This used to be known as arctangent and is still sometimes written as arctan or atan.

An impedance of $Z=R+jX$ has what is known as a conjugate impedance. This is marked by an asterisk, $Z^*=R-jX$. All we have done is reverse the phase of the reactive part. This is very important.

Maximum power transfer occurs when a load is equal to the complex conjugate of the source impedance.

You may have seen the statement that the load and source impedances have to be equal to each other for the maximum power transfer. That statement is only correct at DC, so the use of the term impedance rather than resistance is misleading. Conjugate matching for maximum power transfer is the general rule that applies at DC and RF.

Quick test 1

1) Represent a series impedance of an ideal 50Ω resistor and an ideal 33nH inductor at 100MHz as a complex impedance Z.
2) Evaluate $|Z|$, the modulus of the impedance of question 1.
3) Evaluate $\angle Z$, the argument of the impedance of question 1.
4) Evaluate Z^*, the complex conjugate of the impedance of question 1.

actual voltage on the load is the incident voltage plus the reflected voltage. Mathematically,

$$V_L = V_i \times (1 + \Gamma_L)$$

However, you can regard this term as a calibration factor for the load. Whenever the load gets a certain incident voltage, its response will be the same. What we are more concerned about is the mismatch error given by the term,

$$\frac{1}{1 - \Gamma_L \Gamma_G}$$

This will vary according to the generator reflection coeffi-

Simple transmission lines

The characteristic impedance of a transmission line is Z_0; for a lossless line it is a pure resistance. Throughout this article, the transmission line is considered to be lossless.

When you first apply a signal to a long piece of transmission line, regardless of the load at the end of that line, the line appears to be a resistance of value Z_0. This has been called the *surge impedance* of the line.

Once the applied signal reaches the load, a reflected signal will be generated if the load is anything other than a pure resistance of value Z_0. If there is no reflection then the line is perfectly Z_0-matched.

The incident voltage is defined as the signal that would be at the load, if the load were a resistor equal to Z_0. The actual voltage at the load is defined as the (complex) sum of the incident and reflected voltages. The reflected voltage is therefore the (complex) difference between the actual voltage on the load and the voltage that would be on a Z_0 load.

A load of Z_L in a Z_0 system driven by V_G gives a voltage of,

$$\frac{V_G \times Z_L}{Z_L + Z_0}$$

With a Z_0 load, it is simply $V_G \div 2$. The difference between these two is the reflected voltage,

$$V_G\left(\frac{Z_L}{Z_L + Z_0} - \frac{1}{2}\right) = V_G\left(\frac{2Z_L - Z_L - Z_0}{2(Z_L + Z_0)}\right) = V_G\left(\frac{Z_L - Z_0}{2(Z_L - Z_0)}\right)$$

The reflection coefficient is the reflected voltage divided by the incident voltage giving,

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

which can be re-arranged to give,

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

If the load is resistive and greater than Z_0,

$$VSWR = \frac{R_L}{Z_0}$$

If the load is resistive and less than Z_0,

$$VSWR = \frac{Z_0}{R_L}$$

Note that VSWR is always greater than or equal to 1.
Beware. Don't say that for $|Z_L| > Z_0$,

$$VSWR = \left|\frac{Z_L}{Z_0}\right|$$

It simply is not true. It is essential that Z_L is *resistive* for the simplified formula to be used and the act of writing $|Z_L|$ rather than R_L implies that the load can be a general impedance.

Quick test 2

1) What is the VSWR of an ideal 40Ω resistor in a 50Ω transmission system?
2) A load has a reflection coefficient of 0.345∠36° at 15.9MHz. What is the VSWR?
3) What is the magnitude of the reflection coefficient of an ideal 50Ω resistor in series with an ideal 100nH inductor? Assume that the frequency is 10MHz and that the transmission system is 50Ω.

Simple dimensional analysis

You may have been taught dimensional analysis at school. You take something like force and you analyse it in terms of the fundamental quantities 'mass', 'length' and 'time' using square brackets. Thus,

[force]=[mass]×[acceleration]=
$[M]\times[L]\times[T]^{-2}$

You are then told that in an equation, the dimensions of terms that are added or subtracted must always be the same.

In electrical engineering we actually need an electrical unit as well, and it is conventional to use current as the electrical dimension. However, taking ohms, volts, henrys, and so, on down to their fundamental units is a waste of time.

To simplify the rule, you can say that in any equation, when terms are added, subtracted or equalled the units must be the same.

To further clarify this, let me say that if you are adding something to a voltage term, that thing must be a voltage and not a current, a frequency, a power or anything other than a voltage. This provides a very rapid 'sanity check' on an equation, either being manipulated by you or being published in an article.

With a bit of practice you will spot common terms such as $C\times R$, which you know as a time constant, and therefore has the dimensions of time. If you had to reduce the capacitance and resistance individually to [M][L][T][I] form then you would get bored very quickly!

Quick test 3

Spot any *dimensional* errors in these equations, assuming the standard symbols for voltage, current, resistance, power, inductance, capacitance and impedance. In ordinary use, the terms would have subscripts or suffixes to show where they had come from. Here I have reduced the equations to a more basic form,

1) $V = IR + I^2R$
2) $CR = \frac{L}{4R}$
3) $P = IV + I^2R + \frac{V^2}{R}$
4) $Z = 3R + j2\pi fL - j2\pi fC$

cient and the load reflection coefficient. Note that the equations naturally produce results based on reflection coefficient rather than VSWR. Also, the VSWR of the load tells you the VSWR on the line. The VSWR of the generator has *no* effect on the VSWR on the line.

If given the VSWR, you have to be able to convert to reflection coefficient without difficulty. Do realise, though, that you now have no phase information on the reflection coefficient.

As soon as the phase information on one of the reflection coefficients is lost, you can no longer calculate the mismatch error exactly. All you know is that the value lies between the limits of,

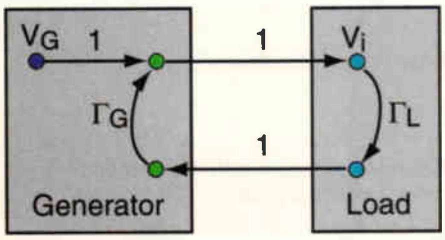
$$\frac{1}{1+|\Gamma_L\Gamma_G|} \text{ and } \frac{1}{1-|\Gamma_L\Gamma_G|}$$

This is then known as the 'mismatch uncertainty'.

Of course you are desperately clinging on, waiting for S-parameters to be mentioned again. Well I have been using reflection coefficients for the generator and the load because this is usual practice. You could call those S_{11} if you wanted. The key thing was to develop the use of the signal flow graph. Now that is done, you can actually work out more complex systems.

Simple signal flow graph

There is a graphical represented of linear equations which is very useful when dealing with S-parameters.



This signal flow graph is for a load connected to a generator through a lossless cable. The number in the middle of the arrows is the (complex) gain for that path. The blobs with the same colour represent the same point in space. The signal flow graph is separating out the forward and reverse travelling waves, which makes it much easier to see where they are going .

Note that there are two paths from the load to the generator. This represents only one physical wire. We are not talking about one signal going down the centre of a coaxial cable and the other going through the outer sheath. Both the signals travel down the same piece of wire, but in opposite directions.

The rules of the signal flow graph are very simple :

- Only go in the direction of the arrows.
- The voltages add where the arrow heads meet.
- The (complex) gain of a path is written on the arrow.
- An arrow going out from a blob (node) does not affect the voltage at that point.

You can now analyse the circuit. The voltage on the bottom blob of the load is $V_i \times G_L$. This signal travels back to the generator without loss (the path has a gain of 1 on the diagram) and gets reflected by passing up to the top blob on the generator.

Coming into the top blob on the generator we therefore have,

$$V_G + V_i \times \Gamma_L \Gamma_G$$

Of course this is equal to the voltage V_i that was originally used as a label on the top blob of the load. The top blob of the generator is connected to the top blob of the load via a path with a gain of one. Hence the two voltages must be equal. Now we have,

$$V_G + V_i \times \Gamma_L \Gamma_G = V_i$$

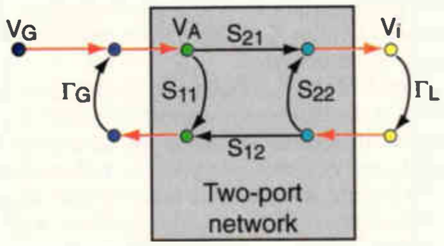
$$\therefore V_G = V_i \times (1 - \Gamma_L \Gamma_G)$$

$$\therefore V_i = \frac{V_G}{1 - \Gamma_L \Gamma_G}$$

I hope you will agree that the maths was not too bad. Although the reflection coefficients are complex numbers, this does not make them any more difficult to handle than ordinary mathematical symbols.

Inserting a two-port network

For simplicity in the signal flow graph below, all paths with unity gain are shown in red.



Assume a voltage at the top left corner of the network of V_A, so that,

$$V_A \times S_{21} + V_i \times \Gamma_L S_{22} = V_i$$

which is the loop on the right of the network,

$$\therefore V_A = V_i \times \frac{1 - \Gamma_L S_{22}}{S_{21}}$$

We also have on the left-hand side of the network that,

$$V_G + V_A \times S_{11}\Gamma_G + V_i \times \Gamma_L S_{12} \Gamma_G = V_A$$

Replacing V_A and rearranging gives:

$$V_G = V_i\left[\left(\frac{1 - \Gamma_L S_{22}}{S_{21}}\right)(1 - S_{11}\Gamma_G) - S_{12}\Gamma_L\Gamma_G\right]$$

$$\therefore V_i = \frac{S_{21}V_G}{1 - S_{11}\Gamma_G - S_{22}\Gamma_L + (S_{11}S_{22} - S_{12}S_{21})\Gamma_L\Gamma_G}$$

Quick test 4

1) What two-port device is represented by the wideband S-parameters,

$|S_{11}| \approx |S_{22}| \approx 0.2,\ \ |S_{21}| \approx 10,\ \ |S_{12}| \approx 0.03$?

2) What two-port device is represented by the wideband S-parameters,

$|S_{11}| \approx |S_{22}| < 0.01,\ \ |S_{21}| = |S_{12}| = 0.1$?

3) Using S-parameters for the attenuator in the appropriate previous question, show how the mismatch uncertainty is reduced by the use of the attenuator in a system where,

$|\Gamma_L| = |\Gamma_G| = 0.3$

4) Repeat 3, but give both ends of the attenuator a VSWR of 1.5 (when the other ends are Z_0-matched.)

More complex systems

The next system to be considered has a two-port network between the generator and the load. Note that there is no need to specify this as a passive attenuator, an amplifier or a filter at this stage. The S-parameters of the network specify what the network does without further qualification.

The calculation is not too difficult and gives some rather important points. The thing to do now is to learn to read the result and work out what it all means.

Firstly, look at the terms on the underside of the equation for V_i. All the terms are multiplied by reflection coefficients which should ideally be zero. In that case,

$$V_i = S_{21} \times V_G.$$

It is now clear that if $|S_{21}|$ is greater than unity, you have an amplifier with port 1 as the input. If $|S_{21}|$ less than unity, then you have an attenuator. Parameter S_{21} is therefore the ideal voltage gain of the network. This is $20 \times \log_{10}|S_{21}|$ when expressed in decibels.

For a linear passive attenuator, $S_{21}=S_{12}$; this is a property called reciprocity. It applies to linear devices such as resistors, capacitors and inductors, and to any network composed of them.

For an amplifier, it is conventional to specify the input as port 1. Thus you always look for the forward voltage gain of the device in terms of S_{21}, with a suitably small value of the reverse voltage gain S_{12}.

You will have heard of the idea of using an attenuator to improve mismatch uncertainty. The principle is very simple. The mismatch occurs by a signal bouncing off the load then bouncing off the generator and returning to the load.

If an attenuator is inserted between the load and the generator, the desired signal is reduced by the attenuation factor of the attenuator; let's suppose this is a factor of ×5. The signal bouncing of the load has to go through the attenuator, bounce off the generator then go back through the attenuator. As a result, this multiply-reflected signal is attenuated by a factor of ×25. The mismatch uncertainty is greatly improved by this, as you will see from the test questions.

For this to work, the attenuator has to have a much lower reflection coefficient than the worst of the load and source reflection coefficients. This fact is often neglected. You do see foolish examples given where the attenuator reflection coefficient is so bad that the overall result would actually be worse! If you complete the quick tests then you will never be caught out by this sort of gross error.

If you have worked through this article and done the tests, you should be in a much better position to understand the books and literature in this subject. Note that almost all texts work in terms of power, not voltage.

Watch out for normalisation though. Rather than use actual voltages, texts often divide by the square root of the characteristic impedance, so that the incident wave squared gives power.

The other 'trick' is to use a characteristic impedance of 1Ω. Both these habits can be spotted by using the dimensional analysis skills mentioned in that panel. ■

Answers

Quick test 1

1) Z= 50+j20.73Ω
2) 54.13Ω
3) 22.52°
4) Z=50–j20.73Ω

Quick test 2

1) 1.25
2) Frequency irrelevant. Phase of Γ irrelevant. VSWR=2.053.
3) X_L =6.283Ω

$$\Gamma = \frac{50 + j6.283 - 50}{50 + j6.283 + 50}$$

$$|\Gamma| = \frac{6.283}{\sqrt{100^2 + 6.283^2}} = 0.0627$$

Quick test 3

1) Left hand side and *I.R* are voltage, but I^2R is power.
2) Time constants both sides. Fine.
3) All power. Fine.
4) The capacitive term is wrong.

Quick test 4

1) This is an amplifier with a voltage gain of around 10 and input and output VSWRs of around 1.5.
2) This is a ×10 (20dB) attenuator with input and output VSWRs of 1.02.
3) For a comparison look just at the denominator (underneath part) of the expression for V_i and take both reflection coefficients as positive,

$$1 + \rho_L \rho_G = 1 + 0.09 = 1.09$$

Do the same with the attenuated system,

$$1 + 0.01 \times 0.3 + 0.01 \times 0.3 + [0.01 \times 0.01 + 0.1 \times 0.1]0.3 \times 0.3$$

$$= (1 + 0.003 + 0.003 + [0.0001 + 0.01] \times 0.09)$$

$$= 1.0069 \quad \text{(much better)}$$

4) $|S_{11}| = |S_{22}| = 0.2$

$$1 + 0.06 + 0.06 + [0.04 + 0.01] \times 0.09 = 1.125$$

You will notice that the mismatch uncertainty can be *worse* when the attenuator reflection coefficient is lousy. In this case the attenuator reflection coefficient is slightly better than both the source and load reflection coefficients and yet the result is still worse.

15-channel graphic equaliser

For a graphic equaliser to be useful in a hi-fi environment, it has to have a large number of channels, argue Michael Slifkin and Leonid Shigris. This complete design uses OP27 op-amps for their precision, low noise and speed.

Graphic equalisers found in recording and broadcasting studios are used to shape the sound. They are not necessarily there to compensate for any deficiency in the frequency response of the audio equipment or studio.

That they should be of interest to the man in the street is somewhat surprising, but there has been a tendency in recent years to equip music centres and radios – often quite cheap ones – with so-called graphic equalisers.

The term graphic equaliser clearly arises from the layout of the instrument, which involves a series of parallel slide potentiometers arranged side by side so that the positions of the slider knobs gives a graph-like plot of amplitude versus frequency.

Commercial equalisers are very expensive instruments. They usually have 31 channels spaced a third of an octave apart and covering a frequency

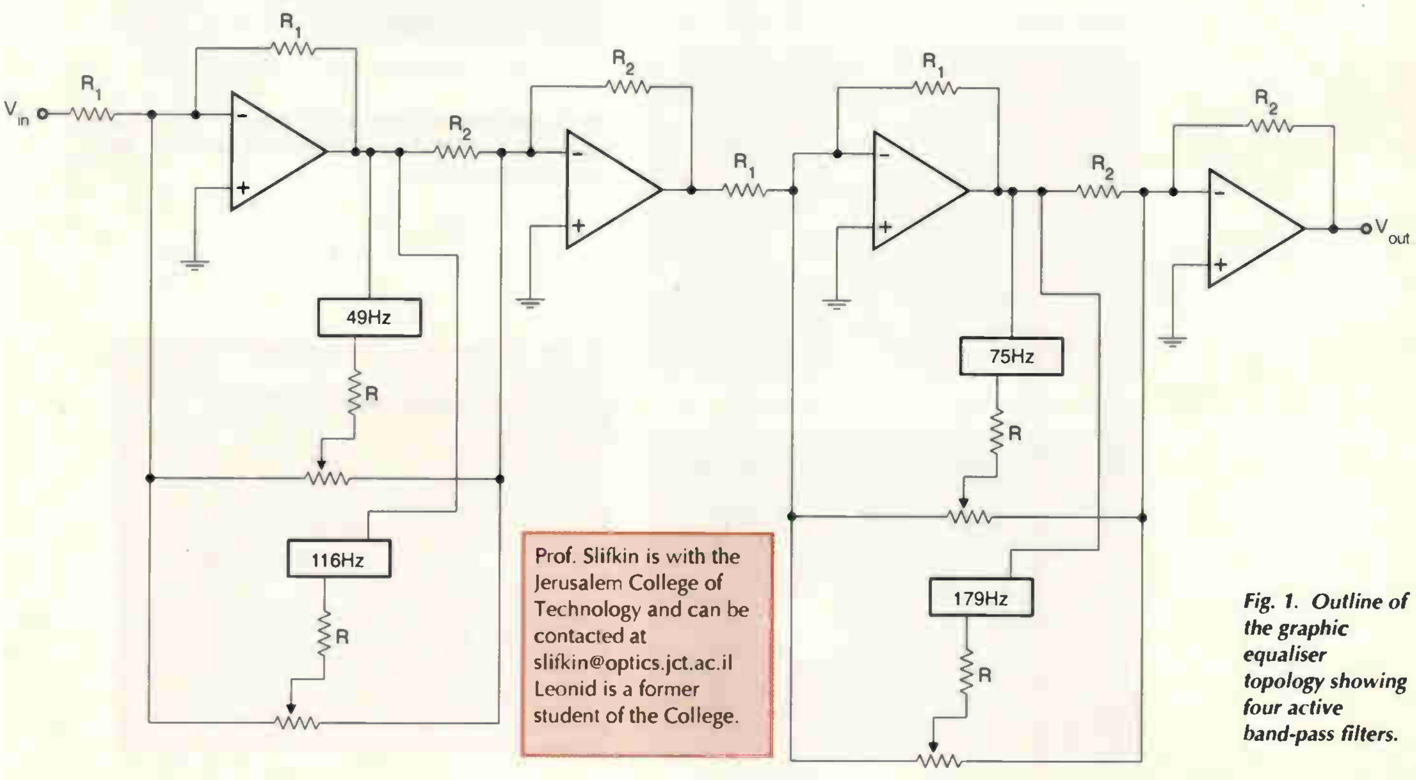


Fig. 1. Outline of the graphic equaliser topology showing four active band-pass filters.

Prof. Slifkin is with the Jerusalem College of Technology and can be contacted at slifkin@optics.jct.ac.il
Leonid is a former student of the College.

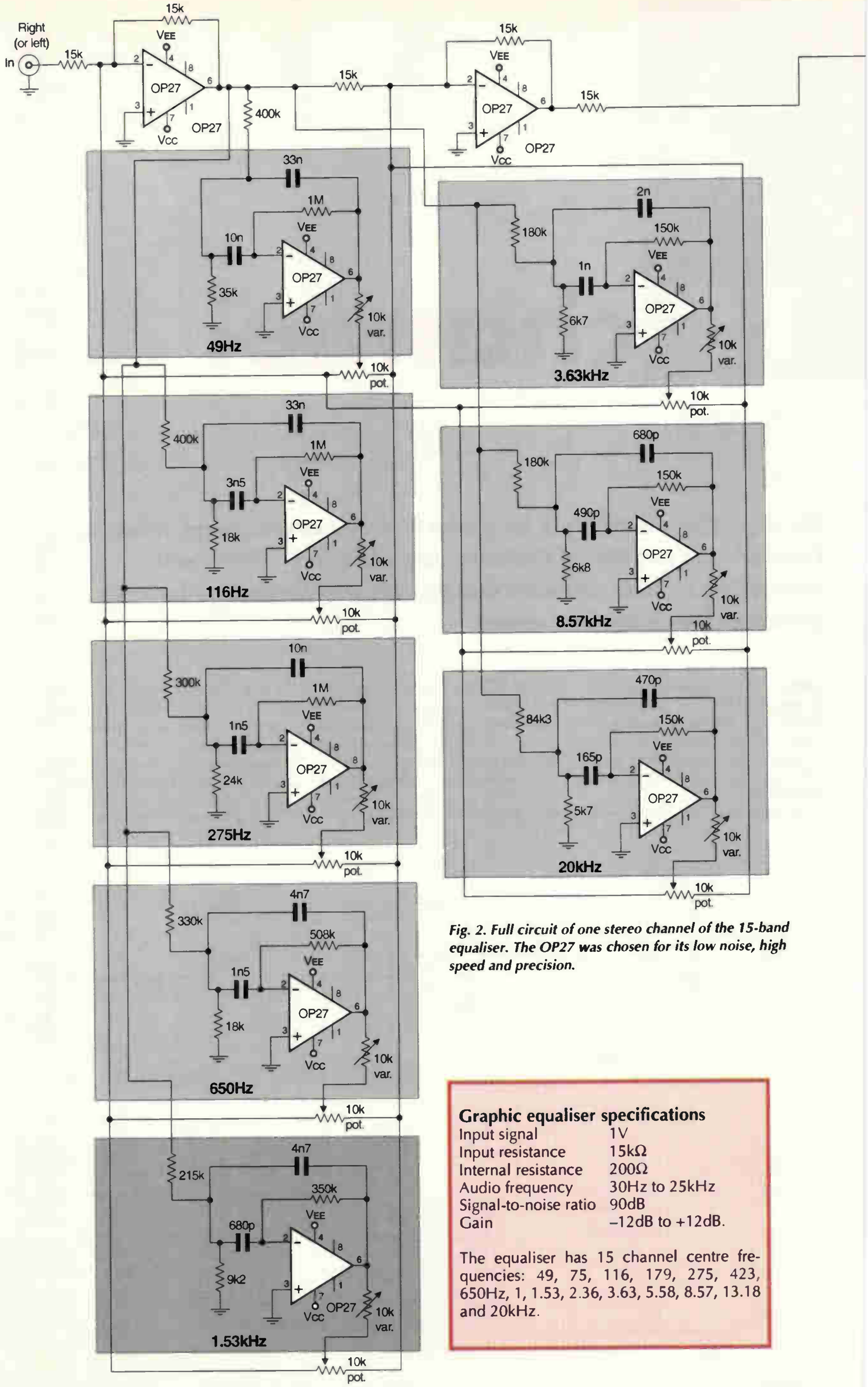
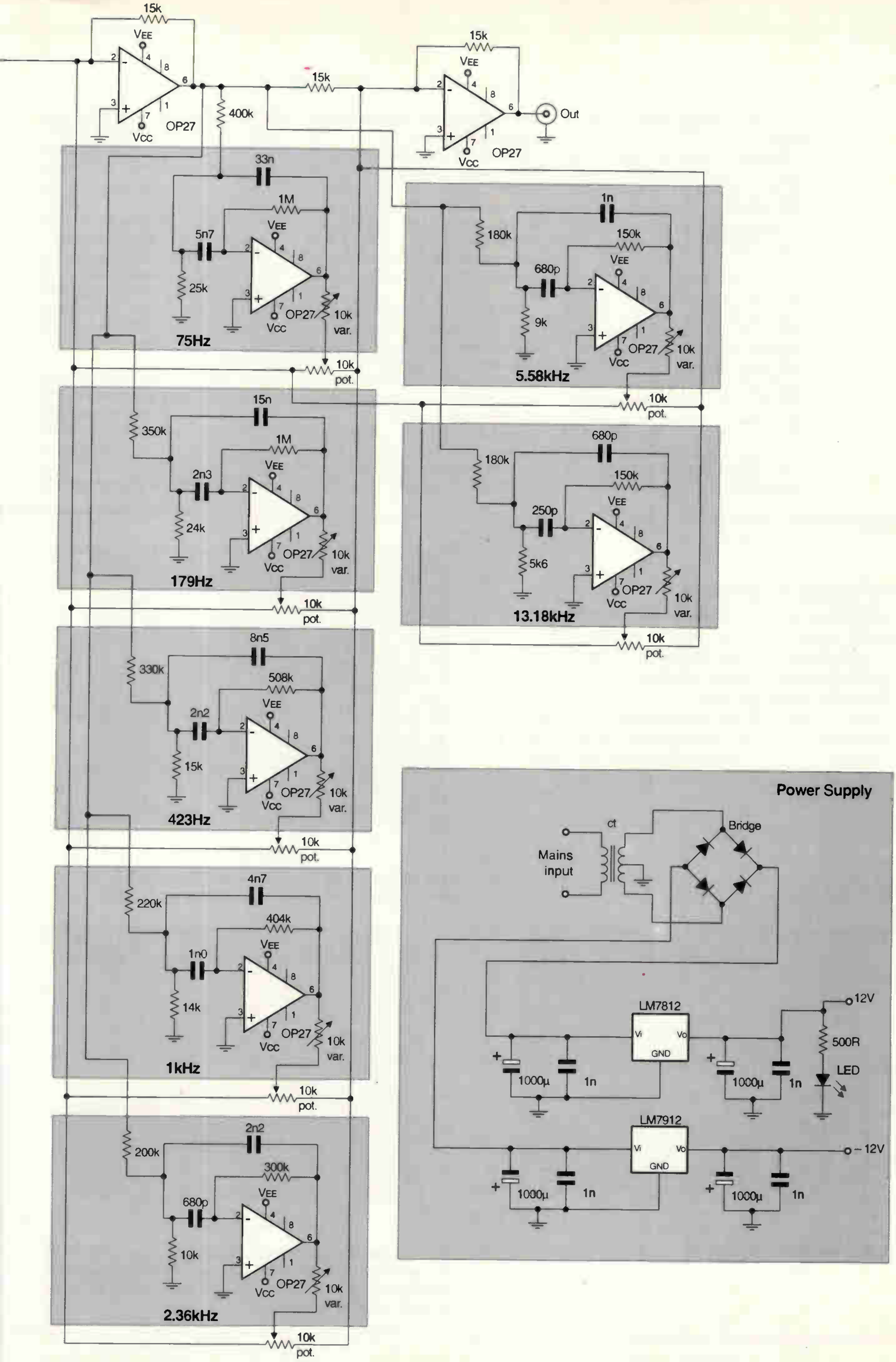


Fig. 2. Full circuit of one stereo channel of the 15-band equaliser. The OP27 was chosen for its low noise, high speed and precision.

Graphic equaliser specifications

Input signal	1V
Input resistance	15kΩ
Internal resistance	200Ω
Audio frequency	30Hz to 25kHz
Signal-to-noise ratio	90dB
Gain	–12dB to +12dB.

The equaliser has 15 channel centre frequencies: 49, 75, 116, 179, 275, 423, 650Hz, 1, 1.53, 2.36, 3.63, 5.58, 8.57, 13.18 and 20kHz.


15k
VEE
OP27
Vcc
400k
15k
Out
33n
1M
5n7
25k
10k var.
75Hz
10k pot.
15n
350k
2n3
24k
179Hz
8n5
330k
508k
2n2
15k
423Hz
4n7
220k
404k
1n0
14k
1kHz
2n2
200k
300k
680p
10k
2.36kHz
1n
180k
150k
680p
9k
5.58kHz
680p
180k
150k
250p
5k6
13.18kHz
Power Supply
Mains input
ct
Bridge
LM7812
Vi
Vo
GND
12V
500R
LED
1000µ
1n
LM7912
−12V

range from around 20Hz to 16 or 20kHz.

Modern equalisers are digital. They allow for pre-programmed settings. There are one or two less well specified equalisers, supposedly for the professional market, that are only 15 channels with the centre frequency every $^2/_3$ octave.

There's also a variety of stand-alone equalisers made for car radios and the like that are 10 or 7-channel devices. These are advertised as giving lift to the bass sound. You can even buy a software program, for use with RealPlayer and similar programs on the computer, which gives a representation of a graphic equaliser on the screen. This enables you to shape the sound from your computer using the mouse.

A popular equaliser for the PC uses 10 channels. See for example, http://cgi2.prognet.com/pluszone/tutorial60/equaliser.html

However, the manufacturer's claim that this equaliser operates up to 65kHz should be treated with some reserve.

The three-channel graphic equaliser in some cheap audio equipment can only be a gimmick. It is difficult to see how they are that much better than the traditional bass and treble tone controls.

The drawback of cheap equipment with small speakers is usually that the bass response is too low but that can be corrected by boosting the bass and/or cutting the treble. Five-channel equalisers are provided on some quite expensive radio/tape recorders.

Normally, the audio frequency is taken to cover the range from around 20Hz to 20000Hz. Not many people will be able to hear the whole of that range though. The upper frequency limit that a human being can resolve falls with increasing age. The effect of adjustments at such high frequencies would be quite unnoticeable. It is unlikely that the average Clapham omnibus rider would have the ear to be able to adjust a 31-channel equaliser.

A quite non-scientific survey among friends and acquaintances with audio equipment equipped with equalisers found that the majority never bother with controls at all after the first few hours – or sometimes even minutes – of ownership.

It is however clear – and one only needs to read the correspondence column of this journal – that there are people who feel very passionately about audio quality. To these people, no doubt a design for a relatively inexpensive but effective graphic equaliser

Performance curves

While these are not ideal curves, as there is clearly some interaction between channels, we nevertheless believe that they are sufficiently good to warrant using the equaliser for audio shaping or compensation.

These curves represent very extreme conditions. In practice, you would not expect to set up major variations in gain in adjacent channels, but rather there would be a relatively smooth transition between channels.

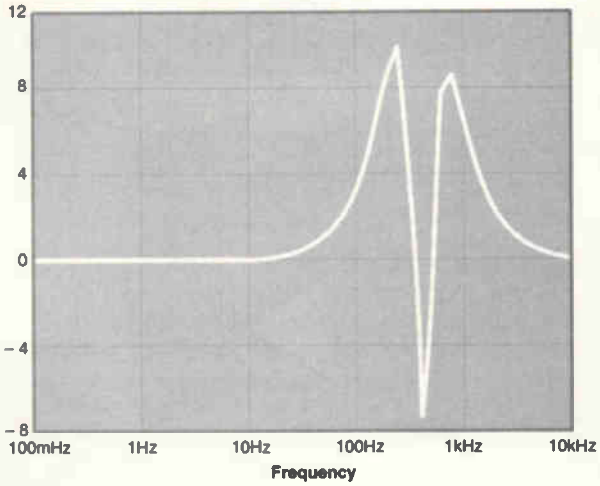


Fig. B. Response of the equaliser with the 275 and 650Hz channels set to +12dB and the 432Hz channel set to –12dB.

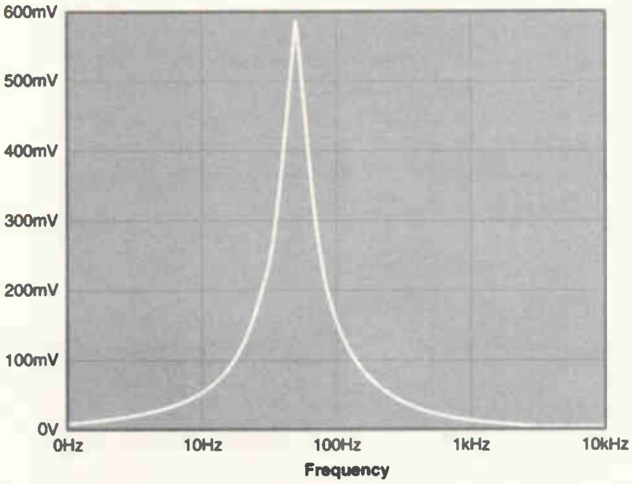


Fig. A. Response of the 49Hz channel.

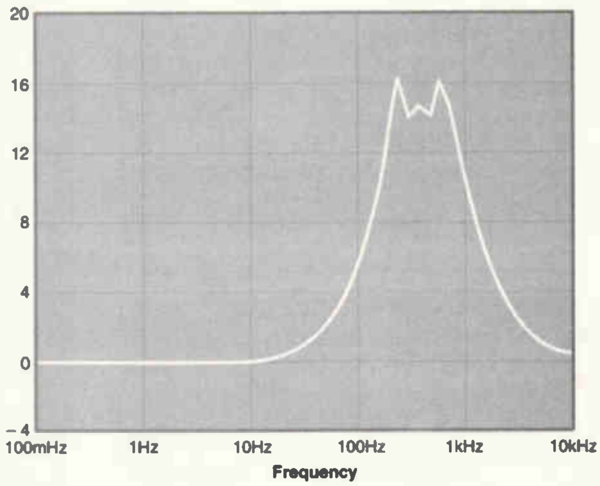


Fig. C. Response with all three previous channels set to +12dB and is a measure of the ripple of the equaliser. A ripple of about 2dB is more than acceptable. In general the ear is not sensitive to changes in sound amplitude less than 3dB.

would be of interest. In addition people with impaired hearing might find some form of audio shaping of value.

To be honest with you, the real impetus for this project was the appearance in a local dealer in surplus electronic equipment of a large number of 10kΩ, four-inch linear slide potentiometers, boxed, unused and at a knock-down price.

Tone controls consist of a high-pass and low-pass filter with amplification and attenuation. Nowadays, you can get TDA1524A tone-control IC that requires only a few additional passive components to operate. However, graphic equalisers require a number of band-pass filters. The ideal filter response would be rectangular. This is unfortunately far from obtainable.

Whereas passive filters require both inductance and capacitance, active filters need only capacitance. An active filter is one using one or more operational amplifiers. Op-amps are necessary to obtain both gain and attenuation and to avoid using inductors.

Narrow band-pass filters are needed to make a useful graphic equaliser. The important factors are the bandwidth, generally the frequency difference between the 3dB points, the flatness of the filter response and the slope of the sides of the response.

A graphic equaliser's design is no more nor less than the design of a narrow band filter and there's a wide range of configuration options available for such filters. At one time, *Wireless World*, as this journal was then called, published a pack comprising about 16 cards in a transparent envelope, each card giving details of a different active filter circuit. For many readers – including one of the writers – this was probably the best instruction they ever received in filter technology.

We designed our filters from the information given in an excellent book by Williams[1], finally opting for a Butterworth type filter. According to Williams, Butterworth filters should be used wherever possible because of their favourable characteristics. They have the flattest top of any active filter but the slope is not as good as others and the phase shift through the filter is somewhat poorer.

We used a two-pole filter – one with two capacitors – to give us a steeper slope than a single-pole filter. The centre frequency of the filter, f_c, is defined in terms of the high and low 3dB attenuation frequencies f_h and f_l as $f_c=\sqrt{(f_h f_l)}$.

We did a computer simulation of a three and five-channel graphic equalis-

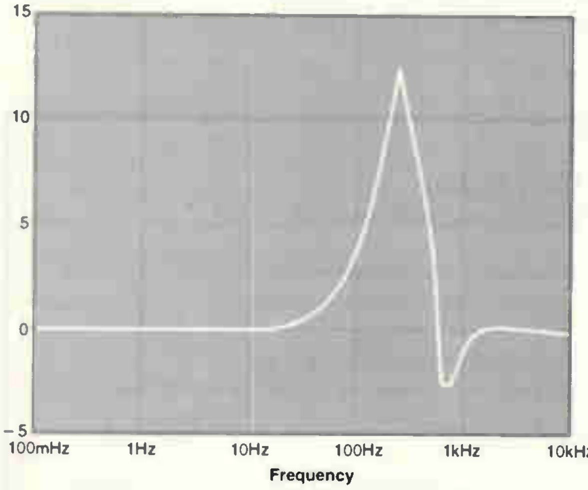


Fig. D. The same channels but with the 650Hz channel set to –12dB.

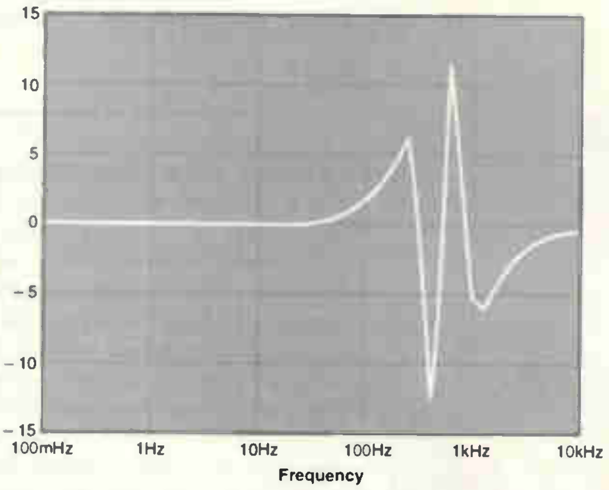


Fig. F. Shows channels 275 and 650Hz amplifying and channels 423 and 1kHz attenuating.

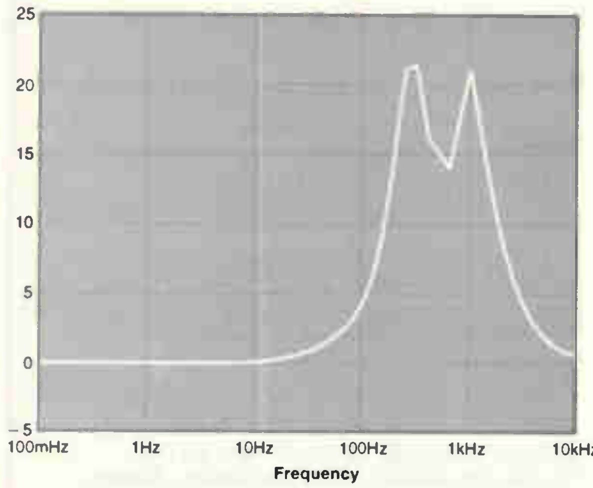


Fig. E. Illustrating the condition in which all the three previous channels plus the 1kHz channel are giving maximum amplification, all others being set at a gain of one.

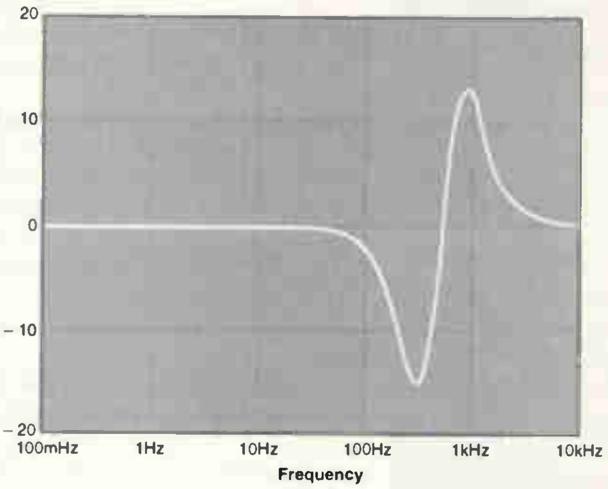


Fig. G. The opposite setting to Fig. E in which channels 275 and 650Hz are attenuating and channels 1 kHz and 423Hz are amplifying.

er using Butterworth second-order filters. We found that such devices were very poor in that adjustment in one channel had a marked effect in adjacent channels. This made it quite difficult to get a prearranged response.

As a result of this simulation, it was clear that using fairly simple filters required a larger number of narrower channels if each channel was not to have an effect at frequencies well outside the nominal channel. We decided to build an equaliser with as near to professional specifications as was feasible on a limited budget.

There are professional instruments on the market using 15 channels and we felt that that would suffice. We opted for the specifications mentioned in the separate panel.

Circuitry

Figure 1 shows the basic idea. We used the OP27 operational amplifier. This is a low-noise, high-speed precision device, making it very suitable for this application. A data sheet for this amplifier can be downloaded from,

http://www.ti.com/sc/docs/products/analog/op27.html

The actual design was based on formulae given in Williams work[1] and is too complex to discuss here. However, certain factors have to be determined. These include the filter selectivity factor, Q, defined as the ratio of f_c to $f_h - f_l$.

The selection of 15 channels over the frequency range gives a Q factor of 2.31 per channel with the minimum frequency of 40Hz and a maximum frequency of 25kHz. The multiplication factor between the adjacent centre frequencies is found from the expression $K=(25k/40)^{1/15}$ and is approximately 1.53.

Figure 1 shows the basic Butterworth two-pole configuration.

Setting up

Figure 2 shows the complete circuit. In each filter section, a 10kΩ slide potentiometer adjusts the feedback to give gain or attenuation. The preset potentiometer in each slide potentiometer's wiper should be adjusted so that the gain is 1 when the slide potentiometer is in its centre position.

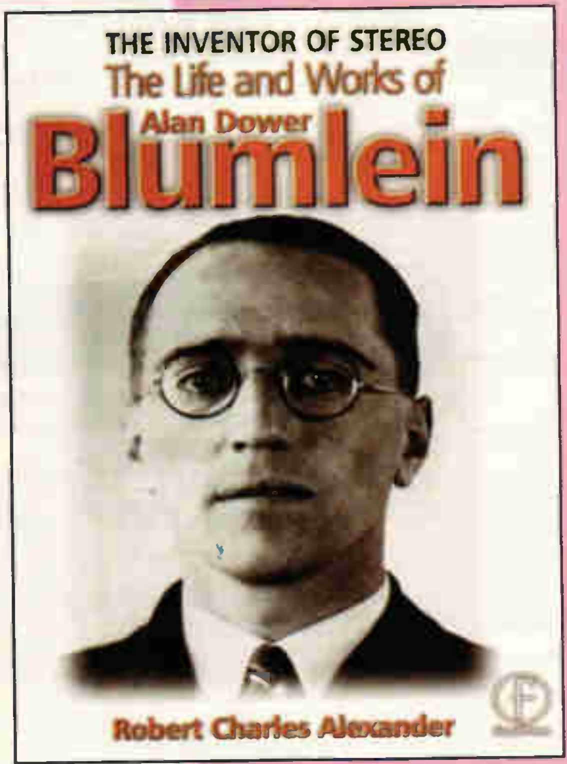
We made up two complete equalisers in one enclosure to use with stereo equipment. According to our ears, the equaliser works well.

Measurements made with a signal generator confirmed that the different channels individually behaved more or less as designed, although the centre frequencies were not as accurate as we had supposed. It should be pointed out that we used standard value components, the nearest in value to those predicted by the equations, which would certainly give rise to some inaccuracy. ■

Reference

1. 'Electronic Filter Design Handbook', A. B. Williams, McGraw-Hill 1981.

BOOK TO BUY



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This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first electronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

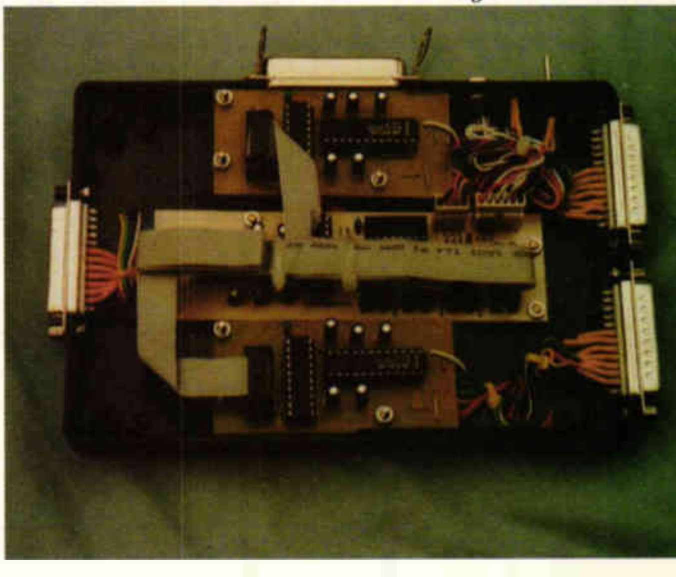
During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' - blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

For many years there have been rumours about a biography of Alan Blumlein, yet none has been forthcoming. This is the world's first study of a man whose achievements should rank among those of the greatest Britain has produced. This book provides detailed knowledge of every one of his patents and the process behind them, while giving an in-depth study of the life and times of this quite extraordinary man.

Contents

Four-way RS232 router

Prototype RS232 router with two daughter boards fitted.



Instruments with RS232 interfacing are abundant, but because the average PC only has one spare COM port, experiments involving a number of instruments are tedious. With Frank Thompson's RS232 switch box, the LPT port selects one of four routes for RS232 communications under software control, essentially expanding one COM port to four.

In software terms, the two standard RS232 COM ports on the PC are readily accessible. Also, there's a considerable number of instruments that are equipped with compatible serial port.

Usually though, at best only one COM port on the PC is free so only one instrument can be interfaced. In most cases, a mouse occupies one COM port and a modem the other. In the case of a lap-top computer the situation may be worse. There may simply not be enough physical space for a second port connector.

Companies such as Thurlby Thandar[1] and Amplicon[2] do offer multi-RS232 port expansion systems, but these are relatively expensive. The following proposed circuit, which we refer to as an RS232 switch box, provides a cost effective alternative. It allows four instrument with RS232 ports to be connected to a single serial port on a PC or compatible.

The RS232 switch box

This design is based on the MAX238 from Maxim[3]. Since the circuit is specifically made to transfer data from TTL voltage levels to the RS232 voltage levels, it proved relatively simple to fabricate a fully-compatible multiplexing system.

The mother board, **Fig. 1**, accepts signals from the computer. It routes RS232 through to one of four daughter boards depending on which interface has been enabled via a signal from the printer port.

*Frank Thompson MSc PhD CPhys MInstP MIEE is with the Dept. of Environmental Geographical Sciences at Manchester Metropolitan University.

Figure 2 shows one of the daughter boards, which plugs into one of the four sockets shown in Fig. 1.

This scheme allows interfacing with each channel to be independent. The bit rate, parity, number of data bits and presence of stop bits are all under program control.

Enabling signals are taken from the 74138 decoder and are specified by writing 0, 1, 2 or 3 to the printer port. Buffering on both the mother and daughter boards is achieved with the 74241 schmitt-trigger IC.

Listing 1, in Qbasic, finds the base address of the printer port. An important feature of the present system is that it isolates an instrument using only a two-wire RS323 interface cable.

Inevitably, a program will be terminated by a 'buffer overflow' error signal if one of these instruments is attached directly to COM1 or COM2 since no handshake signals are provided. By operating through a switch box, the data is switched off before it reaches the buffer.

Using the switch box

As a test of the switch box, I used it to import data from two different instruments. One was a Mettler Toledo[4] PM 460 mass balance with a three-wire RS232 cable. The other was an Instrotech[5] CD 75 conductivity meter, which has a two-wire RS232 cable.

I first found the base address of the LPT1 printer port with the aid of the previous routine. For the IBM Thinkpad being used, a value of 956 was obtained.

With the short Qbasic program of **Listing 2**, readings were taken from both instruments. I found that the switch box operated satisfactorily

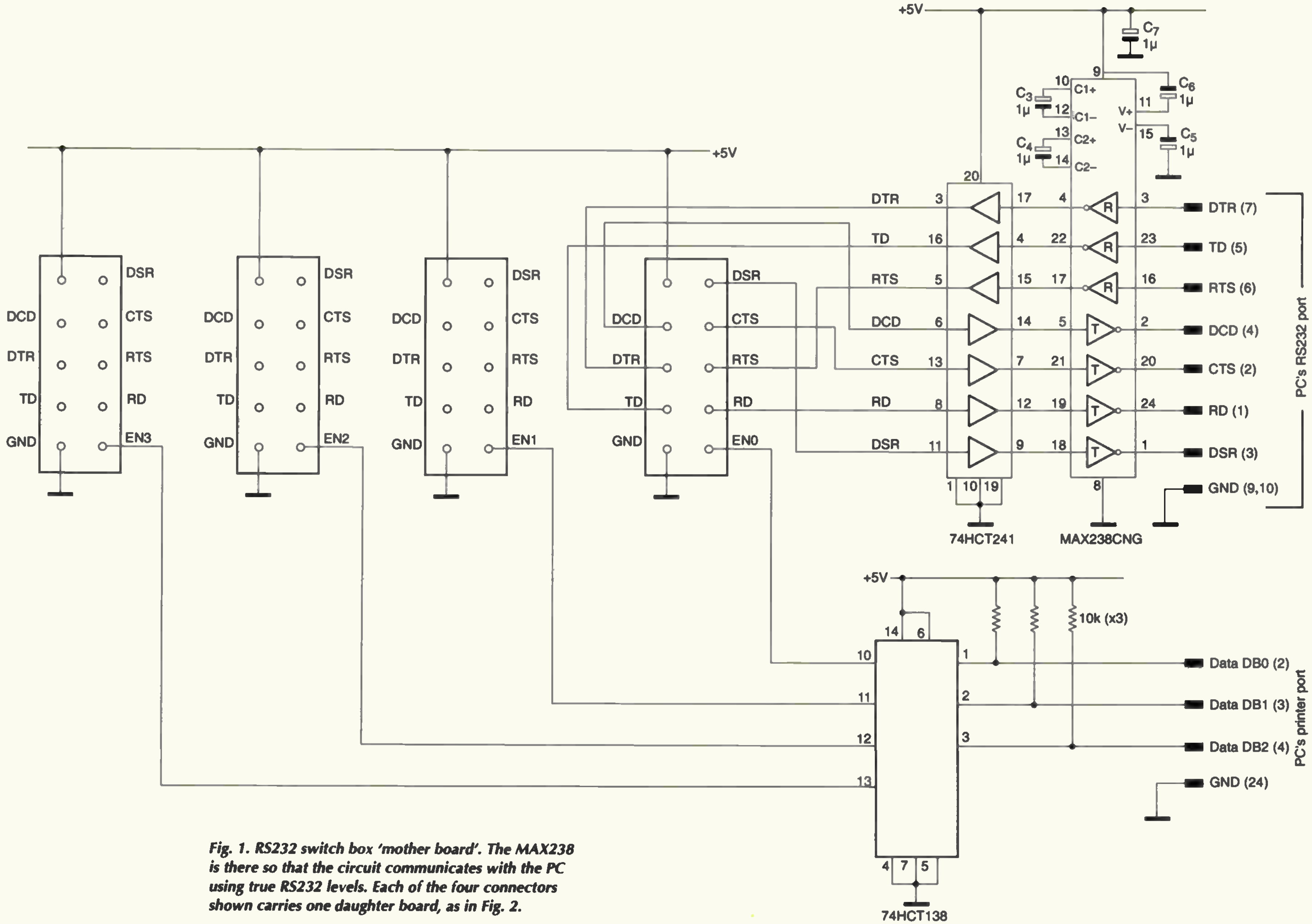


Fig. 1. RS232 switch box 'mother board'. The MAX238 is there so that the circuit communicates with the PC using true RS232 levels. Each of the four connectors shown carries one daughter board, as in Fig. 2.

and data strings were displayed on the screen.

No problems were encountered with the two-wire RS232 cable of the CD75 conductivity instrument.

In summary

Within the speed limitations of any serial port, I found that the RS232 switch box is an extremely useful circuit for interfacing many laboratory experiments to a PC. Importantly, it has also proved to be student proof!

Although four ports are available on the existing switch box, it can be expanded to use all eight data lines on the printer port.

Also, if some form of data-line expansion were then to be used, the number of RS232 ports could be increased even further. The main limiting factor may then be the accumulated time involved with the PC serving all the ports in succession. ■

More information

1. Thurlby Thandar – www.ttinst.co.uk
2. Amplicon – amplicon.co.uk
3. Maxim Integrated Products – www.maxim-ic.com
4. Mettler Toledo – www. mt.com
5. Instrotech – www. instrotech.com

Listing 1. Qbasic routing for finding the the PC printer port's base address.

```
DEF SEG = 0 'access page ZERO vectors
CLS
PRINT "Number of Centronics ports: ", (PEEK(&H411) AND (128 + 64))/64
A = PEEK(&H408) + 256 * PEEK(&H409) 'find base vector
A$ = HEX$(A)
'
'print out number of ports and base address of LPT1
'
PRINT "Address of LPT1 : "; PEEK(&H408) + 256 * PEEK(&H409)
PRINT LPT1 in Hex is "; A$
PRINT "Address of LPT2 : "; PEEK(&H40A) + 256 * PEEK(&H40B)
PRINT "Address of LPT3 : "; PEEK(&H40C) + 256 * PEEK(&H40D)
PRINT "Press any key to return to program
END
```

Listing 2. Qbasic for taking readings from two instruments using the RS232 switch box.

```
'*******Test Switch BOX*****************************************
'*****start with readings from Mettler Balance PM 460
Count = 1 ' count readings
DO
OUT 956, 0 ' open port 1 on SWITCH BOX
OPEN "COM1:2400,E,7,1,CS,DS,LF" FOR RANDOM AS #1 specify RS232
PRINT #1, "S" 'computer sends message to balance
INPUT #1, M$ 'mass string returned from balance
PRINT M$ ' write mass string on screen
CLOSE #1
'******** change RS232 to obtain conductivity readings
'***** readings from CD 75 meter
OUT 956, 1 'open port 2 on SWITCH BOX
OPEN "COM1:9600,N,8,1,CS,DS,CD" FOR RANDOM AS #2
INPUT #2, RESULTS$
PRINT RESULTS$
CLOSE #2
Count = Count + 1
LOOP UNTIL Count > 10 'take 10 readings
END`
```

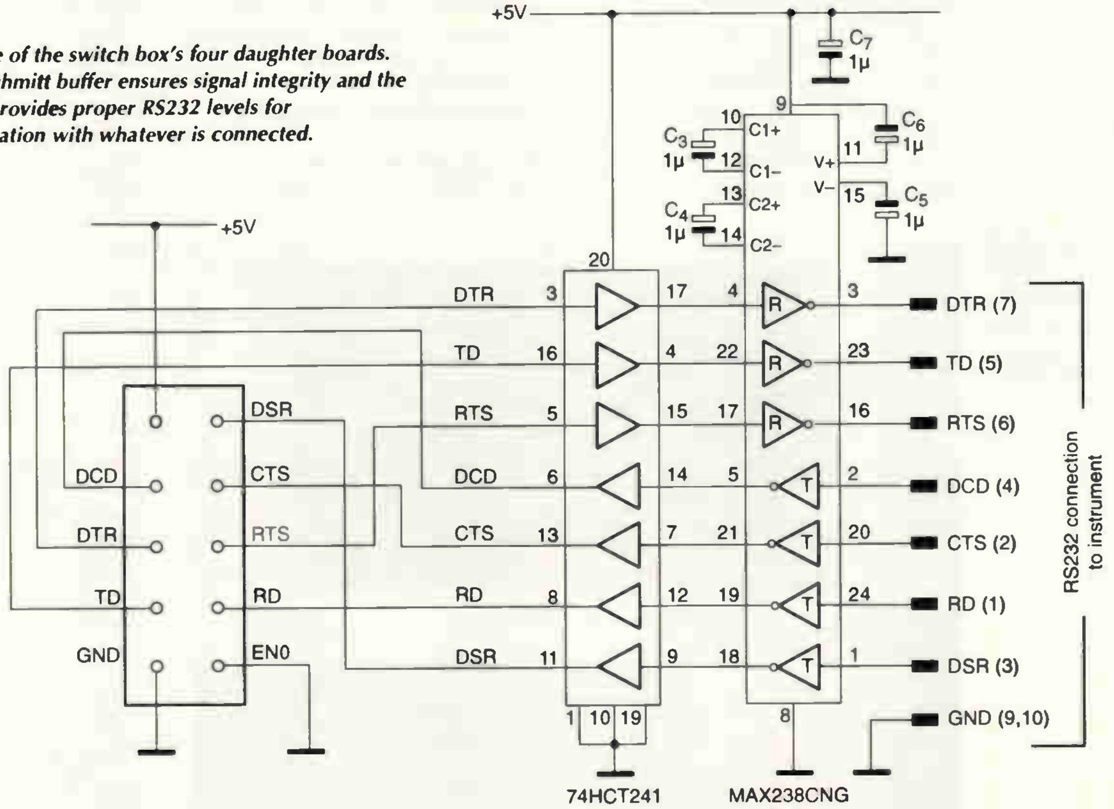


Fig. 2. One of the switch box's four daughter boards. The 241 schmitt buffer ensures signal integrity and the MAX238 provides proper RS232 levels for communication with whatever is connected.

Versatile stimulus for digital test

Digital word generator – software notes. Essential reading for anyone interested in Colin Attenborough's tester for digital systems published in last month's issue.

In last month's issue, my article 'Versatile stimulus for Digital Test' described a PLD-based system capable of producing a preprogrammed stream of digital words. This instrument interfaces to a PC and is intended as a stimulus to digital testing.

Two pieces of software are needed for the tester. One is the firmware for the PLD. The other provides the PC-based GUI that allows the tester to be elegantly and conveniently programmed and monitored.

Both pieces of software were provided on the free CD mounted on the cover of the November issue. The following is a more detailed explanation of the software provided for those of you unfamiliar with some of the procedures involved.

Interested in just getting it working?

If you have no Visual Basic, no Visual C, and no PLD programming software, then the 'Install' directory is the only one that will interest you. You'll need to send an SAE marked 'DT PLD' to Electronics World's editorial offices to obtain a programmed PLD though.

The 'Install' directory contains three files; double-click the 'setup' application to install the word generator's software. The software can be uninstalled using Start/Settings/Control Panel/Add/Remove programs.

For advanced users...

The 'VB source code' directory will be useful to those of you familiar with Visual Basic 6. As usual, double-clicking on the Visual Basic Project File will start Visual Basic and allow you to poke holes in my code.

The file WfmGenDLL.dll is the dynamic link library, or DLL, containing functions called by Visual Basic; this allows control of the printer port to which the hardware is connected. The file 'count.wfm' is an example waveform file.

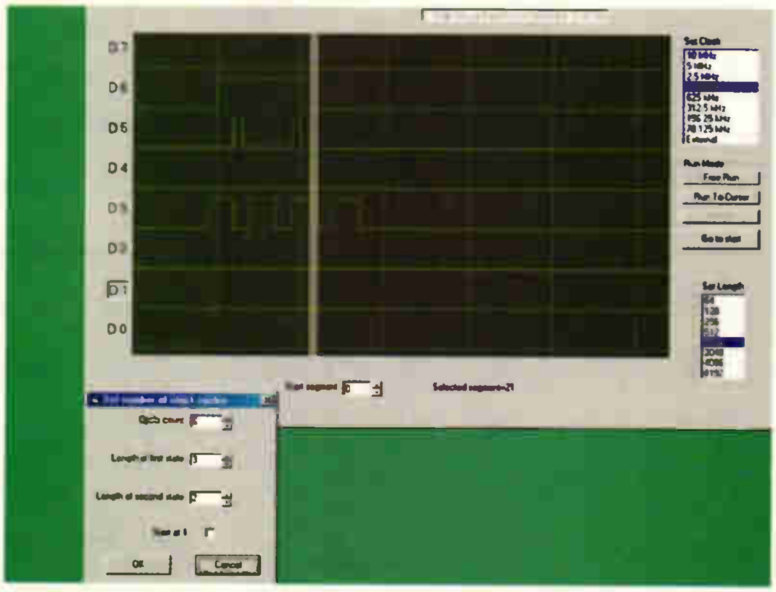
The files in the 'WfmGenDLL' directory are needed to modify the DLL for your own purposes. You'll need Visual C++6, of course. Double-click the '.dsw' file to start Visual C++6 with the project loaded. The file WfmGenDLL.cpp' contains most of the code that I wrote.

Functions made available to the Visual Basic program have names of the form,

```
WFMGENDLL_API return_type
        fname(parameter1,
parameter2, -).
```

These exported functions must be listed in the file 'WfmGenDLL.h' – a point that I missed in the main article. These '.h' and '.cpp' files are the only ones that the programmer must modify; all other files are generated automatically when you choose a DLL in the Visual C++ wizard. See last month's article for details.

The 'Release' directory inside 'WfmGenDLL' contains the resulting DLL. When you select 'generate mapfile', the map file



This is the sort of thing you should see on your PC's screen when everything's up and running.

turns up here too. There's more on this in last month's article.

PLD software details

'WrdGnPLD' contains files associated with the design of the PLD. It will only be of use to you if you have Lattice's PLD software.

Double-clicking the 'wrdgen.syn' file starts up the Lattice software with the project loaded. The directory 'wrdgen' inside 'WrdGnPLD' contains the results of the graphical layout process described in the main article. Significantly, it contains the .jed file which is fed to a blank PLD to program it.

If you install the 'WrdGnPLD' directory somewhere deep in a nest of directories, remember to avoid having a path to which DOS would take exception – keep the directory names short and avoid spaces.

'Sim' contains files that show you how a design may be simulated using Lattice's software. The file 'counter.syn' is the one to double-click to start the software with the counter design loaded. The same strictures about directory names apply here.

Double-click the '.abv' file to edit it; to run the simulation, single-click the '.abv' file, and double-click 'Equation Simulation Waveform'. You can then add signals to the display using Edit/Show from the menu bar.

Remember that the generator needs Windows 95 or 98. Relying as it does on the simple C code,

```
(_outp(PORT,VALUE); )
```

to change the state of printer port lines, it can't be used with Windows NT or Windows 2000.

A tip

Since writing the original article, I've found that there's a more elegant way to achieve something mentioned there.

When I told you how to set up the DLL calling convention by using 'Project/Settings in Visual C++', I said that the calling convention had to be set up separately for the Debug and Release versions of the program – if you have need to use them both. There's a better way.

In Project/Settings, above the left-hand pane, there's a drop-down box, with options 'Win32 debug', 'Win32 release', and – and this is the important bit – 'All configurations'. This last option will do what it says, saving you the trouble of entering the settings separately for each type of build. ■

Colin has put a considerable amount of time and effort into producing and debugging this design. You are free to use and modify the software for your own personal interests, but if you want to make commercial gain from the design – in full or in part – you must first obtain a licence from Colin.

NEW PRODUCTS

Please quote *Electronics World* when seeking further information

Low -profile 100W PFC supply

Bulgin Power Source has introduced a 100W open-frame power supply that incorporates power factor correction (PFC) circuitry complying with the requirements of IEC1000-3-2.

Featuring a maximum height of 26mm, the low profile BPSVP103 switch-mode PSU is suitable for applications in telecommunications, networking and computer equipment. The supply has a universal input of 90-264V AC and can be specified with single outputs of 5, 12, 15 or 24V. Using a 175kHz fixed frequency forward circuit topology, it achieves a typical efficiency of 85 per cent.

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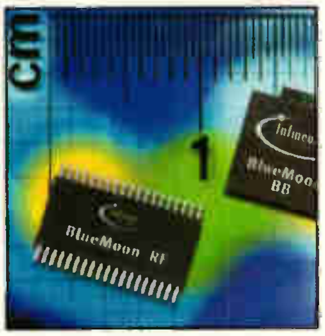
Embedded audio design

Gennum is launching a single-chip embedded audio codec solution for

multiplexing/demultiplexing digital audio streams into, and out of, digital video signals. The GS9023 embedded audio codec supports the multiplexing and demultiplexing of 20 or 24-bit synchronous audio data with a 48kHz sample rate. It incorporates sufficient processing power to multiplex/demultiplex up to four digital-audio channels. In addition, it integrates with popular AES/EBU digital audio receiver and transmitters to simplify system design. Cascadable architecture allows for the multiplexing and demultiplexing of up to 16 audio channels with no external glue logic. The device supports video standards with rates from 143Mbit/s to 540Mbit/s and when in multiplex mode, also supports the generation and insertion of EDH information according to SMPTE RP165.

Gennum
Tel: 01252 747001



Bluetooth chipset

Infineon Technologies has begun sampling its first Bluetooth chip set. The BlueMoon I set includes integrated baseband, link manager and host controller interface chips. There's a separate RF transceiver comprising two ICs – a baseband controller and an RF transceiver. The baseband IC, which comes in either a low profile, fine-pitch BGA81 or TQFP100, incorporates a link controller and PCM interface. There is UART support for both software and hardware handshaking and integrated program ROM. The RF transceiver includes in the receive path an IF-filter on chip. The BiCMOS device is available in small outline TSSOP38 package.

Infineon
Tel: 01344 396313

PCI graphics controller

Based on Intel's 430 TX chipset and supporting low-power Pentium MMX CPU with 166MHz or 266MHz clock, the Profive CPU-T6VEF board from Datasound Laboratories has a VESA compatible PanelLink interface which allows the connection of flat-panel displays within a distance of up to 5m without EMI problems, claims the company. The CPU solders directly onto the board, reducing susceptibility to vibration problems. Beside the ISA-bus and PCI-bus connectors, which belong to the PC1104-Plus

Low-power M16C 16-bit micro

Mitsubishi Electric has added to its M16C series of 16-bit microcontrollers with a low power device, the M16C120, which is a 5Mips device, is available in mask and flash ROM versions, providing 32kbytes of ROM and 1024bytes of RAM or 4kbytes of ROM and 2048bytes of RAM respectively. The device features a 91 basic instruction set and 43 I/O ports including eight LED drive output ports and eight key on wake-up input ports. There is also an eight channel, 10-bit a-to-d converter and six 15-bit timers. The MCU is fully compatible with M16C160. The small outline devices are 10mm square and come in 56-pin QFPS and 52-pin SDIPs. The device also provides enhanced memory to memory operation and bit manipulation instructions. On chip features include a one line watchdog timer and two fast UARTs.

Mitsubishi Electric
Tel: 01707 278900

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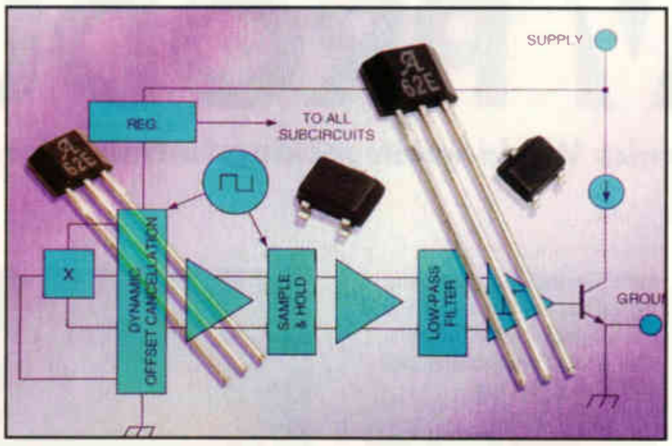
standard, the Profive CPU-T6VEF board has a full featured PCI graphic controller with 2Mbyte SDRAM. Analogue CRT monitors are supported as well as flat panel displays. A 10/100bit PCI Ethernet controller with an adapter board and an 8Mbyte flash-disk has been added on-board.
DSL
Tel: 01462 675530

8-bit flash micro

Hitachi's latest low-power flash micro, the H8/3664F, is based on the H8/300H CPU core and features a range of peripherals not typical in 8-bit micros, says the firm. These include on-chip communications capability, 16-bit timer and on-chip watchdog timer with built-in oscillator. The H8/3664F is suitable for upgrading applications currently using an 8-bit micro to 16 bits without a significant cost penalty, says the maker.
Hitachi
Tel: 01628 585163

Hall-effect switch ICs



The A3361 and A3362 from Allegro Microsystems are two-wire Hall-effect sensor ICs that switch in response to a changing magnetic field. They are for automotive and industrial applications. A dynamic-offset cancellation technique, based on chopper stabilisation, reduces the residual offset voltage normally caused by device overmoulding, temperature dependencies and thermal stress. The A3361 output current goes low in the presence of a south pole of sufficient strength. The A3362 output current goes high. Each includes on-chip voltage regulator, Hall-voltage generator, small-signal amplifier, chopper stabilisation circuitry, Schmitt trigger and a constant-current open-collector output. An on-board regulator permits operation with unregulated supplies at voltages from 3.5 to 24V. Noise radiation is limited controlling output current slew rate. Three package styles are available: miniature low-profile surface-mount package; miniature SOT-89 or TO-243AA transistor-style package for surface-mount applications; and three-lead miniature single-in-line package for through-hole mounting. Operating range is –40 to +85°C.
Allegro Microsystems
Tel: 01932 253355

Framing device

Vitesse has introduced the VSC9142, an OC-48c packet and ATM over SONET framing device that integrates the physical layer functions of serial clock, data recovery, clock generation, multiplication, multiplexing and demultiplexing between serial and parallel data paths to process and map packet and ATM cells into an OC-48c data stream. It is for data networking equipment such as core and edge routers, ATM switches and multi-service (ATM, IP and Ethernet) switches requiring Sonet-quality links between two nodes. The device uses 0.18µm CMOS technology and dissipates 2.5W. The user can extract or insert specific bytes, status information or the entire SONET transport overhead bytes for supporting operations, administration and maintenance. Performance counters and monitoring functions are integrated in the device. The serial physical layer front end complies with SONET Bellcore GR-253 jitter requirements and provides a power-down mode.
Vitesse
Tel: 01634 683393

Solid-state relay

Clare is producing four-pin solid state relays to replace electromechanical and reed relays in security systems. The CPC1008N and CPC1016N, with an on-resistance of 8 and 16Ω respectively, are 100V rated and have 1500V input to output isolation. These devices are immune to magnetic field

Digital transistor design kit

A designer's kit from Infineon contains the products and information needed to let engineers start designing Infineon digital transistors into consumer, automotive, industrial and wireless applications. The 30 devices in the kit include single-chip types (one transistor and two bias resistors) in the SOT23 package with maximum collector currents of 100 (BCR1xx) and 500mA (BCR5xx). Multi-chip versions (two transistors and four bias resistors) are included with maximum collector currents of 100mA in the SOT363 package. For multi-chip and single-chip types, a selection of common resistor bias combinations has been chosen. The kit also contains the BCP72M power switching transistor and the BCR400W silicon MMIC.
Infineon Technologies
Tel: 01344 396313

interference and compatible with surface mount manufacturing techniques. They need a minimum input control current of 2mA.
Clare
Tel: 00 32 12 672002

Fan-motor driver IC

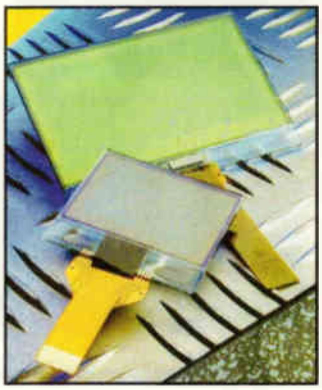
A fan motor driver IC from Rohm Electronics combines SOP8 packaging with integrated application-specific functionality. The BA6428F is a single-phase, full wave fan motor driver IC for use in desktop computers, office equipment and peripherals. Built-in motor protection functionality includes a lock detector, automatic restart function and output terminal that provides an alarm when the motor is locked. An integral thermal shutdown facility protects the IC and the motor from overheating. Operating from a typical supply voltage of 5V, it has a maximum power dissipation of 687mW.
Rohm Electronics
Tel: 01908 282666

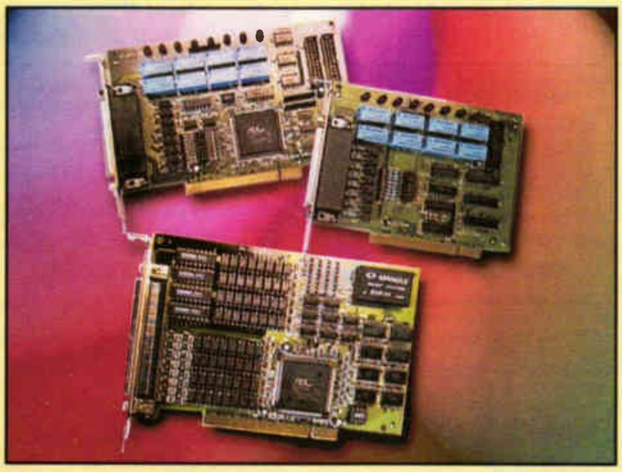
Audio subsystem

Wolfson Microelectronics has released the WM8722 audio subsystem for digital TV applications. It combines the audio processing requirements of a digital TV system on one chip, letting the user control input and output audio source selection, routeing and signal level. It has two stereo analogue outputs, one at line level and one that includes an analogue volume control. This lets the user vary the output to a TV while maintaining a constant volume on the other output. The on-chip tone generator can be routed to the line or variable outputs. There are two analogue inputs to accommodate switching and level control of two mono or a single stereo source. The device supports data input word lengths from 16 to 24-bit and sampling rates up to 96kHz. The chip consists of a serial interface port, digital interpolation filter, multi-bit sigma-delta modulator and stereo d-to-a converter in a 20-pin SSOP. The three or two-wire serial MPU compatible control port provides access to all features including tone generation, digital de-emphasis for CD replay, on-chip mute, attenuation and phase reversal. The programmable audio data input port supports various glueless interfaces to DSPs, audio decoders and S/PDIF, AES and EBU receivers.
Wolfson
Tel: 01316 679386

Chip-on-glass LCD modules

Chip-on-glass LCD modules for custom graphics applications are available from Anders Electronics. Using STN or FSTN technology, the products





PCI digital I/O boards

Diamond Point has introduced the Quatech PCI digital I/O data acquisition board with Daqsuite 3.0 software. The PXB-3210/PCI provides 64 isolated digital I/O channels, which protect against external voltages up to 5kV DC and eliminate ground loops. Inputs can accommodate voltages from 0 to 24V with a 2.4kΩ input resistor. The digital input common junction can be configured as common ground or common power, enabling either current source or current sink inputs. The 32 digital outputs are configured as common ground and provided with a 500mA sink current. It has a dual interrupt trigger that provides an internal interrupt signal on each digital input channel. Also available is the PXB-818R/PCI board, which provides eight optoisolated digital inputs for collecting data in noisy environments and eight relay actuator outputs. It is expandable to 32 inputs and 32 outputs accessed via a D-37 female connector.
Diamond Point
Tel: 01634 722390

are made by Nan-Ya and can interface mechanically with a motherboard via an FPC tail that can be either soldered directly to the PCB or mated with a ZIF connector. With resolutions up to 128 by 64 pixels as a single chip, the modules have glass thickness options of 1.1, 0.7 and 0.55mm and a minimum pixel gap of 0.01mm. They can be supplied with backlight colours including white or blue LED.
Anders
Tel: 0207 388 7171

Power racks

XP's HPR2 2U rack system accepts up to three HPR400-H 400W modules, delivering from 400 to 1200W. It has AC and DC fail alarms as standard. The modular power rack is configured for *n*+1 redundancy, hot swap operation. The HPR3 3U system accommodates up to five HPR400-V 400W modules, providing 400W to 2kW. Units have fuse or breaker output distribution, system alarm module with LVD option and operating range of -40 to +70°C. Efficiency is typically 85 per cent. The HPR4 takes up to three HPR2k8 2.8kW modules, providing a power density system to 8.4kW. Input breakers are standard, and a float-battery control for battery charging is included. Modules deliver 50A at 48-54V DC or 100A at 24-27V DC at efficiency levels of 91 per cent. All versions have DC output voltage adjustment and come with a diode O-ring. Applications include mobile basestations or industrial users requiring critical load redundancy.
XP
Tel: 01189 845515

24V dc-to-dc converter

Synqor has introduced a 24V input dc-to-dc converter. The quarter-brick sized model can operate without a baseplate or heatsink. It supports a 2:1 input voltage from 18 to 36V, with nine versions from 1.5 to 15V output, and can deliver up to 25A or 100W. The module uses synchronous rectification and has full-load efficiencies up to 87 per cent for a 3.3V output unit. Footprint is 3.7 by 5.8cm, height 1cm and weight 34g. Control and protection features include on-off control, remote sense, voltage trim, short circuit, output overvoltage and thermal shutdown. Applications include wireless basestations, process control and industrial.
Synqor
Tel: 01753 860276

Optical transceiver

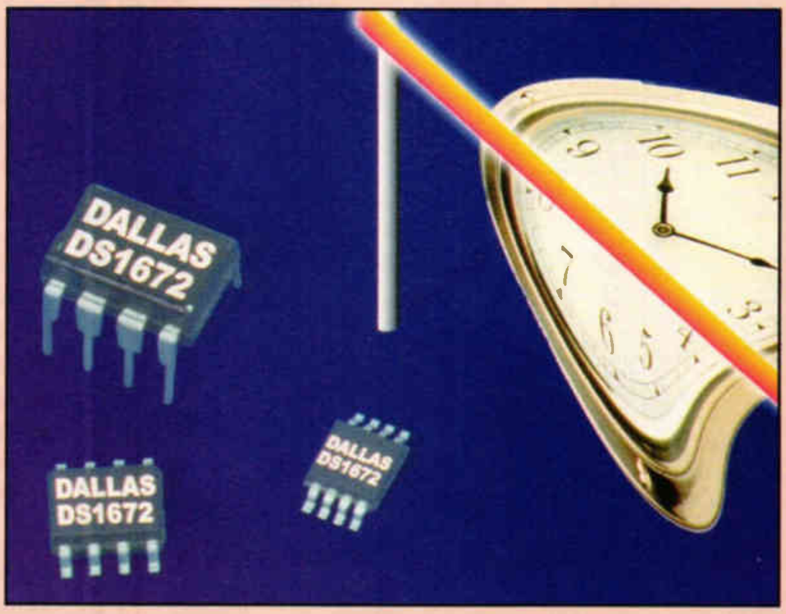
Cypress has introduced an integrated 2.5Gbit/s STM-16 and OC-48 transceiver for optical networking systems. The CY7B9532V is packaged in a 120-pin TQFP and uses 1.3W of power. For STM-16 and OC-48 optical terminator, SDH and Sonet router and add-drop mux subsystems, it integrates an STM-16 and OC-48 transmitter, receiver, clock data recovery circuit and serdes (serialiser/deserialiser) in one chip. The on-chip transmit FIFO allows for a flexible data clocking rate. Support for the LVPecl interface provides connectivity to network mappers and framers while support for the HSTL parallel interface drives low-Z transmission lines and eliminates the need for resistors in short connections.
Cypress Semiconductor
Tel: 01707 378700

Copper pair qualifier

The ALT2000 is a tool for physical qualification, monitoring or maintenance of copper-pair subscriber loops. It has an alphanumeric keypad and independent function keys to control the test process. An LCD shows the results. Automatic measurements check the quality of service being provided, and the instrument can store and recall test results to let a technician provide certifiable results in printed form. These tests can be performed in baseband and high band, dealing with spot requirements and DSL frequencies. Frequency bands are programmable, including the automatic extrapolation of

Serial timekeeper chip with power monitoring circuitry

Dallas Semiconductor's DS1672 serial timekeeping chip has power monitoring circuitry and power-fail switches in the 2 to 3.3V range. It provides the option to trickle charge the backup supply. Communicating with a processor over a two-wire interface, its 32-bit counter counts seconds, from which a software algorithm computes time of day, week, month and year. Applications include cell phones, GPS devices, palm-size computers and laptops. It monitors power supplies for out-of-tolerance voltages. When an undersupply condition occurs, it write-protects timekeeping data registers, resets the processor and switches to backup power to prevent data corruption. On low-power mode, the oscillator maintains timekeeping down to 1.3V, consuming less than 200nA. When power supplies return to normal levels, it holds the processor in reset for 250ms while operating conditions stabilise. Versions are available for 2, 3 and 3.3V with eight-pin DIP, SOIC and µSOP packages.
Dallas Semiconductor
Tel: 001 972 371 4322



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ADSL maximum expected data rate. Using its capability to perform as a return-loss meter, it can measure the level of echo signal caused from impedance mismatching on the line. It can perform attenuation measurements using an insertion loss function. This can be done in-service using live signal data.
Trend Communications
Tel: 01628 524977

Sector antennas cover 3.6GHz

European Antennas has designed two slim panel sector antennas covering 3.4 to 3.6GHz, vertically and horizontally polarised. The SA16-60-35V/579 and SA16-60-35H1584 measure 474 by 88 by 9.5mm and weigh

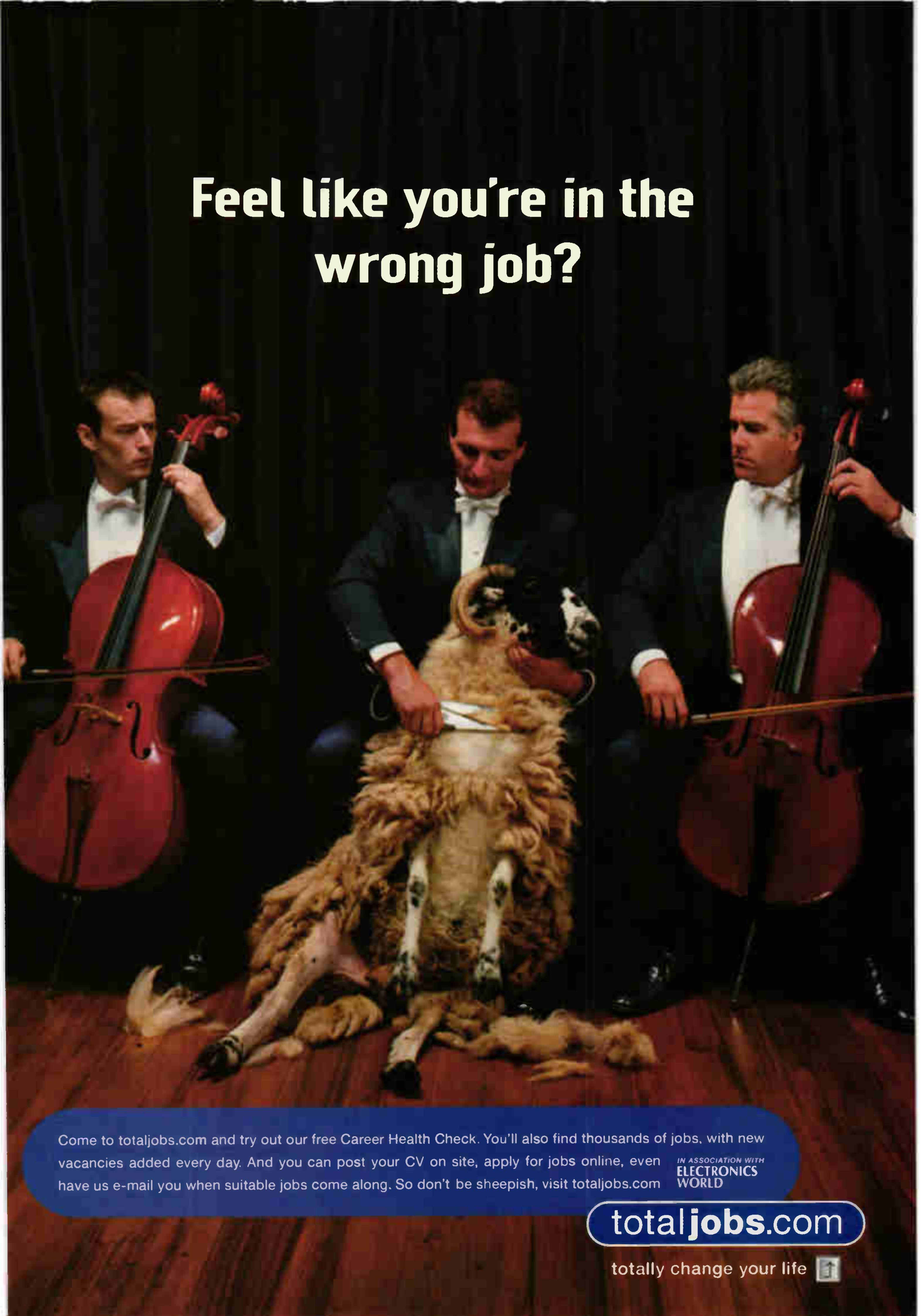
1.15kg including mounting brackets suitable for a 50mm pole. They are housed in a machined aluminium chassis that can withstand harsh environments from –30 to +60°C. They have 16dBi gain, 60° sector coverage and 10° elevation HPBW combined with a fixed electrical down-tilt of 2° for cellular coverage. They comply with ETSI specifications for copolar and cross-polar radiation patterns.
European Antennas
Tel: 01638 731888

24-bit, 40kHz

Burr-Brown's ADS1252 is a delta-sigma a-to-d converter for industrial process control, medical analysis systems and test and measurement applications. Resolution is 24 bits and data rate 40kHz. It consists of a fourth-order delta-sigma modulator, digital filter, control logic and two-wire synchronous serial interface for connection to microcontrollers and digital signal processors. The device operates from a nominal 5V supply and consumes less than 50mW. Specifications include 0.0015 per cent linearity error and 2.8ppm rms noise – effective resolution of 18 bits up to 40kHz. It is packaged in a surface mount SO-8.
Burr Brown
Tel: 01923 233837

160MHz op-amps

From Micrel Semiconductor, the MIC911 and MIC914 operational amplifiers require 1.25mA supply current and achieve 105 and 160MHz gain-bandwidth, respectively. The MIC911 is heavily compensated to make it easier to use; the MIC914 is uncompensated, yet



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unity-gain stable. Supply voltages are ±2.5 and ±9V. Input offset voltage is 1mV typical, signal voltage gain 80dB, PSRR 88dB and CMRR 112dB. The devices come in SOT23-5 packaging. Applications include portable instruments, medical equipment, video and imaging.
Micrel Semiconductor
Tel: 0207 823 3224

Output router

Clare Instruments has launched the G9000 Route Master output routeing device for applying tests to multiple testing points. For operation with G-series microprocessor controlled test instruments, it lets test applications be applied to up to 12 external earth points and four flash or insulation resistance test points, plus a single load

test connection. With 16 channels available, customer variations can be accommodated. It is fully automated via direct control from the G series test station. An LED mimic display indicates test status during the test cycle.
Clare Instruments
Tel: 01903 502551

Multi-control unit

Rittal has improved the SNMP enclosure monitoring and access device on its computer multi-control unit. The latest units are available with 512kbyte flash memory to allow for software upgrades with the addition of extension card driver programs. It was designed as a one unit per enclosure device, for applications such as pure temperature monitoring. But the addition of I²C bus extension cards allows the monitoring of up to 20 enclosures from one unit. Access control of up to five enclosures may be controlled via one unit. It is no longer reliant on an Ethernet connection being present, with an ISDN extension card providing dial-up facilities and SMS messaging. It can be attached directly to sensors via a plug-and-play unit occupying the same 1U rack space at the rear of the rack, still allowing airflow up through the centre.
Rittal
Tel: 01709 704000

Bridge rectifiers

International Rectifier has introduced the DF1A single-phase, full-wave bridge rectifiers for industrial and consumer electronic devices. Applications include power supplies and battery chargers for cellular phones, notebook computers and other portable and rechargeable devices. They follow standard pinouts and are compatible with PCB assembly and soldering techniques. Soldering can be done below 245°C to reduce solder oxidation without losing meniscus and fillet formation. The rectifiers are also suitable for 250 to 260°C soldering for 8 to 10s. Stable operation is from –55 to +150°C. The package

has an electrically insulated, UL-approved case. The junction-to-case thermal resistance is 60°C/W. Maximum repetitive peak reverse voltage range is 50 to 1000V. They are made with glass-passivated die and encapsulated in a four-pin through-hole (D-70) or a surface-mount (D-71) dual in-line package. The through-hole devices are shipped in tubes, while surface-mount devices are supplied in tape-and-reel. ■
International Rectifier
Tel: 0208 645 8001

LF

Radio Data clock

We've published Radio Data decoders before, but Roger Thomas argues that his receiver is easier to implement yet doesn't compromise on performance. Using the decoder in stand-alone mode, you can read Radio Data time on the unit's seven-segment display, or you can interface the unit to a PC for greater flexibility using software from the author.

The BBC uses three synchronised long wave transmitters on 198 kHz (1515m) to provide national coverage of Radio 4. These transmitter sites are located at Burghead (50kW) north Scotland, Westerglen (50kW) in south Scotland, with the main transmitter located at Droitwich in central England (500kW).

Stability of the long wave transmitter carrier is very accurate and can be used as a frequency reference. The transmitted carrier frequency is maintained to an accuracy of 1 part in 10^{11}.

What may not be so well known is that these long wave transmissions also carry a data signal. Digital data is transmitted by directly modulating the 198kHz carrier and provides for 16 different data channels. One data channel is used to transmit an accurate time code.

The radio audio signal and data signal are independent of each other and quality of the programme audio is not affected by the data transmission. The programme audio is used to amplitude modulate the carrier wave, whereas the data signal is transmitted by phase modulation of the carrier wave. This is not a recent innovation as the first trials of the radio data system took place in 1979.

In the December 1993 issue of *Electronics World* a GEC-Plessey design appeared in an article called 'Low-cost 198kHz radio data receiver'. The circuit design seemed to me at the time to be rather complex and did not provide a complete decoding solution.

In this earlier design, the data receiver used an SL6659 FM radio IC requiring a high-Q quadrature coil that had to be wound by hand. Demodulated audio output from the SL6659 was fed to an operational amplifier circuit.

These four operational amplifiers were wired as a filter, amplifier, integrator and comparator circuit to convert the demodulated audio into a data square wave. The circuit did not decode this data and suggested the use of a microprocessor to achieve this.

As you will see, the radio-data circuit of this design is very simple. It requires only three transistors and no coils to wind. This simplicity is due to the transmitted data not being demodulated to a base band signal for subsequent decoding. Instead, it is decoded directly by the PIC 16F877 microcontroller software.

Software in the PIC, as presented later in the article, decodes the time packet for displaying on seven-segment leds. This four-digit numeric display is driven directly by the PIC.

Using the optional software, the Radio Data stream can be sent to a PC via its serial port for post processing and display. A programmed PIC 16F877 is available from the author, as is the Windows 95/98 software for monitoring the channels and displaying the time.

Data modulation

Data modulation of the 198kHz carrier uses bi-phase encoding where a data bit '1' is signified by 20 milliseconds of phase advance of the carrier followed by 20 milliseconds of phase retard, Fig. 2. Conversely a data bit '0' is signified by 20 milliseconds of phase retard of the carrier followed by 20 milliseconds of phase advance. The phase deviation of the 198kHz carrier is ±22.5° and this phase shift changes over several milliseconds rather than as an abrupt phase change.

Bi-phase modulation avoids any net phase shift of the carrier when averaged over a period of one second or more. Thus the frequency stability of the carrier remains and its use an accurate frequency reference is not compromised.

Radio data

Data is sent in 50-bit synchronous packets as a synchronous transmission so there are no inter-packet gaps. Each 50-bit data packet contains a 1-bit prefix code which is always transmitted as a '1', 4 bits of channel identification, 32 bits of data, and 13 bits for error detection.

Transmission data rate is 25 bits per second, thus each 50 bit data packet takes two seconds to transmit. Therefore there are potentially thirty self-contained packets of data that can be transmitted each minute. These packets are numbered 0 to 29 for reference, with the data carried in each packet allocated to any one of 16 different data channels.

Apart from the time packet, information destined for any other channel can be transmitted in any order. Several packets of data sent sequentially and allocated to the same channel is allowed.

Cyclic-redundancy check

The 36 bits of data transmitted has an additional 13-bit cyclic redundancy check, or CRC, data block.

The prefix code bit is not included in the CRC calculations. This CRC data check determines whether the data packet has been correctly received and has no transmission errors. If the data is not synchronised or bits are missing then the CRC check will fail.

Probability of a data packet with errors passing this check is low because the ratio of CRC check bits to data bits is high. There is a small mathematical chance that a corrupt packet will pass the CRC check, but for all practical purposes this can be ignored.

Software does not attempt to try to correct a failed packet because there is a possibility that the 50 bits of data are in fact parts of two consecutive packets. CRC failure may be due to incorrect synchronisation rather than received bit errors.

To determine if the 50-bit packet of data has been correctly received, the CRC for the received 36 message bits is calculated with the aid of a look-up table. Calculating the CRC is achieved by using modulo-two addition – i.e. Boolean exclusive OR – for each '1' bit in the received 32-bit message. The appropriate value for each permutation is returned from the look-up table. This table comprises a CRC matrix derived from the 13-bit generator polynomial used in the original coding.

Once the 13-bit CRC is calculated in software, it is then compared with the received 13-bit CRC. If the two match, then you can be confident that the packet is error free.

An alternative method is to divide all 50 bits, including the CRC bits, by the generator polynomial. If there are no errors, the answer should be all zeros. This is very much a hardware solution using a division register to serially clock in the bit data. Using a look-up table in software is easier to implement.

The only weakness is when receiving data comprising of all zeros. This will pass the CRC check. Such a situation may occur when initially tuning the data receiver. However this will never occur when receiving data. The time packet – which has an application code of '0000' – will invariably have at least a single '1' in the day of week (for Monday), year start day and week number. All other packets will always have a '1' somewhere in the application code and data.

Time data formats

Channel 0 is allocated to the time data and this information is always transmitted in packet 29. This packet is the last packet in the minute sequence so that the boundary between packet 29 and the next packet is the minute edge, Fig. 3.

The time code transmits its time information in UTC, which is short for Co-ordinated Universal Time* and represents the difference between UTC and UK local time. This time offset is rather generous as it allows a local time offset of up to $\pm 15^1/_2$ hours from UTC.

Software in the PIC can display either UTC or local time by using the time zone switch. The PC software displays both times simultaneously. This is useful for radio amateurs and short wave listeners as times are usually quoted in UTC.

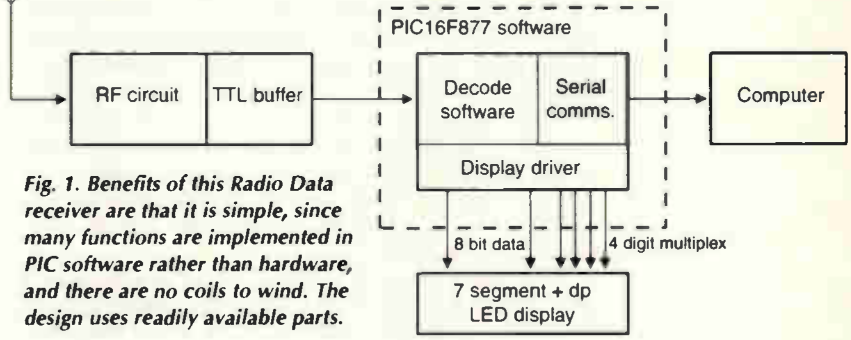


Fig. 1. Benefits of this Radio Data receiver are that it is simple, since many functions are implemented in PIC software rather than hardware, and there are no coils to wind. The design uses readily available parts.

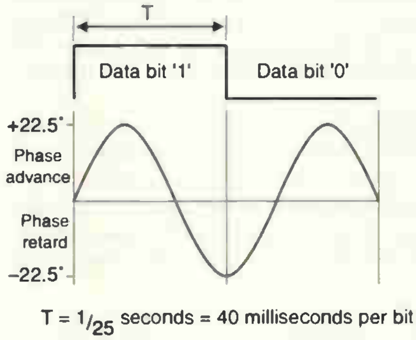


Fig. 2. In bi-phase encoding, as used for Radio Data, a logic '1' data bit is signified by 20 milliseconds of phase advance of the carrier followed by 20 milliseconds of phase retard. Conversely, a '0' is signified by 20 milliseconds of phase retard of the carrier followed by 20 milliseconds of phase advance.

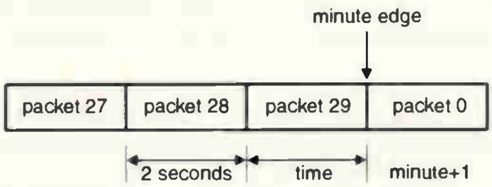


Fig. 3. In Radio Data's encoding system, the transition between the packets 29 and 0 represents the minute changeover edge.

Unlike the Rugby MSF transmissions, the BBC Radio 4 time packet does not include the month or year. Nevertheless, the date can be calculated by working out the number of days in the year from the week number and day of the week. The software process converting this to a date is rather tortuous.

Note that the day of the week and week number is aligned with UTC time not local time. Including the start day of the year – on 1 January – and leap year flag would enable a calendar to be constructed from the time packet, Figs 4, 5.

Time filler code

The first bit after the application code is the 'T' bit. In the time packet, this bit indicates whether the packet is carrying time data or if the time packet is being used as a 'filler', in which case the 'T' bit set to 1.

Filler data bits are arranged in an alternating binary sequence, as you can see in Fig. 6. This code is transmitted where there are no other data packets that need to be transmitted. As the radio data is a synchronous, and to maintain carrier frequency stability, data has to be transmitted at all times.

Radio circuit details

Ferrite antenna coil and variable capacitor form a tuned circuit adjusted to be resonant on the BBC Radio 4 frequency of 198kHz. The 2N3819 JFET transistor has a high input impedance. Here it forms a buffer circuit to prevent the rest

* Universel Temps Coordonné – Ed.

of the circuit from loading the antenna circuit.

Connected to the drain of the 2N3819 is a 198kHz crystal. This crystal forms a passive narrow filter. Ideally only the carrier frequency with its phase modulation – a bandwidth of only 50Hz – should be passed to the PIC microcontroller.

Series resistor R_2 reduces the sharp peak frequency response of the crystal. This prevents the crystal from oscillating and the 198kHz data radio circuit turning into a 198kHz oscillator circuit. Visually the data radio circuit is dominated by this crystal which, with its HC-31U can, measures 22mm by 18mm.

This crystal filter is needed as computer power supplies can create radio interference. Such power supplies are usually switch-mode types and switch at a similar frequency range to the data transmission. Computer monitors can also generate interference. The prototype circuit boards, before being wired into a suitable enclosure, worked reliably when situated within a metre of a PC tower and next to the computer monitor.

After the crystal filter there's a two-transistor circuit that amplifies the radio data signal to that approaching ttl level. The signal feeds a 74LS14 buffer located on the PIC circuit board. This buffer has a Schmitt trigger input to ensure that a constant ttl output signal is fed to the PIC microcontroller. There is signal level variation due to the audio modulation.

Ferrite antenna

My prototype used a LW/MW ferrite rod antenna supplied by Maplin Electronics under the order code LB12N. Using a pre-wound antenna coil gives a reliable circuit that can be easily replicated by others. It also simplifies the construction of the radio.

It is feasible to use a ferrite antenna assembly from a defunct radio that covers long wave. But make sure that the long/medium wave coil switching and tuning capacitor connection is fully understood before dis-assembly.

If you opt for the Maplin ferrite antenna then remove the medium-wave coil, leaving the long wave coil, which has a scramble winding with thicker wire.

The antenna coil connects to a variable tuner capacitor of around 140pF. This tuning capacitor was also from Maplin, order code FT78K. One end of the coil is soldered to the AM antenna pin and the other end soldered to AM ground, i.e. the centre pin. The oscillator connection on the tuner capacitor is not used.

The ferrite coil and variable capacitor should be connected to the Radio Data receiver via screened cable. This allows you to find the antenna's best position independently of the orientation of the data receiver.

Displaying the data

A 4-digit, 7-segment LED displays the time information from the PIC microcontroller. The time format is decoded by the microcontroller software from the time packet.

Is Radio Data more than just a precise clock?

Apart from transmitting time data, the only other known application for Radio Data is the Radio Teleswitching system used by the Electricity Association on behalf of the electricity supply companies.

Radio Teleswitching uses time coded data transmitted for remotely switching night time storage and water heaters installed in the home. It is also used to set the tariff rates on the electricity meters for off-peak electricity usage. Other applications being suggested are regional flood warning systems.

The restricted number of 32 data bits per packet – excluding prefix, application code and CRC bits – precludes any application that requires transmitting free form text as each packet can only contain between 4 and 7 characters, depending on the coding.

Despite this restriction, a format where particular bits represent data – like the time packet – could be transmitted. This could include stock-market data, radio-propagation information, or motorway-traffic information.

When the system was first suggested, one proposal was for the coded data transmission of weather and shipping forecasts, but this was never implemented.

Fig. 4. Radio Data's time packet summary.

P prefix always transmitted as '1'.
A application code.
T time or filler code flag.
Y leap year indicator.
S start day of year (1 January).
W week number.
D day of the week.
H hour.
M minute.
L local offset from UTC.
C cyclic redundancy check.

Sequentially, the packet looks like this:
PAAAATYYSSSWWWWWWDDDHHHHHMMMMMM
LLLLLLCCCCCCCCCCCCC

Fig. 5. Detailed time code packet description

P prefix transmitted as '1' [1 bit]
A application code [4 bits]
  0000 time packet
  0001 data packet
  ...
  1111 data packet
T 0 = time data [1 bit]
  1 = filler data
Y leap year [2 bits]
  00 this year is a leap year
  01 last year was a leap year
  10 leap year in two or more years
  11 next year is a leap year
S start day of year (1 January) [3 bits]
  000 not used
  001 Monday
  010 Tuesday
  011 Wednesday
  100 Thursday
  101 Friday
  110 Saturday
  111 Sunday
W week [6 bits]
  1...53
D day of the week [3 bits]
  000 not used
  001 Monday
  010 Tuesday
  011 Wednesday
  100 Thursday
  101 Friday
  110 Saturday
  111 Sunday
H hour [5 bits]
  0...23
M minute [6 bits]
  0...59
L local offset (hours) [6 bits]
  msb sign ± (1 bit)
  1...14 hours difference (4 bits)
  lsb = $^1/_2$ hour (1 bit)
C cyclic redundancy check [13 bits]

It is necessary to multiplex the display as the microcontroller cannot source the current for all four digits simultaneously. Also there are not enough i/o pins for each segment to be connected directly to the PIC. Each led digit is on in turn for 12ms, **Fig. 7**.

All the segments for each digit are wired together and connected to port D. Each digit is switched, i.e. multiplexed, by the appropriate n-p-n transistor connected to port $B_{1\text{-}4}$, assuming a common-cathode type display.

Each transistor switches the segments in the digit to zero volts to light that particular segment. Any low cost n-p-n transistor should be suitable, provided its maximum collector current capability is adequate.

As current for each led segment is sourced from the PIC port pin, current limiting resistors $R_{10\text{-}17}$ are needed. The PIC can source a maximum current of 200mA and each individual port pin can source a maximum of 25mA. The following formula can be used to determine a suitable value for this resistor,

$$R = \frac{V_s - V_f}{I_{seg}}$$

where V_s is the supply voltage, V_f is the segment forward voltage and I_{seg} is the required current through the led segment. As each segment line has this current limiting resistor it is not necessary to incorporate another in the transistor's collector.

Maximum current flow occurs when displaying the numeral eight and decimal point is lit, as the display is multiplexed only one digit is on at any one time. As the display only shows the time, the eight will only occur as the last digit. The first digit is either blank, or displaying the numerals one or two, so the average current consumed by the led display is much less than the maximum, **Figs 7, 8, 9**.

Time switch

Time zone switching is used to select between local time and UTC time, and to reset the PIC software if required. The display will show either UTC or UK local time, as appropriate.

As the data is held in memory, the time can be re-calculated and displayed when this time button is pressed. If the time display is in UTC, the time led will be lit. Local time is the default.

When local time is selected, the PIC software automatically displays any time changes between UTC and British Summer Time (BST). Consequently there is no need for buttons to set the time manually.

Port RA_0 is polled every 50ms and has the time selection switch connected to it. Although the switch could have been wired to generate an interrupt, it would probably have needed hardware de-bouncing. The associated time led requires an appropriate current limiting resistor, R_9.

If you decide not to use the led display then the time selection switch and led serves no useful function and need not be connected. However the 120kΩ pull-up resistor on port RA_0 still needs to be connected.

Implementing the design

It is possible to implement the Radio Data circuit on strip board. This is not usually recommended due to the capacitance between the copper tracks. But at the frequencies involved here, this is not a problem. Keep all component leads and connections short though.

The design needs a regulated 5V power supply. Type and size of the enclosure will primarily depend on whether the led display is used and if there is an integral power supply. There's no need to add the display if you are only interested interfacing the radio data decoder to a PC.

It is advisable to build the data radio and PIC circuit on separate boards. If you do this, the radio section can be housed in its own small metal box.

Use screened cable for the link between the radio and the PIC. The controller's circuit and the multiplexed display can generate radio frequency interference and should be housed in another metal box with the external ferrite antenna connected via screened cable.

The PIC 16F877 needs to run at 20MHz using a crystal. When running the PIC in high-speed mode, a series resistor is recommended to prevent over-driving of the crystal.

On the prototype, the PIC circuit board seemed to be susceptible to mechanical knocks that could cause the PIC microcontroller to stop. This failure mode was evident on the display as the multiplexer would stop functioning and only one digit would be lit.

I traced the cause to the 20MHz PIC crystal. The solution was to earth the crystal case by wrapping a bare wire over the case and soldering each end of this wire to 0V. Fortunately the crystal had been laid flat on the strip board, which allowed the above wiring to be done without difficulty.

PIC calibration

To decode the radio data signal, the output from the ttl buffer is connected to both the capture inputs of the PIC microcontroller. After reset, the PIC software needs to calibrate itself. As the signal has to be sampled in real time, this

Fig. 6. As t he Radio Data stream is synchronous, data needs to be transmitted continuously. If there is no other data, to transmit the time packet is sent with filler data, as shown.

1-0000-101010101010101010101010101010-1000101111101

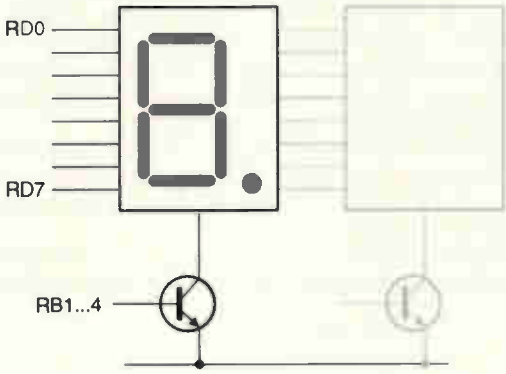


Fig. 7. A multiplexing scheme is needed for the four LEDs as the PIC hasn't the current output capability to drive them all at once.

Fig. 8. Pin allocations for the seven-segment display used.

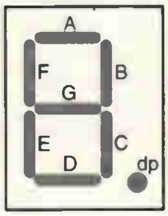


Fig. 9. PIC port allocations for the switch and display LEDs.

RA0 (2)	time switch
RA1 (3)	time switch led
RD0 (19)	segment A
RD1 (20)	segment B
RD2 (21)	segment C
RD3 (22)	segment D
RD4 (27)	segment E
RD5 (28)	segment F
RD6 (29)	segment G
RD7 (30)	segment dp
RB0 (33)	digit 1 (hours)
RB1 (34)	digit 2 (hours)
RB2 (35)	digit 3 (minutes)
RB3 (36)	digit 4 (minutes)

requires a PIC clock speed of 20MHz. A PIC running at 10MHz is not fast enough.

During calibration, the PIC microcontroller displays a 'CAL-'. When the calibration process is finished, the software starts to decode packets. The display shows the number of packets received without error until the first time packet is decoded. This count should increase every two seconds.

The software uses both capture and compare port inputs in capture mode, on the PIC's pins 16 and 17. Timer 1 is 16 bits and runs at maximum speed in capture mode since it is used to time the pulse width. By using the elapsed time between the rising edge of CCP1 and falling edge of the waveform on CCP2 the pulse width is determined, **Fig. 10**.

Sampled over 20 seconds, successive timer calculation gives the average pulse width. If the waveform duty cycle ratio is not exactly 50:50 then this will not affect subsequent calculations – within reasonable limits of course.

The figure calculated in this way averages out any effects that the phase modulation has on the pulse width. Essentially

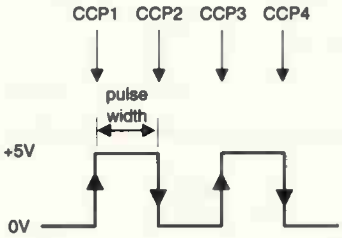


Fig. 10. The PIC software calculates the width of the ttl waveform by measuring the time elapsed between edges CP1 and CP2.

the result should be exactly 198kHz. Thus the software can verify that the radio is tuned to the BBC transmission.

If the PIC software detects a carrier signal but it is not exactly 198kHz then a suitable 'Err' message will be displayed on the led display. On a PC, the message 'not 198kHz signal' is displayed.

Zero crossing

Having worked out what timer values constitute a transmitted '1' or '0', the software now needs to synchronise with the radio data stream. This is done by looking for the zero-crossing point by timing the pulse width and analysing the results.

The software looks for the maximum rate of change. This requires the PIC software to maintain many timer counts including minimum, maximum and several moving averages. The software requires several hundred readings to determine where this change occurs.

You can see from **Fig. 11** that the maximum rate of change occurs half way through the waveform, due to the bi-phase encoding. Once the maximum change has been found then the zero crossing time can be determined.

Once the zero-crossing point has been calculated, the processing requirement falls and the software can now start to decode the digital data and send binary data to the PC.

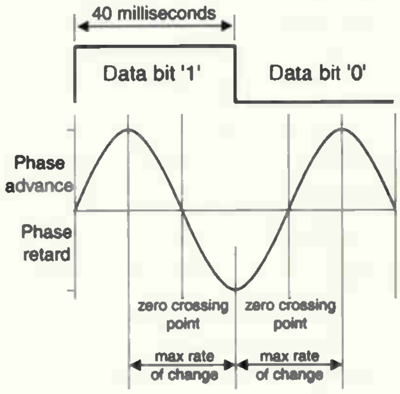
The PIC uses the incoming data stream as a clock so that synchronisation is maintained. By sampling the waveform looking for changes in phase direction around the zero crossing point, transmitted source binary data can be determined.

Fig. 13. PIC calibration error codes. If, during the calibration process, the PIC is unable to find or decode the radio data then 'Err' will be displayed followed by a number, whose meaning is as follows.

1 no signal – nothing found or intermittent signal.
2 signal not 198kHz – carrier found but not Radio 4.
3 duty cycle too low – low input signal.
4 duty cycle too high – signal too strong.
5 no phase modulation found – signal too noisy?

If the data radio is connected to the serial communication port then the PC software will display a similar message.

Fig. 11. Determining the zero crossing point requires a lot of processing power since the PIC has to calculate in real-time where the maximum rate of change occurs in the sine wave.



This sampling needs to be done over a few milliseconds.

Having previously determined the median value of the pulse width – equivalent to the carrier having no phase modulation – subsequent pulse width measurements reference this value. The effect of the phase-shift modulation is to increase or decrease the relative waveform pulse width. This relative width change is small, **Fig 12**.

PC-to-PIC data link

Using the optional software, the PIC transmits the decoded binary data serially to the PC in ASCII form. Binary data is transmitted from the PIC's serial communications port via one of the 74LS14 buffers, the reason for this inverting buffer is that it replaces a RS232 interface chip which in operation would invert the data. The series resistor is there to limit the current flow in case of a wiring or hardware fault.

Serial data from the PIC to the PC is transmitted at 38400 baud using 8 data bits, one stop bit and no parity. But the actual underlying transmission data rate is only 25 baud. As the data rate from the radio data receiver is so low there is no need for any communication handshaking. Windows 95/98

Fig. 12. Pulse width calculations – converting the 198kHz radio frequency to a pulse width.

Firstly, with no modulation,

$$\frac{1000000}{198000} = 5.05\mu s$$

$$\frac{\textit{Pulse width} \times \textit{phase shift}}{360}$$

$$= \frac{5.05 \times 22.5}{360} = 0.32\mu s \text{ phase shift}$$

With a ±22.5° phase shift,

$$= 5.05 - 0.32 = 4.73\mu s$$

and the application software buffers the incoming serial data so it is extremely unlikely that any data will be missed.

The serial connection cable can be built using screened cable, **Fig. 14**. Length of the cable is restricted to approximately 1.5 metres. This allows the data radio to be situated some distance from the PC.

PIC time decode

There is no unique header that would allow the PIC software to recognise the start of a data packet. This would have added

Continued over page

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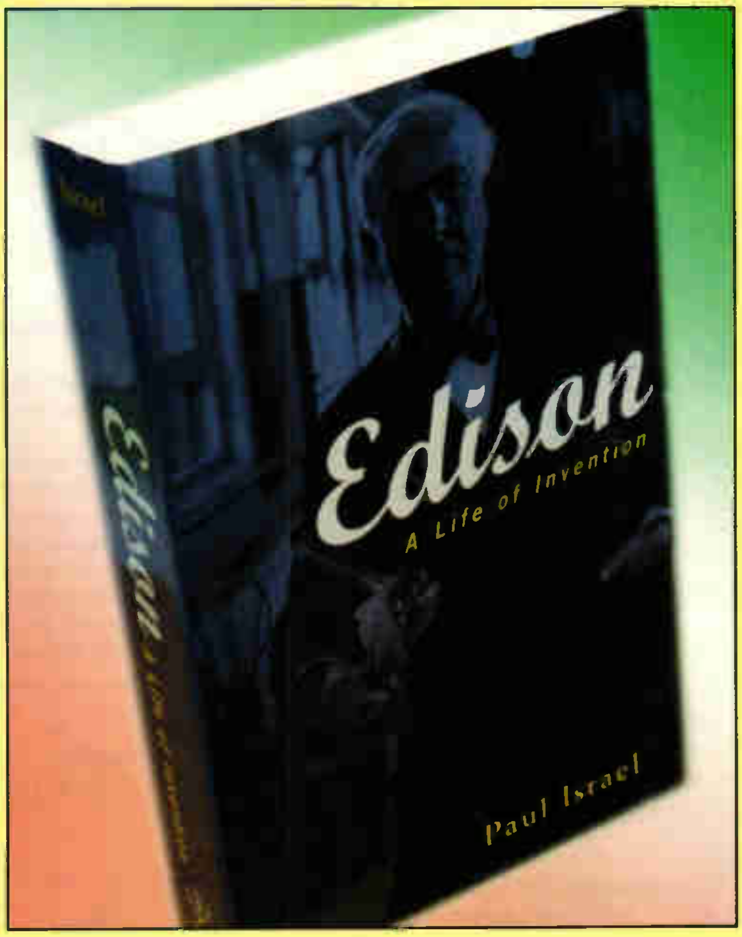

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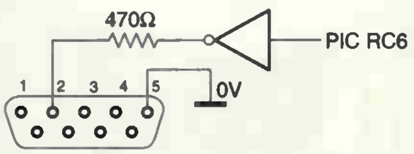


Fig.14. 9 pin 'D' female serial connection. Viewed from the solder side, pin 2 receives data from the PIC while pin 5 is ground.

to the data overhead and with the low data rate available this would be unacceptable.

Instead, the software decoder relies on the fact that only a correctly received packet that is properly synchronised will pass the CRC check.

To establish synchronisation, the PIC software looks for the '1' code – i.e. a prefix bit. Once this is found, the following 49 bits are loaded and the CRC test is applied.

If the packet fails the CRC test then the software will continue to attempt to re-synchronise with the transmission. This is achieved by first searching through the stored data looking for another binary '1'. Then the following bits are moved along (bit shuffle) and the requisite number of bits are read in to restore the number of bits in memory to 50. Finally, the CRC test is applied again.

The process is repeated until a packet of 50 bits passes the CRC test. If for some reason the CRC test subsequently fails on a packet of data then the synchronisation process defined earlier will take place again.

Once the 50-bit packet in memory passes the CRC check and the application code is '0000' you can be confident that time data packet 29 has been found. Any packets with a different application code are discarded.

If the PIC software fails to receive a time packet at the appropriate time then the internal PIC clock software updates the display. A decimal point appears, indicating that this has happened.

The internal software clock is accurate enough to maintain the correct time for many hours should the radio data fail for some reason.

Setting up the radio

It is possible to set the radio up by experimentation. First, the antenna coil former has to be adjusted for maximum signal strength. Once a suitable spot on the ferrite is found the tun-

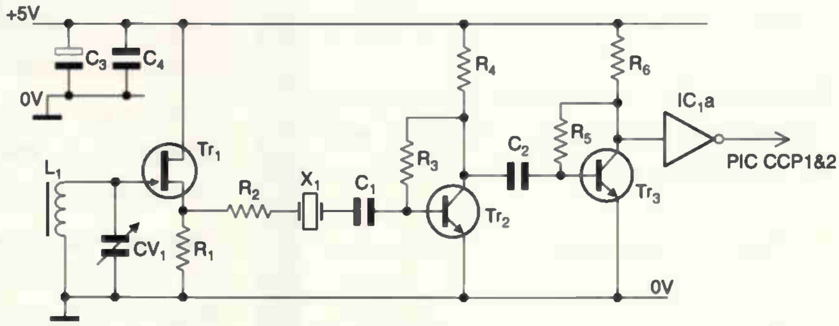
Technical support

A programmed PIC 16F877 and the Windows 95/98 PC software is available from the author at £20.00 fully inclusive. Write to Roger Thomas at 24 Slave Hill, Haddenham, Aylesbury, Bucks HP17 8AZ. E-mail jackie.lowe@rbi.co.uk for a copy of the hexadecimal listing as text.

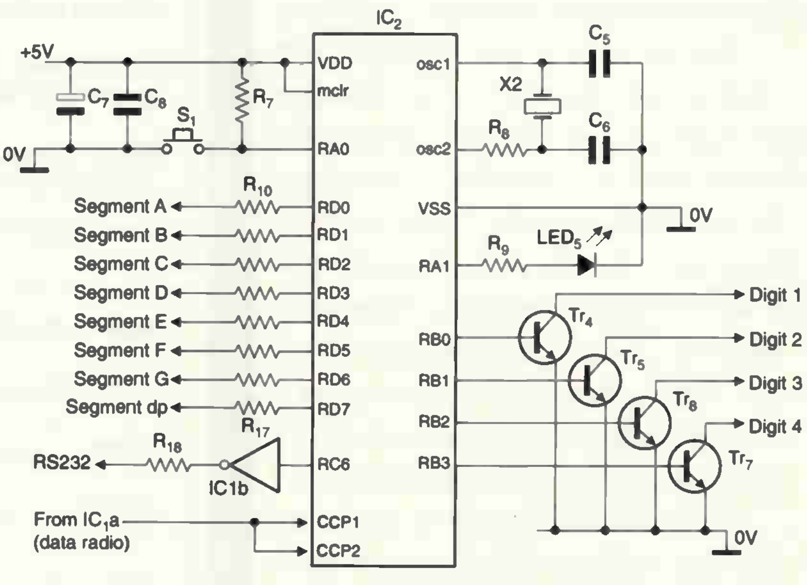
Components

L_1	LW ferrite antenna *	[data radio]
CV_1	tuning capacitor *	[data radio]
$C_{1,2}$	1nF ceramic	[data radio]
C_3	10µF electrolytic	[data radio]
C_4	10nF ceramic	[data radio]
$C_{5,6}$	15pF ceramic	[PIC circuit]
C_7	100µF electrolytic	[PIC circuit]
C_8	10nF ceramic	[PIC circuit]
R_1	2.2kΩ	[data radio]
$R_{2,4,6}$	4.7kΩ	[data radio]
$R_{3,5}$	180kΩ	[data radio]
R_7	120kΩ (time-zone sel.)	[PIC circuit]
$R_{8,18}$	470Ω	[PIC circuit]
R_9	680Ω (sot)	[LED display]
$R_{10\text{-}17}$	*see text*	[LED display]
$LD_{1,2,3,4}$	7 segment LED display	[LED display]
LED_5	led (time zone select)	[LED display]
Tr_1	2N3819 JFET	[data radio]
$Tr_{2,3}$	BC549C NPN	[data radio]
$Tr_{4,5,6,7}$	NPN transistor *see text*	[LED display]
S_1	mom. push to make	[LED display]
IC_1	74LS14 (buffer)	[PIC circuit]
IC_2	PIC 16F877-20 †	[PIC circuit]
X_1	198kHz crystal	[data radio]
X_2	20MHz crystal	[PIC circuit]

* Maplin Electronics.
† Programmed PIC 16F877 available from author.
‡ 198kHz crystal was from AEL Crystals Ltd, Module D Airtech, 2 Jenner Rd, Flemming Way, Crawley, West Sussex RH10 2GA.



Complete circuit of the Radio Data receiver, above, and decoder, below. It is best to keep the receiver and controller circuit separate and to mount them in individual screened enclosures.



ing capacitor is used to peak the response. The orientation of the ferrite with regard to the Radio 4 transmitter will also influence the signal strength.

During this set up process it may be necessary to reset the PIC software so that it can re-calibrate itself. A software reset can be generated at any time by holding down the time zone select switch for approximately 5 seconds. This calibration process sets up all the following measurements and comparisons. If the tuning is subsequently changed then the software may reject packets that would otherwise be acceptable.

The data radio's ferrite antenna should be kept some distance from the data radio and PC to prevent radiated noise being picked up by the antenna. It is notoriously difficult to predict where the best relative position of the data radio, antenna and PC should be as the PC and monitor can generate radio interference.

CRC errors

Most failed CRC packets received can be traced to electrical interference caused by switching on or off of household appliances. This either causes a glitch on the electricity supply or a burst of radio interference. Local lightning can cause reception errors.

With long wave there is little fading of the signal so errors due to adverse radio propagation are rare. I have left the prototype switched on all day without receiving any errors.

PC software

The PC software is beyond the scope of this article, but it is available separately, as detailed in the panel entitled 'Technical support'. It checks the binary data received from the data radio using the same CRC method as used within the PIC software, **Fig. 15**. This ensures the integrity of the communications link between the radio and PC.

Initially, data from the PIC is not synchronised and can start at any point within a data packet. This may give rise to several CRC or prefix errors until the PC software is synchronised to the transmission. Once the PC software is synchronised it may then take up to a minute before the time data packet is received.

Once 50 bits have been received from the PIC, the first bit – the prefix bit – is checked. It should be a binary '1'. If not then all the bits are moved along (bit shuffle) until a '1' is found in the first bit position.

Next, the appropriate number of bits is read from the serial port buffer to make up a packet. This block of data is then passed to the CRC test routine. All packets of data correctly received are displayed as a binary pattern in application code order.

The software can automatically update the PC's internal clock when the sync button is pressed (local time). Note that the computer's time display must be set for 24 hour time display. If not then this can be changed using the regional settings menu.

Radio data activity

During certain times of the day, the filler code is seen more often than other data occupying all the available blocks between time packets. At other times, many channel 2 and 14 data packets are transmitted. At night there are more filler codes, but the same kind of data pattern seen during the day is repeated.

It is probable that channels 2 and 14 are the Teleswitching data as the system needs information sent constantly, not just at off-peak times.

Figure 16 is part of the data taken in the evening using the PC Windows software. Software can save the received data as a binary bit pattern to a text file.

Several channels do not have any data activity. Presumably, these have not been allocated. It is a pity that this resource is not being fully used as the radio signal has reliable national coverage.

Clearly the data transmission capability is not being fully utilised otherwise there would not be any need for the number of filler codes to be transmitted. ■

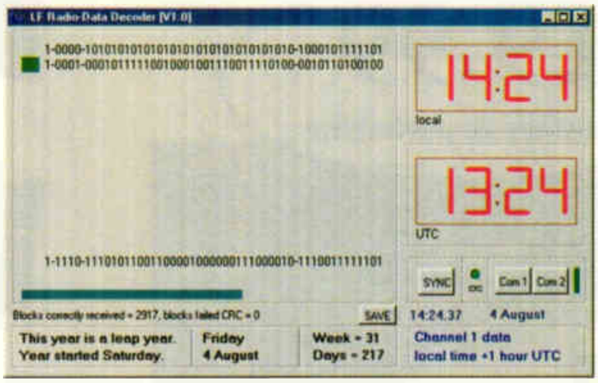


Fig. 15. Using the author's PC Windows software, the entire time packet is decoded and displayed. You can save all the binary data received from the decoder into a text file on disk for later analysis.

Fig. 16. Typical Radio Data transmission showing part of the data captured in the evening using the PC Windows software save data to file function.

```
1-0000-00011001111110110010000000000010-1110010001100 [Friday 1800 UTC]
1-0001-00010111110010001001110011110100-0010110100100 [Channel 1]
1-0001-00010111110010001010000000100110-0001010011111 [Channel 1]
1-0001-00010111110010001101110010101111-0100011010001 [Channel 1]
1-0001-00010111110010001111101101000000-0101101110101 [Channel 1]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0001-00010111110010010000100010100100-0110010000011 [Channel 1]
1-0001-00010111110010010010101101111111-0011000101000 [Channel 1]
1-0001-00011000110010000001110011110100-0000100000100 [Channel 1]
1-0001-00011000110010000001110000111001-0010111001101 [Channel 1]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0001-00011000110010000100110100000000-1011101101010 [Channel 1]
1-0001-00011000110010000111110100100101-0010010011010 [Channel 1]
1-0001-00011000110010001001110011110100-0001010001110 [Channel 1]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0001-00011000110010001010000000100110-0010110110101 [Channel 1]
1-0001-00011000110010001101110010101111-0111111111011 [Channel 1]
1-0001-00011000110010001111101101000000-0110001011111 [Channel 1]
1-0001-00011000110010010000100010100100-0101110101001 [Channel 1]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0001-00011000110010010010101101111111-0000100000010 [Channel 1]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-1110-10101000110001000111010000001111-1110101010010 [Channel 14]
1-1110-10011000000011111001111111100000-1000110010111 [Channel 14]
1-0000-10101010101010101010101010101010-1000101111101 [time filler]
1-1110-10011000000101111001111111100000-1110101101000 [Channel 14]
1-1110-10011001001100010001111111100000-1110101010000 [Channel 14]
1-0000-00011001111110110010000001000010-0100110100111 [Friday 1801 UTC]
```

Note that the PIC software provided in this article is intended for personal use only. Any commercial use is prohibited without the author's explicit written consent.

Listing over page...

Further reading

Radio Data technical information taken from, 'L.F. Radio Data : Specification of BBC phase-modulated transmissions on long wave', December 1984 and 'BBC Long Wave (Low Frequency) Transmissions' information sheet from BBC Engineering Information.

...Continued from p. 967

Radio Code hex listing for the PIC controller

This PIC hex code when programmed into the flash PIC 16F877 allows the decoding and display of the time packet, however this version does not send data to the PC.

When the radio circuit is connected to the programmed PIC the led display will always show the correct time and automatically adjust between changes in BST and UTC. If the time zone switch is incorporated then either BST (local) or UTC time can be displayed.

Microchip's MPLAB assembler software saves the PIC object code in INHX8M format. All numbers are in hexadecimal and each line starts with a colon. After the colon each line starts with the number of data bytes followed by the address and the PIC object code, the last byte is the line checksum.

Use a text editor, such as Windows' Notepad, to enter the hex data as listed. Once the code is typed in then save the data in a file with a hex extension (for example radio.hex).

When programming the flash PIC ensure that the PIC configuration fuse options are set to the following - oscillator mode is set to HS (high speed crystal), watchdog timer is off and power up timer is enabled.

If the PIC programmer is being used in conjunction with the Microchip MPLAB software then select import (import to memory) option from the file menu. Find the appropriate directory and select the radio.hex file.

To view the hex code which will be programmed into the PIC select from the Windows menu the Program Memory option.

```
:020000002728AF
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:1000400071D5D16510E8300D00E500E0900831659
:10005000003088000730 9F00831201309000063086
:10006000970004309D00043083168C00831215081D
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:1000F0000C105C1EA5286B0803198428 6B08A0004F
:10010000 01302002EB008528DD10DD1E8B28053034
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:10012000EB00DD1D97280330EC002630EB005D1D51
:100130009D280230EC002630EB005D1CA328013026
:10014000EC002630EB005D14A72851213121DC1C86
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:10019000E5000030E6000030E7000030E800803085
:1001A000D7000030D8000030D9000030DA0000302D
:1001B000C9000030CA000030CB000030CC00003055
:1001C000CD000030CE000030CF000030AA0000305B
:1001D000AB000030AC000030AD000030AE000030AD
:1001E000AF000030B0000030B1000030B20000308D
:1001F000B3000030B4000030B5000030B60000306D
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:10022000BF00FA30C4000030C500C330DB00C63068
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:10026000 08005C1F4429051C37295C1343295E08DC
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:100300008829E601E70A6708183C031D8829E701E8
:10031000 08000800CF1C0800C701C801CA1E9429A4
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:100330001F30C706CA1FA0290A30C8063E30C706AC
:100340004B1CA6291430C8067C30C706CB1CAC2930
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:080B6000B401B32DC60A080020
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:00000001FF
```

CIRCUIT IDEAS

Fact: most circuit ideas sent to *Electronics World* get published

The best circuit ideas are ones that save time or money, or stimulate the thought process. This includes the odd solution looking for a problem – provided it has a degree of ingenuity.

Your submissions are judged mainly on their originality and usefulness. Interesting modifications to existing circuits are strong contenders too – provided that you clearly acknowledge the circuit you have modified. Never send us anything that you believe has been published before though.

Don't forget to say why you think your idea is worthy.

Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly.

High-fidelity filter for data retrieval

Measurement transducers are usually interfaced with data logging equipment by using a filter to remove unwanted high-frequency noise and prevent aliasing. Although complex filters using conventional analogue or switched-capacitor methods are available, single-pole passive filters are often preferred because of their simplicity and low cost.

Many designers do not realise that transducers often have severe bandwidth limitations and that limiting the frequency response imposes a significant phase lag on the signal. The phase non-linearity can prevent correlation of complex signals.

The circuit shown restores the phase and amplitude of test data stored in digital form. It does so by multiplying the stored distorted signal by the inverse transfer function.

Single-pole filtering of signal V_s produces a signal V, where $V=V_s/(1+sCR)$.

Therefore $V_s=V(1+sCR)$. So to restore the signal V to V_s, it must be multiplied by the function F, where, $F=1+sCR$. This is achieved by the circuit shown, restoring both the amplitude and the phase of the signal.

To test the system, I measured the transfer function of an RC section with R at 10kΩ, C at 4.7μF. The response was –3dB, with 45° phase lag, at 3.4Hz. As corrected by the circuit, the response showed an amplitude variation of +0.2dB maximum out to 18Hz, and a phase lag of 1.5° at 3.4Hz, 10° at 12Hz.

Components R_1,C_1 and C_2 were added to remove high-frequency noise from a d-to-a converter's output. Such noise is minimised by using a high sample rate and high resolution converter, to avoid any large changes between sample values.

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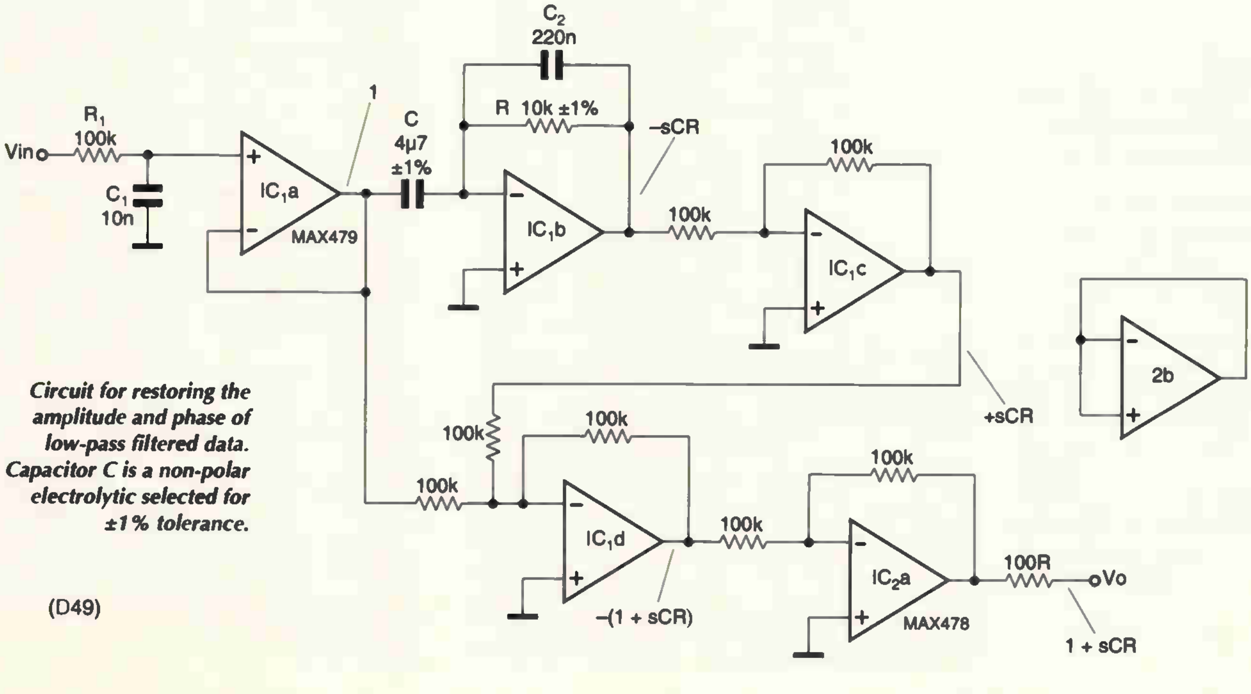
D49



Circuit for restoring the amplitude and phase of low-pass filtered data. Capacitor C is a non-polar electrolytic selected for ±1% tolerance.

(D49)

Single gang potentiometer tunes Wien Bridge

A Wien-type network can be modified to give smooth change of the zero-phase-shift frequency F_0 at constant attenuation by varying a single resistance.

In the diagram C_1, C_2, R_1, R_2 form the basic Wien bridge reactive arms. It is convenient to make $C_1=C_2$, $R_1=R_2$, giving,

$$F_o = \frac{1}{\sqrt{2\pi C_1 R_1}}$$

Added resistances *A*, *B* enable tuning to be adjusted by *P*. When *P=0*, resistor R_2 is connected to R_1 and the network reverts essentially to its basic form. Resistors *A* and *B* both now come in series with the nominally infinite amplifier input impedance and so have no effect.

When *P* is finite, F_o falls. The new, reduced frequency is the basic F_0 divided by $\sqrt{(1+M)}$ where *M* is the ratio of the equivalent resistance of *A*, *B*, *P* to R_2.

Normally the circuit attenuation would change as *P* was varied but for one special tapping point on *A*, *B* the attenuation is constant. With equal *C*s and *R*s in the basic network, this tapping is when *B=2A*; the attenuation factor is then constant at *3*.

To avoid loading the network, the amplifier must be a FET-input type, preferably with a low input capacitance. To set up, first make *P=0* and adjust R_3/R_4 for weak oscillation. Leaving R_3/R_4 as set, adjust *P* to maximum resistance and adjust *A*/*B* for weak oscillation. These settings should hold good for all values of *P*, but if the input capacitance of the amplifier causes a dip at some point make a slight readjustment of R_3/R_4.

The values indicated give a tuning range of approximately 500-6000Hz. This represents about the practical limit of frequency sweep .

To avoid the effects of cramping at the hf end, add a fine tuning resistance of a few kilo-ohms in series with *P*. Any smaller amount of frequency sweep can be set by appropriate choice of *A*, *B* and *P*. This makes the arrangement useful for fine-tuning conventional Wien bridge oscillators.

The arrangement is also usable for some other types of *RC* oscillator. It is even more useful in selective amplifiers where consistent performance can be obtained over a range of frequency.

George Short
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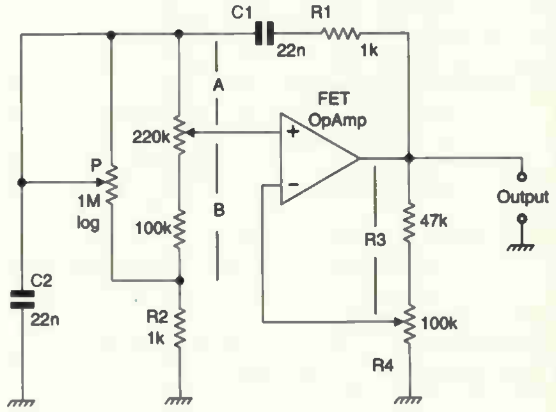
E25



A single-gang potentiometer tunes a Wien Bridge oscillator in this novel circuit.

Simple reversing battery charger

These simple circuits charge primary cells using the periodic current-reversal method. In the left-hand circuit, the 555 oscillates at 50Hz.

When the output, pin 3, goes high, the forward pulse current passes through the cell, charging it. When the output goes low pin 3 is pulled to ground and a reverse current pulse flows from the battery discharging it, thus giving a periodic current reversal cycle.

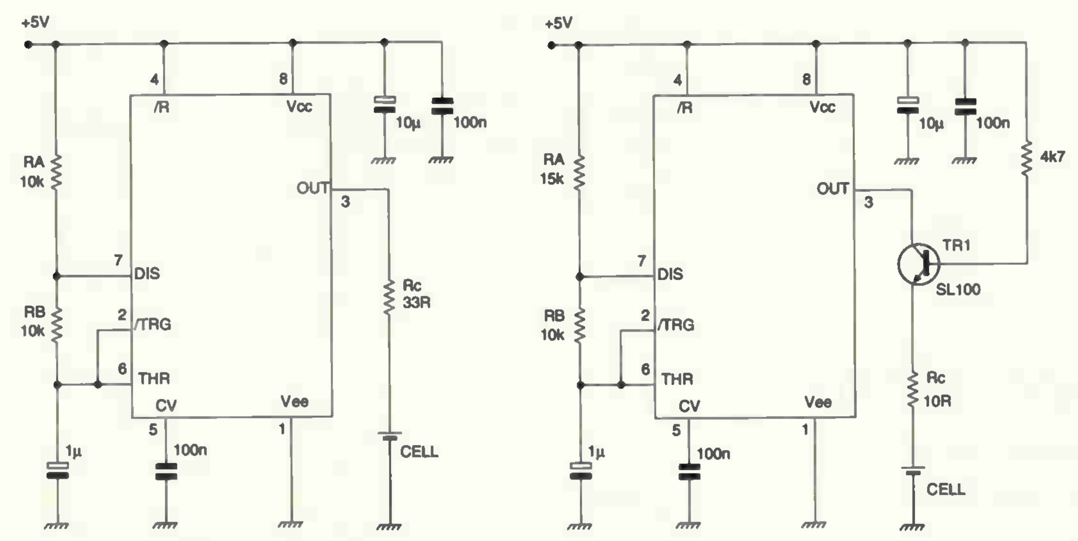
The cell may discharge through the 555 if the supply is switched off. The right-hand circuit overcomes this. It is similar to an earlier circuit on page 322, of *Electronics World* April 1998 issue, but it takes advantage of an inherent 'reverse transistor' mechanism to provide a PCR cycle.

When pin 3 goes high, the base emitter junction of Tr_1 is forward-biased and a forward current flows from collector to emitter, charging the cell. When pin 3 goes low, the collector is pulled to ground and thus the base-collector is forward-biased and the transistor works in the inverted mode. Thus a reverse current pulse flows from emitter to collector discharging the cell, giving a PCR cycle. In the absence of the supply, the base-emitter is reverse-biased preventing discharge.

These circuits were designed for zinc chloride cells. For alkaline cells, increase current by reducing R_c and alter the duty cycle by changing R_a and R_b. The type of transistor used is important.

A locally-made SL100 was used as it performed better than the usual 2N2219.

Dantes John
Kerala
India
E32



Simple reversing charger, left, and a modified version that won't discharge the battery if the power supply to the 555 is turned off. If you implement this circuit, be aware that primary cells can explode or leak under certain circumstances so take necessary precautions. Don't use recharged cells in valuable equipment that could be damaged by leakage.

Adding four hard drives to your PC

Most people are accustomed to thinking that PCs accept at most two hard-disk drives. However, Linux users can use all four IDE (Integrated Drive Electronics) ports, enabling a maximum of eight autotune IDE hard disks.

The port addresses are as shown in **Table 1**, where the CS3FX for ports 3, 4 are undocumented – at least in available manuals. As is obvious from this data, inter-changing A_3 and A_4 converts a primary or secondary port into a tertiary or quaternary port. Any

Continued on page 974...

Routine for detecting hard-disk drives.

```
Program id; uses dos; (*Turbo IDE identification. ©Jonah Faber 1999*)
var i,sel,drv: byte; status,clear: shortint; IDE,x,y,z,u: word; data:interger;
const ma_select=$A0; sl_select=$B0;
day; array[0..6] of string[3]=('Sun', 'Mon', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat');
procedure wait(count:word); var R: registers; begin
      with R do AX:$8301; intr($15,R); clear:=0;
      with R do begin AX:=$8300; BX:=ofs(clear);
      CX:= count; DX:=0; ES:=seg(clear) end;
      intr($15,R)
end;
procedure delay(count:word (* in units of 65.6 msec *) ); begin
       wait(count); repeat status:=port[IDE+7] until (clear<0) or (status>=0)
       end;  (* This enables I/O redirection, Turbo Pascal's own delay() no *)
begin getdate(x,y,z,u);
write(#13#10, 'Hard Drive Detection on ', day[u], ' ', y, '-',z,'-',x mod 100);
gettime(x,y,z,u); writeln(' ' , x, ':', y div 10, y mod 10, '…');
for drv:=0 to 7 do
      begin
           if odd(drv) then sel:=sl_select else sel;=ma_select;
           case (drv and 6) of
                0: IDE:=$1F0; 2: IDE:=$170;
                4: IDE:=$1E8; 6: IDE:=$168
           end;
           port[IDE+6]:=sel; status:=port[IDE+7];
       if status<0 then begin
           port[IDE+6]:=sel; port[IDE+$206]:=4; delay(1);
           if status<0 then       (* sometimes expects command after reset *)
                begin port[IDE+6]:=sel; port[IDE+$206]:=2;
                port[IDE+7]:=0; delay(1)
           end
           end;                                         (*The crux of this code is just *)
           if status>=0 then begin                      (* assume that drive is reset   *)
                port[IDE+6]:=sel; port[IDE+$206]:=2;    (*IDE[6]:=A0 (B0 if slv)        *)
                port[IDE+7]:=$EC;                       (* IDE[206]:=2; IDE[7]:=EC      *)
                delay(20);                              (* wait half a second           *)
                write('hd'+chr(97+drv)+': ');           (* read 256 words from IDE[0]   *)
                if (status and 1)=1 then writeln('command not supported (cdrom?)')
                else if (port[IDE+7] and 8)<>8 then writeln('???')
                else for I:=0 to 255 do begin
                     data:=portW[IDE]; case i of
                          0: if data<0 then write('ATAPI ');
                          1, 3, $36, $37: write(data,'/');
                          6, $38: write(/data/,' ');
                          $15: write(data div 2, 'kB cache ');
                          $1B..$2E: if data<>$2020 then write(chr(hi(data)),chr(lo(data)));
                          $50: if data<>0 then write('ATA-',data,' ');
                          $52: if odd(data) then write ('SMART');
                          $30: write(' '); $FF: writeln
                     end
                end
           end
      end
end.

Hard Drive Detection on Mon 10-4-99 10:33…
hda: 872/16/36 96kB cache H3256-A3 872/16/36
hdb: ???
hdc: command not supported (cdrom?)
hdd: ???
hdg: 8354/16/63 512kB cache ST34310A 8354/16/63 ATA-30 SMART
hdh: ???
```

National Instruments sponsors Circuit Ideas

National Instruments is awarding over £3500 worth of equipment for the best circuit ideas.

Once every two months throughout 2000, National Instruments is awarding an NI4050 digital multimeter worth over £500 each for the best circuit idea published over each two-month period. At the end of the 12 months, National is awarding a LabVIEW package worth over £700 to the best circuit idea of the year.*

About National Instruments

National Instruments offers hundreds of software and hardware products for data acquisition and control, data analysis, and presentation. By utilising industry-standard computers, our virtual instrument products empower users in a wide variety of industries to easily automate their test, measurement, and industrial processes at a fraction of the cost of traditional approaches.

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Our company is best known for our innovative software products. The National Instruments charter is to offer a software solution for every application, ranging from very simple to very sophisticated. We also span the needs of users, from advanced research to development, production, and service. Our flagship LabVIEW product, with its revolutionary, patented graphical programming technology, continues to be an industry leader. Additional software products, such as LabWindows/CVI, ComponentWorks, Measure and VirtualBench, are chosen by users who prefer C programming, Visual Basic, Excel spreadsheets, and no programming at all, respectively.

Hardware

Our software products are complemented by our broad selection of hardware to connect computers to real-world signals and devices. We manufacture data acquisition hardware for portable, notebook, desktop, and industrial computers. These products, when combined with our software, can directly replace a wide variety of traditional instruments at a fraction of the cost. In 1996 we expanded our high-performance E Series product line in PCI, ISA and PCMCIA form factors, shipped our first VXI data acquisition products, and added remote (long-distance) capabilities to our SCXI signal conditioning and data acquisition product line.

Our virtual instrumentation vision keeps us at the forefront of computer and instrumentation technology. National Instruments staff works actively with industry to promote international technological standards such as IEEE 488, PCMCIA, PCI, VXI plug&play, Windows 95/NT, and the Internet. More importantly, we integrate these technologies into innovative new products for our users.

*All published circuit ideas that are not eligible for the prizes detailed here will earn their authors a minimum of £35 and up to £100.

NI4050

The NI 4050 is a full-feature digital multimeter (DMM) for hand-held and notebook computers with a Type II PC Card (PCMCIA) slot. The NI 4050 features accurate $5^1/_2$-digit DC voltage, true-rms AC voltage, and resistance (ohms) measurements. Its size, weight, and low power consumption make it ideal for portable measurements and data logging with hand-held and notebook computers.

- DC Measurements: 20mV to 250V DC; 20mA to 10A
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...continued from page 972

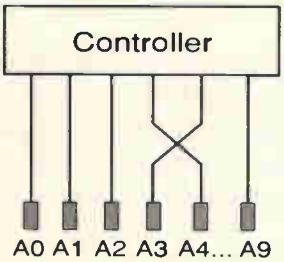
(E)ISA or VL bus IDE controller card can therefore be converted to a tertiary of quaternary IDE port by cutting the A_3 and A_4 lines, cross-linking jumpers, and mapping the interrupt request pin to IRQ_{10} or IRQ_{11} as shown in **Table** 2.

The MCA and PCI buses are address-data multiplexed and therefore not applicable.

A test program is included.

J Farber
Tel Aviv
Israel
D85

Windows should see the extra drives too. Ed.



Modifying the A3 and A4 lines to accommodate extra hard drives on the PC.

Circuit ideas winners

The winner of the final National Instruments digital multimeter, to be chosen from the November and December issues, will be announced in the January issue. The overall winner from the year – who will receive the £700 Labview package – will be chosen shortly after and announced in the February issue.

Table 1. Port addresses for PC hard-drive access.

Port	UNIX device	CS1FX	CS3FX	INTR
primary	/dev/hda	1F0	3F6	14
	/dev/hdb			
secondary	/dev/hdc	170	376	15
	/dev/hdd			
tertiary	/dev/hde	1E8	3EE*	11
	/dev/hdf			
quaternary	/dev/hdg	168	36E	10
	/dev/hdh			

*conflicts with COM3

Table 2. Which lines need to be crossed is determined by whether you are using standard IDE or Vesa local bus.

Bus	A3 pin	A4 pin
ISA	A28	A27
VLB	B39	A37

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Specifications

Switch position 1

Bandwidth	DC to 10MHz
Input resistance	1MΩ – i.e. oscilloscope i/p
Input capacitance	40pF+oscilloscope capacitance
Working voltage	600V DC or pk-pk AC

Switch position 2

Bandwidth	DC to 150MHz
Rise time	2.4ns
Input resistance	10MΩ ±1% if oscilloscope i/p is 1MΩ
Input capacitance	12pF if oscilloscope i/p is 20pF
Compensation range	10-60pF
Working voltage	600V DC or pk-pk AC

Switch position 'Ref'

Probe tip grounded via 9MΩ, scope i/p grounded

BEGINNERS' CORNER

Negative-resistance oscillator

There is a host of different radio-frequency oscillator configurations – Hartley, Colpitts, Clapp, Butler, Franklyn, Pierce and Meissner to mention just a few. But one of the simplest – and one capable of very good performance – is the negative-resistance oscillator. Ian Hickman dissects it, and shows you in simple terms exactly how it works.

In the early days of wireless communications, the receiver was a crystal set or coherer, used in conjunction with a spark transmitter – basically a radio-frequency noise generator. This sufficed for signalling at the rate possible with Morse code.

Modern radio-frequency communications on the other hand would be impossible without high-quality RF oscillators. These produce a single frequency, like a monochromatic spectral line in optical terms, unlike the broad range of frequencies in white light, or in a spark.

There are many different oscillator configurations. Some work best with an *LC* network as their frequency determining element. These involve an inductor and capacitor 'tank circuit'. Others lend themselves to having a quartz crystal as their frequency-determining element.

Whatever the type of oscillator, the frequency-determining part will have associated losses. These must be continually made up, to maintain a constant amplitude output signal.

Most 'maintaining circuits' can be considered, as in the case of the oscillators mentioned above, as an amplifier whose input is derived from the tank circuit, and whose output is fed back into it. Thus the amplifier works as a three-terminal device, with collector, base and emitter – or drain, gate, source; anode, grid, cathode, etc. – all connected to the tank circuit.

Negative-resistance oscillators

The losses in the tank circuit can be considered as a resistance, in parallel with a tuned circuit made with an ideal loss-free inductor and capacitor.

If a resistance that is equal in value to the loss resistance but opposite in sign is connected in parallel, this 'negative resistance' exactly cancels out the loss resistance. Now, a steady oscillation can be maintained in the tank circuit.

One suitable negative-resistance device is the tunnel diode. It can be used to make amplifiers or oscillators up to microwave frequencies.

Unlike the transistor, the tunnel diode is strictly a two-terminal device. But a circuit can also be devised such as to use a transistor as a two-terminal negative resistance. To see just how, it is necessary to investigate how a transistor works in just a little more detail than usual.

Alpha, beta, etc.

Figure 1 shows conventional current flowing into the emitter of a p-n-p transistor, and most of it coming out again at the collector. The ratio of collector current to the emitter current is denoted by α. It is typically 0.99, and often even closer to unity.

The base current, I_b, is the small difference between the emitter and collector current. Greek letter β denotes the ratio of the collector current to the base current.

A line or two of algebra produces the result,

$$\beta = \frac{\alpha}{1-\alpha}$$

But note that $I_e=I_b+I_c$ is only true as far as an arithmetic sum is concerned.

Kirchhoff's First Law states that the

In this series

As explained in a preliminary article in the May 2000 issue, this series is intended to help students – and anyone interested in getting to grips with RF design – gain a background in practical electronic circuitry and troubleshooting.

Originally, the series was developed in response to the government's RF Engineering Education Initiative. Below is a list of the tutorials that have already appeared.

Due to the popularity of the articles so far, Ian is currently working on further tutorials, to be announced next month.

1 Timer circuit using the 555, June 2000 issue
2 Audio oscillator – Wien bridge based, July issue
3 h_{fe} tester, August.
4 Radio-frequency oscillator, Colpitts type, September.
5 Audio frequency filter/oscillator – state variable based, October.
6 Capacitance meter, November.
7 Radio-frequency oscillator/receiver involving negative resistance, this issue.

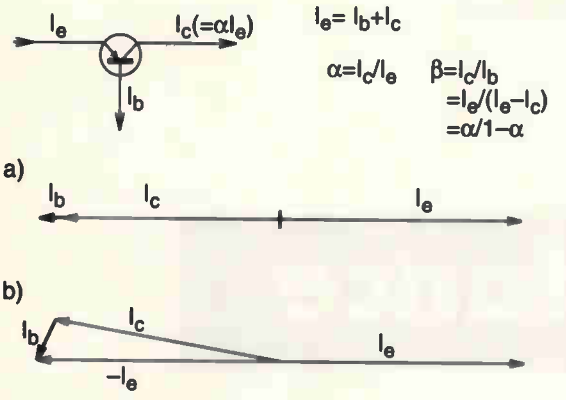

Fig. 1. Most of the emitter current comes out again at the collector, just a little at the base, a). Collector current takes time to get through, so at high frequencies it comes out lagging, b).

algebraic sum of the currents at any node is zero, $I_e+I_b+I_c=0$. So in fact $I_e = -(I_b + I_c)$. When analysing a circuit, I always have to think very hard about just which way this or that current is flowing.

The relationships above apply at DC (0Hz), and β is usually denoted nowadays by h_{FE}. They also apply to small *changes* in current at low frequencies.

Such changes would be caused, for example, by small-signal sinewaves that result in variations of a few percent around the standing collector current. In this case, β is usually known as h_{fe}.

In **Fig. 1**, vector diagram **a)** shows what is going on: the length of the emitter current vector is equal to the sum of the lengths of the other two, but in the opposite direction as shown, in order to satisfy Kirchhoff's First Law.

But at much higher frequencies, things start to get a little more complicated. The current injected at the emitter has to travel through the base region before appearing at the collector.

In the case of a p-n-p transistor, as in Fig. 1, the current is carried by holes. These move rather slower than the electrons which carry the current in an n-p-n device. This is why rf transistors are almost invariably n-p-n types.

Anyway, the net result is that the collector current lags somewhat, as shown in vector diagram **b)** in Fig. 1. But I_b+I_c must still equal $-I_e$, with the result that I_b must be as shown.

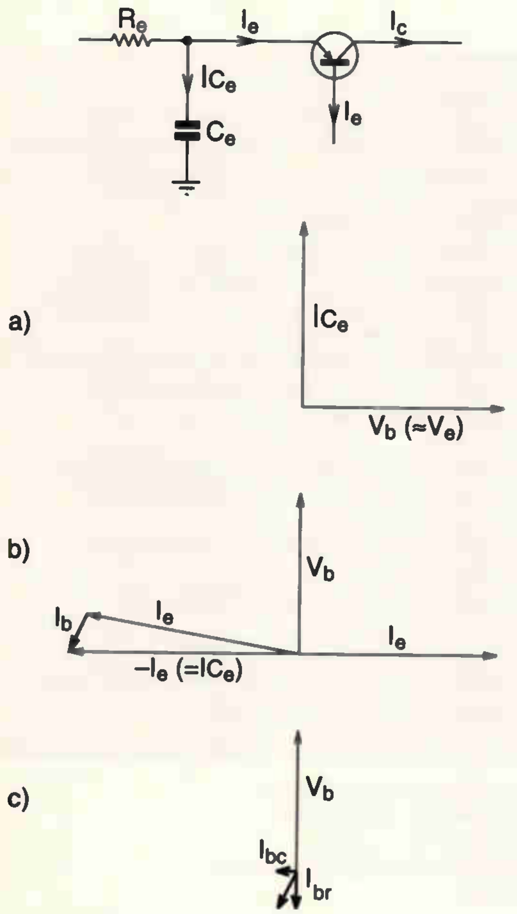

Fig. 2. A capacitor at the emitter draws a leading current, a). As a result, the phase angle between base voltage and base current exceeds 90°, b). With a component of base current in antiphase to the base voltage, the base appears as a negative resistance, c).

Current that flows the wrong way

Figure 1 shows what happens to the relative phases of the currents in the transistor's three leads, as frequency rises. But that is only half the story. One needs to take into account the terminal voltages as well.

Figure 2 shows a transistor just like Fig. 1, but with a capacitor, C_e, connected between its emitter and ground.

Imagine a small high-frequency sinewave connected to the transistor's base terminal. Due to the high transconductance of a transistor, the emitter voltage will, to a first approximation, be the same as the base voltage. This voltage will appear across C_e, causing a leading current of magnitude determined by the reactance of C_e at the frequency concerned.

Assume for the moment that R_e is a very high resistance, returned to a very high voltage – it is there just to provide the necessary standing emitter current to make the transistor work. This being a very high-value resistance, the voltage variations at the emitter will have negligible effect on the current through it. So it can be regarded as open circuit, from the a.c. point of view, as shown.

Figure **2a)**, then, shows V_e – approximately equal to V_b – and the resultant current through C_e. Clearly, and according to Kirchhoff again, I_{ce} must equal $-I_e$, since it is flowing away from the emitter, not into it. You probably see what I mean now about the necessity of keeping careful track of which way the currents are flowing.

So rotating the vector diagram of Fig. 2a) by 90° anticlockwise, and overlaying I_{ce} on $-I_e$, V_b will appear as shown in Fig. **2b)**.

Note that I_b is almost in the opposite phase to V_b. Figure **2c)** shows it resolved into two components – a capacitive component I_{bc} in quadrature with V_b, and a resistive component I_{br}. However, instead of the current I_{br} being in phase with V_b, it is in antiphase.

When the base voltage rises, instead of current flowing into the base as it would into a resistance, it floods out at us, and flows *into* the base when the base voltage falls. In other words, looking into the base, one sees a negative resistance.

Putting negative resistance to work

Figure 3 shows a transistor with a capacitor from its emitter to ground, and its base connected to an *LC* tank circuit. Via this, the base is dc referenced to ground, while the R_e is 4.7kΩ. Here, R_e is returned to −15V, as the transistor is an n-p-n type, that common or garden favourite in a TO92 plastic housing, the BC184.

The BC184 sample chosen proved quite typical, having an h_{FE} of 300 at 3mA – the operating current of circuit Fig. 3. Due to the way the circuit works, as a two terminal negative resistance oscillator, the collector plays no part in circuit action, and is simply decoupled to ground.

To monitor the circuit action, a tap was made on the inductor at three quarters of a turn up from ground. This tap was connected to the 50Ω input of a spectrum analyser via 50Ω coaxial cable.

With C_e formed by a 1.8pF capacitor, the 5–65pF trimmer tuned the circuit over 85–180MHz. Providing a good output over most of this range, the amplitude dropped off markedly towards the lower end, the circuit ceasing to oscillate at maximum capacitance of the trimmer.

Clearly, 1.8pF was sub-optimal, so it was increased to 3.9pF. The oscillator then tuned over the whole range of the trimmer, covering 64–167MHz. The maximum frequency is reduced, due to the larger I_{bc} (see Fig. 2) adding additional stray capacitance across the tank circuit. Output level to the spectrum analyser was +6dBm over most of the range, falling to +4dBm at 167MHz and 0dBm at 64MHz.

Figure 4 shows the +6dBm 100MHz output, with the second harmonic 36dB down, the third 48dB down, the fourth 57dB down and the fifth 70dB down.

Figure 5 shows the output at a much greater dispersion, just 5kHz per division. The shape of the response is little different from that of the analyser's internal filter, showing excellent spectral purity and short term stability.

In fact, the trace is identical to that produced by my Marconi 2022E synthesised signal generator, set to the same output frequency, although of course the latter did not exhibit the typical long term frequency drift of the Fig. 3 circuit.

Building the circuit

For a one-off experimental circuit like this, construction is best done on a scrap of copper-clad board, used as a ground plane. I wound the coil on the shank of a 5.4mm twist drill, for no better reason than that it happened to be lying on my bench.

Wind the four turns tightly together with no gaps between. Turn the two ends at right angles to the turns, parallel to the axis of the coil and snip to a couple of centimetres in length.

Now gently pull the ends apart enough to finish up with half a wire thickness spacing between the turns. Bend one end at right angles at 3mm from the last turn, and solder it to the ground plane, with the coil's axis vertical.

A yellow Mullard 5-65pF trimmer is convenient, with the two legs connected to the moving plates soldered to the ground-plane. Solder the tag from the fixed plates to the free end of the coil, a couple of millimetres above the top turn. Used like this, with a metal tipped plastic tuning tool, there will be no problem with 'hand capacity' altering the frequency when tuning.

Remaining components should be carefully arranged so that all wiring consists of component leads. The only wire you need is for the coil, and of course three supply leads.

Mount the 4.7kΩ resistor between two small capacitors, with leads snipped short, soldered to the ground plane and used as component anchoring points. Likewise, the transistor's base and collector leads are supported on the coil, and a 10nF capacitor respectively. Try to keep all leads *very* short.

Testing the circuit

If you are a student, you will probably be able to arrange access to a spectrum analyser in your college electronics lab.

You can use an oscilloscope with a bandwidth of 100MHz or more if you can't get hold of a spectrum analyser. In this case, do not bother with the tap on the coil. Simply place the tip of a ×10 passive divider probe – with insulating sleeve spring hook – close to, but not actually connected to, the circuit.

On either instrument, the output can be monitored, though only the spectrum analyser will tell you the output level.

If you have no access to either type of instrument, a little ingenuity will suffice. Stand a portable transistor radio, with its telescopic aerial deployed, on the bench near the circuit.

With the radio tuned anywhere in Band II, tuning the oscillator through its range should, at some point, completely silence the background hiss. It may even silence the programme material, if the radio was tuned to a station. The odd 2cm of wire sticking up from the top turn should prove a more than adequate radiator.*

Alternatively, a portable TV can be pressed into service. With the set tuned to the bottom of Band IV-V,

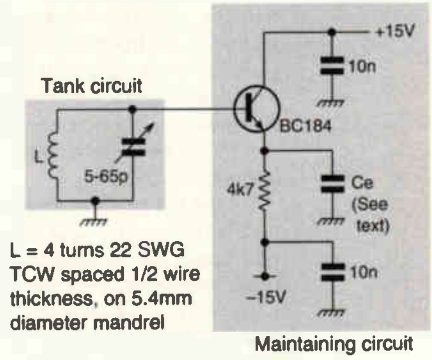

Fig. 3. A negative resistance oscillator is extremely economical on components!

*Carry out these tests as quickly as possible. Bear in mind that you might also be silencing someone else's radio too – or worse. Ed.

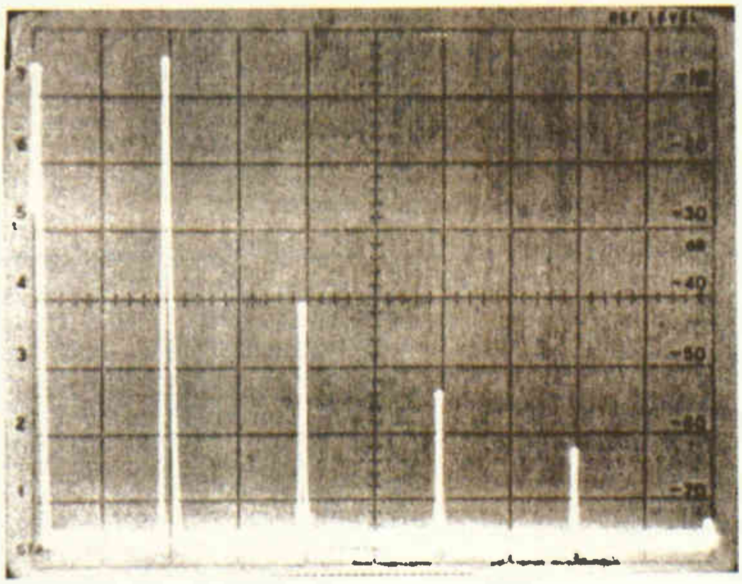

Fig. 4. Output of the circuit of Fig. 3, taken from a coil tapping at ³/₄ turn up from ground. 10dB/div. vertical, top of screen reference level +10dB, 50MHz/div. horizontal, 0Hz at left, intermediate-frequency bandwidth 1MHz, video filter off.

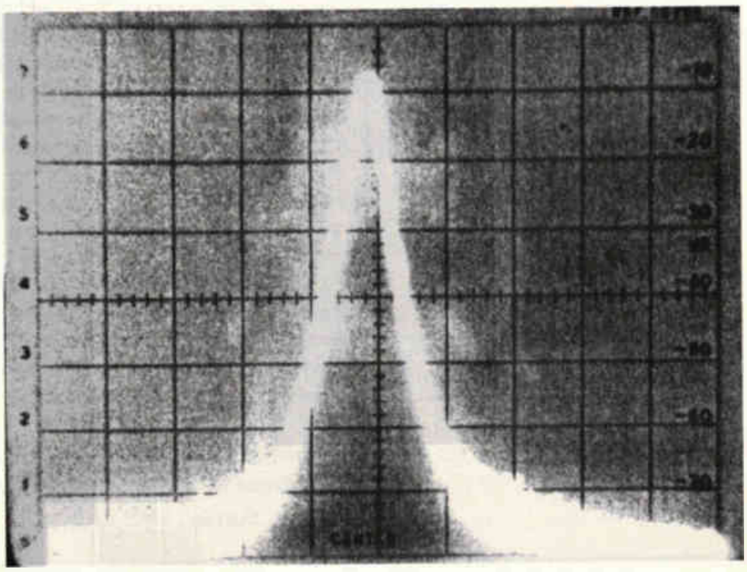

Fig. 5. As Fig. 4, but 5kHz/div. horizontal, centre frequency 100MHz, intermediate-frequency bandwidth 1kHz.

tune the oscillator to somewhere near its maximum frequency, i.e. with the plates of the trimmer out of mesh. The 'snow' on the screen should be replaced by a blank white raster, as the TV picks up the oscillator's third harmonic.

Tuning the negative-resistance oscillator down towards the bottom of it range, the TV should pick up other harmonics, the fourth, fifth and so on. With the oscillator set to its lowest frequency, tuning the TV up the band towards 860MHz should reveal yet other higher harmonics.

It is worthwhile keeping an eye out for a second-hand scanner, as this can be used for the purpose just described, but with a wider coverage than a tranny or TV. It won't tell you as much as a spectrum analyser, but it won't cost as much either, and will still tell you quite a lot.

A scanner can even tell you the frequency of an oscillator operating below the bottom of its tuning range. The frequency spacing between two adjacent harmonics equals the oscillator's fundamental frequency.

For even better performance...

Interestingly, my prototype circuit would oscillate with C_e of zero, but only if the loading due to the tapping was removed. The range then covered was 80-185MHz, monitored with a few inches of wire as an antenna, on the end of the spectrum analyser lead.

With the tap disconnected, the tank circuit runs at a higher Q, i.e. higher dynamic resistance R_d. Thus a higher value of negative resistance suffices to maintain oscillation.

This arrangement should lead to even better spectral purity, and the arrangement is in fact usable – although it might appear not to be – since there is no tap from which to draw an output. The trick is to make use of the collector, which in the circuit of Fig. 3 plays no part.

Instead of returning the collector direct to the well decoupled positive supply, it can be taken instead to the emitter of a another transistor. The base of this is decoupled to ground, making it a 'grounded-base' stage. An output is then taken from its collector.

The circuit now uses the 'cascode' connection. Due to the low input impedance of a grounded-base stage, the arrangement oscillates in just the same way as Fig. 3, and due to the absence of a tap, the tank circuit operates at the maximum possible Q.

Output from the upper transistor will need filtering, so a further tank circuit or a low pass filter will be necessary.

Tailpiece

Here, the explanation of circuit operation has been given in terms of vector diagrams – those exceedingly useful means of clarifying what goes on in a circuit. But each vector represents a *sinewave*. In the case of the diagrams shown, all the vectors are of the same frequency.

My explanation that negative resistance is the cause of oscillation is fair and valid, as far as the *start* of oscillation is concerned. But initially, the value of negative resistance is lower than the dynamic resistance R_d. So the amplitude of the oscillation will build up until non-linearities in the circuit prevent further increase.

The effective value of negative resistance thus rises, until it equals R_d, and the amplitude stabilises at that level. At this level, vector diagrams are no longer valid, as the voltages and currents are no longer sinewaves. Vector diagrams cannot take harmonics into account.

Theoretical analysis of non-linear circuitry becomes very complicated, taking one into Liapunov functions and similar esoteric mathematical regions. But assuming linear parameters, the simple small-signal analysis presented gives a useful, if not complete, insight into the circuit operation. ■

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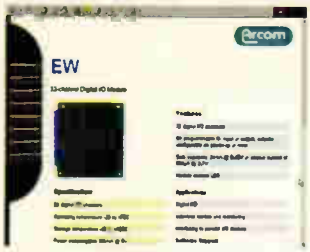

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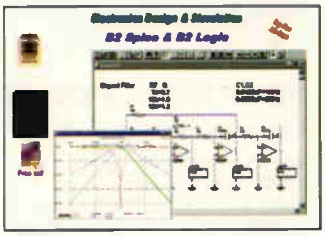

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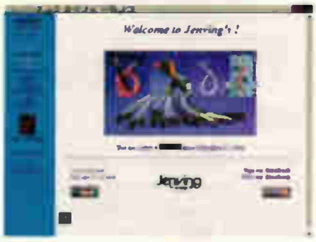

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UK MAILING LIST GROUP

http://www.egroups.com/list/uktvrepair

Following on from the newsgroup discussion last month there is a UK Email group for TV technicians where you can send an Email to everyone in the group. There's just over 30 people in the group at present. For more details and how to register look at the egroup home page. Just a general comment though - you do have to be careful who you give your Email address to so that you can avoid "spamming" - that is getting lots of unwanted Email about dubious Russian site (amongst others).

REED CONNECT

http://www.reedconnect.net/

Another free internet access site, this time from Reed Business Information.

However the site possesses a useful UK People and Business Finder, with an e-mail search. There's also business news and local information, and some good links to directory sites.

REPAIRWORLD

http://www.repairworld.com

Repairworld is a sophisticated US based fault report database which is updated bi-weekly. It operates on a subscription basis and describes itself as an "affordable solution for all technicians". You can see some samples of the material for free, monitors, VCR, DVD and Camcorders being of particular relevance to UK users. The site also provides a "chat room".

Continued from page 925...

Listing 7. Assembler, Main code loop.

```
; ** THE MAIN PROGRAM LOOP STARTS HERE **
Again   Clrwdt          ;Walk the dog
        Call    IRIN    ;Get IR signal from handset
        Bcf     PortA,0 ;Turn off both LEDs
        Bcf     PortA,1
        Movlw   255     ;If IR_DEV=255, look again
        Subwf   IR_Dev,w
        Btfsc   STATUS,z
        Goto    Again
;** Transmit DEVICE code then BUTTON code serially
;** at inverted 9600 baud N-8-1 **
        Movf    IR_Dev,w
        Call    Sout
        Movf    IR_But,w
        Call    Sout
;** If IR_DEV<>1 (TV device code), look Again **
        Movlw   0
        Subwf   IR_Dev,w
        Btfss   STATUS,z
        Goto    Again
;** If IR_But=116 (channel up), illuminate green LED
        Movlw   16
        Subwf   IR_But,w
        Btfss   STATUS,z
        Goto    CH_UP
        Bsf     PortA,1
;**If IR_BUT=117 (channel down), illuminate red LED
CH_UP   Movlw   17
        Subwf   IR_But,w
        Btfss   STATUS,z
        Goto    Exit
        Bsf     PortA,0
Exit    Call    Delay   ;Delay for 10ms (optional)
        Goto    Again
```

PicBASIC Pro's various serial out commands have a lot more tricks up their sleeves. Not only do they allow different baud rates from 600 to 19200 – both inverted and non-inverted – but also output the results as 8 or 16-bit decimal, hexadecimal, binary or ASCII strings. This is ideal for interfacing to the many serially controlled LCD modules on the market.

Task 6

Our final task is to write the main program loop which will call the decoder subroutine, serially transmit both codes, and illuminate the correct LED for a chosen button pressed on the handset.

An assembler version of this is shown in **Listing 7**. Within the loop, the returning values from IRIN are examined. If IR_DEV returns holding 255 then an invalid header was detected so the process is repeated.

If a valid header *was* detected, then both IR_DEV and IR_BUT are transmitted using the Sout subroutine. A check is then made of IR_DEV. If it's not holding a value of one, then it is not a television remote handset, and again, the process is repeated.

If, however, the device code is for a television, IR_BUT is examined, if it holds a value of 16 (channel-up) then the green LED is turned on, and the red LED is turned on if it's holding 17 (channel-down).

The PicBASIC Pro version is shown in **Listing 8**. It has exactly the same function as previously described.

Using the subroutine, IRIN

Both versions of the IRIN subroutine may easily be incorporated into your own programs. A brief outline of the returned variables are,

```
CALL or GOSUB IRIN
IR_DEV returns holding the DEVICE code (0..31)
IR_BUT returns holding the BUTTON code (0..127)
Both IR_DEV and IR_BUT return holding 255 if a
   valid header was not received.
```

In summary

I hope that I've illustrated that to understand both infrared decoding and PIC microcontroller programming, you needn't be a rocket scientist.

Assembly language may never be fully replaced by high-level languages. If you don't mind its steep learning curve and unfriendly form, it still has an edge over higher-level languages if you want to squeeze the last drop of code space and programming speed out of a processor. Assembler is also available free of charge if you know where to look.

All the tools required for software development are downloadable from Microchip's web site. There's also a plethora of data sheets and application notes, downloadable from the same site.

Using a high-level language such as PicBASIC or PicBASIC Pro not only makes programming a more enjoyable experience. It also opens up new areas of electronics that were previously beyond the scope of all but the most advanced enthusiast. Among these are I^{2}C, SPI serial eeprom, analogue-to-digital and digital-to-analogue interfacing. The list is endless.

However, it's not just the enthusiast that can benefit from PicBASIC. Because, both assembler and BASIC may be freely mixed within the same program, extremely powerful and flexible programs may be written.

Such programs can greatly decrease prototyping time, thus reducing the overall costs of a commercial product. After all, time is a precious commodity that should not be wasted

Resources

Further information on infrared encoding and decoding, including a compatible Sony infrared transmitter project may be found in the book, 'Experimenting with the PicBASIC PRO compiler', written by yours truly. This is available via Crownhill Associates' dedicated PicBASIC site at www.picbasic.co.uk.

Furthermore, all the components used in this project are also available from Crownhill at www.crownhill.co.uk – including the infrared sensor and a suitable remote handset, along with the free downloadable source code for both language versions of the infrared decoder. ■

Listing 8. PicBASIC Pro, Main body code.

```
'** MAIN PROGRAM LOOP STARTS HERE **
Again: Low Green_LED:Low Red_LED          'Extinguish both LEDs
       Gosub IRIN                         'Receive an IR signal
       If IR_Dev=255 then goto Again      'Check for valid header
       If IR_Dev<>0 then goto Again       'If not a TV DEVICE code
                                          'then look again
       Serout PortA.3,N9600,[IR_Dev,IR_But] 'Transmit the 2 bytes
       If IR_But=116 then High Green_LED  'If channel up, then green
                                          'LED on
       If IR_But=117 then High Red_LED    'If channel down, then red
                                          'LED on
       Pause 10                           'Delay for 10ms (optional)
       Goto Again                         'Do it forever
```

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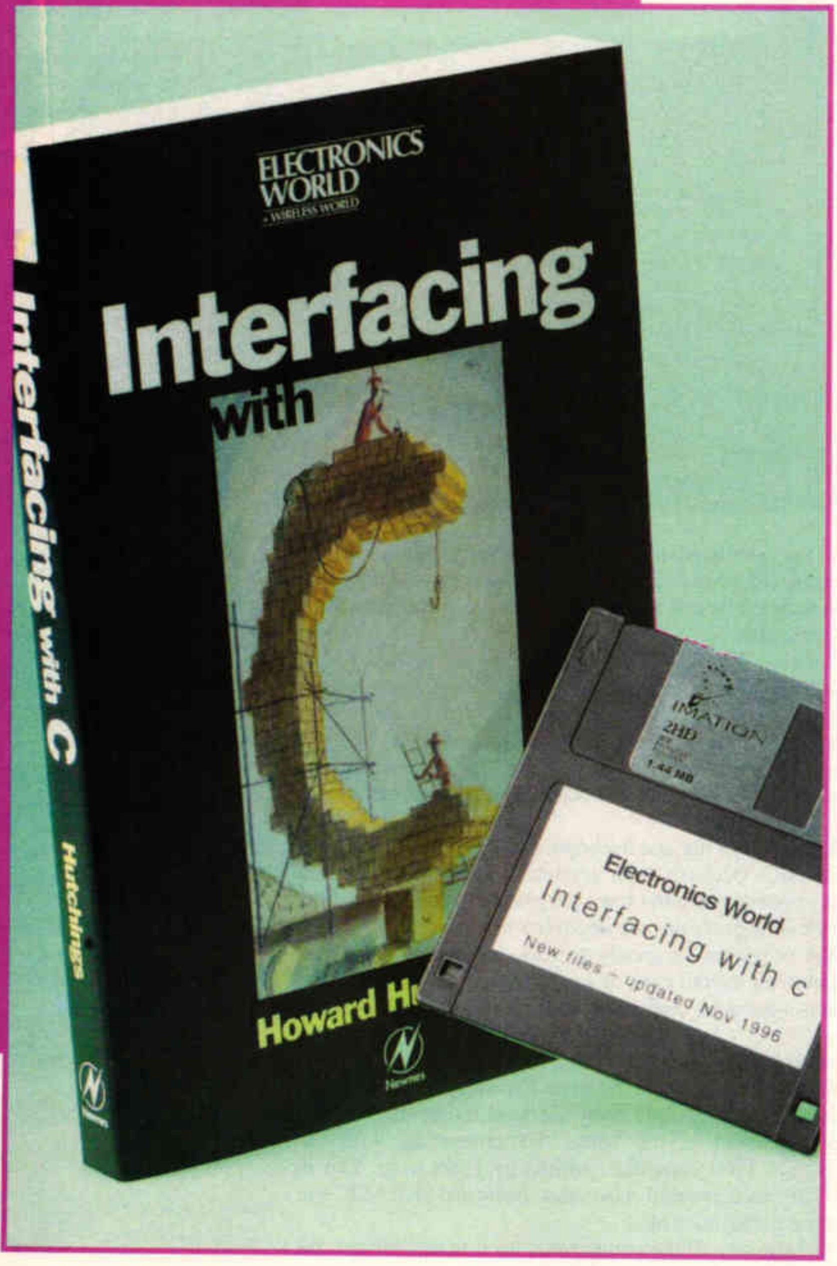

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LETTERS

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

Filters and linearity

In Letters in the August issue, Graham Maynard states that, "Together, 10kΩ+22pF form a low-pass filter that introduces 0.3% harmonic distortion at 2kHz" without explanation.

It defies understanding how a linear circuit can cause nonlinear distortion such as harmonic distortion. It might be possible that the rest of the circuit generates harmonic distortion through some interaction with the filter but under the circumstances described it is hard to see how this might occur.

If the harmonic distortion *does* increase by 0.3% due to the inclusion of the filter, it is likely to be due to sloppy design. The filter will introduce linear distortion. It will affect the frequency response, but this most definitely is not harmonic distortion.

It is also dubious as to whether the filter would produce any audible affect. Few people have much audio sensitivity beyond about 17kHz, and very little phase sensitivity over most of the audio band.

Further, it is ridiculous to fuss over trivial imperfections in power amplifier performance when loudspeakers and their environments are comparatively so deficient.

I warn anybody that might be inclined to listen to music that pushes their amplifiers close to their limits (slew rate or clipping) to enjoy it while it their ears last.

With regard to Jo Atkins suggestion that, "putting half an ohm between amplifier and speaker may suppress this mechanism," I am rather sceptical. Jo should consider that the speaker's voice coil impedance – the nominal 8Ω, which in fact is usually anything but – is already between the amplifier and the back EMF from the speaker. A mere half ohm extra is unlikely to have the desired effect.

Phil Denniss
Dept of Plasma Physics
University of Sydney

Comme une bombe

With reference to the letter on page 799 of the October issue, if French radios started playing "comme une bombe", could they have had directly-heated af output valves. These warm up faster than their indirectly-heated counterparts, commonly used in UK sets. The local oscillator of a superhet normally starts fairly abruptly once its cathode has warmed up. In most UK radios, however, the audio output pentode still hasn't warmed up yet!

At my school, the assembly hymn was sometimes accompanied on a veteran valve electronic organ. If the organist forgot to switch it on in advance, the music would begin 'comme une bombe' at some time during the first verse!

Jeremy Jago
Nottingham

Slew rate matters?

I read with interest the recent exchanges on the subject of slew-rate limiting in audio amplifiers. As long ago as 1982 I built an amplifier using the then new complementary MOSFETs from Hitachi. After some experimentation I settled on a circuit not dissimilar to the Hitachi application circuit.

Basically, this comprised an input p-n-p long-tailed pair driving the main voltage-gain n-p-n long-tailed pair, the latter loaded with a current mirror. This drove the gates of the MOSFETs as source-followers with just a preset resistor to set bias current.

The characteristics of the FETs were such that no temperature compensation or thermal coupling was necessary, so the scheme was very elegant. Harmonic distortion was good, rising to only 0.02% or thereabouts at any power – up to the 50W maximum – at 20kHz.

However, square-wave testing showed that the amplifier was slew-rate limited and that the limit would be reached if driven to full power at a frequency of about 50kHz. The origin of the slew-rate limit was the loop stabilisation capacitor – from collector to base of the voltage-gain side of the n-p-n pair – in conjunction with the finite driving current from the input stage.

Attempts at moving the frequency compensation to a different location, for example to the input stage, averted the slew-limit, but the harmonic distortion was worse. This was probably due to the fact that the MOSFETs presented a significantly non-linear capacitive load to the output of the voltage-gain stage, which was high impedance, and the stabilisation capacitor was providing some welcome local negative feedback. Thus moving the stabilisation component to a position where the resultant gain-shedding was of no benefit resulted in an overall drop in performance.

Returning to the original scheme, I could have elected to increase the currents in the circuit but this had a knock-on effect requiring the addition of heat-sinking and possibly a change to bigger transistors, all of which negated simplicity. Instead, I started to question the need for higher slew-rates.

Viewing the matter bluntly, in order to exceed the slew-rate several conditions would have to prevail. Firstly, I would have to be listening at a volume setting that would reach full power on programme peaks. Secondly, the program material would have to contain spectral information well in excess of the audible bandwidth, and thirdly the program channel would not have to be restricted in any way at high frequencies by the use of pre-emphasis and/or equalisation.

The first criterion is fair enough: we all like to bang head occasionally, be it Led Zeppelin or Shostakovich (try the last ten minutes or so of Symphony no.4).

The second criterion is less easy to satisfy. Both FM stereo and CD are very fundamentally restricted in bandwidth. In the case of vinyl the situation is less clear, and maybe someone more knowledgeable than myself could comment on the reproduction bandwidth limits of the newer information-compressing digital formats.

The third criterion nearly always applies a further restriction. FM is pre-emphasised, CD is sometimes pre-emphasised and vinyl is subject to RIAA equalisation which strives to keep groove displacement in check at low frequencies and maintains an adequate degree of surface noise suppression at high frequencies, but only at the expense of severe tracking limitations imposed by stylus tip mass. This medium is thus seriously limited in its abilities to generate high slew-rates.

Traditional analogue tape recording is no better: if the record-head bias is set for lowest distortion – as is normally the case – much of the ability to record treble at high levels is lost due to partial erasure. Having gone through this argument, I was and am still happy with my amplifier, but I did introduce an input filter with a similar time-constant to the one described by J.N. Ellis but with a different purpose in mind.

My previous amplifier suffered from excessive sensitivity to mains-borne transients to a degree that was irritating, and unchecked RF transients can have enormous slew-rates. I was keen to have the facility to run the program source directly into the power amplifier when not using tone controls, and the input filter was one of a number of measures I used to suppress RF transients and has been entirely successful.

Incidentally, if anyone suspects that program material is causing slew-rate limited phenomena there is now a great deal of data-grabbing instrumentation available. It would make sense to attempt to capture some transients and measure their true slew-rates before jumping to conclusions.

John Wells

E numbers and resistors

The sixties represent the beginning of my formative years in electronics. At the time, the now familiar E12 component value series was confined mainly to resistors, usually with 10 per cent tolerance.

For many years I took the idea of this series for granted, having realised that such components needed to be available in values that form an approximation to a geometric progression. However, more recently I was working out some values one day for a 10dB amplifier and I had a creeping feeling that something was wrong.

The middle value in the E12 series should surely be 3.162 – rounded off to 3.2 and *not* 3.3! Grasping the nearest calculator I discovered that all the values from 2.7 to 4.7 inclusive are too high and should be 2.6, 3.2, 3.8 and 4.6.

Since then, the series has been applied universally to capacitors and inductors and has been 'infilled' to form the E24 series. But it is interesting to note that the E96 series has been derived correctly, so things get even more absurd when designers adopt a cut-down sub-set from the E96 series that approximate in value to the original "wrong" E12 series!

To date no-one has given me a satisfactory explanation as to the origin of the E12 series values. Any offers?

John Wells
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