LOUDSPEAKERS

5" to 15" up to 400 WATTS R M.S.


POWER RANGE

5 WATTS R.M.S. Hi-Fi, Disco.
10 or 15 watts: 1" voice coil. Ground all for construction. Lightweight Treble/Driver. 8-40w. Price £29.99.
12 WATTS R.M.S. Hi-Fi, Disco.
15 WATTS R.M.S. 4" Bass Driver.
30 watts: 3" voice coil. Around all for construction. Lightweight Treble/Driver. 8-100w. Price £59.99.
18 WATTS R.M.S. 5" Bass Driver.

MOTOROLA

CT25SC350 Lead/Guitar/Keyboard/Disco.
50 WATTS R.M.S. Hi-Fi, Disco.
150 WATTS R.M.S. CT25SC350.
200 watts: 3" voice coil. Around all for construction. Lightweight Treble/Driver. 8-300w. Price £149.99.
250 WATTS R.M.S. CT25SC350.

MOTOROLA

CT25SC350 Lead/Guitar/Keyboard/Disco.
50 WATTS R.M.S. Hi-Fi, Disco.
150 WATTS R.M.S. CT25SC350.
200 watts: 3" voice coil. Around all for construction. Lightweight Treble/Driver. 8-300w. Price £149.99.
250 WATTS R.M.S. CT25SC350.

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250 WATTS R.M.S. CT25SC350.
THE ELECTRONIC CAR .......... Keith Brindley takes to the road with a look at the state of electronics in the automotive industry. It's taken a while to persuade the Henry Fords of this world to delve into new technology but it's happening at last.

CIRCUIT THEORY .......... Paul Chappell investigates the fantasy world of Thevenin boxes and the like and finds that electronics is really extremely simple.

HARDWARE DESIGN CONCEPTS . Mike Barwise has found a pal in Palasm. Now he's trying to convince the rest of us.

HARD TIMES .............. Analogue multiplier ICs are lots of fun when you get to know them. Paul Chappell is handling the introductions.

MIDI MASTER KEYBOARD .... The final part of the ETI keyboard to control the whole world. All the loose ends are tied up firmly with software from John Yau.

REMINDALITE .......... A car special project - no more burning the midnight battery acid with this handy project from Bob Noyes.

SONIC REV COUNTER .......... A novel design for an LED rev counter from Gary Calland continues the automotive theme.

CAR ALARM ............... Bob Noyes leaps into action again. This time it's the whole car he is protecting. Joyriders beware.

REAR WIPER ALARM .......... A J P Williams' rear screen wiper is fully protected against overwork. Now, we'd all like that.

KNIGHT RAIDER .......... Paul Chappell trips the light fantastic with the superior version of the best dressed car's fairy lights.

REGULARS

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**BBC Micro Computer System**

**DISC DRIVES**

These are fully cased and wired drives with slim line mechanisms. Drives supplied with cables, manuals and formatting disc suitable for the BBC computer. All 80 track drives are supplied with 40/80 track as standard. All drives can operate in single or dual density format. All floppy drives carry a two year warranty.

- **PD800** (4 x 40K/2 x 640K 40/80) $123 (b)
- **PD810** (4 x 40K/2 x 640K 40/80) $155 (b)
- **DF80** (as PD800 but without PSU) $119 (b)
- **PS85** (1 x 40K/1 x 640K 40/80) $135 (b)
- **DS** $114 (b)
- **PD25** $187 (b)

**3M FLOPPY DISCS**

High quality discs that offer a reliable error free performance for life. Each disc is individually tested and guaranteed for life. Ten discs are supplied in a sturdy cardboard box.

- **5¼" DISCS**
  - 40TS DD $10.00 (d)
  - 40TS DL $12.00 (d)
  - 80TS DD $14.50 (d)
  - 80TS DL $15.50 (d)
  - 80TS DD $23.00 (d)

- **3½" DISCS**
  - 20DDC and 1770 DFS Upgrade for Model B $43.50 (d)

**DISC ACCESSORIES**

FLOPPYLENE Disc Head Cleaning Kit with 20 disposable cleaning discs ensures continued optimum performance of the drives. 3½ £16 (d), 5¼ £14.50 (d)

**£3 DISC CABLE** for WS3000, 4000...

- BBC Printer Lead
- Ribbon
- RS232 Interface * 2K Buffer
- FX80 Tractor Attachment

**MONITOR**

All 14" monitors now available in plastic or metal cases please specify.

- **SERIAL**
  - 14°RGB with PAL & Audio
  - 14°RGB with PAL & Audio
  - 14°RGB with PAL & Audio

- **BBC & IBM Compatible**

**SPECIAL OFFER**

- **2764-25** $2.50
- **27128-25** $2.75
- **6264LP-15** $2.80

**SPECIAL OFFER**

Serial Mix Patch Box

Available at easy method to reconfigure pin functions without rewiring the cable only.

- **ATTENTION**

All prices in this double page advertisement are subject to change without notice.

- **£8 (a)**
- **£2.50 (a)**
- **£1.50 (a)**

**CONNECTOR SYSTEMS**

- **I.D. CONNECTORS**
  - No of Ways
  - 2-way (comms) 100
  - 4-way 200
  - 6-way 300
  - 8-way 400

- **EURO CONNECTORS**
  - 2 x 20 pin St Pin 230
  - 2 x 32 pin St Pin 260
  - 2 x 32 pin St Pin 370
  - 2 x 40 pin St Pin 370
  - 2 x 40 pin St Pin 370
  - 2 x 32 pin St Pin 370

- **GENDER CHANGERS**
  - 25 way D type
  - 25 way D type

- **RS 320 JUMPER**

**EDGECONN CONNCTORS**

- **AMPHENOL CONNECTORS**
  - Solder
  - ZDC

**RIBON**

- **DIAMETER**
  - 10-way 45p 34-way 140p
  - 12-way 65p 40-way 140p
  - 14-way 85p 20-way 140p
  - 20-way 105p 20-way 140p

**DIL HEADERS**

- **Scorob DDC**
  - 14 pin 40p 34-way 140p
  - 16 pin 60p 34-way 140p
  - 20 pin 80p 34-way 140p
  - 20 pin 75p 34-way 140p
  - 28 pin 100p 34-way 140p
  - 36 pin 120p 34-way 140p

**TECHNOLOG VIEWDATA SYSTEM**

Using 'Preselector' type protocols and computer systems.

- **TECHNOLOG VIEWDATA SYSTEM**
  - 0-450 7964, 24 hour service, 7 days a week.
### Linear ICs

<table>
<thead>
<tr>
<th>IC Type</th>
<th>Package</th>
<th>Voltage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM3202</td>
<td>SOIC-8</td>
<td>5V</td>
<td>Dual Operational Amplifier</td>
</tr>
<tr>
<td>LM3203</td>
<td>SOIC-8</td>
<td>5V</td>
<td>Dual Operational Amplifier</td>
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<tr>
<td>LM350</td>
<td>DIP-14</td>
<td>5V</td>
<td>Dual Operational Amplifier</td>
</tr>
<tr>
<td>LM324</td>
<td>DIP-14</td>
<td>5V</td>
<td>Quad Operational Amplifier</td>
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<tr>
<td>LM358</td>
<td>DIP-14</td>
<td>5V</td>
<td>Quad Operational Amplifier</td>
</tr>
</tbody>
</table>

### Computer Components

#### CPU

- Intel Core i7
- AMD Ryzen 5
- Intel Pentium G4560
- AMD Ryzen 3

#### Memory

- DDR4 8GB
- DDR3 4GB
- RAM 16GB
- RAM 32GB

#### Storage

- SSD 240GB
- SSD 120GB
- HDD 1TB
- HDD 2TB

#### Power Supply

- 650W
- 750W
- 850W

#### Graphics Card

- NVIDIA GeForce GTX 1080
- AMD Radeon RX 580
- NVIDIA GeForce GTX 1660

#### Motherboard

- ASUS Prime B450-Plus
- Gigabyte GA-Z370X-UD3
- MSI Z270-A Pro

#### Network

- Gigabit Ethernet
- Fast Ethernet
- Wireless AC

### Voltage Regulators

**Fixed Plastic**

<table>
<thead>
<tr>
<th>Type</th>
<th>Package</th>
<th>Output Voltage</th>
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<tr>
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<td>DIP-7</td>
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<td>7812</td>
<td>DIP-7</td>
<td>5V</td>
</tr>
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<td>7905</td>
<td>DIP-7</td>
<td>±5V</td>
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</tbody>
</table>

**Switching Regulators**

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<tr>
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<td>DIP-7</td>
<td>5V</td>
</tr>
<tr>
<td>7905</td>
<td>DIP-7</td>
<td>±5V</td>
</tr>
</tbody>
</table>

**Other Regulators**

- Texas Instruments LM723N
- National Semiconductor LM317T
- STMicroelectronics SN754410

#### Optional Features

- DDR4 8GB
- RAM 16GB
- SSD 240GB
- NVIDIA GeForce GTX 1080

**Please note all prices are subject to change without notice.**

**Opto-Electronics**

- Opto-Isolators
- Opto-Couplers
- Opto-Dectors

We also stock a large range of Transistors, Diodes, Bridge Rectifiers, Triacs, and Zeners. Please call for details.

**PLEASE ADD 50p p&p & 15% VAT**

**Orders from Government Designated Colleges etc. welcome.**

**Detailed Price List on request.**

**Stock items are normally by return of post.**
**Portable Workstation Takes Off**

The FLT-101 workstation from Flight Electronics combines power supply, signal generator, metering and a large breadboard in a portable, benchtop unit. According to Flight, the FLT-101 costs less than the equivalent individual items of test equipment and is ideal for use in design and development work or as an individual workstation in electronics training establishments. The breadboard has 1680 tie points and accepts most standard components. The power supply provides 5V/1A and ±15V/0.3A DC outputs and is fully regulated and protected while the function generator offers sine, square and triangle wave outputs from 1Hz to 10kHz. Other features include a voltmeter covering the range 0-30V, a 10uA ammeter, a loudspeaker and various switches and potentiometers. The FLT-101 costs £200 plus VAT from Flight Electronics Ltd, Ascupart Street, Southampton SO1 1LU. Tel: (0703) 227 721.

**A Plug For The Lead-Less Tester**

The neon screwdriver has been brought firmly into the microchip era with the launch of the Amba Multi-Function Tester. This single-handed probe detects mains live voltages and also acts as a continuity tester. It is housed in a slim rectangular case and features an insulation-piercing probe tip, a red indicator LED and a small metal touch panel. It runs from a 9V battery but has no on/off switch — it only operates when someone completes the external circuit by touching the metal panel. For mains testing it is used in exactly the same way as a neon screwdriver. The person using it completes the circuit to earth simply by holding the tester and the LED lights up when the probe is touched against a live terminal. In continuity testing the user touches some part of the circuit under test with their other hand, so completing a circuit through the tester. This removes the need for a probe lead. The LED will light when there is a connection between the user's hand and the tip of the probe.

The Amba Multi-function Tester has a recommended retail price of £12.60 and comes with a two-year guarantee. It is being distributed by The Goport Company Limited, York House, Empire Way, Wembley, Middlesex HA9 0QH. Tel: 01-903 2065.

**Imports Hit Electronics Sales**

Sales of consumer electronics products in this country rose sharply between 1983 and 1985 but the profit margins of British manufacturers fell substantially over the same period. The disparity came about because of increased competition from Japanese and other foreign manufacturers according to a recent report from ICC Business Ratios. This conclusion will confirm the fears of many people who believe that money from tax cuts and cheaper credit has been spent largely on imported goods.

The report shows that sales of consumer electronics goods in this country rose by 13.9% in 1983/84 (compared with 1982/83 figures) and by 18.6% in 1984/85. At the same time average industry profit margins fell from 4.3% to 2.8%. Figures for return on capital also fell over the period from 18% to 10.5%.

The only manufacturing company which did particularly well was Amstrad. ICC suggest this is because Amstrad has many of its products manufactured in the Far East and relies on established rather than emerging technologies.

The report, entitled The Consumer Electronics Industry, is available from ICC Business Ratios, 28-42 Banner Street, London EC1Y 8QE. Tel: 01-253 3906.

**Technology Centre Loses Funding**

The Technical Change Centre is to close following withdrawal of its remaining research council funding. The Centre provides advice on technology to industrial users and also seeks to keep government and the general public informed on the likely impact of changes in technology. A committee set up by the Economic and Social Research Council and the Science and Engineering Research Council reviewed the Centre's operations early in 1985. Its report called for some restructuring but recommended that funding be continued for a period of five years. In spite of this the SERC withdrew its core funding in April last year. A recent decision by the E&SRC to withdraw its funding has removed the Centre's other major source of income. Efforts to attract funding from other sources have failed and the Directors now say they have no option but to close the Centre down.
ATE Takes On Complex Chips

A new research programme at London's Imperial College will look into the problem of testing electronic circuit boards which include complex ICs.

The programme reflects concern that advances in IC design will soon produce circuit boards which cannot be handled by existing automatic test equipment.

Known as FLAIR (Fault Location Algorithms — a programme of Integrated Research) the project will receive backing from factron Schlumberger, a major manufacturer of automatic test equipment (ATE). The company will provide an ATE system plus a 32-bit workstation and will loan Imperial College one of its staff, Dr. Bill Rae.

According to Dr. Rae, design tools such as CAD have enabled engineers to design advanced ICs which often cannot be tested when they are in circuit. He suggests that research into diagnosing the situation where functional ATE will be able to detect faults but not locate them.

FLAIR will investigate a number of approaches including the use of real-time interaction between the ATE and the circuit under test. At present ATE systems generally use determined input which remain unchanged throughout the test. The programme will also look into the use of probability theory whereby actual and predicted patterns could be compared.

It is hoped that the results of the research will be useful both in the development of future generations of ATE and in the production of CAD tools which can check new designs for testability.

Factron Schlumberger, Ferndown Industrial Estate, Wimborne, Dorset BH21 7PP. Tel: (0202) 893 535.

Sparking Off Muscle Growth

It may soon be possible for anyone to have a fit, muscular body without having to do any exercise, according to a recent report.

Fitness-freaks could watch television while a sequence of electrical signals triggered their muscles to produce exercise.

The technique is known as neuro-muscular stimulation and involves passing tiny electrical impulses through the skin to underlying muscles. Stroke victims and others who have suffered a loss of mobility are already being treated in this way.

The report (no. 737) is produced by International Resource Development, 6 Prowitt Street, Norwalk, Connecticut 06855, USA.

German 'AVOs' have Analogue Display

Thorn-EMI are marketing a range of digital multimeters which feature a high-resolution analogue display and an unusually rugged case design.

Manufactured by Metrawatt GmbH of West Germany, they will be sold under the well-known AVO brand name following a recent agreement on marketing and development.

The meters combine a 9.5mm high 3½ digit display with a 70-division analogue scale traversed by a moving pointer. Thorn-EMI says the resolution available is far higher than on other analogue/digital meters.

The case design features two side 'buffers' made from an impact-absorbing material which provide a high degree of protection should the meter be dropped or otherwise mishandled.

The five models in the range all offer voltage measurement up to 1000V AC and DC, resistance measurement from 300Ω to 30MΩ and at least one AC/DC current range rated at 10A but capable of handling 20A for short periods. Range selection is generally automatic but there is an additional switch-selected 300V AC/DC range and all models incorporate a diode test function. Prices range from £89 to £210 plus VAT and a list of dealers is available on request.

Thorn-EMI Instruments Ltd, Archcliffe Road, Dover, Kent CT17 9EN. Tel: (0304) 202 620.

American Rabbits Invade Britain

The VCR Rabbit is presumably so-named because it 'breeds' TV signals but the term rabbit-like might also be applied to the way in which the machines themselves have been multiplying.

The manufacturer claims to have sold 600,000 of them in America since the product was launched a year ago and the Rabbit is now set to over-run this country too.

The Rabbit takes the signal from a video cassette recorder and multiplies it for use by up to five television sets around the house: The only cabling required is a single, 0.7mm thick wire between units and if the VCR has a remote control facility the Rabbit will allow it to be operated from any of the five TV positions.

The system uses a transmitter which connects directly to the VCR and one adjacent TV set while the remaining TVs are connected to receiver units which are 'chained' along the wire. The UHF signal from the VCR is converted to a low-frequency signal for transmission along the wire and then converted back to a UHF signal at each receiver unit.

Further details from S.A.R. Chipstone, 27 Northolt Road, Harrow, Middlessex HA2 0LS. Tel: 01-864 7512.

- Philips Test & Measurement has published a short brochure on the IEEE 488 instrument communications standard. The brochure explains the rationale behind IEEE 488 and lists all the Philips test equipment products currently available with this capability. Copies can be obtained free-of-charge from The Sales Promotion Department, Enquiry Handling Section, Pye Unicam Ltd, York Street, Cambridge CB1 2PX. Tel: (0223) 358 866.

- Micrologic have copies of a new 5-page guide to advanced logic devices from Monolithic Memories Incorporated. The range includes numerical processing, FIFO and memory support ICs and the guide includes a set of tables which compare the performance of MM1 products with those from rival manufacturers. The guide is available free of charge from Micrologic Ltd, The Cornerstone, The Broadway, Woking, Surrey GU21 5EZ. Tel: (0486) 29551.

- Bulgin's complete range of electrical and electromechanical components is described in a new 227-page illustrated catalogue. It includes all necessary technical data and is laid out in an easy reference format. Aimed at design engineers and buyers it is available from The Marketing Department, A.F. Bulgin & Company PLC, Bypass Road, Barking, Essex IG11 0AZ. Tel: 01594 5580.

- The popular Analyser II software package from Number One Systems is now available for use with Research Machines Nimbus microcomputers. Reviewed in the March 1987 issue of ETI (in its BBC micro version), the package allows the user to build up a circuit on screen and then analyse it for gain, phase, group delay and impedance characteristics over a wide range of frequencies. For details and price contact Number One Systems Ltd, 9A Crown Street, St. Ives, Huntingdon, Cambridgeshire PE17 4EB. Tel: (0480) 61778.

- How many electric motors would you expect to find in the average motor car? Five! Six! Seven or more! According to a recent report by a research company Frost and Sullivan Ltd, the number of electric motors used in cars is expected to rise considerably in the near future from its present figure of only one motor per vehicle. Sixteen! And that is the figure for an average car which is unlikely to include automatic windows or anything fancy like that. If you can list sixteen electric motors on an average car you're doing a lot better than the ETI staff did!
EEK! IT'S EEG
Tense? Nervous? Brain not working? Forget the aspirin, what you need is an ETI brainwave monitor. Starting next month, the ultimate electronic health project. Aquaint yourself with alpha. Battle with beta. Get along with gamma. Defy delta. ETI is committed to making this a better world to live in and the ultimate experience. Tune in next month for your dose.

Summer's nearly over (what do you mean you haven't noticed it start yet?) so it's time to think about those long cold winter's nights when the thermostat goes on the blink and the boiler will only heat the water to 12°C. Fit an ETI Boiler Controller now while there's still time.

THE SEPTEMBER ETI — OUT 7th AUGUST
Superconductivity Research Hots Up

Scientists at Plessey's Caswell Research & Technology centre claim to have achieved superconductivity at just below -185°C, the highest temperature yet reported by a British laboratory. They are confident that the process can be repeated at even higher temperatures, allowing superconductivity to be achieved using conventional freezing agents such as liquid nitrogen. This would open up the way for a whole range of practical applications including zero-loss power distribution cables, frictionless magnetic bearings and lower power, higher speed logic circuits.

The benefits of superconductivity have been known for many years. Electrical conductors lose all their resistance below a certain temperature with the result that electrical energy can be transferred without losses. A current made to circulate in a loop of superconducting material will continue indefinitely without a power source to drive it.

Unfortunately, superconductivity has hitherto been achieved only at very low temperatures indeed, and the cost of maintaining such an environment far outweighs the benefits. Plessey claims to have overcome these problems through the use of a ferroelectric ceramic material. Ceramics act as electrical insulators at normal temperatures, but recent research showed they could also act as superconductors. With over 30 years experience of ceramic materials research to draw on, Plessey set up the Caswell programme early this year and began formulating a new ferroelectric crystal two months ago. Tests on the new material led to the announcement of a breakthrough on May 18th.

Plessey is continuing its research work in an effort to achieve superconductivity at temperatures nearer to normal atmospheric conditions. Potential applications include the distribution of electrical energy over long distances without loss, removing the need for high-voltage cables and pylons. In mechanics it could be used in magnetic levitation systems, opening up the prospect of friction-free bearings. It could also revolutionise such fields as telecommunications, radar and computing.

High-Res Graphics From Micro Concepts

The board has extensive I/O facilities and supports several popular software formats.

Electronics in Engineering Design — September 15-18th
NEC, Birmingham. Exhibition and conference on mechanical/electronic systems interfacing. Contact Cahners at the address below.

Design Engineering Show — September 15-18th
NEC, Birmingham. See July '87 ETI or contact Cahners at the address below.

IDEX '87 — September 21-23rd
Metropole Exhibition Halls, Brighton. See April '87 ETI or contact Nutwood Exhibitions on (04846) 25891.

Semiconductor International — September 29-October 1st
NEC, Birmingham. See July '87 ETI or contact Cahners at the address below.

Internecon — October 6-8th
Metropole Convention Centre, Brighton. See July '87 ETI or contact Cahners at the address below.

Digital Audio Post Production — October 11th
BAFTA, London. Training seminar organised by the BKSTS. Contact them at the address below.

Automotive Electronics — October 12-15th
The IEE, London. See July '87 ETI or contact Cahners at the address below.

Computer Graphics Exhibition and Conference — October 13-15th
Wembley Conference Centre, London. For details contact Online on 01-868 4466.

Conference For Young Engineers — October 16-18th
Strand Palace Hotel, London. See July '87 ETI or contact the IEE at the address below.

International Video & Communications Exhibitions — October 18-21st
Metropole Exhibition Centre, Brighton. See July '87 ETI or contact Peter Peregrinus Ltd at the IEE address below.

Radar '87 — October 19-21st
Kensington & Chelsea Town Hall, London. See July '87 ETI or contact the IEE at the address below.

Testmex '87 — October 20-22nd
Business Design Centre, London. See July '87 ETI or contact Network Events at the address below.

Interact '87 — November 17-19th
Kensington Exhibition Centre, London. See June '87 ETI or contact Network Events at the address below.

Addresses:
British Kinematograph Sound and Television Society, 547549 Victoria House, Vernon Place, London WC1B 4DJ. Tel: 01-242 8400.

Cahners Exhibitions Ltd, Chatsworth House, 59 London Road, Twickenham TW1 3SZ. Tel: 01-891 5051.

Institution of Electrical Engineers, Savoy Place, London WC2 OBL. Tel: 01-242 8400.

Network Events Ltd, Printers Mews, Market Hill, Buckingham MK18 1XJ. Tel: (0280) 815 226.

Amstrad Computer Show — July 10-12th
Alexandra Palace, London. Dominated by software, etc, for the PC1512 IBM-clone but there should be plenty to interest owners of other Amstrad machines. Contact Database Exhibitions on 061-456 8835.

Radio Frequency Techniques — July 19-24th
University of Bradford. Vacation school. Contact the IEE at the address below.

Satellite Communications System — July 26-31st
University of Sussex. Vacation school. Contact the IEE at the address below.

Television By Numbers — September 11th
The IBA, London. Seminar on digital television techniques. Covers the subject from first principles for the benefit of managers, analogue engineers and others unfamiliar with the technology. Contact the BKSTS at the address below.

Designing For Electromagnetic Compatibility — September 13-18th
University of Sussex. Vacation school. Contact the IEE at the address below.

7th International Display Research Conference — September 15-17th
The IEE, London. See July '87 ETI or contact the Institute of Physics on 01-235 6111.

Eurodisplay '87 — September 15-17th
The IEE, London. Conference covering all aspects of electronic display research. Contact the Institute of Physics.

ETI AUGUST 1987
TRANSISTORS
BC107A 0.15
BC107B 0.15
BC108A 0.18
BC108B 0.18
BC109A 0.18
BC109B 0.18
BC119 0.18
BC1212 0.12
BC1213 0.12
BC121B 0.12
BC121C 0.12
BC121D 0.12
BC548 0.12
BCY70 0.22
BCY71 0.22
BD131 0.60
BD132 0.60
BD135 0.34
BD136 0.35
BD239A 0.50
BF258 0.60
BF685 0.40
BF688 0.40
BFY50 0.37
BFY51 0.37
BFY52 0.39
TIP1 0.42
TIP2A 0.48
TIP2B 0.56
TIP2C 0.54
TIP2A 0.42
TIP2B 0.42
TIP3A 1.00
TIP4A 1.63
TIP4A 0.55
TIP455 0.76
TIP465 0.76
TZ3X00 0.17
TZ3X00 0.17
ZN3053 0.60
ZN3054 1.60
ZN3707 0.12
ZN3707 0.12
ZN3771 1.40
ZN3904 0.15
ZN3905 0.15

DIODES
IN4001 0.05
IN4002 0.06
IN4003 0.06
IN4004 0.06
IN4007 0.08
IN4488 0.06
IN4448 0.06

IC SOCKETS
low profile
8 pin DIL 0.07
14 pin DIL 0.12
16 pin DIL 0.13
24 pin DIL 0.20
40 pin DIL 0.30

OPTO ISOLATORS
TIL 111 transistor o/p 1.10
TIL 111 Darlington o/p 1.20
3021 Triac driver 1.50

LEDS
T1/2 5mm
Red 0.18
Yellow 0.18
Green 0.18
Super bright T1/2 5mm
Red 0.35

TRIACS
TIC206D 3 Amp 400V 0.75
TIC22SD 6 Amp 400V 0.90

ZENER DIODES
BZY86C 500m W
4V7 0.10
10V 0.10
12V 0.10
BZK55C 500m W
24V 0.10
BZK65C 1.3 Watt
4V7 0.60
10V 0.20
12V 0.20
24V 0.20

VOLTAGE REGULATORS
LM317T 1.5 AMP
+1.2V to 37V 1.50
LM341P 500MA +5V 0.60
LM7905 1.5 AMP
-5V 0.70
7808 +8V 1.5 AMP 0.60

BRIDGE RECTIFIERS
W004 1.5A 0.50
6005 6A 0.90

VERO BOARD
0.1” matrix
Unclad breadboard 0.1”
10x65mm 0.65
Copper clad 37 strips wide
4p per hole
Copper clad 41 strips by 40 holes
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CAPACITORS
Electrolytic axial or radial
10uF 25V 0.08
47uF 25V 0.10
100uF 25V 0.10
470uF 25V 0.28
1000uF 25V 0.36
2200uF 25V 0.15
Tantalum
0.1uF 35V 0.10
0.22uF 35V 0.10
0.47uF 35V 0.10
1uF 35V 0.10
2.2uF 35V 0.10
4.7uF 35V 0.20

Ceramic
220pF 500V 0.06
470pF 500V 0.12
1000pF 500V 0.06
2200pF 500V 0.06
4700pF 100V 0.06

RESISTORS
Metal Film 5% 1/2 Watt
2p each
100R 680R 1K 1K2 2K2
4K7 5K6 6K8 10K 12K
15K 22K 27K 33K 39K
47K 56K 68K 82K 100K
120K 150K 180K 220K
270K 330K 390K 470K
560K 680K 820K 1M

B.T. APPROVED TELEPHONES
B.T. Statesman with last number redial
Stone 31.26
Brown 31.26
Maroon 31.26
Grey 31.26
B.T. Wiscount with last number redial
Beige 26.04
Ice Grey 26.04
Red 26.04
White 26.04
B.T. Freeway cordless 700m range Security coded.
last number redial with base paging
Ivy 26.04
Sockets, extension leads, cable, enquire for prices

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LETTERS

READ/WRITE

Crossed Line

A slight error crept into the excellent article on 'The Telephone System' in the June issue. The out of service resistor in a master socket is not to hold a call. It is in series with the bell capacitor so that when all phones are unplugged the terminal still presents an AC (but not DC) path to line testing equipment at the exchange. A full disconnection therefore indicates a line fault. When a phone is plugged in, it's bell simply shunts the resistor.

D. B. Lyall
Cheltenham, Gloucestershire.

Keith Brindley says the UK phone system is the best in the world — rubbish!
The UK system is the worst in the world and the most costly. If you want a box changing it will cost £25 and to put in a phone costs £100. Then there's standing charges on top of that plus the £3.10 a month for the set. Phone boxes are years out of date and always vandalised by the public fed up trying to get through.

The US system is the best. The UK system is rubbish and 50 years out of date.

H. Hollins
Leeds, Yorkshire.

To be fair, Keith Brindley only suggested the UK system itself is the world beater and cited its non-failure during the recent engineer's strike as proof. The prices charged by BT and their organisation he is as vocal about as the next man, as regular readers of his Open Channel column will know.

Phone box vandalism is rarely due to disgruntled BT customers but a fact of today's life (both here and in the US). It is to counteract this very fact that BT is currently (and controversially) replacing the 'out of date', but extremely popular, red boxes with new high tech booths.

Our thanks to D. B. Lyall and all the others who wrote in to put us right on the out of service resistor.

Out Classed

The May Issue of ETI has just passed across my desk and I found two articles of particular and peculiar interest.
The first was Andrew Armstrong's article 'The Truth About Hi-Fi' which examined many popular items of misinformation put about by those who 'know' about hi-fi. Regrettably they usually know very little but will readily jump on this week's fad.
The second article was Ian Pitt's review of the Sage Audio power amplifier modules. Not only did he insist on going into all the nebulous arguments which Andrew Armstrong had shown to be fallacious, he even had the gall to include some very obviously impossible statements.

He says, for instance, that the modules feature a class A output stage. He then claims an efficiency of 70% — not only clever but impossible. A class A output stage has a maximum efficiency of 50% and this assumes 100% efficient output devices and no other current required for driver circuitry, etc.

With a claimed power output of up to 150W RMS, the total dissipation within the amplifier would be a little under 780W and a transformer of at least 1kVA per channel would be required. This makes a mockery of Ian Pitt's argument for using a 500VA transformer in preference to a 225VA unit.

No wonder the general public is taken in by all the rubbish printed about hi-fi when even ETI technical authors believe all they read in manufacturers' handouts!

J. Howes
Salisbury.

Ian Pitt replies: Sage claims to have developed a high-efficiency 'dynamic' class A system for use in the Superamp and SuperMOS modules. Given more space and a chance to see the circuit diagrams it would have been worth exploring this claim in some detail. As it was, I could only pass on the claims and then review the modules as I found them.

The modules exhibit the sort of efficiency normally associated with class B designs. This may be because they use some stunning new variant of the class A system or because they use good old-fashioned class B, but I have no means of knowing. I can only report what I found, which is that the modules work perfectly well with a 225VA transformer.

As for Mr. Howes' opening remarks, I'm glad he liked 'The Truth About Hi-Fi' article but I wasn't aware Andrew had 'shown' any arguments to be fallacious. What he did was to express his opinion that some arguments were illogical. I would agree with much that he said but I would also differ on some points.

How Much RIAA?

Armed with the knowledge ETI has given me I design and build hi-fi preamps. They usually outperform commercial equipment.

So, while I thank you for Wilfred Harms' interesting article on RIAA networks, pragmatism demands a simple question: forgive my evil suspicion but is it possible the record companies only use the same kind of two resistor/two capacitor networks (which Mr. Harms wishes to modify) for the RIAA pre-emphasis in the first place.

I'd love to know whether this striving for accuracy is worth the bother.

R. Leach
Hurst Hill, West Midlands.

Far be it from us to spread malicious rumours but we wouldn't be surprised if some of the smaller record companies cut a few corners in this department. However, the likes of Deutsche Gramaphon are hardly likely to skimp on the EQ so if you listen to this kind of material it will be worth it.

Timely Advice

I am glad to see you welcome letters on any topic 'past, present or future' (Read/Write, June 1987). Well, after completing the time machine project from the January 2196 issue it has developed a fault while testing and has stranded me here (and now).

Unfortunately I did not bring the circuit diagram but I think the problem lies in the Bramble-woven Bozon warp vortex control circuit, possibly in the superconducting coils of the vortex bottle.

I can only describe the noise it makes on starting as the sound of a C5 (the basis of all personal transport in the 22nd century) embedding itself in the underside of a juggernaut. I do hope you can help.

Per Isstak
Dundee, Scotland.

No problem, this one. We were sent the circuit details by the ETI photocopy service from 2196 via the (working) prototype. We have forwarded all the details you need by C5-mail. However, I'm afraid our calculations show this will take around 2091 years to get to Dundee.

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- 15-way expansion bus

All sections of the interface are memory mapped in the 1MHz expansion map for maximum ease of use and compatibility with existing peripherals.

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- 8-bit input port
- 8-bit output port
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THE ELECTRONIC CAR

Keith Brindley has found that electronics is beginning to stretch to more than just the cassette/radio in the modern car.

On the surface modern automobiles have changed little since Ford's Model-T. Granted, modern cars cost a bit more and come in a greater range of colours but they do the same job and arguably are only marginally better than the original mass-produced car.

Yet a great deal is happening to the modern motor car that is hidden away under the bonnet. After what was probably a slow start, car makers at the turn of the decade realised that electronic systems and computer (particularly microcomputer) controls were going to have an enormous impact on the automobile market. Indeed, over the last ten years cars have seen more changes (most of them barely detectable to the customer) than they had experienced in the previous 70 years of their existence.

To be fair to the car manufacturers there were reasons why electronics and computers weren't adopted into motor vehicles they way they have been adopted into the home (in the form of home computers, hi-fis, videos etc). The main reason is the very fact that the car carries with it its own extremely hostile environment. Temperatures and humidities in and around a car vary over an enormous range — far more than the average turn-of-the-decade electronic circuit could cope with. Winter temperatures can be well below freezing and summer cockpit temperatures rise into the 50s and 60s (Celsius) even in our 'temperate' climate. Given this and the vibration, acceleration, and deceleration common in all cars, manufacturers were faced with the probability of an unreliable product which would give too much trouble.

Electronics reliability started with Large Scale Integration (LSI). Since the turn of this decade, LSI has really taken off. For the motor car makers LSI heralded the beginnings of a new age in cars, allowing them to offer the customer a number of changes which previously weren't possible. Some of these changes have been the result of governmental regulations on safety and pollution. On the other hand, some changes were customer initiated, brought about by rising fuel costs, extra demands for comfort and the quest for greater reliability.

It's not just the addition of electronics which has brought about this new age of motor cars. Associated transducers have been developed specifically for use in cars, allowing the control system to sense necessary inputs through sensors and control necessary functions with the help of actuators.

We can break down electronics systems in the car into two main areas, engine control and safety, and these are the areas we'll cover here. Additionally a fair amount of electronics is appearing inside the cockpit in instrumentation display and comfort control systems but to do justice to such systems would require more space than we can afford here.

**Engine Control**

Most readers will know all too well the principles of the spark-ignited, internal combustion, four-stroke engine. It only remains for us to see how modern electronics has invaded the carburation and ignition processes.

Carburation and ignition are pretty simple processes in terms of electronics but the overall engine performance relies totally upon them. If the right quantity and strength of the fuel/air mixture is not present in the...
right cylinder at the right time and if the spark generated by the ignition system is not produced at the right spark plug at the right time, for every load condition imposed on the engine, then the engine will not perform to its maximum capabilities. As we'll see soon, one system relies upon the other to a very large extent.

Manufacturers' first problem is to make carburation and ignition systems more precise. To do this, a number of different engine management systems have evolved. Some of these systems maintain carburation and ignition as physically separate (though interdependent) systems. Others combine the two in a complete system.

**Carburation**

One of two control strategies is used in all electronic carburation systems. The basic non-electronic carburation principle is shown in Fig. 1a, where air and fuel are inputs to the engine and exhaust gasses are the output. The first control strategy (Fig. 1b) is a closed loop in which the exhaust gas is monitored to ensure the correct fuel/air ratio is maintained, so indicating that the engine is using fuel to its maximum capabilities. A control unit uses the information from the exhaust gas monitor to determine how much air and fuel should enter the engine, and performs control with the two valves.

The second principle (Fig. 1c) is an open loop one in which the air and fuel entering the engine are measured. The control unit in this case uses the valves to ensure the fuel/air ratio is kept at a predetermined level. There are pros and cons in both strategies. The first is relatively easy to construct and ensures low noxious exhaust emissions at all times. The second is more adaptable to suit varying load conditions imposed on the engine and so will maintain highest performance. To date, closed loop control has been used in all but a handful of North American engine control systems, whereas the typical European approach is to use open loop control. Both strategies can and do give accurate engine control. Some engine management systems use both strategies to give optimum performance under all conditions.

Often, the 'old' carburettor is maintained as the heart of the carburation process. This makes some sense, at least initially, when you consider that a great deal is known about carburettors and how they operate. Control of the carburettor is taken out of the driver's hands, however, and made fully automatic. Generally, pretty conventional carburettors are used and merely adapted for the task in hand.

The principle of control is shown in a block diagram in Fig. 2. The inputs of engine speed, throttle angle, temperature, pressure and exhaust emissions are measured by the control unit and relevant control over the fuel/air ratio and amount of fuel/mixture is the outcome.

By measuring temperature (both ambient and engine), the control unit can decide whether the engine is being cold-started and operate the choke valve giving fuel enrichment when required. By measuring outside pressure the control unit can take into account altitude variations, adjusting fuel/air ratio and quantity to suit. A measurement of exhaust emissions allows the control unit to maintain exactly the right proportions of fuel and air to ensure all the fuel is being used and no waste chemicals are being exhausted into the atmosphere. So, a closed loop control of this type ensures reasonable economy of fuel and helps to meet stringent exhaust emission regulations.

**Transducers**

Varieties of electronic carburettors differ only in the actuators used to control choke and throttle valve position. Typically, the actuators will be servomotors, turning their central spindles through 0° to 90° in response to control signals. Such devices offer accurate control and high speed so rapid variations of each carburettor valve setting can be made — useful when kick-down acceleration is required because the fuel/air mixture can be enriched momentarily to aid acceleration. Other types of actuators used in an electronic carburettor include torque motors, electropneumatic actuators, stepper motors, and so forth.

Sensors in the system of Fig. 2 are used for measuring ambient temperature and engine temperature (both simple thermistor or thermocouple devices), the driver's depression of the accelerator pedal (rotary potentiometer mounted on the pedal itself), engine speed and exhaust gas. Engine speed is usually monitored by sensing the rotational speed of the crankshaft with a simple coil arrangement in which a voltage is induced each time a tooth of the flywheel passes the sensor. Sometimes, however, engine speed can be measured optically or with a Hall effect sensor again detecting crankshaft speed or by simply counting the number of ignition sparks over a period of time or using numerous other methods.

The Hall effect approach is probably the most suitable for a number of reasons. No interfacing circuits are required between the sensor and the control unit, a digital (squarewave) output is obtained (unlike inductive/reluctive and tachometrical methods), sensor performance is not degraded by dirt or corrosion (unlike optical methods) and reliability is good.

Exhaust gas is typically monitored using a sensor capable of detecting residual carbon monoxides, nitrogen oxide, or unburnt hydrocarbons in the exhaust emissions. The main principle behind the use of exhaust gas sensors is that a weak fuel/air mixture (too much fuel) will cause nitrogen oxide to occur in the exhaust emissions (Fig. 3). Apart from unwanted gas, engine power is reduced. On the other hand, if a strong fuel/air mixture (too much fuel) is supplied to the engine then although engine power is a maximum and emissions of nitrogen oxide are reduced, carbon monoxide and hydrocarbons will be present in the exhaust gases.

Complete combustion of petrol and air occurs when the fuel/air ratio is approximately 15:1. At this ratio the mixture is said to have an excess air factor, sometimes called the equivalence ratio or $\lambda$, of one, where:

$$\lambda = \frac{\text{actual quantity of air}}{\text{theoretical air quantity}}$$

That is, when $\lambda = 1$, combustion is theoretically complete.
and few hydrocarbons are emitted in the exhaust. When \( \lambda \) is less than one the fuel/air mixture is too rich, creating carbon monoxide and hydrocarbon emissions. When \( \lambda \) is greater than one the mixture is too weak, reducing engine power and emissions of nitrogen oxide are quite high. Because of this oxygen sensors used to measure exhaust emissions are often called 'lambda sensors'.

The two main types of lambda sensors are the zirconia oxide type, and the titanium oxide type. Functions of both types are similar — any oxygen present in the exhaust emissions are diffused into the porous material, allowing a voltage to be generated across two electrodes which changes sharply at the \( \lambda = 1 \) point. Generally, lambda sensors are available in a small package (Fig. 4) which bolts directly into the exhaust pipe.

Control process is quite simple: reduce the amount of air entering the engine until the point where levels of carbon monoxide and hydrocarbons just start to increase rapidly. At this point the fuel is being used most efficiently. To allow for changing engine load conditions altering the fuel/air requirements, it is necessary for the control systems to constantly monitor the exhaust gas levels in a cycle, increasing the amount of air intake until carbon monoxide disappears then backing off until it is just sensed again.

**Burning Ambition**

In America and Japan lambda sensors have been used since 1976 in closed loop control systems of this sort to reduce unwanted engine emissions. They run the engine exactly at the \( \lambda = 1 \) point, then use a catalytic converter in the exhaust system to further reduce noxious unwanted wastes. As yet, the UK has no regulations requiring such low emissions and as the cost of catalytic converters is high this technique has not found favour in UK vehicles. Economy seems to be the European market's primary concern.

However, considerable interest has been shown recently in Europe about the fact that nitrogen oxide emissions fall off as the excess air factor increases well above one (as the fuel/air mixture gets very weak). Lambda sensors have been used in this way to produce the 'lean-burn' engines now available. These run the engine at an excess air factor up to 1.5 as long as the engine's full power is not required (when coasting or on an open road). Whenever power is needed the control unit automatically adjusts the excess air factor.

**EFI**

Electronic carburation allows reasonably accurate control of fuel/air mixture ratio and amount. One of its few disadvantages is that the fuel/air mixture is still sucked into the cylinder from the carburettor via the inlet manifold. It's a bit of a sloppy method, when you think about it, which can't ensure that all of the fuel/air mixture produced by the carburettor for a particular cylinder actually gets into that cylinder. Some may remain in the inlet manifold until the next cylinder inlet valve opens. This can be overcome by having a separate carburettor for each cylinder but that's a bit of a Heath Robinson arrangement and is costly so most car manufacturers have gone to electronic fuel injection (EFI) systems to get round the problem.

In the best EFI systems (using 'multi-point injection') separate fuel injectors place a precisely measured quantity of fuel into individual cylinders, at precisely the right moment — an instant before the inlet valve for that cylinder opens. In systems with slightly lower specifications, fewer injectors may be used (as few as one per engine simply replacing the carburettor — single point injection) and timing of the injection may not be so precisely controlled. Nevertheless, any type of EFI system represents a great advance in the engine carburation process and more and more cars will be fitted with EFI as time goes by. Their higher accuracy in terms of control over fuel/air ratios mean that exhaust emissions can be kept to low levels without sacrificing engine performance.

A typical EFI system is shown in Fig. 5. It is classed as a multi-point system (because it has one injector per cylinder) and a control unit turns each injector on at the required time, for the length of time necessary to inject the required amount of fuel. Fuel pressure is maintained at a constant level with the use of a pressure regulator.

![Prototype electronic carbeurter designed by Weber for Fiat.](https://example.com/probe.png)

It would be perfectly possible to use the closed loop control strategy of Fig. 1b with a lambda sensor to measure exhaust emissions and maintain the optimum fuel/air mixture (indeed, some systems do). EFI systems often use the other engine control strategy (Fig. 1c), in which fuel and air quantities are measured to ensure the correct fuel/air mixture. A few of the more modern EFI systems even use both strategies with the microprocessor determining which strategy to follow at any particular time. The main reason for this approach is that closed loop control is more of an analogue approach and doesn't easily take into account such engine operations as cold-starting (when a rich mixture is required for a considerable period), warm-starting (when a quick burst of rich mixture is required) and heavy load conditions. An open loop control strategy, on the other hand, lends itself to microprocessor-based control methods which can easily cater for both usual and unusual load options.

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However, considerable interest has been shown recently in Europe about the fact that nitrogen oxide emissions fall off as the excess air factor increases well above one (as the fuel/air mixture gets very weak). Lambda sensors have been used in this way to produce the 'lean-burn' engines now available. These run the engine at an excess air factor up to 1.5 as long as the engine's full power is not required (when coasting or on an open road). Whenever power is needed the control unit automatically adjusts the excess air factor.

**EFI**

Electronic carburation allows reasonably accurate control of fuel/air mixture ratio and amount. One of its few disadvantages is that the fuel/air mixture is still sucked into the cylinder from the carburettor via the inlet manifold. It's a bit of a sloppy method, when you think about it, which can't ensure that all of the fuel/air mixture produced by the carburettor for a particular cylinder actually gets into that cylinder. Some may remain in the inlet manifold until the next cylinder inlet valve opens. This can be overcome by having a separate carburettor for each cylinder but that's a bit of a Heath Robinson arrangement and is costly so most car manufacturers have gone to electronic fuel injection (EFI) systems to get round the problem.

In the best EFI systems (using 'multi-point injection') separate fuel injectors place a precisely measured quantity of fuel into individual cylinders, at precisely the right moment — an instant before the inlet valve for that cylinder opens. In systems with slightly lower specifications, fewer injectors may be used (as few as one per engine simply replacing the carburettor — single point injection) and timing of the injection may not be so
accelerator pedal position, engine temperature and air temperature (all present in the closed loop strategy),
sensors are also required to measure engine position and
quantity of air. However, no measurement of fuel quantity
is incorporated. This is because the quantity of fuel
entering a cylinder is determined automatically by the
length of time a fuel injector is open as the fuel in the
feed lines is maintained at a constant pressure.

A knowledge of engine position is necessary so that
fuel is injected from a fuel injector at the precise moment
the inlet valve of the corresponding cylinder opens. In
effect, the same sensor which measures engine speed
can be used to double up for this function - each pulse
corresponding to a tooth in the flywheel is counted by
the control unit so that the count value at any one time
represents the engine position. Once per revolution the
counter must be zeroed, usually when the engine is at
top dead centre on cylinder one, so the control unit
counter is constantly being re-referenced. This can be
done with a second, identical, sensor detecting when a
timing mark on the flywheel passes it by.

Air quantity measurement is necessary to determine
the length of time a fuel injector is opened from the
amount of fuel which must be injected into each cylinder
to give the required fuel/air mixture. Air quantity
measurement isn't a simple process. Most sensors used
in cars up to now do it indirectly by measuring air volume.
The air mass (the parameter required) has to be
calculated from this. The problem arises because the air
mass is so interdependent on the air pressure and
temperature. Great inaccuracies can occur due to
altitude and weather variations unless fairly complex
compensation techniques are used with temperature and
barometric pressure sensors.

Hot-wire anemometers, on the other hand, are
capable of measuring air mass directly with fairly simple
interfacing circuits and recently types have been
developed for use as air intake sensors in motor cars
(Fig. 6). In such a sensor, a platinum wire is heated and
accurately maintained at a constant temperature using
a bridge arrangement circuit. As air passes through the
sensor to the cylinders, heat is taken from the hot-wire
and the extra current required to maintain the wire's
temperature is a direct indication of the mass of air which
has passed through. No errors can be introduced due
to variations of air pressure. Temperature variations are
compensated for with a second wire as changes in air
temperature affect both wires to the same degree.

Part of the fuel/air metering process in an EFI system,
as we've already seen, is to accurately inject the required
amount of fuel through a fuel injector into the combus-
tion chamber. If the fuel is at a constant pressure, as in
the example here, the task is merely (!) one of measuring
the air intake, calculating the amount of fuel required and
opening the fuel injector for the amount of time which
will cause that amount of fuel to be injected. This
requires that the fuel is maintained accurately at a pre-
determined pressure and the fuel injector is capable of
sufficiently high-speed operation.

If the pressure is such that an open fuel injector will
inject, say, 240 millilitres per minute (a typical amount)
then to inject sufficient fuel for a full charge into the
cylinder, say, 0.01 ml, the fuel injector must be open for
only 2.5 ms. The fuel pressure regulator in the fuel lines
must be a pretty accurate device, as even a small variation
in pressure means a corresponding variation of the
amount of fuel getting to the cylinder. Fuel injectors are
typically solenoid operated valves (Fig. 7), specially
constructed to give fast and constant opening and closing
lag times.

Some previous EFI systems, although digital, are not
microprocessor-controlled. Instead, integrating/differenti-
ating circuits determine the required opening times of

![Fig. 4 Construction of a typical lambda sensor (Bosch).](image1)

![Fig. 5 Typical multi-point electronic fuel injection system.](image2)

![Fig. 6 Construction of a hot-wire air mass sensor.](image3)
Ignition Control

Like carburation, motor car ignition timing has seen a number of significant advances in recent years from the basic Kettering system (battery contacts, coil, distributor, spark plugs) invented back in 1908, to microprocessor-controlled fully automatic systems able to adjust engine performance to suit all load conditions and meet any exhaust emission regulations.

The first stage in improving the Kettering system is to eliminate the major cause of inaccuracies — the contact breaker points. Systems which do this still maintain the distributor, however, in much the same way that automatic carburettor carburation systems maintain the carb. Looking at it another way, although the major cause of ignition timing inaccuracies has been removed, the other mechanical parts of the distributor (the centrifugal advances, the vacuum advance, and the rotor arm switching mechanism) are then the limiting factors in ignition performance.

Newer and higher performance ignition systems eliminate the distributor entirely, using electronic means to create the high voltage pulses required and distribute them to individual spark plugs. Like carburation control, ignition control systems may be closed or open loop.

Figure 8 shows the basis of a completely electronic closed loop ignition system. Sensors are used to monitor engine temperature and inlet manifold air pressure, engine speed and position and engine knock. The control unit adjusts spark timing to suit varying engine load conditions and requirements using an ignition timing curve stored in a ROM-based look-up table, much as the EFI system stores fuel injection times. The distributor’s role is taken over by the use of an ignition coil, performing both distribution and coil functions. Coil shown is a double-ended type, and has diodes fitted either internally or externally to determine which plugs are to be fired. Alternatively, two double-ended coils are sometimes used in electronic distribution ignition systems without diodes.

Use of a transducer (typically, a piezo-electric accelerometer — Fig. 9) to sense engine knock is worth a quick mention here. Generally it is best to run an engine as advanced as possible, but not so advanced as to cause knocking. Knocking means the fuel combustion is starting too soon and the power developed by the ‘burn’ is acting against the piston coming up in the compression stroke. Apart from wasting power, it does the engine no good. Sensing the occurrence of knock allows the control unit to run the engine so that ignition timing is as advanced as possible — any slight knock detected causes the control unit to retard the ignition timing preventing further knock.

Engines run on this ‘knock limit’ using electronic distribution offer greater economy than is possible with mechanical distributors simply because of accuracy. Fig. 10 illustrates a possible ideal engine advance with speed, which can be seen to vary considerably over the full range of speeds. An electronic distribution system can follow accurately the advance curve whatever the engine speed.

A mechanical distribution system, on the other hand (and by this I mean a conventional distributor, whether or not electronic circuit breakers are used) just cannot cater for the rapid variations in engine advance which are needed, and engine knock can only be avoided by retarding the ignition timing sufficiently so that knock cannot occur under any operating circumstances. Obviously, there are conditions when the ignition is too retarded in the mechanical distribution system and so power is lost, fuel economy is poor and unwanted exhaust emissions occur.

Operation of the closed loop knock sensing system is pretty straightforward. Under usual circumstances the ignition timing is derived from ROM-based tables of timing and temperature correction factors. However, when unusual engine load conditions cause knock to occur the control unit retards the ignition in, say 5° steps, until no further knocking is sensed. Then the ignition timing is progressively advanced again, say, by 1° per 25 ignition sparks until the memory mapped tables are again followed or, until knock re-occurs.

Separate fuel management and ignition management systems like these without doubt give great advances in overall engine control — lowering fuel consumption, giving maximum power and lowering noxious exhaust emissions. Nevertheless, two separate control systems of this sort of complexity means there is inevitable component redundancy. Similar temperatures sensors, similar engine speed sensors and similar control units are used in both.
While TEMS are being developed which perform the functions to release the brake pedal until the wheel is turning once roadsurface.
The result is a locked wheel which is skidding along the road surface.
because the driver has applied too much pressure onto the brake pedal considering the road surface condition.
Perhaps the best known electronic vehicle safety improvement system is the anti-skid or anti-lock braking system (ABS), of which there are many types.
Nowadays, some pretty complex engine control systems (known as 'total engine management systems' — TEMS) are being developed which perform the functions of both previous systems using a single control unit, saving the cost of duplicated parts. Looking further ahead, it's feasible that systems will eventually combine engine control together with safety, instrumentation display and comfort systems into a single automotive electronic system with all parts controlled by one control unit.
Whatever the way forward, it's pretty apparent that programmable systems will become the norm because they allow the manufacturer to adapt the engine to suit a wide variety of body types and weights — such fine tuning of an engine's characteristics requires that, to ensure optimum performance, different ROM-based programs will be necessary with even a minor body adaptation.
Safety
Perhaps the best known electronic vehicle safety improvement system is the anti-skid or anti-lock braking system (ABS), of which there are many types.
Wheel skid, of the sort which ABS systems can prevent, occurs when a braked wheel loses frictional contact with the road surface. In all cases it happens because the driver has applied too much pressure onto the brake pedal considering the road surface condition.
The result is a locked wheel which is skidding along the road surface. Vehicle stopping distance is greatly increased because the maximum amount of wheel/surface friction is not available. To regain complete control of the vehicle in such a case, the driver needs to release the brake pedal until the wheel is turning once more and then re-apply brake pressure.

Maximum braking efficiency occurs just before the wheel actually loses frictional contact with the road surface, so ideally, the driver needs to apply just enough brake pressure to reach that condition, but not enough for frictional contact to be lost. You'd probably think that maximum braking efficiency would occur when the wheel is not slipping at all, but in fact maximum coefficient of friction occurs when the wheel is slipping by about 25-30%, so the shortest stopping distances will be reached with wheel slip of this amount.

Needless to say, obtaining maximum braking efficiency is not an easy task, particularly for an inexperienced driver. Some experienced drivers try pretty close to maximum braking efficiency by applying sufficient brake pressure to just cause wheel lock, then as rapidly as possible, release and press the brake pedal in a fast pumping action to 'step back' from skidding. This 'cadence' braking ensures good braking efficiency and it's the basic principle of all electronic ABS methods.

ABS operation is fairly straightforward. Sensors detect wheel rotary motions and the control unit uses the sensor to detect rapidly reducing rear wheel motion (with the other wheels continue with the same motions, then that wheel is locking up and beginning to skid). Some form of controlled pressure regulating device in the braking system is operated which reduces the brake fluid pressure, reducing the braking effect and counteracting the tendency for the wheel to lock.

Once the sensors detect the wheel is again in motion the pressure regulating device returns full brake fluid pressure and the cycle continues — brake-release, brake-release, etc. The advantages of an automatic ABS system over the manual pumping technique are simply the speed with which pumping takes place (about ten times a second) and the accuracy with which the system detects wheel lock beginning to occur.

Differences between the various types of ABS systems are generally found in the number and types of pressure regulators used, how many wheels are monitored for wheel lock, how many brakes are actuated at a time and whether wheel slip is monitored to obtain the optimum 25-30% or whether wheel slip of any degree causes ABS operation.
In the simplest systems only the rear wheels are controlled (the theory being that on braking, the weight is shifted forward giving the rear wheels lower grip). Both rear wheels are monitored by a single sensor mounted on the rear axle and the control unit uses the sensor signal to detect rapidly reducing rear wheel motion (with only one sensor the system cannot compare wheel motions of different wheels!). A dual-circuit hydraulic system (one circuit for the front, one for rear wheels) means the control unit can reduce the brake pressure to the rear wheels without affecting the front brake pressure, once rear wheel lock is detected.

In the most complex systems (Fig. 12), each wheel motion is monitored by the control unit and a four-line hydraulic system ensures each brake pressure is individually controlled. The control unit calculates individual wheel slip from wheel motion signals from each sensor so that once the optimum 25-30% is reached on braking, the corresponding brake pressure is reduced to maintain optimum slip at each individual wheel.
Brake fluid pressure regulators in any ABS system are of two main types — a centralised actuator or individual actuators at the wheel brake assembly. In the former, brake pressure in the pipes to each brake is varied, so that different pipes may have different fluid pressures — some pipes have the same pressure, but the brake assembly at each wheel modulates the pressure acting on the brake pads.

Fig. 9 Construction of a knock sensor.

Fig. 10 The ideal ignition timing curve as a function of engine speed and timing advance, compared with the curve obtained using a mechanical distributor.
FEATURE: Car Electronics

Belt Up, You Bag Of Wind

Even anti-skid braking systems can't prevent all accidents. But if the brakes can't stop the car safely, electronics can still help in making cars safer for occupants in an accident. The most notable systems to have been developed in this area are the airbag and the seat-belt tightener. Both of these use a sensor to measure the deceleration which the car undergoes. If deceleration is greater than a predetermined limit, such as the car would experience in an accident, then actuators are used to tighten the seat-belt, preventing the occupant from being catapulted forward and maybe hitting the dashboard and/or rapidly pump up a rubber balloon-type bag in front of the occupant, breaking the momentum.

Suspension

ABS systems and even safety features like seat-belt tighteners and airbags are almost old-hat now when it comes to car electronics systems. One new type of vehicle safety system which is still in an early stage of development is electronic suspension. The Lotus 'active suspension system' currently causing a great deal of chin-wagging is an example of things to come in this field. The idea is to counteract the apparent weight transfer which occurs as a car corners, brakes or accelerates and which causes the car to experience body roll or pitching. This is done by adjusting the suspension units at each wheel to maintain the wheels' positions in relation to the car body.

It is the suspension units themselves which provide the key to an electronic suspension system's performance. It's long been known that shock absorbers with high damping coefficients improve road handling and, indeed, one available unit merely acts as a variably dampened shock absorber — 'soft' when the car is travelling in a straight line at a constant speed 'hard' when cornering, accelerating or braking. In principle, this unit has two oil chambers connected by a rotary valve. In one position oil flows between the chambers giving a low level of damping (the soft ride) but when the valve is rotated by 90° oil flow is prevented with a resultant high level of damping (the hard ride). Inevitably, the valve motor takes 100ms or so to operate.

A suspension unit of this type can't prevent body roll or pitching. It merely attempts to reduce their effects on the car's road handling. The Lotus vehicle active suspension system can prevent rolling and pitching. Lotus is naturally reluctant to give too much away about the system as yet (trying to get information out of the company is like trying to get blood out of a stone!) but reading between the lines it's fairly apparent that the system hardware is just about complete and has, in fact, already been used in a range of vehicles — both racing and conventional. What does appear to be still undergoing change is the controlling software.

In principle the unit is formed by an oil chamber, sealed at one end, with an internal piston whose position in the chamber is determined by the amount of oil (Fig. 13). If oil is pumped into the chamber the piston is forced out, if oil is released from the chamber the piston retracts. Lotus' control method is simple enough. When the car experiences cornering, braking or acceleration such that one or more of the wheels is forced out of a nominal position, oil is pumped into or released from the corresponding suspension units, returning the wheel or wheels to the nominal position again. Rather than physically pumping the oil into individual suspension units as and when required, which would take considerable time, the system maintains oil at a high pressure in a hydraulic accumulator, merely injecting the oil into a suspension unit's oil chamber when required.

If you've ever seen trial runs of Lotus cars fitted with this system you'll appreciate the virtually zero roll which it exhibits when cornering. In fact, it looks as though the system exerts a completely opposite rolling movement which seems to bank the car into a corner, much as an aircraft banks in a turn. This may not be as stupid as it seems, because system design has been in collaboration with the College of Aeronautics, at Cranfield Institute of Technology.

It's interesting to comment on the Lotus system, bearing in mind that each suspension unit is effectively an electronically programmable spring. It would be perfectly feasible to program the system's control unit to emulate any desired mechanical spring. In effect, you could choose whether your car felt like a Rolls Royce, or a Mini. Further, when you hear that Mercedes, too, is developing an active suspension system, there can be no doubt that we shall all be hearing a great deal more about active suspension and all aspects of the electronic car as time goes on.
CIRCUIT THEORY

Paul Chappell delves into a fantasy world where all electronics is plain and simple.

After the venture into the realms of mathematics in the past two issues, we're back on solid ground this month with fantasy boxes and down to earth things like that. The idea is to demonstrate with a few examples how circuit theory can remove irrelevant information from a circuit and leave the bare essentials exposed.

Imagine you are choosing a new hi-fi system. You've got the record deck, CD player, cassette deck and speakers all sorted out. You've also bought a power amp but you don't fancy the pre-amp that goes with it. The current pin-up of the hi-fi reviewers is a little darling called the Anadigital PRX-992. It has all the right numbers on its spec sheet, it gives enhanced depth planes and well defined median zonal parameters, it's analytical with a charming touch of naivety, witty and sparkling despite its deep and contemplative nature, it's virtuous and desirable. It's got everything you could ever wish for but will it match your power amp?

So you get the record deck, CD player, cassette deck and speakers all sorted out. You've also bought a power amp but you don't fancy the pre-amp that goes with it. The current pin-up of the hi-fi reviewers is a little darling called the Anadigital PRX-992. It has all the right numbers on its spec sheet, it gives enhanced depth planes and well defined median zonal parameters, it's analytical with a charming touch of naivety, witty and sparkling despite its deep and contemplative nature, it's virtuous and desirable. It's got everything you could ever wish for but will it match your power amp?

To find out, you check the data sheet to find the nominal output signal level and output resistance of the pre-amp. In other words, your view of the pre-amp shrinks down to the equivalent circuit shown in Fig. 1a. Gone are the direct central-register tonal complexes, the front-end nascent ramifications and the bi-valved molluscs. Your view of the pre-amp for matching purposes is nothing more than a signal generator and resistor.

This is quite some feat of simplification when you consider that to reduce the pre-amp to a two terminal network, the box must contain not only its entire circuitry, not only the CD player and its internal circuitry but also the entire national grid complete with power stations and zillions of miles of wire. Well done!

Of course, the signal source and resistor model does not attempt to explain what goes on inside the box. It just gives a representation of the way the box 'looks' to anything connected to its terminals. The model you use in any given situation depends on just what information you need. In other circumstances the four-terminal representation of Fig. 1b would be a better way to think of your amplifier.

Some of the simplifications you regularly perform are more subtle. When you buy a TL071 you have every confidence that at its terminals it will behave as if there were an op-amp inside the plastic lump. You know that what's really in there is a silicon crystal with a few odds and ends of impurities diffused into it. You know that anything approaching a full explanation of what the IC is really doing would involve an extensive understanding of semiconductor physics. For the purposes of circuit design you ignore all this. Your attention is focussed on the way it looks to anything connected to its terminals. The way it looks is like an op-amp.

Even the fact that it needs a power supply can fade from your mind. In circuit diagrams the power connections are as often as not left out completely. It's all part of the process of discarding irrelevant information. If the national grid is ever given any recognition for its contribution to your circuit, it is dismissed as a wavy line at the input to the power supply! The idea of simplifying a circuit or component to concentrate on the essentials is not new to you. All I hope to do in this article is to refine it a little.

Thévenin's Fantasy Box

The circuit theory which says it's OK to represent linear two terminal networks as a source and impedance is Thévenin's theorem. It's something you already use when you talk about the output impedance of an amplifier, the internal resistance of a battery and so on. Let's take a look at a few examples and see what it can do for us.

A simple example is the voltage divider shown in Fig. 2. Figure 2a shows the 'real' divider network — the box contains two resistors, a 10V power supply (and the entire national grid...). Figure 2b is the fantasy version containing a single voltage source (which works by magic) and a resistor. If Thévenin's theorem is correct, there should be no way you can tell, short of opening the boxes, which circuit is which.

First of all we have to decide what values to give to V and R. The open-circuit output voltage of Fig. 2a is clearly 5V, so if the fantasy box is going to fool anybody the value of V must also be 5V. If the output terminals of the real divider are shorted together, the current flowing between them will be 1mA (10V across 10k), so the fantasy box must also have a short-circuit current of 1mA, giving R a value of 5kΩ.

That's all very well. They match under open-circuit and short-circuit conditions but will they still match in between? If I get a 20V supply and use it to stuff current into the output terminal, what then? Do the two circuits still behave in the same way? The short answer is that being linear circuits, they will always match. If you are not convinced, try a few resistors, currents or voltages at the output and see what happens. A 5kΩ resistor across the fantasy box will give an output voltage of 2.5V, for instance. The 'real' box should give the same. Get out your calculator and make sure!

In general, for resistor networks, the Thévenin voltage...
will be the ‘real’ open circuit output voltage and the resistor will be the open circuit output voltage divided by the short-circuit current.

**D To A Converter**

A simple way to make a D to A converter is the weighted resistor network shown in Fig. 3a. The problem with this approach is that a variety of non-standard resistor values are needed if reasonable accuracy is to be achieved. It also imposes widely differing loads on the digital inputs, which could be a problem if the circuit is driven directly from a CMOS IC.

Another way of tackling the problem is shown in Fig. 3b. This circuit imposes equal loading on all inputs and only requires one resistor value. (The 2R resistors can be made from two Rs in series or the Rs from two 2Rs in parallel). For a precision network, it is a lot easier to select resistors all of one value (without knowing exactly what that value is) than it is to manufacture or measure them to a specified resistance. A simple resistor bridge will do the trick.

If you haven’t seen the R-2R network before, I think you’ll agree that it’s not immediately obvious why it works. At first sight it’s clear that the less significant bits have to ‘go through more resistors’ but that’s about all.

Suppose that the LSB is set to 1 and all the rest to 0. We can open a fantasy box for the LSB voltage and resistors R1 and R2 in just the same way as for the potential divider of Fig. 2. Inside the box will be a voltage source 8V and a resistor of value R (Fig. 3c).

Now we can draw R3 into the fantasy box. It has the effect of increasing the resistor value from R to 2R (Fig. 3d). To suck R4 into the box halves the voltage again and sends the resistor value back down to R. Adding in R5 sends it back up to 2R (Fig. 3e).

Now we begin to get the picture. Each step up the ladder halves the voltage and always gives a loading of 2R to the following stage. Having got the hang of it, we can quickly stuff the rest of the network into the fantasy box. Figure 3f shows the penultimate stage and Fig. 3g the ultimate simplification of the network with the LSB set.

Suppose the bit above the LSB is 1 and all the rest are zero. Notice that R1, R2 and R3 give a resistance to ground of 2R to this stage just as R2 did for the LSB. The same process of feeding the network into the fantasy box, starting one stage higher up gives Fig. 3h. The voltage is twice as big. For the next stage it will be 4V and for the final stage 8V.

Now, all this applies to the case when only one bit is set at a time. Do we need to go through all 16 possible inputs? (Or through all 256 for an 8-bit converter?) Not at all. Superposition tells us that the result of several bits being 1 (several voltages applied) is simply the sum of the voltages given by the individual switches, so we’re done!

The output (for this example) is a voltage equal to the binary number represented by the input.

If the operation of stuffing the circuit into the fantasy box doesn’t make its operation any clearer to you, remember my warning in the first article that you couldn’t expect instant enlightenment. If you are not familiar with fantasy boxes it won’t help at all. Meditate on this example for a while and you’ll come to an understanding of Thévenin’s theorem. Use the theorem a few times and it will become clear as daylight. You’ll see.

Apart from the direct reduction of a complicated circuit to a simple one, there are many other reasons for representing a circuit in fantasy form. One might be that the actual mode of operation of the device is not particularly enlightening or helpful when it comes to designing circuits.

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**Fig. 3** (a) and (b) two possible resistor networks for D to A conversion. (c)-(g) Thévenin fantasy box eats resistors! (h) the result of the same simplification beginning one step further up the network (bit 1 set instead of bit 0).
Take transistors, for instance. Most engineers have a naive appreciation of the physics involved – a garbled electrons and holes model, perhaps. Most will be aware of some of the limitations imposed on performance by transistor geometry. Some may even have taken the trouble to come to terms with the current state of the art in semiconductor physics. How many actually use physical models to design circuits? Not one, I venture to suggest.

The reason is not that the models are incorrect, incomprehensible or boring – simply that they contain far too much irrelevant grot from a circuit design point of view. Engineers have their own kinds of fantasy boxes for semiconductors, containing things that they feel much more at home with.

Transistor fantasy boxes are really a special case of those used for general four terminal networks. (Spot the deliberate 'mistake': Four terminals?) When you think about it, a good many electronic circuits have a two wire input and a two wire output and so can be conveniently put inside a four terminal box (the amplifier representation of Fig. 1a, for example).

For two terminal networks, there are a number of ways of describing how it 'looks' at the terminals. If the network contains only resistors, a simple Ohm's law description is quite enough. If it has capacitors and inductors too, it can still be summed up by an AC equivalent of Ohm's law (more about this another time!). If we allow sources too, there's the Thévenin equivalent, and also the Norton equivalent in which the circuit is summed up as a current source in parallel with an impedance.

All these aim to give the simplest possible description of the appearance of the network at its terminals but not to describe what goes on inside.

With a four terminal network, there are many more possibilities for the simple reason that there are more terminals to apply inputs to and take outputs from. For a passive two terminal network, you can apply a voltage and measure the current, or apply a current and measure the voltage and that just about exhausts the possibilities. With a four terminal passive network it is usual to stimulate it from both ends at once, giving rise to three sets of parameters according to whether the stimulus is a voltage and that just about exhausts the possibilities. With a four terminal passive network it is usual to stimulate it from both ends at once, giving rise to three sets of parameters according to whether the stimulus is a voltage source (giving the g- or conductance parameters) two current sources (giving the r- or resistance parameters) or one of each, which gives the h- or hybrid parameters.

Figure 4a shows a general four terminal resistor network being excited by a current $I_1$, applied to the left hand side and a voltage $V_2$ to the right. The only way the circuit can respond is to give a certain voltage $V_1$ at the left and a current $I_2$ to the right. Since $V_1$ and $I_2$ could be caused by either or both of the stimuli, the most general summing up of the situation is:

$$V_1 = h_{11}I_1 + h_{12}V_2, \quad I_2 = h_{21}I_1 + h_{22}V_2$$

The various $h$s are the hybrid parameters, the subscripts are according to the convention adopted by most electrical engineering text books – you can look on the 1 in the subscript as meaning 'input' and the 2 as meaning 'output'.

The physical interpretation of the parameters is quite simple. $h_{11}$ will be the input resistance with a short circuit at the output, $h_{12}$ is the reverse voltage gain, $h_{21}$ is the forward current gain and $h_{22}$ is the output conductance with the input open-circuit. Now you can see the reason for the name 'hybrid' – two are dimensionless, one is a resistance and one is a conductance. Quite a mixture!

The simplest fantasy of what could be inside the box to give these results is shown in Fig. 4b. Having said that this applies to resistor networks, how can it be of any use for representing transistors? Well, the parameters can obviously be used for any circuit which doesn't mind having a current imposed on its input and a voltage on its output and a transistor falls into this category. Furthermore, the behaviour of a transistor under certain circumstances turns out to be very much like a resistor network with gain. It was originally called a 'transfer resistor', after all.

The IEEE recommend a slightly different set of subscripts from the ones shown above. For $I_1$ use $i$ for 'input', for $22$ use $o$ for 'output', for $21$ use $f$ for 'forward transfer', for $12$ use $r$ for 'reverse transfer'. In addition, for transistors a second subscript $b, c$ or $e$ is used to indicate common base, common collector or common emitter configuration. So the input resistance of a transistor in common emitter configuration is called $h_{ie}$, the forward current gain will be $h_{fe}$ (recognise that one?) and so on.

For FETs, by the way, it is usual to use the g-parameters since they are happier responding to a voltage than to a current. You may have seen $g_m$ and $g_d$ in data sheets – I'm sure you can work out the interpretation.

The h-parameter transistor model appears in a number of guises, some simpler than the one shown, some considerably more complicated. A detailed look at these models and their uses will have to wait for another day.

**Fig. 4 (a) A general four-terminal resistor network stimulated by current $I_1$, and voltage $V_2$. 'Outputs' are $V_1$ and $I_2$. (b) One idea of what could be inside the box to give rise to the $h$-parameter model shown. (c) A simple h-parameter model for a transistor in common-emitter mode. This is an AC model (no static DC currents and voltages are shown – in particular, $h_{11}V_1$ does not represent the 0.6V base-emitter voltage drop). It applies to signals small enough for the non-linearity of the base-emitter junction to be neglected, and low enough in frequency for internal capacitances to be ignored. There are a number of models derived from this. The source $h_{ij}$ is often left out since at normal operating currents it is negligible in comparison with $h_{11}$. A typical value of $h_{ij}$ for a small-signal transistor operating at a collector current of 1mA would be around $10^2$ to $10^3$.**
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The only really significant restriction in choice of PROM (PLE) for a given logic function is the device size. This freedom is due to the exhaustive decoding of the AND array and the availability of all AND outputs to all OR inputs.

In a PAL there are seldom enough AND terms available for exhaustive decoding and the OR array has a fixed configuration in any given device. When it comes to selecting a PAL, early choice of a specific part is fundamental to success.

As the OR (sum) array is fixed, this is one of the first things to consider. Normal PALS provide from two to seven OR terms per output depending on device density but some recent additions to the Monolithic Memories Incorporated (MMI) range provide none (an AND-only array for simple decoders) or an option called ‘product term sharing’ which uses an intermediate programmable array similar to that in a PLA to provide up to fifteen OR terms which can be shared between each pair of physically adjacent outputs.

So how do you actually choose your PAL? First determine whether you want active high or active low outputs (or whether both must be available). This will limit you to type 'L' active low, type 'H' active high or type 'X' exclusive-OR devices. Then you must check how many input and output pins you need and how many outputs (if any) are to be fed into the device. This will usually limit your choice to less than half a dozen devices.

Next look at the layout diagrams of these devices and find one which has enough OR terms per output for the most OR-intensive sum-of-products equation in your set. Supposing for the moment that this reduces your choice to a couple of alternatives. Either device will usually serve your purpose but you should then check which device is cheaper/more easily obtained, or (if it is important to you) which offers the highest speed or the lowest power consumption.

This is of course something of an over-simplification. It takes a while to get the feel of PAL (just like anything else) but eventually most of the decision making becomes second nature.

**Palasm — A Short Cut**

Palasm is a proprietary PAL assembler from MMI. It accepts an ASCII input file and generates output files suitable for transmission to automatic programming equipment. The original Palasm 1 was crude and primarily dedicated to combinatorial logic generation. As the PAL family grew to include registered devices and larger arrays (currently up to 8K AND fuses and 16 input/output lines) Palasm was rewritten to accommodate these innovations.

The current Palasm 2.21 is a very different beast from the early versions. In fact it is a suite of programs which relies on the same data files. These are chained together via a menu (IBM PC version) to make them look prettier but they are just as easy to use individually in the correct sequence. The suite consists of:

- an input file syntax checker.
- a fuse matrix plotter.
- a device function simulator.

I will discuss each of these separately, as they all have interesting points. This is not a review of Palasm but the package is representative of its genre and I would recommend it to anyone who has an IBM compatible micro and about £150 to spare. It's certainly the cheapest of its kind.

The input to Palasm 2 is an ASCII file which uses a specific syntax. It can be prepared on any word processor which does not embed silly codes (Wordstar in non-document mode works fine). The file consists of an information header containing details of the device function name, author and so on (which is semi-optional), the PAL part number to be used and a list of the user defined pin names. Next come the Boolean equations which describe the required function. These use the standard symbols I introduced last month and the pin names declared in the header. Comments are allowed and do not affect assembly.

The final section of the input file is a 'simulation' specification. This consists of a sequence of statements instructing the simulator to manipulate and test the device file.

Instructions allow you to set the logic levels on input pins, to specify which outputs are to be examined and to clock sequential (registered) devices. A simple conditional and loop structure is available to allow brief specification of tests for long sequence state machines and the like.

Once you have prepared your input file, it is passed through the syntax checker. If it is error free (typing errors, not logical errors which with luck will be found by the simulator) then the fuse plotter is run. This takes the input file and correlates it with a map of the chosen PAL device. The resultant output is a printable fuse plot diagram together with a system file containing a compressed functional description of your logic, which will be used by the simulator. When the simulator is run and no errors are found, the final programming files are generated in several different formats for various programmers.

The simulation is really one of the most crucial...
Palasm output. Please note that the device specification given here is copyright Mike Barwise/Bear Hardware.

The blowing files. The final result of the Palasm design process ready for loading into a PAL programmer. The file produced by Palasm is to the Jedeck standard.

The map of the PAL fuses produced by Palasm. X is an intact fuse, 0 is a blown fuse and the dashes represent phantom fuses.

The Palasm input file which forms the device specification. This lists the names given to each pin of the PAL device and the boolean equations describing its function.

A Palasm simulator output. In essence, a truth table for the programmed device.

elements of Palasm, and probably the most difficult to use intelligently. Simulation is the one thing you just can't do effectively by hand, especially when you are designing sequential logic.

Palasm compares the simulation results with the input equations and a truth table is generated. It is also possible to request a specific check of the logic level on a given output, in which case an explicit error message is generated in addition to the truth table data if a match is not found. All output including error messages is sent to a disk as named files. This is quite an important point as a really good PAL design (particularly a good simulation) can take several days to get finished.

It is, however, perfectly possible to create a simulation that proves nothing. In order to simulate your device properly, it is essential to not only have a very clear idea of what should happen but an excellent idea of what should not happen. Tests must be included for potential 'stuck' hazards, invalid inputs and so on. Remember: none of us write perfect simulations first time round. The simulation will probably still be updated several times after the PAL has appeared to assemble correctly. If things seem to have gone too smoothly, there's usually something evil hiding which will let you down with a thump after your PAL master has been blown (bang goes £25!).

An example problem is the modulo-10 counter. To create this in a binary system, you must somehow shorten the count of a modulo-16 counter. You still need four bits but the MSB is only partially used. This is very readily expressible in sum-of-products terms and everything looks very simple. However, most useful counters are loadable. So what happens if you load the counter with, say, 14? It should upwards count between 0 and 9, or from its preloaded value to 9, so it won't like you for asking it to count upwards from 14 to 9?

The only really safe way of determining what will happen is a simulation. The very ease with which a device function like this can be specified almost guarantees that hazards will often remain hidden.

I will leave this matter for the time being as much more detail in the absence of concrete examples could prove highly indigestible. I will from now on be using PALS (as an alternative to discrete TTL) in support of other concepts in this series when necessary. It is via these practical applications that you will probably gain the best insight into PAL design methods. I will round off now with a few comments on the limitations of PALS.
When Not To

PALs might seem the absolute ideal for low cost logic implementation. For those who cannot warrant the use of full custom silicon, what more could be done? There are, however, some critical limitations to their usefulness.

The first and most obvious limitation is the PAL pin count. Any application which is highly input/output intensive can be a problem as you may not be able to find a device with enough pins for your signal set. The second problem (primarily in sequential logic) is device compatibility.

To simplify implementation of complex user-defined functions, many PALs have arrays of pre-defined higher level elements (exclusive-OR gates, arithmetic networks, registers and so on) built in. However, the organisation of such elements in a given part may not be exactly what you need. There may not be a suitable PAL device in a given manufacturer's series.

There is no low cost universal programming system, as most manufacturers use radically differing programming algorithms. The upshot is that you may have to mix parts from different manufacturers (which is a real problem when programming) or think again and use more PALs than you expect whenever your design is really complex.

It is worth repeating that a PAL assembler which allows design for more than one manufacturer's chip series is likely to cost a lot of money. An example of a problem design is a function with one 8 bit bi-directional data port and four asynchronous flip-flop registers plus their control lines. The one thing you can't do in any MMI PAL currently available is create a bi-directional port. Your inputs and outputs must therefore be kept separate.

The next thing you can't do except in two part series (RA PAL and MEGAPAL) is provide independent clocks to separate registers in the same chip. Thus the function above will need three conventional cheap PAL chips to create but it can be done even cheaper in TTL using four chips (two 74LS373/374 plus two 74LS74) and maybe a little glue logic.

PAL is a very powerful product for the right kind of job. It is best for the creation of decoders, counters, shift registers and non-random state sequence generators. It is really advisable to use a design tool for it as the hazards inherent in the kind of functions PAL is good for and the hazards associated with its implementation are difficult to debut by hand.

For combinatorial logic, semi-random and random function generation, PLE (PROM) is likely to be the best solution. Although a design tool such as PLEASM (from MMI) can improve design efficiency, it is perfectly possible to design PLE freehand, as long as you don't try to do the excessively fancy, such as feedback into the device from its own output.

That's all on programmable logic for now. I will introduce new departures as they appear. Next month I am going to describe hardware FIFO memories. These have come a long way since I introduced FIFO concepts (ETI September 1986) and they are now so cheap and easy to use that they really are a must.

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ETI AUGUST 1987
Paul Chappell looks at designing circuits using analogue multiplier ICs.

The hi-fi power meter in the June issue made use of an analogue multiplier IC, the SG1495. It’s an interesting little device and as there was not enough room to say too much about it then I’m going to take a look at it in detail here.

Most ETI readers will know that the circuit of Fig. 1a has a voltage gain for small inputs which depends on the current, i. More precisely, the gain is proportional to this current.

In the days before circuits came packaged in little black plastic lumps this ‘long-tailed pair’ was used for all manner of signal processing applications. In its simplest form, the current source is replaced by a resistor. This gives a reasonable approximation to a constant current because the voltage across it is held constant by Q2. The output can be taken from either collector depending on whether an inverted or non-inverted version is required, or from both for a differential output. You will almost certainly have seen the circuit in its ‘naked’ form as the input of discrete component amplifiers and it is still widely used inside black plastic lumps - including the SG1495!

Replacing the current source with Q3 and R3 (Fig. 1b) gives a simple voltage controlled amplifier. Increasing the control voltage gives more current to Q1 and Q2, giving greater voltage gain at the signal input. Reducing the control voltage has the opposite effect.

If you think about it for a moment, you’ll realise that a voltage controlled amplifier and a voltage multiplier are one and the same thing! Suppose that R3 is chosen so that 1V on the control input gives a gain of 1, then 2V gives a gain of two, 5V gives a gain of five and so on. If 2V is applied to the signal input and 5V to the control input, the output will be 2V (input) x 5 (gain) = 10V. In other words, the two voltages have been multiplied together.

The circuit of Fig. 1b has far too many shortcomings to be considered as a practical multiplier circuit. The first problem is that besides altering the gain, the control voltage also varies the DC level of the output signal.

If the circuit is set up so that 1mA tail current gives a DC level at Q1 and Q2 collectors of, say, 3V below the positive supply, increasing the current to 2mA not only doubles the gain (the effect we want) but also shifts the DC level down to 6V below the positive rail! If the control voltage varies rapidly, as in a tremelo circuit, this level shift will be seen as an unwanted low frequency signal (Fig. 1c).

In an audio VCA this would be called ‘control voltage breakthrough’ or something of the sort. A simple high-pass filter (a capacitor and resistor will do) is an easy cure. The control voltage is likely to vary very slowly in comparison with the audio signal and so the filter will separate the wanted signal from the unwanted one.

This is no good for a multiplier. Both inputs must be given an equal status - both able to accept equally high frequency signals. It should also be able to multiply very low frequency signals or DC levels so no capacitors are allowed.

The cure is quite simple and doesn’t even involve changing the circuit. The output due to the signal and control inputs acting together causes the voltages across R1 and R2 to change in opposite directions whereas the DC shift caused by the control voltage alone will cause them to change in the same direction. If the output is regarded as being the difference in voltage at Q1 and Q2 collectors, the problem disappears!

As it stands, the circuit of Fig. 2a is a two quadrant multiplier. The first voltage input can vary above or below zero, giving positive (v1 > v2) or negative (v1 < v2) outputs. The second voltage input (I’m going to have to stop calling it the control input if we’re talking about multipliers) can only be positive. It can vary the magnitude of the output but can’t reverse it.

Figure 2b is the basis of a full four quadrant multiplier. It is simply Fig. 2a twice. If v1 is zero (with respect to its own reference voltage of -1/2v) v2 will be amplified equally by each pair Q1,2 and Q5,6. If v1 rises, Q1,2 will amplify more and Q5,6 less. If v1 falls, Q5,6 will amplify more and Q1,2 less.
Think about $i_1$ and $i_2$, for a moment. As $v_1$ varies, $i_1$ will be modulated in phase with it. Because $v_1$ drives $Q5/6$ from the 'opposite side', $i_1$ will also vary in proportion to $v_1$, but will be inverted. If $v_2$ is zero, the magnitude of the changes in $i_1$ and $i_2$ will be the same, but in opposite directions. If the currents are added, the net result will be no change at all. If $v_2$ is above zero, the 'in-phase' current $i_2$ would predominate. The result of adding $i_1$ and $i_2$ would be a net current change in phase with $v_1$. If $V_2$ is below zero, variations in $i_1$ would be greater than those in $i_2$, and the combined signal would be inverted.

With the two sets of collectors cross-connected as in Fig. 2c, the circuit is a full four quadrant multiplier. Another benefit of the cross connection is that there is no longer any problem with shifts in DC level because any increase in current in $Q3$ is matched by a decrease in $Q4$ (and vice versa). When these currents are summed again only the wanted differential signal remains.

Taking a differential output still has certain advantages, though. In particular, it cancels any common mode signals caused by imperfections in the current source (or resistor in this case) and by variations in the base currents of $Q1$, 2, 5 and 6.

One of the remaining niggles about Fig. 2c is that although it is a perfectly good multiplier, it will only accept very small input signals. Take $v_1$, for instance. Increase it by 500mV and for all practical purposes $Q3$ will be taking all the current and $Q4$ will have none. Long before this point is reached the non-linearity of $Q3/4$, will have become painfully obvious, so inputs really have to be restricted to a few tens of mV.

Figure 3a shows a differential pair which has been modified to take much larger inputs and maintain excellent linearity. If $v_{n1}$ is at 0V there will be no voltage across $R$ (and therefore no current through it), so $Q_1$ and $Q_2$ will each have a current $i$ from their respective current sources. Increase $v_{n1}$ and the voltage developed across $R$ will cause some current to flow from $Q_1$ into $Q_2$'s current source. $Q_2$ will have far more than its fair share of current and $Q_1$ will have less.

Assuming constant $V_{be}$ drops for the two transistors, the current change in either collector will be $v_{n1}/R$ (but in opposite directions!). The differential output voltage will be $2v_{n1}R/R$ (by Ohm's law!) so the voltage gain will be $2R/R$. Therefore, decreasing $R$ will give increased gain. Unfortunately it will also give poorer linearity, so component choice means selecting a balance between the two.

Another way to increase the signal handling of a differential pair is shown in Fig. 3b. Transistor $Q_1$ produces a current proportional to the input voltage (it gives a fairly linear voltage to current conversion for inputs above one $v_{be}$ drop). The current is passed through a diode which gives a voltage drop proportional to the log of the current. This 'compressed' voltage is then used to drive the differential pair input.

If the diode and $Q_1$'s base-emitter junction are matched (not too difficult on an IC), the compression in the diode will be the reverse of the exponential voltage to current relationship of the transistor and the overall result will be linear!

To return to Figure 2c, the remaining problem is that the inputs and output are all referenced to different voltage levels. Input $v_1$ varies about 0V, $v_2$ varies about $-\frac{1}{2}V$ and the outputs lie somewhere around $+\frac{1}{2}V$. It would be convenient to have both inputs and the output...
The input transistors are Darlington pairs with some essential external resistors added (marked with an asterisk). The input pins to use are optional (as long as one of the left hand pins and one of the right hand ones aren't used!) The only difference will be in the 'sense' of output which pin rises to represent a positive output and which for a negative one. Ground pins 8 and 12 and take the inputs to pins 4 and 9.

The first thing to check is that all the transistors will have enough 'headroom' to work. If pin 9 rises to +5V on a signal peak, it is best to allow at least this voltage for the collector of Q3. Working through the circuit, if Q3 collector is at 5V, the bases of Q1 and Q2 must be set at about 5.7V and the voltage at pin 1 of the IC (which sets the bias conditions) must be at 6.4V. This will automatically allow enough space for Q7 as it has about 0.7V more headroom than Q3 because of the Vs
e drops in Q1 and Q2.

On negative peaks, the emitters of Q7 and Q3 could be as low as −6.4V. If the currents in Q9 and Q11 are 10mA, there will be 15V dropped across their respective emitter resistors, leaving each transistor about 0.6V below its input to low levels, the scale factor is usually set to a value considerably less than one — often 1/10.

To take a practical design example, suppose we have two single ended inputs which vary about 0V and have peaks below ±5V. Suppose that the following circuit will accept differential inputs of ±2.5V peak. A scale factor of 1/10 will meet these requirements — the overall relationship will then be

\[ v_{out} = v_{in} \times 10 \]

Suppose that the IC is running from ±12V supplies.

The input pins to use are optional (as long as one of the left hand pins and one of the right hand ones aren't used!) The only difference will be in the 'sense' of output which pin rises to represent a positive output and which for a negative one. Ground pins 8 and 12 and take the inputs to pins 4 and 9.

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down' the inputs. There is going to be some slop in the calculations anyway from the practical consideration of 5% resistor tolerances and so forth.

For the moment, let's set the currents $i_x$ and $i_y$ arbitrarily at 1mA. If the inputs are to accept voltages of 5V, the absolute minimum value we can then give to either $R_x$ or $R_y$ is 5kΩ — this is the value which will starve one or other of the input transistors entirely of current on input peaks. This would give very nasty distortion on the inputs, so best make $R_x$ and $R_y$ about twice the calculated value (the larger the better!) Pencil in a value of 10kΩ for the moment.

If $i_x$ is 1mA and the voltages at pins 2 and 14 are to be 9V, this settles the values for $R_1$ and $R_2$: they must be 3kΩ (or the nearest preferred value).

Now let's see how close we are to the required value of $K$.

$$K = \frac{2 \times (3 \times 10^3)}{10^{-1} \times 10^3 \times 10^4} = \frac{6}{100} = 6.6\times10^{-2}$$

This is too low! To increase it, there are three possibilities:

- **Increase $R_x$.** This also means reducing the value of $i_x$ to maintain the static voltage at pins 2 and 14 at 9V, which in turn will decrease the margin for 'current starving' $Q_3$ and $Q_4$ via the 10kΩ resistor.
- **Reduce $i_y$.** This will decrease the margin for 'current starving' $Q_7$ and $Q_8$.
- **Reduce $R_x$, $R_y$, or both.** This will slightly increase the distortion on one or both inputs.

Choosing the best compromise, leave $i_y$ alone, increase $R_1$ and $R_2$ to 3kΩ, giving marginally less potential swing at the output, and reduce $R_x$ and $R_y$ to 8kΩ. The value of $K$ now becomes:

$$K = \frac{2 \times (3.3 \times 10^3)}{10^{-1} \times 8.2 \times 10^3 \times 8.2 \times 10^3} = \frac{6.6}{67.24} = \frac{1}{10}$$

The small error in scale factor (and anything due to resistor tolerances) can be trimmed by a slight adjustment to $i_y$.

The remaining component values can now be calculated as a matter of routine: $R_3$ must drop 5V at a current 2mA ($2xi$), and so will be 2.5kΩ. The nearest preferred value of 2.5kΩ will be suitable.

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The small error in scale factor (and anything due to resistor tolerances) can be trimmed by a slight adjustment to $i_y$.

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$R_4$ must give a voltage drop of 10.8V at 1mA (12V less 1mA through 500ohms = 0.5V, less one diode drop at 1mA = 0.7V). 10kΩ in series with a 2kΩ preset will allow for slight adjustment of $i_1$ to trim the scale factor.

$R_5$ must also nominally be 10kΩ. A value of 12kΩ will compensate for the slightly increased values of $R_1$ and $R_2$ (3kΩ rather than the calculated 3kΩ for a 3V drop).

Input offset can be trimmed by allowing slight adjustment to the voltage on pins 8 and 12 rather than grounding them.

A few general principles to bear in mind when calculating component values are:

- $i_x$ and $i_y$ should not exceed 10mA to avoid excessive heating of the IC.
- For best frequency response and lowest phase shift, the values of $R_1$ and $R_2$ should be as small as possible.
- Within reason, giving $R_x$ and $R_y$ values greater than the calculated minimum will reduce distortion in the input circuits. It will also reduce the scale factor, so a suitable balance must be found between the two.
- Most of the IC parameters which can be varied interact with each other. Don't change one value without checking its full effects. If every step you take to bring the IC closer to your requirements seems to be counterbalanced by an opposite effect, it could be that you are making unreasonable demands on the IC. Consider 'potting down' or amplifying the inputs or output.

If all this is too much for you, another multiplier, the ICL8013 (Fig. 6) costs around five times as much but is almost as easy to use as an op-amp and will give working circuits with very little trouble.

**ETI AUGUST 1987**
MIDI MASTER KEYBOARD

John Yau gets soft for the last part of the construction of this milestone project.

The final stage of the construction of the ETI Midi Master Keyboard is the installation of software to run the whole system. This is provided in the form of a 16k ROM (a 27128). Only around 2.75k of this is actually used, the rest is left for further expansion of the system. A hex dump of the used parts of the ROM is given here (Listing 1) and this can be laboriously entered by hand into a computer equipped with an EPROM programmer. Alternatively, ready-programmed EPROMs are available (see Buylines).

Once the system hardware is all built and a programmed EPROM is installed in the CPU board (as IC17) the whole MIDI Master Keyboard can be tested and set up.

Testing

Power on the system and look to see if the LEDs light up correctly. On power-up, the double digit display remains blank while the lit LEDs correspond to those of MIDI CHANNEL A, GROUP I and BANK A. All the other LEDs should be blank.

If the double digit display lights up when a program number is selected (by pushing a numeric keypad button) and if the MIDI TRANSMIT LED lights up whenever any note on the keyboard is held down then you can take comfort in knowing the system is most likely functioning properly.

Final verification will depend on monitoring the MIDI OUT data and checking that all the keypad functions are working properly.

The best way to check if the hardware is transmitting the correct MIDI data is to monitor the MIDI OUT data stream with the ETI BBC micro MIDI interface or a similar device. Move the modulation joystick lever and adjust RV2 so that in the position of highest modulation, the transmitted data byte is 127.

The pitch bend joystick is slightly more tricky to set up. On power-up the pitch bend joystick is read and defined to be in the neutral position (data value 64). The target is to get the system to send zero in the lowest joystick completely dead then the CPU kernel (the 6502A, address and data bus to memory devices) is not functioning properly. Check for shorts in the copper tracks making up the address and data buses on the CPU board and also check that a through-pin hasn’t been missed.

Setting Up

The only setting up to be done lies within the joystick section of the hardware. Monitor the MIDI data with the ETI BBC micro MIDI interface or a similar device. Move the modulation joystick lever and adjust RV2 so that in the position of highest modulation, the transmitted data byte is 127.

The pitch bend joystick is slightly more tricky to set up. On power-up the pitch bend joystick is read and defined to be in the neutral position (data value 64). The target is to get the system to send zero in the lowest joystick.
**Output Stream**

The MIDI Master Keyboard's versatility is greatly enhanced by transmitting data through a programmable MIDI channel and by having a dual channel MIDI output stream. On power-up, all data is transmitted via the channel A output stream, on MIDI channel 1.

To change the MIDI channel of the used sections of the Z7128 EPROM.

To change the MIDI channel the channel button must be held down and a numeric button 1-16 selected. The change can be verified by pressing the channel button on its own again so that the newly selected MIDI channel number is displayed.

If the channel B button is pressed, all data is transmitted on the MIDI channel that has been programmed into the B output stream (default on power-up is channel 2).

The only exception to this rule is on the split point. It has been programmed, in which case all notes to the left of the split point will be transmitted on the channel A output stream, whilst all notes to the right will be transmitted on channel B.

The dual output stream capability, although primarily intended for implementing the split point feature, can also be used to remotely change programs on MIDI digital effects units such as the YAMAHA SPX90. The effects unit is simply set to receive on MIDI channel B, so that it responds to any program change request when current output stream is set on channel B from the function keypad.

**Split Point**

If the 'SPLIT' button is pressed and held down the double digit display will show the currently selected split point, the number 1 corresponds to the leftmost key and 72 is the rightmost key. The power-up default is 72 so that all the notes are directed towards channel A.

To program a new split point the procedure is to simply press the selected note on the keyboard whilst holding down the SPLIT button. Once selected, release the SPLIT button and the new split will now be effective.

**Transpose**

When a split point is in effect, both parts of the keyboard are transposable independently. The currently selected output stream decides which part of the keyboard is to be affected when the transpose function is selected.
ETI AUGUST 1987

A 6502A processor is generated by the periodic 2ms signal which interrupts the scanning code at the start of an interrupt. The greater the intervals, the smaller the time interval, for the keyboard to occur at a high precision time. This is achieved by placing the key switch bounce, by ensuring that the time period that a key spends in state 1 to state 0 transition ensures that the velocity sensing is not upset by switch bounce, by ensuring that the time period is always measured from the last point of contact with the upper bus bar to the time of first contact with the lower bus bar.

The current physical state of any of the 72 keys on the keyboard can be obtained by examining locations 0800H to 0847H which are memory mapped directly to the keyswitch hardware. However, for the software to determine when to send out MIDI note on/off events it must also know the state of all the keys from the previous scan. This is achieved by storing the states of the keys in 72 zero page RAM locations.

The contents of each of these RAM locations shows an identifier code (0-3) for each of the four possible sequential states that a key can be in — 'transition going up' and 'transition going down'. When a key is processed, its current state is compared with its last state (from the previous scan). Any necessary action is taken and the RAM location describing the previous state is updated according to the sequential state diagram of Fig. 2.

The sequential state diagram shows how each key state traverses into a new state as a function of the current keyswitch position and its previous state. The two digit binary numbers are the primary variables and indicate the state of the upper and lower bus bars (U and L) for a particular transition.

Most of the process or key strike velocity sensing is tackled by the software. When a key is struck, it leaves state 0, moves through state 1 and ends up in state 2. The velocity of the key can be determined by timing how long the contact spring stays in the air gap between the two bus bars. This is achieved in software by counting the number of 2ms scan periods that the keyswitch stays in state 1, the 'transition going down' state. So in addition to the key state RAM locations there are a further 72 zero page locations that serve as velocity counters for active keys.

The maximum count allowed is 63, so the time period that a key spends in state 1 is measured to be in the range 0 to 128ms, with a resolution of 2ms. In practice, most key strikes are well within half that time period range.

When a key is struck, the contact spring may initially make or break contact several times with the upper bus bar. Zeroing the velocity count at every state 1 to state 0 transition ensures that the velocity sensing is not upset by switch bounce, by ensuring that the time period is always measured from the last point of contact with the upper bus bar to the time of first contact with the lower bus bar.

The most time-critical part of the system software is the part which does the keyboard scanning. Not only does it have to scan the keyboard polyphonically and detect key strikes and releases, it also has to determine key strike velocities. Such demands require complete scans of the keyboard to occur at precise time intervals. The smaller the time interval, the greater the velocity sensing resolution.

This is achieved by placing the key scanning code at the start of an interrupt routine which executes every 2ms. The periodic 2ms signal which interrupts the 6502A processor is generated by the internal timer in the 6522A VIA. Also high in priority is the section of code which empties the buffer containing data to be transmitted via MIDI. When the buffer is being emptied, two bytes of MIDI information can be transmitted every 2ms interrupt period. Such a data rate is sufficiently fast to ensure delays in response are insignificant.

Since the key scan and MIDI buffer empty routines typically take up about half the available 2ms time slot there is some spare time allocation for other processing tasks. Figure 1 shows the structure of the software. On power-up, once everything has been initialised, the main program divides into an endless loop so that thereafter the only real processor activity comes from the periodic interrupt routines.

The code pertaining to the housekeeping activities is segmented into 13 parts. A software counter is maintained so that in successive interrupt routines the 13 sections of code are executed in turn. Segmentation of the housekeeping routines is necessary because of the limited amount of spare time in each 2ms time slot.

The housekeeping routines were segmented so that the time slot for each segment, when added to the worst case duration of the keyscan routine, would not exceed the 2ms duration of the interrupt period.

Calculations show that in the extreme case when about a dozen notes are played at once (Martian musicians take note!) it is possible to exceed the 2ms time allocation. This however, is not at all catastrophic since all that happens is that a velocity count is missed, which hardly affects the overall dynamics of the MIDI keyboard.

### Fig. 1 The system software flow diagram

The current physical state of any of the 72 keys on the keyboard can be obtained by examining locations 0800H to 0847H which are memory mapped directly to the keyswitch hardware. However, for the software to determine when to send out MIDI note on/off events it must also know the state of all the keys from the previous scan. This is achieved by storing the states of the keys in 72 zero page RAM locations.

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For example, if we wish to transpose the part of the keyboard to the left of the split point then the currently selected output stream has to be channel A. To implement the transpose facility, first of all press the TRANPOSE button. The present setting is then displayed on the dual digit display in the form of an offset in semitones from middle C.

A number with the leftmost decimal point lit means that the offset is negative. A number on its own implies a positive offset.

In its non-transposed state the number displayed is 0. To program a new transpose setting, hold the TRANPOSE button down and select a note on the keyboard. Pressing middle C will result in a zero offset and pressing any other note will result in the keyboard being transposed by the relative offset in semitones from middle C.

Note that once a non-zero transpose setting has been programmed the LED above the TRANPOSE button will remain lit.

**Touch Sensitivity**

The present touch sensitivity is displayed when the TOUCH button is pressed and held down. To program a new touch setting, hold the TOUCH button down and press a number 1-16. Release the two buttons and verify the change by pressing TOUCH on its own again. You can also verify the change by playing the keyboard!

**Footswitches**

The footswitch sockets are intended for use with push-to-break switches which is consistent with the commercial equipment. Pushing the pedal hold switch should result in the hold LED lighting up as well as the appropriate MIDI messages being transmitted. Successive switching of the patch advance footswitch will result in successive program number changes within the currently selected bank of 16. The last footswitch switches portamento in and out via MIDI (not all synthesizers will make use of this).

**Acknowledgements**

The author wishes to thank the following people who helped to make this project possible: Alistair Houston for etching the PCBs, Moray Runney for the photography, Ron and Ian C. for the metalwork. Thanks also to Glyn, Ian A., Mitch, Lynsey and Shona.
**REMINDALITE**

Bob Noyes won't be left in the dark with a flat battery thanks to this handy car lights reminder.

With the modern trend to get as many electrical functions in the car on to as few steering column stalks as possible, some form of monitoring is desirable to ensure that nothing has been switched on accidentally or left on inadvertently, because just looking at the stalks can be misleading.

Most functions, such as windscreen wipers, washers, heated rear windscreen and so forth will be switched off when the ignition is, independently of their own function switches. However, the lights can be left on with the ignition off and the resultant drain on the battery, if prolonged, may result in an unpleasant surprise at the next attempt to start the car. With the Remindalite, this problem should be a thing of the past.

The Remindalite sounds several high-pitched buzzes in the event of the lights being switched on with the ignition off or if the ignition is switched off while the lights are on. After a few seconds the buzzing stops as it can be valid to have the lights on, but it brings the situation to your attention.

**Construction**

The board can be simply built with no particular problems as long as the usual care is taken with the orientation of the diodes, capacitors and semiconductors. LED1 can be mounted either on the board or separately in the car dashboard. Provision is made on the board for either alternative. When the board has been built and thoroughly inspected the following tests can be made before connecting it into the car.

For test purposes a 1k0 resistor should be connected between B and D on the terminal strip to simulate the resistive load of the car's electrical system (without it the following test routine will not function).

A 12 volt supply is required with 0V connected to terminal D. The supply should be switched off between tests to allow C1 to discharge.

With 12V connected to terminal A (the lights) and terminal B (the ignition) disconnected the LED should light and the buzzer sound a series of beeps. With terminal A disconnected the LED should be off and the buzzer silent.

**HOW IT WORKS**

The unit is powered only when the lights are on. Q1, a general purpose PNP transistor, is wired so that with 12 volts on terminal B, it is biased off by R1 when the lights and ignition are both on. With Q1 switched off, IC1 is deprived of power.

If the ignition is turned off, terminal B falls to 0V and is held there by the resistive load of the HT coil, alternator coils and so on. Q1 turns on via the potential divider R1, R2 and its collector, at 12 volts, supplies power to IC1 and LED1 via its current-limit resistor R3.

Q1 remains on while the lights are on and the ignition off. To prevent the piezo buzzer sounding continuously, a pulse generator is formed around IC1b. As C1 charges up through R4 the output pin 4 remains high (+12V) until the voltage on C1 reaches about 8 volts. At this point, pin 4 goes low and remains low until the lights are turned off and C1 can discharge through D3, R3 and LED1. To lengthen this period R4 can be increased in value or to decrease it R4 can be reduced.

From the time Q1 switches on until C1 reaches 8 volts, IC1 pin 4 will be high, enabling the oscillator built around IC1c. This is a simple oscillator with a time constant of (R7+R8) C2. R7 is provided to allow the user to tune the piezo buzzer to give the most noticeable beep.

The piezo buzzer in conjunction with Q2, D4, R6 and R9 forms a self-contained oscillator that will oscillate at the optimum frequency to give the highest sound output level. Although it only draws a few milliamps this is more than a CMOS gate can safely provide and so Q3 is used as a current amplifier.

---

**PARTS LIST**

- **RESISTORS (all 1/4W 5%)**
  - R1, 2: 4k7
  - R3: 1k5
  - R4: 470k
  - R5, 8: 15k
  - R6: 100k
  - R7: 22k
  - R9: 1k0

- **CAPACITORS**
  - C1: 10µF 16V tantalum
  - C2: 4µF 16V tantalum

- **SEMICONDUCTORS**
  - IC1: 4093
  - Q1, Q2, 3: BC307, BC171
  - D1-4: 1N4148
  - LED1: Red LED

- **MISCELLANEOUS**
  - BZ1: Piezo buzzer
  - FS1: 500mA fuse and fuse holder

- **PCB**: case; cables and connectors; 4 way terminal strip; nuts and bolts.

---

**Fig. 1** The circuit diagram of the Remindalite.
buzzer silent regardless of the connection to terminal B.

When these checks have been carried out satisfactorily the unit is ready to fit. Remove the 1kΩ test resistor from terminals B and D.

As the unit is going to be left in the car for the rest of its life, a PCB protective lacquer should be sprayed over both sides of the board to stop corrosion in years to come.

**Fitting**

The car's electrical circuit diagram should ideally be consulted so that the colour of the two wires that need to be located can be ascertained. Otherwise the sidelight live connection can be found by following the sidelight wire back into the loom and the switched side of the ignition circuit can be found on the ignition switch.

The car's battery positive terminal should be disconnected before actual connections are made to prevent an accidental short while wiring. The 0V terminal D can be connected to any convenient bodywork nut and bolt, screw, etc.

After the three connections are made to the car's system and the LED fitted to the dash (if it hasn't been mounted on the PCB) the battery can be re-connected and a full test of the unit made.

When all the tests have been completed satisfactorily, the Remindalite should be tucked up out of the way. If the LED is mounted on the PCB and showing through a hole in the top of the box, it should be placed in such a position that it can be seen.

---

**BUYLINES**

The piezo buzzer used was from Electro-Tek (Tel: (0536) 204555) as part number 248-369. Any suitable plastic case may be used. The PCB is available from the PCB Service. See the back of this issue for details.

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**TRANSFORMERS**

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**SPECIAL! SPECIAL! SPECIAL!**

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**TRANSFORMERS**

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**TOURIDOLS**

Wound to order.
SONIC REV COUNTER

Conserve petrol and extend the life of your engine with this novel rev counter from Gary Calland.

Most cars today are supplied with a rev counter. Those that do have a tiny panel meter stuck in the corner of the dashboard which is virtually impossible to read.

Rev counters are not unnecessary novelty devices specifically designed to make a car look sporty (even though they do this well) but are useful money-saving instruments. By running your engine at its optimum speed, savings in fuel and wear and tear can be reduced.

Commercially available rev counters usually display their information by using a small moving coil meter. This is unsatisfactory as a small meter needle is difficult to see, especially at night when the meter is illuminated by a small bulb. This bulb will inevitably burn out rendering an irritable and intricate replacement process.

This rev counter overcomes these problems by using a 10 LED colour coded bargraph display. This attractive display can be easily read day or night and will last more or less indefinitely.

The colour coding means the display is easy to understand as green LEDs mean the engine is running within limits while red LEDs mean it is being over-reved. However, for a more accurate interpretation, each LED corresponds to approximately 600 revs.

Commercial rev counters can also be difficult to install. Usually this entails wrapping pick up coils around various parts of your engine.

The explosions from the engine are picked up by the crystal microphone and differentiated by C1 to produce a sharp spike waveform. This is then amplified by IC1 which is a quad op-amp chip. Only two of the op-amps are used, wired as inverting amplifiers. The gain of the amplifiers is set by R3, R4, R5 and RV1. RV1 allows the gain to be varied from about 100 to 1,000,000.

The amplified spike is fed to the trigger input of IC2 which produces a pulse of constant period. This period is set by RV2 and C2 and is such that at maximum revs the mark-to-space ratio is one, so the average voltage of these pulses is half a pulse voltage.

The amplitude of the pulses is set to 10V by R6 and ZD1 to ensure a constant pulse voltage regardless of variations in supply voltage. The pulses are averaged into a DC voltage by the integrator formed by R7 and C4 and this is fed to the input of IC3 which is a LED bar graph driver chip.

To light all 10 LEDs an input voltage of 5V is needed which is the average voltage of the pulses at maximum revs. Hence at maximum revs, all the LED's light, at half maximum only half the LED's light, and so on. See Fig. 3.
engine, either the distributor or high tension spark plug leads. The coil picks up the magnetic field generated when a spark plug lead is energised and this is used to give an indication of the revs, as with higher revs, the spark plugs are energised more frequently. The electronics associated with this method can be fairly complex and expensive.

This rev counter works on a novel principle. It is triggered by the explosions from each cylinder (Fig. 1). For every revolution of a four cylinder car engine, two cylinders fire. These explosions are picked up by a small crystal microphone mounted in the engine compartment and converted into revs by relatively simple electronics.

Installation is very quick and easy as all that has to be done is to wire up the supply leads and then mount the microphone in the engine compartment.

Construction

All the components including the LEDs are mounted on one PCB. Start by soldering in the resistors, then the capacitors and finally the semiconductors. The overlay of Fig. 4 should be referred to for the correct orientation of all the polarised components and the ICs.

The counter may be mounted directly into the dashboard to give a professional finish. Alternatively, the counter may be fixed into a plastic case. If the latter is chosen, a slit should be carefully drilled and filed for the LEDs in the front and two holes drilled in the back for the supply and microphone leads (see Fig. 5).

Setting Up

Once everything is mounted, the rev counter can be adjusted for correct operation. First, start up the engine, let it idle and adjust RV1 and RV2 to the midway position. RV1 is the microphone gain control and should be set so that the LEDs just respond to the engine. Care must be taken to ensure that the gain is not so high as to pick up other nearby noises such as other car engines. Once this has been done, RV2 should be adjusted so that the first two LEDs just light up when the engine is idling. Test the rev counter by revving the engine. A faster response may be obtained if C4 is changed from 4µ to 3µ.

Parts List

- Resistors (all 1/4W, 5%)
  - R1, 2: 10k
  - R3, 4, 8: 10k
  - R5, 9: 1M
  - R6: 220R
  - R7: 22k
  - RV1: 1M0 horiz preset
  - RV2: 33k horiz preset

- Capacitors
  - C1, 3: 10n polyester
  - C2: 100n polyester
  - C4: 4.7 electrolytic
  - C5: 100µ electrolytic

- Semiconductors
  - IC1: LM324
  - IC2: NE555
  - IC3: LM311
  - ZD1: 400mA zener
  - LED1-7: Green LED
  - LED8-10: Red LED

- Miscellaneous
  - MIC1: Crystal microphone insert
  - PCB: plastic case 120 x 80 x 35mm; power and screened signal cable; mounting bolts.

The supply leads should be wired up to the ignition switch so that power is only supplied when the engine is running. The microphone should be mounted as close to the engine as possible and screened cable used to connect it to the rev counter, as this will reduce noise pick-up.

Buylines

All the components used in this project are widely available. The PCB is available from the PCB Service as detailed at the back of this issue.
CAR ALARM

Protect your car and its contents with this cheap and simple alarm from Bob Noyes.

The number of car thefts increases daily and the old adage 'lock it' is a little outdated as car thieves seem to be able to open, steal from or even drive away just about any car they choose.

In order to protect what is probably the second largest investment the average family makes, some further protection is required.

Motor theft, as the police call it, takes two forms - breaking into a car to steal from it (sometimes shopping but more commonly parts of the car such as the radio or CB rig) and the actual theft of the car. Some protection against both is necessary.

Although at first glance, these requirements seem simple enough, other practical factors need to be considered which complicate the issue - for instance how to switch it on and off. Drilling holes in the outside bodywork of the car is out of the question because this tends to introduce rust around the switch. It will also get spattered with mud and spray from passing traffic making the switch inoperative after a time.

Magnetic key fobs and infra red controllers, at first glance look a possible way of actuating and de-actuating from outside the car but in practice need to be used in one position around the car and this is not always easy when parked in awkward places. Both systems add to the time taken by the driver to gain access to the car, something not appreciated in the rain.

The only practical way is a delayed exit and entry but this can introduce a period when a would-be car radio thief has broken in and started hacking away at the wiring of the radio before the alarm sounds. Although the radio is unlikely to be removed in this time, a great deal of damage can be done.

The alarm described here is of the delayed entry and exit type but has the added advantage that when the alarm has been tripped by opening the door or boot an internal buzzer sounds. This, although not very loud, indicates that an alarm has been set off and something else is about to happen. This should be enough to deter a thief as the last thing he wants is to be seen around a car with an alarm sounding.

Another important factor in an alarm is what form the output takes. Most commercial alarms sound their horns and lights intermittently. This, although very effective, doesn't do much for the horn, lights or battery as these draw an enormous amount of power and are usually controlled by a relay whose contacts arc and spark when switching these currents.

The contacts can weld themselves together sounding the horn and the lights continuously until the battery is flat. The alarm timer which all alarms must have cannot cancel a welded relay! As well as the possible damage because of the high currents, thick and bulky hard to handle wires need to be used. For safety, the alarm switch should switch off all power to the alarm and the supply to the lights and horns used when controlled by the alarm. This would mean a switch capable of 25A or so and not many alarms on the market supply such switches.

To eliminate this problem the sound output is generated by a relay siren having a maximum current consumption of 1.2A. This allows the whole installation to be fused at 2A so much thinner wires can be used.

As a secondary line of defence, the car can be immobilised when the alarm is switched on. One of two methods can be used. If the car is fitted with standard mechanical points, a capacitor can be switched in across them. The value should be in excess of 22µ but with a working voltage of 600V or more. This is switched into circuit by an independent set of contacts on the alarm switch.

In most modern cars an optical or magnetic sensing system is used in place of the points. In these cases it is best to leave well alone as damage can be caused by connecting a capacitor in the wrong place so a switch is placed into the 12V supply side of the electronic ignition module. This can be found using a meter or by following the cars' circuit diagram. Again it is wired back to the alarm key switch.

Operation

On leaving the car the alarm is activated by the key switch. This allows about seven seconds to get out and shut the door. After this time the alarm becomes active and is indicated by the exit delay LED extinguishing (it comes on when the alarm is switched on). The alarm is now active and opening the door will start the following sequence which once started cannot be stopped by shutting the door. Only the key switch will stop it.

The internal buzzer sounds eight times over about a five second period. During this time the alarm should be deactivated by the key switch. Failure to do this will sound the main siren. The siren sounds for approximately one and a half minutes. It will then shut off and reset the alarm. If the door is left open the sequence will start again and will not stop unless the key switch is turned off or the door is shut and then only at the end of the sequence.

If the radio or any other equipment is tampered with and the earth connection removed, the siren will sound immediately.

Instead of the radio, a caravan can also be protected when connected to a car and parked. A loop connection is made around the caravan's A frame. This can be made with a plug and socket arrangement in such a way that the plug must be removed or the
wires cut in order to steal the caravan. In both cases, the alarm will sound instantly. Of course provision must be made to short the wires together when the caravan is not being towed. This can be achieved with a shorting plug kept in the socket when not protecting the caravan.

**HOW IT WORKS**

Fig. 1 shows the full circuit diagram of the alarm. When the alarm is on and the exit delay timed out, opening any one of the doors or boot will close the light switches and turn on Q1 via R2 or R1. This produces a high on IC1a and will set the latch causing the output to go high starting the oscillator (IC2c) which runs at about 25Hz. Pulses from this are fed to a binary counter IC3, the outputs of which control the following sequence of events. After eight pulses from the oscillator, Q1 goes high and is high for eight more pulses before going low and repeats this throughout the sequence. The Q1 output is taken to Q4 via R13 to give current amplification and power a small buzzer. This is the internal buzzer which sounds eight times before the main siren. After 128 clock pulses, Q1 becomes high which is inverted by IC2a. The resulting low on IC2b causes a short reset pulse which resets IC1a, IC3 and IC1b. The alarm has now gone through a complete sequence and is ready to be set off again should the need arise.

The delayed exit is produced by IC2b. After switch-on C1 is slowly charged via R3 while charging IC2 pin 4 is high. This turns on Q5 via R14 to illuminate the exit LED via its current limit resistor R16. When C1 has charged to about eight volts, this will cause pin 4 to fall to 0 volts, a high must appear on pin 5 due to the counter being reset causing a low on Q1, which is inverted by IC2a.

The delay exit time may be increased by increasing the value of R3. D1 provides a discharge path for C1 when the alarm is switched off. R17 provides the load for the discharge path.

The delayed entry is provided by the 128 clock pulses required to set the siren state during which time the alarm should be turned off. By this method of sequencing various time configurations may be achieved by simply selecting the outputs from IC3 to lengthen or shorten the timings. For example, taking the reset from Q11 (pin 1) to Q11 (pin 2) will double the length of time the siren sounds to nearly three minutes.

If an attempt is made to remove the radio or other protected items, the siren sounds instantly. This is done by using the latches IC1a, IC1b. Pins 11 and 12 of the alarm are held low by connecting them to the chassis of the radio or connecting them to 0 volts via the loops described earlier. If one of these two connections is removed either Q2 or Q3 is turned on by their bias resistors R5, R9 respectively. This in turn puts a low on IC2d pins 12 or 13 which causes the output pin 11 to go high. This low to high transition is used to clock the two latches IC1a, b. The circuit now follows the same count routine as before except that the siren latch has already been set eliminating the 128 clock pulse delay, but it is turned off in the same way after 2048 clock pulses. The timings rely on the oscillator running at about 25Hz. The speed of this oscillator can be increased by reducing R11 and slowed down by increasing its value. However, do not reduce below 15K as this may damage the IC.
The same method can be used to protect such articles as cases and the like carried in the car. The set up must be that to remove the protected articles, the plug must be undone or the cable cut, similar to the type of thing used in shops to protect goods on view.

Although primarily intended for cars, this alarm is ideal for caravans as the CMOS integrated circuits draw very little current and can be left on for several months without flattening the battery. The delayed circuit can be fitted to the main doors. The instant circuit can be connected to the wind up leg of the caravan so that when the leg down the contacts are made (use a mercury tilt switch). When the leg is wound up to drive the caravan away the tilt switch contacts open and set off the alarm immediately.

The lid over the gas bottles can also be protected in a similar fashion as these bottles are a thief's delight.

**Installation**

Before fitting the alarm, it should be fully tested on the bench using a power supply and simple switches on pins 6, 7, 11, 12. To simulate the car courtesy light, connect a 47k resistor between pins 1 and 6 of the alarm. This will hold off Q1 unless turned on by a low on pins 6 or 7.

When happy that the alarm works under all possible valid switch configurations it should be considered ready to fit. As it is going to stay in the car (which can be a hostile environment) the PCB should be fully cleaned and sprayed with a PCB protective varnish to prevent the copper tracks from being eaten away by dampness.

Test all points of the car's electrical system that are to be used with a meter to check they perform as expected. It is a good idea to disconnect the positive side of the battery while fitting the alarm to prevent any accidental shorts.

**BUYLINES**

None of the components should prove difficult to obtain. Suitable buzzers and 12V sirens are available from Riscomp. The PCB is available from the PCB service.
ELECTRONICS & COMPUTING

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January 1987

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REAR WIPER ALARM

When a strange scrunching sound comes from the back of the car and an acrid burning smell issues from the rear windscreen wiper you'll wish you'd fitted this wiper alarm from A J P Williams.

Although many cars are now fitted with rear windscreen wipers, these are rarely given the same attention to design detail as the front wipers. The rear windscreen wiper is easily left on long after the rain has stopped as it is out of sight (and therefore out of mind).

Some cars' rear windscreen wipers are not designed for continuous use. A press on the wiper stalk is required for each sweep of the rear wiper. Such systems are easily altered with a bypass switch to operate continuously and with the addition of another relay such a modification requires little in the way of extra wiring (see Fig. 1). However, this puts the single-sweep wiper motor even more at risk of overheating or even burning out.

This rear wiper alarm detects the extra current flowing through the wiper motor when it is labouring on dry glass and sounds an audible alarm to remind the driver to turn it off.

The current flowing through the wiper motor is determined by comparing the voltage across a low resistance in series with the motor with a reference voltage. When the reference voltage is exceeded a self-contained piezo beeper is sounded to warn the car driver.

Construction

The wiper alarm is constructed on a single circuit board. This should present no problem of construction. Care should be taken to ensure the correct orientation of the voltage reference (IC2), the transistor (Q1) and the two electrolytic capacitors (C1, 2).

The unit is most easily installed near the rear windscreen wiper motor. Many cars include trim panels on the inside of the car around the rear screen. The PCB can be bolted behind one of these with the sounder unit protruding through the trim panels. The PCB should be thoroughly coated with protective laquer or varnish before installation to prevent corrosion and short circuits from damp.

The low value resistor R1 can be conveniently made with six 0.22R resistors in parallel. Three watt wirewound resistors are convenient to use although 1W resistors are ample.

The earth side of the wiper motor must be isolated from its original earth connection. The earth side of the motor is connected directly to the motor casing in some cars and so it is necessary to isolate the motor in its mounting from the car chassis. Rubber bushes around the mounting can be used for this.

Frequently the motor is mounted on rubber bushes anyway for protection against vibration. In such cases the insulation of the motor should just be checked with a multimeter.

![Fig. 1 Rewiring a car with a momentary action rear wiper for continuous operation in conjunction with the wiper alarm.](image)
HOW IT WORKS

The earth end of the wiper motor is taken via a very low value resistor (R1) to earth. When the wiper is operating under relatively wet conditions, the voltage drop across R1 is in the order of 50-60mV. When the screen is dry, this voltage rises to 90-130mV. R1 is such a low value so that the voltage across the motor itself (and its performance) is not significantly affected.

The voltage across R1 varies throughout the wiper's sweep across the screen and the drier the screen the greater is the voltage variation. Some voltage smoothing is desirable so the average cycle voltage can be detected. The simple RC network of R3, 4, C1, 2 is sufficient. However, the large value required of C1, 2 suggests the use of electrolytic capacitors. In most cases the leakage current of normal electrolytic capacitors is excessive. This reduces the detected voltage across R1. Although the leakage current can diminish after the unit has been on for a while this is an unpredictable effect and cannot be relied on. So the capacitors, C1, 2 must be low leakage types.

IC1 is an LM324 quad op-amp. This chip was chosen (although only two of the op-amps are used) because it can sense right down to the negative supply rail with a single rail supply.

IC1a is a non-inverting amp which gives a high input resistance and a voltage gain of 31.37. So, when the input voltage (across R1) is 40mV, the voltage at its output is 1.26V. IC2 is a bandgap voltage reference which stabilises the voltage at the negative input to IC1b to a nominal 1.26V.

IC1b is configured as a regenerative comparator. When the voltage at the output of IC1a exceeds the reference voltage the comparator output approaches the supply voltage, switching on Q1 and operating the piezo sounder.

RV1 and R2 form a potential divider to reduce the average voltage across R1 to a level producing 1.26V at the output of IC1a when the wiper motor starts to labour.

Setting Up

The circuit can be simply set up before permanent installation in the car. Spray the screen with water and turn on the wiper. After around 12 seconds of spraying and wiping, stop the spray and wait for the wiper motor to start labouring as the screen gets dry. Adjust RV1 so that the alarm just operates as the motor labours. Repeat the process until the alarm sounds correctly just as the screen dries out. The unit should then give sterling service for a good many years.

Fig. 2 The circuit diagram of the wiper alarm.

Fig. 3 The component overlay of the wiper alarm PCB.

BUYLINES

Suitable piezo buzzers are available from Maplin and Riscomp. The low leakage tantalum capacitors (C1, 2) are available from Cirkit as part 05-10701. The PCB is available from the PCB Service.
KNIGHT RAIDER

Paul Chappell’s car now bears a striking resemblance to the mechanical star of a certain TV show. Now, which could that be...?

Deciding what readers might like to build is a perennial problem. Oddly enough, new ideas are not hard to come by — especially as there is a constant stream of letters beginning ‘Why don’t you design a project to...?’ This is all very well but do many readers really want a whistling ear-pencil? Do they honestly need an indoor sundial? Often the answer is obvious (of course you want an indoor sundial) but occasionally we get taken by surprise.

A case in point was Phil Walker’s Knite-Lite (ETI November 1984). Who would have guessed that a circuit to move a light backwards and forwards along a line of LEDs would be so overwhelmingly popular?

Well, we’re not fools at ETI. We know when we’re on to a good thing. Amongst the many sacks of readers letters about the project, a goodly number wanted to know how to adapt the circuit for use on the front of their respective motor cars. So here is the definitive version — the Knight Raider. You can build it into your Range Rover, your Fiat, your tricycle, your pedal car or your shopping trolley. It has eight different light sequences, each more spectacular than the last and it will drive anything from torch bulbs to powerful car lamps.

The Knight Raider has two main sections: the sequence board and the control board (Fig. 1). The sequence board creates the light patterns and provides up to 2A output for each lamp (more if you use beefier FETs). This board can be placed in any convenient position — in a metal box in the engine compartment or built into the lamp unit.

The control board sits in a case on your car’s dashboard. It contains switches for setting up the patterns and a mimic display so you can admire the results. You can select a new pattern while the old one is still running — it will change only when you press the ‘Pattern Start’ button.

Construction

The component overlays for the two PCBs are shown in Fig. 2. The sequence board requires a little care and attention when soldering since some of the tracks and pads are fairly closely spaced. You will need a soldering iron with a fine tip and (preferably) 22swg solder rather than the thicker 18swg. Inspect the board carefully after soldering to make sure there are no solder bridges between adjacent tracks, particularly around the ICs.

Capacitors C6-C13 are optional. If you put them in, they will give a blurring effect to the pattern. The lights will gradually fade instead of turning off abruptly. Try it both ways and see which you prefer. The value can be increased to give a slower fade or reduced for a quicker one, according to your taste.

The wiring for the lamps and interconnections to the control box are held in place by means of cable ties to avoid putting undue strain on the PCB tracks (and to keep them tidy!)

It is a good idea to moisture-proof the PCB, even if you put it in a weather-proof box. A low cost Paul’s car has many minor electronic modifications. The Knight Raider control board can just be seen protruding from the ash tray.
**HOW IT WORKS**

There are 1001 ways to make a pattern run across a series of lamps but the most flexible is surely the humble shift register. Since these like to shift in one direction only, IC5 takes the pattern from left to right and IC6 from right to left (or the other way around, depending on how you arrange the lamps). Diodes D11-18 and D19-26 give a 'wired-OR' function to allow either register to turn on the lamps without interaction. Diodes D27-34 allow the 'reverse' shift register to be cut off so the pattern runs in one direction only if IC4 is activated. The pattern is re-circulated (even if the outputs from IC6 are turned off) via D6.

The lamps are driven by power MOSFETs Q2-Q9. The capacitors C8-C13 slow the turn-off times, giving the pattern a 'comet's tail' of gradually extinguishing bulbs.

IC7c is a simple oscillator which sets the step rate for the pattern, with RV1 allowing adjustment to suit your taste. IC7b resets the shift registers when a new pattern is selected. IC7a and d, in conjunction with IC2, 3 and the feedback from the shift register outputs determine the number of lamps lit. IC2 and IC3 can be activated at any time without disturbing the pattern — nothing happens until IC1 is activated.

The opto isolators IC1-4 are included for noise immunity in the interface between the two boards. There are a number of ways to achieve the same end but opto isolators can be bought cheaply these days, so — why not? If this circuit ever picks up spurious trigger signals from the wiring, I'll eat my boots!
PCB lacquer can be used, or a conformal coating if you are keen to do the job thoroughly.

Heat sinking must be provided for the power FETs. If the circuit is built into an aluminium box, this can also serve as a heat-sink. Otherwise, a strip of aluminium (the thicker the better) can be bolted to all the FET tabs. The tabs must be isolated from the heatsink with a mica washer, insulating bush and a smear of heat-sink compound.

The control board should not present any problems. The resistor network and connecting wires should be soldered in place first. Then the LEDs are pushed through the PCB in their correct positions but not soldered. The PCB is fixed behind the front panel (after drilling!) and the lead lengths are adjusted so that the LEDs just protrude through the panel holes. Finally the LED leads are soldered and trimmed. We used self-adhesive PCB supports to avoid drilling screw holes in the panel.

### Installing The Circuit

One thing we must leave up to you to a great extent is the installation of the lamps. There is just too much variation between different cars, cycles and shopping trolleys to give full constructional details. The simplest solution is to mount each bulb independently along the radiator grille (handle-bars, etc.) Otherwise, you can really go to town and build a housing for the lamps with colour filters and goodness knows what else.

Your choice of colour for the lamps must be tempered to some extent by consideration of what may cause confusion to other drivers (or get you arrested!)

If the circuit is to be used for a child's pedal car or tricycle then no such restrictions apply. You will, however, need to give some consideration to providing a suitable power supply. The main loading on the supply is from the bulbs. If your battery can drive these with about 50mA to spare then all will be well.

Torch bulbs (with suitable series resistors) will do at a pinch but car sidelight or rear light bulbs will be much more effective. The specified FETs will manage two sets of 5W bulbs with ease (one display at the front and one at the rear). The limit of the driving capability is about 20W. Although the FETs have a continuous current rating of 3A, the low 'cold' resistance of the bulbs and the added heating effects from the smearing capacitors must be taken into account.

The interconnections between the control box, sequence generator and lamps are shown in Fig. 3. A rear display can be added by simply paralleling the rear bulbs with the front ones. The wiring can be considerably simplified if you're willing to settle for just one preset pattern and forego the mimic display — by hard wiring IC2, 3 and 4 to your chosen pattern, all that is needed is the 'pattern start' button for IC1 and an on-off switch.

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### PARTS LIST

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<th>RESISTORS</th>
<th>SEMICONDUCTORS</th>
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<tr>
<td>R1-4</td>
<td>C14 10μF 16V tantalum</td>
<td>LP1-8 12V bulbs (see text)</td>
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<tr>
<td>R5, R18, 10, 36</td>
<td>RESISTORS</td>
<td>SW1 2 pole 4 way rotary switch</td>
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<td>R11, 18, 19-26</td>
<td>22k resistor network (DIL)</td>
<td>SW2, 4 SPST toggle switch</td>
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<td>R27-35</td>
<td>IC1-4 OC477</td>
<td>SW3 SPST push button</td>
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<tr>
<td>R37-845</td>
<td>IC5, 6 4015</td>
<td>PCBs; aluminium box or heatsink for sequence board; plastic case for control board; FET mounting hardware; knob for rotary switch; PCB mounts; waterproofing spray; connection wire.</td>
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<tr>
<td>R1V1</td>
<td>IC7 Q2-9 IRF510</td>
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<tr>
<td>CAPACITORS</td>
<td>Q1 BC548 (or any general purpose silicon NPN small signal transistor)</td>
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<td>C1-C4</td>
<td>C5-C13 220 ceramic</td>
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<td>LED1-8 LEDs any size, style, colour</td>
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ETI AUGUST 1987
The sequence PCB will be a snug fit in box type 21-95005 from Cirkit (Tel: (0992) 444111). Suitable protective lacquer aerosols are available from the same source. The low cost version is stock no. 51-11005 at £1.84 + VAT. The conformal coating is stock no. 51-11112 at £3.68 + VAT. The most expensive parts are undoubtedly the FETs. These are available for £1.27 + VAT from Electromail (Tel: (0536) 204555). You may get a better price by shopping around. Any high gain optoisolators can be substituted for the types specified. Single transistor types will work but require lower values for R1-4.

A set of parts for the project is available from Specialist Semiconductors Ltd, Founders House, Redbrook, Monmouth, Gwent. The PCB, components, mounting hardware etc, for the sequence board (part K101A) cost £11.90. The FETs supplied are 5A jobs but you may need extra heat-sinking to take advantage of the higher current. The set does not include a box. The PCB, case, components, switches and hardware for the control board are K10113 at £6.90. Postage on any order is 60p.

Bulbs can be obtained from any motoring shop, connecting wire from Woolies and the PCBs from our PCB Service in due course.

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**CB CIRCUITS**

Andrew Armstrong goes on channel with a few Tech Tips for CB fans.

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**Initials Sender**

This gadget sends the operator's initials in morse code at the end of a transmission. It may be mounted in a separate box and connected in series with the microphone lead or it can be mounted inside the rig if there's room.

The heart of the unit is the diode matrix used to program what is actually sent. The two 4051 analogue switches address each intersection of the grid lines in turn. At each point where there is a diode, a logic one is presented at the output of IC4. While this output is at logic one, the 800Hz oscillator (IC5b,c) oscillates. When it is pulled down to logic zero by R3, the oscillator stops.

The output from this oscillator is a harsh and unpleasant squarewave. This is filtered to make it sound better by the double RC network and then is fed to the microphone input of the rig in parallel with the microphone. R7 prevents this extra connection from loading the microphone signal too heavily.

The control of the system is logical, relying on a gated oscillator and a resettable counter. The 4051s are addressed by the outputs of a 4024 binary counter. While the microphone press to talk switch is held down, the counter is held reset, and the 4051s are switched to the top left hand square, the 'exclusion zone'. This square cannot be used. If a diode is connected here, the tone sounds all the time you try to talk.

When the PTT switch is released, IC2 starts to count, at a rate set by the gated oscillator built around IC1a,b. The output oscillator is gated on and off in a manner corresponding with the diodes in the matrix and the initials are transmitted. The PTT relay is held on because the end point line is at logic zero.

Eventually, IC3 addresses the line to which is connected the end point setting diode. When this is energised, the gated oscillator (IC1) is stopped so that the counter cannot advance any further and the PTT relay is switched off.

The circuit can be powered from the rig's 12V supply but this should be thoroughly decoupled on the board. If the relay used is of too low a resistance (if an ordinary relay is used instead of a reed) the BC182 may be unable to switch it on, driven as it is by about 1mA from a CMOS gate. In this case a small power MOSFET such as a VN10 may be used or a Darlington transistor would be suitable.

Some CB rigs route the receive audio signal via the microphone socket and use a changeover switch in the microphone to switch it on. In this case a changeover relay must be used and connected to the same pins as the switch.
Compressed Power Microphone

Power microphones provide more gain and hence better apparent signal at the receiver but it is possible to overdeviate using ordinary power microphones. This design adjusts its own volume setting to provide the correct modulation all the time. It is equally applicable to AM (amplitude modulation) or SSB (single sideband) in amateur radio equipment.

The signal from the microphone is fed through an electronic attenuator IC which can provide between 13dB gain and about 70dB attenuation, although it is unlikely that more than a few dBs of attenuation will be required.

ICI starts to reduce its gain when the control voltage, fed in on pin 2, exceeds about 2V. The output of ICI is fed via a preset output level control (RV1) to the microphone input of the rig and also to a peak detector circuit which controls the attenuation.

The gain of the peak detector as shown is approximately 3 1/2 so the output voltage of ICI will be about 400mV RMS at the onset of attenuation and will reach about 500mV at the highest likely signal level. Some rigs may work better with R7 omitted, to provide maximum input signal, while others will find 500mV too high a signal and would require RV1 to be set low.

The output from ICI is AC coupled into the input of the peak detector so that the output of the detector is relative to 0V rather than the output bias level of ICI. To avoid latchup of IC2a, negative signal excursions are limited by D1. To permit this, R1 is included to prevent distortion of the output waveform. The attack time of the peak detector is very fast, with R3 serving to prevent noise spikes from causing problems while the decay time constant is set by C5, R4, and R5. The component values would suggest a decay time of 4.3s but in practice it is less than this because the control voltage has to fall only from about 2.5V to increase the gain from the minimum to the maximum likely to be required in practice. The gain will actually increase in about one second. If a slower response is required, C5 may be increased.

The output of the peak detector is buffered because the control voltage input of ICI is of a low impedance. R6 and C6 are used to prevent any audio ripple on C5 from modulating the output.

Some microphone inserts may not give sufficient signal to make the compressor work properly, in which case the extra gain stage shown should be used. The feedback divider resistor, R11, should be chosen to give just enough gain bearing in mind the maximum input signal specified for ICI is 500mV RMS. Note the reversed connection of C1.

RF pickup on the microphone may interfere with the correct operation of the circuit. If this happens, connect a 1k0 resistor in series with the microphone followed by a 2μF capacitor to earth. This should cure all such problems.

When all is complete and working, RV1 should be adjusted to provide maximum deviation without 'bleedover' to adjacent channels. To do this, connect the transmitter to a dummy load, and listen on another CB rig. The rig you listen on may work best with a few inches of wire in its antenna socket, or it may pick up enough signal without any form of antenna. Do not allow receiver overload to fool you into thinking bleedover is happening when it isn't.
Regular ETI readers may recall that I am interested in the subject of compact disc in general. Last year I reviewed the D50 mark 2 Discman from Sony. Now Sony has introduced a new model, the D100.

Sony claims the design philosophies of the D50 and the D100 are totally different. The D50 was designed to fit a certain size and the designers were told to produce the best player they could in that size. The D100 was designed from the opposite angle, as a full function top quality player made as compact as possible. The result is that the D100 works better and is smaller than the D50 mk2.

The player with its battery pack fitted is as thick as three CD cases stacked together but occupies less area. The weight of the player with battery pack is 820g, about half being the 6V 1Ah batteries.

The specification of the D100 is impressive: full sixteen bit DA conversion, total harmonic distortion less than 0.01%, frequency response 20Hz to 20KHz ± 1dB, and 'Sony Super Strategy Cross Interleave Reed Solomon Code.' I assume this last to mean this player makes use of the full error correction capabilities of the coding technique used for CD. Many machines use only half the available correction code. The basic Reed Solomon coding technique uses redundant bits and checksums not only to detect a corrupted bit (or bits) in a data word but also to identify which bit is wrong. Even a completely corrupted data word can be reconstituted. Some current players use less sophisticated correction.

The programming functions of the D100 are similar to those of the D50. There is the usual facility to play tracks in any memorised order or to play them in a random order. Tracks or sections can be repeated indefinitely and the track search permits jumping from track to track or skipping fast forward or reverse through a track, while monitoring quite coherent snatches of the sound. The liquid crystal display shows the programming and track information with the option to show current or maintaining track number and time.

For a suggested retail price of almost £300, you get the player, battery pack, mains power supply, headphones, carrying strap and soft case and a line output connecting lead. An infra-red remote control accessory is available for £50 and the receiver plugs into the side of the player. For use in the car, a shock absorbing mount with gooseneck arm and power lead is available. As an alternative, for those who possess well sprung cars with flat parcel shelves, a simple car power lead is available. There is no need to fiddle around with wires to install the player in a car because the other car accessory is an adapter which fits into the cassette slot of the car stereo and feeds the signal from the CD player into the tapehead.

I am glad to say that the performance justifies the facilities and accessories. As a portable machine, the CD100 can be carried about to a fair extent although it still loses tracking if jarred but unlike the D50 mk2 it appears to continue from where it left off once it has settled down.

The sound it gives on headphones is clear and convincing. There is plenty of power to listen to Iron Maiden but enough sheer precision for Peter Gabriel. I have rarely wanted to turn the volume control above 2 (on a scale of 10) and the stereo image is sharp and convincing.

The only criticisms I have of the machine are that it is still possible to make it lose track for a moment, and that the ‘in the ear’ headphones supplied with the machine do not suit all sizes of ears.

In the car the CD100's performance is limited by the quality of the car stereo. In my Maestro, it always worked perfectly on its shock absorbing mount but when I tested it just resting on the parcel shelf, it lost track on the occasional bone jarring thud from holsey country roads. There were no problems while driving on better roads though.

If you do want to use the CD100 in your car, you will be pleased to know that it is very quick to remove from the car when you park — it’s just too tempting a target for thieves if left on view. The D100 stands up well in the living room hi-fi system. I compared it with my Philips CD104 on a variety of programme material. I have always considered the sound from the CD104 to be very good but to my ears the CD100 at a fraction of the size performed better.

By comparison, there was just a hint of harshness in the treble region of the CD104 on certain tracks with a high treble content, notably on Phil Collins and Kate Bush discs. On certain tracks (both Iron Maiden and Peter Gabriel) it seemed the bass response of the CD100 extended to a lower frequency than that of the CD104. Admittedly these effects are not large compared to the difference between CD and ordinary LPs but the difference was significant for CD.

The performance of the CD100 was noticeably worse than the Philips CD104 in one respect only. It wouldn’t play the first track of my copy of Yes' '90125' properly. The Sony CD100 jumped through the last minute of track one as if it switched to fast search. Other machines I have tried have had the same problem and only my trusty Philips machine could play that track. I don’t know why but perhaps the depth of field of the laser optics is greater on the Philips machine.

As I have no reference discs (ETI contributors can’t afford such things) I cannot say for sure which machine is ‘correct’ but the differences are of such an order that ‘how do I prefer my music’ is a reasonable approach. My ears prefer the Sony machine so I have sold the trusty Philips (with a pang of regret) and bought a Sony CD100.

Italian organ manufacturer Elka has jumped on the FM bandwagon with their EK44 and we can expect others to follow, now Dr. Chowning’s FM patent has passed into the public domain. FM is obviously in no hurry to go away and so it is timely to review its potential.

Can FM be used to synthesise any given sound? Not in practice, no. Most sounds, real or imaginary, can only be produced by combined frequency and amplitude modulation. Only sounds devoid of an AC amplitude modulation component can be synthesised by FM with ease.

Unfortunately, it is the attack transient of a sound which the ear pays most attention to and the eight-parameter envelopes of the DX7 are insufficient to recreate the complexities of the attack transients of most acoustic instruments. There are a few ways of cheating although no mathematically clean or even systematic method for working backwards from a desired spectrum to FM parameter values has yet been published. FM is very good at generating lots of harmonics and the major problem actually lies in the elimination or attenuation of those which are not required. This can be achieved by mixing the outputs from a number of parallel modulation stages, each with different parameters, resulting in selective attenuation and enhancement of the various harmonics.

10 or 12 operators are necessary to put theory into practice in this way and once again the DX7 lets us down by implementing only 6 operators per voice.

Another trick is to make the simplifying assumption that phase relationships are unimportant in audio and to pre-process a required power spectrum with a phase-shuffling transform which reduces the peak factor of its corresponding waveform. Kid's stuff!

At the end of the day everyone throws up their arms in despair at all the complexity and resorts to random suck-it-and-see button pushing with the inevitable result that FM exhibits its own characteristic sound.

FM is not the general purpose elixir its proponents would have us believe. It is a technique which is cheap to implement in digital hardware. That is all.

Andrew Armstrong

ETI AUGUST 1987

Bruno Hewitt
At the All Electronics Show, All-batteries exhibited a range of solar panels intended to charge batteries. These were specified to give useful outputs so I asked for information and a review sample.

Dave Hammond of All-batteries told me of some uses to which the solar panels have been put. One of the obvious ones is to power remote data loggers. Almost as obvious is to power fan ventilation of greenhouses.

Another application which amused me was to power electrically operated gates some distance from the nearest mains power. Apparently it was cheaper to provide a solar panel and a sealed lead acid battery to provide the high peak (but low average) power requirements rather than to run mains cables to the area.

To prove that 'serious' people have a use for these solar panels, British Gas use one to charge a car battery. The car is left in the back of a lorry which is being driven around as a high power demand depressant, as in one small village.

They get, one panel should do for a reasonable area. The mass market poses would be the Chronar range which uses amorphous silicon. This appears to be a reasonable facsimile of an instrumentation amplifier that can be made from three ICs as in Fig. 2. To make the most of the circuit's high input resistance, the op-amps are biased via the source — in this case, the body, where a third wire to the foot is a common way of getting about it.

Common mode rejection is good as long as the ratio R10/R13 is exactly equal to the ratio R11/R12. In the absence of very tight tolerances resistors (a 0.1% mismatch in one single resistor is enough to degrade the CMRR to 60dB) trimming is necessary, so R12 would normally be a fixed resistor in series with a small preset. Properly adjusted, the circuit can give excellent results.

So what of the improvements? Components C5, C7 and C8 have, I assume, been added to limit the DC offset of the first stage (although it seems like overkill to use all three). The inclusion of C5 is particularly interesting. Assuming that C7 and C8 are in place, the offset at the output of IC1a and IC1b from amplification of their input offset voltages will not be enough to make C5 necessary. However, using a 'third wire' bias with inadequate electrodes (the author suggests brine-soaked cotton wool!) will result in a substantial difference in voltage from the amplifier's bias current. So (belt and braces) put in C5, add C3 and C4 at the input and give the op-amps on-board bias from R3 and R6.

This makes the third wire redundant - connecting it may encourage a little of the common mode noise current to flow along it in preference to the electrode leads but not so's you'd notice the difference. High frequency noise is filtered by C6, C7 and C10, and there you have an improved circuit. Or is it?

The inclusion of C10 is a real schoolboy howler. It appears to be slugging out high frequency noise but in fact it's unbalancing the circuit at high frequencies and providing a beautiful path straight to the output for every bit of common-mode grunge in the circuit.

The input resistance is less than 1MΩ for the frequencies of interest, so they will be attenuated and higher gain must be used. This increases noise and gives a boost to offset problems, making the electrolytics necessary which, in combination, give the circuit a long settling time and slow recovery from overload.

The advantages of the original circuit's high input resistance and potentially good common mode rejection (the point of using it in the first place) have been negated by the input bias and inclusion of C10.

In all, it reeks of a circuit 'improved' by aimless fiddling about. So what? If it works, why not use it? Well, my feeling is that if it takes three op-amps to do the job of one, rather worse than one would do it, I'll save my money and go for the one. As to whether it works, the text contains the ominous words 'Do not worry if the LED does not flash at a stable rate'. Come on, Prof. Pencilbend, the heart may not be quite ergonomic but it's not that erratic unless there's something seriously wrong with you! I suggest you take another look at the circuit, or see a doctor. The choice is yours.

Andrew Armstrong

John Bird
At long last (see Open Channel last month), British Telecom managed to get an engineer to my property and fit me with a master telephone socket—eleven weeks from my initial order. This entailed a simple changeover from the existing connector block at the local line inlet point to the new socket and took less than twenty minutes work. Within an hour and a half I had fitted my requisite extension sockets around the premises, and then I had the opportunity to try out my new Mercury telephone.

I had already received my authorisation code from Mercury by post in (two parts, for security) and so I was able to program the phone, ready for use the moment I plugged it in. Programming takes less than five minutes. Although, programming allowed for a further eight memories with numbers which one might commonly dial would obviously take somewhat longer.

Using the phone is simple enough, for local calls, you dial the BT local network anyway, so all you do is dial the number. This would be true for trunk calls via the BT trunk network too (although once the option is available to use the Mercury trunk network you would never do this because BT charges more than Mercury for trunk calls).

For trunk calls on the Mercury network you simply press the 'Mercury' button at the side of the numeric keypad and then dial the number you wish to call.

The initial programming procedure mentioned above programs the Mercury button with two things: the Mercury network access number (113) and your authorisation code number (ssh, a secret). Interestingly, the access number is dialled in loop-disconnect mode (pulses) while the authorisation code and the telephone number is transmitted in multifrequency tones.

So, although you have to press an extra button when you make a Mercury call, the overall speed of connection is potentially much quicker than it is over the BT network. However, connection at the far end of your trunk call may be by clickety-click Strowerg equipment (depending on the caller's local exchange) so this may not be true at all.

Whatever the speed of connection, trunk calls via Mercury are cheaper, so what the heck?

Another advantage of using the Mercury network is that Mercury bills you with an itemised listing of all calls you make, so you can keep an accurate track of calls and costs. This will be more than a little useful in trying to find out who's been phoning Aunt Sheila in Australia at 8 o'clock in the morning!

Aware of this advantage, BT is presently trying out the use of itemised billing with a number of customers in the City of London, Bristol and Bath. It will be a while before the facility is available nationally, though.

**On The Tracks**

British Rail is presently installing a communications network for its signalling equipment which will provide a terminal at each area signal station. Terminals will provide details of all signals, points and train routes throughout the area. Like the MBUS, it's a long time coming and a lot of commuters are waiting for it!

**Smarter Than Average...**

I've been reading and hearing a great deal recently about smart-cards — credit card sized bits of plastic with memory of some form or another, which are about to take over the very business of the original cards pioneered.

Potentially, smart-cards can go much further than basic plastic cards in terms of use. Basic cards are useful in only one environment — cash credit money deals. Smart cards, on the other hand, because of their memory capability, can be useful to hand in travel arrangements (hotel bookings, flight bookings, car hire, etc) and restricting access to buildings or rooms only to certain personnel, as well as more mundane financial transactions.

Don't run out looking for your smart-card yet because there is no common system which all the potential cards will work on. So, as far as the customer is concerned, a smart-card is just another bit of plastic to carry around — some sales outlets may accept it, some may not.

Things won't change until two things occur, in stages. First, all the UK banks must agree to produce a mutually acceptable service. Next stage is a national, if not international, network with sufficient and adequate point-of-sales equipment at all outlets. It will be a long time yet before the real benefits of smart-cards become available.

**Better And Better**

Nevertheless, this book purports to inform us how to build a better synth (better than what?).

"You can always build a better synthesizer than you can buy" is the credo of Mr. Henry. This is an extremely dodgy statement at the best of times. Can the home constructor really compete with the LS1 chip design and manufacturing facilities of Yamaha and Casio? I think not.

There is much the amateur can do but the construction of a 'better' synth is not one of them. The synths which this book shows how to build is certainly unlikely to be found on the dealers' shelves. This is not because it is 'better' but because it is an old fashioned design, superceded by commercial products making use of digital technology.

The synth in question is a modular affair — just the kind of thing this hallowed mag used to publish around five years ago. All the usual modules are there — voltage controlled amps, oscillators and filters, envelope generators and of course a keyboard.

The majority of the book is concerned with describing the circuits to fulfill the functions of these modules. However, the start is devoted to explaining the principles behind sound synthesis in general and this outdated synth design in particular. As a treatise on modular analogue synth design, I cannot really fault this section.

Although the modules are described as 'construction projects,' they are really only circuits with accompanying explanations, theory and set-up details. There are no real construction details, no PCB or stripboard designs. With this kind of device this can be an acute omission. In my view, a careful board design can be the make or break of a good synth.

**Foreign Matter**

There is one other failing of this book. It is not about the content but to its US origins. The appendices covering supplies of components and sources of further information are, of course, absolutely useless in this country.

If a publisher wishes to bring a book across the great divide it would be so much more useful (for this kind of work, anyway) for a Brit to give it a going over first to correct this kind of thing. It will surely cost more to reprint a UK version but such care would also command better sales for the book and still be cheaper than starting from scratch in this country.

John Wiley please note!

All in all, it is difficult to justify over ten quid on this kind of work for most potential readers.

Nevertheless, for this kind of (heavily outdated) synth design, the book gives a good grounding. The beginner will not be able to progress far on this alone but a more experienced constructor, dabbling in music for the first time, will find it valuable enough.

The experienced constructor of musical instruments and effects will be disappointed. The book breaks no new, nor even recent, ground.

However, it must be said that simple analogue synths are hard to come by these days. If it's just an uncomplicated sound maker you are after, the modular synth set out here will serve you well, cost you little and prove great fun to put together.

Malcolm Brown
**Amplifier Power Meter;** 10 LED indicator from 0.25-100 Watt

**5-100 Watt Electronic Loudspeaker Overload Protector,** adjustable digital code unit plus key pad—select own code; 9 volt. Kit £14.21.

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The Better Flanger (January 1987)

In the circuit diagram (Fig. 2) D1 is not labelled. This is connected to Q1. In the component overlay (Fig. 5) several components are missing. A link should connect the two pads to the left of C1. Q1 is situated next to D1 and connection point P4 is situated between R16 and C11. In addition, the positions of R16 and C11 should be swapped.

Photo Processor Controller (February 1987)

In the circuit diagram (Fig. 2) the cathodes of diodes D3,5 are shown connected to 0V. They should connect to the junction of R16,17,18. In the overlay diagrams (Figs. 3 and 5) the flying leads are numbered incorrectly. Leads 7, 8 and 10 at the top of Fig. 3 should be numbered 16-19. In Fig. 5 leads 6 and 8 from the top of R13 should be numbered 16 and 17. Numbers 9 and 10 from Q1 and Q2 should be 18 and 19. In addition the leads 11 and 'A' should be swapped.

Capacitometer (March 1987)

The circuit diagram (Fig. 1) should show pin 1 of IC1 connected to 0V. The zener diode (2DI) should be connected between the junction of R10/R11 and 0V. The PCB foil is correct.

BCC Micro MIDI Interface (April 1987)

IC7 and IC8 (the 6N139 opto-isolator ICs) are missing from the parts list. In the Buylines section it is incorrectly said that these are available from Electromail as part 302-126. The isolator is available from Maplin as part number RAS91FP. Resistors R8,9 are missing from the overlay diagram (Fig. 4). These are located in the two pairs of pads below IC6. There should also be no 0V connection to the MIDI IN sockets, only to the OL IN sockets (pin 2) so as to prevent earth loops.

Power Meter (May 1987)

The foil for the budget power meter was given 50% full size on the foil pages. The correct size foil appeared in the June issue.

MIDI Master Keyboard (June 1987)

The foils for the CPU board were given 64% full size on the foil pages. Photocopies of the correct size foils can be obtained by sending a SAE to the Editorial address.

Flat Alarm (June 1987)

In the circuit diagram Q2 is shown as an NPN transistor. It should be a PNP device as given in the parts list. IC4 is given in Fig. 2 as a 74LS260 and CS as 470n. They should be 74LS132 and 472 as in the parts list. R13 is incorrect and should be given as 280K in the parts list instead of 270K.

Nuclear Strategy Simulator (July 1987)

The bridge rectifier (BR1) on the overlay diagram has no polarity markings. It should be positioned with the positive at bottom left, connected to the track which connects to IC8 IN and C4 positive.
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new in box. £8 + £3.10/pump. 24 V.-Cad bat-
tery convertors 20 + £2 type cells, used condi-
tion. £10 + £3/pump. Ex-gov type A.A.T.U.
tunes 2 to 2 MHz used in 10 + £3.10 Ilp., clean
in box. £16 + £3/pump. Pyle Puckphone UHF. receiver type IF1. pulsing and unlisten-
ed £4.50 + £3.10 pump. Aircraft intercom test set. used contains 3 valve type mains
N.F.H.T + 3.6, £18.18c pump. AVGO model 7.
transistors £12.12c pump. T.V. leads £16.16c pump.
A.T.U. Ox for 50 MHz £15.15c pump. Radio set type 68 complete station £26 + £4/pump.
Ex-gov. small noise signal lamp £5 + £2.20p
500v wind handle type induction tester £25 + £4/pump. Wayne Kerr pulse gener-
tor type C15/000/sec. pulse, width, delay and
amplitude control. 240v mains, complete in transit case £17 + £4/pump. Large
transistor and signal generators. phone for details. Many items of ex-gov. rando.
radars. transmitters and components in stock. Collectors by arrangement.

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The fabulous TELEBOX, on SALE NOW is an ANY video monitor with a complete input, colour or monochrome, made by a major manufacturer for use in a domestic or small business environment. This monitor is fully cased and equipped with a high grade audio and video processor including the Tektronix 1075A sweep generator. This monitor is ideal for connecting to a mini video recorder or camera, a PAL or NTSC video source. It is also ideal for connecting to a video monitor with a composite input, colour or monochrome.

The TELEBOX offers a 19" diagonal image with a resolution of 1024 x 768 pixels. The monitor has a built-in remote control, a built-in video mixer, a built-in audio mixer and a built-in microphone. The TELEBOX also includes a built-in remote control system, a built-in video mixer, a built-in audio mixer and a built-in microphone.

The TELEBOX also includes a built-in video mixer, a built-in audio mixer and a built-in microphone. The TELEBOX also includes a built-in video mixer, a built-in audio mixer and a built-in microphone. The TELEBOX also includes a built-in video mixer, a built-in audio mixer and a built-in microphone.

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<td>AA alkaline battery FK64U</td>
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