TOMORROW'S TECHNOLOGY

ALTIMETER
PERSONAL STEREO AMP
REACTION TIMER

New Series
TEACH-IN '93
A complete electronics course aimed at GCSE and "A" level students
AMSTRAD PORTABLE PC's FROM £149 (PPC1512SD).

286 MOTHER BOARDS. New and tested with complete technical manual. £49.00 ref 4P39R.

FM WIRELESS BATTERY CHARGER Takes AAs, C's and D's. £12.00 ref 12P42R. Hi-fi outputs one for power and one for pulsed power (programmable) switches. Complete with 4 digit display, digital clock, and 2 relay operated £15.00 at keyboard and new set 96 key keyboards £15.00 ref 15P12R.

AMSTRAD MP3

FM PRINTED STEREO ATTACHMENT £25.00 ref 25P1.

CAPACITOR PACK 1.100 assorted non electrolytic capacitors £2.00 ref 2P50R.

RESISTOR PACK 10 x 50 values (500 resistors) 1/4 watt 2% metal film, £5.00 ref 5P10R.

QUICK Coppa. 12v immersion heater with power and lighter switch. £6.00 ref 6P10R.

LED Pack. 50 red, 50 green and 50 yellow LEDs at 5.00p each ref 5P10R.

AMSTRAD 1460DD BASE UNITS

BRAND NEW AND CASED.

Two built i 5 1/4" drives £79.00 ref 79P1.

FUSION MAGNIFYING LENS £3.00 £1 at cash desk £0.75 at BOOTH.

12V AHA TRANSFORMER. Ex equipment but otherwise ok. Our price £20.00.

ULTRASONIC ALARM SYSTEM. Once again in stock these units consist of a detector that plugs into a 13A socket in the area to protect. The receiver plugs into a 13A socket anywhere in your home on the same supply, both detectors guarding properties. Each complete system £25.00 ref 25P25R additional detectors £11.00 ref 11P1.

BULL ELECTRICAL

250 PORTLAND ROAD Hove sussex BN3 5Q Telephone 0273 203505 MAIL ORDER TERMS: CASH PO OR CHEQUE WITH ORDER PLUS £3.00 POST PLUS VAT.

PLEASE ALLOW 7 - 10 DAYS FOR DELIVERY.

SPEAKER WIRE

Brown twin core insulated cable 100 feet £2.00 ref 2P79R.

Customer returned units mixed capacities (up to 4.4W) We have not sorted these so you will get the next one on the shelf. Price is only £1.00 ref 1P20R.

MICROPHONE 12000 MAGNIFICATION Incorporates auto gain, hatchery, shrill, suppressed, glide, echo. £99.00 ref 9P29R.

LIGHT HARMONY GIG. Keeps your patients at ease. Monitors that warn of major heart beat changes in light control. Complete with an ann with sounds that for a peaceful time is only £7.00 ref 7P1.

JOYBALLS

Back in. new and popular Commodore Amiga equips (palpable standard) £4.00 ref 4P25R.

200 3" DISC DRIVE

New brand new units made by AVCO complete with tech info just £19.00 ref 19P25R.

CAR BATTERY CHARGER

New brand new units with complete panel with leads and 6 or 12v output £7.00 ref 7P29R.

4 PIN CONNECTOR

Properly insulated. Monitors that warn of major heart beat changes in light control. Complete with an ann with sounds that for a peaceful time is only £7.00 ref 7P1.

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Projects

EPE ALTIMETER by John Becker 694
A self-contained "pocket" altimeter for anyone who reaches a high.

REACTION TIMER by T. R. de Vaux-Balbirnie 710
Test your reactions with this inexpensive unit

BATTERY TO MAINS INVERTER
DAUGHTER BOARD by Mark Daniels 718
A fix for the obsolete chip in the original design

PERSONAL STEREO AMPLIFIER by I. A. Duncombe 720
An excellent easy to build design with various power supply options

MINI LAB by Alan Winstanley and Keith Dye 736
A versatile test, development and prototyping board specially designed for Teach-In '93

VIBRATION ALARM by M. G. Argent 742
Ingenious design that uses the piezo sounder as the vibration transducer

Series

ALTERNATIVE ENERGY – 4
by T. R. de Vaux Balbirnie 714
Power from water; tides, waves, hydro-electric and hydrogen

TEACH-IN '93 – 1 by Alan Winstanley and Keith Dye 726
Our series for everyone learning about electronics and particularly GCSE and "A" level students

TECHNIQUES–ACTUALLY DOING IT by Robert Penfold 740
Component substitution for project building

CIRCUIT SURGERY by Mike Tooley 744
Clinic for constructors – your problems solved

INTERFACE by Robert Penfold 747
Stepper motors; Pads–PCB program

AMATEUR RADIO by Tony Smith G4FAI 756
What's in a name; Skilled involvement; Annual report; Numbers up

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A little crystal ball gazing – consumer product developments

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Technological developments that could produce the products of the future

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Component buying for EPE projects

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A range of educational videos

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Selected technical books, our own books and all Babani books

PRINTED CIRCUIT BOARD SERVICE 754
A special PCB SALE (while stocks last) – boards for EPE projects

FREE WITH THIS ISSUE – GREENWELD 196 PAGE CATALOGUE 760
Banded to the magazine

ADVERTISER'S INDEX 769
**COMPUTER SCOOPS**

PC AT 386 20-6X FULLY LOADED FOR £499!

- 20 Mhz DX processor
- 2 megs RAM. Exp 10 meg
- 40 meg hard drive
- 1.2 meg 5-1/4" floppy
- 32K cache exp. 64K

The MP386 quality made by Mitsubishi to last a lifetime! Brand new with all manuals and software plus Super Quick-Disk adapter for nondrive access.

**£499 (F)**

**A COMPLETE IBM PC COMPAT SYSTEM FOR ONLY £99!!**

Just plug in and go - fully expandable - the Display PC-99! System supplied complete with 12" mono monitor, 32K RAM, 506-51-6 floppy disk drive, 128K hard disk, 5-1/4" double parallel ports and power supply. Many other features include: 7 slot backplane, all metal case, 150 watt PSU and US made mother-board. In very good condition with 90 day guarantee. In an attractive two tone quality TV case. Perfect for Schools, Shops, Disco, Clubs. Superbly made UK manufacture. PIL all solid state colour monitor. 13" W x 12" H. The front cosmetic frame is extruded teak style case. Perfect for Schools, Shops, Disco, Clubs. Superbly made UK manufacture. PIL all solid state colour monitor. 13" W x 12" H. The front cosmetic frame is extruded teak style case. Perfect for Schools, Shops, Disco, Clubs. Superbly made UK manufacture. PIL all solid state colour monitor. 13" W x 12" H. The front cosmetic frame is extruded teak style case. Perfect for Schools, Shops, Disco, Clubs. 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VERSATILE INFRA-RED REMOTE CONTROL

There are many applications for which constructors would like remote control. This versatile unit has been designed for application in a diverse range of equipment. Everything from one button operation of garage doors to 32 codes for three different receivers in one room, a total of 96 combinations. The entire system, transmitter and receiver, uses just three i.c.s is compact and easy to build. Various output decoding and switching options are discussed and full detail of interfacing to our Mains Appliance Remote Control (MARC) system, published in 1990, are given. If you want remote control for almost anything this article should meet your needs.

BULL ELECTRICAL CATALOGUE

MIDI LEAD TESTER

This unit enables MIDI connecting leads to be quickly checked, and it will show up broken wires/connections or short circuits from one lead to another. In use it is much quicker and easier than using a multimeter or continuity checker. Checking leads with ordinary test equipment is easy enough provided you have four hands (two for the test leads and two for the plugs!) It should be possible to build the tester for less than the cost of ready made units, some of which seem to be rather crude in comparison to this device. It can help to greatly speed-up checks on a faulty MIDI system.

COMBINATION SWITCH

The Combination Switch or Combination Lock is a versatile project which may be used to unlock a door or switch off an alarm etc. The user’s password is held in memory, which is protected by a back-up battery in case of power cuts. The password may be re-programmed by the user at any time, and up to 12 digits can be stored. If the wrong password is entered more than three times, a siren output is activated for a minute or so. There is also provision for a switch input so that the siren sounds if the switch is closed before the correct password has been entered. This may be used to detect a door or window being forced. The project may be fully integrated with an alarm system if required.

EVERYDAY WITH PRACTICAL ELECTRONICS

DECEMBER ISSUE PUBLISHED FRIDAY 6TH NOVEMBER.
Everyday with Practical Electronics, November 1992

**SURVEILLANCE PROFESSIONAL QUALITY KITS**

No. 1 for Kits

Whether your requirement for surveillance equipment is amateur, professional or you are just fascinated by this unique area of electronics SUMA DESIGNS has a kit to fit the bill. We have been designing electronic surveillance equipment for over 12 years and you can be sure that all of our kits are very well tried, tested and proven and come complete with full instructions, circuit diagrams, assembly details and all high quality components including fibreglass PCB. Unless otherwise stated all transmitters are tuneable and can be received on an ordinary VHF FM radio.

**UTX Ultra-miniature Room Transmitter**
Smalllest room transmitter kit available. Incredible size of 10mm x 20mm!
Connects to line (anywhere) and switches on and off with phone use.
All conversations transmitted. Powered from line. 500m range

**MTX Micro-miniature Room Transmitter**
Best-selling micro-miniature Room Transmitter
Just 17mm x 17mm including mic. 3-12V operation. 1000m range.

**STX High-performance Room Transmitter**
Hi performance transmitter with a buffered output stage for greater stability and range.
Measures 22mm x 22mm including mic. 6-12V operation. 1500m range

**VT500 High-power Room Transmitter**
Powerful 250mW output providing excellent range and performance. Size 20mm x 40mm. 9-12V operation. 1000m range

**VXT Voice Activated Transmitter**
Triggers only when sounds are detected. Very low standby current. Variable sensitivity and delay with LED indicator. Size 20mm x 67mm. 9V operation. 1000m range...

**MTX Subcarrier Scrambled Room Transmitter**
Scrambled output from this transmitter cannot be monitored without the SCDM decoder connected to the receiver. Size 20mm x 67mm. 9V operation. 1000m range...

**SCDM Subcarrier Decoder Unit for MTX**
Connects to telephone line anywhere, requires no batteries. Output scrambled so requires SCDM connected to receiver. Size 32mm x 37mm. 1000m range

**SCDM* Micro Height Telephone Recording Interface**
Connects to telephone line (anywhere) and cassette recorder. Switches tape automatically as phone is used. All conversations recorded. Size 4mm x 32mm. Powered from line

**DTX/ULTX Dual小型 Room Transmitter**
Smalllest room transmitter kit available. Incredible size of 10mm x 20mm!
Connects to line (anywhere) and switches on and off with phone use.
All conversations transmitted. Powered from line. 500m range

**TLL700 Micro-miniature Telephone Transmitter**
Best-selling telephone transmitter. Being 20mm x 20mm it is easier to assemble than UTX. Connects to line (anywhere) and switches on and off with phone use.
All conversations transmitted. Powered from line. 1000m range...

**STLX High-performance Telephone Transmitter**
High performance transmitter with buffered output stage providing excellent stability and performance. Connects to line (anywhere) and switches on and off with phone use.
All conversations transmitted. Powered from line. Size 22mm x 22mm. 1500m range

**CD400 Pocket Bug Detector/Locator**
LED and piezo bleeper pulse slowly, rate of pulse and pitch of tone increase as you approach signal. Gain control allows pinpointing of source. Size 45mm x 54mm. 9V operation...

**CD600 Professional Bug Detector/Locator**
Multicoulour readout of signal strength with variable rate bleeper and variable sensitivity used to detect and locate hidden transmitters. Switch to AUDIO CONFORM mode to distinguish between localised bug transmission and normal legitimate signals such as pagers, cellular, taxis etc. Size 70mm x 100mm. 9V operation...

**QLX180 Line Powered Crystal Controlled Telephone Transmitter**
For monitoring any of the 'CI' range transmitters. High sensitivity unit. All RF section requires the use of a scanner receiver or our ORX180 kit (see catalogue). Size 20mm x 67mm. 9V operation. 1000m range

**QLX180 Crystal Controlled Telephone Transmitter**
As per QTX180 but connects to telephone line to monitor both sides of conversations. Size 20mm x 67mm. 9V operation. 1000m range...

**OQRX180 Crystal Controlled Telephone Transmitter**
As per QTX180 but draws power requirements from line. No batteries required. Size 32mm x 37mm. Range 500m

**OQRX180 Crystal Controlled FM Receiver**
For monitoring any of the "O" range transmitters. High sensitivity unit. All RF section supplied as a pre-built and aligned module ready to connect on board so no difficulty setting up. Output to headphones. 60mm x 75mm. 9V operation...

A build-up service is available on all our kits if required.

UK customers please send cheques, POs or registered cash. Please add £1.50 per order for P&P. Goods despatched ASAP allowing for cheque clearance. Overseas customers send sterling bank draft and add £5.00 per order for shipment. Credit card orders welcomed on 0827 714476.

OUR LATEST CATALOGUE CONTAINING MANY MORE NEW SURVEILLANCE KITS NOW AVAILABLE. SEND TWO FIRST CLASS STAMPS OR OVERSEAS SEND TWO IRCs.
SPARKOMATIC 4 x 150 watt CAR AMPLIFIER

The SA3200 is our top of the line 4 channel Amplifier which can be used in a wide variety of applications and features separate bass and treble terminals which gives the user the possibility of reducing bass response to the front speakers and adding treble for soft furnishing and sound reflections from glass.

1. 4 x channel Crossover
2. 4 x 150 Watts max. at 4 Ohms less than 0.5% T.H.D. at 2 x 80 Watts plus 1 x 160 Watts at less than 0.5% T.H.D.
3. Separate bass and treble controls for front and rear channels
4. 2, 3 or 4 channel operation
5. Separate sensitivity controls
6. 33000µF 16V 27A can type electrolytic capacitor
7. Heavy duty power wires
8. Glass bonded aluminum heatsink
9. High current capacity £251.65 plus £7 p&p

SPARKOMATIC 2 x 150 watt CAR AMPLIFIER

The SA1500 is a very highly specified 2 Channel Amplifier with built-in sub bass crossover. The SA1500, which is ideal for powering monoblock systems, monte Carlo etc, will also operate in bridge mode as a 150 Watt mono amplifier.

1. 2 x 150 Watts max. into 4 Ohms 2 x 70 Watts per channel at 0.5% T.H.D.
2. Bridge mode operation
3. Sensitivity 250mv 4ohms - 1100mv 8ohms
4. Heavy duty power wires
5. Built-in sub bass crossover
6. Glass bonded aluminum heatsink
7. High current capacity £117.65 plus £6.50 p&p

SPARKOMATIC 80 watt CAR POWER AMPLIFIER

The AMP 7000 produces high power at low distortion.

The amplifier accommodates low level, high level and high power radio signal inputs. The response is linear and extends beyond the capability of all music sources. This unit normally has its own mounts easily and its quick connect terminals accept RCA or straight wire input terminals. Power rating 2 x 40 watt per channel. Max 2 x 20 watt responses 20Hz-20kHz. Size 160mm x 130mm x 45mm £32.95 plus £3.90 p&p

11 BAND COMPONENT GRAPHIC EQUALIZER FOR CAR

This new unit connects between the line output of your car stereo and your power amplifiers so that you are able to adjust the sound as in a studio compensating for the distortion and sound aberrations from glass and other features. It also has a sub woofer output to drive a separate amplifier for that extra deep bass sound. FEATURES: 2 channel inputs 4 channel outputs via phono sockets. CD input via 3.5mm jack 11 band graphic. SPECIFICATION RANGE: 20Hz-20kHz THD 0.05%. S/N RATIO: 95dB. EQ FREQUENCIES: 60Hz, 120Hz, 250Hz, 350Hz, 1kHz, 2kHz, 3kHz, 4kHz, 5kHz, 6kHz, 10kHz. Hi pass (boost cut of ±12DB) Size 178mm x 25mm x140mm. £32.70 postage £1.90

EMINENCE 4 PROFESSIONAL USA MADE IN CAR CHASSIS SPEAKERS

All units are built with big magnets "Nomex" Voice coils NOT ALUMINUM, "Nomex" is very light and can also be used in very high temperature ranges from glass and other features. It also has a sub-woofer output to drive a separate amplifier for that extra deep bass sound. FEATURES: 2 channel inputs 4 channel outputs via phono sockets. CD input via 3.5mm jack 11 band graphic. SPECIFICATION RANGE: 20Hz-20kHz THD 0.05%. S/N RATIO: 95dB. EQ FREQUENCIES: 60Hz, 120Hz, 250Hz, 350Hz, 1kHz, 2kHz, 3kHz, 4kHz, 5kHz, 6kHz, 10kHz. Hi pass (boost cut of ±12DB) Size 178mm x 25mm x140mm. £32.70 postage £1.90

MAIL ORDER BARGAIN PACKS

MAIL ORDER TERMS, POSTAL ORDERS and or CHEQUES all items prefixed with MO number MAIL ORDER only or £1.50 + p&p. Overseas readers write for quote on delivery.

No. Qnty. per pack
M020 1 30W dome tweeter by Eagle/Japan Made size 30mm £1
M021 1 80W hist tweeter made for Jamco UK size 50mm £1
M022 30 watt 8 ohm Hi/Hi speakers. Made for MA Audio Systems size 125mm x 25mm with large 75mm magnet £9.00 + £2.00 p&p
M023 1 Pyle Car Speakers. Mounted in black plastic grill with grille and clamp terminals finished in black vinyl £18.95 + £6.50 p&p
M024A 30 watt. 8 Ohm Classic speakers made for Roadstar of Switzerland. Fitted with dual polypropylene cone and foam rubber surround. Price includes circular magnet for good bass response. Supplied with grills fixing screws 4x 2mm, size 55mm x 55mm £19.95 + £6.50 p&p
M025 2 EMINENCE U12 Size 320mm x 710mm V12 120W Max. V6 8" 300W Max. Coils NOT ALUMINIUM, "Nomex- is very light and can also be used in very high temperature ranges from glass and other features. It also has a sub-woofer output to drive a separate amplifier for that extra deep bass sound. FEATURES: 2 channel inputs 4 channel outputs via phono sockets. CD input via 3.5mm jack 11 band graphic. SPECIFICATION RANGE: 20Hz-20kHz THD 0.05%. S/N RATIO: 95dB. EQ FREQUENCIES: 60Hz, 120Hz, 250Hz, 350Hz, 1kHz, 2kHz, 3kHz, 4kHz, 5kHz, 6kHz, 10kHz. Hi pass (boost cut of ±12DB) Size 178mm x 25mm x140mm. £32.70 postage £1.90

EMINENCE 4 PROFESSIONAL USA MADE IN CAR CHASSIS SPEAKERS

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We are anticipating a very heavy demand for this issue and have printed 43,000 copies in an effort to make sure everybody who wants one gets one. However we do want to make sure you can also get your copy next month. So why not take out a subscription (see page 738), or fill in the blue “Shop Save” card stitched into this issue. This card will also get you into our free draw for one of two Maplin multimeters, each worth £30 (UK readers only).

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There has been so much pressure on space this month that we have had to leave out one or two items. These include our Readout (EE) or Wavelengths (PE) readers pages. We hope to fit this in next month so keep those letters coming, we should have room for a lively selection.

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Measure up to the outdoor high-life with this handy pocket altimeter

Anyone with an interest in the ups and downs of outdoor activities, walkers, climbers, cyclists, balloonists, hang-gliders, pot-holers and so on, will find their curiosity further satisfied through using the EPE Altimet. It is a handheld unit which uses two sensors, a DPM (digital panel meter) chip and an l.c.d. (liquid crystal display) to monitor and display data about altitude in metres and feet, barometric pressure in millibars, and temperature in Fahrenheit or Celsius.

The maximum readout range is +/−1999 metres relative to sea level. To facilitate setting-up, access to a digital multimeter, a good thermometer and a nearby hill is recommended!

PRESSING FACTS

The earth is surrounded by an envelope of air extending to around 500 miles above its surface and having an estimated total weight of 5,000 billion tons. At sea level, the pressure exerted by this mass of air is on average 14.72 pounds per square inch (PSI), or 1 kg per square centimetre. This average is also defined as a pressure of one atmosphere, or one bar, although meteorologists more commonly regard it as 1013.25 millibars (mb).

As one rises higher into the atmosphere, so the air pressure decreases, reducing to about one half (500mb) at 5,000 metres – see Fig. 1. At 16,000 metres the pressure has dropped to 100mb, while at 100,000 metres it is barely 0.001mb.

Although the pressure versus height relationship is not linear, for some purposes it may be regarded as such within the range of 0 to 5000 metres. It can thus be stated that up to a height of 5000 metres a change of 1mb represents a change of 10 metres.

However, the atmosphere is in a constant state of turmoil and the total weight of air above a given location can vary considerably. Under extreme conditions the pressure can range from about 940mb to 1060mb, as indicated by the scale on a standard aneroid barometer. Obviously, therefore, an altimeter using the barometric principle must have a separate control to adjust for natural changes in atmospheric pressure.

Variations in height plotted against millibars across the range of 940mb to 1060mb is shown in the conversion graph Fig. 2. If the pressure at sea level is 1000mb (horizontal axis) and a barometer shows a reading of 900mb (right hand column) the barometer is at a height of 1000 metres (left hand column). If the pressure at sea level is 1060mb and the barometer's altitude is 1000 metres it should show a reading of 960mb.

PRESSURE SENSOR

A piezo-resistive device, the Motorola MPX100A, is used as the pressure sensor in the EPE Altimet. Its schematic functional details are shown in Fig. 3.

In manufacture, a transverse voltage strain gauge is diffused on a thin silicon diaphragm which is mounted across an evacuated cavity. In the presence of an excitation voltage across the strain gauge, when pressure is applied to the diaphragm the resistance of the gauge changes, causing a change in the output voltage directly proportional to the pressure applied.

The MPX100A produces a voltage change of between 45mV and 90mV, Fig. 1. Basic altitude to millibar graph.

Fig. 2. Altitude to variable atmospheric pressure conversion graph.

Fig. 3. The MPX100A pressure transducer internal structure and function details.
the guaranteed minimum to maximum manufacturing tolerance range, for a pressure change of 100 kiloPascals (kPa). 100kPa equals 14.5 PSI, which is approximately equal to one bar.

Taking the typical output as 60mV per 100kPa, a 1mb pressure change will produce a voltage change of approximately 0.06mV. Likewise, a change in altitude of one metre (below an altitude of 5,000 metres) produces a change of 0.006mV.

Consequently, the interface between the sensor and the I.C.D. readout must convert the voltage changes by a factor which will cause each 0.006mV step to result in a barometric display change of one unit per millibar. This factor then has to be multiplied by 10 for the metres display, and by a further 3.28 for the feet display (1 metre = 3.280839 feet).

In the practical circuit, whose block diagram is shown in Fig. 4, the sensor output is in fact multiplied by a factor related to unitary changes on the feet scale, and then separately divided for the metres and millibar scales.

**SENSOR CIRCUIT**

In order to ease the understanding of the EPE Altimet circuit, it has been divided into three sections: pressure sensor and PSU; temperature and battery level; and I.C.D. display and controller.

The details of the sensor amplification and division scaling circuit diagram is shown in Fig. 5. It also shows the power supply details.

TX1 is the pressure sensing transducer. Its internal resistance is predetermined in manufacture within the range of 400 to 550 ohms. The value of the resistor R5 in series with TX1 is selected to suit the resistance of the transducer at 25°C.

Several of the transducer parameters are temperature dependent and the value of resistor R5 is instrumental in minimising part of the effect of their changes. This will be discussed later.

**Fig. 4. Full block diagram for the EPE Altimet.**

The transducer TX1 has two differential outputs, pins 2 and 4. The voltage span across them decreases as atmospheric pressure falls. Both are fed to the non-inverting inputs of op.amps IC2a and IC2b, which are configured respectively as a unity gain buffer and differential amplifier with a gain of about 3.3 by IC2a. Preset control VR2 in series with resistors R13 and R14 varies the bias at IC2c pin 12 so enabling the basic output voltage at IC2c pin 14 to be preset.

Before being further processed by IC2d, the voltage at IC2c pin 14 is tapped to provide barometric pressure data. Preset VR5 in series with resistor R20 divides the voltage by 32.8, presetting the span range required by the I.C.D. readout circuit. The inclusion of preset VR4 in series with resistor R21 is used to impose a bias voltage on one side of VR5 to increase the barometer readout by approximately 1000mb.

Whereas a barometer shows a decrease in reading with a decrease in pressure, an altimeter has to show an increase. Consequently, IC2d is used to invert the voltage change direction but, within the tolerances of resistors R16 and R19, does not change the amplification.

A panel-mounted control VR3 provides IC2d with a variable bias voltage, allowing the altitude readout to be set to compensate for normal meteorological changes in atmospheric pressure. The range controlled by VR3 is about 300 metres. This may be increased by increasing the value of VR3 or by reducing the value of R17.

The output of IC2d directly provides the voltage data for an altitude readout in feet. For the metres scale, the output of IC2d is tapped by preset VR6 in series with resistors R22 and R23, dividing the voltage by 3.28. Switch S2 selects between...
the Feet and Metres modes and feeds to switch S1 which selects between Height and Barometric modes.

**TEMPERATURE COMPENSATION**

In any d.c. amplification circuit there is a tendency for voltage levels to change as temperature changes. The component which causes most drift in the EPE Altimeter is the transducer TX1.

Even with resistor R5 chosen correctly, the transducer's offset voltage typically changes with temperature by about $\pm 15$ microvolts per degree Celsius. In the test model, the offset drift after amplification was 63mV per 40°F (22.2°C).

Compensation for this and other minor drifts is effected by the temperature-related change in voltage across the forward biased diode D3. The voltage at the junction of D3 and resistor R7 increases to that across D3 (Fig. 5).

The voltage across D4 changes at a similar rate to the temperature sensing element, shown in Fig.6 as D4. Resistor R24 and preset VR9 form a potential divider across the +5V and 0V power lines providing a bias voltage to D4. The voltage across D4 changes at a similar rate to that across D3 (Fig. 5).

Preset VR9 adjusts the displayed temperature value and VR7 preset the voltage/temperature output span. The choice of whether temperatures are shown in Fahrenheit or Celsius is made when setting up the unit, and simply entails adjusting VR7 for the desired ratio. S3a selects between temperature display and the modes routed via switch S1 as shown in Fig. 5.

Whereas height and barometric readings are shown as integer values, temperature is displayed to within one tenth of a degree. The decimal point control being switched in by S3b.

In height and barometric modes, the decimal point is pulsed in phase with the I.C.D. backplane clock, so rendering the point inactive. In temperature mode, the point is activated by connecting it via the OR gate around diodes D1, D2 and resistor R18 to two segments of the I.C.D. hundreds digit, one or other of which will always be active irrespective of the number displayed.

Also shown in Fig.6 is a battery check facility. Resistors R8 and R9 form a potential divider across the battery input lines. The tapped voltage is switched to the I.C.D. circuit (Fig. 7) via switch S5, an action which switches the previous mode selectors out of circuit.

The R8/R9 ratio causes an I.C.D. readout of approximately 90 for a battery voltage of 9-0V. There was insufficient room in the case to fit a d.p.c.o. switch to activate a decimal point in a similar way to S3.

**L.C.D. READOUT**

The circuit diagram which converts the monitored voltages levels into an equivalent I.C.D. display is shown in Fig. 7. The DPM chip IC1 is the heart of the circuit. It assesses the input voltage level and relates it to the reference voltage set by VR8 in series with resistor R2, timing the rate at which capacitor C4 charges and discharges.

The timing is clock controlled at a rate set by resistor R1 and capacitor C1 and an internal counter counts the number of pulses required to discharge capacitor C4. The counter outputs are internally decoded to control the four I.C.D. digits and a negative polarity symbol.

The backplane pulsing and phasing necessary for controlling I.C.D.s is automatically generated by IC1 and internally set at a sub-multiple of the main clock frequency. (Note that I.C.D. segments should *NOT* be controlled by a d.c. voltage since this steady state could damage them.)

Irrespective of the reference voltage set, the full scale range for that voltage is represented by 1999 steps. Input voltages outside the reference range cause the I.C.D. to blank the three right-hand digits and turn on the left-hand digit.

Preset VR8 is used to vary the reference voltage to suit the output voltage span produced by the transducer's amplifier stages. In effect, VR8 serves as an additional gain controller. This means that

---

Fig. 7. Circuit diagram of the display section and interconnection details between the display driver IC1 and the I.C.D.
when VR5 and VR6 have been set to the relative span ranges for their mode scales, a common increase or decrease to the altitude and barometer mode gains can be effected by adjusting VR8.

It will be seen that the lines controlling the polarity symbol and the thousand's digit are apparently connected to unused pins of the i.c.d. These connections correspond with the equivalent 1000 and polarity segments of a 4-digit i.c.d. module which may be used in place of the 3.5 digit version.

The battery voltage is run down to about 7.3V before ICI fails to regulate satisfactorily. A PP3-sized battery could last for weeks or even months.

The transducer in the prototype has a resistance of 433 ohms at 25°C and the value for R5 was calculated as 1548 ohms (1k548). The resistor with the measured value closest to this which was conveniently available was 1567 ohms. Although not the precise calculated value, the tolerance margin has proved to be acceptable.

Two or more resistors in series or parallel may be used to optimise the value. (There was not enough space on the p.c.b. to substitute a preset potentiometer for R5.)

Component Tolerances

Standard carbon-track miniature skeleton preset potentiometers and 5 per cent 0.25W carbon film resistors were used in the prototype, providing accuracy and stability well within the author's own requirements. A more tightly controlled performance can be obtained by using cermet presets and one per cent 0.25W metal film resistors. The main advantage of cermet over carbon presets in this application is the smooth linearity of their tracking, allowing more precise adjustment of their settings.

Metal film resistors have a better temperature stability than the standard carbon film variety. Typical temperature coefficients for the latter are -150 to -800 parts per million (ppm) per °C, whereas for metal film they are typically +/- 50 ppm per °C. Even though temperature compensation is provided, the use of metal film resistors could still be beneficial.

Resistance Matching

Since the correct value for resistor R5 is related to TX1 transducer's resistance at 25°C (77°F), it is preferable to take into account the transducer's temperature at the time that the measurement is made. The Nomogram in Fig. 8 shows how the resistance at a known temperature can be converted to its equivalent at 25°C (77°F).

Clip the leads of a digital multimeter to the transducer pins 1 and 3, and switch the meter to a range suitable for measuring up to about 550 ohms. Place a thermometer alongside the transducer and allow the temperature to stabilise.

Measure the resistance and note the temperature. Place a ruler so that its edge passes through the resistance value in the chart's left hand column and the temperature in the centre column. Read off the value in the right hand column and multiply it by 3-577 (a factor specified by the transducer manufacturer). This is the optimum value for R5.

POWER SUPPLY

A regulated +/−5V supply is generated from a single 9V battery. Referring back to Fig. 5, the battery voltage is switched on by S4 and is regulated down to +5V by IC3.

Using an internal pulsed inverter, IC4 generates an almost equivalent negative voltage from the +5V supply. The load driven by IC4, though, will slightly reduce the voltage from the nominal −5V to around −4.7V.

Capacitor C8 is associated with the chip's internal switching and C9 is the output reservoir capacitor. There is inherently a very slight residual ripple of IC4's clock frequency left on the negative line, though the final effect of this upon the signal input to ICI is nulled by the inclusion of resistor R3 and capacitor C3 in Fig. 7.

The current drawn by the circuit is around 13 5mA. If, as intended, the unit is used intermittently throughout a journey, a PP3-sized battery could last for weeks or even months.

Under continuous switched-on use, a PP3 battery life of around eight hours seems a reasonable expectation. The battery may be run down to about 7.3V before ICI fails to regulate satisfactorily. A NiCad battery may be used.

RESISTANCE TRANSUDER AT 25°C

Fig. 8. Pressure transducer MPX100A resistance/temperature nomogram.

The topside printed circuit board component layout and full size underside copper foil master pattern is shown in Fig. 9. This board is available from the EPE PCB Service, code EE807.
Before mounting the components, check that the board fits the case satisfactorily, trimming off any excess fibre-glass if necessary. It may also, with some models of the case, be necessary to trim down the internal partitions to allow the board to fit lengthwise while still allowing for the battery and switches to be inserted.

The front panel drilling measurements and layout used in the prototype model is shown in Fig. 10. Check that they apply to your case before drilling any holes!

CIRCUIT BOARD

There are several link wires required on the p.c.b., some of which go below i.c. positions (see Fig. 9), and these should be inserted and soldered first, but omit links TP1/TP2 and TP3/TP4 until later. The preset "pots" and d.i.l. sockets for the i.c.s and the l.c.d. should be inserted next.

The board has been designed so that the display is mounted above ICI. This is achieved by first soldering two 20-pin s.i.l. (single-in-line) sockets into the i.c.d. position. If s.i.l. sockets are not available, cut a 40-pin d.i.l. socket in half. Once assembly is complete, a second level of s.i.l. sockets to hold the i.c.d. is plugged into the first.

Fig. 9. Printed circuit board component layout and full size foil pattern.

Fig. 10. Case drilling details.

Approx cost guidance only £50
Solder in the components in order of resistors, diodes, capacitors and voltage regulator IC3. Next mount the rotary potentiometer VR3 in its p.c.b. hole, shaft protruding from the component side, using an insulating washer between its body and the back of the board to prevent shorting across soldered joints. The transducer TX1 is also mounted on the trackside of the board, carefully bending its leads through ninety degrees so that its body lies parallel to the p.c.b. in the direction of IC3.

Two versions of the MPX100A may be available (Fig. 12), one enclosed in a plastic case, the other not. Either may be used, but the unenclosed version must have insulating tape placed between its body and the p.c.b. tracks. Do NOT cover the hole in the transducer's centre, and under no circumstances poke anything into the hole below which is the very delicate pressure diaphragm.

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Fig. 12 Pressure transducer pintout details.

in circuit, but the l.c.d. and other i.c.s omitted, switch on and check that close to +5V is present at TP6 and that about –5V is present at TP7. Check the voltages at TP6 and TP7 again when IC1, IC2 and the display X1 have been inserted, but note that TP7 may now have fallen to about –4.7V. Any large deviation of the supply voltages will indicate a fault condition, such as a wrong component polarity or a track short or break.

**Bench Setting**

Throughout this section of the setting-up, the figures obtained from the model are quoted in square brackets as an example. They will vary slightly for other units.
Setting-up falls into two parts, "workshop alignment" and fine tuning under "field conditions". Since the response of the transducer can vary in manufacture between 45mV and 90mV per 100kPa, the final alignment can only take place after subjecting the unit to known changes in barometric pressure, such as those experienced when using it at the top and bottom of a hill of known height.

However, the millibars and metres presets VR4 to VR6 are aligned without the transducer fully in circuit, using the test circuit shown in Fig. 13. The circuit consists of R24 and VR9 from the temperature readout circuit, with the addition of a resistor R25 across VR9 to temporarily reduce its span range.

Temporarily link the outer terminals of the rotary control VR3 to TP6 and TP1 instead of to their normal designated points in Fig. 9. Set presets VR1, VR2 and VR3 midway, VR4 to ground, VR5 and VR6 to maximum output, and set VR8 for a reference voltage of about 200mV at TP8.

Clip a digital voltmeter across TP9 and TP10 and on its lowest suitable range measure the voltage when the wiper of VR9 is at its maximum resistance [4.9mV]. Link TP2 to TP9 and TP4 to TP10 (as links TP1/TP2 and TP3/TP4 have been left out, the transducer is not presently connected to IC2).

Assume for the moment that the transducer will have a span of 60mV per 100kPa and that 1000 metres = 10kPa. Therefore, 1000 metres represents a 6mV swing from the transducer which equals 3,280 feet (1000 x 3.28). Calculate the number of feet that the measured millivolt span range of VR9 represents: [3,280/6mV x 4.9mV = 2,678 feet].

**FEET**

Set the switches for Feet mode. Set VR9 midway and adjust VR2 and VR3 until the display X1 shows a reading of about zero (within a hundred units or so). Note the

![Fig. 13. Alignment and setting-up test circuit diagram.](image)

layout function switches on the front panel and position of the p.c.b. inside the case, showing wiring to track side and switches S4, S5 either side of the battery compartment.

**METRES**

Switch S2 to the Metres range. Divide the maximum feet reading by 3-28 to produce the metres integer equivalent [1373/3.28 = 418 597561 = 419]. Without touching VR8, adjust VR6 until the I.c.d. reads as close as possible to the calculated metres value [419].

Set VR9 to minimum and check that the I.c.d. readout is the metres close equivalent to the minimum feet readout [ 1305/3.28 = 397 865854 = 398]. There is likely to be a slight non-linearity between the feet and metres conversion figures within about 10 metres either side of a zero height readout.

Switch S1 to the Millibars range, set VR9 midway and adjust VR4 until an I.c.d. readout of about 1000 is produced. Do not adjust VR8. From the measured swing range of VR9 [4.9mV] calculate the millibar range that this represents:

\[60mV = 1000mb \text{ therefore } 4.9mV = 82mb\].

Swing VR9 back and forth across its range and adjust VR5 until the total I.c.d. range difference is the calculated millibar value [975 to 1057 = 82].

**TRANSUDER BALANCING**

The next step is to put the transducer fully into circuit and adjust preset VR1 to compensate for I.c.d. readout drift with temperature. Remove "test" resistor R25 from across VR9, disconnect the temporary TP10/TP4 and TP9/TP2 links, link TP1/TP2 and TP3/TP4, and reconnect VR3. Switch to the Feet or Metres range, then raise and lower the unit between floor and ceiling and observe that the display registers the height changes, even though accurate altitude setting has not yet been made.

After leaving the unit switched on for a few minutes to allow temperatures to stabilise, note the room temperature (as shown on a good mercury-filled thermometer). Switch to the metres range, set VR1 midway, adjust preset VR3 and/or VR2 for an I.c.d. readout of about zero. Note the I.c.d. readouts with VR1 at minimum, midway and maximum resistance settings.

Allow the room temperature to rise by as many degrees as is feasible, 20°F or 10°C for example. Note the I.c.d. readings at the three VR1 settings and judge approximately which value of VR1 produces the maximum readout change.

(A hair dryer blowing low heat across both sides of the p.c.b. was used in the original tests, allowing the temperature to rise slowly over about 15 minutes. Cooling to low temperatures was assisted by a fridge!)

Beware, though, that rapid temperature changes and uneven p.c.b. heating can produce misleading results. If condensation forms on the unit when removed from the fridge dry it off using the hair dryer.)

Let the room and the unit cool naturally back to the original temperature, set VR1 to two or three positions close to the estimated value noting the I.c.d. readings. Allow the temperature to rise again and note the I.c.d. figures at each chosen VR1 position. Set VR1 to the resistance setting at which the minimum output change occurs.

The transducer TX1 and temperature compensation diode D3 may respond at different rates affecting the apparent stability of the readout during the early minutes of a significant temperature change. Once the transducer and diode reach the same temperature the readout should have returned to its original figures.

**HYSTERESIS**

It should be recognised that there are component hysteresis factors which affect the maximum practical balance obtainable. Hysteresis applies particularly to the transducer and dictates that at any given pressure or temperature there will be a difference in the output voltages produced depending on whether this pressure or temperature is approached upwards or downwards.

The MPX100A has typical pressure and temperature hysteresis factors of +0.05% and +0.5% of full scale (100kPa) respectively. Without temperature drift correction the I.c.d. output
change on the test model was about 15 metres per °F (27 metres °C) the equivalent of around 1.5mV per °F (2.7mV °C). Although impaired by hysteresis, the compensation circuit allowed the drift to be kept down to only 20 metres over a massive 40°F (22.2°C) temperature change.

Hysteresis and drift factors, however, should be seen in context with the scale of potential atmospheric changes. A barometric change of only one millibar will cause an apparent change of 10 metres on the altimeter. At the time of writing, the weather forecast predicts a 15mb change from 1020mb to 1035mb over the next 24 hours. The effects of normal ambient temperature changes become minor by comparison.

**TEMPERATURE AND BATTERY READOUTS**

The unit may be set for either Celsius or Fahrenheit temperature readout scales, depending on the range set by preset VR7. Set VR9 and VR7 midway, switch to Temperature mode and note the display reading and that of a thermometer alongside the p.c.b.

Allow the room temperature to change across a reasonable range and note the difference in the I.C.D. reading and the difference in temperature. Adjust VR7 up or down as appropriate and again change the room temperature. Repeat until the temperature and I.C.D. spans are the same, and then adjust VR9 so that the I.C.D. reading matches the thermometer reading.

The values for resistors R8 and R9 should be selected after I.C.D.'s final reference voltage has been set by VR8. The ratio of R8 to R9 should cause the I.C.D. to show a reading of approximately 900 with a battery voltage of 9.0V. If the reading is low, increase the value of R8 or decrease R9.

**FIELD SETTING**

Final altitude alignment can only be done by checking the unit's height readout against a known height change. Consult a local Ordnance Survey (OS) map, preferably the large scale Pathfinder (green) series, and find two locations where the heights are known and of several tens of metres apart.

Go to one location and using the rotary control VR3 set the height on the I.C.D., also noting the temperature. If the temperature is changing and the unit's temperature balance is not exact, while still at the same location note the I.C.D. height reading at different temperatures. Go to the other location and repeat.

Take two readings made at the same temperature and calculate the difference between the I.C.D. change and the actual height change. Slightly reduce or increase the setting of preset VR8 as appropriate and repeat the procedure until the actual and displayed height spans correspond. An I.C.D. reading change of 55 metres compared to an actual height change of 60 metres, for example, would require adjustment of VR8 to decrease I.C.D.'s reference voltage.

It is preferable for the time between high and low readings to be kept short to minimise the likelihood of atmospheric pressure changes occurring between readings. It is advisable, for the same reason, to choose a day when the BBC TV weather forecast maps show the isobars well spaced out.

Once VR8 has been finally set, the current millibar setting for your area (watch BBC TV again!) can be set by adjusting VR4. It should be remembered that weather forecast charts give millibar figures referenced to sea level. If you live significantly higher than sea level, the true atmospheric pressure for your location can be calculated from the simple equation + 10 metres = - 1mb.

**USING IT**

Since atmospheric pressure is constantly changing throughout the day, the height trimming control VR3 should be adjusted prior to each outing, setting the display to show the correct height in metres for the starting location as established from an OS map. If significant isobar changes are forecast it is advisable to re-trim VR3 in association with an OS map occasionally throughout a prolonged land-bound journey.

It is assumed that balloonists and other leisure-aeronauts will not be aloft long enough for meteorological changes during their flight to have any significance. Try to avoid subjecting the EPE Altimeter to rapid or excessive temperature changes.

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- All-In-One Design System

**What The Press Said About RANGER1**

For most small users, Seetrax Ranger 1 provides a sophisticated system at an affordable price. It is better than EasyPC or Tilen's Boardmaker since it provides a lot more automation and takes the design all the way from schematic to PCB - other packages separate designs for both, that is, no schematic capture. It is more expensive but the ability to draw in the circuit diagram and quickly turn it into a board design easily makes up for this.

**Source: JUNE 1991 Practical Electronics**

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**EVERYDAY WITH PRACTICAL ELECTRONICS, NOVEMBER 1992**

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701
Amateur Radio Morse Test

The Radiocommunications Agency has announced proposed changes to the format of the 12 words per minute Amateur Radio Morse Test.

It is claimed that the new format will prepare candidates better for the sort of operating conditions they can expect to encounter "On Air". It follows the same lines as the five words per minute test which was successfully introduced last year.

The new test will come into operation from January 1, 1993. Candidates who have studied under the old format will still be able to take the old test until March 31, 1993 when the new test will become compulsory.

Simultaneously with the introduction of the new style test, 1 January, 1993 will also see a new procedure for the identification of candidates. Instead of written proof of identity, candidates will have to bring to the test centre two recent passport sized photographs of themselves.

- Shades of code breaking?

In the new test, the candidate will be required to receive a minimum of 120 letters and 7 figures in the form of a typical exchange between radio amateurs. A manual Morse key will be used to send the message. This portion of the test will last approximately 2½ minutes and a maximum of six uncorrected errors will be permitted.

In the sending test, the candidate will be given a text to send by hand on a straight Morse key consisting of not less than 75 letters and five figures, also in the form of a typical exchange. This portion of the test will last approximately 1½ minutes. There must be no uncorrected errors in the sending and not more than four corrected errors.

The Radio Society of Great Britain conducts both the five and 12 w.p.m. Morse tests on behalf of the Agency. Further information on taking the test may be obtained from: Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE.

Patent News

The first ever report published by the Patent Office since becoming a Trading Fund on 1 October, 1991, and its accounts, prepared for the first time on a full commercial basis, show a surplus of £603,000 for the six month period to 31 March, 1992.

However, in volume terms, patent applications in 1991 were two per cent down on 1990, while trade mark (including service mark) and design applications were down by 12 per cent respectively. A similar trend was evident in the European Patent Office where a down-turn in activity was recorded for the first time.

The new format is expected to prepare candidates better for the sort of operating conditions they can expect to encounter "On Air". It follows the same lines as the five words per minute test which was successfully introduced last year.
BRIGHT LIGHTS

Changes in light intensity can be used or monitored with high accuracy using one of the new family of light-to-voltage optical sensors (types TSL250/51/52) from Texas Instruments. The devices combine, in a single three-pin package, a large area photodiode, an operational amplifier and feedback components.

The devices operate from a single variable supply voltage (3V to 9V), and each device provides a voltage output proportional to the incident light intensity. Because the output is a voltage level, the devices can be easily interfaced to comparators or A/D converters.

Integrating an amplifier and a photodiode together on the same chip not only simplifies designs, but also enhances the noise immunity of the device. Thus they are particularly useful at low light levels or in noisy environments.

Potential applications for the TSL250/1/2 include light control, IR remote control, security systems and medical chemical testing.

Further details from: Texas Instruments Ltd, Dept EPE, Manton Lane, Bedford MK41 7AP.

Cable Gains

The number of homes connected to broadband cable systems rose in July to 330,630, according to the Independent Television Commission's (ITC) latest cable statistics. This was a net increase of 39,000 (13.5%) over the last three months and of 139,000 (72.5%) over the last year.

Because research has shown cable households to be larger than average (3-1 people aged four years and over), it is claimed this means that over one million viewers now receive multichannel television via one of Britain's cable franchises. The take-up rate has increased by 2-25 percentage points over the last year.

The Car CD Multiplay (code GK74R) from Maplin.

In-Car Stereo CD

The closest thing yet to a sound studio on wheels is one of the claims from Maplin for their new add-on In-Car Stereo 6X CD Autochanger System. - Mind you at £329.95 its only what you'd expect.

The unit takes standard 5 in. discs and also 3 in. types with adaptors (not supplied). A stereo pair of phono sockets are supplied for the audio output, but if the radio cassette does not have spare CD inputs, there is no problem. The CD autochanger includes an ingenious v.h.f. f.m. modulator which can be simply inserted between the plug of the aerial lead and input socket of the radio unit - in principal just like a video recorder between antenna and TV at home.

The f.m. modulator provides an interface between the CD autochanger and the f.m. stereo radio. But please note: The radio unit must be f.m. stereo - the unit cannot work with MW and LW receivers.

The main CD autochanger player can be fitted distant from the existing stereo system, and is remotely controlled via a small keypad which can be fitted on the dashboard by means of the self-adhesive Velcro pad supplied.

The Car CD Multiplay (code GK74R) from Maplin.
For at least ten years the Japanese electronics companies have been trying to engineer the marriage of audio and video. They have many times promised consumers a single AV centre in the living-room, with TV screen, hi-fi sound system, video tape and disc and surround-sound speakers, perhaps with a computer keyboard and telephone tagged on. But most consumers - if only for convenience in room layout - still prefer to have a separate TV set and hi-fi system in different parts of the room, a telephone on the wall or table, and a computer in another room.

The situation is likely to change over the next ten years, because it becomes increasingly hard to draw any dividing line between audio, video and telecommunications. Also consumers are becoming increasingly unhappy with the proliferation of different audio, video and telecommunication formats and all require their own cockpit of wiring. The time will soon, finally be right for a more unified approach to electronics in the home.

Digital Recording

No-one can yet predict which of the two competing new digital home recording systems (DCC or Mini Disc) will win the standards battle due this winter, or whether both will fail and let recordable CD fill the gap. Whatever happens, digital sound recording will become a way of life, and with it legislation and technology to restrict cloning but at the same time legitimize some degree of copying - probably with the implementation of a tax on blank media.

Until now, making an audio recording has been a relatively troublesome business, with the need to set gain controls to avoid overload, or rely on automatic gain control circuitry which compresses the sound. With digital recorders, making a copy is as easy as copying computer data from disc to disc.

Once the public gets a feel for this there will be no turning back - just as people who have bought CD players seldom go back to playing vinyl LPs. It is not so much the sound quality which sells CDs, but the glorious convenience of the system.

Armchair Record Store

From the success of any home digital audio recording format, it will be a logical step to combination units, which hard wire to CD players to a digital recorder. Digital audio broadcasting, whether by terrestrial transmitter or satellite, will open the door to what has been dubbed "the armchair record store". This is a digital recorder which copies broadcast material, for a fee, and with copyright payment, as an alternative to record retailing.

Digital TV, whether conventional or high definition, will provide more channels from available terrestrial and satellite bandwidths. Viewers will need a digital decoder, which will probably double as a de-scrambling device for subscription entertainment and very probably control a VCR to tape and decode only what the viewer has paid to watch.

The advent of digital TV transmission will create the need for a new kind of home video recorder, which works digitally. This will tape the raw broadcast data stream for later decoding. Where several programmes are interleaved into the same stream, the video recorder will tape them all. When the tape is replayed the viewer will be able to decode which of them to decode and watch. If some or all of the programmes are scrambled, the viewer will have to pay a fee to decode and watch them.

The broadcasters are already using digital video recorders to originate and edit programmes. The advantage of digital recording is that it allows repeated copying, through many generations, without loss of quality. For special effects work, TV producers may well have to copy through a dozen generations. There are several different digital formats on offer to professionals and as the technology matures it will become cheap enough to spin off into the domestic market.

Home Videos

Many people already use camcorders to make point and shoot video movies. An increasing number of hobbyists edit their home videos. These people will welcome the chance to use digital technology, and so avoid generation loss.

Recordable discs systems will let editors work much faster than they can from tape. Sony's Mini Disc may well find applications in video, with first generation units recording video as an f.m. analogue signal and later as digital code.

All the new digital audio and video formats will rely heavily on compression, with data rate drastically reduced by real time analysis of the signal by a coder which discards any redundant information.

Interaction

The new audio and video transmission technologies will be used with cable systems, and with the added benefit of interaction. Viewers will be able to control the choice of programmes and services sent to them by feeding signals back up the same cable. They will be able to vote too, whether in quiz shows or political ballots.

Although a lot of effort has been made to provide interaction control without a keyboard, this will change. To anyone who uses a keyboard, it is infuriatingly clumsy to have to type text by using a mouse or similar control to select letters from a displayed alphabet. And more and more people are growing up with keyboards. Within a few years it will be commonplace to provide TV viewers with a portable keyboard which connects to the TV set by infra red link.

The growth of cable will be stimulated by growing realisation by the public that the Mercury service already offered or promised by twenty cable franchisings gives a hassle free alternative to British Telecom's practical monopoly to date.

Much of the talk about video phones is ill-informed, because few people need or want to watch who they are talking with by phone. Picture information can most easily be sent by fax. But cable links and/or the new ISDN phone lines should make it easier for video phones to provide security surveillance. This will marry the phone to a domestic TV screen.

CD-I

Although no-one knows how long it will take, interactive CD (almost certainly Philips CD-I format) will become a way of life, with games probably seeding a new revolution in home entertainment and education. Kodak's Photo CD looks likely to be a short lived product, simply because the compatibility bridge between CD-I and Photo CD has already made the Photo CD player little more than a CD-I player with a few microchips or wires removed to justify the lower price.

With full motion video, and Photo CD imaging technology, and the ability to play CD audio discs, the CD-I player could become the CD player of the future. There is likely to be a second standard, which quadruples the amount of information stored on disc, thereby doubling picture quality and playing time. This makes the five inch disc a carrier for movies as well as games, education, audio etc. So although digital FMX picture quality cannot yet match the twelve inch analogue Laser Disc, this will change. Pioneer, currently relaunching Laser Disc in Europe, is researching digital video technology.

Standard

The big advantage of digital video disc is that the programme can be easily copied many times. Indeed this is seen by the movie studios as a very real disad-
TOMORROWS
TECHNOLOGY

IAN POOLE

TECHNOLOGY is advancing at an ever increasing rate. The necessity to stay ahead of the competition feeds companies with the incentive to spend many millions of pounds each year on research and development. This brings many advantages to the electronics enthusiast.

New components which are much better than anything previously available are constantly being launched onto the market. It does not normally take long after they are launched for them to fall in price quite dramatically and become normal every day devices.

BRIEF HISTORY

To illustrate this fact it is worth looking back over technological advances of the past 21 years. Some of the components we take for granted today were very much at the forefront of technology, if they were even available, at that time. The one which stands out above all the others must be the introduction of the microprocessor.

The first microprocessor was in fact launched 21 years ago in 1971. Designed by the Intel Corporation, microprocessors arose out of the first calculators which were beginning to hit the market.

The first microprocessor was the 4004. It contained about 2500 transistors – a very large number for a single i.c. at the time, and it used a 4-bit word.

Along with the processor itself Intel launched a number of other companion i.c.s. These included a RAM i.c., memory control, and an I/O expansion chip.

A year later Intel announced their first 8-bit processor, the 8008. Then in 1974 this was followed by the 8080. This processor was a great improvement on the previous chips. It used NMOS technology for increased speed and it soon became an industry standard.

Intel was not the only company in the microprocessor race, many other manufacturers started to produce them. These included many famous names. One was Motorola who launched their 6800, also in 1974.

MICROPROCESSOR DEVELOPMENT

The introduction of the microprocessor was a revolution in itself. It reflected many of the advances which were taking place particularly in i.c. manufacture. However, developments within the whole field of electronics were involved. If these had not been made then the idea of a microprocessor would not have been possible.

One of the major advances which enabled the very large scale integration used in microprocessors to become possible was the development of MOS technology. Bipolar i.c.s were limited in the number of transistors which could be placed on a single chip. This was because of the current they consumed and the resulting heat which had to be dissipated.

The foundations for MOS technology were laid in 1959 when the first f.e.t.s were produced. They caught on only slowly because they were expensive and unreliable. However development continued and improvements came. By 1970 MOS technology was well established and it was widely used. Suitedly refined silicon was available. In addition to this complementary MOS (CMOS) was becoming a standard because it enabled less power to be used than ordinary bipolar technologies.

The development which lead to all of this was the integrated circuit itself. Two people are credited with its discovery. One was Jack Kilby who worked for a small company called Texas Instruments. The other was Bob Noyce of Fairchild (who later co-founded Intel). They were both investigating ways of making electronics equipment smaller. By the end of 1961 their work had led to both their companies producing small quantities of i.c.s.

During the 1960s and 1970s tremendous amount of effort was placed into research of i.c. technology. The American defence and space industries gave impetus to these developments and gradually their cost fell and they became far more widely used.

In fact, today much of the research and development in the electronics industry is devoted towards i.c. technology. Some of it may not bear any fruit, but some of it may be just as revolutionary as the i.c. or the microprocessor.

CURRENT EXAMPLES

Today a very large amount of research is allied to improvements in computer related technologies. This is not to say that other areas of electronics are not seeing major developments. However computer sales represent one of the major electronics sales areas.

Within the computer related developments there are a number of main areas of research. Size is obviously one major concern. Although today’s personal computers represent a considerable achievement in terms of miniaturisation there is still a need to make the basic elements within i.c.s smaller. If this can be done then operating speeds can be increased.
and production costs for the final units can be reduced.

One interesting development is being undertaken at IBM's Research Centre in California. It is aimed at enabling much more to be packed into integrated circuits. Currently the dimensions of the smallest transistors are around 0.5μm. It is expected that this will be reduced to about half by the end of the century. This naturally limits the ultimate size of any i.c. which is made.

To make any major reductions in the size of basic i.c. components a complete review in thinking is needed. This is exactly what the IBM researchers have been doing. They have performed some experiments which have shown how the movement of a single atom can act as a switch. In these experiments a single atom was successfully moved between two electrodes spaced apart by a few atom diameters (Fig. 1). The effect was monitored by looking at the change in tunnelling current as the atom changed its position. The two different values of current can then be equated to the different logic levels.

Unfortunately it is not easy to demonstrate the effect. A temperature of −269 degrees C is required together with some very specialised equipment. It is hardly surprising that the effect is not in a state where it can be used commercially. However it is likely to have an impact on future generations of miniaturised devices. Also if a method is found whereby it can be incorporated into an i.c. then it could help solve many of the problems facing i.c. designers today.

**SUPER-CONDUCTING I.C.S**

Another interesting idea which is more likely to bring some direct results in the near future uses superconducting technology in i.c.s. The advantage of it is that it enables i.c.s to operate at very fast speeds whilst dissipating only minute amounts of power. This is a great advantage because today's fast i.c.s are power hungry. This is a problem because the heat generated by the i.c. has to be removed otherwise the chip will overheat.

Using this superconducting technology, a company in the USA, called Hypress Inc. has made a shift register. It can operate at frequencies up to 4GHz whilst only dissipating 40μW. In fact it is estimated that i.c.s using these techniques could be able to operate at 25GHz and more.

Another advantage of these devices is that the fabrication process uses temperatures of only 150 degrees C. This means that it is ideal for making i.c.s with both silicon and gallium arsenide on the same chip.

The first superconducting i.c.s are likely to find uses in military equipment, particularly in radar systems where very high speed signal processing is required. Another use is in radio communications equipment where very high speed analogue to digital converters could be made and used with high speed processors for advanced digital signal processors.

Longer term aims are very exciting. It is hoped to build a complete computer processor with them. Current estimates indicate that it should be possible to make a computer processor out of 16 chips. It would have 1000 times less processing power of a VAX11/780 and it would consume less than one watt in power.

**GALLIUM ARSENIDE RISES TO THE FRONT**

Gallium arsenide has long been thought of as the answer to many problems. It has many advantages over silicon, especially in terms of speed, but until recently it has only been used in applications where current consumption is not of major importance. Accordingly its uses tend to be confined to high performance r.f. circuits and very high speed logic. In none of these applications can it compare with the low power used by fairly standard silicon technologies like CMOS.

The high current consumption and power dissipation of gallium arsenide i.c.s has also limited the scale of integration of any i.c.s made from it. Honeywell have been looking at ways of reducing this power requirement. It has long been accepted that complementary circuits like those used in CMOS are the key to low power consumption. However until now it has not been possible to make this type of structure in gallium arsenide. By generating a new type of structure called a complementary HFET (C-HFET) Honeywell have been able to create complementary structures.

The first departure from the normal is that these chips do not consist of straight gallium arsenide. Instead they use a structure containing aluminium gallium arsenide and indium gallium arsenide to achieve much better results. Like CMOS this new structure only draws current when it changes state. This means that power consumption is considerably reduced and integration levels can rise.

To produce the new structures required for this process it has been necessary to use a process called molecular beam epitaxial deposition. This enables the very precise structures required for the C-HFETs to be made (Fig. 2).

Although the development of these devices is still in its very early stages, a 4K bit static RAM has been produced. In tests this had an access time of only 4nS and it dissipated only 100mW. This is about one fifth of that used by a standard gallium arsenide memory of the same size. These new devices are not available yet because there is still plenty of work to do. However they are likely to be very much in demand when they hit the market place.

**3-D STORAGE**

Memory development is one area of electronics which is also receiving plenty of attention. Whatever the capacity of disc drives people always want more. This has fuelled the development of various storage media for many years. It is only about 15 years since disk drives for anything apart from a personal computer were housed in 19 inch rack mounting units. Now with much smaller disk drives available, development is still progressing quickly.

One of the major problems with disk storage is that it is relatively inefficient in terms of space because it can only use the surfaces of the discs. When the two sides of the disc are insufficient then several disks can be stacked to increase the capacity. Unfortunately this does not really overcome the root of the problem.

To overcome this new idea of using 3-D storage blocks is being developed. Data can be stored in all positions in the cube and this means that the storage capacity can be dramatically increased.
NEW MATERIALS

To achieve this, radically new techniques and materials are needed. The basic idea involves the use of a specialised organic material which changes state when it is energised by two intersecting light beams. It is very fast and its storage density is very high. In fact the density is limited by the definition and registration of the light beams and not the material, which works at the atomic level.

The system is based around the fact that the material is normally absorbent to UV light and clear to wavelengths in the visible section of the spectrum. However when it is excited by two intersecting beams of light, its absorbency changes (Fig. 3). It then starts to absorb light in the red/green part of the spectrum. These two states of absorbency can be used to represent the two digital states.

To read data from the material an equivalent process is used. Two intersecting UV beams detect the absorbency of the material. The resulting light can then be detected by an array of photodiodes which convert the information into electrical signals.

Although the write process is fast, it can be speeded up even further by projecting an array or pattern of data onto the material. The second light beam is then used to fix the data in the correct plane in the cube. Using the process in this way large amounts of data can be stored exceedingly quickly.

Work on this idea is still very much in its experimental stages and there are many problems to be overcome. One is that the storage material which is used at the moment is only stable at low temperatures. If the process is to be widely used then it must be able to operate at room temperature. To achieve this other substances are being investigated.

The possibilities of this new technology are very exciting. Its size and speed mean that it could very quickly out-perform any other type of storage for many years to come. There are even further possibilities. Being an optical form of storage it could be ideal in linking into optical computers which are being discussed as the next revolution for the future. Not surprisingly many companies are taking a keen interest in this work.

NEW BATTERIES

Not all the developments which are taking place in electronics are associated with computers. Some are equally important and likely to have a large impact on the electronics world. One interesting area for research is in batteries.

Existing technologies have many drawbacks. Non-rechargeable or primary cells are expensive. They have to be discarded once they are used despite the fact that they remain basically intact after use. Their disposal also poses problems in this age when people are rightly conscious about the environment.

Rechargeable cells offer a very attractive alternative. Of the technologies which are available NiCads hold a virtual monopoly despite a number of difficulties. Firstly they only produce 1.2 volts instead of the 1.5 produced by a primary cell. They also have a finite number of charge/discharge cycles. Under ideal conditions this can be as many as several thousand, but under normal use it is somewhat less. One major mode of failure occurs as a result of the mechanical stresses which are set up in the cathode as a result of even normal use.

A new battery technology which is emerging could overcome these problems. The batteries use a form of ceramic called a ternary oxide. There is a wide variety of these ceramics and by choosing the correct types voltages over a relatively wide range can be generated. This means that it is possible to make batteries using this technology which will give a voltage of 1.5 volts.

The other advantage of these ceramic batteries is that they can endure an almost unlimited number of charge/discharge cycles. This results from the fact that there are almost no internal stresses set up during normal use: a fact which has been verified using X-rays.

Work is progressing quite rapidly on developing these cells. Although the results look very promising it will still be a few years before they are available.

SILICON LIGHT

Light emitting diodes are now a standard component, used in a wide variety of applications. However they have always been made from gallium arsenide. Whilst gallium arsenide performs very well it is difficult to handle and more expensive than silicon. If a process could be devised to use silicon then enormous savings could be made in view of the extensive use of l.e.d.s.

Some progress is now being made towards this goal. The key to it is based around a process being developed by Siemens. It involves an electrochemical process which creates minute pores in the silicon about 1nm in diameter.

These holes have the effect of restricting the movement of the charge carriers i.e. holes or electrons. In turn this causes the silicon to exhibit properties more like that of gallium arsenide where light emission and absorption are concerned.

Work is still in its early stages. Experiments using the treated silicon have shown that it can be stimulated into generating red or yellow light when exposed to a blue laser. The actual colour of the light which is generated is dependent upon the size of the pores. Now it remains to generate light using an electric current.

FOR THE FUTURE

It is very difficult to gaze into the future and predict how the electronics world will likely to be in 21 years time. A few people have managed to produce predictions which have come true. For example Isaac Asimov talked about a man using a small hand-held calculating machine with its red numerals. This was many years before the calculator with either l.e.d. or l.c.d. displays was available.

To have an idea of what technology may be like in a few years time it is possible to look at today's research and see where it could lead. Alternatively one can look at today's needs and see how this could stimulate research and development.

SMALLER AND FASTER

Much of today's research seems to be associated with faster, more powerful and smaller computers with more memory. The need for this seems to have been amply demonstrated by the fact that whenever a more powerful computer comes on the market then it can be used immediately. The same can also be demonstrated with even the comparatively humble PC. Even today programs are being written which require more memory and higher speeds.

The original 8080 or 8086 machines cannot cope with most programs on the market today. Even the 286 machines are becoming obsolete and the 386 is being overtaken by the 486.

Storage is another area where there will be major advances. PCs today now have their fast storage called RAM. Even the humble PC. Electronic programs are being written which require more memory and higher speeds.

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Storage is another area where there will be major advances. PCs today now have their fast storage called RAM. Even the humble PC. Electronic programs are being written which require more memory and higher speeds.
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PLEASE PHONE/WRITE FOR ITEMS NOT LISTED.

Everyday with Practical Electronics, November 1992
This Reaction Timer project was originally designed for fun at a party. However, it could have other more serious applications – in school science lessons, for example.

Reaction time is the time taken for a person to detect something (a stimulus) and for the brain to process it and make something happen. For example, when a child runs out in front of a car, the motorist applies the brakes as quickly as possible. The time elapsing between seeing the child (stimulus) and producing an action (pressing the brake pedal) is the reaction time.

The Highway Code uses the term thinking distance since here the reaction time is translated into the distance travelled at various speeds. This is more easily understood by motorists. For example, if a car is travelling at 30mph, the Highway Code tells us that the thinking distance is 30ft. A simple calculation can turn this into a reaction time:

\[
30\text{mph} = 44\text{ft/second}.
\]

So 30ft is covered in

\[
\frac{30}{44}\text{ second} = 0.7\text{s approx.}
\]

Fig. 1. Complete circuit diagram for the Reaction Timer.

**THINKING TIMES**

Thinking distance or reaction time depends on several factors. Firstly, the personal experience – some people have faster reaction times than others and, to some extent, this depends on the person’s age. Secondly the state of alertness. The time will be greatly increased if the subject is tired or not concentrating.

Finally, the type of stimulus – the reaction time for a visual stimulus may not be the same as that for an aural one. Also, the effect of alcohol and some medicines (such as cough mixtures and so-called “cold cures” containing certain antihistamines) – these will increase the reaction time.

**IMPORTANT WARNING:** Under no circumstances must this reaction timer be used to indicate the ability to drive safely or to judge any impairment on driving due to the effects of alcohol.

The Reaction Timer is a battery-powered circuit housed in two interconnected units each built in a small plastic box. The main section has an on-off switch, a row of nine I.e.d.s (light emitting diodes) and a pushbutton (Freeze) switch. It also contains the circuit panel and battery. The remote section has a Start/Reset pushbutton switch mounted on top.

**TESTING TIMES**

Two people are needed to perform the test. The person performing it (the tester) sits with the remote section in such a way that the person being tested (the subject) cannot see the Start/Reset switch and possibly anticipate the start. The subject sits in front of the main unit with his or her finger ready on the Freeze button.

The unit is switched on and the tester presses the Start/Reset button whereupon the first I.e.d. in the display lights up. After some random time the button is released.

At this point, the I.e.d.s in the display operate one by one in rapid succession. As soon as the subject sees the first I.e.d. go off, he or she presses the Freeze button and keeps it pressed. This stops the display and the I.e.d. which remains lit indicates the reaction time against a scale of values marked alongside.

The button is now released ready for another try. Normally, several trials will be performed on the subject and an average time taken.

The prototype unit measures the reaction time in 0.1 second (100ms) increments up to 0.8s (800ms). If there is a delay of more than 0.8s between observing the display and pressing the button, the unit “locks out” automatically and all I.e.d.s go off. The circuit could be adjusted at the setting-up stage to go up in larger steps, say, 150ms giving a maximum display readout of 120ms (1.2s).

In the prototype model, the first three I.e.d.s are green, the next three yellow and the last three red. These could be used to indicate Good, Fair and Poor reaction times.

**CIRCUIT DESCRIPTION**

The full circuit diagram for the Reaction Timer is shown in Fig. 1. IC1 is a 555 timer i.e. which is connected as an astable multivibrator. Thus, while a supply exists – that is, with On-Off switch S3, on, pulses are produced continuously from the output, pin 3, at a nominal rate of 10 per second (10Hz).

The exact frequency depends on the values of fixed resistors, R1 and R2, preset potentiometer VR1 and capacitor, C1. To allow for component tolerances, and to enable different rates of operation, VR1 forms the adjustment for the pulse repetition frequency. The setting-up procedure for getting this right is described at the end.

**Constructional Project**

**REACTION TIMER**

**T. R. de VAUX-BALBIRNIE**

Just how fast do you think you are?
The pulses supplied by IC1 are applied direct to the clock input pin 14 of IC2, a CMOS decade counter. This device has ten outputs, 0-9, each one (apart from number nine) being responsible for lighting one i.e.d. in the display. D2 to D10.

As each pulse is received, successive outputs 0-9 (pins 3, 2, 4, 7, 10, 1, 5, 6, 9 and 11 respectively) go high (supply positive voltage) and each i.e.d. lights in sequence. Since only one i.e.d. is on at a given time, they can all share the same common current-limiting resistor, R5.

Normally, on the tenth pulse, IC2 would reset the display by applying a high state to pin 15. This action also inhibits the clock by making pin 13 high.

- This action also inhibits the clock by making pin 13 high.

The Start/Reset switch, S1, on the remote section resets the display by applying a high state to IC2 reset input (pin 15). In the reset state, output 0 goes high and the first i.e.d., D2, lights.

When S1 is released, pin 15 goes low via resistor R3 which enables the clock. The test then proceeds in the manner already described.

Since IC2 cannot supply a large output current, low current i.e.d.s were used in the prototype unit coupled with a relatively high value of current-limiting resistor, R5. Standard i.e.d.s could probably be used but they would not be very bright.

**COMPONENTS**

**Resistors**
- R1, R3, R4 100k (3 off)
- R2, R5 10k
- All 0.25W 5% carbon film

**Potentiometer**
- VR1 2M2 skeleton preset, horiz.

**Capacitors**
- C1, C2 100µf ceramic (2 off)
- C3 100µp.f.c.b. mounting elect. 10V

**Semiconductors**
- D1 1N4148 signal diode
- D2 to D10 Low current i.e.d.s: red (3 off); yellow (3 off); green (3 off)
- IC1 555 bipolar timer
- IC2 4017 decade counter

**Miscellaneous**
- S1, S2 Miniature push-to-make switch (2 off)
- S3 Miniature toggle switch
- B1 PP3 battery and connector
- Stripboard, 0.1-in. matrix, size 15 strips by 27 holes; plastic boxes, size 114mm x 76mm x 38mm and 50mm x 37mm x 24mm; 8-pin d.i.l. socket; 16-pin d.i.l. socket; 10-way "rainbow" ribbon cable; stranded connecting wire; twin multi-strand connecting cable; stand-off insulator; fixings; solder etc.

**Circuit Board**

Construction of the Reaction Timer is based on a circuit panel made from a piece of 0.1-in. matrix stripboard, size 15 strips x 27 holes.

**Fig. 2** shows full top-side component layout and the track breaks required on the copper strip side.

Begin by cutting the material to size, drilling the single fixing hole and making all track breaks and inter-strip links as indicated. Follow with the soldered on-board components but do not insert the i.c.s into their sockets until the end of construction.

Note that diode D1 and capacitor C3 are polarity-sensitive components and must be connected the correct way round.

Leave the anode (a) end of diode D1 unconnected for the moment. Solder a short stalk (clipped-off resistor end) to board matrix position H19. At the end of construction D1 anode end lead will be soldered to this stalk so completing the connection.

The reason for doing this is to help in the setting-up procedure at the end.

It will help construction if 10-way "rainbow" ribbon cable is used for the edge connections to strips D, E, G, H, I, J, K, L, M and O on the right-hand side of the circuit panel. This will keep the wiring neat and help in avoiding wiring errors later.

Solder a 10cm piece of red light-duty stranded wire to strip C and solder the black battery connector "negative" wire to strip N as shown in Fig. 3. Solder a similar piece of wire to strip N on the left-hand side.

Leave VR1 adjusted to approximately mid-track position.

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**Everyday with Practical Electronics, November 1992**
side to be held clear of the I.e.d. connections. A long 6BA nylon bolt with three nuts was used for the purpose in the prototype— one nut to secure the bolt and two to sandwich the circuit panel.

Use a piece of thin plastic p.v.c. tape to provide some insulation for the copper strips if necessary. Secure the battery to the base of the case using an adhesive fixing pad.

**REMOTE UNIT**

Drill holes in the remote box for Start/Reset switch, S1, and for the interconnecting lead to pass through. A keyboard-type switch was used in the prototype but any small push-to-make switch will do.

Mount switch S1, pass the twin wire interconnecting cable through the hole and tie a knot in it to provide strain relief. Solder the two end wires to S1 terminals leaving some slack in the wire so that it cannot pull free in service.

Back to the main unit. After a check for errors, insert the i.c.s with the correct orientation— note that IC2 is “upside down” compared with IC1. In theory at least, as IC2 is a CMOS device it can be damaged by any static charge which may exist. To be safe, touch a water tap or other earthed object before removing it from its packaging. Alternatively, avoid touching the pins when inserting it into its socket. Switch S3 off before proceeding.

**TESTING AND ADJUSTMENT**

Commence the testing and setting-up by connecting the battery and switching S3 on. The I.e.d.s should light rapidly one by one in sequence then start again (the cycle keeps repeating because one end of diode D1 has been left disconnected).

If any I.e.d. fails to light, suspect that it has been connected the wrong way round in the circuit. If any I.e.d.s operate out of sequence, they have been connected to the wrong IC2 outputs.

By timing ten complete cycles and adjusting preset VR1 to make this exactly 10 seconds (since it cycles through ten outputs), you will know that the time taken for the display to advance by one I.e.d is 0.1 is (10 lens). This was found to be satisfactory in practice but it could be speeded up or slowed down as required by suitable adjustment to VR1.

Once this operation has been carried out, the wire stalk at board matrix position H91 may be soldered to diode D1 anode. When tested, the unit should behave as before except that all I.e.d.s will go off after the first cycle.

It only remains to label the switches and I.e.d. display— this may be done in milli seconds i.e. 0.1, 0.2, 0.3 so on— see photograph. Use dry print lettering to give a professional appearance.

**REACTION**

It is interesting to note that most people have a reaction time shorter than the Highway Code seems to suggest. This is probably because the situation in driving is not the same as here.

In these tests, the level of concentration is greater since it only needs to be kept up for a relatively short time. In driving, it would be impossible to maintain this degree of concentration.

This could be investigated by allowing a long time before releasing the Start/Reset switch. This will usually be found to increase the reaction time of the subject.
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*Everyday with Practical Electronics, November 1992*
This is the fourth article in a short series about renewable energy - that is, sources of power which will last for ever unlike those derived from the fossil fuels - coal, oil and natural gas - which will eventually run out. This month we shall examine various ways of using water power.

The Department of Energy has funded a programme of research and development into alternative energy methods since 1974. Some ideas turn out to be economically and technically attractive, some could be promising in the medium term and others are long shots and unlikely to be used in the foreseeable future.

The Government is working towards an electrical generating capacity of 1000MW from renewable energy sources by the end of the century - equivalent to the output of one large coal-fired power station. Technically, renewable energy sources could furnish all our needs but they are diffuse - that is, the power is spread out over a large area and this often makes exploitation difficult and therefore expensive.

WATER, WATER EVERYWHERE

Water power in its various forms, together with on-shore wind energy, geothermal energy and schemes producing energy from waste material (of which more will be said next month), are likely to make a significant contribution to Britain's total energy needs in the 21st century. This, together with nuclear power and a smaller contribution from the dwindling supplies of fossil fuels, should maintain our increasing energy needs.

Water power in some form is an ancient technology - water wheels have been used for milling corn and other purposes for centuries. There is a reference to water power having been used in Greece during the First Century A.D. and in the Middle Ages the water wheel was in widespread use in several countries.

The traditional overshot and undershot types of water wheel are shown in Fig. 1. Today, the water wheel would be described as a turbine where the water turns blades on a shaft which can then provide useful work.

There are several ways of obtaining energy from water and hence to generate electricity - from the tides, from waves and from the power of falling water - that is, hydroelectric power schemes. It is also possible to use naturally-occurring hot water - springs and geysers - and this method will be discussed in more detail next month. Unlike tides, springs and geysers, both wave energy and hydroelectric schemes actually use indirect solar power.

Waves are caused by the wind blowing across the surface of the sea and it is the sun which causes the differences in temperature which cause the wind to blow. As well as causing horizontal currents, the water is made to move up and down. It is this movement which carries vast amounts of energy and which may be exploited to generate electricity.

Hydroelectric power is also derived indirectly from the sun since it is the heat of the sun (solar radiation) which evaporates the water in the first place and carries it up as vapour to the high ground where it falls as rain. The energy held by the water on the high ground is called potential energy (energy due to position). As it falls, the power may be transferred to a turbine which turns the shaft of a generator and produces electricity.

We saw in a previous article that approximately 20 per cent of solar energy falling on the earth causes evaporation of water but much of it happens very diffusely with small amounts of flowing water spread out over a very large area. It would be uneconomic to extract the energy from such small amounts of slow-moving water.

EBB AND FLOW

Tidal energy is an "odd man out" because here the power has not come from the sun. Tides are caused chiefly by the gravitational pull of the moon and, to some extent, the sun on the mass of water which makes up the oceans of the world. Although the sun is massive in comparison to the moon, it is also much further away so it is the moon which has the greater influence. The gravitational force causes the water to pile up and it moves as the earth turns on its axis.

Most parts of the world experience two tides each tidal day - that is, every 25 hours and 5 minutes. When the sun aligns with the moon there is a larger than normal gravitational force and a particularly high tide results. This occurs twice a month and is called a spring tide.

When the sun and the moon are in opposition, a smaller gravitational force results and this gives rise to a lower tide than usual called a neap tide. Even so, tides are very complex and far removed from the pattern suggested by simple theory. The size of a tide is influenced by the shape of the coastline with funneling effects tending to increase the tidal range.

Advisors to The Department of Energy believe that tidal energy and wind power (which has been discussed in previous parts of this series), have a promising future and together have the potential to generate a
potential sites for tidal barrage schemes.

A significant fraction of the total electricity needs of the U.K. We may draw on the experience of the French, Americans and Canadians who have had large-scale tidal power schemes in operation for several years.

In Britain, we are fortunate in having some of the highest tides in Europe and these are ideal for economic exploitation. It is thought that the tidal range needs to exceed about five metres to make this method commercially worthwhile and many such sites are to be found around the west coast and elsewhere—see the map of potential barrage scheme sites.

In the Severn Estuary, funnelling and other effects combine to provide one of the largest tidal ranges in the world—over 11 metres in the region between Barry and Weston-Super-Mare (see Fig. 2). The flow of water carries a vast amount of energy and using this to generate electricity is a very attractive and economically viable proposition.

By maximum commercial exploitation, we could generate at least 20 per cent of Britain’s total electricity needs by tidal power alone—rather more if we did not look too coldly at the commercial aspects but weighed them up against the indirect benefits. Even if we abstracted energy only from the largest tides—those of the Severn, the Mersey and a few more, 10 per cent of our total energy needs could be realized. The eight largest schemes used together could save Britain about 25 million tonnes of coal per year.

We presume that by drawing energy out of the tidal system, we are slowing down the rate at which the earth spins on its axis. However, this effect is so small as to be imperceptible and is happening all the time anyway.

**TIDAL BARRIERS**

To exploit tidal energy, a barrage or dam needs to be built to control the flow. A river basin is thus formed. The barrage has a number of turbines set into it and as water flows in and out of the basin with each change of the tide, the turbines rotate, turn generators and make electricity (see Fig. 3).

The proposed Severn Tidal Barrage scheme is, at the moment, undergoing extensive study. The Severn Tidal Power Group has completed a programme of investigations and has confirmed that a suitable barrage could be constructed using existing technology. It is further believed that, once built, the scheme would be capable of delivering electricity to the public supply network for more than a century.

The Severn Barrage project, if put into operation, would be the largest tidal power scheme in the world. The barrage itself would be enormous—some 16km (10 miles) in length stretching between Lavernock Point (between Barry and Cardiff) to a point near Weston-Super-Mare (see Fig. 2). The basin would enclose an area of 480 square kilometres.

Into the barrage would be set 216 turbines each with a diameter of 9m and each having a generating capacity of 40MW giving a total power output of 8640MW—that is, it would exceed the output of eight large coal-fired power stations. This would provide seven per cent of the total electrical energy requirement of England and Wales.

Despite the grand capital cost—some £8 billion (at 1988 prices)—the potential for saving fossil fuels would be vast—some 8 million tonnes per year. The reduction in carbon dioxide emission would be almost 18 million tonnes per year with consequent relief from the greenhouse effect.

Construction of the Severn Barrage would probably involve floating large hollow concrete sections to the site. Each section—called a caisson—would carry one of the turbines. It would be necessary to provide locks to allow the largest ships to pass to the ports along the river and some means of allowing fish through without harm. The construction time scale would be approximately 14 years—about five years for preparation, a further seven for construction and first power production and a further two years for full-stream operation.

**ACROSS THE MERSEY**

A similar but much smaller Mersey barrage project would use a dam 2km in length with a basin enclosing 61 square kilometres. There would be 28 turbines set into it, each having a diameter of 8m and each with a generating capacity of 25MW. This would provide a total peak output of 700MW. The Mersey is well suited to such a scheme with spring tides reaching a range of 8m.

The preferred siting for the barrage is between the Liverpool Garden Festival site near the city centre and a point close to New Ferry on the Wirral—see Fig. 4. As in the Severn project, a system of locks would be required to allow the passage of ships to the Manchester Ship Canal.

The Mersey barrage scheme would save some 700,000 tonnes of coal per year. Constructional cost is estimated at £880M (at 1989 prices). If the scheme were approved by Parliament, the project could be complete and generating power within two years.

In addition to the two largest projects outlined above, Britain has the potential for several less ambitious schemes each making a small but significant contribution. A study made in 1986 identified 34 such sites each with the potential to generate between 30 and 150MW.

A feasibility study on a possible Conway Barrage (North Wales) Barrage shows the potential to generate 33MW while a Wyre Barrage (near Fleetwood in Lancashire) could
produce 47MW of electricity. Scotland tends to have lower tides so there are fewer commercially attractive sites there. However, Scotland has a greater potential for hydroelectric schemes than England and Wales.

**EFFECTS ON THE ENVIRONMENT**

Tidal energy has the advantage of being less diffuse than many other forms of renewable energy. Also, the energy in moving water is easily turned into electricity by well-known and relatively inexpensive technology. However, the use of tidal energy is not without some cost to the environment.

Abstraction of tidal power alters the pattern of water movement and lessens the speed of the currents. This can cause sediment build-up and lower turbidity with possible effects on wildlife. Within the river basin, the tidal range would be reduced and the low-water level raised.

It is thought that lower turbidity could increase the availability of food for fish and birds but, on the negative side, there would be a reduced mudflat area for feeding wading birds. However, taking everything into account, tidal power is thought to rank within the wind in being among the most environmentally-friendly sources of power.

Because a tidal energy scheme controls the flow of water, it prevents flooding along large stretches of the river during extreme high tides. Other methods of flood prevention would therefore not be required and the savings made here offset some of the constructional costs of the barrage itself.

**WAVE ENERGY**

It is well known that waves carry an enormous amount of energy. Our coast has a history of broken seawalls and seaside piers having been destroyed during violent storms. Research into abstraction of wave energy has been carried out since the mid-1970's and extensive studies have been made to find the best types of device for the job - some 300 ideas in all.

The best places for large-scale wave energy exploitation lie between latitude 40 and 60 degrees and many parts of Britain have a near-ideal situation. Off the West Coast, in the NW approaches, there is said to be available some 70MW of power per km of coastline - that is to say, over a stretch of approximately 15km (about 10 miles) there is available the equivalent energy of a large coal-fired power station.

In fact, the waves around our coast carry all the energy we need but its abstraction would prove very expensive and difficult. Also, the power of the waves is notoriously unpredictable depending as it does on wind speed and the exact way and time for which the wind blows across the water surface.

**OFFSHORE**

There are basically two wave energy extraction technologies - offshore and shoreline. Large off-shore wave energy projects are exciting and many seemed attractive on account of the vast amounts of energy available. The up and down wave energy could be extracted by transferring the motion to floating nodding ducks in the manner developed by Professor Salter of Edinburgh University (see illustration). The motion would then be transferred to an electrical generator. However, off-shore wave technology is difficult.

The mighty 2000MW off-shore proposals originally investigated by the Department of Energy now seem far too expensive to imple-
homes and industry falls off considerably. The generating companies wish to boost demand in the off-peak period to provide a better balance between off-peak and on-peak usage since this makes for more efficient operation of the network.

Schemes such as Economy-7 help to do this by offering electricity to the consumer at a discounted price between certain hours of the night and early morning. In this way, storage heaters and other pieces of equipment may be used to take advantage of the lower price.

On a much larger scale, off-peak power may be used to pump water from a lake at the bottom of a mountain to a reservoir at the top. At times of peak demand or perhaps when there is a sudden unexpected need for power such as during a spell of cold weather, the water is allowed to flow downhill again, turn the turbines, and generate electricity just as in a conventional hydroelectric scheme.

A pumped storage scheme does not make much use of renewable energy resources, since mainly fossil fuel energy is used to raise the water to the higher level in the first place. However, by providing a more even distribution system, this amounts to 10 percent approximately.

In the BMW system, the hydrogen is liquefied and so stores much more energy in a given space than the gas. This method means that the exhaust is totally harmless and non-polluting. There is no carbon dioxide produced and therefore no contribution to the greenhouse effect.

**HYDROGEN AS A FUEL**

A further way of obtaining energy from water — this time a chemical one — is to use hydrogen gas as a fuel. Water consists of only two basic materials (elements) — the gases hydrogen and oxygen. If hydrogen is removed from water, it may then be used to power a car. A conventional petrol-burning engine may be adapted to use hydrogen. However, as every schoolboy chemist knows, hydrogen must be treated with respect since it forms a highly explosive mixture with air.

To remove the hydrogen (and the oxygen) from water involves passing an electric current through it — that is, to perform electrolysis. Obviously, in order to do this, the electricity has to come from somewhere and this may be derived from fossil fuels, nuclear energy or some renewable energy source.

When the hydrogen burns and delivers power to the engine, we are simply regaining the energy which generated the electricity in the first place. However, there are some advantages in doing this. Firstly, the relatively inexpensive and well-known technology of internal combustion engines may continue to be used. Also, hydrogen is a perfectly clean fuel.

The only product of combustion is water — that is, the water which was electrolysed. This means that the exhaust is totally harmless and non-polluting. There is no carbon dioxide produced and therefore no contribution to the greenhouse effect.

**GAS CAR**

Since the early 80's, the German car manufacturer, BMW, has been carrying out a research programme to examine the use of hydrogen as a fuel for motor vehicles. The idea is to use solar cells to generate electricity which is then used to electrolyse water and produce hydrogen gas.

In the BMW system, the hydrogen is liquefied and so stores much more energy in a given space than the gas. This method brings certain problems, however. The greatest of these is that liquid hydrogen only exists at a temperature of −253°C.

In practice this means that the storage tank must be very well insulated to prevent the fuel from boiling off rapidly into the atmosphere. The fuel tank specially developed for the purpose is double-walled with very sophisticated insulation. This is capable of holding 93 litres (20.5 gallons) of liquid hydrogen which provides a range of 300km (190 miles approximately).

The tank is fitted in the 6-cylinder 3.5 litre long-wheelbase 735iL model across the luggage compartment. This avoids problems with the rear seating which is unaffected.

Developing engines to produce maximum power using hydrogen fuel demands difficult and expensive technology. BMW see one possible way forward in not trying to develop maximum power but to reduce it by some 30 percent compared with using petrol. A lean mixture is then used and this simplifies the procedure and reduces costs.

**HAZARD**

Even with the high degree of insulation used on the fuel tank, liquid hydrogen does boil off and is released through safety valves. A maximum of two per cent of the fuel is lost to the atmosphere this way each day. There are concerns about the safety aspects associated with this free hydrogen and also the possibility of damage to the fuel tank in an accident leading to large-scale release of gas into the atmosphere.

It is impossible to remove all risk but this must be compared with the hazard due to the storage of petrol. At least, unlike petrol, hydrogen is not ignitable and when mixed with air it is quickly diluted, and rapidly becomes harmless. An interesting feature prevents accidental build-up of hydrogen in the passenger compartment. If a predetermined concentration of gas is exceeded, a sensor detects it and an electronic circuit causes the sliding roof, windows and boot lid to open so preventing an ignitable mixture accumulating.

In the event of an accident, the doors unlock, the windows and boot lid open and the sun roof slides back. Taking everything into account, it is doubtful if a car burning hydrogen as a fuel involves any more risk than a conventional petrol-driven car.

BMW are taking their Hydrogen Drive research project very seriously. To improve the development of hydrogen-burning engines they started to use the world's first purpose built test bed in March, 1989. This uses a complete data processing system with results being recorded electronically in a measuring and control room. Data is then analysed and optimum working conditions determined.

**VIA BLE**

Research into hydrogen-powered cars suggests that this fuel could make a viable alternative to petrol. At the moment costs are still too high, however, and problems still remain. Experimental cars have been built using hydrogen compressed into cylinders but the quantity of gas is not sufficient to provide a satisfactory range. A further idea is to absorb the gas into various materials but this method has not been altogether successful either.

A variation of the method is to use fuel cells. Here, instead of burning the hydrogen in an engine, the hydrogen and oxygen obtained by electrolysis are passed over special porous plates. The two gases re-combine to provide water and in the process a voltage is formed between the plates. Thus, electrical energy is produced direct from the fuel. This may then be used to operate an electric motor to power the car. At the moment fuel cells are rather bulky but further research could possibly bring them down to a manageable size.

Next month we shall look at some further examples of renewable energy sources — those using household waste, biomasses and geothermal energy. We shall also look at some aspects of nuclear power to see how this fits into the complete Alternative Energy picture.
**BATTERY TO MAINS INVERTER DAUGHTER BOARD**

**MARK DANIELS**

An add-on board for a past project.

**CIRCUIT DESCRIPTION**

The circuit shown in Fig. 1, comprises two standard low power CMOS i.c.s., IC1(1) and IC1(2). IC1(1) is a 14 stage binary counter with an on board crystal oscillator section designed for connection to an external crystal. A number of the stages are made available on the device pins, but in this application the largest division ratio is chosen, giving an output of 200Hz at pin 3, using the original crystal, X1 (see original article).

The counter/oscillator IC1(1) has only a single output and a division ratio which is insufficient for our requirements, so extra stages in the form of a dual bistable, IC1(2) are added at its output.

The two bistables in IC1(2) are cascaded to provide a further division by four thus reducing the 200Hz at its input to the required 50Hz complementary outputs. Reference to Fig. 1 will show how the replacement components connect to the pins of the original IC1 position, using all other existing components on the parent board in their original positions and with no changes in their values.

**CONSTRUCTION**

The full size foil pattern and component overlay for the small daughter board are given in Fig. 2. For ease of construction it is recommended that sockets are used for the two i.c.s.

Eight lengths of 20 s.w.g. tinned copper wire (30 amp fuse wire) approximately 30mm long are soldered to the remaining pads on the reverse of the p.c.b. to make the connections to the parent board.

If the parent board is already assembled IC1 and its socket (if fitted) will need removing before the daughter board can be offered up.

Feed the tinned wires into IC1 holes in the parent board allowing sufficient clearance above the parent board components to preclude the possibility of short circuits in the future. Check that the board is correctly aligned: the figures on the daughter board corresponding to the original IC1 connections, before soldering the connections. Reference to the photograph should clarify any obscurities.

Before fitting the two new i.c.s. it may be sensible to check that the power rails are all present and correct. 0V on IC1(1) pins 8 and 12 and IC1(2) pins 4, 6, 7, 8 and 10. Twelve volts should be present on IC1(1) pin 16 and IC1(2) pin 14.

**TESTING**

Fit the two i.c.s, observing CMOS handling precautions and polarity requirements and switch on.

The inverter should start immediately if the parent board was working prior to modification. If not, fault finding is pretty much the same as in the original design, with the possibility of a check for 200Hz at pin 3 of IC1(1). Use Fig. 1 of this article in conjunction with the main schematic of the original article if fault finding should become necessary.

**CONNECTION CLARIFICATION**

The small transformer T2 in the original article appears to have caused confusion among some readers, as its secondary is incorrectly labelled in the main circuit diagram, Fig. 2. It should be labelled 12V-0V-12V, not 0V-12V as shown. The p.c.b. layout of Fig. 3 is also incorrectly labelled, and should be marked 12V-0V-12V, the centre-tap lead being cut off as it is not required in this application.

Editorial Note: The author is presently working on a 250W inverter design together with an uninterruptable power supply add-on, which we hope to publish in a few months time.

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*Fig. 1. Circuit diagram of the Daughter Board. Numbers outside the dotted line correspond to the original pin numbers. Fig. 2. (right) P.C.B. construction.*
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**PERSONAL STEREO AMPLIFIER**

I. A. DUNCOMBE

**CIRCUIT DESCRIPTION**

The complete circuit diagram for the audio stages of the Personal Stereo Amplifier is shown in Fig. 1. It is based upon the very popular audio amplifier i.e., the TBA820. This is capable of delivering a maximum of 1.6W, although in this design it is slightly lower than this.

The incoming stereo signal is applied, via plug PL1, to the individual volume controls VR1/VR101 and hence to the input, pin 3 of IC1 (left) and IC101 (right channel). Resistor R1, (the remainder of the description applies equally to the right hand channel - prefixed with one hundred), sets the input impedance and R2 the gain. The open loop gain is 70dB but is reduced substantially in this design.

Capacitor C4 provides for ripple rejection of the power supply. Capacitor C6 provides for a degree of “bootstrap” feedback and C5 adjusts the frequency response. Components R4 and C7 form a Zobel network.

The output signal is passed to the speaker via the electrolytic capacitor C8. This is a non-standard value and some constructors might wish to insert a 470µ type. This will not affect the performance.

No tone controls are provided as it is assumed that the personal stereo will already possess these, even if it is in the form of a simple tone control rather than combined bass/treble controls.

**POWER SUPPLY**

The power supply (Fig. 1a) is a conventional full-wave one and consists of a 6VA transformer T1, “bridge” diodes D1 to D4 and smoothing capacitor C10 and provides a basic 14V to the main amplifier. The voltage regulator IC2, enables a variable stabilised voltage to be produced, which can be used to power most personal stereos.

The output voltage from IC2 may be varied, using preset-potentiometer VR2, from 5V (the regulator voltage) up to around 12V, thus making it fairly universal for most applications. A changeover switch S3 is provided to change the polarity of the d.c. applied to the personal stereo’s d.c. input.

Fig. 1. Full circuit diagram of the audio section of the Personal Stereo Amplifier. The “preset” power supply circuit is shown opposite, output voltage is set by VR2.
Socket SK2 allows for the user to use an already existing a.c.-d.c. adapter instead of the internal mains supply. A changeover switch is not necessary here as the bridge rectifier formed by D1 to D4 protects the circuit from any reverse voltages.

**DESIGN OPTIONS**

One or two features of the present design could be omitted or changed if desired. For example, the internal mains supply could be omitted – saving the cost of the transformer and associated components – and utilising the existing a.c./d.c. adapter. Note that the main amplifier will work off a variety of voltages and does not need the voltage to be especially stable.

The design used two separate volume controls as this is the writers' preference although it is probably more convenient to use a "ganged" stereo variable potentiometer. Note that whichever method is used, the control(s) must be of LOG law type.

A bridge rectifier in a single encapsulation could be substituted for the four separate diodes if this is more convenient. The author also preferred push switches for S1 and S2, (mainly because these were already to hand!) as they look more attractive than toggle switches. The constructor may wish to change these, in which case the mains neon could be omitted as the toggle switch will show if the unit is switched on or off.

The Mono/Stereo switch could also be omitted as most cassette tapes and radio programmes are in stereo, but was considered to be useful for a.m. medium wave broadcasts.

**CONSTRUCTION**

The amplifier is built on a single-sided printed circuit board (p.c.b.), the topside component layout and full size underside copper foil master pattern being shown in Fig. 2. This board is available from the EE PCB Service, code EE808.

Some readers may note that the p.c.b. is reasonably spacious, not using in its construction any vertical mounting components (except the regulator). This allows a degree of flexibility in the size of components, particularly that of the capacitors. If desired (not part of the PCB Service) the p.c.b. could be scaled down to fit whatever case you may have.

If desired the circuit could also be constructed on plain perforated board following a similar layout as in the p.c.b. design. Stripboard is NOT recommended due to the capacitive effects of the unwanted tracks.

Before continuing with construction decide carefully on the options described earlier and vary the construction as you go.
COMPONENTS

Resistors
R1, R101 10k (2 off)
R2, R5
R102 470 (3 off)
R3, R103 56 (2 off)
R4, R104 1 (2 off)
All 0.25W 5% carbon film

Potentiometers
VR1, VR101 4k7 min. rotary carbon, log (2 off)
VR2 1k horizontal p.c.b. mounting preset, lin.

Capacitors
C1, C101 47μF axial elect., 25V (2 off)
C2, C3, C4, C6, C102, C103, C104, C106 100μF axial elect. 25V (8 off)
C5, C105 1200μF polystyrene (2 off)
C7, C107 220μF polyester (2 off)
C8, C108 330μF axial elect. 25V (2 off)
C9, C12 1000μF polyester (2 off)
C10 220μF axial elect. 25V
C11 330μF polyester

Semiconductors
D1, D2, D3, D4 1N4002 1A 100V rectifier (4 off)
IC1, IC101 TBA20M audio amplifier (2 off)
IC2 7805 5V 1A positive regulator

Miscellaneous
PL1 "Stereo jack plug 2.1mm or 2.5mm"
PL2 "Mono line jack socket 2.1mm or 2.5mm"
SK1, SK101 Loudspeaker chassis socket (2 off)
SK2 "Chassis mounting jack socket 2.1mm or 2.5mm"
S1, S2 "Single pole push or toggle switch"
S3 "Standard d.p.d.t. slide switch"
LP1 Mains neon 240V
T1 Mains 6VA transformer, mains primary; two secondaries 0-9V at 300mA or one secondary 0-9V at 600mA

Printed circuit board available from EE PCB Service, code EE808; metal case, leather-grain finish, size 200mm x 125mm x 50mm; two control knobs; 8-pin d.i.l. socket (2 off); stereo screened cable; mono screened cable; 3-core mains cable, connecting wire; solder, hardware etc.

Items marked * - See text

Approx cost guidance only £25

Everyday with Practical Electronics, November 1992
Fig. 2. The printed circuit board component layout (above left) and the full size underside copper foil master pattern (above).

Fig. 3. (bottom left). Suggested front and rear panel component layout.

Fig. 4. Interwiring details from the circuit board and front and rear panel mounted components. Layout of components inside the completed unit is shown in the photograph left centre.

First though, examine your personal stereo and ascertain the diameter of the d.c. input socket and the headphone output socket. They will either be 2.1mm or 2.5mm, choose the correct type and fit them where shown.

The recommended layouts of the front and rear panels are shown in Fig. 3 and could, of course, be varied as desired. It is important though to use a metal case to provide a certain amount of screening.

**INTERWIRING**

The final wiring details are shown in Fig. 4. Check carefully the connections to the transformer as those shown may not correspond exactly to the type you are using. It is most important to insulate ALL mains wiring using either sleeving or insulating tape.

It is very important that the p.c.b. "earth" be connected to the metal case chassis, by means of a solder tag under the transformer mounting. Also, if you are using the mains supply connect the Earth lead of the mains input to a similar tag.

Remember to use screened cable when wiring from the potentiometer(s) to the p.c.b. and input plug to the potentiometers. The left-hand channel is normally the "tip" connection on the jack plug, but do check first.

If you are going to use the amplifier with just one type of stereo, then switch S3 may be omitted and the d.c. output cable can be connected permanently in whatever polarity is required. Use screened cable for this.

Some readers may note the lack of heatsinking on the amplifier i.c.s. and regulator. In the prototype version this was not a problem, although the regulator did operate slightly warm.

If needed then small squares of aluminium may be Super glued to the amplifier i.c.s and bolted to the regulator. No more than one square centimetre will be needed for the i.c.s, and perhaps slightly larger for the regulator.

Finally, remember to fit a 3A fuse in the mains plug, as the unit is not itself fused.

**IN USE**

Using the Personal Stereo Amplifier is quite straightforward. Simply plug the "A.F. In." lead into the Headphone output socket of the personal stereo, and the "D.C. Out." lead into the D.C. in socket of the stereo. If you are not using the internal mains supply then you will need to plug the stereo's a.c./d.c. adapter into the "DC In" socket on the amplifier.

Remember to adjust preset VR2 for the voltage required for the type of personal stereo you are using. Set the volume control of the stereo to three-quarters of maximum output – absolutely no more – if you do so distortion will be introduced and will overload the amplifier. It will be wise to experiment with the setting of the stereo's volume control to achieve a correct balance.

**ON NO ACCOUNT** connect the output from the amplifier to headphones of any type. Even with just over one watt output damage to the ears could result.

Remember that resistor R2 sets the gain, the smaller the value the larger the gain and hence larger the output. Conversely, increasing the value reduces the output and this may be a consideration if the output of the personal stereo overloads the amplifier even if the volume is well turned down.
Mini Lab

It is important when buying components for the Teach-In '93 series Mini Lab project that the items will fit on the p.c.b. and are suitable for use with the series. These components must be of the correct type and manufacture and therefore we have provided the following detailed information.

The variable resistors are PIHER fully enclosed types with the optional clip-on terminals not supplied. Available in various colours, these come from Cricklewood Electronics. Toggle switches are from the C&K Z101 range available from Farnell, 148-705, or Maplin, FH04A. Although designed for panel mounting, they fit the p.c.b. without adaption.

The current rating is important because this switch later turns the 5V rail on/off, and 1A+ rating is required. Other types either do not fit the p.c.b. or have low ratings. ElectroValue also sell C&K toggle switches but they haven't been tried. We think they will also fit.

The push switches are from the MEC range available from Farnell as follows (a limited range is listed by Maplin - part numbers in brackets): switch body 148-464 (FPS1F); switch with various leads available, switch body 148-474 (FPS2H, black); buttons engraved 1, 2 or 3 149-245/6/7 (UH58N red unengraved).

It is important that the correct turned-pin s.t.l. sockets are used. We recommend beginning with two 32-way strips: Farnell 170-715 or Cricklewood Electronics also supply. The RS 402-642 (available from Electromail - see note below) is the more expensive wire-wrap version. These are repeatedly used in future parts, so buy in a small stock. No other types are suitable.

The buzzer or audible warning device is a loudspeaker mounted on a plastic base. It is 250W and 8ohm. Farnell 149-315/6/7 (UH58N red unengraved). The current rating is important because the unit is switched off. Be sure to make it ideally suited for the p.c.b.

P.C.B. mounted "pluggable" screw terminals, The Pluggable types permit the terminal blocks to be removed without having to unscrew/unscrew terminals, thus reducing strain on the p.c.b. track. The screw terminal may be used with a board-mounted pin header. Extremely convenient to use. RS 426-142 (2-way) and 426-143 (4-way) plus 24-way pin header 426-165. Trouble is, RS only sell in packs of five. Therefore, choose the identical Farnell 105-499 (2-way), 150-007 (4-way) and one pack of 25 loose pins 105-503, all available singly. Alternatively, use normal screw terminal blocks but you need a screwdriver to unhook wires all the time.

The altimeter printed circuit board is available and was used in the final version, hence its inclusion on the working diagram. The special pressure transducer type MPX100 called for in the EE Altimeter project is to be used, it must be in one of our component advertisers.

The TBA820M 2W power amp i.c. seems preferable to use the cased version and this is to be used, it must be in one of our component advertisers.

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ACCESS, AMEX, MASTERCARD, VISA Welcome.
Teach In '93 continues a tradition of offering an interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics or GCE Advanced Levels, and starts with fundamental principles to give the student a solid foundation before proceeding onto further topics.

IN ACCORDANCE with the recommendations contained in the various GCSE Electronics Syllabuses, which themselves comply with the National Criteria for Science, no attempt is made to explain the "physics" behind any electronic components. Instead, we are much more interested in what they look like and how to use them, rather than what makes them work in the way they do. Many text books on electronics start with the very dry theory of atoms, electrons and semiconductor physics, much of which in our opinion may deter the less able candidate: apart from being of academic interest only, it can also be a bit boring!

We invited a highly-qualified and experienced Moderator and GCE A Level Examiner to join us and the text incorporates his very valuable suggestions to enable Teach In to have maximum appeal to those candidates undertaking GCSE or GCE examinations and coursework. Teach In we hope will also appeal to the experienced Everyday with Practical Electronics reader who might like to brush up on his or her theory.

INTRODUCING THE MINI LAB

As a means of helping to demonstrate various topics, the authors have designed a unique electronics "Mini Lab" which should be of great assistance to the novice or student following the series. Once the series has been completed, the Mini Lab will be of on-going use to help readers develop ideas of their own, no doubt utilising many principles gleaned from Teach In.

The Mini Lab consists of a single printed circuit board (p.c.b.) which is divided into various areas. As we proceed through the Teach In course, the areas will gradually fill with a variety of interesting and economical circuits which demonstrates a topic and forms a useful piece of equipment to aid the student.

Although it is necessary to solder components to the board, the use of a p.c.b. helps to ensure a high success rate for candidates, with less chance of any disappointing failures. The component count is spread over many months, and the use of plastic boxes and enclosures is avoided, helping to keep construction costs down. A solderless plug-in prototyping board is incorporated which is regularly used to connect up reusable electronic components to form a circuit.

The Mini Lab develops from basic principles, working all the way through from switches, batteries and bulbs to a microprocessor development system - the "Micro Lab" - which is connected to the Mini Lab through an expansion unit. Constructional details relating to the Mini and Micro Labs are given separately, as and when required.

BREADBOARD

We'll shortly be using the plug-in "breadboard" area of the Mini Lab. This is essentially a set of spring contacts interconnected to form a pattern of conducting rows. You can simply push components into them and connect parts together, without the need for soldering. Obviously you can remove and re-use the parts too. The breadboard we have chosen is the popular "Vero-block" type, and several blocks can be joined together to form larger units for more ambitious designs.

Take care of your new breadboard: the wires of components should slide in and out easily. Don't force unduly large wires into the socket strips, and avoid bent or deformed wire ends which might damage individual
sockets. A pair of fine-nose pliers might help when inserting or removing wires. Used with care, your breadboard will last many years. In the meantime, welcome aboard to Teach In!

Our analysis of electricity starts with some simple battery and bulb experiments, and the Mini Lab is immediately pressed into service to help demonstrate a few basic principles. We won’t let you proceed until the foundations are firmly laid!

ELECTRICITY – WHAT IS IT?

For the first two parts of Teach In the Mini Lab is operated by a battery at a safe low voltage. Later, as the Mini Lab grows, a mains power supply is described which you will be able to build with complete confidence. Take a look at Fig. 1.1(a), which shows a very simple electrical circuit consisting of nothing more than four 1.5 VOLT (V) “dry cells”, labelled B1 to B4, and a bulb (L1).

Don’t worry too much about any symbols which may be unfamiliar, because soon you will be able to read a circuit diagram as easily as reading this text (we hope). We will always introduce new symbols by highlighting them separately next to the circuit diagram. The symbols which you see represent the cells and bulb: B1 to B4 are four 1.5V cells, and the circle with a cross is a simple indicator bulb, like a torch bulb.

All four cells are connected together one after the other to make a six volt battery – just like you might need in a radio or cassette recorder, for example. It’s important that they are all connected the right way round with respect to each other or the circuit simply won’t work.

As you will undoubtedly know, cells have two terminals marked “+” and “−”. The negative terminal of one is connected to the positive of the next. The diagram shows you which terminal is which. Often designers don’t bother showing all four cells in the circuit diagram, just the “first” and “last”.

The bulb is labelled “L1” for “Lamp 1” and the supplier’s catalogue says that it’s rated at “6V 100mA”. What do these ratings mean? To find out, let’s build the circuit shown in Fig. 1.1(a).

BATTERY PACK

As we have said in the initial stages of this series, your Mini Lab is powered by an external battery pack. In Part Three it becomes mains-operated via a versatile power supply unit. For now, you must select the “EXT BATT” option as your source of power by inserting a selector shorting plug between the appropriate sockets of the “Power Supply” section: this is clearly marked on the board. You must do this, otherwise your battery pack will remain disconnected.

An on-off switch is also fitted to the Mini Lab, so that you can easily turn the 6V battery supply on or off when required. It’s best to switch off before making any modifications to your experiment.

VOLTAGE

Batteries are a source of electrical energy. We call this the “electromotive force” or e.m.f. for short. The energy is still there in the battery even if you disconnect it from the circuit (unless the battery is flat).

Across the terminals of each individual 1.5V cell exists a potential difference of 1.5 volts. Fitting B1 to B4 together in the holder connects the cells in series to make an overall potential difference of 6 volts. So a potential difference (p.d.) can exist between two points in a circuit, compared with an electric current which flows through the circuit. This is the most fundamental of all rules in electronics.

Strictly speaking it’s wrong to talk of “+ 6 volts and −6 volts” because this implies that the p.d. is actually 12 volts. More accurately we should say “+6 volts with reference to 0V”, the p.d. is then 6 volts. This becomes important when we talk later about split power rails, which have both positive and negative voltage supplies with reference to 0V.

If no p.d. exists between two points, then no electromotive force is present and so no current can flow if you try to make a circuit. A voltage needs to exist before current can flow, and the current always flows from the higher voltage (the most positive one) to the lower voltage (the least positive/most negative) in the circuit.

Because the current only flows one way in this instance, it’s called direct current or “d.c.” for short. In other areas of electronics, we will be looking at currents which flow forwards then backwards – alternating current or “a.c.” for short. You might see “240V a.c.” marked on an electrical appliance designed to be plugged into the mains. When you’re dealing with batteries, the voltages are always understood to be d.c.

CURRENT

The electric current which flows through the circuit is actually a measure of the rate of flow of electric charge past any given point. Electric charge is the fundamental “raw material” of electric current which in simple terms consists of nothing more than a flow of electrons. More electric charge on
the move implies a greater rate of flowing electrons – this means that a “faster” or higher current is flowing. By convention it’s easiest to think of current flowing from the most positive to the most negative potential: this theory dates back to the days of the earliest discoveries of the principles of electricity. The trouble is, we now know that the theory isn’t true!

Scientists have since discovered that electrons have a negative charge and are attracted to a more positive charge (just like dissimilar poles of a magnet are attracted to each other), so in real life electrons actually flow from the most negative to the most positive potential and not the other way round.

There’s no need to worry: mercifully everyone still talks in conventional current terms, where current is deemed to flow from positive to negative potentials. This doesn’t affect circuit design or our understanding of electronics whatsoever. Those studying atomic physics, for instance, might talk in terms of what’s happening in real life at sub-atomic level – but in electronics, we don’t need to.

Some substances are very good at letting current flow through them. Copper is commonly used as the conductor in electric wire because it lets current flow through it extremely easily – it has plenty of loose electrons available which can carry lots of electric current. Other conductors include aluminium, steel, lead, gold, silver and tin. Gold is a particularly useful element which is often used to make electrical contacts, so that they don’t corrode with age and become unreliable.

INSULATORS
An insulator contains hardly any free electrons and so is very poor at letting current flow. For example, an electrical cable supplying your TV will have copper cores carrying “live” electric current, each core being insulated with a plastic such as P.V.C. The insulator will not allow current to flow through, so it protects you from electric shock. Other examples of insulators are glass, wood, ceramic and rubber.

Current is given the symbol I and is measured in Amperes, or often “Amps” (A) for short. Voltage is given the symbol V and, not surprisingly, is measured in Volts.

Sometimes the units of volts and amperes can be too large to be of use in electronics. Designers often have to use prefixes when talking about volts and amps to make them more manageable units. Common prefixes which we will use a lot when describing current and voltage are:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PREFIX</th>
<th>FRACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>milli</td>
<td>1/1000</td>
</tr>
<tr>
<td>µ</td>
<td>micro</td>
<td>1/1000000</td>
</tr>
</tbody>
</table>

Example:
1 mV = 1 millivolt = 0.001 volts.
so 100 mV = 100 millivolts = 0.1 volts.
1 µA = 1 microamp = 0.0000001 amps.

To answer our question posed earlier, LP1 is rated at 6V (the bulb’s maximum reliable operating voltage), at which voltage a current of 100mA (0.1 amperes) will flow through the bulb. We’ll talk about milliamperes, microamperes, and also millivolts, as necessary from now on – it saves having to write lots of zeros. There are other prefixes which we use in other areas of electronics, which we’ll introduce when appropriate.

SWITCHES
On its own, our circuit of Fig. 1.1(a) isn’t much practical use (except as a torch!) but...
operate a switch? You might find this sort of circuit in everyday use as a lighting circuit in a house – switches at the top and bottom of a staircase can control the light at the top of the stairs.

There are many other types of switches available. Some types have two wipers, and can switch two completely separate circuits at the same time. These double pole (d.p.) switches, and some more switches besides,

Multimeters are available in two types: analogue which uses a standard moving-coil meter movement, and digital which is much easier to read and generally more precise. They can measure current, voltage and resistance. Some can also measure other additional parameters like frequency or capacitance or even test transistors.

Multimeters, especially moving-coil types, are not perfect. When used to measure voltages, meters “look like” resistors in a circuit and can affect the circuit under test (see “Potential Dividers” for an explanation of loading effects). Typically, an analogue meter will be described as “20,000 o.p.v.” (ohms per volt), which means that on, say, a 2V d.c. range, the meter acts like a 40k ohm resistor. The higher the o.p.v. specification, the more accurate your voltage readings will be. In GCSE Electronics, “perfect” meters are always assumed so you need not worry about accuracy.

VOLTAGE MEASUREMENTS

When reading voltages, you need to make sure that your multimeter doesn’t load your test circuit too much or you will obtain misleading results. Try to use a voltmeter on the highest range setting possible, so that the resistance of the meter is as large as practical. However, it’s pointless trying to read a voltage of 500mV on a 50V f.s.d. (full scale deflection) scale, so you will have to compromise somewhere.

Voltmeters are of course used to measure potential differences across components such as resistors. It’s wise to ensure that the resistance of your voltmeter (calculated from its o.p.v. rating) is at least ten times greater than any resistor across which you are measuring a voltage – see the “Ten Per Cent Rule”. This way, you will not load the circuit excessively and will obtain acceptable accuracy.

CURRENT MEASUREMENT

Current flows from the most positive potential to the most negative, so connect the positive and negative test leads from your meter the right way round – see the section on “Resistance and Ohm’s Law” where we measure current through a resistor.

Always de-energise the circuit first, then insert the ammeter before powering up again. Start with a high current range, so that you avoid damaging the meter by overloading it. You can always switch to a lower range afterwards, but you should disconnect the power from the circuit in between switching ranges – unless you have an autoranging digital multimeter, which will take care of itself.

An ammeter “looks like” a short-circuit (almost) between its terminals. Never treat an ammeter as a load in itself – don’t put it across a battery or power supply to see what happens, because any high short-circuit current which flows (several amps, in the case of an alkaline battery) may damage your meter and the battery.

RESISTANCE

If you have an analogue meter, you will notice that zero ohms is on the extreme right of the scale. Higher resistances are on the left, but the scale is non-linear and the calibrations tend to become cramped on the left. You should always “zero” your meter before testing resistance: do this by shorting the leads together and adjust the meter’s zeroing control accordingly. You have to repeat this every time you change the resistance range.

Testing resistors etc. in situ in a circuit can often give strange results: this is generally because there might be other components actually in parallel with the component, which affects the resistor value – see “Resistors In Parallel” and “Potential Dividers” in the text.

Ohmmeters use an internal battery to enable them to measure resistance. You must always ensure that the circuit under test is fully de-energised when the meter is set to any resistance range, or damage may result.

RESISTOR COLOUR CODE

Most resistors you see have four coloured stripes to indicate their resistance and tolerance. How do you know which way round to read the resistor? The gold or silver stripe features last in the code.
are summarised in Fig. 1.6. We also show a one pole 3-way rotary switch.

Some switches are biased which means that they are spring-loaded in one direction. Press them to operate them, and release them to return to the previous state. An electric lawnmower uses this sort of switch — why?

Alternatively, some push switches are latching, which means that you press them once to operate them, and they stay like that when you release the actuator. Press them again to return to the previous state. A table lamp might use such a switch. Have a look through some catalogues to see if you can recognize different sorts of switches yourself.

In fact, we cheated a little when we designed the Mini Lab; you will have noted that both the n.o. and n.c. push switches (Figs. 1.2(b) and 1.3(b)) are both one and the same switch. It's actually a s.p.d.t. push switch which can form either a n.o. or n.c. function by selecting the relevant socket strip on your Mini Lab. Check it out by using the battery pack and bulb to confirm how it works.

Switches have electrical ratings which are indications of how large a voltage they can be allowed to switch without being damaged, and how much current their contacts can carry. Exceeding these ratings could be dangerous. This is of particular importance when we examine how to safely switch mains electricity supplies, which is fact, we cheated a little when we designed the Mini Lab; you will have noted that both the n.o. and n.c. push switches (Figs. 1.2(b) and 1.3(b)) are both one and the same switch. It's actually a s.p.d.t. push switch which can form either a n.o. or n.c. function by selecting the relevant socket strip on your Mini Lab. Check it out by using the battery pack and bulb to confirm how it works.

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RESISTANCE AND OHM'S LAW

Take a look at the circuit diagram of Fig. 1.7(a) — it's just like the battery and bulb of earlier experiments but included in series with the bulb is a zig-zag symbol, R1. (Many Examining Boards use an equally acceptable rectangle symbol instead of the traditional zig-zag.) This new component is a Resistor and not surprisingly, its job is to introduce resistance to electric current. If you imagine electric current as water flowing through a hosepipe, introducing a resistor is like squeezing the hosepipe to slow the water down.

We can examine the operation of the resistor by taking some measurements with a multimeter. We show you separately how to use your test meter — if necessary, read that section in conjunction with this part.

Resistors all look the same, though they have different sizes and can be made of different materials. We measure resistance in ohms. The value of their resistance is shown in a series of coloured stripes printed on the body of the resistor. For now, you need to acquire a 47 ohm resistor. The coloured stripes to look for are yellow/violet/black/gold. Buy a "quarter watt carbon film" type. (We'll explain the jargon later.)

Using the breadboard area of the Mini Lab, construct the circuit as shown in Fig. 1.7(b), connecting the battery pack and indicator bulb using jumper wires. (The bulb will glow when the circuit is completed.) Select the voltmeter function of your multimeter by choosing the "d.c. voltage" range, say 10V full-scale deflection (f.s.d.), which is safe for our circuit where the maximum voltage anywhere will be 6 volts. A voltmeter is represented by a circle containing the letter "V" and because voltmeters are polarised, you must connect them the right way round.

MULTIMETER

Connect the + terminal of your multimeter to location "A", and the - terminal to location "B" and read the voltage from the scale, noting it down as "Result 1" in the table below. Then repeat, with the + terminal to "B" and the - terminal to "C" (Result 2), and finally read the voltage at "A" (+) and "C" (-) to obtain Result 3.

What has happened is that the potential difference (p.d.) across the battery pack has been split up between the resistor R1 and the bulb. The 6.3 volts of the battery is no longer placed solely across the bulb — some
of it appears across the resistor. In our own results, a small voltage (0.07V) actually appeared across the meter, which proves that meters aren't perfect, or all the battery voltage would be split between the bulb and resistor.

**CURRENT MEASUREMENT**

Now we are going to use the multimeter for another function, to measure the current flowing through the circuit. The symbol for an Ammeter is depicted in Fig. 1.7(c). To measure current, we have to break the circuit and insert the meter so that the current in the circuit flows through the meter to produce a reading. This is different to reading a voltage, where we simply take a measurement between two points in a circuit. Don't attempt to measure the current "across" the battery, because you will short out the battery pack and probably damage your multimeter.

Construct the circuit on the Mini Lab as in Fig. 1.7(d). Set your multimeter to "d.c. current" and select a high full scale deflection (f.s.d.) to be on the safe side, say 500mA (0.5 amps), and simply touch the + meter probe to point "A" (battery + terminal), and the – probe to "B" (resistor R1). This will complete the circuit, current will flow through the meter and the bulb will glow. Note the reading on the current range of your multimeter.

We took a reading of 62mA. Call this Result 4, and note it here:

<table>
<thead>
<tr>
<th>OUR READING</th>
<th>TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result 4</td>
<td>62mA</td>
</tr>
<tr>
<td>(Current flowing through the circuit)</td>
<td></td>
</tr>
</tbody>
</table>

In this simple circuit, the current flows through the ammeter, resistor and the bulb, and the current will be the same wherever you measure it. Putting the ammeter in the circuit say between the bulb and the battery negative terminal instead, will produce the same result. Try it.

Now short out the resistor with a jumper wire and repeat the experiment. What happens to the bulb? This is in effect exactly the same as the very first circuit we saw in Fig. 1.1(a), because the resistor is now bypassed and no longer has any effect. What is the current reading on your multimeter now? We measured 97mA. Call this Result 5, and note it here:

<table>
<thead>
<tr>
<th>OUR READING</th>
<th>TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result 5</td>
<td>97mA</td>
</tr>
<tr>
<td>(Current flowing through the bulb, resistor shorted out)</td>
<td></td>
</tr>
</tbody>
</table>

**OHM'S LAW**

The Ohm's Law Equation states that:

\[ V = IR \]

Where V is the voltage appearing across the resistor, I is the current flowing through the resistor and R is the value of the resistance measured in Ohms.

From Fig. 1.7(a) \( V = \text{Result 1} = 3.15 \text{V} \) and from Fig. 1.7(c) \( I = \text{Result 4} = 62\text{mA} \) (0.062 Amps).

Using our actual measurements and Ohm's Law, the resistance of R1 works out as 50 ohms (3.15 / 0.062). Looking at our various test results, we can also state that by adding a resistor into a circuit, two things happen:

1. It reduces the current flowing through the circuit. Compare Result 4 (resistor in circuit) with Result 5 (resistor shorted out with a wire). More resistance causes less current to flow. Current always takes the path of least resistance.

2. A voltage appears across the resistor. Not all the voltage of the battery now appears across the bulb. Some of it is wasted by the resistor. We say that the resistor has produced a "voltage drop".

But wait! We reckoned we had put a 47 ohm resistor into our circuit (identified by its colour code), but our calculation using Ohm's Law showed it to be actually 50 ohms! (You might get slightly different results from ours.) Don't worry, here's why:

Manufacturers of resistors have a tolerance to work to. This means that the resistor values might not be exact, but will be within a certain range. The gold band of the colour code tells us that the tolerance is ±5 per cent, so in fact our 47 ohm resistor could be anywhere between roughly 44 to 50 ohms. Rarely do you need a "tighter" tolerance, though sometimes you might see precision one per cent or two per cent types for critical circuits.

**COLOUR CODE**

We show separately the RESISTOR COLOUR CODE which enables us to identify the ohmic value of any common resistor. Rather than have an infinite number of different resistances, manufacturers also produce resistors in a range of preferred values. The so-called E12 values you will commonly use are:

- 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, and 82 and their multiples of ten. Larger resistor values are abbreviated and simplified by using prefixes to describe their value. We say kilohm (or letter "K") to mean thousands of ohms, and megohms (letter "M") for millions. The letter is a multiplier abbreviation which is often used in place of the decimal point to indicate the resistance value. You might see the letter "R" used instead of the Omega symbol (or nothing at all) just for convenience. Here are some examples:
  - 47R = 47 ohms.
  - 820 = 820 ohms.
  - 1k = 1 kilohm = 1,000 ohms.
  - 2k2 = 2.2 kilohms = 2,200 ohms.
  - 10k = 10 kilohms = 10,000 ohms.
  - 390k = 390,000 ohms.
  - 1M = 1 megohm = 1,000,000 ohms.
  - 47M = 47,000,000 ohms.

When current flows through a resistor, the electrical energy is turned into heat. The temperature of the resistor will increase though you might not notice. We say that the resistor is dissipating power.

An electric fire element is an example of a large resistor which is deliberately allowed to dissipate so much power that it becomes red hot and warms the room. The filament of a light bulb is actually a resistor which dissipates so much power that it becomes white hot. (They are actually much more efficient sources of heat than light!)

The power dissipation, or rate at which the resistor converts electrical energy into heat, is determined by the simple formula:

\[ P = I \times V \]

where \( P \) = Power dissipation (Watts, symbol "W") \( I \) is the current flowing through the resistor (Amps) and \( V \) is the voltage across the resistor (volts.)

In our earlier experiment of Fig. 1.7(b) the power dissipated by the 47 ohm resistor will be 0.062 \times 3.15 = 0.19 Watts. The 47R resistor is rated at 0.25 Watts which is satisfactory. Exceeding the power dissipation rating of a resistor may damage it.

Substituting Ohm's Law into the above formula, we obtain two further formulae which can be very useful:

\[ P = I^2 \times R \]

Alternatively, \[ P = V^2 / R \]

Different materials are utilised by manufacturers when making resistors but the most common type you will use will be cheap and cheerful carbon film. Larger resistors can dissipate more power; for instance the electric fire element is actually a large unrestrained resistor. Have a look through some supplier's catalogues to see if you can now recognise other types. What values are available? What tolerance (%) do they have? How much power can they dissipate? Lastly, how do they compare for cost?

**RESISTORS IN SERIES**

Three resistors in series are shown in Fig. 1.8(a), values 100R, 470R and 220R, connected across the 6V battery pack. Obtain suitable 0.25 watt carbon film five per cent resistors and build this circuit on the breadboard of the Mini Lab as per Fig. 1.8(b).

Firstly measure the voltage across the resistor chain at points "A" and "B", using your multimeter set to a d.c. voltage range of 10V f.s.d. Also record the voltages across each resistor. Then break into the circuit and measure the current I with your multimeter set to its "d.c. current" range, say 10mA f.s.d., recording all your readings below.

Again, we show you what we obtained when we ran the experiment.

Fig. 1.8(b). Resistors R1 to R3 in series on the breadboard. Measure the current by placing your multimeter (set to 10mA) at the location "X". Then substitute with a jumper wire and measure the voltages as per the text.
The voltage A represents the voltage across the ends of the resistor chain. Of course, it's the same as the voltage across the battery in this example. Using Ohm's Law, we can calculate the actual value in real life of the overall resistance chain:

\[ R_{\text{total}} = \frac{V_1}{I} \]

YOUR CALCULATION:

\[ = \frac{6.2V}{0.0079} = 784 \text{ ohms.} \]

Don’t worry if your results are a little different to ours. Remember that resistors have a tolerance, so results are likely to vary somewhat in practice.

The formula for any number of resistors in series is simply:

\[ R_{\text{total}} = R_1 + R_2 + R_3 \ldots \]

Thus in our circuit of Fig. 1.8(a) we could simply replace all three resistors with a single component of 100 + 470 + 220 ohms = 790 ohms, if one existed.

To calculate the overall value of the resistance chain, a practical alternative approach is to measure the resistance with a multimeter set to its Ohms range. Try this:

Disconnect the breadboard from the battery pack. Choose a low resistance range (say 1k F.s.d.), adjust your meter for zero ohms if required, and measure the resistance between points “A” and “B” in Fig. 1.8(b). We noted an overall resistance of 780 ohms using our digital multimeter, which compares favourably with the value of 784 ohms we calculated using Ohm’s Law. Your own multimeter reading should be almost exactly the same as the value you calculated yourself with Ohm’s Law.

In actual fact, if each resistor in the chain has a tolerance of five percent, then the tolerance on the overall value of the resistors in series will also be five percent. So our actual reading of 784 ohms falls within the expected resistance range for the resistors in series, namely 750 to 829 ohms (790 ohms ±5%).

The other aspect to note is that by connecting several resistors in series, the potential difference applied across the chain (voltage AB) is split up across the resistors. Total up the voltages across R1, R2 and R3 and compare against the p.d. across the chain: they should be the same. We promise we didn’t fix our results!

RESISTORS IN PARALLEL

Two resistors, both connected to our 6V battery pack are shown in Fig. 1.9(a). We also show a current I which is flowing into the resistor network. At the junction where R1 and R2 are joined, I divides into two currents Ia and Ib, which themselves are determined by the values of the associated resistors.

Assemble the two resistors onto the Mini Lab breadboard using 0.25W types, and measure the currents with your multimeter. Set it to a “d.c. current” range of about 100mA, and break into the circuit at locations A, B and C in succession, as shown in Fig. 1.9(b).

Clearly what happens is that current I splits into two components Ia and Ib. This leads us to Kirchhoff’s First Law (or Current Law) which states that the amount of current flowing into the junction of the resistors is the same as the sum of the currents flowing out of it – because 42mA flows into the junction which divides into two currents coming out of 13mA and 29mA. The same is true if you have three or more currents coming out of a junction: they all add up to the value of the single current going in.

In Fig. 1.9 the two resistors are said to be connected in parallel. The formula for calculating the overall resistance of two resistors in parallel connection is:

\[ R_{\text{total}} = R_1 \times R_2 / (R_1 + R_2) \]

An alternative formula yielding the same result is:

\[ 1/R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3 \ldots \]

(Use the reciprocal of 1/Rtotal to reveal the answer.)

Our 470R and 100R resistors could thus be replaced by a single resistor of 150R. It’s useful to remember that by placing two resistors in parallel, the overall resistance will always be smaller than either of the two individual resistors. It’s impossible to make a resistance larger by placing another resistor in parallel with it.

Additionally, when you have two or more resistors in parallel with each other, the potential difference across each of the resistors is bound to be the same. In our example, the p.d. across both resistors happens to be that of the battery voltage.

POTENTIAL DIVIDERS

Earlier we saw how a potential difference across a chain of resistors in series, is divided up amongst those resistors. A p.d. appears across each resistor and when added together, they equal the p.d. across the extreme ends of the resistor chain.

A simple network consisting of two resistors is shown in Fig. 1.10. \( V_{\text{out}} \) is the voltage from the 6V battery pack and \( V_{\text{out}} \) is the output voltage from the potential divider.

Three different sets of values are shown in the table for \( R_b \) and \( R_c \) construct this simple network on your breadboard using 1k, 2k2 and 4k7 0.25W five per cent carbon film resistors, then measure the voltage \( V_{\text{out}} \) – the p.d. across Ra – with your multimeter and record this in the table. Our results are shown too. If you are uncertain of the resistors’ colour codes, double-check their values using your multimeter set to an ohms range.

This type of circuit is called a potential divider, it is very useful in electronics for reducing the level of an input or output voltage. The output voltage from the divider depends on the ratio of the values of the two resistors. In fact it’s possible to calculate the output from a simple formula:

\[ V_{\text{out}} = V_{\text{b}} \times R_b / (R_b + R_c) \]

How try calculating the values of \( V_{\text{out}} \) and compare it against your actual test readings just recorded.

Our formula assumes that there is no current (I) drawn by anything connected to the output. By adding a “load” as shown in Fig. 1.11, in effect you reduce the resistance of the bottom half of the potential divider, by adding \( R_L \) in parallel with \( R_b \). This has the effect of lowering the output voltage of the divider as it is “pulled down” towards 0V.

There comes a point when the potential divider formula may give misleading results, because it does not take into account the “shunting effect” – if any – which a load connected to the divider may have on \( R_b \). How much effect the load has depends on its resistance – a lower resistance will pull down the output even more. We’ll see in future parts of Teach In, how the load could be something more complex than a resistor.
1. Fig. 1 shows a buzzer in series with a pair of resistors.

![Buzzer Diagram](image)

(a) The coloured bands on one of the resistors are labelled. Use the colour code to find the resistance of that resistor. \[ \text{[2]} \]

(b) The buzzer is rated at 6 V. When connected to a 12 V supply, it must have a resistance of 60 Ω in series. What is the value of the unlabelled resistor of Fig. 1? \[ \text{[1]} \]

(c) Select a suitable value for the unlabelled resistor from this table of preferred values. Draw a circle round your choice. \[ \text{[1]} \]

<table>
<thead>
<tr>
<th>Value</th>
<th>Band 1</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>gold</td>
<td>black</td>
<td>red</td>
<td>brown</td>
</tr>
<tr>
<td>16</td>
<td>green</td>
<td>red</td>
<td>brown</td>
<td>green</td>
</tr>
<tr>
<td>27</td>
<td>yellow</td>
<td>blue</td>
<td>red</td>
<td>yellow</td>
</tr>
<tr>
<td>43</td>
<td>gold</td>
<td>red</td>
<td>brown</td>
<td>green</td>
</tr>
<tr>
<td>68</td>
<td>red</td>
<td>yellow</td>
<td>blue</td>
<td>green</td>
</tr>
</tbody>
</table>

(d) Write in the colours of the bands on the unlabelled resistor. \[ \text{[3]} \]

(e) Draw on Fig. 1 a voltmeter which measures the potential difference across the buzzer. \[ \text{[2]} \]

MEG 704

**GCSE QUESTION**

**MIDLAND EXAMINING GROUP**

General Certificate of Secondary Education

**ELECTRONICS**

PAPER 1

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2

1. Fig. 1 shows a buzzer in series with a pair of resistors.

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(d) Write in the colours of the bands on the unlabelled resistor. \[ \text{[3]} \]

(e) Draw on Fig. 1 a voltmeter which measures the potential difference across the buzzer. \[ \text{[2]} \]

MEG 704

**THE TEN PER CENT RULE**

It's best to ensure that the output current from the divider is no more than 10 per cent of the current flowing through the divider itself, so that you don't unduly load the divider. Firstly work out the current flowing through both the load and the divider with no load attached. This is calculated very simply with Ohm's Law: \[ I = \frac{V_o}{R_a + R_b} \]

We know that the current \( I \) into the divider will equal the current through the two resistors plus the output current, refer to Fig. 1.11. Ignoring the load current \( I_o \) and with the values for \( R_a \) and \( R_b \) set at 10k for example, utilising a 10V supply the current through the divider is 0.0005 amps or 0.5μA.

The output current should be no more than 10 per cent of this, i.e. 50 microamps. This means that the load resistor should preferably be the equivalent of 100k or more, i.e. 5 volts (\( \frac{V_o}{50} \)) microamps.

The circuit of Fig. 1.12 shows a 4k7 resistor and a normally-open push switch connected between the 6V and 0V rails of the battery pack. Build this circuit on the Mini Lab itself, and measure the d.c. voltage output using the multimeter, recording the result both when the switch is open and closed.

Resistor R1 serves as a pull up resistor because it "biases" the output towards the +6V rail when the switch is open. Pressing the switch shunts the output to 0V. This is one way of obtaining a signal which is normally at 6V (or whatever the supply rail happens to be) and which is sent to 0V as a result of an operation.

A similar circuit is shown in Fig. 1.13 but this time a pull-down resistor R1 biases the output to 0V. Thus the output will be at zero potential when the switch is open, but a "high" signal of +6V is generated when the switch is closed. Prove it by building it on your Mini Lab.

These simple "input systems" enable us to obtain a suitable electrical signal - normally high or normally low, whichever we need - as a result of performing a mechanical operation. Both these functions are of great importance when we come to look at the world of digital systems. These only need - as a result of performing a mechanical operation - both these functions are of great importance when we come to look at the world of digital systems. These only have two states - on and off, or high and low.

It's even more relevant when we introduce the Micro Lab, an optional microprocessor expansion unit for the Mini Lab, later on.

**VARIABLE RESISTORS**

The simple switching systems just introduced enable one of two states - "high" or "low" - to be obtained from simply pushing a button. There will be many times when you want to vary a voltage. A very common method of doing this is based on a variable potential divider. Fig. 1.14(a) introduces the potentiometer (pronounced "pot-en-ti-oh-meter") which is a three terminal variable resistor. Fig. 1.14(b) introduces the variable resistor. Build this on the Mini Lab yourself, and measure the d.c. voltage output using the multimeter, recording the result both when the switch is open and closed.

By connecting the potentiometer as a voltage divider to an input voltage \( V_{in} \), it's easy to change the output voltage \( V_o \), by rotating the shaft of the potentiometer. The varying voltage output is available at the wiper of the pot. Thus by performing a mechanical operation (rotating the spindle), an electrical function is carried out.

A very common application of this arrangement is a volume control of a radio or a hi-fi. Sometimes you need to adjust a volume just once, in order to set up a signal, perhaps on a television circuit board. Small "trimmer resistors" or "preset potentiometers" are available, and these are generally fitted to a circuit board so that they
**GCSE QUESTION (see previous page)**

The Teach In Reader would have no problems with this straightforward question which concerned resistors in series. The following answer would have earned you full marks.

(a) Simply use the resistor colour code. The brown and red bands mean that the numerals of the code are 12. The black band means that the multiplier is 1R (x 1).

**Answer 12 ohms (12R).**

(b) Use the formula for resistors in series. We are told that the total resistance in series with the buzzer must be 60 ohms. We have shown one of the resistors to be 12 ohms – the unlabelled component must therefore be 48 ohms.

(c) The nearest preferred values to 48 ohms in the table are 47 or 51 ohms. Either was marked as correct.

(d) Resistor Colour Code again. 47R is yellow/violet/black. 51R is green/brown/black.

(e) The voltmeter is drawn in parallel with the buzzer. Voltmeters measure the voltages (p.d.) across components, i.e. between two points in a circuit.

**N.B. No extra marks would have been awarded by mentioning the resistor tolerance.**

Also, the Resistor Colour Code was shown on the Exam Paper for reference.

---

**Fig. 1.14(a). A preset variable resistor. Physical forms are also shown.**

**Fig. 1.14(b) (below).** Connecting one of the preset potentiometers mounted on your Mini Lab. Measure the voltage between “B” and 0V, when you rotate the control.

*Fig. 1.15(a) (above right). The Relay, used here to switch between a bulb and the buzzer. Add the buzzer (WD1) after building and testing the rest of the circuit.*

*Fig. 1.15(b) (right). Operating the buzzer and bulb with the changeover contacts of the relay. Connect WD1 the right way round.*

---

**NEW SYMBOLS**

Additional symbols are shown on the Exam Paper for reference.

**NEW SYMBOLS**

The symbol for a preset (or trimmer) is also shown in Fig. 1.14.

---

The simple switching systems we have looked at so far are limited by the current they can carry and the voltage they can switch. The smallest switches available can only carry a few tens of milliamps and switch up to 20V d.c. or so. In some applications, this could be far too restricting when we want to switch a heavy load such as a motor.

A relay is an output device in which a small current can be used to control a much larger current. They take advantage of the electromagnetic effect where a potential applied to a small coil turns it into an electromagnet. This magnetically operates some contacts to form a switch.

Only a small current is needed in the coil to enable the switch contacts to join together. The contacts themselves may be capable of switching very heavy currents, in the order of several amps or more. Fig. 1.15(a) is a demonstration circuit of a relay RLA, the coil of which is activated by pressing S1. The relay actually has changeover contacts (RLA1) so that a load can either be switched on or off when the coil operates. Here, a bulb LP1 is connected as the load. The whole circuit is powered by the 6V battery pack.

Build this on your Mini Lab as shown in Fig. 1.15(b). When you press S1, you will hear the relay click and the bulb will illuminate. How does the audible warning device (correctly polarised) between the n.c. terminal (buzzer +) of RLA and 0V (buzzer –). What happens now when you press the switch?

The relay used on the Mini Lab has the following specification:

- Coil Resistance: 100 ohms
- Coil Voltage: 6 volts
- Contact Current: 3 amps maximum
- Contact Voltage: 24V d.c./120V a.c. maximum

**Contact Configuration:** single pole changeover

What will be the current flowing through the coil when 6 volts is applied? Use Ohm's Law \( I = \frac{V}{R} \) and compare your answer (60mA) against the much higher contact current which the relay can safely switch.

We need to take certain precautions when using relays in transistorised circuits. Next month we see how relay coils can generate some unbelievably high voltages when they are switched off. This can ruin certain electronic components unless precautionary measures are taken. We also introduce more electronic devices.
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Everyday with Practical Electronics, November 1992
Teach-In Project

MINI LAB

Alan Winstanley & Keith Dye B.Eng(Tech) AMIEE

The Everyday with Practical Electronics Mini Lab has been created to accompany Teach In '93, and enables the reader to assemble demonstration circuits by following the clear instructions and diagrams contained in the main text, with every chance WYE working first time. The Mini Lab is an exciting learning aid which brings electronics to life in an enjoyable and interesting way: you will both see, and hear, the electron in action.

A specially-designed printed circuit board (p.c.b.) forms the heart of the Mini Lab which includes a "breadboard" area or plug-in contact block with which basic circuits can be tested. One Veroblock breadboard is required initially and the Mini Lab has room for another. Ancillary components such as presets, switches and buzzers etc. which cannot be plugged directly into the breadboard are also permanently fitted to the Mini Lab board, and are easily connected to the Veroblock through breadboard-type sockets which are conveniently located nearby.

All the areas are interconnected to a common power supply and the Mini Lab becomes mains-operated in due course. However, only low voltages are ever present on the Mini Lab, so the unit is completely safe to use at all times. A microprocessor expansion port facilitates connection to our Micro Lab microprocessor add-on system which is introduced later in the series for GCE A Level.

When the Mini Lab is finished, you will possess an excellent self-contained development unit complete with a range of test and demonstration items which will help you to widen your knowledge and produce your own designs. We hope that you will enjoy building and using your Mini Lab, and find it of continued use when Teach In '93 draws to a close. Thereafter, we hope to follow up with occasional articles which will utilise the Mini and Micro Labs in some interesting applications.

Should you have any particular queries or problems, please write to us c/o The Editor — we'll be only too glad to help. We also welcome any comments and constructive criticism from both teachers and students alike, so do get in touch with a progress report: we'll be delighted to hear from you!

Alan Winstanley and Keith Dye.

The printed circuit board designs of the Mini and Micro Labs are () Copyright Dytronics 1992.

FIRST STEPS IN CONSTRUCTION

The Teach In Mini Lab is constructed on a p.c.b. measuring approximately 295mm x 210mm (the size of a page of EPE) and is divided into distinct sections. Every month Teach In discusses a particular topic and accompanying the text will be a brief constructional article describing a relevant circuit which fills one of the sections on the Mini Lab board. There is, however, the requirement to solder a number of components to the board each month, so a little practice with a soldering iron will be useful. Space precludes us from exploring the circuits in any depth: the main thing is to build them!

For Part One of Teach In, it is necessary to assemble the "general-purpose" central area of the Mini Lab which contains the plug-in breadboard and other components. The breadboard readily copes with most of the electronic components used in Teach In, but cannot directly handle certain parts like switches, bulbs or preset potentiometers. These components are instead soldered directly to the Mini Lab p.c.b., then the components' terminals connect via the p.c.b. to adjacent groups of contact strips which form breadboard-style connection points for these parts.

It therefore becomes very easy to connect switches, pots etc. to the breadboard with standard solid core 0.28mm² insulated wire, see Fig. 1. Simply cut some wire to length, strip about 5mm of insulation from each end and push the jumper wire into the relevant sockets on the Mini Lab and connect over to the Veroblock. You might often find it easier to use a pair of fine-nose pliers to grip and locate the wires into the sockets. The system works perfectly but it's important that you use both the correct socket strips and also the right gauge of wire so that a reliable connection can be made each time.

COMPONENTS

The Components List gives all those parts which you can solder to the Mini Lab board for Part One. It does not list the extra parts required to fill the other sections of the board: these will be gradually introduced as required in each month's article which makes the Mini Lab extremely cost-effective. Also, rest assured that we have chosen the most economical components wherever
Fig. 2. Construction of the central part of the Mini Lab as required for Part 1 of Teach-In. The photograph below shows the complete Mini Lab.
possible. We also give a list of other requirements for tools, etc. which the newcomer might find useful.

The top side of the Mini Lab p.c.b. is fully silk screen printed with the descriptions and location of the various components, and you should find the initial assembly very straightforward. Fig. 2 shows the arrangement of the central part of the Mini Lab which can now be constructed.

**BATTERY PACK**

Also assemble the battery pack (B1 to B4); use four 1.5V cells such as R20S types and connect them the right way round into a suitable holder to make 6 volts. It is connected to the Mini Lab through screw terminals on the printed circuit board, see Fig. 3. We recommend "pluggable" terminals, so that the relatively bulky battery can be conveniently unhitched when desired, without straining the printed circuit board.

The battery must be selected for use by inserting a shorting plug (see Parts List) between two small sockets marked "EXT BATT", and also a d.c. on-off switch is fitted, so that you can readily disconnect the battery. Later, this switch serves a different purpose: it turns the main supply on and off for digital circuits, once the battery has been replaced with a very comprehensive Mains Power Supply.

**I.C. MOUNTING**

The s.i.l. ("single in line") socket strips are designed to carry integrated circuits and mainly come in lengths of 32 terminals, and these are snapped off as required to form small groups which can then be soldered to the p.c.b., perhaps using sticky tape to hold them down while you solder the pins. Because they are central to the whole design, we again emphasise that only "turned pin" s.i.l. sockets should be used; other types will not work in this application. Invariably, some terminals will break, so allow for a little wastage.

Many parts have to be pin-compatible with the hole layout in the p.c.b. or they will not fit, so consider the Components List and Fig. 2 are only used here for the purpose of helping you to assemble this part of the Mini Lab. In the main tutorial of Teach-in, you will find that the components are given different designations in various circuit and interwiring diagrams.

**TOOLS**

The following is a list of basic requirements for tools and equipment, and is given as guidance to those approaching the subject for the first time:

- Solder 60/40 22 s.w.g.
- Soldering iron, 15 Watt mains operated pencil type with fine tip, preferably with bench stand.
- Soldering Iron Tip Cleaner and Tinner (Multicore TCC1).
- Screwdrivers, small flat-bladed and cross-head No. 0 and No. 1 types.
- Wire stripper, variable gauge, with built-in wire cutter.
- Round-jaw pliers (luxury, useful for bending leads neatly).
- Soldering iron, 15 Watt mains operated pencil type with fine tip, preferably with bench stand.
- Small Freezer aerosol (handy)
- Multimeter, 10,000 ohms per volt or higher; reading 250V d.c./500mA d.c. minimum plus resistance range. Or Digital Pocket Multimeter, same readings or better. A modest multimeter will be quite adequate for following Teach-in.

MAILTECH
ELECTRONIC COMPONENTS

Everyday with Practical Electronics, November 1992

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LAST MONTH the topic of customising projects was discussed. This is something that even experienced constructors indulge in, and it adds to the interest and enjoyment obtained from the hobby. You do need to be slightly careful when doing your own thing though, and in particular, you need to be careful when using substitute or equivalent components.

SUBSTITUTION

There are several possible reasons for using substitutes. One is simply that you cannot find exactly the right component listed in any of the component catalogues.

Another is that you have almost the right component in your spares box, and that you would prefer to use this rather than buy the right component. A third possibility is that the project under construction is an old design, and that some of the components used in the original unit are no longer available.

It is clear from readers’ letters that many constructors are simply not sure if certain components are the right ones or not. A fair percentage of queries from readers who are having difficulty getting projects to work include inquiries about the suitability of one or more components. In most cases the components in question seem to be perfectly suitable, but in a few cases a misunderstanding has resulted in a totally unsuitable component being used.

For complete beginners at electronic construction the best advice is to only build projects using what you are certain are the correct components. When building a project from "Everyday with Practical Electronics" remember to consult the Shop talk feature. If for one reason or another you cannot obtain all the right parts, then it is best not to go ahead with the project. Once you have gained a small amount of experience it is probably safe to start making some simple substitutions.

SWITCHES

In theory, provided a switch has the right number of ways (contacts) and a sufficient number of poles ("moving contact"), it will do the job. It does not matter whether you use a pushbutton, slider, rotary, or rocker type.

In reality you need to be very careful that the switch contacts have suitable current and voltage ratings. The most important point to watch is that you do not use an unsuitable switch on the mains supply. This could be lethal for the switch and anyone who uses it!

Generally speaking, miniature switches are not intended for use on the 240V AC mains supply. Most of those that are intended for use on mains supplies are only suitable for continental and US supplies of around 110V to 120V. For mains operation use the larger switches that are intended for use on switching of the 240V UK mains supply.

Sometimes a components list specifies that a switch should be a make-before-break or a break-before-make type. These terms only apply to change-over and multi-way switches, not simple on/off types.

With a "make-before-break" switch, as the moving contact is shifted from one terminal to the next it momentarily short circuits the two terminals together. With "break-before-make" switches the moving contact (pole) becomes briefly isolated from both terminals as it is switched from one to the other.

In most cases it does not matter which of these switch types is used. However, where one type or the other is specifically called for in a components list it is essential to use the right kind. Otherwise you might, for example, find that the power supply is short circuited each time you operate the switch. At best the switch would be short lived, and at worst expensive damage would be caused to other components in the circuit.

CAPACITORS

If you look in one of the larger electronic component catalogues there will almost certainly be more than a dozen different types of capacitor on offer. Capacitors that operate well in some respects tend to be less impressive in others.

Circuit designers therefore have to look at the important requirements for each capacitor, and choose a type which measures up to these requirements. Using a capacitor having the right value, voltage rating, etc., but having the wrong type of construction, may not be a safe substitute.

Ceramic capacitors provide good performance at high frequencies. They are often used for supply decoupling and signal coupling in radio frequency circuits. In other respects the performance of ceramic capacitors tends to be poor.

The tolerance figures are mostly quite high, and the values drift significantly with changes in temperature and the passage of time. They can also give problems with microphony in audio circuits (i.e. they act like crude microphones). It is usually not simple to substitute another type of capacitor for a ceramic type, or to use a ceramic capacitor where some other kind has been specified.

The various plastic foil capacitors, such as Mylar, polyester, polystyrene, and polycarbonate types have broadly similar characteristics. In fact components lists sometimes just specify "plastic foil" capacitors rather than a particular type within this category.

Provided the electrical ratings are suitable it is unlikely that there will be any problem if one kind of plastic foil capacitor is substituted for a different type. Bear in mind though that there are substantial variations in the sizes and shapes of plastic foil capacitors. A substitute capacitor might have suitable electrical characteristics, but can it be fitted onto the circuit board?

POLARISED

Higher value capacitors are mostly of the electrolytic and tantalum types. The latter are physically very small, and have superior electrical characteristics. Accordingly, a tantalum type can be used instead of an electrolytic type. A substitution in the opposite direction is unlikely to give good results though. In a timing circuit for instance, the higher leakage of an electrolytic capacitor could result in greatly extended times, with the times possibly carrying on indefinitely.

Tantalum and electrolytic capacitors are polarised components which must be connected the right way around, or they will not function properly. It is not a good idea to use a polarised capacitor in place of a non-polarised type. The signal across a polarised capacitor must include a d.c. component if the component is to function reliably.

If a large non-polarised capacitor is called for, it is likely that this d.c. component is not present, or that the application is a critical one where the quality of a polarised component would simply not be good enough anyway.

Silvered mica capacitors are sometimes specified for radio frequency circuits. These are very high quality components with price-tags to match. Micro capacitors are still available, but are becoming increasingly difficult to track down. A good quality polystyrene capacitor is about the only reasonable substitute for a mica type.

LOUDSPEAKERS

The main ratings of loudspeakers are the physical size, the power rating, and the impedance. Using a slightly smaller or larger loudspeaker than that specified is fine, but only if the substitute component has a sufficiently high power rating. Be especially careful about using a loudspeaker that is smaller than the specified size.

In general, the larger the physical size of a loudspeaker the higher its power rating. Some miniature loudspeakers have very low power ratings. Bear in mind that seriously overloading a loudspeaker can burn out the coil, or (more probably) result in it literally ripping itself apart.

If an eight ohm impedance loudspeaker is required there should be no difficulty in obtaining a suitable component, since virtually all loudspeakers have this impedance. The main exceptions are the high impedance types, where there is a definite lack of standardisation.

By Robert Penfold
A variety of impedances from about 50 to 80 ohms are used. Using a loudspeaker of not quite the right impedance should not cause any difficulties. A 64 ohm component should work perfectly well in place of (say) a 50 ohm or 80 ohm loudspeaker. Substituting an eight ohm loudspeaker instead of a high impedance type. This could damage the semiconductors in the circuit driving the loudspeaker, and (or) result in severe overloading of the loudspeaker. Substituting a high impedance loudspeaker for a low impedance type should be quite safe, but the maximum output power and volume will both be substantially reduced.

DIODES
Occasionally a special diode of some kind will be required, but in most cases projects just use "bog standard" silicon types such as the 1N4148 and 1N914, or very occasionally germanium diodes such as the QA50 and QA91. Substituting one silicon diode for another, or one germanium device for another should not give any problems. However, do not use a germanium diode in place of a silicon type, or vice versa. They have very different characteristics, and are not usually interchangeable.

On the face of it there is no problem in using a silicon rectifier such as a 1N4002 instead of a germanium diode such as a 1N4148. In practice this is not usually a good idea. There are subtle differences between the two types of component which could cause difficulties.

Rectifiers generally have lower forward voltage drops which could cause problems in biasing applications. They also have slow response times which could produce poor results in a.c. applications.

Substituting a rectifier having a higher than specified voltage or current rating is perfectly safe. For example, a 1N4002 (1A 100V) rectifier can be used in place of a 1N4001 (1A 50V) type. Going up to a higher current rating is safe from the electrical point of view, but bear in mind that a higher current rating usually means a much larger physical size as well.

Never use rectifiers having lower voltage or current ratings than the specified components. Apart from the almost certain and spectacular destruction of the substitute rectifiers, other components in the circuit could be damaged.

RESISTORS
Most components list specify something like "0.25 watt 5 per cent carbon film" for all the resistors. This is a minimum requirement, and it is quite in order to use higher quality components such as one per cent metal film resistors.

It is also in order to use a higher wattage than that specified in the "Comps list." However, note that in many cases this would mean trying to use resistors that were far too large to fit into the available spaces on the circuit board.

In the vast majority of cases you can get away with using one value up or down from the correct one (e.g. a 12k or 8k2 resistor instead of a 10k type). This may cause some loss of performance though, and it is advisable to fit the correct value as soon as a suitable component can be obtained.

If you try using a "logarithmic", (log.) potentiometer instead of a "linear" (lin.) type, or vice versa, the project will work properly. The substitute potentiometer will have rather an odd control characteristic though.

For example, suppose you used a logarithmic potentiometer instead of a linear type for the balance control in a stereo amplifier. This would provide the correct channel balance with the control set almost at one end of its adjustment range, rather than at a roughly middle setting. This is again fine for a temporary fix until you can obtain the right type, but does not provide a satisfactory long term solution.

TRANSISTORS
With projects that operate from a small 9V battery and use transistors as simple amplifiers and switches, BC549s and BC559s can respectively be used in place of virtually any npn and pnp transistors. There are plenty of other transistors which are suitable as general purpose npn/pnp substitutes (BC109/179, BC547/555, etc.).

When using substitutes make sure that you connected the transistors correctly. The fact that two transistors have the same case style does not necessarily mean that they have the same pin leadout configuration.

Using substitutes where higher powers and higher frequencies are involved is rather more tricky. Even very experienced constructors can run into difficulties when attempting this type of thing. For the beginner the best advice is to not bother trying substitutes for any transistor that is at all out of the ordinary.

INTEGRATED CIRCUITS
In general it is not possible to use substitutes for integrated circuits (i.c.s.) due to their specialist nature. However, one exception is operational amplifiers.

There are plenty of operational amplifiers which are designed to be superior versions of the industry standard μA741C. This includes popular devices such as the TIL071CP, TIL081CP, CA3140E, and LF351N. Using one of these instead of a μA741C, or in place of another "super" 741C device is almost invariably all right.

Using a μA741C instead of a "super" 741C is more dubious. The project is almost certain to work, but with some reduction in performance.

Some circuits make use of the CA3140E's ability to operate with a single supply rail in situations where other types require dual supplies. Using a substitute in such a circuit is more or less guaranteed to prevent it from working at all.

There are various families of TTL logic integrated circuits, with each family having "pin-for-pin" equivalents to the devices in the other families. Compatibility between these logic families is actually quite an involved topic, but there is a fairly high degree of compatibility between most of them.

Compatibility is to some extent dependent on the exact way in which a device is used. A substitution might be successful in one circuit, but unreliable in another.

Compatibility is very good between the original 74 series, the popular 74LS series, and the increasingly popular 74HCT devices. It is highly unlikely that an unsuccessful substitution will cause any damage, so the "suck it and see" approach is quite acceptable.

In practice with 74 series substitution you seem to be able to get away with rather more than the theory would dictate. Unfortunately, this is not the case with most component substitution.

Everyday with Practical Electronics, November 1992
Safeguard your valuables with this novel alarm. Endless possible applications in and around the home.

The vibration alarm circuit to be described here consists of a piezoelectric sounder (which is used both as a vibration sensor and also a mini speaker), a latch and two oscillators formed by a CMOS quad 2-input NAND Schmitt trigger i.e., and two transistor amplifiers.

**HOW IT WORKS**

The circuit block diagram is shown in Fig. 1. Vibration of the piezoelectric transducer WD1 generates small voltages which are amplified by the transistor amplifier TR2 and provides a negative "feedback" pulse to flip the latch IC1a and IC1b.

When the unit is switched on, the latch automatically resets itself. When triggered by TR2, the latch changes over, and remains in this "alarm" state until the unit is switched off.

The output of the latch enables two oscillators, creating the required pulsed tone for the alarm sound. The output from the last oscillator is connected to the same transducer WD1 as is used for the alarm sensor. This eliminates the need for two piezoelectric devices and also provides a regenerative action, guaranteeing positive triggering.

**CIRCUIT DESCRIPTION**

The full circuit diagram for the Vibration Sensitive Alarm is shown in Fig. 2. The latch, IC1a/IC1b, mentioned earlier is reset by the resistor capacitor combination R1/C2. Capacitor C2 always starts up from the uncharged state due to it being shorted out by the On/Off switch S1 each time the unit is switched off.

The latch output at IC1 pin 3 will be "low" (0V) when the unit is on but not triggered. When the latch changes state, due to a negative pulse from TR2, it's output goes "high" (+9V) enabling the low frequency oscillator formed by IC1c.

This oscillator pulses on and off a high pitched audio oscillator IC1d, providing the alarm sound. The frequency of the second oscillator is adjustable by VR1 to set the loudest (and most nauseating) frequency. This is then buffered by transistor TR1 to drive the piezo sounder WD1.

Piezoelectric devices are excellent for low power consumption but are not generally loud enough to be heard far away. This problem is easily overcome by connecting an inductor L1 across it. When transistor TR1 is switched on an off at the high pitched audio frequency, L1 "rings" and provides a large voltage swing across the transducer WD1, giving a greatly increased volume than otherwise available.
If an inductor is not readily available, it can be substituted with a resistor, typically 10 kilohms, and the unit will function as normal except for the reduced volume, which might still be sufficient in many cases.

Diode D1 is provided to protect the unit against accidental battery reversal.

**CONSTRUCTION**

The complete unit can be built up on a piece of 0.1-in. matrix stripboard, size 36 holes by 17 strips, and the topside component layout is shown in Fig. 3. There are 14 copper track breaks required and these are shown in the underside plan view.

Commence construction by inserting the J1 link wires and i.c. socket. This provides a good reference point when mounting components later. The i.c. should not be mounted in its socket until all wiring has been completed and checked.

The small links can be made with bare off-cuts from component leads, but the longer ones should be made with insulated wire. Before adding the components, double check the position and wiring of the links; this will save a lot of headaches at the testing stage.

The rest of the components should now be mounted and soldered on the circuit board. The order should be in ascending size, i.e. diodes, resistors, capacitors, transducer.

It might be wise to leave the transistors until last as they are not to happy about being exposed to heat and they must be put in the right way round. Also, be careful to check the polarity of the diodes and the electrolytic capacitors.

It only remains to wire the slide switch to the board and the battery clip leads to the board and switch. In this design, the On/Off slide switch is wired in the negative, black, battery lead. This is to ensure that in the off position the electrolytic capacitor C2 is discharged.

No details have been provided for a case and this has been left to individual choice. However, a small hole or series of holes should be drilled in the case above the sound transducer.

**TESTING**

Once assembled, check the board for any errors or solder shorts across copper tracks, plug the i.c. into its socket and connect up the battery. The diode D1 protects against reverse battery polarity.

Switch on and wait a few seconds while the unit resets itself, via R1/C2. Tap the piezoelectric transducer WD1, this should give out a pulsed high pitched sound.

Leave the alarm running and adjust preset VR1 for the loudest and most annoying output. This type of sound carries a long way and would, hopefully, deter most unwanted intrusions.

---

**COMPONENTS**

<table>
<thead>
<tr>
<th>Resistors</th>
<th>See SHOP</th>
<th>£4 plus case</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1, R6</td>
<td>100k (2 off)</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>1M5</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>47k</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>3k3</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>1M</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td>220k</td>
<td></td>
</tr>
<tr>
<td>All 0.25W 5% carbon film</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Potentiometer**

VR1 100k skeleton carbon preset, lin.

**Capacitors**

C1 100µf axial elect., 35V
C2 10µf radial elect., 16V
C3, C5 100µf ceramic or poly (2 off)
C4 10n ceramic or poly

**Semiconductors**

D1, D2 1N4148 signal diode
TR1, TR2 BC108 npn silicon transistor (or similar)
IC1 4093 quad 2-input CMOS Schmitt trigger

**Miscellaneous**

L1 10mH p.c.b. mounting choke
S1 Single-pole slide or toggle changeover switch
WD1 Piezoelectric transducer
Stripboard, 0.1-in. matrix, size 36 holes x 17 strips; 9V PP3 battery and connector leads; plastic case to choice; board spacers; fixing nuts and bolts; solder etc.

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Approx cost guidance only

---

**Fig. 3. Stripboard component layout and underside details of breaks required in the copper tracks.**
Welcome again to Circuit Surgery, our regular clinic for readers' problems and a particularly warm welcome to readers of Practical Electronics. For the benefit of our new readers, Circuit Surgery provides a regular "self-help" forum for readers problems. We aim not only to provide a regular cocktail of practical hints and tips but also some rapid feedback (including modifications and trouble-shooting information) concerning many of the projects which have appeared in the pages of both Everyday and Practical Electronics. Naturally, this column relies almost entirely on input from readers, so please drop me a line and let me know what topics you would like me to cover.

This month's Surgery should have a particular appeal to the audio enthusiast. We shall be describing some simple circuitry for compressing audio signals, a power supply for a low-noise pre-amplifier stage, and also suggesting some useful background reading on "digital audio".

Finally, for those who may not be so interested in audio, we include some information on the popular RS-232 serial communications interface.

**Constant level**

Audio enthusiast Chris North writes from Bristol with a request for a simple circuit which will help him keep the level of a microphone signal reasonably constant. Chris writes:

"I am regularly involved with public address work and often have difficulty with varying microphone levels. I need a circuit which will accept a signal from a medium impedance dynamic microphone and deliver a constant output signal to the power amplifier."

The solution to this particular problem is a circuit which will provide a rapidly falling voltage gain as the amplitude of an input signal is increased above a threshold level. Such a circuit is known as a "compressor" and a practical example (based on two commonly available operational amplifiers) is shown in Fig. 1.

The compressor circuit can be used to replace an existing microphone pre-amplifier but offers the advantage that its output remains reasonably constant (at about 2V peak-peak) for any input greater than 20mV peak-peak. The circuit has a frequency response which extends from 100Hz to over 10kHz and thus should be more than adequate for most public address work.

Preset VR1 sets the amount of compression provided by the circuit and the correct setting for this component will usually require a little experimentation. If no compression is required, VR1 should be set to minimum (slider at 0V). In this case, the circuit will operate as a "straight" pre-amplifier with a voltage gain of about 750 (the signal shunt, TR1, will never be driven into conduction).

If high-quality low-output microphones are to be used, greater sensitivity may be required. In this case both R2 and R7 can be increased to 470k. The onset of compression will then be reduced to approximately 5mV with VR1 at maximum setting.

**30V power supply**

Regular reader Simon Jones writes from Liverpool with a request for information on the design of a 30V power supply. Simon writes:

"I am constructing an ultra low-noise pre-amplifier based on a TDA3410. This requires a 30V power supply. Can you provide me with a circuit which can power two identical pre-amplifiers using this chip?"

The TDA3410 requires a fairly modest supply current (approximately 10mA) and thus a simple
transformer/rectifier/regulated combination should suffice, see Fig. 2.

The 14-pin d.i.l. regulator (IC1) is capable of operation over a very wide voltage range (2V to 37V at a maximum load current of 150mA) and thus should be more than adequate for this application. The output voltage of the power supply is set by means of VR1 whilst the current limiting resistor (R2) has been chosen so as to provide a maximum output current of 100mA (sufficient for several TDA3410 devices). The mains transformer, T1, should be rated at 6VA (or more) and should have two 12V secondaries (each rated at 250mA) prevent hum and induced noise. Furthermore, an earthed metal enclosure should be employed (with ground connections taken to a single common earth point in order to prevent earth loops) and all internal signal wiring should use screened audio cable.

Modem connections

George Smith writes from Edinburgh with a query relating to the serial port connections on a BBC Micro:

"On reading your Circuit Surgery article in which you supplied Mr Ron White with circuit terminating details of the SCART connector, I wonder if you could help me with a similar problem.

I purchased a British Telecom Mainstream modem model FM 1200 from a mail order catalogue. Unfortunately it did not contain any technical data. The problem is that there is a 25-way D-connector on the rear panel of the modem which I wish to connect to the 5-pin d.i.l. DIN socket fitted to the RS-232 port of a BBC Micro.

The pins on the RS-422 port are: A - data in; B - data out; C - 0V; D - RTS; and E - CTS. Do you have any idea of the pinout of the 25-way D-connector?

The RS-232/CCITT V.24 interface undoubtedly reigns supreme as the most widely used standard for serial communication between microcomputers, peripheral devices, and remote host computers, which were not defined under RS-232C. The standard was first defined by the Electronic Industries Association (EIA) in 1962 as a recommended standard (RS) for modem interfacing.

RS-232 relates essentially to two types of equipment: Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE). Data Terminal Equipment (e.g. a microcomputer) is capable of sending and/or receiving data via an RS-232 serial interface. It is thus said to "terminate" a serial link.

Data Circuit Terminating Equipment (formerly known as Data Communications Equipment), on the other hand, is generally thought of as a device which can facilitate serial data communications and a typical example is that of a modem (modulator-demodulator) which forms an essential link in the serial path between a microcomputer and a conventional analogue telephone line.

Next month:

In next month's Surgery we shall be attempting to explain the mysteries of "safe area protection". We shall also be taking a look at several probes which can be used to extend the functions provided on basic test equipment. We also have a "round-up" of hints and tips sent in by readers over the past six months.

In the meantime, if you have any comments or suggestions for inclusion in Circuit Surgery, please drop me a line at: Faculty of Technology, Brooklands College, Heath Road, Weybridge, Surrey, KT13 8TT. Please note that I cannot undertake to reply to individual queries from readers however I will do my best to answer all questions from readers through the medium of this column.

Digital audio

Judging from the number of readers' letters "Digital Audio" is quite a "hot" topic these days! Unfortunately the subject often does not feature in many of the older textbooks and several readers have asked me to suggest sources of information. Two books which are well worth reading are:

The Art of Digital Audio (Focal Press, ISBN 0-240-51270-7) by John Watkinson provides an excellent introduction to the subject. It contains all of the essential theory of digital audio and should appeal to those with little previous experience of the subject. John Watkinson provides a very detailed description of digital audio coding, processing and conversion without getting too bogged-down in complex mathematics. The book then continues with a description of a number of current digital standards and error correcting techniques before describing a variety of equipment.

Digital Audio and Compact Disk Technology (Heinemann Newnes, ISBN 0-434-91868-7) is edited by staff from the Sony Service Centre (Europe) and contains a wealth of information relating to a wide variety of digital audio equipment. The book provides a useful introduction to the principles of digital signal processing, sampling, quantization, conversion and coding and also contains chapters on Compact Disk players, Video 8, Digital Audio Tape (DAT) and Digital Audio Stationary Head (DASH) formats.

Data terminal equipment (DTE) is normally fitted with a male connector whilst data circuit terminating equipment (DCE) conventionally uses a female connector (note that there are a few exceptions to this rule). Fortunately the solution to Mr Smith's problem should be fairly straightforward since the BBC Micro uses only a subset of the full set of RS-232 port connections. Furthermore, the wiring of the 25-way modem connector should be reasonably standard and should obey the following convention in respect of the most important signals present:

<table>
<thead>
<tr>
<th>Pin Signal</th>
<th>Function</th>
<th>no:</th>
</tr>
</thead>
<tbody>
<tr>
<td>FG</td>
<td>Earth connection to the equipment frame or chassis.</td>
<td>1</td>
</tr>
<tr>
<td>TXD</td>
<td>Serial data transmitted from DTE to DCE.</td>
<td>2</td>
</tr>
<tr>
<td>RXD</td>
<td>Serial data received by the DTE from the DCE.</td>
<td>3</td>
</tr>
<tr>
<td>RTS</td>
<td>When active, the DCE is signalling that it wishes to send data to the DCE.</td>
<td>4</td>
</tr>
<tr>
<td>CTS</td>
<td>When active, the DCE is signalling that it is ready to accept data from the DTE.</td>
<td>5</td>
</tr>
<tr>
<td>DSR</td>
<td>When active, the DCE is signalling that a communications path has been properly established.</td>
<td>6</td>
</tr>
<tr>
<td>SG</td>
<td>Common signal return path (0V).</td>
<td>7</td>
</tr>
<tr>
<td>DTR</td>
<td>When active, the DTE is signalling that it is operational and that the DCE may be connected to the communications channel.</td>
<td>8</td>
</tr>
</tbody>
</table>
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JUDGING from readers' letters, playing around with stepper motors is currently a popular pastime for the electronic hobbyist. Driving stepper motors is actually much more simple than many people seem to imagine. It looks complex because most stepper motors have about six leads, as opposed to the two of an ordinary d.c. motor.

Also, stepper motors are normally driven via special driver circuits which are almost invariably based on dedicated integrated circuits. The circuit diagram therefore gives few clues as to what is going on.

Next Step

The stepper motors that are available to the hobbyist are virtually all of the four-phase variety. You need to be slightly wary of cheap surplus stepper motors as these are often something other than four-phase types, and could be very difficult to drive properly. Fig. 1 shows the basic way in which a normal four-phase stepper motor functions.

The basis of the motor is two electro-magnets in an "X" formation. Each electro-magnet has two coils wound in anti-phase, so that the polarity of the magnetic field can be changed by switching over from one coil to the other. Obviously the same thing could be achieved by having a single coil and changing the polarity of the drive voltage. However, the driver circuit can be more simple if twin anti-phase windings are used.

A bar magnet is fitted to the drive shaft, and the orientation of this magnet will depend on the polarities of the electro-magnets. Bear in mind here that like poles repel, and unlike poles attract.

As you will see from Fig. 1, by altering the polarities of the electro-magnets in the correct manner the bar magnet can be dragged round in 90 degree increments. By repeating the sequence over and over again the magnet can be made to rotate continuously. By reversing the sequence it can moved in the opposite direction.

In a practical stepper motor there are usually several sets of electro-magnets, giving much smaller steps. The Maplin stepper motor for instance, has 7.5 degree steps, or some 48 steps per complete turn.

Clearly a much finer degree of control will be needed in most applications, but this can be provided by some step-down gearing. For example, with an eight-to-one step-down ratio there would be 384 steps per turn, and slightly better than one degree resolution.

Stepping Power

An important point to bear in mind is that stepper motors are not very powerful, and even with the aid of step-down gearing they can only drive light loads. It should also be borne in mind that they are not really a good choice where continuous rotation is required. An ordinary d.c. electric motor can usually handle that type of thing perfectly well, and at a fraction of the price.

Four-phase stepper motors have six leadout wires. Two of these are "common" leads which simply connect to the positive supply rail. The other four are driven from open collector outputs, which should include protection diodes because the solenoids in the motor obviously provide highly inductive loads.

One way of handling things is to simply control the solenoids directly from some digital outputs of the computer. Outputting the appropriate values in the correct order then steps the motor in the required direction. Most people prefer to use a proper driver circuit, which usually means one based on the SAA1027 integrated circuit. Control of the motor is then very straightforward, and is achieved using two outputs. Pulses on the outputs provide stepping of the motor, while the logic state of the other output determines the direction of the motor.

Next month we will consider some practical stepper motor interface circuits.

P.C.B. Shareware

In the past there has been plenty of high cost software for producing printed circuit board designs on a computer, but there has been little low cost commercial or shareware software of this type. In recent times some good low cost p.c.b. software has appeared, some existing programs have been subjected to spectacular price cuts, and some good shareware p.c.b. programs for the PCs have appeared. I reviewed the British produced "Quickroute" a couple of months ago, and this was probably the first shareware program to offer a real alternative to the low cost commercial p.c.b. programs.

Pads-PCB

Now there are two new shareware p.c.b. programs for the PCs in the form of "Pads-PCB" from the USA, and "LAY01" from France. These are both sophisticated programs, and "Pads-PCB" would seem to be the most advanced shareware p.c.b. program currently available. It has facilities which rival the cheaper and mid-priced commercial offerings.

Unfortunately, it is sufficiently advanced to be unusable on many PCs. To run this program you require at least an 80286 based PC fitted with 640K of RAM and a hard disk with at least seven megabytes of free space. A V.G.A. display is also needed, and some super V.G.A. modes are also supported.

Part of a screen dump from "Pads-PCB". Showing a zoomed "ratsnest" and menu bar and status information.
Control of the program is via a combination of the keyboard and a Microsoft compatible mouse. The program is supplied on three high density 3-5 inch or 5-25 inch disks.

There are really two programs, one of which is a front-end which is used to produce circuit diagrams (or "schematics" in American terminology), and to produce netlists which are fed to the second program. A netlist is basically just a components list together with details of all the interconnections.

The second program takes the netlist and converts it into physical representations of the components, complete with a "ratsnest" of interconnections. The components can be placed onto the board manually, or there is an auto-placement facility which can be used. This is quite an advanced feature which is normally only found on very expensive p.c.b. design programs.

In the "ratsnest" each connection runs straight from one pin to the next, probably crossing several other tracks and a few pads on the way. Each track therefore has to be carefully routed to avoid any short circuits. The routing can be performed manually, and there are plenty of editing tools which permit corners and angles to be placed in the tracks, the track width to be varied, etc.

Auto-Routing

There is also an automatic routing facility with various options that can alter its approach to routing a "ratsnest". In common with other auto-routers which use "maze-search" and other relatively simple methods, it will work quite well with certain types of board, but is virtually useless with many other types.

The problem with virtually all auto-routers is that they tend to produce complex two-sided layouts, whether or not the design really justifies it. Also, they generally complete about 90 per cent or so of the tracking, leaving the user to finish the rest.

This would be fine, but most auto-routers tend to "paint you into corners", possibly leaving a board that is impossible to finish without some substantial redesigning. Simple auto-routers are great fun to try out, but are not usually of much practical help.

The "Pads-PCB" actually has two auto-routers, and these seem to be better than most. Although the success rate is not exceptionally high, the routers do seem to route the tracks more sensibly than much of the competition.

Both routers are also much faster than many other auto-routers I have tried. Great claims are made for the 100 per cent rip-up-and-try again and "power" routers, but unfortunately these are not included in the shareware version of the program.

The netlist approach is the one favoured by most professional p.c.b. designers, but it is a bit over the top if you only need to draw up relatively simple printed circuit designs. Like most p.c.b. design programs, "Pads-PCB" allows you to use the p.c.b. design part of the program as an electronic drawing board if that is all you need.

The program can output to a wide range of devices, including dot-matrix printers, laser printers, plotters, and photo-plotters. I tried printing out one of the demonstration designs on a 24-pin dot-matrix printer and a 300 d.p.i. laser printer, and the quality seemed to be about as good as the printers would allow.

In a short review of this type it is impossible to cover such a complex piece of software in detail. It is a very sophisticated and well thought out program, and it seems to be reasonably bug-free. There is plenty of documentation in the form of ASCII files on the disk, and the documentation is very concise and complete by shareware standards.

If you have a suitable computer and you are interested in electronics, then this is a program that you should definitely try. The running demonstration for the p.c.b. section of the program will give you a good idea of what "Pads-PCB" can do.

The shareware version is limited to logic boards having about 30 integrated circuits, or analogue boards having an equivalent number of interconnections. However, this should be sufficient for the majority of do-it-yourself projects.

If the shareware version is sufficient for your needs, then "PADS Software Inc." are apparently quite happy for you to go on using their program, with no registration fee being required. All you pay is the £18-00 (including V.A.T. and postage) for the three high density distribution disks. This must be one of the best software buys of all time!

LAYO1

It is difficult to comment on the "LAYO1" program. It is produced in France, but the on-disk documentation is in English. At least, it is almost in English. Unfortunately, the documentation is rather cryptic and contains more than a few errors. The program seems to be fairly sophisticated -- it includes an auto-router for example. I found it difficult to get this program to do anything worthwhile though.

The hardware requirements seem to be similar to those of "Pads-PCB", and the program is supplied on a single high density disk. Be warned that the installation program generates a large sub-directory structure which it fills with dozens of files. If you have suitable computer equipment it is probably worth giving this program a try, but you will need plenty of time to work out how to use it!

"LAYO1" and "Pads-PCB" are available from The PDSL, Dept EE, Winscombe House, Beacon Road, Cradbrooke, Sussex, TN6 1UL (0892 663298), and are on disks H027 and H031 A/B/C respectively. They might be available from other shareware libraries, but will have different catalogue numbers.
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**Everyday with Practical Electronics, November 1992**
PCB SERVICE

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<td>Inverter Daughter Board</td>
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Everyday with Practical Electronics, November 1992
WHAT'S IN A NAME?

From the earliest days, radio amateurs in the United States have been known as "radio hams", or simply "hams", although amateurs in some countries have resisted the term for various reasons, preferring to be known as "radio amateurs". Some are simply resisting the spread of "Americanisms", and others see it as a derogatory term, wrongly implying a less than satisfactory level of competence.

There are many different explanations of the origin of the term. One version credits three amateurs whose combined initials spelled out the word HAM to provide their station's call-sign. This particular station is said to have been discussed by Congress when considering a Wireless Regulations Bill in 1911, and nationwide publicity of the proceedings resulted in the term being used from that time on to describe all amateur radio stations.

Another version describes how Home Amateur Mechanic magazine, in the early 1900's, published details of how to build the "Home Amateur Mechanic" (HAM for short) radio. Thus, those who built and used these sets became known as HAM radio operators.

A less complimentary explanation is that landline Morse operators used the word to describe inexperienced or poor operators. I have copy of The Telegraph Instructor by G. M. Dodge, proprietor of Dodge’s Institute in Indiana, 4th edn. 1908, for instance, which defines a "ham" (or alternatively a "plug") as a telegraph operator who is not proficient. It has been suggested that the professionals extended this term to apply to the new amateur radio operators who were trying to emulate their skills.

AMATEUR SSB ENHANCER

A recently unveiled amateur radio version of its Link-Plus digital signal processing technology, called the MULE (Multi-Use Link Enhancer), is claimed by Link Plus Corp. of Columbia, Maryland, USA, to eliminate most noise and interference from single sideband voice communications, thus producing a significant boost in effective signal strength.

In 18 separate tests, carried out on three links over a range of conditions, the MULE achieved a 22dB improvement in HF-SSB signal-to-noise ratio. In layman’s terms, this unprocessed signal had, on average, 160 times more noise content than the Link-Plus signal.

The MULE connects to any HF radio by means of external cables, but at $2,995 it is probably beyond the reach of most amateurs at the present time. (W5YI Report)

33,280 Amateur Radio "A" Licences, 27,738 "B" Licences, 46 Novice "A" licences, and 378 Novice "B" licences, representing an increase of 558 in the total number compared with the previous year.

The Radio Investigation Service continued to investigate interference and other problems over the whole range of licensed transmissions covered by the Agency. Four amateurs were prosecuted for interference and convicted for activities contravening the licence regulations, and warning letters were sent to three others.

The Radio Investigation Service, which received 15,537 complaints during 1991/92, confirmed the view of users that CB should continue to be a licensed service and licensing was centralised through SSL. The new arrangements are expected to save some £200,000 which would otherwise have had to be recovered by the licence fee.

As at 31 March 1992, there were 64,944 CB licences on issue compared with 69,803 the previous year. 112 persons were prosecuted and convicted for licence offences and 655 warning letters were sent out. A revised set of CB information sheets has been published and these are available from the Library Service, as above.

An intriguing implication of the licence statistics suggests that if the present trend continues the number of amateur licences next year may well exceed the number of CB licences on issue. This compares dramatically with the situation following the introduction of CB in the UK when the number of licences surged initially to around a quarter of a million.

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- RP13 60 x 60 mm axial
- RP14 70 x 70 mm axial
- RP15 80 x 80 mm axial
- RP16 90 x 90 mm axial
- RP17 100 x 100 mm axial
- RP18 120 x 120 mm axial
- RP19 140 x 140 mm axial
- RP20 160 x 160 mm axial
- RP21 180 x 180 mm axial
- RP22 200 x 200 mm axial
- RP23 220 x 220 mm axial
- RP24 240 x 240 mm axial
- RP25 260 x 260 mm axial
- RP26 280 x 280 mm axial
- RP27 300 x 300 mm axial
- RP28 320 x 320 mm axial
- RP29 340 x 340 mm axial
- RP30 360 x 360 mm axial
- RP31 380 x 380 mm axial
- RP32 400 x 400 mm axial
- RP33 420 x 420 mm axial
- RP34 440 x 440 mm axial
- RP35 460 x 460 mm axial
- RP36 480 x 480 mm axial
- RP37 500 x 500 mm axial
- RP38 520 x 520 mm axial
- RP39 540 x 540 mm axial
- RP40 560 x 560 mm axial
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