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Go to next section

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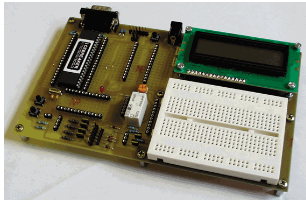
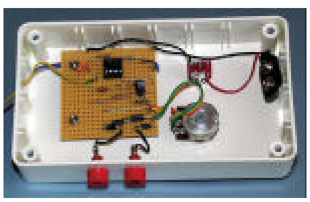
Go to next section

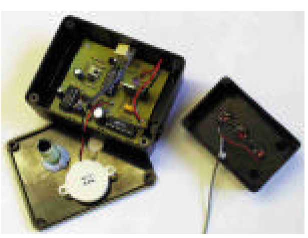
Contents

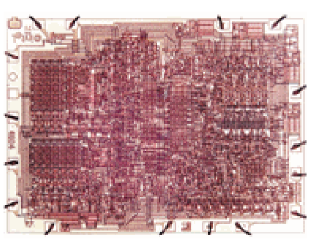


PROJECTS AND CIRCUITS

SERIES AND FEATURES







REGULARS AND SERVICES

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Editorial

BASH, WIND, WIRE

Occasionally a project comes along that makes you realize just how clever some of our modern ICs are. One such project is the Micro-PICscope to be featured next month (see the **Next Month** page for more details). When the editor of the hard copy edition of EPE – Mike Kenward – was an apprentice with the Ministry of Aviation (now MoD), back in the distant past, he built a *Wireless World Oscilloscope* – in those days *Wireless World* (now *Electronics World*) actually published constructional projects.

To build the 'scope they first spent a week "chassis bashing", and they also had to weld up the sides of the aluminum chassis (and if you have ever tried welding aluminum you will know that many of them had to start again when the prized chassis fell into holes under the welding torch!) Then they fitted the transformers, valve bases, switches, potentiometers, tagstrips, and the oscilloscope tube, inside its mu-metal screen; after which they could start wiring it all up. Oh, by the way, they also had to wind their own mains transformer and EHT transformer before we started on the electronics.

By the time the unit was finished it weighed about 10kg and measured around 500mm x 300mm x 250mm, plus the performance was rather limited and it took five minutes to warm up! Now just 30 years on we can do roughly the same thing with two chips and a liquid crystal display (LCD), put it in your pocket, power it from a battery and build it for under 20 UK Pounds. Accepted the performance is very limited and so, too, is the display, but it is a useful little tool for any hobbyist. We expect it to be very popular and there are a couple of other PIC-based items of test gear in the pipeline.

TERRY

We dedicate this issue to Terry Farmiloe, the Typesetting Manager of the printed edition of EPE, who died on Jan. 2nd, aged 61. Terry had a gruff exterior that hid a heart of gold. While his name will not be known to readers, he has been responsible for running the EPE typesetting department, and thus the production of EPE and other publications, for the last 10 years.

Good luck on your onward journey, Terry, we miss you greatly. Our sympathy goes to your loving family.

Clive Maxfield & Alvin Brown

Go to next section

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Next Month

MICRO-PICSCOPE

It's astonishing what opportunities are continuing to be revealed for the recently introduced PIC16F87x series of microcontrollers. The Micro-PICscope is a prime example of a design idea whose implementation was greatly simplified by using one of these devices.

The Micro-PICscope is a handy little item of test gear and of benefit to anyone's workshop. Using an alphanumeric liquid crystal display, it is basically a signal tracer, but one with the great advantage that it shows a representation of the signal waveform being traced. This is shown across eight of the LCD character cells and is a real-time trace of the monitored waveform.

Not only that, the display also shows the frequency of the signal being monitored, and its peak-to-peak voltage. The frequency range covered is basically for audio, but frequencies well to either side of this range can be traced.

Several ranges of control are offered by push-button selection, covering the sampling rate, and synchronization on/off for the 'scope display. The signal input is switchable to provide different maximum peak voltage monitoring ranges. Selection of AC or DC input is provided.

The entire design requires only two ICs, a PIC microcontroller and an opamp, plus a 2-line by 16-character intelligent LCD. Probably the simplest and cheapest 'scope ever.

FLASH SLAVE

Cameras have undoubtedly increased in sophistication over the last ten years or so, with features such as auto-focus and built-in flashguns now being commonplace. On the other hand, a few "standard" features seem to have become rarities that are featured on little more than a few up-market cameras. The humble flash socket certainly falls into this category.

For most users, this lack of an external flash connector is probably of little consequence, but it is a major drawback for anyone wishing to go beyond simple "point and shoot" flash photography. This easy-to-build, inexpensive little unit will fire a secondary flash without any connections to the camera, thus overcoming the problem.

GARAGE LINK

This circuit helps to prevent the garage door (or either door in the case of a double garage having twin doors) being left open all night. It works by establishing a radio link between the garage and some point inside the house. The unit indoors then provides an audible warning in the form of a short bleep every 45 seconds. It could also be used to monitor a range of other things around the home.

Go to next section

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Constructional Project

PARKING WARNING SYSTEM

by TOM WEBB

How to avoid having an unwanted rear entrance to your garage!

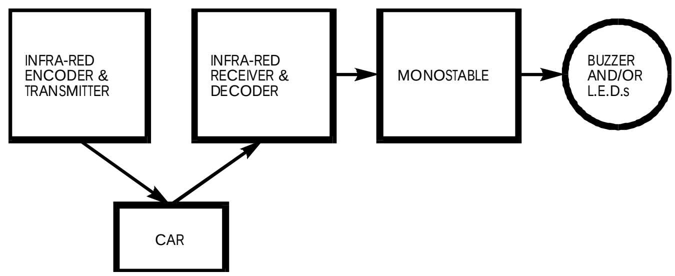

Fig.1. Parking Warning System block diagram.

This is a device to aid you in parkiar in a garage by providing a visual and audible warning. It is easily set up by mounting it onto the wall at the end of the garage.

The device produces a coded infrared (IR) beam which detects the proximity of the vehicle by bouncing IR off it as it approaches, without being confused by other IR sources. When the vehicle is within the preset range, an audible warning is given and a group of light emitting diodes (LEDs) are turned on.

The block diagram in Fig.1 shows how the circuit is split up into separate sections.

INFRARED CODING

A system based on a continuous IR signal would fail in this type of application, since the receiving circuit would be heavily influenced by stray background IR emission from lights etc. A coded IR signal is better since the receiver can be set up to only accept a specific code.

There are a number of encoding and decoding ICs available, but two from Holtek are used for this circuit. The HT12B transmitter encodes the signal and adds a 38kHz carrier signal for greater reliability. A separate demodulating sensor detects the coded signal and provides a clean output waveform with the 38kHz carrier removed. An HT12D decoder then decodes the signal to give a steady output.

CODED TRANSMITTER

Either the HT12A or HT12B transmitter devices may be used in the coded transmission circuit. They work in exactly the same way except the four data outputs of the HT12A are inverted as compared with the HT12B. However, since these outputs are not used in this circuit, this is of no importance.

Referring to the full circuit diagram in Fig.2, pins A0 to A7 of the transmitter IC2 set the coded signal for the IR transmission, which can only be accepted by a decoder chip (IC3 in Fig.2) with the same settings. The printed circuit board is designed so that pins A0 and A1 are connected to the 0V supply line, pins A2 to A7 being left unconnected.

Pin 9 of IC2 is connected to 0V and pin 18 connected to the

Fig.1. Parking Warning System block diagram.

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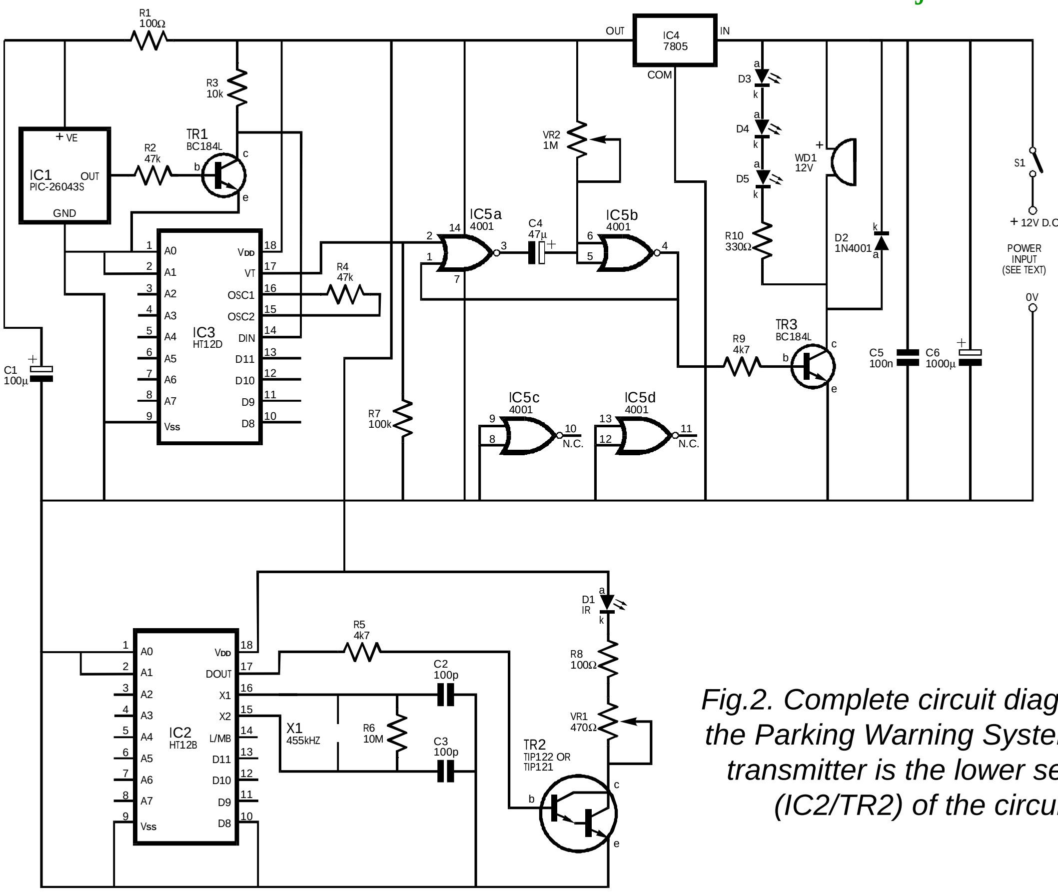

Fig.2. Complete circuit diagram for the Parking Warning System. The transmitter is the lower section (IC2/TR2) of the circuit.

positive supply, which should not exceed +5V. IC2 pins 11 to 14 are not used. The pins labeled X1 and X2 are the oscillator control pins, and require a 455kHz ceramic resonator (component X1) along with resistor R6 and two capacitors, C2 and C3.

The D_{out} pin provides a coded output superimposed on a carrier signal of 38kHz which, with the aid of Darlington transistor amplifier TR2, operates the IR light emitting diode D1.

Potentiometer VR1 allows the transmission power to be varied. Ballast resistor R8 prevents a power supply short circuit through D1 and TR2 when VR1 is set to minimum resistance.

IC2 pin 10 is connected to ground to hold the transmitter perpetually triggered.

INFRARED RECEIVER

The IR sensor/amplifier/demodulator, IC1, is housed in a package resembling a small power transistor. The receiver rejects all IR transmissions except the required 38kHz signal, and provides a clean output (easily viewed on an oscilloscope). There are three possible receivers that perform the functions required, but in tests the best performer for this circuit was the PIC26043S (not a PIC microcontroller!).

When the detector detects a signal having a frequency of 38kHz, its output goes high. Transistor TR1 inverts this level and supplies it to the decoder IC3 at DIN (pin 14).

The code to which IC3 responds is set by its pins A0 to A7. Since pins A0 and A1 on transmitter IC2 are connected to 0V, the same pins on IC3 are also connected to 0V.

Resistor R4 sets the oscillation frequency for IC3 to the required 150kHz. The value is chosen to suit a power supply of between 4·5V and 5V. When IC3 receives a correctly coded signal, its pin 17 (VT) goes high. This triggers the monostable formed by IC5a and IC5b. When the VT pin of IC3 is open circuit (no signal being received), resistor R7 draws the input pin of the monostable to 0V. Once triggered, the monostable's output remains high for a period set by the values of C4 and VR2.

The formula used to calculate this period is T = 0·7 x R x C. With VR2 set to 100kW, the period will be 0·7 x 0·1MW x 47uF = 3·29 seconds.

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COMPONENTS

Resistors
R1, R8 100 ohms (2 off)
R2, R4 47k (2 off)
R3 10k
R5, R9 4k7 (2 off)
R6 10M
R7 100k
R10 330 ohms

Potentiometers
VR1 470 ohm miniature horizontal skeleton preset
VR2 1M miniature horizontal skeleton preset

Capacitors
C1 100u radial electrolytic, 25V
C2, C3 100p (2 off)
C4 47u radial electrolytic, 25V
C5 100n ceramic
C6 1000u radial electrolytic, 25V

Semiconductors
D1 IR diode
D2 1N4001 rectifier diode
D3 to D5 red LEDs (3mm or 5mm)
TR1, TR3 BC184L *npn* transistors (2 off)
TR2 TOP122 (or TIP121) *npn* Darlington transistor
IC1 PIC26043S IR receiver
IC2 HT12B (or HT12A) encoder
IC3 HT12D decoder
IC4 78L05 +5V 100mA regulator
IC5 4001B quad NOR gate

Miscellaneous
S1 s.p.s.t. toggle switch (optional)
WD1 buzzer, 12V
X1 455kHz resonator

Printed circuit board available from the *EPE Online Store*, code 7000258 (**www.epemag.com**); plastic case to suit (2 off, see text); 14-pin DIL socket; 18-pin DIL socket (2 off); connectors for power and LED cables (see text); PCB pillars (4 off); connecting wire, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only **$29**

The output from the monostable, at IC5b pin 4, is fed to transistor TR3 via resistor R9. When the output level is high, TR3 is turned on and drives the warning buzzer WD1 and turns on LEDs D3 to D5. Diode D2 prevents back EMF from the buzzer which might otherwise damage the circuit. R10 is a ballast resistor to limit the current through the LEDs.

POWER SUPPLY

Power to the circuit is intended to be from a 12V mains adapter as the circuit will need to be left switched on for long periods of time. A supply of 12V is required in order to power the buzzer. The power supply is regulated down to 5V by IC4 to suit the rest of the circuit.

If a buzzer is not being used, then diode D2 can be omitted and a supply of 5V (or 4·5V) could be used by inserting a wire link in the place of regulator IC4 (between its In and Out pins). However, in this case, the value of LED ballast resistor R10 should be reduced to about 180 ohms. This also means that batteries could be used as the standby current is less than 10mA.

Capacitors C5 and C6 decouple the power fed to IC4. Capacitor C1 and resistor R1 smooth out the voltage supplied to the receiver device, IC1.

CONSTRUCTION

Apart from the buzzer and LEDs, all the components are contained on a single printed circuit board (PCB). The topside component layout and full size underside copper foil master are shown in Fig.3. This board is available from the *EPE Online Store* (code 7000258) at **www.epemag.com**

Begin construction by soldering in the resistors and the four wire links. Ensure the correct orientation in the PCB for components C1, C4, C6, TR1 to TR3, D1 and D2. Capacitors C2, C3 and C5 may be connected either way round.

Note that on the IR diode, D1, the long leg is likely to be the cathode (k), but check this with the component supplier's catalog.

Infrared receiver IC1 has a "dome" on its sensitive side, which should face outwards from the PCB. Once soldered in, IC1 should be bent back to so that the dome is facing upwards.

Use IC sockets for IC2, IC3 and IC5. Do not insert the dual-in-line (DIL) ICs until construction has been completed and fully checked.

CASING

Two plastic cases will be needed as the LEDs need their own separate case in order to be seen through the rear windscreen of the car.

The circuit board is mounted in its own case on small PCB supports which firmly secure it in place, see Fig.4. Drill holes in the case to suit the positions of the IR receiver and IR diode, see photographs. The hole for the IR receiver should not be too small otherwise the range will be reduced. If maximum range is required then the IR receiver should be positioned right by the hole.

If you prefer to have plugged connections for the power supply input and for the output to the LEDs, suitable holes should also be drilled for their sockets. You also need a hole for the power on/off switch if you decide to use one, although one was not used on the prototype.

Additionally, two holes are required to allow adjustment access to the two preset potentiometers, using a small screwdriver. All holes should be drilled accurately to correspond

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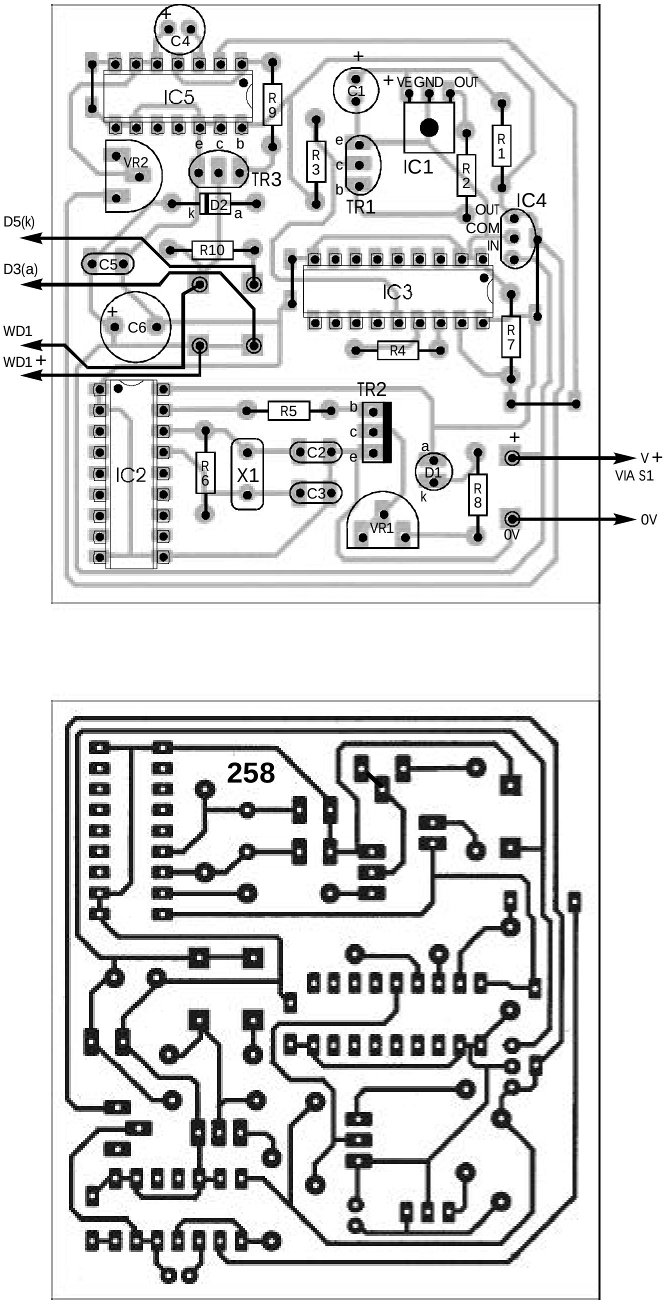

Fig.3. Printed circuit board topside component layout and (top right) approximately full-size underside copper foil master.

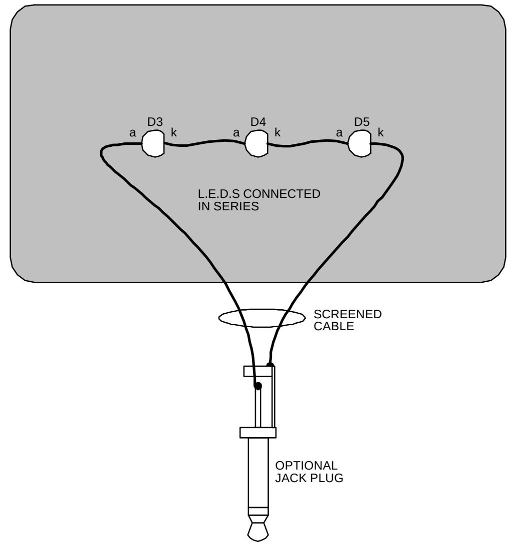

Fig.4 (below). Wiring from the circuit board to the optional LED jack socket and power connector.

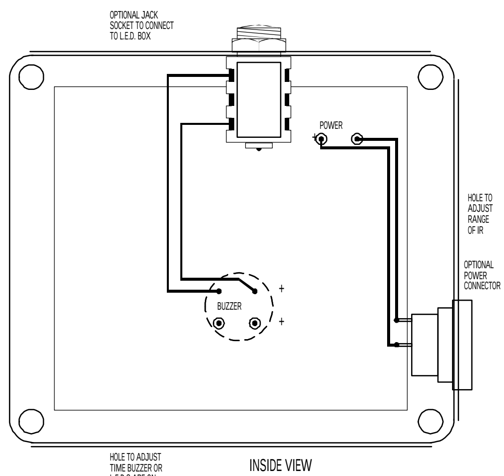

Fig.5 (above). The LEDs mounted in a separate case and connected via screened cable and jack plug to the

with their respective components.

The LEDs mounted in their separate case can be connected to the circuit using single screened wire, as shown in Fig.5.

TESTING

The first check is to make sure the voltage regulator IC4 is the correct way around. Connect the circuit to the 12V power supply and then check that 5V is present on the output pin of IC4. If it is, then disconnect the power and insert the remaining chips, correctly orientated.

Testing of the IR modules presents a problem as if one doesn't work then the other will seem not to be working as well. If in doubt use a voltmeter or oscilloscope as follows:

Test the voltage on the VT pin (pin 17) on IC3 of the receiver module. It should

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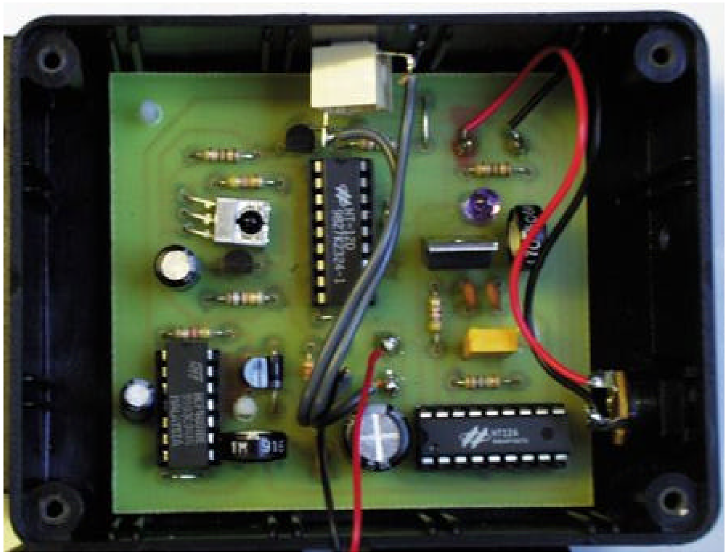


Completed circuit board mounted inside its box.

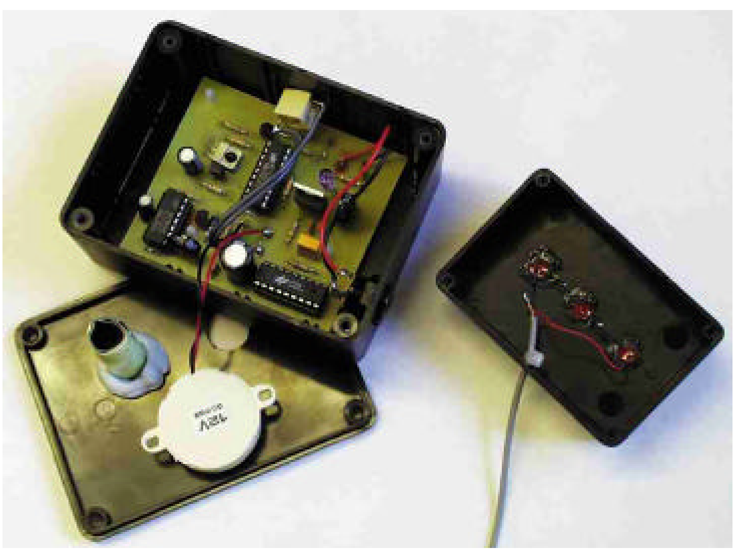
normally be at 0V but change to about 5V when a signal is received. Now check the voltage on the pins of IC1. Pin 3 should be at 5V and pin 2 at 0V. When a signal is not being received, pin 1 (the output pin) should be at just under 4V. When a signal is received this voltage should fall by about 1V.

Note that as the signal is oscillating, a voltmeter provides a rather approximate guide to voltage. If an oscilloscope is available it should be possible to view the encoded signal, in which case the trace will rise and fall between 4V and 0V. If this test fails then try sending a signal from a TV remote control unit. The signal will not be decoded, but you will at least know if the receiver IC is working, and hence determine if the fault lies in the transmitter or receiver or both.

If the output from IC1 is working, test the signal at pin 14 (Din) of IC3 on the receiver module. It should be at about 0V when no signal is received, rising to about 1·3V (as seen on a voltmeter) when a signal is received. Again, an oscilloscope will show that the signal actually pulses to about 5V.

If the VT pin on the receiver is working then simple voltmeter tests should establish the position of any other faults.

If the circuit is triggered straight away then IC1 may be receiving IR straight from the IR diode D1, through stray reflection inside the case. If this happens the transmitter should be surrounded by a rolled piece of black card.



The transmitter/receiver case and the smaller LED box with their lids removed. Note the "tube" of black card to stop stray reflections from reaching the IR receiver chip.

SETTING UP

The presets VR1 and VR2 can be adjusted to suit the user's own particular needs. The following is a summary of their functions:

VR1: Adjusts the range of the IR beam by decreasing or increasing the power going through IR diode D1. Reducing the resistance extends the range.

VR2: Sets the time the buzzer and LEDs stay on by controlling how much recharging current is input to the monostable. Reducing the resistance reduces the time.

COMMON PROBLEMS

Typical mistakes include dry joints and bridged pads, i.e. adjacent pads accidentally

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joined together with solder. Other problems include failure to insert wire links. Also check that the components are correctly placed, and the correct way round. Note again that some IR LEDs are unusual in that the longer lead denotes cathode (k).

IN USE

Completed remote LED warning box.

This Parking Warning System should be set up with the IR sensors lining up with the extremity of the car, e.g. bumper. The LED box should be positioned so as to be seen through the rear windscreen. The time the LEDs and buzzer are on, and the range of the IR can easily be changed using a screwdriver to adjust the presets VR1 and VR2.

Go to next section

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HIGH PERFORMANCE REGENERATIVE RECEIVER

by RAYMOND HAIGH

Provides continuous coverage from 130kHz to 30MHz. Capable of receiving broadcast and amateur stations from around the world.

ORIGINS OF REGENERATION

Almost a hundred years ago, scientists and engineers in Europe and America were trying to develop more sensitive circuits for the reception of radio signals.

C. S. Franklin in England and A. Meissner in Germany were both working on similar lines, but the credit for discovering the benefits of applying positive feedback to a tuned circuit is generally attributed to that great American radio pioneer, E. H. Armstrong. Known as "regeneration", the technique produces a truly dramatic increase in receiver sensitivity and selectivity.

Armstrong filed his patent in October 1913, just two months before his 23rd birthday. At this amazingly young age he had pushed forward the frontiers of technology and made man's dream of long-distance radio reception a reality.

HOW IT WORKS

Tuned circuits, formed by an inductor (coil) and a capacitor, are crucial to the working of radio receivers. By varying one of the components (usually the capacitor), the circuit can be tuned to resonate at a particular frequency.

This combination magnifies a signal to which it is tuned. The degree of magnification is dependant on the quality of the tuned circuit, and this is defined by a figure of merit known as the *Q*-factor. A figure of 100 is common. If a signal of 1mV is applied to a tuned circuit with a "*Q*" of 100, a voltage of 100 x 1mV, or 0·1V will be developed across it.

Armstrong (and others) discovered that, by connecting a triode valve to the tuned circuit and feeding back a tiny portion of the amplified signal to the coil, its *Q* can be dramatically increased. By this means, *Q* factors of several thousand can be achieved before the onset of oscillation, and the wanted signal is greatly amplified.

It is this phenomenon which imparts such a high degree of sensitivity and selectivity to simple regenerative receivers.

POPULARITY

Regenerative radio sets were produced in large numbers throughout the 'twenties. Skill is required to get the best out of radios of this kind: in particular, the regeneration control has to be carefully adjusted when receiving weak signals. Largely because of this, the easily operated superhet (also invented by Armstrong) began to challenge the popularity of the regen' in the 'thirties.

During the Second World War, Germany manufactured regenerative sets for military use, and the British incorporated circuits of this kind into clandestine transceivers. Manufacture for domestic

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listeners continued almost to the end of the valve era, with Ever-Ready producing a two-valve battery-operated set (their *Model H*) during the 'fifties.

AVOIDING PROBLEMS

Regenerative receivers are easily overloaded by powerful signals. They are also affected by aerial characteristics.

When an aerial system, which is directly connected to the tuned circuit, is resonant at the reception frequency (or a harmonic), it absorbs energy and inhibits regeneration. Known as "suck-out", the phenomenon manifests itself as dead spots in the tuning range.

Overload and "suck-out", together with an erratic feedback control, can ruin the performance of regenerative radios. They are avoided in this design.

WAVE TRAP

Powerful local radio transmitters can swamp regenerative receivers (they even cause problems with superhets of advanced design). The answer to this is the inclusion of what is known as a "wave trap".

An inductor L1 and capacitor C1 form a parallel tuned circuit, which presents a high impedance at resonance, see Fig.1. When the inductor/capacitor combination is set to the frequency of the offending transmitter it blocks it out.

The problem is invariably encountered on Medium Waves, and suitable component values to tackle this problem, should it arise, are scheduled in Table 1.

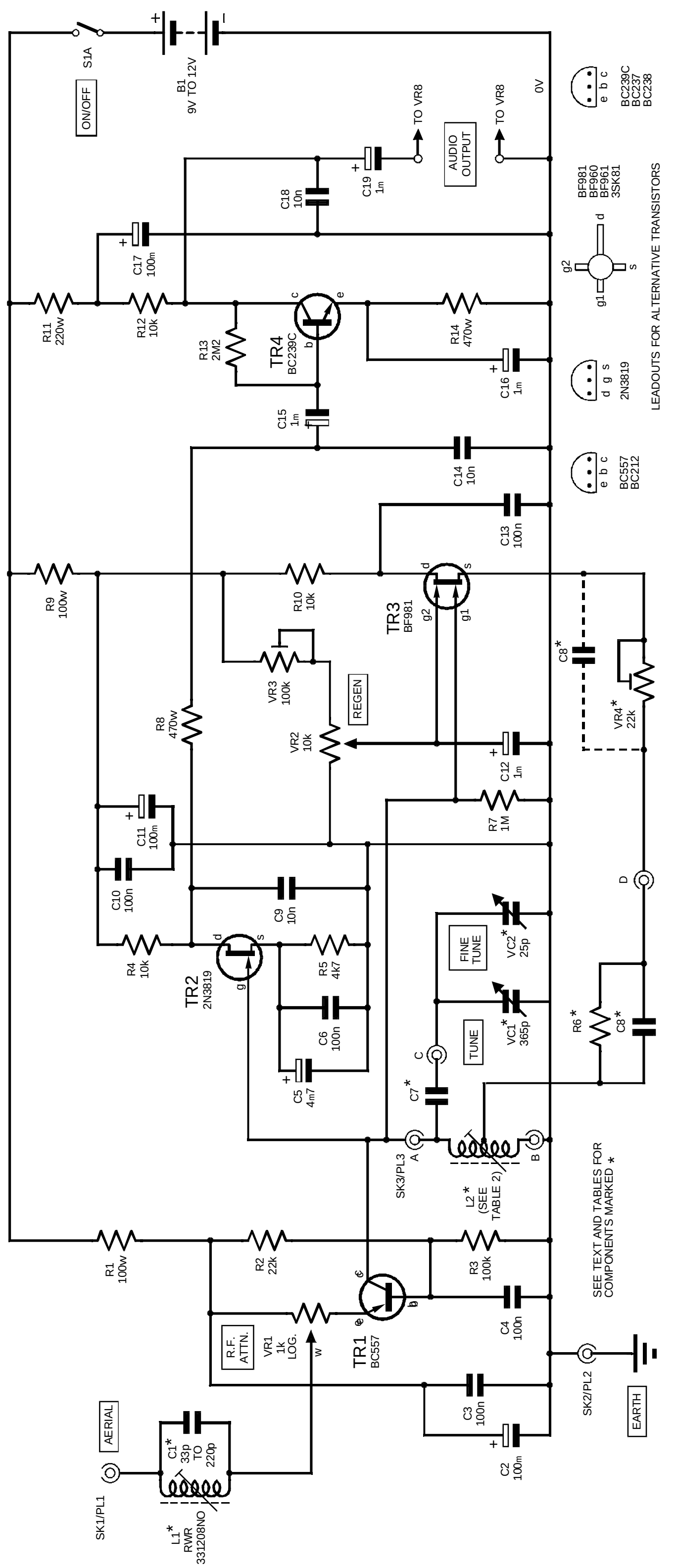

Fig.1. Circuit diagram of the High Performance Regenerative Receiver.

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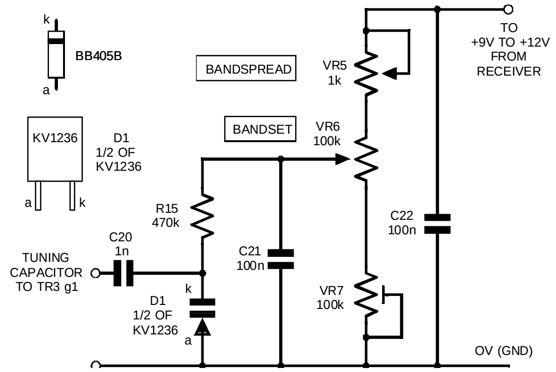

Fig.2. Alternative electronic tuning system. For fine tuning only, delete VR5 and C22, use a BB405B varicap diode, and

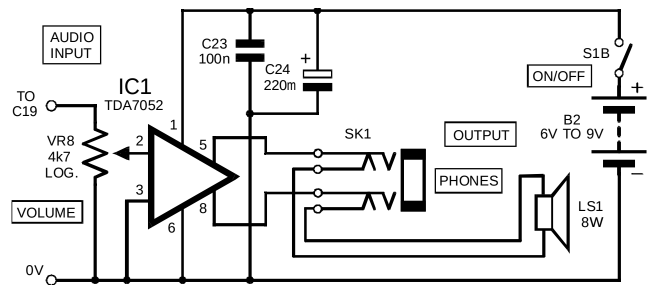

Fig 3. The audio power amplifier stage.

C1 pF	Frequency (kHz) at max inductance (core fully in)	Frequency (kHz) at min inductance (core fully out)
33	1300	1700
47	1100	1400
68	900	1200
120	700	900
220	550	700

CIRCUIT DETAILS

The circuit diagram of the High Performance Regenerative Receiver is shown in Fig.1. Grounded-base transistor, TR1, acts as a radio frequency (RF) amplifier. Whilst its most important function is to isolate the regenerative stage from the aerial, it also provides a useful amount of gain.

Signal input is fed to the emitter (e) of TR1, and potentiometer VR1 acts as an attenuator: an essential feature that prevents overload on strong signals. Bias is fixed by resistors R2 and R3, and C4 is the base (b) bypass capacitor. The RF stage is decoupled from the supply rail by R1, C2, and C3.

The output impedance of a grounded-base stage is high enough for TR1 to be connected directly to the tuned circuit, and the use of a *pnp* device enables its collector (c) to be taken to supply negative via the coil L2.

DETECTOR

Old valve receivers invariably combined the functions of signal detection and regeneration (or *Q* multiplication) in a single stage. With the use of transistors, better results, without recourse to specially designed coils, can be achieved by separating them.

Field effect transistor TR2, biased by resistor R5 into the non-linear region of its characteristic curve, functions as a sensitive, drain-bend detector.

Source decoupling at RF and audio frequencies (AF) is provided by capacitors C5 and C6. The output of TR2 is developed across drain load resistor R4 and C9, R8 and C14 remove residual RF.

Q-FACTOR

Dual-gate MOSFET TR3 provides the modest amount of RF gain required for regeneration or *Q* multiplication. Arranged as a Hartley oscillator, feedback from TR3 source (s) is connected to a tapping on coil L2, via bias components resistor R6 and capacitor C8. *(Hartley oscillators were introduced in detail in the July 1999 installment of our six-part series on oscillators. For more details bounce over to* ***www.epemag.com/frmoscii.htm****, Ed.)*

Preset potentiometer VR4 is included on the printed circuit board (PCB) for use during the setting-up process, after which it is shorted out and replaced by fixed resistor R6. Bypass capacitor C8 assists regeneration when the feedback winding is comparatively small. It is not required on all coil ranges.

Feedback, or regeneration, is controlled by potentiometer VR2, which adjusts the voltage on gate 2 of TR3, thereby varying its gain. Preset VR3 fixes the range of control, capacitor C12 decouples gate 2 and eliminates potentiometer noise, and resistor R10 and capacitor C13 decouple the stage from the supply rail.

When the tuning coil L2 is removed for band changing, the signal gates of TR2 and TR3 are kept at 0V by resistor R7.

TUNED CIRCUIT

The receiver is tuned by inductor (coil) L2 and variable capacitors VC1 and VC2. The

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COMPONENTS

Resistors
R1, R9 100 ohms (2 off)
R2 22K
R3 100k
R4, R10, R12 10k (3 off)
R5 47k
R6 various values (see text and Table 2 next month)
R7 1M
R8, R14 470 ohms (2 off)
R11 220 ohms
R13 2M2
*R15 470k
All 0.25W 5% carbon film

Potentiometers
VR1 1k rotary carbon (logarithmic law if obtainable)
VR2 10k rotary carbon, linear
VR3, *VR7 100k enclosed horizontal preset (2 off)
VR4 22k enclosed horizontal preset
*VR5 1k rotary carbon, linear
*VR6 100K rotary carbon, linear
VR8 4k7 rotary carbon, logarithmic

Capacitors
C1 axial polystyrene, See Table 1
C2, C11, C17 100 uF radial electrolytic (3 off)
C3, C4, C6, C10, C13, *C21, *C22, C23 100nF disc ceramic (8 off)

Capacitors (continued)
C5 4u7 radial electrolytic
C7 axial polystyrene, see text and Table 2 (next month)
C8 ceramic, see Table 2 (next month)
C9, C14, C18 10n disc ceramic (3 off)
C12, C15, C16, C19 1u radial electrolytic (4 off)
*C20 1n (1000p) or 50p polystyrene (see Fig.2)
C24 220uF radial electrolytic
VC1 365p Jackson O-type air-spaced tuning capacitor (see text)
VC2 25p Jackson C804-type air-spaced tuning capacitor (see text)
All capacitors 12V working or greater

Semiconductors
*D1 KV1236, KV1235, or BB405B varicap diode (see text)
TR1 BC557 *pnp* silicon transistor
TR2 2N3819 *n*-channel field effect transistor
TR3 BF981 *n*-channel dual-gate MOSFET
TR4 BC239C *npn* silicon transistor
IC1 TDA7052 low voltage 1W power amplifier

See also the SHOP TALK Page!

Miscellaneous
L1 RWR331208NO inductor (TOKO), only required if "wave trap" is needed (see text)
L2 tuning band coils (TOKO), (8 off) see text and Table 2 (next month)
PL1 to PL8 9-pin D-type plugs for L2 (8 off) see Table 2 for other components
S1 d.p.d.t. toggle switch
SK1, SK2 screw terminal post (Aerial and Earth)
SK3 9-pin D-type socket (for plug-in tuning coils)
SK4 switched stereo jack socket
B1 9V to 12V battery pack
B2 6V to 9V battery pack

Printed circuit boards available from the *EPE Online Store*, codes 7000254 (receiver), 7000255 (Electronic Tuning), and 7000256 (Amplifier); 9-pin D-type plugs (8 off for tuning coils); aluminum or diecast box; 8-pin DIL socket; plastic control knobs (4 small, 1 large); reduction drive for tuning capacitor; multistrand connecting wire; card for tuning dial; nuts, bolts, washers, and stand-offs; solder pins, solder, etc.

Note: All components marked with an asterisk (*) are for the optional electronic tuning system.

Approx. Cost Guidance Only ***(Excluding batteries and tuning capacitors)*** **$56**

larger of the two capacitors, VC1, acts as a coarse (Bandset) tuning control. The smaller one, VC2, provides fine (Bandspread) tuning. These components are discussed later. Fixed capacitor C7 limits the maximum value of VC1 on the shortwave ranges. The reduced swing makes tuning less critical and consistent regeneration easier to achieve.

Details of the coverage obtained with a range of Toko coils, together with the associated values of C7, R6, and C8, are given in Table 2 (next month).

AUDIO AMPLIFIER

The base (b) and emitter (e) bias of audio amplifier, TR4, are fixed by resistors R13 and R14. Signal output is developed across collector (c) load resistor R12; and R11 and C17 decouple the stage from the supply.

The low value of emitter bypass capacitor C16 results in gain-reducing negative feedback at the lower audio frequencies. This improves clarity. Coupling and DC blocking capacitors C15 and C19 have a low value for the same reason.

Response to the higher audio frequencies is curtailed by capacitor C18. Constructors who find the tone too “bright” should increase the value of this component to 47nF or 100nF.

ELECTRONIC TUNING

The use of a separate *Q*-multiplier stage (TR3) makes the receiver tolerant of electronic tuning. (The somewhat modest *Q* of high capacitance varicap diodes inhibits the operation of most regenerative sets).

A suitable, add-on, electronic tuning circuit is given in Fig.2. Potentiometer VR6 controls the reverse bias on varicap diode D1 and varies its junction capacitance. This forms the coarse, or Bandset, tuning control.

Potentiometer VR5 permits a small adjustment of the bias

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voltage, and acts as the fine, or Bandspread, control. Preset VR7 fixes the lowest level the bias voltage can fall to, thereby determining the maximum value of the tuning capacitance. (Diode junction capacitance increases as the reverse bias is reduced.)

The varicap diode D1 is coupled into the main circuit via DC blocking capacitor C20 and resistor R15 isolates the signal path from the potentiometer chain. Potentiometer noise is prevented by capacitors C21 and C22.

High value varicap diodes have a relatively large minimum capacitance, and an additional coil may be needed in order to secure continuous coverage. Furthermore, performance above 20MHz or so is not quite as satisfactory as that afforded by a traditional variable capacitor.

These disadvantages do not apply when the electronic tuning circuit is used with a VHF diode solely to provide fine tuning (VR5 is omitted and the top end of VR6 is connected directly to the positive supply rail). This arrangement has the advantage of low cost and conveys a freedom to locate the DC operated Bandspread control in a position remote from the tuned circuit. The prototype Receiver, shown in the photographs, incorporates this arrangement.

POWER AMPLIFIER

The circuit diagram of the additional, single chip, audio power amplifier stage is given in Fig.3. This amplifier has its own 6V to 9V power supply to avoid any possible interaction with the receiver section. Designed around a TDA7052 low voltage power amp IC, the only external components are capacitors C23 and C24 which ensure the stability of the device. Potentiometer VR8 acts as the volume, or AF gain, control.

The power amplifier IC1 is short-circuit protected, requires no heatsink and can deliver a clean 1W of audio into an 8 ohm speaker with a 6V supply. It is also claimed that there are no switch-on or switch-off clicks with this device.

POWER SUPPLIES

Current drain is extremely modest, being only 2mA for the radio section and 50mA for the power amplifier when it is delivering a good speaker volume (5mA when ’phones are used).

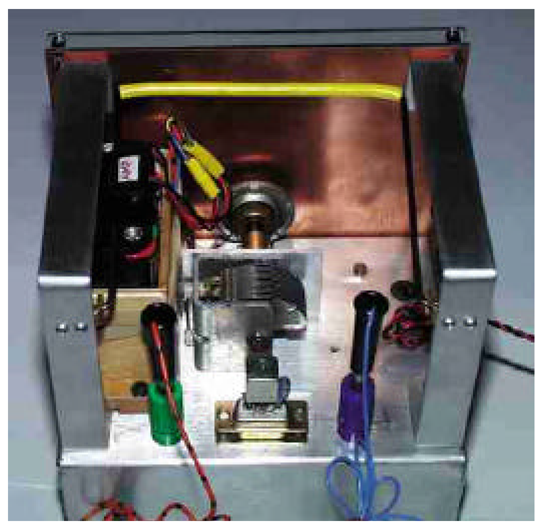
Battery supplies are, therefore, eminently suitable, and any possibility of hum and interference from the mains is avoided (regenerative receivers are very susceptible to this and require a carefully designed supply unit when they are mains powered).

The power amplifier current swings between 6mA and 60mA or more when it is being driven hard. The resulting supply voltage fluctuations would disturb the operation of the *Q*-multiplier, despite heavy decoupling.

Separate battery supplies for the Receiver and Power Amplifier sections are, therefore, strongly recommended. They are essential when electronic tuning is adopted. A double-pole toggle switch, S1a and S1b, connects the two separate battery packs into circuit.

COMPONENTS

Before we commence construction, a few words now on choice of components may help. Readers are also directed to our **Shoptalk** page for details of possible suppliers for some off those “hard to find” items.



The chassis of the prototype was fabricated from aluminum and a wooden case with hinged lid holding the loudspeaker made to house the receiver. The lid can be raised and held up by a hinged wire frame (shown above) when in use.

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Coils

All of the inductors used in this Receiver are from the Toko range. Their frequency coverage is shown in Table 1 and Table 2 (next month) together with suitable tuning capacitor values.

Coils can also be hand wound. As a very rough guide, when 20mm to 25mm diameter formers are used, feedback tappings should be about 10 turns up from the "earthy" end on Long waves, 5 turns on Medium waves, and 2 or 3 turns on Shortwaves.

Transistors

Transistor types are not critical. The *Q*-multiplier circuit works well with a range of dual-gate MOSFETS, including the 40673 and the MFE201. The 3N201 was not tried, but it should prove satisfactory.

A 2N2905 *pnp* transistor worked well in the RF stage, and a 2N5827 or a 2N5828 should be suitable for TR4.

The alternative devices mentioned here have different case styles to those depicted in Fig.1, and the lead-outs must be checked.

Tuning Capacitors

A Jackson 365pF O-type air-spaced tuning capacitor is the preferred component for bandset control VC1, and a 25pF Jackson C804 type is ideal for VC2, the Bandspread control. If this latter value produces a bandspread tuning rate which is too fast, connect a 10pF or 5pF polystyrene capacitor in series with it to reduce its swing.

Inexpensive, polythene dielectric variables, of the kind used in transistor portables, can also be used. Some of these have comparatively low values, and both sections may need connecting in parallel to obtain the required tuning range. (A swing of at least a 10pF to 200pF is needed to give continuous coverage from 150kHz to 30MHz with the coils listed in Table 2). The 25pF FM tuning section of one of these capacitors can act as the bandspread control VC2.

If salvaged tuning capacitors are used, make sure that they are clean and dry, that the rotor contacts are satisfactory, and that the vanes are not shorting.

Varicap diodes are retailed by a number of suppliers and should not be too hard to find. Any 450pF varicap designed for 9V bias, should be suitable for full electronic tuning.

NEXT MONTH

In Part 2 next month we'll go over the constructional details for this project.

Go to next section

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Constructional Project

AUTOMATIC TRAIN SIGNAL

by ROBERT PENFOLD

An easy-to-build, low cost starter project for your model radio system.

This very simple project, suitable for beginners, is a two-color (red/green) signal for a model railway. It uses a simple form of automatic operation, and if you stop the train in front of the signal it automatically switches from "green" to "red". When the train is restarted the signal automatically switches to "green" again.

To an onlooker it appears as though the signal is changing color and the train is responding to the change. In reality the train and the signal are both responding to changes in the track voltage. The signal will, in fact, go to "red" wherever the train is stopped on the layout, but this is of no practical importance, as the state of the signal is irrelevant except when the train is approaching it.

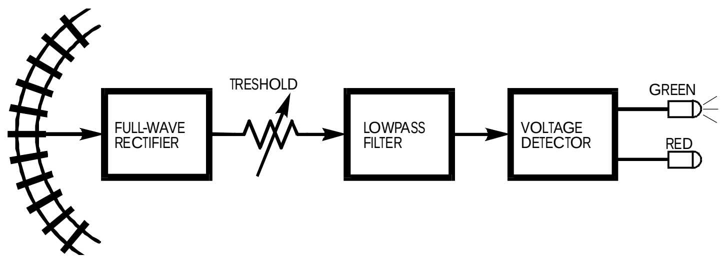

Fig.1. Block diagram for the Automatic Train Signal.

SYSTEM OPERATION

The block diagram of Fig.1 helps to explain the way in which the *Automatic Train Signal* functions. The voltage from the track is fed to a full-wave rectifier circuit. The voltage on the track is a DC signal, but its polarity depends on the direction of the train.

To operate the main circuit reliably it is important that the input signal has the correct polarity, and the purpose of the rectifier is to ensure that the main circuit is fed with a positive signal regardless of the train's direction. The output of the rectifier is fed to a potentiometer that enables the output voltage to be reduced. This enables the user to adjust the threshold voltage at which the signal changes state.

The threshold level used is not critical, but the signal should not go to red while the train is still moving. On the other hand, some types of train controller never produce an output level

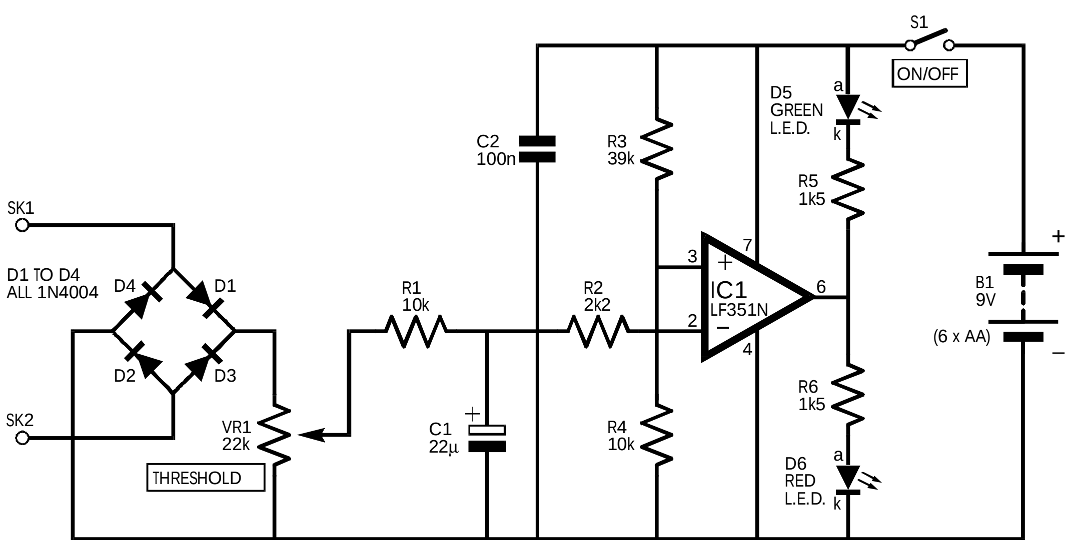

Fig.2. Complete circuit diagram for the Automatic Train Signal

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that is right down at zero volts, and the threshold level must be high enough to ensure that the signal does go to red when the train stops.

It cannot be safely assumed that the signal across the tracks is a steady DC potential. The motor in the train is likely to introduce large amounts of noise onto the track voltage, which might not be a simple DC signal anyway. Many train controllers use some form of pulsed output signal, where the motor is controlled by varying the average output signal. Others use the rectified but non-smoothed output from a mains transformer.

In order to avoid problems with noise on the input signal, and to accommodate pulsed controllers, the output from the threshold control is fed to a low-pass filter. This provides a reasonably smooth DC output signal at a potential that is equal to the average input voltage.

Finally, this signal is applied to a simple voltage detector circuit. With an input voltage of up to about 1·8V the detector circuit activates the red signal LED, but with higher input potentials it switches on the green LED instead.

CIRCUIT OPERATION

The full circuit diagram for the Automatic Train Signal is shown in Fig.2. The voltage from the rail tracks is connected to sockets SK1 and SK2, which feed into a full-wave bridge rectifier (D1 to D4). The positive DC output signal from the rectifier circuit is fed to a volume control style variable attenuator (VR1) and then to a simple low-pass filter comprised of resistor R1 and capacitor C1.

The cut-off frequency of this filter is low enough to ensure that there are no problems with flickering of the signal lights when the track voltage is near the threshold level. On the other hand, it is not so low that the unit is slow responding to changes in track voltage.

An operational amplifier, IC1, is used here as a voltage comparator. Resistors R3 and R4 form a potential divider that biases the non-inverting input of IC1 (pin 3) to about 1·8V. The output of IC1 at pin 6 will go high if the inverting input (pin 2) is taken below this potential, or low if it is taken above the reference level.

The voltage fed to the inverting input will be very low with the train stationary, sending the output of IC1 high. As a result red LED D6 is switched on, but green LED D5 is switched off.

When the train is started, the voltage fed to the inverting input rises, and eventually becomes greater than the reference level at the non-inverting input. The output of IC1 then switches to the low state, switching off D6 and switching on D5. Things revert to their original states when the train is stopped again, with the red LED switched on.

COMPONENTS

Resistors
R1, R4 10k (2 off)
R2 2k2
R3 39k
R5, R6 1k5 (2 off)
All 0.25W 5% carbon film

Potentiometer
VR1 22k rotary carbon, linear

Capacitors
C1 22u radial electrolytic, 25V
C2 100n ceramic

Semiconductors
D1 to D4 1N4004 rectifier diodes (4 off)
D5 green LED, 3mm or 5mm diameter (see text)
D6 red LED, 3mm or 5mm diameter (see text)
IC1 LF351N opamp

Miscellaneous
B1 9V battery pack (6 x AA cells in holder)
S1 s.p.s.t. miniature toggle switch
SK1, SK2 4mm socket (2 off)

Medium size plastic case (see text); 0.1 inch pitch stripboard, size 20 holes x 20 strips; 8-pin DIL socket; control knob; PP3 battery clip; multistrand connecting wire; single-sided solder pins, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only (Excluding Batteries) **$11**

ON TRACK

The current consumption of the circuit is about 7mA. A PP3 size battery is just about adequate to supply this, but a battery pack consisting of six AA size cells in a holder will provide cheaper running costs.

Operation from a mains power supply unit is made slightly awkward by the fact that neither supply rail can be earthed. This is

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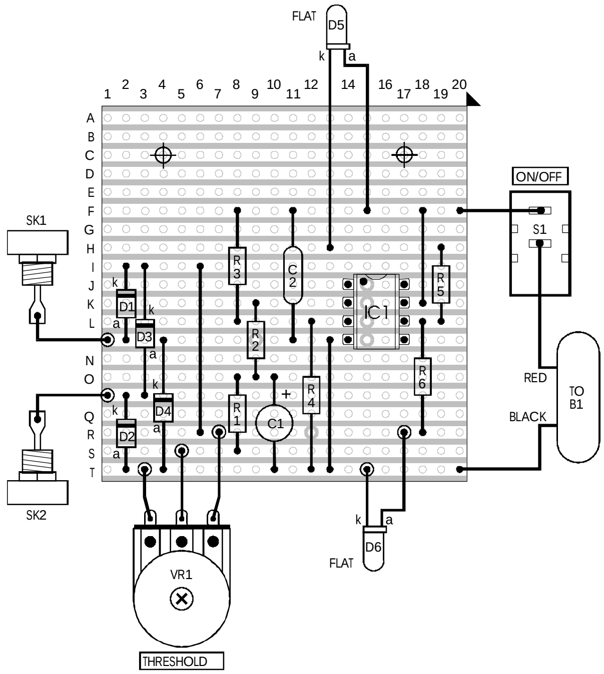
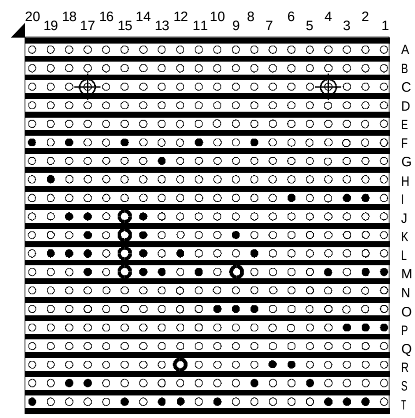


Fig.3. Stripboard component layout, interwiring to off-board components and details of breaks required in the underside copper strips.



because one of the input lines might be earthed, and neither of these lines connects to a supply rail of the signal circuit.

Earthing one rail of the signal circuit could produce an unwanted connection that would prevent the unit from working, and could result in a heavy current flowing through the input rectifier circuit. The most practical solution is to use a 9V or 12V regulated battery eliminator. These use double insulation and have neither supply rail earthed.

CONSTRUCTION

The Automatic Train Signal circuit is built up on a piece of stripboard containing 20 holes by 20 copper tracks. The component layout, together with details of breaks required in the copper strips, is shown in Fig.3.

Construction follows along the normal lines with a standard size board being cut down to the correct size using a hacksaw. Next drill the two mounting holes, which have a diameter of 3mm and accept Metric M2·5 mounting bolts. There are just six breaks in the copper strips. These can be made using a special tool or by using a small hand-held twist drill bit of about 5mm diameter.

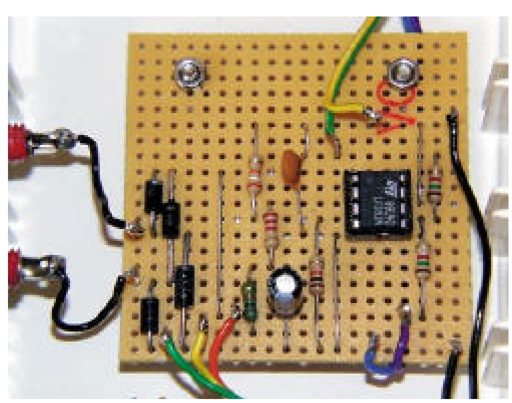
The board is now ready for the components and the three link-wires to be added. It is generally considered best to start with the small components and work up to the largest, but in this case the components are all quite small.

It is probably best to work across the board methodically, being careful to get everything in the right place. In the cases of IC1, C1, and the four rectifier diodes (D1-D4) you must also be careful to fit them the right way round. The LF351N used for IC1 is not a static sensitive component, but as with any DIL integrated circuit it is still advisable to mount it on the board via a holder.

It might be possible to make the link-wires using the wire trimmed from the resistor leads, but one or two of them might be too long to permit this. They will then have to be made from 22s.w.g. or 24s.w.g. tinned copper wire. Fit single-sided solder pins at the points where connections will be made to the controls, LEDs, and sockets.

CASING UP

If the unit is powered from a PP3 size battery it should be possible to fit it into practically any small plastic box. A medium size case about 150mm or so long will have to be used if an AA battery pack is to be accommodated.



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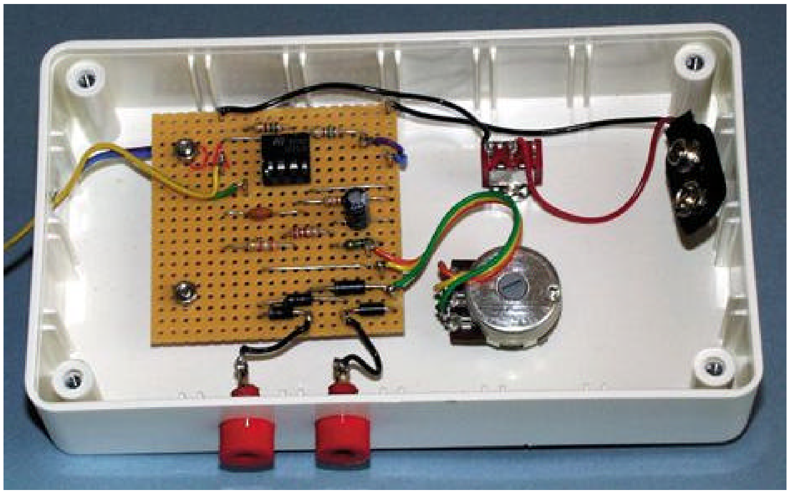

Layout of components inside the small plastic box. Note, the input sockets must be fed with the track voltage.

Threshold control VR1 and On/Off switch S2 are mounted on the front panel, while input sockets SK1 and SK2 are mounted on one side or at the rear of the case, see photographs. An exit hole for the lead to the signal LEDs is required in one side or the rear of the unit.

The circuit board is mounted in any convenient space, and it is advisable to use some extra nuts or short spacers between the board and the case. This avoids any tendency for the board to buckle and break when the mounting nuts are tightened.

To complete the main unit the hard wiring is added. This is all shown in Fig.3 and is perfectly straightforward.

SIGNAL BOX

Construction of the "signal" is left to the ingenuity of individual constructors. At its most basic the signal can just consist of a very small plastic box for the two LEDs. However, it should not be too difficult to fabricate a more convincing signal from balsa wood, bits of dowel, etc. Provided you know what you are doing, it would probably be possible to adapt a ready-made signal "tower" to work with this circuit.

The size of the signal must be varied to suit the gauge of the model railway, as must the size of the two LEDs. For the usual smaller gauges 3mm diameter LEDs are the best choice, but for larger gauges 5mm types would be better. The LED current is not very high, so "high brightness" types are preferable.

Unlike filament bulbs, LEDs will only work if they are connected with the correct polarity. Having the cathode (k) lead slightly shorter than the anode (a) lead is the normal way in which the polarity of a LED is indicated. There may also be a "flat" on the cathode side of the encapsulation.

TESTING

Input sockets SK1 and SK2 must be fed with the track voltage, and the way in which this is done must be varied to suit the equipment with which the signal is used. In most cases the easiest way is to make up a twin lead fitted with 4mm plugs to connect to SK1 and SK2, and small, insulated covered, crocodile clips at the other end. The power connectors on the track are often quite crude, and will permit power to be tapped off using the crocodile clips.

Alternatively, by simply leaving some bare wire at the ends of the leads it might be possible to make connections to the screw or spring connectors on the train controller, being careful to leave the connections to the track intact. Failing that, it will be necessary to make up a dual supply lead to enable both the signal and the track to be fed from the controller.

With Threshold control VR1 at a roughly middle setting the signal should work quite well, with "red" and "green" signals being obtained when the train is respectively stopped and running fast. The signal will probably be at "red" when the train moves very slowly, or possibly at "green" when the train has stopped. A little experimentation with various settings for VR1 should soon get the signal switching

Go to next section

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Constructional Project

EPE ICEBREAKER by MARK STUART

A real-time PIC In-Circuit Emulator (ICE), programmer, debugger, and development system

This project combines Microchip's MPLAB development software with the advanced self-debugging features of the latest PIC chips. The result is a user-friendly advanced development system for a very low cost.

DEVELOPMENT SYSTEMS

Developing projects with microcontrollers is extremely interesting, especially the ability to alter the way hardware responds just by making simple changes to program code.

The problem is that each change of code has to be written, compiled (converted into suitable form for loading) and programmed into a chip before it can be tested. Several low cost systems – such as the *EPE PICtutor* are available (see our web page at **www.epemag.com** for more details) and are adequate for the development of simple programs, but for larger changes and programs it can be tedious, and errors are almost as easy to introduce as to eliminate.

Better methods of testing programs rely on more advanced software that can "run" in a virtual chip on a PC screen and advanced hardware which communicates with the program in the PC, reads input pins, and switches output pins to match the levels of the virtual chip. Such a system is called an In-Circuit Emulator or "ICE" and professional systems are available for practically every type of microcontroller.

The problem with this is cost. A professional ICE for the PIC series of chips costs a reasonable 2000 UK Pounds or so – not a lot if you are a professional programmer being paid twice that each month – but more certainly enough to make your eyes water if you are an amateur!

Just lately a new type of development system has appeared called In-Circuit Debugging (ICD). This requires a chip with special built in hardware (known as a "Background Debugger") and software which can communicate its status via a serial link.

The chip is fitted to its working printed circuit board (PCB) and all external hardware is connected and active. Code is then programmed, run, and debugged under PC control, until it is running correctly. For Microchip PIC users, the good news is that the PIC16F877 and its close relatives the '876, '874, and '873 have built in ICD facilities and can be used to develop

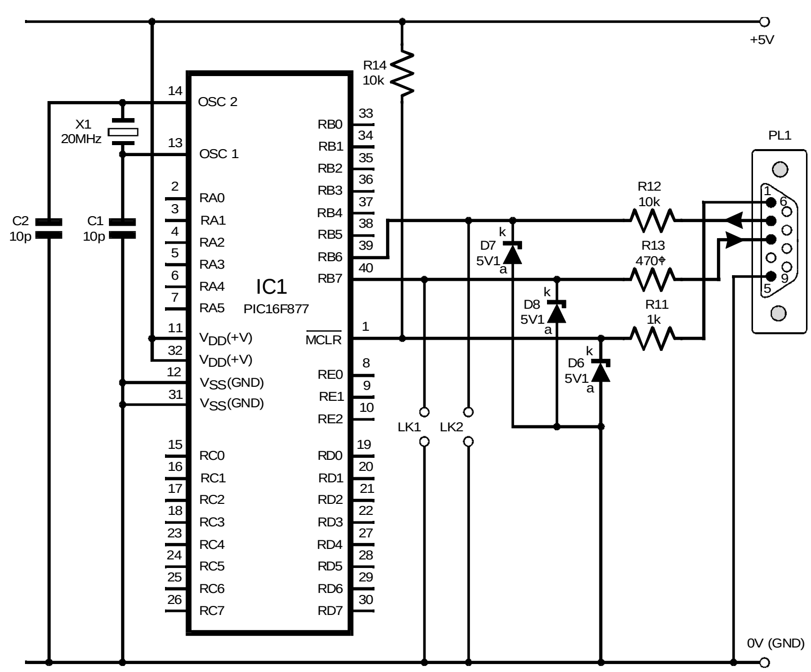

Fig.1. Minimum circuit for using the PIC16F877 as a "background" debugger.

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code which can be run in these and smaller chips in the range – such as the most popular PIC16F84.

PIC IN-CIRCUIT DEBUGGING

This article is intended as an easy introduction to ICD with very simple demonstration programs, users can then progress to using the more complicated features of the chips. It is *not* intended as a programming tutorial, but the operation of some programs is described in the course of demonstrating the ICD hardware.

Simple programs can be loaded, run and debugged without knowing much about the entire ICD system which is extremely complicated and occupies many pages of the PIC data sheets. The Microchip web site (**www.microchip.com**) provides an enormous amount of information for those wishing to know more.

MINIMUM ICD SET UP

The minimum hardware required for ICD, using the PIC16F877, is shown in Fig.1. Communication to a computer serial port is achieved via the Port RB6 and RB7 pins of the chip, which cannot be used for other functions. As there are plenty of other port pins available this is not a significant limitation.

Port RB6 receives data from the computer, and RB7 transmits data to the computer. Both of these pins operate at simple 0V to 5V logic levels. Some computer serial port output pins swing 10V positive and negative, and so limiting resistors and 5·1V Zener diodes are used for protection.

The serial data sent back to the computer should also be capable of swinging 10V, but it has been found that practically all computers read serial data correctly when 0V to 5V swings are used. A third connection links the serial port RTS output to the VPP or MCLR pin of the chip. This allows control of the programming voltage (programming at 5V, as opposed to the 12V normally required) and resetting of the chip by the computer.

After a Reset, the chip checks if pins RB6 and RB7 are shorted to 0V. If they are, it ignores the ICD functions and just runs the code directly starting from location 0. Links fitted in the positions marked LK enforce this option.

As well as the hardware connections, the computer needs to run a program to communicate with the chip, and the chip must have a program to communicate with the computer. The program in the chip is loaded and copy-protected into the upper half of the chip's 8K program memory.

It may seem wasteful to use half of the chip's memory for protected code, but in practice, the 4K remaining is a vast amount of space for the PIC program and it is very doubtful that it will ever be filled. Once working code has been developed and debugged it can be loaded and will run alone in any chip in the 16x range – the protected communication code is required only in the chip used for debugging.

Connections for suitable serial leads are shown in Table 1. These are standard connections, but can be made up with 4-way cable (flat telephone cable is ideal) if required. Take care when making leads to get the pin numbering correct – it is very confusing, the only safe way is to read the molded numbers on the connectors.

The port connections for the PIC 16F877/874 and the alternative connections for the 28-pin PIC16F876/873 versions of the chip are shown in Fig.2.

HARDWARE

Whilst the minimum system could be used, it is unlikely that any PIC application would operate without external hardware. Most systems have power supplies, input switches, output devices and so on. It is irritating and time consuming to have to set up these simple hardware requirements when the object is to get a

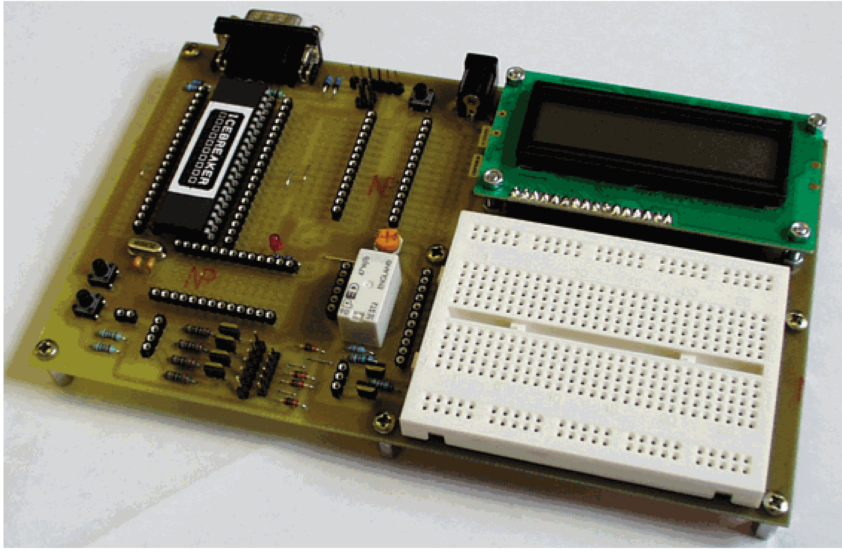

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Table 1: Serial Lead Connections.

9-way to 9-way ICE	Computer
1	7
2	3 TxD
3	2 RxD
5	5 GND

9-way to 25-way ICE	Computer
1	4
2	2 TxD
3	3 RxD
5	7

program written and tested. *EPE ICEbreaker* was designed to include a number of input and output devices along with a solderless connection system so that many applications could be tested from a notebook PC without the use of a soldering iron.

The full *ICEbreaker* circuit diagram is shown in Fig.3, whilst Fig.4 gives the PCB details.

Resistors R11 to R13, and R14, Zener diodes D6 to D8 and links LK1/2 are the same as the minimum system. PL2 allows the power and computer connections to be extended so that the PIC could be fitted into another board with other hardware and still debugged via the same computer lead.

Voltage regulator IC2 allows a range of power adapters to be used connected to 2·1mm power socket SK5. Links 3 and 4 allow positive inner or outer connections to be set. If accidental power reversal is possible, the positive link connection can be made using a 1A diode (e.g. 1N4001) instead of a piece of wire. Power is indicated by light-emitting diode (LED) D5 via resistor R8.

Switch S1 provides an alternative hardware reset which can be useful for stopping programs quickly and for restarting from location 0.

For ICD operation the PIC needs accurate timing. A 20MHz crystal X1 together with capacitors C1 and C2 provide the standard oscillator components. Alternative positions (X2) and (C3, C4) are to be used with 28-pin chips.

Resistors R15 and R16 allow *RC* oscillator options to be used if required for testing or running fully debugged code, but as *RC* oscillator stability is poor, this option is not recommended for ICD use. Other crystal frequencies can be used and the computer serial port speed altered accordingly. 20MHz gives the fastest communication (38,400 BAUD) and is best if there are no other special frequency requirements.

Stepping motor driving is a very popular PIC application. Transistors TR1 to TR4 and associated resistors R2 to R5 and protection diodes D1 to D4 provide four open collector drivers for four-phase unipolar motors. Connectors PL3 and PL4 allow for 2·54mm and 2mm pitch motor connectors. Input to the drivers is via SK4. The transistors can also be used individually as simple open-collector *npn* switches for driving relays, lamps and similar loads up to 24V and 400mA.

Two other output transistors are fitted. TR5 is a simple open collector *npn* device and TR6 drives a double-pole changeover relay RLA. These two devices are useful for bidirectional control of a DC motor. RLA can be wired as a reversing switch and the motor can be

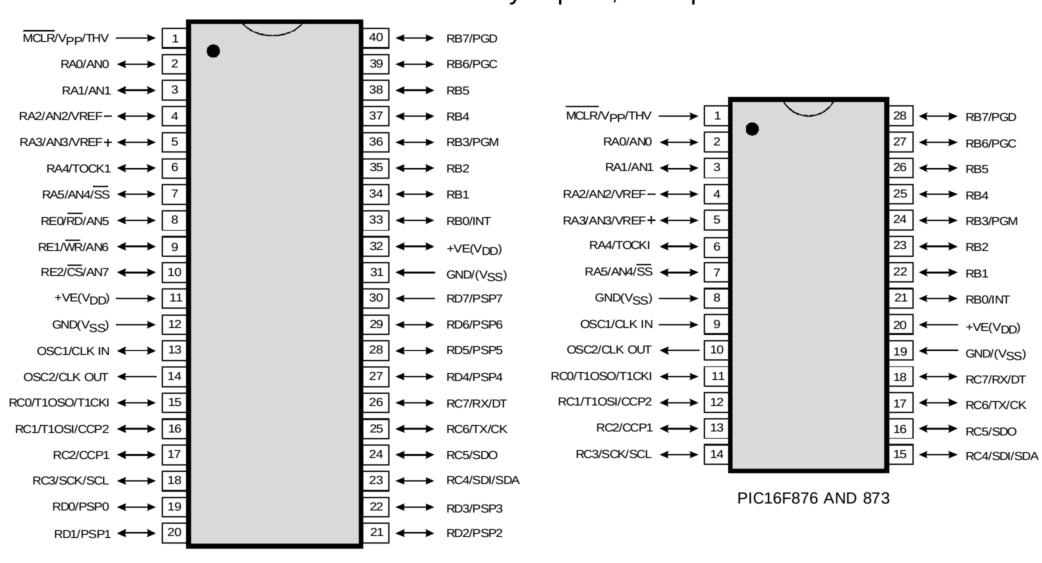

Fig.2. Port connections for the PIC16F877/874 and the alternative 28-pin PIC16F876/873.

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turned on and off by TR5.

Many applications require display of information, and an intelligent LCD module is an ideal display device. X3 has standard 4- or 8-bit drive capability, and requires a minimum of six output lines for driving. All pins are available at connector SK1. Preset VR1 allows the contrast of the LCD to be altered to suit the lighting conditions and viewing angle.

Just two input devices are fitted. S2 and S3 are simple single-pole push-to-make switches with pull-up resistors R6 and R7.

Whilst the circuit diagram seems simple, the PCB layout shows that there are far more connection points, and that a prototyping area with a solderless breadboard is provided. Each side of the main integrated circuit (IC) sockets there are spaces for rows of turned-pin sockets. The inner two rows connect to the adjacent IC pins, whilst the outer two rows are power and ground connections.

Turned-pin socket strips can be fitted in all rows, but it is more practical to have a single row of sockets each side of the chip and leave the other spaces blank so that pull up or pull down resistors can be soldered in position if required. An additional "patch" area is provided below IC1 and is ideal for adding "permanent" hardware such as LEDs or presets.

ICEBREAKER SOFTWARE

ICEbreaker must be run from a PC with at least *Windows 95*. This helps keep the software simple, and is not a serious restriction as PCs that can run Win95 are available at very low prices. A standard Pentium 133 without special sound, graphics or multimedia is more than adequate provided it has a spare serial port (COM 1 – 4).

The software is designed to be run in conjunction with Microchip's MPLAB software. This is available from many sources – the Microchip web site is the ideal one as it allows the very latest version to be loaded, alternatively the Microchip CD-ROM is widely available and good for those without internet access.

MPLAB is used in "editor only" mode to allow assembly language source code to be written and then assembled to produce the necessary **.HEX** code for programming into the chip. MPLAB also produces a **.COD** file which is used by the *ICEbreaker* software to keep track of the program execution when debugging, single stepping and running the program. Like many other PC programs, MPLAB has a lot of features that are not regularly used, however the advanced features don't get in the way when using it at the simple level required by *ICEbreaker*.

The *ICEbreaker* software is a simple stand-alone application that can be run directly from a floppy disk if necessary. This article assumes that the contents of the *ICEbreaker* disk are copied into a new folder (directory) on the C-drive, which has been labeled "**icebreak**". The only files required are **icebreak.exe** and **icebreak.ini**, but it is also convenient to store program files in the same directory.

ICEbreaker and MPLAB should be run together, and the "Alt" and "Tab" keys or the taskbar buttons used to switch from one to the other.

CONSTRUCTION

The *EPE* ICEbreaker printed circuit board component layout and (approximately) full size copper foil master are shown in Fig.4. This board is available from the *EPE Online Store* (code 7000257) from **www.epemag.com**

Assembly of the board is straightforward. Begin by fitting seven 12mm pillars with short M3 screws before adding any components. Refer to the component layout drawing and then fit plain uninsulated wire links in all of the positions shown. Fit two-way pin headers in the position for LK1 and LK2 so that two shorting links can be connected if required.

Links LK3 and LK4 provide the facility to set the input power socket for positive or negative inner connection. For positive inner fit the links in position B, for negative fit them in position A. As mentioned previously it is possible to add a diode in place of one of the links to protect against polarity reversal. To do this, fit the cathode of the diode to the point marked with a + sign, and the anode of the diode to the appropriate A or B position.

Fit the diodes and resistors next, taking care to identify the type and polarity. Usually the cathodes are marked with a black or dark blue band, which should be positioned to match the line on the component layout diagram. The transistors TR1 to TR6 are all the same type and are fitted with their curved sides as shown in the diagram. They should be fitted close to the board surface so that they cannot get bent and

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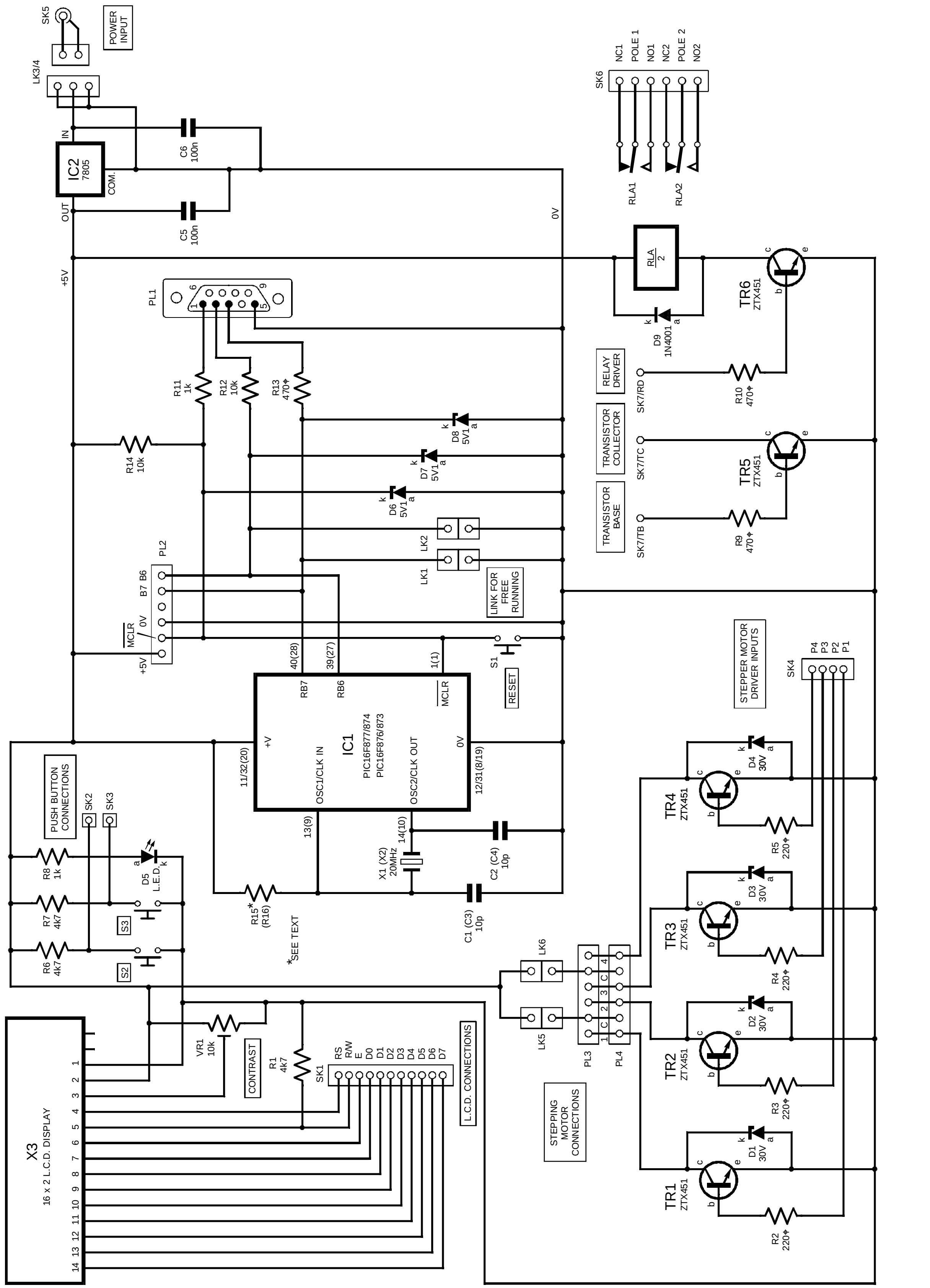

Fig.3. Complete circuit diagram for the EPE ICEbreaker.

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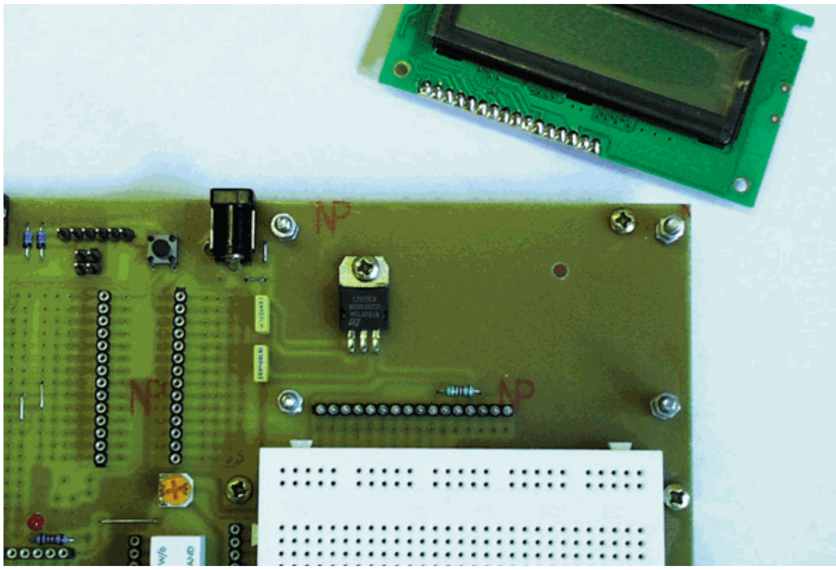
moved around when the board is handled.

Use turned-pin socket strips for the 40 and 28-way IC positions, and position a second row of sockets alongside. Note that there is also the option of a narrow-bodied version of the 28-pin device, and holes have been drilled to allow for this type to be used. If required, socket strips can be fitted for both types without causing any difficulty. Also fit turned-pin socket strips for SK1, SK2, SK3, SK4, SK6, and the three connections TB, TC, and RD. Also fit two 13-way strips to the upper and lower rows of the patch area – these are the positive and negative "rails" and make very convenient connection points for taking power to the breadboard.

Fit pin headers for PL2, PL3 and PL4 – the holes for these are made tight to give extra support and so the pins may need pressing home against a hard surface. Fit push-switches S1, S2 and S3, preset VR1, relay RLA and the voltage regulator IC2; an M3 screw and nut should be used to secure the tab. A heatsink is not required for most applications, but there is space to fit a low profile type, or even a small piece of aluminum if higher current loads are to be used.

The 20MHz crystal and its associated capacitors C1 and C2 should be fitted if the (usual) 40-pin device is being used for IC1. If a 28-pin version is used then fit these components to the alternative locations X2, C3 and C4. If both types of device may be used, it is possible to fit two crystals and two pairs of capacitors.



Display module removed from the PCB to reveal the regulator IC mounted underneath.

DISPLAY MODULE

The LCD module fits above the board on 16mm long 6BA or M2.5 screws. Fit the four screws from the track side of the board and secure them with nuts. Fit four more nuts and position them equally so that the LCD lies level and approximately 10mm from the board. The connections to the LCD are made to allow it to be unplugged for access to IC2 and for use in other applications.

Fit a 16-way pin-to-pin connector to the board, with the slightly thinner pins upwards. Fit (but do not solder) a 16-way wirewrap turned-pin socket strip to the LCD so that the sockets face downwards and plug onto the pin-to-pin connector. Make sure the LCD is level, solder the wire wrap pins to the LCD and cut off the excess. The LCD can now be secured by fitting another four nuts.

The serial port connector PL2 and power connector SK5 fit directly onto the board. Make sure that they are pressed fully home before soldering.

The solderless breadboard is secured to the board simply by its self-adhesive backing. Make sure that it is accurately positioned (and the right way up) before pressing it firmly into place.

TESTING

Once the hardware has been assembled and before fitting IC1, check for dry joints, solder bridges and component polarities.

Once everything looks correct, connect the power supply. Check that D5 lights and, if a meter is available, check the 5V regulated supply. The LCD contrast control VR1 should alter the density of a single top row of block characters as the LCD initializes itself for one-line mode.

Switch off, insert IC1 and connect a suitable lead between SK1 and the serial port of the PC, which has MPLAB and the *ICEbreaker* software (see the **Shoptalk** page) installed.

SOFTWARE INITIALISATION

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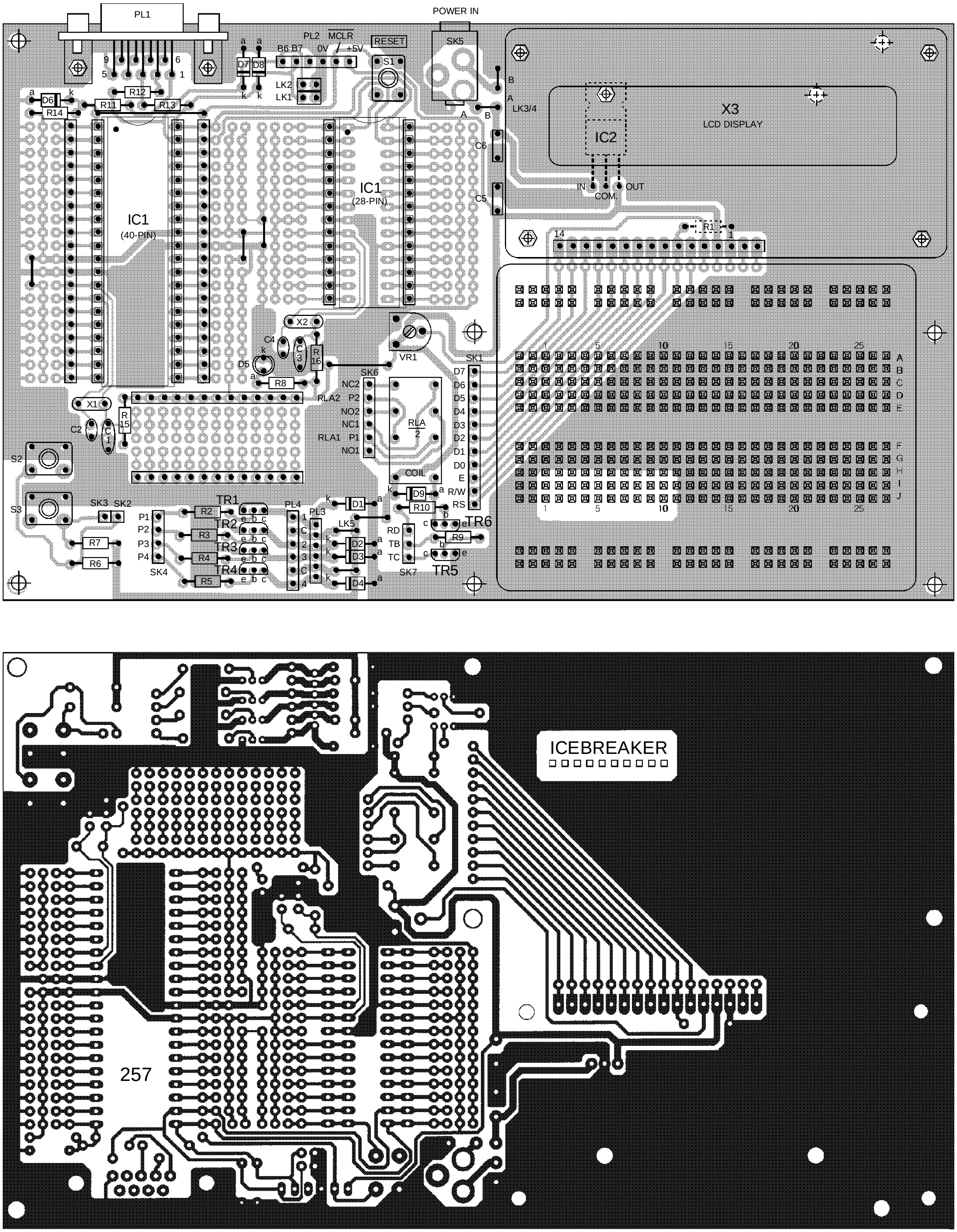

Fig.4. Printed circuit board component layout and (approximately) full-size copper foil master pattern.

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COMPONENTS

Resistors
R1, R6, R7 4k7 (3 off)
R2 to R5 220 ohms (4 off)
R8, R11 1k (2 off)
R8, R10, R13 470 ohms (3 off)
R12, R14 10k (2 off)
R15, R16 See text
All 0.25W 5% carbon film

Potentiometer
VR1 10k carbon preset

Capacitors
C1 to C4 10p ceramic, 2.5mm pitch (4 off), see text
C5, C6 100n multilayer polyester (2 off)

Semiconductors
D1 to D4 30V 400mW Zener diodes (4 off)
D5 3mm low-current red LED
D6 to D8 5.1V 400mW Zener diodes (3 off)
D9 1N4001 diode
TR1 to TR6 ZTX451 *npn* transistors (6 off)
IC1 PIC16F877P20 microcontroller, pre-programmed
IC2 7805 voltage regulator
X1 (X2) 20MHz low-profile crystal (see text)
X3 16x2 alphanumeric LCD module

Miscellaneous
Socket strips to make up the following: 11-way (SK1);
1-way (SK2, SK3 -- 2 off); 4-way (SK4); 6-way (SK6)
SK5 2.1mm PCB power connector
S1 to S3 s.p.s.t. push-to-make switches (3 off)
RLA d.p.c.o. 5V coil relay (BT47)

PCB available from the *EPE Online Store* code 7000257 (**www.epemag.com**); breadboard; 9-way 90° male D-type connector (PL1); 6-way 0.1in. pin header (PL2, PL4 -- 2 off);
6-way pin strip, 2mm pitch (PL3); 2-way 0.1in. pin header with DP link plug (2 off -- LK1, LK2); socket strips, 20-way (4 off), 14-way (2 off), 13-way (2 off); 16-way pin-to-pin strip
for LCD; 16-way long-pin socket strip for LCD.

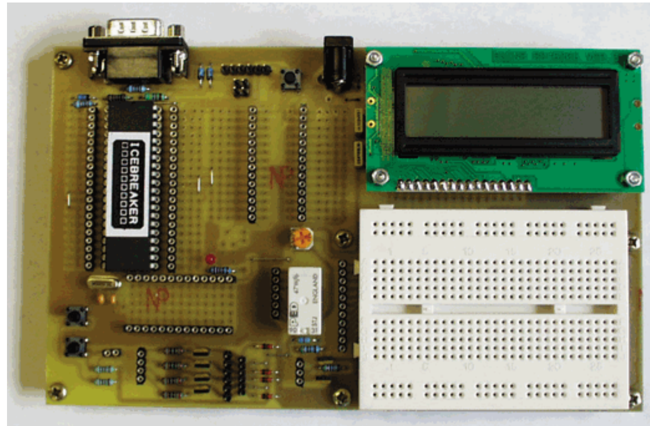
Hardware: 12mm M3 HEX pillars (7 off); M3 screw x 6mm (7 off); screws CSK (4 off) and 12 nuts (6BA or M2.5) for LCD mounting.

See also the SHOP TALK Page!

Approx. Cost Guidance Only **$60**

Run MPLAB, select the “project” tab and then “new project”. In the directory box select **c:\ icebreak** and set up a project named **ib.prj** and edit the project so that it contains the simple test program **ib1.asm** which is included on the *ICEbreaker* disk. Close the “Project Edit” window then select “File” and **ib1.asm**. This will open the **ib1.asm** file on the MPLAB screen.

Next select “Project” and “Make project”. This will then run the MPASM program and produce



Layout of components on the completed EPE ICEbreaker PCB.

files called **ib1.lst**, **ib1.hex**, **ib1.cod**, and **ib1.err** in the **icebreak** directory. The **ib1.err** file will contain a few warning messages, which can be ignored.

Leave MPLAB running, but minimize it by clicking on the appropriate box. Open the **icebreak** file and double click on **icebreak.exe** to start the program. The screen will display the main *ICEbreaker* window as shown in Fig.5, and possibly the Watch and Source windows (Figs. 7 and 8). In the main *ICEbreaker* window click on “Options” and then select “Programmer” this will produce the communications set up box shown in Fig 6. In this box set up the serial COM port that you are using. If a 20MHz crystal is fitted the Baud box must be set to 38400. Other crystal frequencies can be used and the Baud rate adjusted proportionally – e.g. a 5MHz crystal would operate at 38400/4 or 9600 Baud. Once set up close the box by pressing OK.

Fig.5. Main ICEbreaker window.

Back in the main box select “File” and “Open”, which will reveal a standard file select dialog window listing the files in the **icebreak** directory. Select and load **ib1.asm** and then open the source code window by selecting ‘Window’ and then ‘Source’. The window should contain the **ib1.asm** source file with numbered lines as shown in Fig.7.

Before the program can be run it

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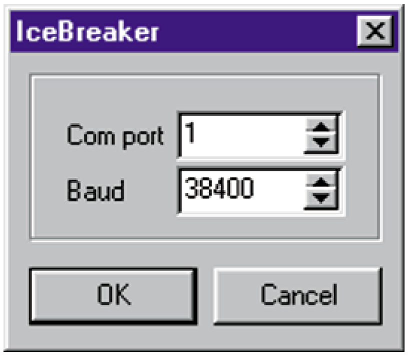

Fig.6. Setup box.

must be sent to IC1 by selecting “Program” and then “Program” in the main *ICEbreaker* window. A progress bar appears and *ICEbreaker* sends the program to the first 4K of the program memory in IC1. Once this is completed, it should be possible to step, run, and reset the code one line at a time using the “Step” button in the main window. In single step mode, at each step, a highlight line progresses through the source code window, and the main *ICEbreaker* window shows the Program Counter, the contents of the W register and the Status register bits.

Sometimes the highlight does not track the source code exactly, and is one line above or below the current line. This is due to the communications between the computer and IC1 and depends upon the way some of the source code is written; it is only a minor inconvenience as the actual line of code is easily worked out from the program counter in the *ICEbreaker* main window.

Other registers may be set up in the “Watch” window – select “Windows”, “Watch” in the main window. Fig.8 shows the main Watch window and Fig.9 the “Add” window. Registers may also be “Watched” by setting the first location and entering the number of registers in the “Array” box.

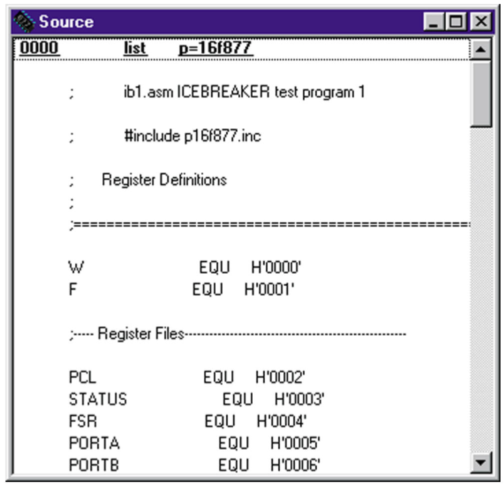

Fig.7. Source file window.

The selector box in the “Watch Add” window allows a choice of locations, labels and registers to be selected. It is important to understand that some of these options are not what they seem, for example the W option returns not the value of the W register, but the number 0 which has been assigned to the label W in the fifth line of the source code.

TESTING A PROGRAM

Once some familiarity has been achieved with the *ICEbreaker* windows, it is time to connect some hardware and see how it operates. As with all good microcontroller hardware systems, the first thing to do is flash a LED! The **ib1.asm** program counts up through PORTA, which is set to output mode, and so all that is necessary is to connect a LED from pin 2 of IC1 via a current limiting resistor (anything from 100W to 2k2) to 0V.

Using solid core 1/0·6 connecting wire links it is an easy matter to put the LED and resistor on the breadboard and make the two connections to the turned-pin socket strips. The row of 13 sockets at the bottom of the patch area is a good place to find 0V. Provided the program has been set up correctly and loaded into IC1, the LED should flash when the program is set to “Run”.

In order to flash the LED slowly, the program has three nested counting loops. To single step through them would take years, and so it is impractical to go right through all of the states of PORTA. The alternative to single stepping is to insert a breakpoint and run the program to there.

Select “Options”, “Breakpoint” from the main *ICEbreaker* window and set the value to 24. Fig.10 shows the “Breakpoint” setting window. Entering a breakpoint highlights the line in the “Source” window. “Reset” and then “Run” the program and it will now stop at the breakpoint. Press run again and it will loop again to the same breakpoint – each time incrementing the value at PORTA so that the LED on PORTA 0 turns on and off alternately. Try connecting the LED to IC1 pin 3 PORTA 1 and see that it switches every other loop.

Now that a LED can be flashed, it is just a few more steps to controlling all sorts of peripheral devices, and whilst the PIC16F877 cannot run the proverbial “Power Station” it is capable of an amazing number of very complicated feats. The development of longer programs controlling more hardware is so much easier when it is possible to test the programs

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quickly in this way. Single stepping and watching the program and data registers allows even complicated routines to be tested and debugged, and simple changes can be made and checked immediately.

To make a simple change to the **ib1** program, select "Program", "Code" from the icebreaker main menu and then select location 14. The contents can be read and should be 30FF, which means MOVLW FF. Modify the value to 3010 which will load the value 10 instead of FF and press the "Write" button. Clear the breakpoint, "Run" the program, and see the change in speed.

The program in IC1 has been modified, but remember that the Source Code has not, and so will need changing to the new value once the required speed has been set. To modify the source code run MPLAB, modify **ib1.asm**, recompile the code by selecting "Project", "Make project" (or by pressing the appropriate shortcut button) and then switch back to *ICEbreaker* .

Select "File", "Reopen" and the modified source code will appear in the *ICEbreaker* "Source" window. To complete the operation select "Program", "Program" and the new code will be loaded into IC1. Although the program in IC1 had already been modified, it is always good practice to reprogram with the newly compiled code to prevent simple errors creeping in – especially when a number of modifications might have been made.

As well as changes to the program memory, the same procedure can be used to modify the EEPROM, and register

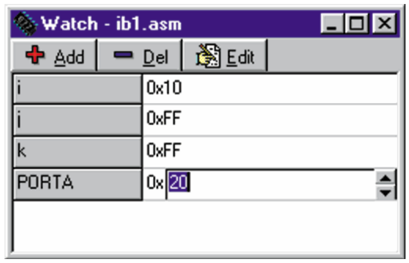

Fig.8. ICEbreaker "Watch" window.

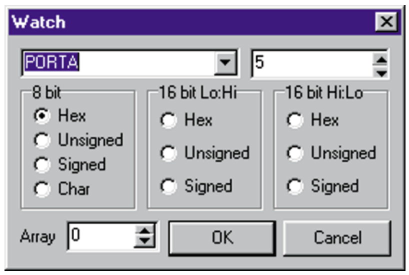

Fig.9. ICEbreaker "Watch Add" window.

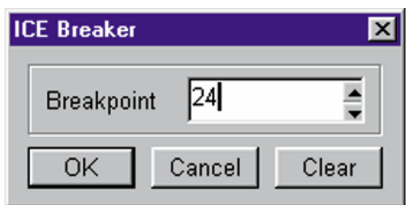

Fig.10. ICEbreaker "Breakpoint" window.

files. Changing register file contents is particularly useful when combined with single stepping, as it allows routines to be tested with a range of values, for example a timing loop can be set up with 00 in the loop counting register and single stepped to see what happens at the end of the loop.

Once experience is gained, the range of tools available will be understood, and it will become easy to set up and check simple routines and combine them into full programs.

OTHER PROGRAMS

Program **ib2.asm** is a simple driver for the stepping motor. Connect PORTA 0 to 3 to the four stepping motor drive sockets P1 to P4 and then follow the procedures used for **ib1.asm** to compile, load and run the program. Notes are included in the code suggesting modifications that can be made to the code for altering speed, direction, and duration of travel.

Program **ib3.asm** runs the LCD. It uses six connections from PORTC 2 to 8 to connect to RS, E, and D4, 5, 6, and 7 of the display in that order. The code initializes the display, and then can be set up as a subroutine to write any character to any display location. The source code has notes to explain the operation and to suggest possible changes for more advanced applications.

COMPLETED PROGRAMS

Once a program has been debugged and is working correctly, it can be programmed into another PIC16F877 or any other suitable PIC chip using an appropriate programmer (*PIC Toolkit Mk2* from the May and June issues of *EPE Online* is ideal – **www.epemag.com/0599p1.htm**). The *ICEbreaker* code does not have to be in the chip and so any blank chip can be used with this method. The *ICEbreaker* board can only program chips that already contain the special **icebreak** code – this is necessary because the chip has to communicate with the PC via the standard serial port interface. Chips with **icebreak** code are readily available – see the **Shoptalk** page.

Once programmed, *ICEbreaker* chips will run normally in other circuits if required to do

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so but it is important to make sure that the two pins RB6 and RB7 are connected to 0V. This is because the *ICEbreaker* software automatically starts to run, and immediately checks for ground connections on these pins. If it finds that they are grounded, the program jumps to location 0000 and starts running the program from there, as a normal chip would.

THE NEXT STEPS

It is tempting to continue and describe the many features of the PIC16F877, but it really is an impossible task because the chip is so powerful (see also our *PIC16F87x Mini Tutorial* in the Oct '99 issue of *EPE Online*). The beauty of the PIC range of devices is that it is possible to run the same code on many different chips.

EPE ICEbreaker allows programs that are intended to be run on much simpler chips to be checked and debugged. All that is necessary is to ensure that the ports and register addresses are compatible with the smaller chips. Applications for the PIC16F84 are particularly suitable for development using *ICEbreaker*, and so the programs previously published by *EPE* can be used. Note though that the MPLAB environment uses MPASM code, and so the *PIC Toolkit Mk2* software will be necessary to convert the original TASM source code to MPASM assembly language.

ICEbreaker provides an advanced way to learn programming. Along with the PIC programming and data sheets and back issues of *EPE,* it will become an indispensable tool for learning, development, and testing of PIC projects.

Go to next section

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Ingenuity Unlimited

ROLL-UP, ROLL-UP!

Ingenuity is our regular round-up of readers' own circuits. We pay between $16 and $80 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas must be the reader's own work **and must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

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Delay-On Timer – More Time to Boot

A simple circuit was needed to turn on a computer cooling fan a short period after the power was applied, and so the Delay-On Timer of Fig.1 was devised. It consists of a thyristor CSR1, which acts as a latch to turn on the relay RLA.

The thyristor CSR1 is triggered by a signal to its gate, and is delayed by the RC network comprising resistor R1 and capacitor C1. It continues to conduct once the trigger signal has been received.

With the thyristor and RC values shown, the delay is around 10 seconds before the relay is activated. Other thyristors could be substituted.

The circuit was constructed on a small piece of stripboard and has been used successfully in a PC, where it allows the PC to boot up before the fan is switched on.

Abdul Rahman Mansor
Penang, Malaysia

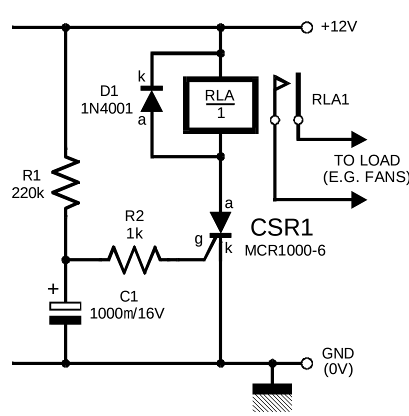

Fig.1. Delay-On Timer circuit

555 Power Supply – On The Panel

A 555-based oscillator circuit is shown in Fig.2, which provides an inexpensive DC isolated power supply for digital panel meters without the need for transformers or inductors. The circuit oscillates at approximately 60kHz, as determined by resistors R1 and R2 and capaci-

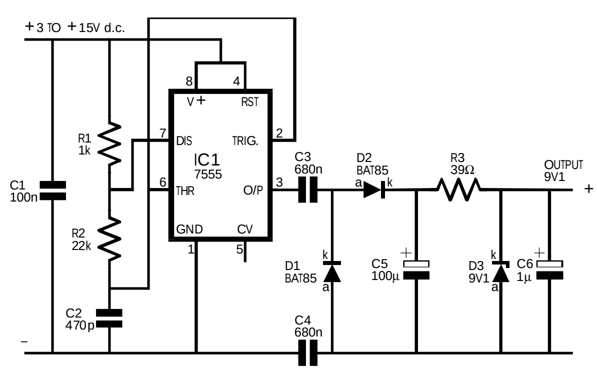

Fig.2 Power supply circuit using a CMOS timer chip

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tor C1 as normal.

The output square-wave pulses are fed into a modified Cockroft-Walton multiplier, which features two Schottky diodes D1 and D2. The charge stored on capacitr C5 gives a voltage slightly less than the 555 supply voltage, and is sufficient to drive most LCD panel meters which only require a few microamps.

A 9·1V Zener diode D3 provides good output regulation up to about 1mA. The maximum DC voltage isolation is the voltage ratings of capacitors C3 and C4 minus the supply voltage. The circuit runs from 3V to 15V and a low drop-out regulator could be used for operation at higher voltages (at lower voltages the full 9·1V may not be achieved). Note that a CMOS timer should be used for IC1.

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Fichardt Park
South Africa

PIC Adapter Socket – Pinwise

After experimenting with Arizona PIC microcontrollers, using the excellent *EPE PIC Tutorial* circuit board, I needed to use an external oscillator for one of my own experiments. Rather than modify the board, I built the simple plug-in adapter socket shown in Fig.3.

Using a pressed contact 18-pin DIL socket (a turned-pin type will not work), I carefully folded pin 15 and pin 16 out to the side. This socket was then inserted into the existing socket already on the board, and the PIC pressed into the new adapter socket. A sliver of plastic tape prevented any contact between the folded out pins and the original socket.

The external oscillator was powered from the board and its output was connected to pin 16 of the adapter. Note that in this configuration, there is no connection to pin 15.

A. Langton
Aberdeen, Scotland

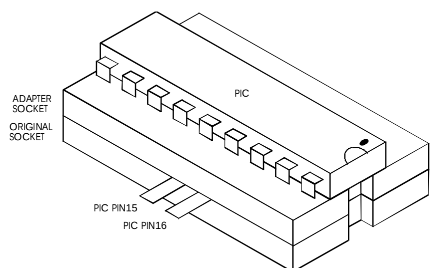

Fig.3. Simply plug-in adapter socket.

Shaky Dice – It's a Rollover

A simple but novel circuit application for a custom die chip is shown in Fig.4. This circuit imitates a traditional die in that it starts "rolling" when you shake it.

It is based around the Holtek HT2070A chip, which will generate a traditional style of die readout when the sealed vibration switch S2 is operated. The piezo sounder WD1 is a disc transducer which emits a sound as well, and it operates from a 3V battery controlled by a miniature toggle switch S1.

Our own model was housed between two semi-transparent curved colored disco light filters, which were bolted together using nylon fasteners around the rim. (The filters can be carefully drilled for this purpose.) The circuit was then installed with the light-emitting diodes, D1 to D7, being arranged in an H-shape as shown.

Andy and Rose Morell
Winchester, UK

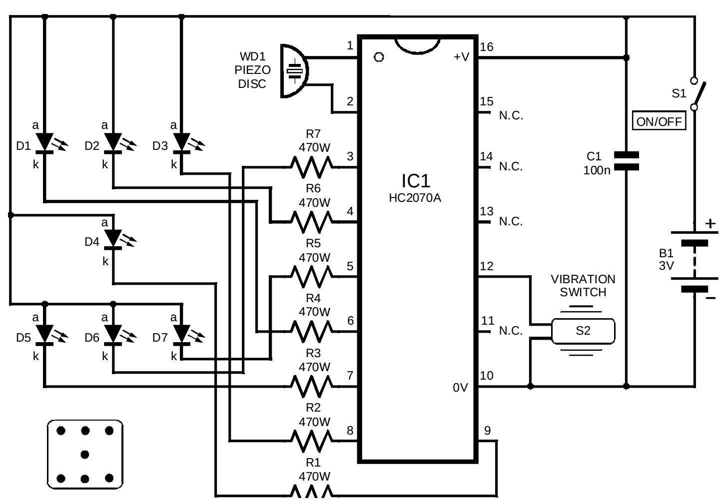

Fig.4. Circuit diagram for the Shaky Dice.

Go to next section

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New Technology Updates

IAN POOLE INTRODUCES THE MRAM, WHICH (IT IS HOPED) WILL POSE A REAL THREAT TO "FLASH" MEMORIES AND OTHERS.

Memory is one of the crucial elements in today's technology. There have been many improvements in disk based technology over recent years, but there are similar levels of progress taking place in the memory more directly associated with the CPU itself.

To illustrate this, it was less than thirty years ago when ferrite core memory was used. Fortunately this was superseded by electronic forms of memory when the levels of integration of circuits grew to a sufficient degree to allow them to be used.

Now there are a variety of different forms of memory that can be used dependent upon the exact requirement that needs to be fulfilled. SRAM, DRAM, EPROM, EEPROM and a variety of others including Flash memories are available, each having their own forte and area where they perform to their best.

However, if it were possible for only one type of memory to be used, then this could lead to more efficient use of the circuitry, and possible cost savings. For this to be feasible, an all-purpose, yet low cost memory would need to be available, and this may be just around the corner because a new technology is about to hit the market.

Known as magneto resistance random access memory, or MRAM, the new memory is creating significant interest in the semiconductor industry. It is a non-volatile form of random access memory claimed to be faster than Flash, which will be its main competitor when it is launched onto the market. However, as prices fall and MRAM gains wider acceptance it is likely that it will be used in many more memory applications.

SPECIFICATIONS

For a given speed and geometry the new MRAM technology consumes less power and this is a particularly important factor in today's technology where many items are battery powered. The power reduction also means that the power supply requirements for the unit as a whole may be reduced, and this can reflect in a decrease in costs – all-important in today's fiercely competitive marketplace.

As the speed of the new devices is faster than Flash, this too is another selling point as the speed of flash devices can be such that it impacts on the operation of the whole unit. Although not much faster at the moment, improvements are anticipated that will give the new technology a significant advantage.

MRAM has further advantages. It does not suffer from the wear out mechanism experienced with Flash devices. Although great improvements have been made in this area with Flash devices, they still have a limited life and this means that they cannot be used in high usage areas of a computer's architecture.

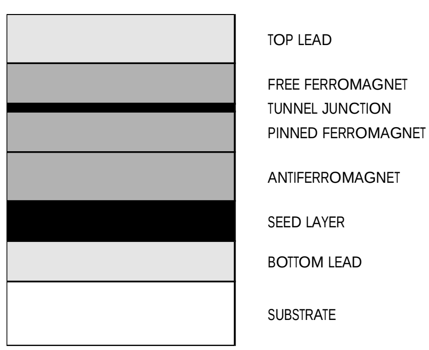

Fig.1. Structure of an MRAM cell.

OPERATION

The operation of the new memories is based around a structure known as a magnetic tunnel junction (MTJ). These devices consist of sandwiches of two ferromagnetic layers separated by thin insulating layers.

A current can flow across the sandwich arising from a tunneling action and its magnitude is dependent upon the magnetic moments of the magnetic layers. These layers can either be the same, when they are said to be parallel, or in opposite directions when they are said to be antiparallel.

Magnetic tunnel junctions comprise sandwiches of two ferromagnetic (FM) layers separated by a thin insulating layer which acts as a tunnel barrier (Fig.1). In these structures the sense current usually flows parallel to the layers of the structure, while the current write is passed perpendicular to the layers of the MTJ sandwich.

The resistance of the MTJ sandwich depends on the

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direction of magnetism of the two ferromagnetic layers. Typically, the resistance of the MTJ is lowest when these moments are aligned parallel to one another, and is highest when antiparallel.

To set the state of the memory cell a write current is passed through the structure. This is sufficiently high to alter the direction of magnetism of the thin layer, but not the thicker one. A smaller non-destructive sense current is then used to detect the data stored in the cell.

CONSTRUCTION

A wide range of structures and materials have been investigated to obtain the optimum structure. In view of the potential of the new technology a number of manufacturers are investigating different approaches. Motorola, IBM and many others all believe there is a future for the new idea.

IBM have fabricated junctions using computer-controlled placement of up to eight different metal shadow masks. The masks were successively placed on any one of up to twenty 25mm diameter wafers with a placement accuracy of approximately ± 40um. By using different masks, between 10 to 74 junctions of a size of approximately 80 x $80um^2$ could be fashioned on each wafer.

The tunnel barrier was formed by *in-situ* plasma oxidation of a thin aluminum layer deposited at ambient temperature. Using this technique, large levels of variation in resistance due to magnetoresistive effects were seen. Investigations into the dependence of MR on the ferromagnetic metals comprising the electrodes were made.

It was anticipated that the magnitude of the MR would largely be dependent on the interface between the tunnel barrier and the magnetic electrodes. It was found that thick layers of certain non-ferromagnetic metals could be inserted between the tunnel barrier and the magnetic electrode without quenching the MR effect. However, the MR was quenched by incomplete oxidation of the aluminum layer.

OTHER DEVELOPMENTS

IBM is not the only manufacturer investigating these structures. Apart from Motorola, IMEC, Europe's leading research center for the development and licensing of state-of-the-art microelectronics technologies, is also making significant developments with MRAM technology.

They have succeeded in developing a demonstration MRAM matrix cell array with a DRAM style of architecture. This brings MRAM technology a step closer to the production of a viable alternative to the existing non-volatile memory. The memories produced in this development used a similar structure to that employed by IBM, i.e. two magnetic layers separated by an insulating layer.

Bit-selective addressing was based around a GaAs diode. The GaAs technology was selected because of its flexibility and tolerance relative to silicon.

In the next stage of development it is hoped to use a silicon diode or transistor to reduce the fabrication costs. This will bring the final version nearer and ensure that its unit costs will be such that it can effectively compete with existing technologies.

The new MRAM technology is an exciting development that could revolutionize current trends in electronic memory. The migration from magnetic core memory in the early 1970s proved to be a major step forwards. Now the introduction of MRAMs could provide similar levels of benefit.

Go to next section

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TECHNOLOGY TIMELINES

Part 2 - DAYS OF LATER YORE

by Alvin Brown and Clive “Max” Maxfield

Boldly going behind the beyond, behind which no one has boldly gone behind, beyond, before!

The purpose of this series is to review how we came to be where we are today (technology-wise), and where we look like ending up tomorrow. Our first step is to cast our gaze into the depths of time to consider the state-of-the-art as the world was poised to enter the 20th Century.

In Part 1 we considered physics, electronics, and communications prior to 1900. In this installment we shall first examine the state of computing prior to 1900. We shall then turn our attention to the key discoveries in fundamental electronics that occurred in the 20th Century.

COMPUTING PRIOR TO 1900

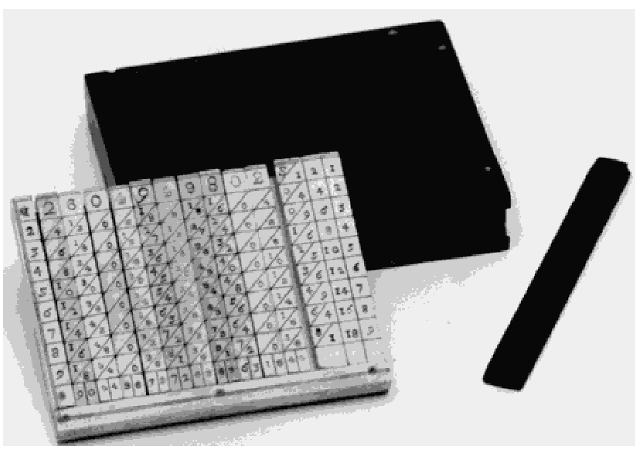
The first tools used as aids to calculation were man’s own fingers. Thus, it is no coincidence that *digit* refers to a finger (or toe) as well as a numerical quantity. Similarly, small stones or pebbles could be used to represent larger numbers than fingers and could also store intermediate results for later use. This explains why *calculate* is derived from the Latin word for pebble (*calculus*).

DECIMAL NUMBER SYSTEM

Throughout history, humans have experimented with a variety of different number systems. For example, the ancient Babylonians used a base-60 system, which is why we have 60 seconds in a minute and 60 minutes in an hour. Some people used their fingers and their toes for counting, so they ended up with base-20 systems, which is why we still have special words like *score*, meaning *twenty*.

Similarly, some groups experimented with base-12 systems, which is why we have special words like *dozen* (meaning 12) and *gross* (meaning 12 x 12). The fact that we have 12 months in a year and 24 hours in a day (2 x 12) are also related to these base-12 systems.

However, the number system with which we are most familiar is the decimal system, which is based on ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. The name *decimal* is derived from the Latin *decam*, meaning *ten*. As this system uses ten digits, it is said to be *base-10* or *radix-10*, where the term *radix* comes from the Latin word meaning *root*.



Napier’s Bones, simple multiplication tables inscribed on wood or bone. John Napier went on to invent logarithms. Courtesy of IBM.

THE ABACUS

The first actual calculating mechanism (at least that we know of) is the *abacus*. Some authorities hold that the first abacus was invented by the Babylonians sometime between 1,000 BC and 500 BC, but others believe that it was actually invented by the Chinese.

Although the abacus does not qualify as a mechanical calculator, it certainly stands proud as one of first mechanical aids to calculation.

THE SLIDE RULE

In the early 1600s, Scottish mathematician John Napier

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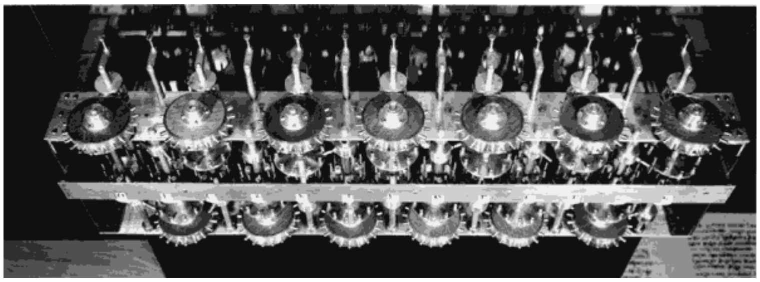


A modern construction of a mechanical calculator inspired by a drawing in one of Leonardo da Vinci's notebooks. Courtesy of IBM.

invented a tool called *Napier's Bones*. These were simple multiplication tables inscribed on strips of wood or bone. Napier also invented the concept of *logarithms*, which were used as the basis for the slide rule by the English mathematician and clergyman William Oughtred in 1621.

The slide rule was an exceptionally effective tool that remained in common use for over three hundred years. However, like the abacus, the slide rule does not qualify as a mechanical calculator in the modern sense of the word.

REDISCOVERED NOTEBOOKS

Leonardo da Vinci was a genius: painter, musician, sculptor, architect, engineer, and so forth. It is well known that he sketched concept designs of such futuristic devices as tanks and helicopters, but until quite recently there was no indication that he had ever turned his mind to mechanical calculation.

However, two of da Vinci's notebooks dating from around the 1500s were rediscovered in 1967. These priceless tomes contain a wealth of drawings, some of which may represent a mechanical calculator (see Part 1). Working models of a mechanical calculator loosely based on these drawings have since been constructed, although some people believe the reconstruction is far more sophisticated than anything Leonardo had in mind.

FIRST MECHANICAL CALCULATOR

Sometime around 1625, the German astronomer and mathematician Wilhelm Schickard wrote a letter to a friend stating that he had built a machine that "… *immediately computes the given numbers automatically; adds, subtracts, multiplies, and divides*''. Unfortunately, the original machine was destroyed in a fire, but working models have since been constructed from Schickard's notes.

ARITHMETIC MACHINE

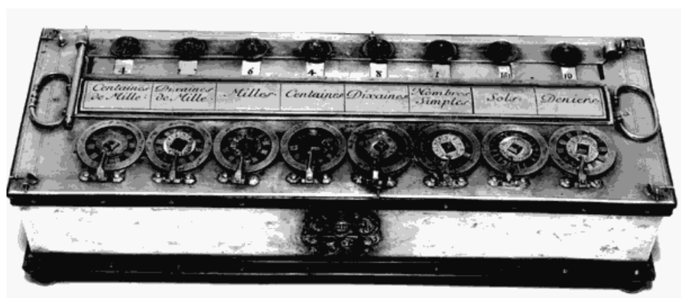
For reasons unknown, many references ignore Schickard's device and instead credit the French mathematician, physicist and theologian, Blaise Pascal with the invention of the first operational calculating machine.

In 1642, Pascal introduced his *Arithmetic Machine*, which could add and subtract numbers (multiplication and division operations were implemented by performing a series of additions or subtractions).

STEP RECKONER

Mechanical calculation was taken a step further in the 1670s by a German Baron called Gottfried von Leibniz. After receiving his bachelor's degree at seventeen years of age, Leibniz developed Pascal's ideas and, in 1671, introduced the *Step Reckoner*. In addition to performing additions and subtractions, the Step Reckoner could multiply, divide, and evaluate square roots.

The mechanical calculators created by Pascal and Leibniz were the forebears of today's desktop computers, and derivations of these devices were in widespread use for over two hundred years until their electronic counterparts finally became available and affordable in the early 1970s.



Blaise Pascal's Arithmetic Machine. Courtesy of IBM.

FIRST MECHANICAL COMPUTER

In the 1800s, books of mathematical tables such as logarithmic and trigonometric functions were in great demand

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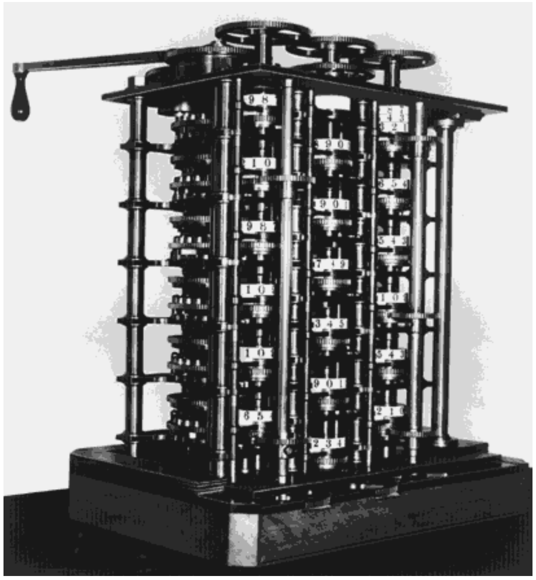


Modern construction of Babbage's Difference Engine. Courtesy of IBM.

by navigators, engineers, and so forth. Such tables were generated by teams of mathematicians working day and night on derivatives of the primitive mechanical calculators invented by Pascal and Leibniz. These mathematicians were referred to as *computers* because they performed all the computations.

In 1822, the eccentric British mathematician and inventor Charles Babbage proposed building a machine called the *Difference Engine* to automatically calculate these tables.

Babbage had only partially completed the *Difference Engine* when he conceived the idea of a much more sophisticated machine called an *Analytical Engine*. (This is often referred to as Babbage's Analytical *Steam* Engine, because he intended for it to be powered by steam).

The Analytical Engine included many concepts that would eventually be featured in modern computers, including a processing unit that could change the flow of a program depending on the results of previous computations. Babbage worked on the Analytical Engine from around 1830 until he died in 1871, but sadly it was never completed in his lifetime.

FIRST COMPUTER PROGRAMMER

Augusta Ada Lovelace, the daughter of the English poet Lord Byron, was one of the few people who had any clue what Babbage was talking about. Ada created a program to compute a mathematical sequence known as *Bernoulli* numbers, which would have been extremely interesting had Babbage's machine ever actually worked.

Ada is now credited as being the first computer programmer, and the ADA programming language was named in her honor in 1979.

In fact, one of Babbage's earlier Difference Engines was eventually assembled by a team at London's Science Museum from his original drawings. The final machine was constructed from cast iron, bronze and steel, consisted of 4,000 components, weighed in at a whopping three tons, and was 10 feet wide and 6·5 feet tall (3m x 2m).

In the early 1990s, more than one hundred and fifty years after its conception, Babbage's Difference Engine performed its first sequence of calculations and returned results to 31 digits of accuracy, which is far more accurate than most of today's electronic pocket calculators!

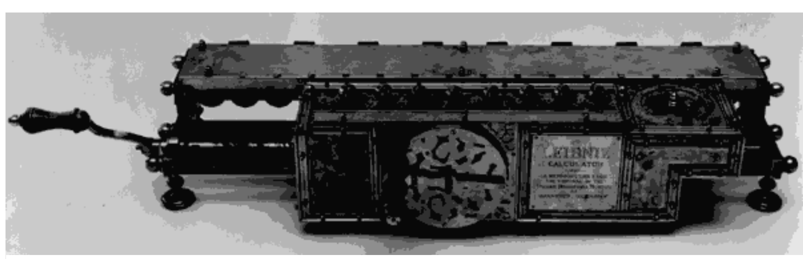
TABULATING MACHINES

These days we can only imagine the problems besetting the American census takers in the latter part of the 19th Century, because it was estimated that the 1890 census would include more than 62 million Americans.

The problem was that the existing system of making tally marks in small squares on rolls of paper and then adding these marks together by hand was time-consuming, expensive, and prone to error. In fact it was determined that if the existing system were used for the 1890 census, then the processed data would not be ready until after the 1900 census, by which time it would be largely worthless!

During the 1880s, a lecturer at MIT called Herman Hollerith came up with a solution to this problem, which was to use punched cards to represent the census data, and to then read and collate this data using machines.

The result of Hollerith's labours was an automatic tabulating machine with a large number of clock-like counters that



Gottfried von Leibniz's Step Reckoner of 1671.
Courtesy of IBM.

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Hollerith's Tabulator/Sorter unit.
Courtesy of IBM.

were used to accumulate and display results. Operators used switches to instruct the machine to examine each card for certain characteristics, such as gender, profession, marital status, number of children, and so forth.

An electrically controlled sorting mechanism detected any cards that met the specified criteria and gathered them into a separate container. The ability to quickly and easily collate data in this way drove statisticians of the time into a frenzy of excitement.

Following their application to the census problem, Hollerith's machines proved themselves to be extremely useful for a wide variety of applications, and some of the techniques they used were to prove significant in the development of the digital computer in the 20th Century. In fact, in February 1924, Hollerith's company changed its name to International Business Machines, or IBM!

POISED ON THE BRINK …

So now we are poised on the brink of the 20th Century. It's 11:59pm on December 31st 1899. Queen Victoria is still on the throne of England. Light bulbs are considered to be amazingly cool (but almost no-one has electricity in their homes). The vacuum tube has yet to be invented. Rudimentary telephones are available only to the favored few, and "computers" are the ill-used mathematicians who furiously hand-crank their mechanical calculators in the dead of night!

Tick-tock, tick-tock . . . the second hand is wending its way towards the beginning of a new century. Who can guess what surprises the future will hold?

FUNDAMENTAL ELECTRONICS IN THE 20TH CENTURY

For our purposes here, electricity may be considered to consist of vast herds of electrons migrating from one place to another through some conducting medium like a copper wire. The art of electronics comes in controlling these herds: telling them when to start, when to stop, where to go, and what to do when they get there.

However, as with most things (especially small children), control is easier to talk about than it is to achieve. With the exception of simple manipulation and modulation using devices such as transformers, or rectification using crystals, the most sophisticated form of control prior to the beginning of the 20th Century was the mechanical switch (or its electromechanical counterpart, the relay).

When it comes to coarse control like turning a light bulb on or off, then a mechanical switch is definitely worth considering, but if you're looking for fine control, mechanical switches generally leave something to be desired. Similarly, a mechanical device is only of use if you only wish to turn something off every now and then, but such devices have a maximum capability of only a very few cycles per second.

So one key requirement as we entered the 20th Century ("we" meaning the human race, not the authors personally you understand) was for a more sophisticated way to control electricity.

VACUUM TUBES – FLEMING'S DIODES

As we discussed in Part 1, the American Inventor Thomas Alva Edison demonstrated his first incandescent light bulb in 1789 (one year after the English inventor Sir Joseph Wilson Swan demonstrated his bulb, but let's not delve into that debate again here).

Four years later in 1883, an engineer working for Edison – William Hammer – observed that he could detect electrons flowing from the lighted filament to a metal plate mounted inside the bulb. Even though Hammer discovered this phenomena, it subsequently became known as the *Edison Effect*, because Edison was the man in charge.

Sad to relate, Edison himself did not take the time to investigate

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Sir John Fleming (1849-1945), British physicist and inventor of the thermionic valve. Courtesy of the Science Photo Library.

the effect any further. This was unfortunate, because electronics as we now know it might have taken a giant leap forward had he done so.

In fact it wasn't until the Edison Effect's twenty-first birthday in 1904 that the English electrical engineer, John Ambrose Fleming, filed a patent for the first vacuum tube device based on this effect. (Due to the fact that these devices are created using evacuated glass tubes, they are still referred to simply as *tubes* in America. However in England they became more commonly known as *valves*, because this name – derived from pneumatic and hydraulic valves – better reflected their control function.)

What Fleming had discovered was that the electrons in his vacuum tube only flowed from the cathode (the heated filament) to a positively charged anode. Thus, Fleming had created a form of *diode*, which is a device that only conducts electricity in one direction.

This was of particular interest, because some electrical equipment like radios will only work with unidirectional, or direct current (DC), but most electrical supplies are based on alternating current (AC), because this provides a more efficient way to transport electricity over long distances. Fleming's vacuum tube diode could therefore be employed in the role of a rectifier to convert AC to DC.

An Audion triode from about 1914. Right: An MO Valve Co. triode from about 1920. Courtesy of Radio Bygones (**www.radiobygones.com**).

LEE DE FOREST'S TRIODES

In 1907, the American inventor Lee de Forest introduced a third electrode called the *grid* into his version of a vacuum tube. The resulting three-terminal device was called a *triode*.

This device was particularly cunning, because a small signal applied to the grid could be used to control a much larger signal flowing between the cathode and the anode. The result was a device that could be used to amplify signals, and de Forest used his triodes to build many of the early radio transmitters (he also presented the first live opera broadcast and the first news report on radio).

In addition to acting as an amplifier, de Forest's triodes could also be used in the role of switches (the presence or absence of a signal on the grid terminal could turn the output – the anode – on or off). This ability to act as switches meant that vacuum tubes were destined to play a significant role in digital computing.

As we shall see in a future installment, early digital computers (circa 1940) were either mechanical or electromechanical (based on relays), but they soon came to be constructed from vacuum tube switches, because these were much, much faster.

Unfortunately, vacuum tubes have a number of disadvantages, not the least that the metal forming the cathode evaporates over time causing a performance degradation. Also, in addition to requiring dangerously high voltages, vacuum tubes occupy a lot of space, they generate a lot of waste heat, and they are not particularly reliable, which becomes especially noticeable when they are used in large numbers.

For example, the ENIAC computer, which was constructed at the University of Pennsylvania between 1943 and 1946, used approximately 18,000 vacuum tubes. This monster was 10 feet (3m) tall, occupied 1,000 square feet (93 m2) of floor space, and required 150 kilowatts of power, which was enough to light a small town at that time.

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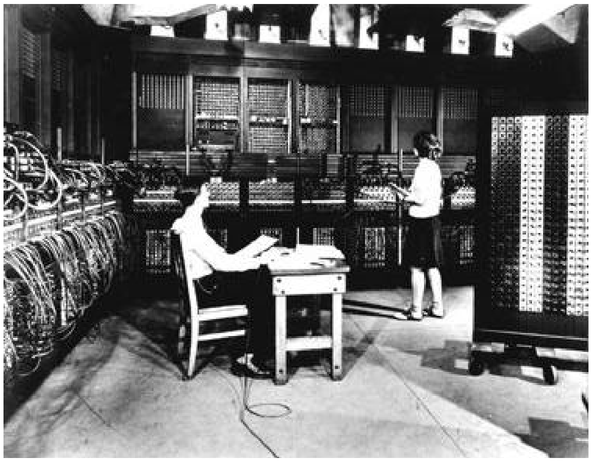


Part of the ENIAC computer. Courtesy of IBM.

However, whilst it was a tremendous achievement for its time, ENIAC was painfully unreliable due to the vacuum tube technology of the day. In fact 90 per cent of ENIAC's down-time was attributed to locating and replacing burnt-out tubes – sometimes as many as 50 a day!

CRYSTAL GAZING

The fact that certain crystals have special properties had been known for a long time. For example, in 1880, the French physicist Pierre Curie had discovered the piezoelectric effect. In this case, certain crystalline substances produce an electrical charge if they are squeezed, and correspondingly they change size if an electric current is applied to them.

This effect subsequently found many diverse applications in electronics, from sensors (including microphones) to actuators (including extremely loud alarms).

Prior to Fleming inventing his vacuum tube diode, early radios relied on the use of crystals for rectification. At that time no one really understood how crystals could convert an AC signal into its DC counterpart, and following the advent of the vacuum tube most people really couldn't care less.

However, some scientists, inventors and engineers did remain interested in crystals in general, especially as they began to discover more of the special properties associated with different crystalline structures. For example, in 1907 a letter from Mr. H.J. Round was published in the American *Electrical World* magazine as follows:

To the editors of Electrical World*: Sirs – During an investigation of the unsymmetrical passage of current through a contact of carborundum and other substances a curious phenomenon was noted. On applying a potential of 10 volts between two points on a crystal of carborundum, the crystal gave out a yellowish light.*

Mr Round went on to note that some crystals gave out green, orange, or blue light. This is quite possibly the first documented reference to the effect upon which light-emitting diodes (LEDs) are based.

Similarly, as far back as 1926, Dr Julius Edgar Lilienfield of New York filed for a patent on what we would now recognize as an *npn* junction transistor being used in the role of an amplifier (the title of the patent was the *Method and apparatus for controlling electric currents)*.

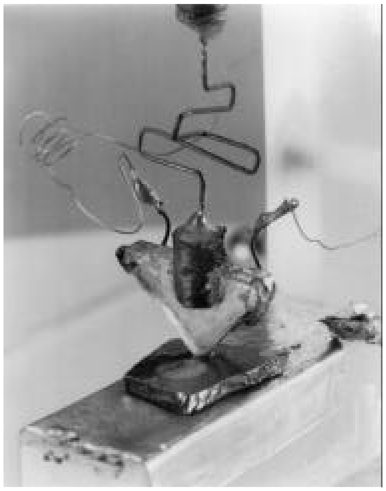
SEMICONDUCTORS

Some substances facilitate the conduction of electricity and are therefore known as *conductors*. Other materials resist the flow of electricity, and these are known as *insulators*. What the early pioneers didn't fully understand is that by adding impurities to certain crystalline structures, it is possible to create a special class of materials known as *semiconductors*, which can exhibit both conducting and insulating properties.

Sad to relate, serious research into semiconductors did not really commence until World War II. At that time it was recognized that devices formed from semiconductors had potential as amplifiers and switches. If it proved possible to create them, these new devices could be used to replace prevailing vacuum tube technology, with the advantages that they would be much smaller and lighter, they would consume much less power, and they would be far more reliable.

TRANSISTORS

In the early 1940s, scientists at Bell Labs in the United States started to experiment with impure



The first ever transistor, created on 23 December 1947. The photo scale is approximately twice life size. Courtesy of Bell Laboratories/Lucent Technologies.

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TIMELINES

1901: Hubert Booth invents the first vacuum cleaner.

1902: Robert Bosch invents the first spark plug.

1902: America. Millar Hutchinson invents the first electrical hearing aid.

1904: England. John Ambrose Fleming invents the vacuum tube diode rectifier.

1904: First ultraviolet lamps are introduced.

1904: First practical photoelectric cell is developed.

1906: First tungsten-filament lamps are introduced.

1907: America. Lee de Forest creates a three-element amplifier vacuum tube (triode).

1908: Charles Frederick Cross invents Cellophane.

1909: Leo Baekeland patents an artificial plastic that he calls Bakelite.

1909: General Electric introduce the world's first electric toaster.

1910: First electric washing machines are introduced.

1910: France. Georges Claude introduces neon lamps.

1911: Dutch physicist Heike Kamerlingh Onnes discovers superconductivity.

1912: The Titanic sinks on its maiden voyage.

1912: America. Dr Sidney Russell invents the electric blanket.

1913: William D. Coolidge invents hot-tungsten filament X-ray tube. This Coolidge Tube becomes standard generator for medical X-rays.

1914: America. Traffic lights are used for the first time

crystals of germanium. The first true semiconductor components were two-terminal diode devices. On the 23rd December 1947, a team comprising the scientist William Bradford Shockley and the theoretical physicists John Bardeen and Walter Brattain succeeded in creating the first point-contact *transistor* (whose name was derived from *trans*fer res*istor*).

Like the triode, this was a three terminal device that could be used both as an amplifier and a switch. Once they had proved that their creation worked, the team broke up to celebrate the Christmas holidays, which is why many (lesser) references state that the first transistor did not make an appearance until 1948.

In 1950, Shockley invented a new type of device called a *bipolar junction transistor* (BJT), which was more reliable, easier and cheaper to build, and gave more consistent results than point contact devices. Then, in 1962, Steven Hofstein and Fredric Heiman at the RCA research laboratory at Princeton, New Jersey, invented a new family of devices called *field effect transistors* (FETs).

Although germanium exhibits more desirable electrical characteristics, for a variety of reasons silicon is easier to work with, and so by the late 1950s silicon had replaced germanium as the semiconductor of choice. (As silicon is the main constituent of sand and one of the most common elements on earth – silicon accounts for approximately 28 percent of the Earth's crust – we aren't in any danger of running out of it in the foreseeable future.)

Very quickly after the first transistors had been developed they started to appear in commercial products. For example, 1952 saw the appearance of the transistor-based hearing aid, quickly followed by Sony's pocket-sized transistor radio. It was also obvious to computer scientists that they could now make machines much smaller (the size of a room instead of a house), but only a very few forward thinkers had any idea as to what was yet to come …

INTEGRATED CIRCUITS

Sometime after the invention of the transistor, people began to think that it would be a good idea to be able to fabricate entire circuits on a single piece of semiconductor. In fact, the first public discussion of this concept is generally credited to a British Radar expert, G. W. A. Drummer in a paper he presented as far back as 1952. However, it was not until 1958 that a young engineer called Jack Kilby actually succeeded in creating multiple components as a single device.

To a large extent the demand for miniaturization was driven by the requirements of the American armed forces and also by rocket research. At that time, one technique that was receiving a lot of attention was the Micro-Module program, which was sponsored by the US Army Signal Corps.

Using this technique, all of the components were created with a uniform size and shape, and the wiring was built into the components themselves. These Micro-Modules could then be snapped together to form circuits.

Texas Instruments was working on the Micro-Module program when Jack Kilby joined the company in May 1958. In the middle of the summer, most of the plant was to shut down for a mass vacation, but as a new employee

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(in Cleveland, Ohio).

1917: Clarence Birdseye preserves food using freezing.

1919: The concept of flip-flop (memory) circuits is invented.

1919: Walter Schottky invents the tetrode (first multiple-grid vacuum tube).

1921: Czech author Karel Capek coins the term *robot* in his play *R.U.R.*

1921: Albert Hull invents the magnetron (a microwave generator).

1921: Canadian-American John Augustus Larson invents the polygraph lie-detector.

1921: First use of quartz crystals to keep radios from wandering off-station.

1923: First neon advertising sign is introduced.

1923: First photoelectric cell is introduced.

1926: America. First "pop-up" bread toaster is introduced.

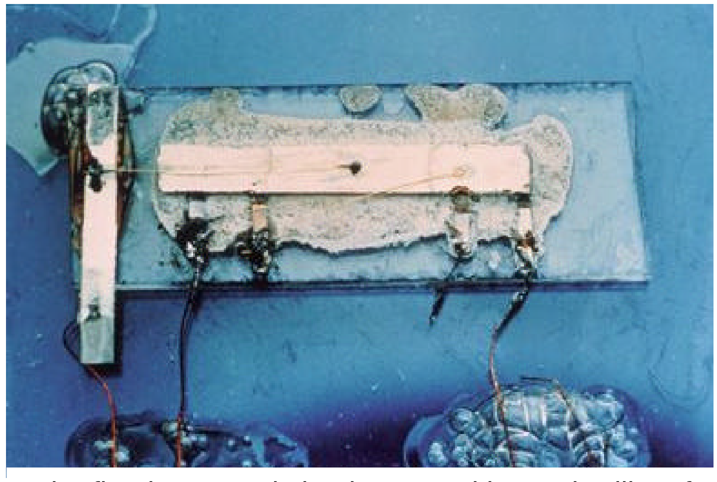
1926: America. Dr Julius Edgar Lilienfield from New York filed for a patent on what we would now recognize as an *npn* junction transistor being used in the role of an amplifier.

1927: Harold Stephen Black conceives the idea of negative feedback which, amongst other things, makes hi-fi amplifiers possible.

1927: First five-electrode vacuum tube (the pentode) is introduced.

1928: Joseph Schick invents the electric razor.

1928: America. First quartz crystal clock is introduced.



The first integrated circuit, created by Jack Kilby of Texas Instruments in 1958. Courtesy of Texas Instruments.

Kilby did not have any vacation time coming, so he was left to his own devices.

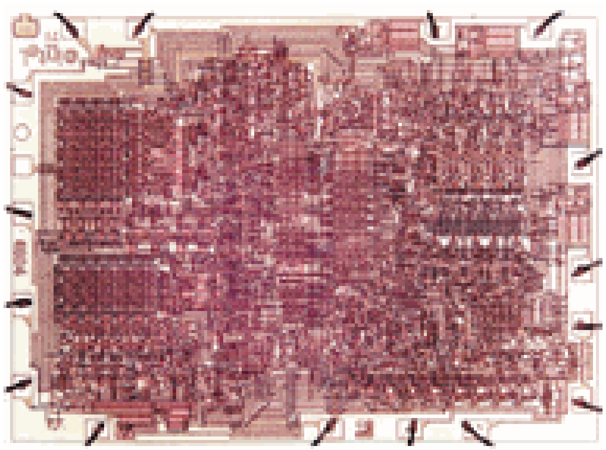
In a desperate attempt to avoid being consigned to working on Micro-Modules for the rest of his career, Kilby started pondering the fact that multiple devices such as resistors, capacitors and transistors could be fabricated on a single piece of semiconductor and connected together *in situ* to form a complete circuit.

As soon as his boss returned from vacation, Kilby explained his ideas and received permission to experiment further. On 12th September 1958, he powered up his first prototype – a phase shift oscillator – which immediately started to oscillate at approximately 1.3MHz.

Although manufacturing techniques subsequently took different paths to those used by Kilby, he is still credited with the manufacture of the first true *integrated circuit*.

The original bipolar junction transistors were manufactured using the mesa process (named after flat-topped, table mountains), in which a doped piece of silicon called the *mesa* (or *base*) was mounted on top of a larger piece of silicon, which formed the *collector*. The third terminal – the *emitter* – was created using a smaller piece of silicon, which was embedded in the base.

In 1959, the Swiss physicist Jean Hoerni invented the *planar process* in which optical lithographic techniques were first used to diffuse the base into the collector, then the



The first microprocessor, Intel's 4004, of 1971. Courtesy of Intel.

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1930: America. Sliced bread arrives.

1936: Fluorescent lighting arrives.

1938: Hungarian Lazlo Biro patents the first ball-point pen.

1938: Walter Schottky discovers the existence of holes in the band structure of semiconductors and explains metal/semiconductor interface rectification.

1938: America. Claude E. Shannon publishes an article (based on his Master's thesis at MIT) showing how Boolean algebra could be used to design digital circuits.

1939: Light-emitting diodes were patented by Messers Bay and Szigeti.

1943: German engineer Paul Eisler patents the printed circuit board.

1945: Percy L. Spensor invents the microwave oven (the first units go on sale in 1947).

1947: America. Physicists William Shockley, Walter Brattain, and John Bardeen create the first point-contact germanium transistor on the 23rd December.

1948: First atomic clock constructed.

1950: Maurice Karnaugh invents Karnaugh Maps (circa 1950), which quickly become one of the mainstays of the logic designer's tool-chest.

1950: America. Physicist William Shockley invents first bipolar junction transistor.

1952: England. First public discussion of integrated circuits is credited to a British radar expert, G.W.A. Dummer.

1954: America. C. A. Swanson company markets the first "TV Dinner''.

1955: Velcro is patented.

1957: America. Gordon Gould conceives the idea of the laser.

1958: America. Jack Kilby, working for Texas Instruments, succeeds in fabricating multiple components on a single piece of semiconductor.

1959: Swiss physicist Jean Hoerni invents the planar process, in which optical lithographic techniques are used to create transistors.

1959: America. Robert Noyce invents technique for creating microscopic aluminum wires on silicon (leads to development of integrated circuits).

1960: America. Theodore Maimen creates the first laser.

1962: America. Steven Hofstein and Fredric Heiman at RCA Research Lab invent field effect transistors (FETs).

1962: America. Unimation introduces the first industrial robot.

1967: America. Fairchild introduce an integrated circuit called the Micromosaic (the forerunner of the modern ASIC).

1968: America. First Static RAM IC reaches the market.

1970: America. Fairchild introduce the first 256-bit static RAM called the 4100.

1970: America. Intel announce the first 1024-bit dynamic RAM, called the 1103.

1971: America. Intel creates the first microprocessor, the 4004

1975: England. First liquid crystal displays (LCDs) are used for pocket calculators and digital clocks.

emitter into the base.

One of Hoerni's colleagues, Robert Noyce, invented a technique for growing a layer of silicon dioxide insulator over the transistor, and then etching this layer to expose small areas over the base and emitter. Thin layers of aluminum were subsequently diffused into these areas to create wires. The processes developed by Hoerni and Noyce led directly to modern integrated circuits.

By 1961, both Fairchild and Texas Instruments had announced the availability of the first commercial planar integrated circuits, comprising simple logic functions. Only nine years later in 1970, Fairchild introduced the first semiconductor-based 256-bit static RAM, while Intel announced the first 1024-bit dynamic RAM.

Then in 1971, Ted Hoff *et al* at Intel invented the world's first *computer on a chip* – the 4004 microprocessor. The successors of this device (the 4040, 8008 and 8080) heralded a new area in computing. Systems small enough to fit on a desk could be created with more processing power than monsters weighing tens of tons only a decade before.

Almost unbelievably, individuals could now own their own personal computer. As we shall see in future parts, the effects of

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these developments are still unfolding, but it is not excessive to say that electronics in general, and digital computers in particular, have changed the world more significantly than almost any other human invention.

MORE INFO

The way in which components like transistors and integrated circuits perform their magic is discussed in greater detail in *Bebop to the Boolean Boogie (An Unconventional Guide to Electronics)*, while the history of the early computers is discussed in more detail in *Bebop BYTES Back (An Unconventional Guide to Computers)*. By some strange quirk of fate, both of these books are available from the *EPE Online Store* at **www.epemag.com**

NEXT MONTH

In Part 3, we shall consider the development of communications in the 20th Century.

HUMBLE APOLOGIES

Before you reach for your pen or computer keyboard to send us a stern letter of chastisement, we crave your indulgence and ask you to accept our humblest apologies for all of the things we had to leave out. The history of cunning devices such as light-emitting diodes (LEDs), laser diodes, phototransistors and suchlike would make fascinating reading.

Who could deny that interconnection and packaging technologies like printed circuit boards (PCBs), flexible circuit boards, hybrids, and multichip modules (MCMs) really deserve an article in their own right. Image capture and display technologies like charge-coupled devices (CCDs), cathode ray tubes (CRTs), liquid crystal displays (LCDs) and so forth are certainly entitled to be acknowledged.

Devices and techniques such as masers, lasers, fiber optics, magnetrons (leading to both Radar and microwave ovens), mercury delay lines and magnetic core stores also deserve a hearing. And of course a tremendous variety of other technologies, ranging from plastics to storage (batteries), have all played a large part in the evolution of electronics as we know it today.

Unfortunately, space limitations meant that when "push came to shove" we had to make some stern decisions. And when one peels the outer layers away, it becomes obvious that the three absolutely core electronics developments of the 20th Century are the vacuum tube, transistor, and integrated circuit, as discussed above. Of course, if you disagree (or if you simply crave more once this series is finished), please feel free to vent your feelings by inundating the Editor with your letters and emails.

Go to next section

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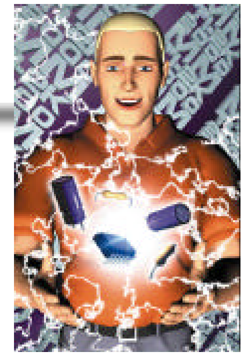
TEACH-IN 2000



PART PART 5 – Waveforms, Frequency, and Time

by John Becker

What we are doing during this *Teach-In 2000* series (of at least 10 parts) is to lead you through the fascinating maze of what electronics is all about! We are assuming that you know nothing about the subject, and are taking individual components and concepts in simple steps and showing you, with lots of examples, what you can achieve, and without it taxing your brain too much!

In the first four parts we discussed (and gave you practical experience of) several types of commonly used electronic components. Last month we also showed you how to interface your experimental circuits to a PC-compatible computer, allowing pulse waveforms to be displayed on the screen. We now discuss other waveforms and how to observe them on your PC, adding just one more component to your breadboard.

Greetings again! We expect you've got your breadboard coupled to the computer, all powered-up and ready to go. But, wait, is the oscillator on your breadboard the same as that described in Fig.4.1 and Fig.4.3 of *Teach-In* Part 4 last month? If not, make it so, then we're ready to start…

MAKING WAVES

Last month, we left you with the suggestion that you should explore two of our simulation programs: *Computer as Frequency Counter* and *Pulse Input Waveform Display. (Remember that this software is available for free download from the EPE Online Library at* **www.epemag.com***, Ed.)*

In the second of these programs, at some stage of your experimentation, hopefully you produced a screen display that looks something like that in Photo 5.1. It is *waveforms* that are the main subject of our discussion this month.

Before that, though, we shall discuss a little more fully not just the above two programs, but also the preceding one, *Parallel Port Data Display/Set*. In doing so we shall also introduce you to the first of several concepts in Digital Logic, that of the AND function.

From the main menu, call up the *Parallel Port Data Display/Set* program to your screen. Connect the computer's parallel port to your breadboard, *without* the oscillator connected to any of the five input points (IN0 to IN4).

INPUT REGISTER

Now look at the *Direct Input Byte* box on the screen (Photo 4.8 last month). What you should see is the *Original Byte* value shown as 10000xxx binary (where x can be either 1 or 0).

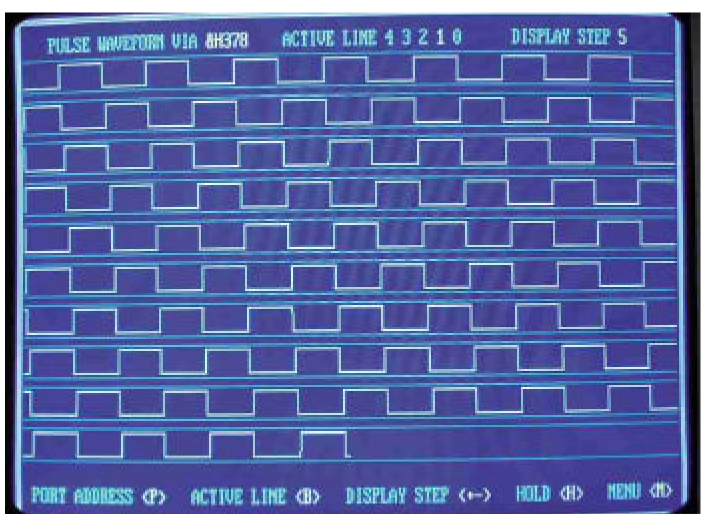


Photo 5.1. Typical pulse waveforms input to the computer via the simple interface board.

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Bit	Power	Decimal	Binary
7	2^7	128	10000000
6	2^6	64	01000000
5	2^5	32	00100000
4	2^4	16	00010000
3	2^3	8	00001000

This indicates that the computer's input port *register* (a special form of digital storage device) believes that its eight bits are at the logic states shown.

Your breadboard interface circuit only uses five bits, but which five of the eight bits apparently available? Probably from your experiments you already know the answer, the left-hand five, bit 7 to bit 3 are those used in connection with breadboard inputs IN4 to IN0.

As far as the computer is concerned, bits 2 to 0 are not to do with data input (what their logic values are depends on your computer system – the author's various computers return different values).

What might also be puzzling you (although you've possible just shrugged your shoulders over it and thought *that's the way it is*), is that bit 7 is always set at the opposite logic to what you expect through connecting signals to IN4 on the board. Well, you're right, that *is* the way it is, bit 7 *is* inverted by the computer.

Underneath the upper boxes is the correction formula used to change the value directly received by the port register (box 1) to that in box 2, *Corrected Input Byte*. The meaning will become clear after Binary Logic has been discussed in Part 6. Basically, all that is being done is to re-invert bit 7 and shift all the bits along to the right by three places. This allows the correct logic on all five breadboard inputs to be seen as such in box 2, as the *New Byte*.

This type of manipulation can be extremely useful when using the computer as an item of test gear to monitor a digital circuit.

FREQUENCY COUNTER

It is also possible to read the status of each register bit by ANDing it with particular binary values (a Binary Logic subject coming in Part 6), and this is what is done in the *Computer as the Frequency Counter* program. Call it up from the menu, and couple your oscillator IC1a pin 2) to IN0 as you have done before. It is best if diodes D2 and D3 are omitted and a 1kW resister used in position D3 (also as you've done before).

You will have discovered that the program only responds to frequency input signals from one interface input path at a time, and that for this path to be seen as active by the program, the *Active Bit* in the screen box has to be appropriately set from the keyboard (key <B>). Each active bit has an associated AND value stated – each value is one of the powers of decimal 2:

When ANDing one binary number with another, individual bits in the answer will only be at logic 1 if the same bit in both starting values is also at logic 1. If either or both bits are at logic 0, so the same bit in the answer will also be at logic 0. For example, to test for bit 4 being high in a register that probably has other bits set as well (bits 3 and 6 in this example):

Register value = 01011000 (decimal 88)
AND value = 00010000 (decimal 16)
ANDed answer = 00010000 (decimal 16)
therefore bit 4 is high. Conversely:

Register value = 01001000 (decimal 72)
AND value = 00010000 (decimal 16)
ANDed answer = 00000000 (decimal 0)
therefore bit 4 is low.

Thus all that is needed to isolate the status of a bit is to AND it with the required value. If the bit is low an answer of zero will result; if it's high an answer greater than zero will result. So you simply check whether or not the answer is zero and act accordingly. The AND command/facility is a powerful tool in computing and electronics.

Note that in the computer program that actually controls what you are now seeing on screen, binary values cannot be recognized as such, consequently the *decimal* equivalent is that used in the *Frequency Counter* program.

This program has been written to isolate the bit as selected in the screen box and to detect each time it changes state during a period of one second, dividing the answer by two to find out how many times the bit has been high in that period. This result is displayed on screen as the (approximate) frequency at which your oscillator is running.

The internationally agreed unit of frequency is the *Hertz*, abbreviated to Hz, as shown on the screen. (Strictly speaking, Hertz in this context should be written with a lower-case initial – *hertz*.) In the present example we have a frequency of 1Hz (one cycle per second). Back in history, frequency was actually defined in cycles per second – CPS or C/S).

PULSE DISPLAY

In the *Pulse Input Waveform Display* program (call it up on

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screen), AND is again used to isolate the selected bit. In this case, though, the result causes the drawing of a horizontal line to represent the bit's status, high or low. The "vertical" line is simply drawn by the program at the detected transition between logic levels.

Having completed one crossing of the screen, the waveform re-commences on the next allocated path, erasing any previous waveform. The rate of transition is selectable via the Display Step option (note that this does not actually change the rate at which the register input is examined – *sampled* – it just changes the distance the line travels for each sample). It is not possible to assess frequency from this display (a true oscilloscope would allow this to be done, however).

The facilities offered by this display and the previous pulse counting program can be of great use when testing other circuits in the future.

HARMONICS

We would now like to illustrate a problem that can occur when monitoring a waveform, and one which can also affect the correct response when digital electronic circuits are used in real-life situations – that of relative rates of response between one circuit and another. The effectiveness of the illustration on screen, though, rests on how fast your computer is running. If it runs too slowly, it may be difficult for the required effect to be produced. Nonetheless, let's try it.

First, set your oscillator to a slow speed so that the individual pulses (as square waves – equal length highs and lows) are clearly seen and with wide spacing. It is probably best to select a *Display Step* value of 10 (use the <+> key).

Slowly increase the oscillator's rate and watch the pulses close up to each other (you may need to change capacitor C1 to a smaller value). Eventually, the pulses will be so close together

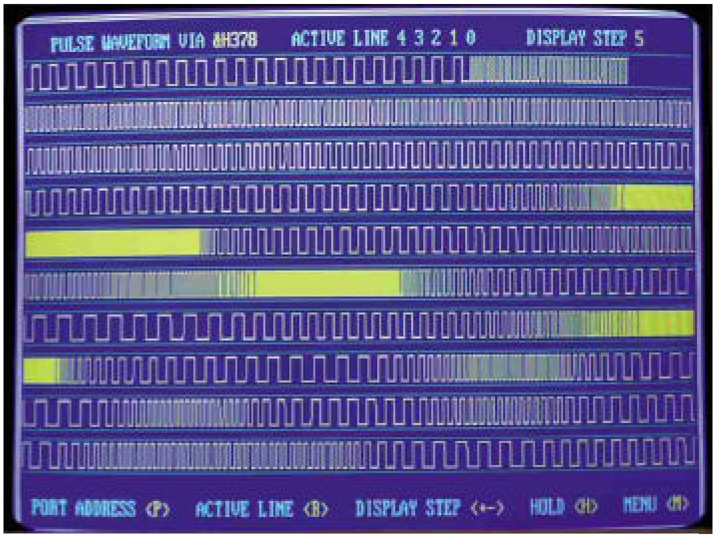

Photo 5.2. Example of "under-sampled" pulse waveforms into the computer via the simple interface board.

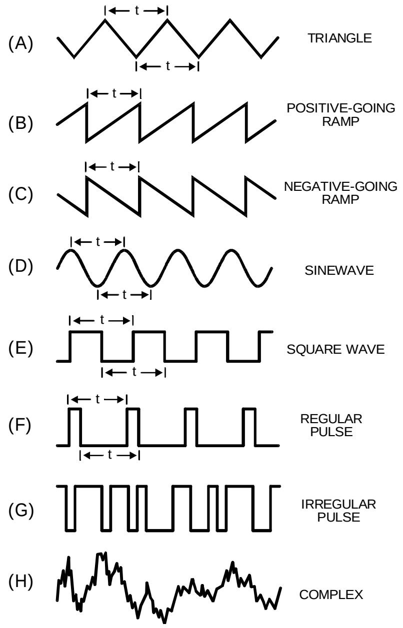

Fig.5.1. Examples of waveform types. Frequency measurements can be assessed for periods arrowed for (A) to (F), but cannot be meaningfully measured for irregular or complex waveforms.

that you can probably not distinguish between them.

Continue to increase the frequency – what you should see next (your computer's sampling speed permitting) is that as you increase the frequency, the waveform spaces start to widen, probably with uneven spacing (see Photo 5.2). *Why?*

The answer is not that your oscillator has decided to run erratically or more slowly all of a sudden. What is happening is that the computer now does not have time to respond to each pulse. So what you are seeing on screen is a *sub-harmonic* of the actual frequency being monitored. The unevenness of the spacing is due to the computer's sampling rate and the speed of the oscillator not being synchronized.

If you try this with the *Frequency Counter* program, you

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will see the apparent frequency rate change downwards as the transition to sub-harmonic sampling occurs.

It is even possible that as the oscillator's frequency is increased still further, sampling may occur on every *third* pulse, or every *fourth* pulse, and so on, almost indefinitely. It is unlikely, though, that our demonstration program will actually allow you to go beyond one-in-three.

This situation is one that you have to consider very carefully when using a frequency counter or oscilloscope (whether as true items of test equipment, or as computer-based sampling programs). It is also something to be considered when you start designing digital logic circuits – can all the digital integrated circuits keep pace with the rat e at which others expect them to? Highly unpredictable results can occur if they can't!

Not only does the problem reveal itself in *digital* electronics, but you can also experience allied situations when dealing with *analog* signals – a signal at one frequency adversely (or desirably in some cases) affecting a signal at another.

In a future part we shall show you how two analog signals respond to each other.

WAVEFORM TYPES DISPLAY

Put your breadboard assembly to one side for the moment (you'll need it again for the *Experimental* article, though). Let's show you examples of some different waveform types. We shall also explain how you can do some simple calculations in respect of frequency and time. From the main menu select *Frequency and Time* (well, what else?!).

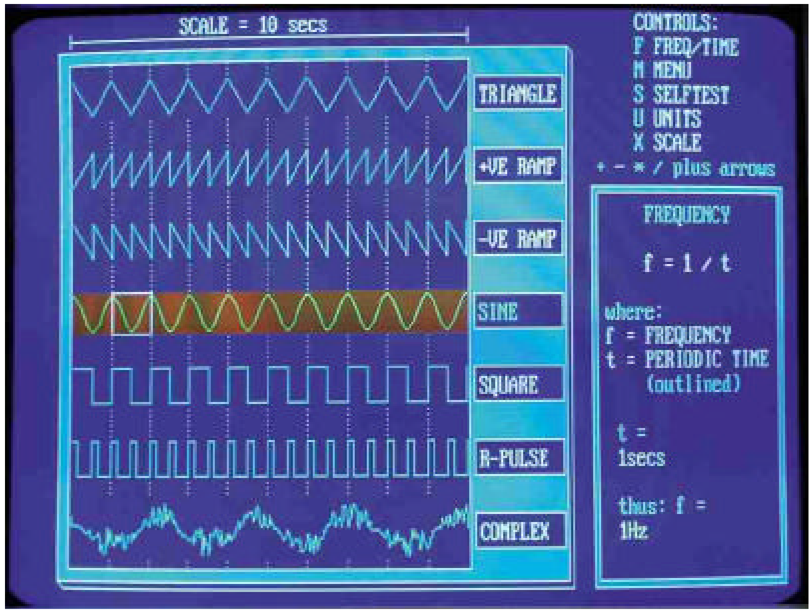

Fig.5.3. Relationships between upper and lower sections for a uniformly alternating waveform.

Examples of seven different types of waveform will be seen on screen (see Photo 5.3 and Fig.5.1) as follows:

- o) Triangle
- o) +VE Ramp (positive-going ramp – upwards)
- o) –VE Ramp (negative-going ramp – downwards)
- o) Sine
- o) Square
- o) R-Pulse (regular pulse)
- o) Complex

In fact an eighth waveform is available via the screen – press the down arrow key three times. Where R-Pulse was will now become I-Pulse (Irregular Pulse) and the pulses will be seen to be very irregular.

SCALING AND CALCULATIONS

The screen display is scaled, at present to represent a period of 10 seconds from the start of any waveform to its end. Vertical dotted lines indicate the 1-second interval points.

Press the up-arrow key so that the orange background is on the square wave.

Note the point at which any one of the pulses first becomes high and the point at which it ends being low (and the next pulse commences). You will see that the square wave has a white box around it to indicate this period. In Fig.5.1 it is represented by the "t" arrows.

This period is known as a *cycle*. On screen you will see that it takes just one second. When a waveform consists of many equal length cycles its *frequency* is defined as the number of cycles that occur in one second, which, as we said a few paragraphs back, is expressed in Hertz.

In the right-hand box you will see that the time (*t*) for one pulse and its consequent frequency (*f*) is stated:

$t = 1$ secs, $f = 1$Hz

Press key <X> to change the screen's scale to 1 second. Each vertically dotted interval is

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now 0·1 seconds. The frequency represented is therefore 10 cycles per second – 10Hz. The right-hand box confirms this.

You/we have been able to do the conversion from time to frequency in our heads, almost instinctively. As shown in the box, though, there is a formula for it:

$$f = 1/t$$

Conversely, if you want to find out the cycle period (time) of a waveform whose frequency you know, the formula becomes:

$$t = 1/f$$

Press <F> and this formula will be shown, together with the calculated answer.

Press any of the <+ – * /> keys to expand or contract the waveform, and variously swap between the two formulae using <F>. The units in which *f* and *t* are expressed are changeable by using <U>.

These formulae can be applied to any regular waveform, including the first six on screen (and in Fig.5.1). With irregular waveforms, such as those for I-Pulse and Complex, periodic time and frequency for the waveform as whole cannot be ascertained.

All that can be assessed from the irregular pulse, for example, is the period of any individual pulse. In terms of overall frequency of the waveform, this answer is meaningless.

It is possible, of course, to use a frequency counter with this irregular pulse chain and determine the number of pulses that occur in any 1 second, but the answer for each 1-second sampling period is likely to be different.

With the complex waveform, there are in fact a great many different frequencies involved in its make up, but they are all likely to be at different amplitudes. To separate each frequency and its amplitude out from the main waveform requires very complex equipment (such as a *frequency analyzer* – expensive!).

WELL-DEFINED

It should also be obvious that even with a well-defined waveform, you need to be able to time the *complete* period of a cycle. It does not matter, though, at which point you actually start the timing.

With the square wave you can start timing as the pulse rises (at its *leading edge*) and end at the start of the leading edge of the second pulse. Alternatively, you can start as the pulse falls (at its *trailing edge*) and end as the next pulse's trailing edge begins to fall. The white outline box on the waveform illustrates this point when you set it to lower frequencies (also see Fig.5.1).

When looking at a waveform on a screen (whether it is a computer screen as in this simulation, or an oscilloscope screen), the commencement of a cycle does not necessarily occur where you first see the waveform appear; the cycle may have started long before the screen responded to it. Always take a measurement when it is obvious where the exact start of the cycle occurs. Our simulation program, you will notice, takes this into account.

Examine the position of the white box for all the waveforms that can display it and observe at which points of a cycle measurements may be taken.

It is worth noting that most oscilloscopes have a facility for placing a horizontal line across the screen. This can be moved up or down and placed so that it crosses any point on the waveforms. Timing measurements can then be taken between any two or more points where the horizontal and waveform lines cross.

SELF-TEST

For a bit of timely entertainment, we've added a *Self-Test* option to test your use of time and frequency calculations – press <S> to enter or exit it.

CYCLE POWER

In Part 3 we explained that the amount of current consumed by a circuit can be defined according to the voltage applied across it and the resistance through which it flows, I = V/R. When the voltage is at a nice steady DC level and the resistance is constant, the current drawn is the same at all instants of measurement.

If we want to calculate current (or any of the factors defined in Ohm's Law and its derivatives – Part 3) in relation to a changing voltage (e.g. waveform) rather than steady conditions, the situation becomes more complex.

For any particular instant, we can of course say that conditions are constant at that instant, and calculate accordingly. However, we often need to know the current drawn over a *period* of time, rather than instantaneously.

With a square wave or regular pulse waveform, average current can be calculated according to the period for which the pulse is high (full current flow) relative to the period for which it is low (minimum current flow).

When the pulse is changing between 0V and a known voltage value, it's just a matter of

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ratios of the on to off (high to low) periods of the pulse.

For example, if a 0V to +5V pulse is high for 0·5 seconds and low for 0·5 seconds (i.e. a square wave), we can say that the *average* current drawn in one second is half that which would be drawn if the *maximum* current flowed for 1·0 seconds.

If the on-off periods are not equal, the formula used is just:

Average Current = On Period/ Cycle Period x Maximum Current.

For the above example, and assuming a continuous maximum current of 2 amps, this relationship becomes:

$I_{average} = T_{on}/T_{cycle} \times I_{max} = 0{\cdot}5$ sec/ 1 sec x 2 amps = 1 amp per second.

TRIANGULATION

For waveforms such as triangle and ramp, the calculations are just as simple, irrespective of their relative rise and fall times.

By definition, the voltage of triangle waveforms rises at one constant rate, and falls at another constant rate. This is true irrespective of the relative rates of rise and fall for the waveform.

In the case of a uniformly-shaped triangle (isosceles – having two equal sides), rise and fall periods are equal in length. Note that a ramp waveform is a special case of triangle, in which the vertical edge occurs instantaneously, making the ramp duration the same as the cycle period. (In fact an *instantaneous* change in level *never* occurs in electronics – every change takes some amount of time, no matter how small, see Part 6 next month.)

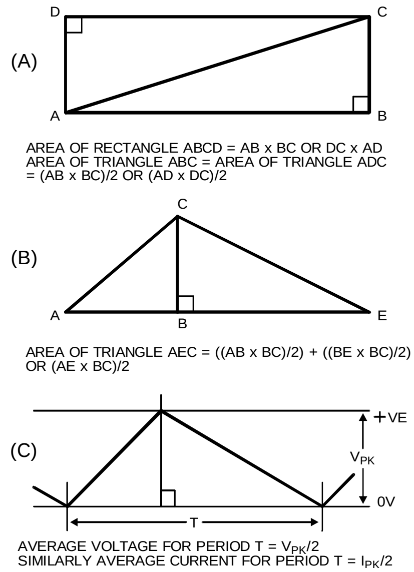

Photo 5.2. Example of "under-sampled" pulse waveforms into the computer via the simple interface board.

The maximum peak current is a predictable or measurable value (that when the voltage is at its maximum), so too is the minimum current (that when the voltage is at 0V, i.e. a current of zero amps).

Consequently, when a triangular waveform is alternating between 0V and a given maximum voltage, the average current drawn during one cycle is half that of the peak current.

Do you remember from school days how you found the area of a triangle having sides of different lengths? (See Fig.5.2.) The principle for finding average current per unit of time in respect of a triangular waveform is the same: multiply the height (voltage

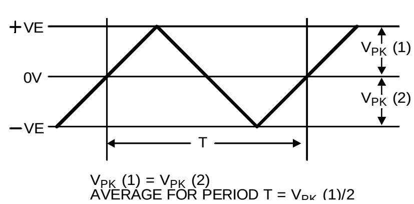

Fig.5.3. Relationships between upper and lower sections for a uniformly alternating waveform.

or current) by the length (time) and divide by two, e.g.:

$I_{av} = I_{max} \times T_{cycle}/2$, or:

$I_{av} = (I_{max}/2)$ per cycle time

Suppose a peak current of 100mA is drawn when power is supplied by a triangular waveform alternating between 0V and +5V and the cycle period is 1 second. The minimum current drawn is zero. Therefore the average current drawn is simply 100mA/2 = 50mA per second.

If the waveform is alternating between two other levels, a similar principle applies, but requires just a bit of extra calculation. Suppose, for example, that the waveform causes the current to alternate between 100mA maximum and 20mA minimum:

First take the difference between the two extremes: 100mA – 20mA = 80mA. The average of the current difference for this waveform is 80mA/2 = 40mA. But there is the "standing" current of 20mA, which has to be added to the average difference. Thus the overall average current drawn = 40mA + 20mA = 60mA.

What happens, though, if the waveform is evenly alternating between –6V and +6V, for example? Instinct might just suggest that if 100mA is drawn at +6V, then –100mA is drawn at –6V, thus the average current drawn is zero. *But,* you might wonder, *doesn't that mean the battery would never run down?* Sadly, not so…

It's certainly true to say that the average current or voltage value of a waveform which alternates symmetrically above and below a zero value will be zero if measured over a long enough period, although this does not mean that the *power* consumed is zero.

When it comes to expressing an *average* in relation to a

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triangular waveform *uniformly* alternating above and below a zero point, it is usually taken as the average over just *half* of a cycle, not over the *full* cycle. The half cycle can be either on the negative or positive side of the zero midway level. The effective answer is same. (See Fig.5.3.)

However, what we can say with respect to both sides of the waveform is that it has a *peak-to-peak* value twice that of its *peak* value. The peak value in the previous example is 100mA, therefore its peak-to-peak value is 200mA.

WAVING PROOF

If your computer has QuickBASIC or QBasic installed, you can prove for yourself that for a triangle wave the average voltage or current for one side of its ramp is half the peak value, using the following BASIC routine:

```
ramplength = 10: ' (seconds)
totalvolts = 0
FOR volts = 0 TO ramplength STEP 1
totalvolts = totalvolts + volts
NEXT volts
averagevolts = totalvolts / ramplength
PRINT averagevolts
```

You will get an answer of 5V.

Now do the same for a half a sine wave (having an angular change of 0° to 180°) and whose peak voltage is 1V. Remember that the sine of 0° is 0 and that the sine of 90° is 1.

```
CONST pi = 3.141592653589# / 180
volts = 1
totalvolts = 0
FOR angle = 0 TO 180
totalvolts = totalvolts + (SIN(angle * pi)* volts)
NEXT angle
averagevolts = totalvolts / 180
PRINT averagevolts
```

The answer now will be 0·6366036V (approximately), say 0·636V.

SINE WAVES

Since sine waves are obviously subject to a different set of rules to triangle waves, let's examine them a bit more closely. From the main menu select *Sine Wave Value Relationships*. Photo 5.4 shows what you should see displayed.

The relationships we now discuss are specifically those with regard to *pure* sine waves. They do not apply to any other type of waveform. Furthermore, if you see any waveform relationships referred to anywhere and the shape of the waveform is not actually stated, then the relationships are assumed to refer to sinusoidal conditions.

Looking at your screen display (and Fig.5.4), you will see the representation of a pure sine wave swinging symmetrically above and below a zero level and plotted horizontally with respect to time. Four vertical arrows indicate four major relationships exhibited by a sinusoidal voltage waveform:

- o) Vpk — peak voltage
- o) Vav — average voltage
- o) Vpk-pk — peak to peak voltage
- o) Vrms — r.m.s. voltage

Vpk – the peak voltage is that relating to just one half of the cycle. Since a sine wave is symmetrical above and below 0V, Vpk is the same whatever half (positive or negative) of the waveform is measured.

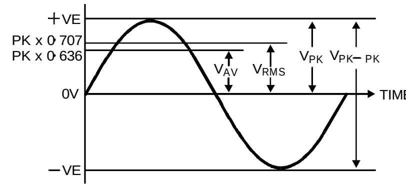

Fig.5.4. Definition of the four value relationships for a pure sine wave.

Vav – as said in the previous section, a sine wave's average voltage is that taken over one complete half-cycle. We showed that it has a value 0·636 times that of the peak voltage.

Vpk-pk – the peak-to-peak voltage is obviously twice that of the peak voltage (Vpk).

Vrms – well, first we had better explain the concept of RMS:

RMS VALUES

You have discovered in earlier parts that when a current flows through a resistance, power is dissipated. We went on say that heat is generated by that dissipation. For a fixed resistance, and steady (DC) voltage or current, the heat generated is calculable – often expressed in watts (see Part 1). In the Ohm's Law section (Part 3) you saw that power can be calculated in several ways, such as $P = I^2 \times R$, $P = V^2/R$, and $P = I \times V$.

An RMS (root of the mean square) value states the *effective* value of alternating current or voltage in terms of the heat that will be generated through a resistance. By definition, the value is that which will produce the same amount of heat in the resistance as would a direct voltage or current of the same magnitude.

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Any waveform shape can be related to an RMS value, but the value is really only meaningful when referred to a known shape. For a sinusoidal waveform the RMS value is 1·414 times the peak value.

SINE WAVE RELATIONSHIP

The four sine wave units of measurement listed in the previous section have their relationships tabulated at the bottom of the main screen box displayed.

The screen display relationships are interactive (although the waveform itself is not). Each formula can be selected using the four keyboard arrows. Various values can also be set through the smaller left-hand box. Thus you can have the computer calculate relationship answers in respect of values of your choosing.

On entry to the screen you will see a highlight on Pk x 0·636, allowing you to find the average value (AV =) when the peak value is known. Referring to the values box, Pk is shown as 1V. At the top of the main box is shown the answer to the calculation, in this case the same answer that we illustrated earlier with the BASIC sine wave calculation example.

We suggest you experiment with the different formulae and values of your choice (the options vary depending on the formula). Try to memorize some of the formula (two useful ones are AV = Pk x 0·636 and Pk = RMS x 1·414). The scaling of the values is changeable using <X>.

You will find this facility to be of enormous value when you design your own circuits in the future (or wish to analyze those of other designers).

SELF-TEST

Finally for this month's Tutorial – through the *Self-Test* option the computer randomly selects sine wave related questions. You are expected to use your calculator, and then compare your answer to the computer's, which will be displayed when you press <A>. You can cheat a bit if you want by changing the values offered by the computer!

And thinking of changing values, do please read and digest our "measured observations" discussion in Panel 5.1 following the *Experimental* section.

EXPERIMENTAL

In this month's *Experimental* section we show you how to add another circuit to the interface board. This allows you to actually view on screen the various waveforms you've been generating with the variable mark-space oscillator of Fig.4.3 last month,

These include triangle, rising ramp, falling ramp, square wave, and regular pulse. Sine waves, irregular pulses and complex waveforms we shall illustrate via your breadboard later in the *Teach-In* series.

NEXT MONTH

In Part 6 next month, we return to Binary Logic (briefly discussed when the Parallel Port Data Display/Set program was described). The discussion will include Digital Logic Gates – OR, NOR, XOR, XNOR, AND, NAND. As usual, the screen displays will be interactive.

TEACH-IN 2000
EXPERIMENTAL 5
ANALOG-TO-DIGITAL CONVERTER

We are now going to describe a very simple circuit that you can assemble on your breadboard, and which will allow you to use your computer to view various analog waveforms, such as the triangle and ramps discussed in this month's *Tutorial*. It is capable of displaying other waveforms as well.

However, we won't try to deceive you – the circuit is highly useful, but it's also very limited!

Commercial equipment such as oscilloscopes, or commercial software for computer-based virtual 'scopes will do far more than our simple demo software. The author's Virtual Scope project of *EPE* Jan-Feb '98 is also an extremely sophisticated item of computer-based test gear, but it has to be said that the construction of its complex printed circuit boards is not suited to novices.

The intention of the *Teach-In* analog interface is basically to let you view the various waveforms that you create on your breadboard. However, it can be used not only with the demo circuits we describe

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throughout this Teach-In series, but it will be of use with some of your own future designs.

Should we have space later in the series, we'll describe the sort of facilities you should expect from a fully-fledged oscilloscope (and which need not be very expensive).

ANALOG INTERFACE

A very simple analog-to-digital converter (ADC) integrated circuit (IC) is the only active component in this part of your interface assembly. The circuit diagram for its connections is shown in Fig.5.5.

We shall discuss the nature of the ADC (IC2) later on in this article. In the meantime, we want you to assemble the circuit on the breadboard and have a look at some waveforms on your screen.

The breadboard layout for the ADC (and the computer interface from last month) is shown in Fig.5.6. Assemble the components into the breadboard, following the latter's numbered holes.

The oscillator should be same as that referred to at the start of this month's *Tutorial* (i.e. with diodes D2 and D3 included). Use a 100uF capacitor for C1 and adjust preset VR1 to a midway position.

Connect the resistor/capacitor junction on the oscillator (IC1a pin 1) to the ADC at its input pin 2 (Signal Input as shown in the breadboard layout). Also connect the ADC's data output pin 6 (D OUT as shown in Fig.5.5) to IN1 on the computer interface part of the board. Crocodile-clipped links will do in both cases.

Power up the board and run the *Analog Input Waveform Dis-*

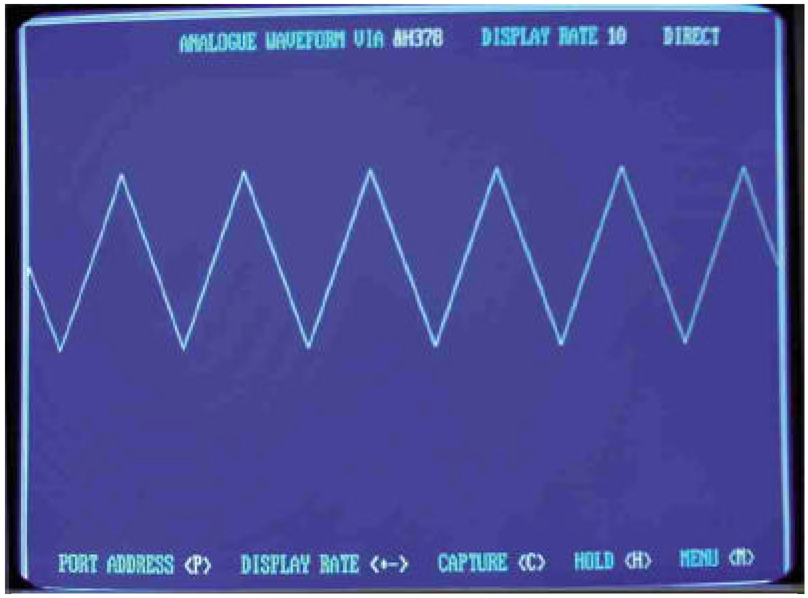

Photo 5.6 Typical analogue waveform as demonstrated using the complete interface circuit

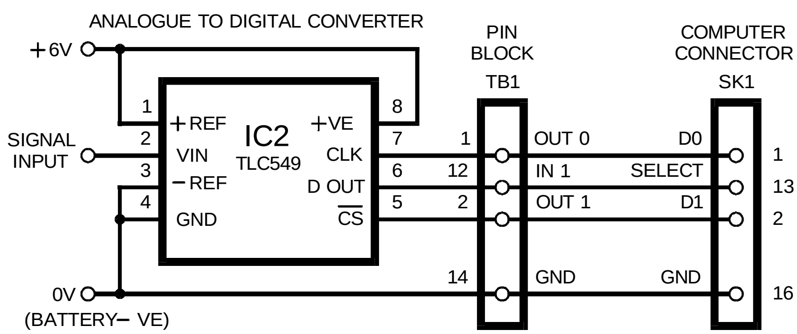

Fig.5.5 Circuit diagram for the serial analog-to-digital converter interface.

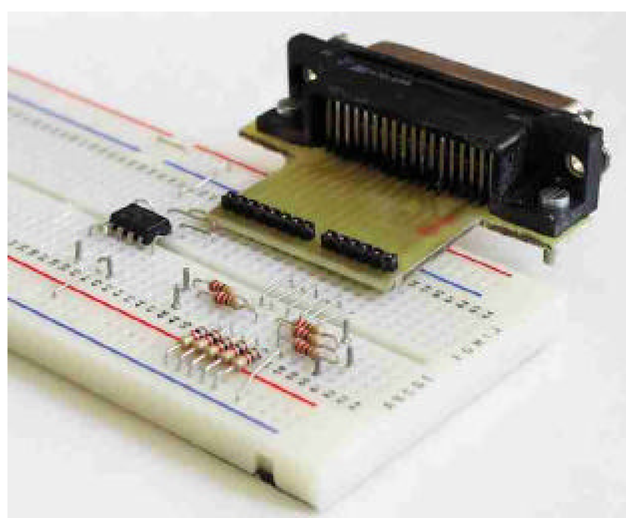

Photo 5.5. Detail of the interface board with the ADC included.

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play. On entry to the display, a yellow line should be seen traversing the screen from left to right, its vertical position moving up and down. Adjust VR1 (or change the value of C1) until the moving line begins to show several cycles of a triangular-like waveform, as you saw demonstrated in the simulation program *Frequency and Time*, see Photo 5.6.

Should the yellow line just be sitting towards the bottom of the screen, check that the Port register selected is still the correct one (as discussed in Part 4). Also double-check that your ADC's breadboard assembly corresponds to the connections shown in Fig.5.6, and that the oscillator is still correctly assembled.

Towards the top right of the screen is shown the *Display Rate*, 10 at the moment. Using the <+> and <–> keys, this can be set to any value between 1 and 10 and controls the rate at which the waveform line crosses the screen. The slower the rate, so more waveform cycles are shown.

Note that changing this rate also changes the rate at which data is acquired (sampled) from the ADC. We shall discuss analog sampling in a moment.

Also at the top right of the screen is the single word DIRECT. This means that data is being sampled in real-time (here and now).

By pressing <C> the word CAPTURE appears instead. In this mode, the computer samples the data as fast as it can and temporarily stores it in memory. Once a full set of samples (640) has been received, the computer then plots them as a screened waveform.

This technique allows higher speed waveforms to be sampled than does the Direct method. The drawback is that there is a pause between each full screen change of data (computer speed dependent).

Experiment with different oscillator frequency rates and waveforms, using preset potentiometer VR1, and different values for capacitor C1. Also find out how Direct/Capture and Display Rate settings have their benefits. Note that each time the Display Rate is changed, the waveform line restarts from the left of the screen.

Also see whether you can replicate some of the stranger waveforms you have seen through the ADC-Demo program. (It has to be said that those of you with higher-speed computers will fair more easily since the waveforms will be traced faster on the screen.)

Just for interest, try connecting the oscillator's digital output (F OUT, IC1a pin 2) to the ADC instead of the analog waveform.

SERIAL ADC DEVICE

As the Analog-to-Digital Converter's name states, it allows an analog signal (e.g. voltage waveform) to be input, and converts the voltages to equivalent binary numbers. You saw in Part 4 the representation of a number in both binary and decimal (*Parallel Port Data Display/Set*).

The ADC is capable of "reading" the voltage level at many thousand times per second and is controlled by logic level signals from the computer (or other device in other applications). The ADC used in this *Teach-In* demo is a serial ADC, which means that its output data is read one bit at a time.

Parallel ADCs also exist, in which the 8-bit data is read as a single 8-bit byte. Parallel ADCs are much faster to read than serial types, but require more computer control and data lines than we have (readily) available for your *Teach-In* breadboard.

To start each voltage level sampling and digital conversion, the computer sets the ADC's CS input (chip select) high via output data line D1. This action causes the ADC to "read" the voltage present on its signal input (Vin) at that moment.

The ADC has an internal high-speed oscillator that then controls the data conversion process. (Incidentally, chip is a term frequently encountered in electronics and is colloquially used to mean any integrated circuit device.)

The result of the conversion is a binary number between 00000000 and 11111111 (decimal 0 to 255). A conversion value of zero results from an input voltage of zero. The maximum conversion value of 255 occurs (in this breadboard assembly) when the input is at the same voltage level as the ADC's power supply. This conversion range is determined by the voltage levels to which the ADC's +REF and –REF pins are connected (6V and 0V in this case).

In other applications, the pins may be connected to other reference voltages to provide a different conversion range. The reference voltages must lie at or between the power supply voltages. (Note that the maximum voltage at which this ADC can be powered safely is +6·5V.)

READING BITS

Once conversion is complete, the binary data can be read bit-by-bit by the computer. It is read in order of bit 7 to bit 0 of the binary conversion value.

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(In theory, about 40,000 conversion and data-read cycles per second can take place – but not with this *Teach-In* demo!)

To read each bit, the computer takes the ADC's CLK (clock) pin high via output line D0 (OUT0). The data is then read from the ADC's Dout pin via the breadboard's IN1 path – computer parallel port register bit 4.

The data on register bit 4 will either be at logic 1 or logic 0. As discussed when we described the data input process in Part 4, the value of the bit is isolated from the other register bits (using an AND command) and set into the rightmost (bit 0) position of the 8-bit binary value being assembled by the computer. Between each bit, the value is multiplied by two to shift all the bits left by one place.

The computer then sets the ADC's CLK line low, causing it to set the next bit of its binary conversion onto the output pin. Taking the CLK line high again allows the computer to now read this bit, and so on for all eight bits.

At this point, the computer does whatever it has been told to do with the data, in our case it either stores it or draws a screen line in relation to it. After which the next sample can be taken.

As an example of the computer's data acquisition routine, take the conversion value of binary 10010111 (decimal 151). The computer first sets its data storage value to 0 (00000000). The reading routine results in the following binary values of the chip and the assembled data storage:

The computer's assembled value at step 8 is the same as that of the original ADC conversion value.

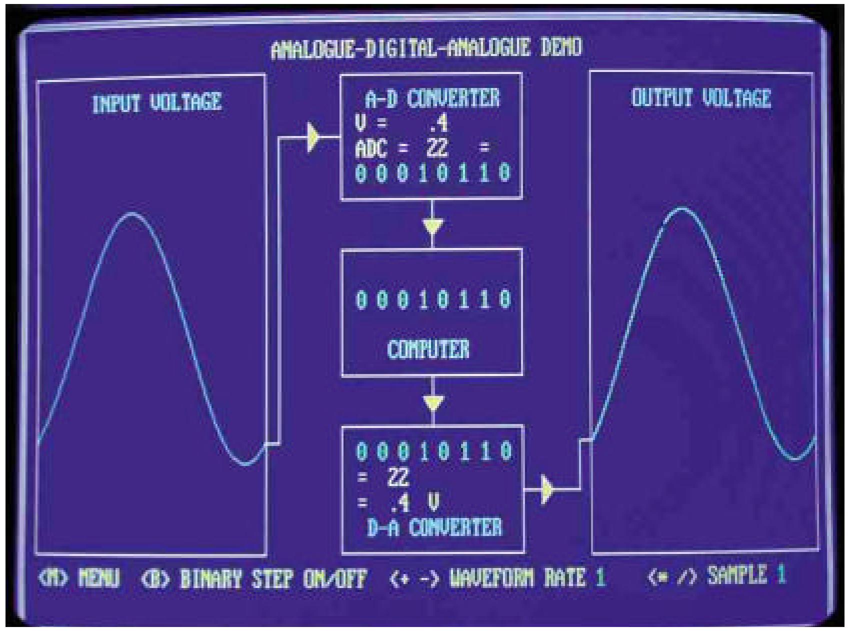

Photo 5.7. Analog-digital-analog demonstration screen. You can observe each bit being "assembled" to a binary number, and change the sampling step rate.

ADC DEMO

Run the *Analog-Digital-Analog* Demo program from the main menu to see the animated principle of how the ADC conversion is output from your breadboard to the computer (see Photo 5.7).

The left-hand box (Input) shows a single sine wave, cycling between 0V and +5V. It is shown feeding into the serial Analog-to-Digital converter, where the present voltage level is given, together with the ADC conversion value in both decimal and binary. For the sake of this demo, the ADC is assumed to be referenced so as to generate an output of 0 for 0V and 255 for +5V.

Step	ADC Value	Assembled Value
0	10010111	00000000
1	00101110	00000001
2	01011100	00000010
3	10111000	00000100
4	01110000	00001001
5	11100000	00010010
6	11000000	00100101
7	10000000	01001011
8	00000000	10010111

The ADC is shown connected to the computer. At present, the immediate ADC binary value is repeated as the computer's received value. The computer then feeds this value into a Digital-to-Analog Converter (DAC). DAC devices will be discussed another time – this one converts the 8-bit binary into an equivalent output voltage, in this example having the same scale as the ADC.

Also at present, the DAC shows the same values as the ADC, and the resulting waveform is displayed in the right-hand box (Output).

To see how the computer reads in the ADC's binary conversion value bit, press <B>.

Note how the left-hand ADC bit (bit 7) drops down and moves right to insert itself into bit 0 of the computer's storage value (which starts off at zero for each cycle of eight bits).

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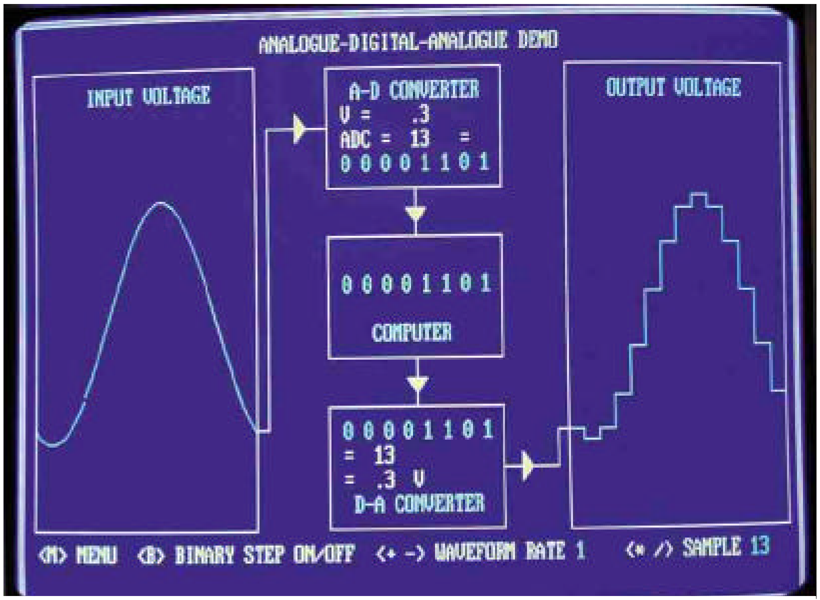
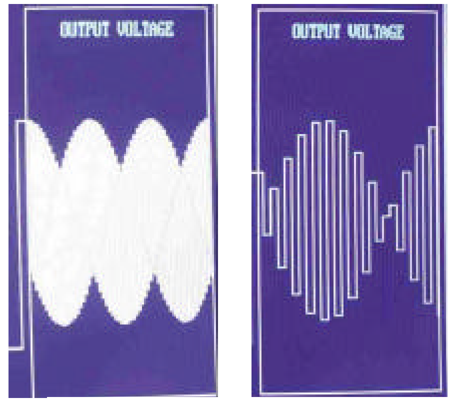


Photo 5.8. Another example of the ADA demo screen, this time showing (right) the result of using fewer sampling steps.



Photos 5.9 and 5.10. Examples of the screen demo set for different waveform and sample rates.

Note also how the ADC and storage values shift left by one binary place during the copying process, with the previous bit 7 being "lost". A zero value enters the ADC value at bit 0 at each shift left.

When all eight bits have been input to the computer, the final byte value is copied to the DAC, and the process starts again by the ADC taking another sample, with the Input waveform having shifted slightly to the right.

Please be aware that the process illustrated is not intended to represent the behavior of any particular serial ADC device, it is a very generalized interpretation.

To terminate the bit-shifting process, press <B> again.

SAMPLING RATES

While discussing pulse frequency counting in Part 4, we referred to the problems of sampling data at rates slower than ideal. We can now illustrate one way in which the problem manifests itself.

With binary step sampling off, first note the shape of the two sine waves (Waveform Rate 1, Sample 1, as stated in the bottom text line).

Although you will notice that the waveforms have slightly rough edges, they are as close to sine waves as we can get with the program that creates the display you are watching. Just for background interest – the waveforms are plotted as 180 steps (pixels) across the screen, and 140 steps vertically between top and bottom waveform extremes.

For every step made by the input waveform, the output waveform makes the same step, i.e. the sampling rate is just right in order to replicate the original.

However, the output waveform will become an imperfect copy of the input if its sampling rate is reduced – press the <*> key once, to set a sampling rate to half of what it was (Sample 2). Now observe the extra jaggedness of the output shape.

Press <*> a few more times and observe the increasing distortion.

What is happening is that the output waveform is being "traced" horizontally across the screen at a given rate. The movement represents the *Time* axis we discussed in the *Resistor-Capacitor Charging Graph* of Part 2, and in the waveform period timings discussion in this month's *Tutorial*.

The sampling rate, though, is not fast enough to keep pace with the trace, which continues to show the vertical value last sampled until the next one is taken. The steps become even more pronounced the more you press <*>, and the less recognizable the output waveform becomes.

RATEABLE LESSON

The lesson we hope you will take in from this is that when sampling an electronic signal, whether it's digital or analog, the sampling rate should be carefully chosen to obtain the optimum results. Too slow a rate is obviously undesirable.

A further example of sampling is discussed next month when we illustrate Logic Gates

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PANEL 5.1 – MEASURED OBSERVATIONS

You might think, perhaps, that in order to know the true state of affairs regarding component values, timings, voltages and currents etc., all you need to do is take some measurements. True, measurements of anything that happens in electronics can be taken, though for some of them extremely sophisticated equipment is needed.

But, and this is a big “But”, no measurement can be taken instantaneously, it’s spread over a “window in time”. Consequently, the measurement does not show the actual state of the condition being measured at a specific point in time, it simply shows an averaging-out of what might be numerous values occurring within the period of measurement.

Furthermore, the value reading shown on the measuring instrument only reveals the value to within so many decimal places, or within an estimated fractional distance from a marker on a scale. Fortunately, in many electronic circumstances, only a close approximation to the actual value is needed, although there are instances when greater precision would be desirable.

There is a further important factor which affects the accuracy of measuring some aspects of electronic circuits – the measuring instrument itself can affect the characteristics of the circuit point being measured; significantly so in some instances, and sometimes it is necessary to take ingenious steps to try to circumvent the problem, but even then a degree of interference will still exist. Electronics is riddled with practical examples of the *Principle of Uncertainty!*

(program *Digital Sampling and Logic Demo* is the one we shall discuss in this context – see the main menu).

Play around with other input *Waveform Rates* (<*> and </>) and *Sample* values (<+> or <–>) and see what you observe. You’ll come across some quite remarkable output waveforms.

In some cases, especially at higher input waveform rates (25, 26, 44 and 59 for example – with *Sample* = 1), you will notice that another waveform appears to be superimposed on the top and bottom of the overall input screen display. This illustrates another by-product of how two frequencies can react with (modulate) each other.

The result is two new frequencies, one that is the sum of the originals and one that is the difference between them. The effect is known as heterodyning (from the Greek *heteros*, meaning “other”, and *dynamis*, meaning “strength”).

Suppose, for example the two base frequencies are 2kHz and 3kHz, the sum of the frequencies is 5kHz, and the difference is 1kHz. These two new frequencies replace the original base frequencies.

It should be pointed out that the reason for the Input display also showing heterodyning is because it too is actually created through sampling, in this case in the computer simulation program, where the sine wave is calculated according to an angle count being incremented – small increments for slow waveforms, greater for higher rates.

Nonetheless, heterodyning is a very real effect; undesirable in some cases (audio sampling for example), but highly beneficial in others (e.g. radio reception).

The word superhet is derived from the term, although the full term in the radio reception context is actually supersonic heterodyne – a superhet receiver mixes the incoming radio frequency with a local oscillator frequency, to produce a specific (fixed) intermediate frequency (IF) from the which the desired signal can be more easily amplified and extracted.

DIVERSION END

After that diversion, and coming back to the ADC subject, you should now have a greater understanding of what it can achieve and what its failings can be.

In addition to the subjects listed at the end of the *Tutorial*, next month we shall examine Sampling in greater detail. Before then, see what you can discover for yourself about the subject with the aid of your digital and analog waveform sampling displays.

Till next month, the author waves goodbye and exits screen-right!

CORRECTION

Part 4, Feb. ‘00, Fig.4.6.
SK1 pin 23 should read pin 32.
SK1 pin 16 should read pin 23.
The PCB is correct.

Go to next section

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SURFING THE INTERNET

Net Work

By Alan Winstanley

Radio Bygones Message Board

Welcome to our monthly column related to Internet issues. On the web site for the print edition of *EPE* at **www.epemag.wimborne.co.uk** you will find indexes listing the projects contained in issues dating back to 1996, and also further details, including color photos, of the constructional projects which have appeared in *EPE* within the last 18 months or so. Some readers will also know from the *EPE Chat Zone* that a full redesign is now being considered, as the site has evolved over the past four years and is getting ready for a total rebuild. A shopping cart system is under trial, as well. We welcome your suggestions and feedback by email regarding our Internet presence to **webmaster@epemag.demon.co.uk**

We have also just opened a message board system for *Radio Bygones readers* – check in at (deep breath) **www.epemag.wimborne.co.uk/radiobygones/wwwboard** to leave messages or to follow up regarding antique radio sets or just share your nostalgic memories. Advertisements from the antique radio sector are also welcomed – and they're free!

Still on the subject of *Radio Bygones*, we can announce that we have now obtained the domain of **www.radiobygones.co.uk** and a web site related to our sister magazine will be open in the near future. You will be able to subscribe online using a secure server and generally see what the magazine is about. American and Canadian readers are welcome to have a look at **www.radiobygones.com** and an on-line version will hopefully be produced in the very near future.

Search and you will find... an advert

If you type in the URL **www.altavista.digital.com** you will of course be redirected to the popular search engine of AltaVista, now at **www.altavista.com**. Apart from a web site refresh, the development of this interesting and important search engine has largely gone unnoticed by many UK users. For the benefit of newcomers, AltaVista was originally created by the computer manufacturer Digital Equipment Corp. (DEC) as a showcase for their Unix and NT mainframes and servers. Digital Equipment saw their powerful search engine as a good advert, to demonstrate the power of their Alpha processors and servers to search their enormous database of the world wide web, and to sally forth with the closest matches to a search enquiry. Indeed AltaVista has always been a personal favourite, partly because it offers Boolean command search options that come as second nature to many electronics enthusiasts (especially if you followed our series *Teach-In 98: An Introduction to Digital Electronics*).

AltaVista's powerful "spider" (a network search and retrieval program) would traverse the web in search of links, which would then be cataloged and added to the enormous AltaVista database back home. You could also add your own URL manually just to be sure, and indeed the task of registering one's own URL into all the relevant search engines – there are some 1,500 or more of them – is now an important element when creating new web sites. (Apparently only I see the joke in AltaVista's "Add URL" confirmation message stating that "this URL was retrieved in 4.997 seconds and will be added in a day or two.")

In January 1998, Compaq (**www.compaq.com**) acquired DEC along with its Alpha microprocessor technology and the AltaVista engine, and nearly two years later in November 1999 Compaq announced a new line-up of "supercomputer" Alpha-based servers and workstations for 3D, CAD and Internet server applications. Compaq hadn't been idle with AltaVista though, and the trusty old search engine was destined for greater things. Very early last year Compaq announced the development of AltaVista as a separate company – and at about the same time it announced that it had purchased **www.shopping.com**, a very popular online retailer in the US.

Then in the middle of last year Compaq announced that it had sold a majority stakeholding in AltaVista to the Internet business development and management group CMGI (**www.cmgi.com**), formerly College Marketing Group Information Services. CMGI will develop AltaVista further into what they

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hope will become the world's largest portal.

Coupled with the fact that Compaq Internet-ready desktop PCs were to include a ready-made link to AltaVista, it became clear how Compaq was starting to embrace the commercial forces of the Internet and steer business the way of AltaVista. Compaq said that they would meld their consumer Presario Internet PCs with CMGI's Internet services, by providing keyboard and web browser access to AltaVista and other CMGI web offerings.

An updated AltaVista web site was mooted in June '99. The old logo and layout would be replaced by a fresh new number in cheerful yellow along with all the usual portal offerings of news, travel, shopping, jobs and so on. The shopping.com site would also be restructured and enhanced.

AltaVista has already grown into a key portal site, which was rated at the ninth largest domain on the entire Internet in early 1999, and conveniently accessible from Compaq desktop PCs. A quick look at the Compaq Presario web pages (**www.compaq.com/mypresario/internetservices/**) on "How to Search" takes you directly (surprise) to My AltaVista, where users are encouraged to configure a start-up page.

Disappearing URLs

One potential problem seems to be surfacing with AltaVista: users are complaining that their own web site seems to have disappeared from its listings, and this can be attributed to the rebuild at the end of last year. Webmasters should do a quick search for themselves (literally) on AltaVista and resubmit their URL. This option is buried in the Advanced Search page (Add/Remove a URL). Some users have quoted a period of up to six weeks before their URL appears again, which obviously means that they will lose traffic or business opportunities during that time.

For those of you wishing to ensure that your web pages receive a higher scoring in search engine listings, you should have a look at www.searchenginewatch.com. This provides details on most of the commonest engines and other tips.

It is interesting that there seems to be no objection to Compaq's eagerness to provide a direct link to AltaVista, which by Compaq's own admission is also intended, in turn, to route consumer Internet traffic to e-commerce sites (to the tune of several million hits over Christmas 1998 alone). Yet many PC users rebelled when Windows 95 included a direct and unwanted desktop link to MSN, its fledgling mail service and Internet Content Provider. This was immediately branded a prime example of Microsoft's own (failed) attempts at Internet empire-building.

Users and manufacturers complained even more when Microsoft's Internet Explorer browser was being foisted on them, to the alleged detriment of Netscape, yet they seem happy for consumers to be steered from their home desktops towards a portal site which, with a bit of luck, will ultimately entice them into breaking out their credit cards in a *"seamless information and shopping experience"* as Compaq calls it.

Nevertheless, AltaVista remains a firm favourite as a search engine, although on my own recently redesigned web site (**http://homepages.tcp.co.uk/~alanwin**) there is a Google search engine installed on my "Links" page. Google is tremendously fast and slick, with none of the portal padding of AltaVista.

You can contact me, as always, by email at **alan@epemag.demon.co.uk**

Go to next section

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Circuit Surgery

by ALAN WINSTANLEY and IAN BELL

Our surgery writers continue their exploration of operational amplifiers by delving into the innards of typical devices to explain basic opamp principles of operation.

A few months ago now readers **Mohab Refaat** and **Tony Soueid** inquired about the use of one of the most fundamental building blocks of electronics, the operational amplifier or opamp. Mohab asked about choosing opamps and we explained all the major opamp characteristics in the Dec '99 and Jan '00 issues.

We now go on to address Tony's main point: *"I don't know what is inside that 'black box'… it's based on a differential pair of transistors, but it's far from being that simple. Can you please supply me with some information?"*

This is a big topic, one that can and does fill whole textbooks, but we will try to give a brief overview of some important points.

IDENTICAL TWINS

Tony is right to say that opamps are based on the "differential pair", which we'll look at in detail in a moment, but first look at Fig.1 which shows a general block diagram of an opamp.

The circuitry of an operational amplifier often comprises: a **differential input stage**, with voltage gain followed by one or more further, **single-ended voltage gain stages**, often with frequency compensation, and finally an **output buffer** providing power gain to drive external loads, but with no voltage gain. All of

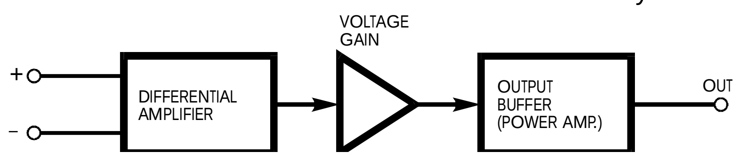

Fig.1. Typical opamp block diagram.

these stages are *direct-coupled*, which means they are connected without coupling capacitors. Direct coupling means that opamps are able to amplify DC and very low frequency signals.

The circuit diagram for the basic differential pair is shown in Fig.2a. Notice the symmetry of this circuit – it is the key to its operation. The symmetry is so important that in order for this circuit to work well the two transistors must have exactly the same characteristics, i.e. they must be ***matched.***

These characteristics must remain matched all the time – something that, given the high temperature sensitivity of semiconductor devices, can only really be achieved if the two transistors are physically close together on the same piece of silicon. Also, integrated circuit designers use special layout techniques to make sure that transistors that should be matched do indeed have the same characteristics, despite temperature variations and any imperfections in the semiconductor manufacturing process.

This would seem to make life difficult for the hobbyist or student who is interested in experimenting with these circuits using individual components, however it is possible to purchase matched transistors (such as the National Semiconductor

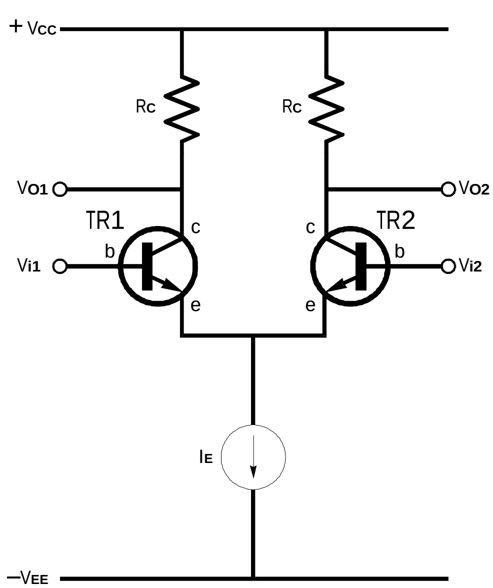

Fig.2a. Basic differential pair.

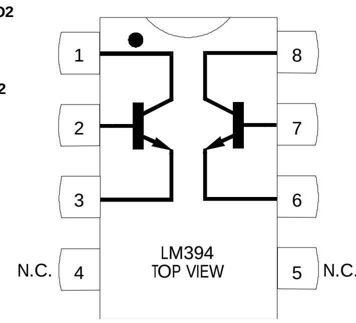

Fig.2b. Pinout details of the LM394 supermatch pair (National Semiconductor).

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LM394 "Supermatch pair" in Fig.2b) and some transistor arrays also contain differential pairs (e.g. the CA3086 "*npn* array") for just this kind of role.

SINGLE-MINDED

The basic differential pair (Fig.2a) has two inputs V_{i1} and V_{i2} and two outputs V_{O1} and V_{O2}. Each transistor has a collector resistor R_C as a load. Small differences in the input voltages cause relatively large changes in the output voltages, also in a differential manner (i.e. as one output voltage increases, the other will decrease by the same amount). We can, however, choose to use only one output (referred to as taking a "single-ended output").

Key points to understanding the circuit's operation are firstly that a transistor's collector and emitter current are very sensitive to changes in its base voltage, and secondly that the emitters are connected to a **constant current source**. The following discussion assumes that both transistors are switched on – that is, their base-emitter voltage is greater than about 0·6V.

The constant current source means that the sum of the two emitter currents must always be equal to I_E. If the two base voltages are equal, and the transistors are identical, then it follows that I_E will split equally between the two transistors, they will draw the same base current, and their collector currents will be equal. As the two collector resistors are equal, the voltages dropped across them will also be equal (assuming there is no output current).

If the two input voltages change together (this is known as a *common-mode input signal*) then the symmetry will not be disturbed and I_E will still split equally between the two transistors. You may think that changing the input voltage must change the collector and emitter currents, but it does not have to, because the emitter voltage is free to change whereas I_E is fixed by virtue of the constant current source.

The ability of the matched-transistor circuitry to reject signals which are the same on both inputs (common mode) is not only important because it gives us the function of a differential amplifier, but also because it makes the design of high-performance, high-gain DC amplifiers possible. For example, if the temperature of a single transistor amplifier changes then the bias currents change too, and so therefore do the circuit voltages.

In capacitively coupled (i.e. AC) circuits this does not matter because the temperature changes are slow and are below the cut-off frequency due to the coupling capacitor. However, if there is no capacitive coupling (as in an opamp), any changes in voltages due to temperature (or other forms of "drift") are effectively indistinguishable from the required low frequency signals and will be amplified by subsequent stages.

However, if the temperature of a properly matched differential pair changes, both transistors are affected equally and there is no change in the output (the drift is a *common mode signal*). The worst place to get drift is in the first stage as the error is amplifier by all subsequent stages, so having a differential pair as the first stage is a good way of reducing drift.

If we change the (still equal) input voltages by a large enough amount then the circuit will cease to function as just described. For example, if we take the input voltages down to near V_{EE} then the current source may no longer function properly. This would determine the opamp's common mode input range. Any lack of matching between the transistors would probably result in some shift in output voltage as the inputs varied together, which would manifest itself as a non-ideal common-mode rejection ratio (CMRR) for the opamp.

INVERTED VIEW

The high sensitivity of the transistor's collector and emitter currents to base voltage comes in to play when we make the voltages at the two inputs slightly different. This breaks the symmetry and causes a larger proportion of I_E to flow in one transistor than the other.

For example, if we increase V_{i1} slightly and decrease V_{i2} by the same amount, then more of I_E will flow in transistor TR1 than in TR2. This will cause TR1's collector to fall lower than TR2's, so output V_{O1} will be lower than V_{O2}. Thus, if we take a single-ended output from the collector of TR2, V_{i1} will act as the **non-inverting** input (+) and V_{i2} will act as the **inverting** (–) input. This denotes what effect a signal on either input has on the polarity of the output: increase the non-inverting input and the output effectively increases too. Increasing the inverting input at V_{i2} will cause the output V_{O2} to fall (invert).

Note that differences over a few tens of millivolts (mV) result in most of I_E flowing in one or other of the two transistors.

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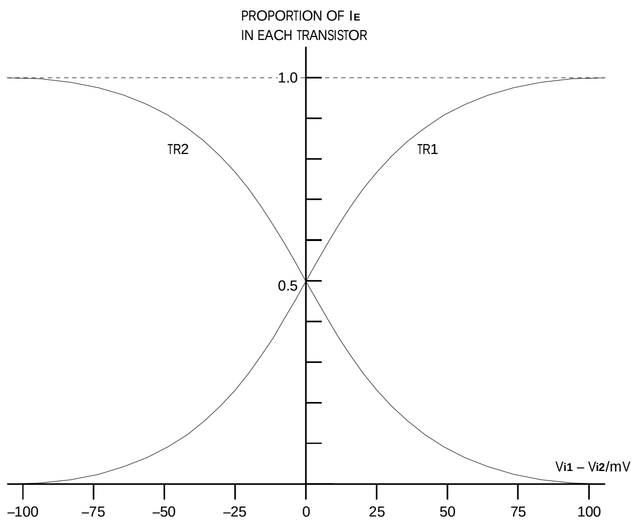

Fig.3. Typical characteristics of a basic differential pair.

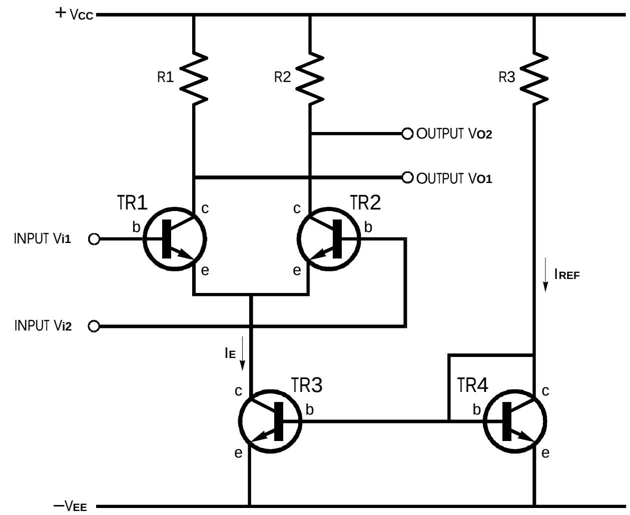

Fig.4. Basic differential pairs – simple current mirror biasing.

Over a large input difference range the response of the circuit is exponential (see Fig.3), but for just a few millivolts difference between the inputs the change in the output voltage difference is near-enough directly proportional to the input difference (the central part of Fig.3). So we have the linear differential amplifier that we require for an opamp input stage.

To turn Fig.2a into a practical circuit we need a current source, this can also be achieved using a couple of matched transistors such as the Supermatch pair, although there are also more sophisticated current sources employing more transistors. For a more detailed discussion of current sources please refer to *Circuit Surgery* May and June 1999 in which we discussed these types of circuit in depth.

MIRROR CURRENT

A basic differential pair with current mirror biasing is shown in Fig.4, which will hopefully be familiar to regular readers. The emitter current can be set using:

$$I_E = (V_{CC} – V_{EE} – V_{BE(TR4)}) / R3,$$

where VBE will be typically 0·6V to 0·7V. To choose the R_C collector resistors (R1 and R2) for maximum swing, set the quiescent (“idle”) output voltage to half the positive supply. Thus the quiescent voltage across the collector resistors is $V_{CC} / 2$.

Since we set I_E above and the collector current is approximately $I_E / 2$, then R_C for each transistor in the pair can be calculated using:

$$R_C = (V_{CC} / 2) / (I_E / 2)$$
$$= V_{CC} / I_E.$$

So if the supplies are ±9V and we chose a bias current of about I_E = 1mA then we get R3 = 18K and R1 = R2 = 9K.

For any given transistor I_E / 2 should be chosen to give optimal performance (transistor gain etc. varies with bias current). The supply current required may also be a consideration when choosing I_E. Although a device such as the LM394 Supermatch pair has a maximum collector current rating of 20mA, National guarantees most parameters over a range of 1uA to 1mA.

OPAMP SELECTOR

Table 1 shows a comparison between a number of popular opamps. It is by no means comprehensive, as thousands of opamps are available, but it will at least enable you to compare the specifications of many well-established types. You can use the information we have provided in previous issues to decipher the meanings of the data: expressions such as “Open Loop Gain” and “Slew Rate” should now be readily understood (we hope).

The manufacturers’ data must be consulted for more design information as needed, as our figures may often only apply under certain conditions (supply voltage, temperature etc.). The World Wide Web offers for the first time the possibility of readers fetching data directly from the manufacturer. It’s usually in Adobe Acrobat PDF format, which needs the free Acrobat reader from **www.adobe.com**

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Next month we will look at how gain can be improved by using transistors instead of resistors as loads, and consider the problem of getting all the bias voltages right when you cannot isolate stages using coupling capacitors. *IMB.*

HOT REGULATOR

I built a 1A power supply with a 317-type variable regulator. The data says that it is a 2A regulator but when I draw 1A, the regulator gets very hot and the voltage slowly drops. Why?

So asked a reader in the *EPE Chat Zone* on our web site (**www.epemag.wimborne.co.uk**) recently.

Regulators are usually protected against excess current and thermal overload. It sounds as though you haven't heatsinked the device properly (if at all). It's imperative that the regulator is allowed to dissipate any power efficiently, to prevent the chip from overheating.

Fortunately, the LM317 – like many other three terminal regulators – will suffer no immediate damage from inadequate heatsinking, because it will simply current-limit and gradually shut itself down. As you saw, the output voltage slowly falls during this shut-down process. However, any repeated cycling like this can stress a device over time, ultimately leading to some lasting damage. Simply bolt it to a generously-sized heatsink and it will perform fine. Proper thermal resistance calculations are the best way of determining what size heatsink to use. *ARW.*

CONVENTIONAL CURRENT

Do you know why the plate of a valve (vacuum tube) is called an anode whilst the plate on a semiconductor diode is called a cathode? Most confusing. ***E.J. Bibby.***

When I first started reading up on electronics in the early 1970's, my very first text book started with valves (but hey, I'm not *that* old!). Their operation was described in terms of real electron flow, i.e. what actually happened in terms of the physics of the electron. The simplest vacuum tube is the diode, consisting of a cathode (which is a piece of metal warmed up by a heating element) together with an anode "plate".

Electrons boil off the hot cathode and, being negatively charged, are attracted towards the anode, which when positively biased will "accept" these negative electrons. The current of electrons which flows through the valve in this way is called the **anode current**.

By placing an electrode between the cathode and anode and applying a grid bias voltage to it, the anode current can be controlled – thus a triode valve is created which can be used as an amplifier. This, together with my scant knowledge of Nuffield Physics (as my schoolteacher of the time would testify), meant that I started out in electronics knowing that electric current flowed towards the most positive electrode. It all made sense.

The trouble is, in modern semiconductor electronics we talk in terms of *"conventional current flow".* We all do this without thinking, but it's extremely bizarre to anyone coming into electronics from other sciences (notably physics and chemistry). Under this convention, electric current is deemed to flow from positive to negative, although in real life it flows in the other direction.

More than one Physics teacher has torn a strip off me for apparently not knowing which way current flows in a circuit: my apologies to Physics teachers everywhere but unfortunately the convention is now so well entrenched around the world that it will never change. (Can you imagine the chaos if it did? Which way round would you connect your multimeter?)

In a semiconductor diode, conventional current flows in the direction of the arrowhead symbol – from *anode to cathode*. In a silicon diode, the anode (a) must be 0·7V more positive than the cathode (k) for a "forward current" to flow from anode to cathode. However, the anode (electron) current in a vacuum tube flows from *cathode to anode*.

I'm afraid that we have history to blame for this conundrum, but in practice everything works fine. After all, we know what we mean, don't we? *ARW.*

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	Maximum supply voltage	Differential input voltage	Maximum input voltage	Max power diss. (mW)	Supply current	Output voltage swing	Output short circuit current	Open loop gain V/mV	Input bias current	Input resistance	Input offset voltage drift uV/ºC	Input offset voltage mV	CMRR dB	Slew rate V/uS	Bandwidth (GBW)	Supply voltage rejection ratio dB	
TL071	+/-18V	+/-30V	+/-15V	680	1.4mA	+/-13.5V	--	200	65pA	10^{12}ohm	18.0	3.0	100	13.0	3MHz	100	Fast slew, jFET input, low noise
TL081	+/-18V	+/-30V	+/-15V	680	1.4mA	+/-13.5V	--	200	30pA	10^{12}ohm	18.0	3.0	86	13.0	3MHz	86	Low power, jFET input
TLC27M2C	18V	+Vdd	-0.3 to +Vdd	725	285uA	--	--	275	0.7pA	--	2.1	1.1	94	0.62	650kHz	93	Dual, low voltage, precision
TLC27M7	18V	+Vdd	-0.3 to +Vdd	725	285uA	--	--	275	0.7pA	--	2.1	0.19	94	0.62	635kHz	93	Low offset, low power
LT1013AC	+/-22V	+/-30	Vcc- -5 to Vcc+	--	0.7mA	+/-14V	28mA	2500	-12nA	400M	2.5	0.04	117	0.4	800kHz	120	Dual, single rail, high gain
OP07C	+/-22V	+/-30V	+/-22V	500	--	+/-13V	--	400	+/-1.8nA	33M	0.5	60.0	120	0.3	600Hz	103	Low noise, bipolar input
OPA27GP	+/-22V	+/- 0.7	+Vcc	500	3.3mA	+/-13.8V	--	1500	15nA	2G	0.4	0.025	122	1.9	8MHz	120	Low noise, low offset, low drift, precision instrumentation
OPA177GP	+/-22V	+/-30V	+/-Vs	--	1.3mA	+/-14V	--	12000	0.5nA	45M	0.7	0.02	115	0.3	600kHz	115	Precision, bipolar, instruments
OPA544T	70V	--	V+ +0.7 to V- -0.7	--	12mA	--	4.0A	--	15pA	10^{12}ohm	--	1.0	106	8.0	1.4MHz	--	High voltage, high current, TO220
AD711JN	+/-18V	Vs	+/-18V	500	2.5mA	--	25mA	400	20pA	$3x10^{12}$ohm	7.0	0.3	88	20.0	4MHz	95	Precision, high speed, low offset
AD744JN	+/-18V	Vs	+/-18V	500	3.5mA	--	25mA	400	30pA	$3x10^{12}$ohm	5.0	0.3	88	75.0	13MHz	95	Precision, FET input
741	+/-18V	+/-30V	+/-15V	500	1.7mA	+/-14V	25mA	200	80nA	2M	15	1.0	90	0.5	1.5MHz	96	Obsolete general-purpose bipolar
LM10	45V	+/-40	--	--	270uA	--	--	400	10nA	500k	2.0	0.3	102	--	--	96	Low voltage, reference output
LM308	+/-18V	--	+/-15V	500	150uA	+/-14V	--	300	10nA	40M	6.0	10.0	100	--	--	96	Low voltage, battery operation, precision
LF411	+/-18V	+/-30V	+/-15V	670	1.8mA	+/-13.5V	--	200	50pA	10^{12}ohm	7.0	0.8	100	15	4MHz	100	Low offset, jFET input
LF441	+/-18V	+/-30V	+/-15V	670	150uA	+/-13V	--	100	10pA	10^{12}ohm	10.0	1.0	95	1.0	1MHz	90	Low power, jFET input
LMC6001-AIN	-0.3 to +16V	+/-Vs	--	--	750uA	14.6V	+/-30mA	1400	25fA	>1T	10.0	0.35	75	0.8	1.3MHz	80	Ultra-low input, instrumentation
LMC6081	15V	Vs	--	--	450uA	14.5V	--	1400	10fA	>10T	1.0	0.35	85	--	1.3MHz	94	Precision, low offset CMOS
EL2044	+/-18V	+/-10V	Vs	--	5.2mA	+/-13.6V	75mA	1.5kV/V	2.8uA	15M	10	0.5	90	325	60MHz	80	Low power, low voltage
EL2001	+/-18V	--	+/-15V	--	1.3mA	+/-11V	+/-100mA	998	1.0uA	8M	--	2.0	--	2000	70MHz	75	High slew rate, high speed buffer
NE5534	+/-22V	0.5	+Vs	1150	4.0mA	<+/-16V	38mA	100	400nA	100k	5.0	0.5	100	13.0	10MHz	--	Low noise, audio, instrumation
CA3130	16V	8.0	+V +8 to -V -0.5	--	300uA	<15V	20mA	100	5pA	1.5T	10.0	8.0	90	<30.0	4MHz	74	MOSFET input, rail-to-rail output
CA3140	36V	8.0	+V +8 to -V -0.5	--	1.6mA	13V	+40mA	100	2pA	1T	6.0	5.0	90	7.0	3.7MHz	80	MOSFET input, bipolar output
CA3420	22V	15.0	+V +8 to -V -0.5	9.0	150uA	--	2.6mA	100	0.05pA	150T	4.0	5.0	80	0.5	0.5MHz	90	Low voltage, portable instruments

Table 1: Opamp Selector.

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Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

In a previous *Practically Speaking* article we considered the subject of capacitors, and this month we move on to that other humble component – the *resistor.*

At a guess, in most projects about half the components are resistors, so beginners have to get to grips with resistors right from the start.

The basic unit of resistance is the ***Ohm***, but this is a small unit of measurement. Hence the cir- cuits often have values of sands or even millions of ohms.

The usual abbreviation for

(W

case letter "R" is sometimes

(In and EPE omega symbol up to 999 ohms).

either kilohms (k or just k) or

W

kilohm is equal to 1,000 ohms,

ohms.

COLOUR BAR

One immediate problem facing the beginner is that most resistors are not marked with values using normal text characters. Instead a system of "color coding" is used, and there are four or five colored bands marked around the body of each component.

This may seem to be an unnecessarily awkward way of handling things, but you have to bear in mind that the average resistor is an extremely small component. You will often be dealing with resistors that are no more than about one millimeter in diameter.

Any lettering on a component this small would have to be minute, and would also be easily obliterated. Color codes are relatively easy to read, and even if they become damaged it should still be possible to read the values of components correctly.

The normal resistor color code has four bands, with three bands grouped together. It is these three that indicate the value of the component while the other one shows the tolerance rating of the component. The tolerance is simply the maximum deviation from the marked value given as a percentage. Thus, if a 100 ohm resistor has a tolerance rating of five percent, its actual value would be between 95 and 105 ohms.

The group of three bands indicates the first two digits of the value and the multiplier. Fig.1 shows the function of each band. Table 1 shows the mean-

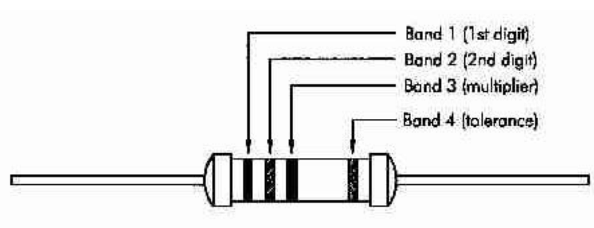

Table 1: Resistor Color Code

Color	Band 1	Band 2	Band 3	Band 4
Black	0	0	x1	--
Brown	1	1	x10	1%
Red	2	2	x100	2%
Orange	3	3	x1000	--
Yellow	4	4	x10000	--
Green	5	5	x100000	0.5%
Blue	6	6	x1000000	0.25%
Violet	7	7	--	0.1%
Gray	8	8	--	--
White	9	9	--	--
Gold	--	--	x0.1	5%
Silver	--	--	x0.01	10%
None	--	--	--	20%

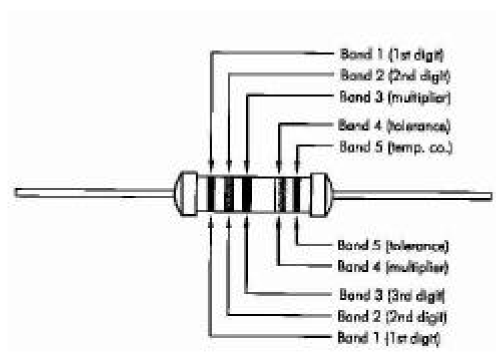

Fig.2. Two methods of five-band resistor color coding.

Table 2

1.0	1.1	1.2	1.3	1.5	1.6
1.8	2.0	2.2	2.4	2.7	3.0
3.3	3.6	3.9	4.3	4.7	5.1
5.6	6.2	6.8	7.5	8.2	9.1

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ing of each color when it appears in each band.

As an example, suppose that a resistor has *red–violet–orange–gold* as its color code. The first two bands indicate the first two digits of the value, and in this case red and violet respectively indicate that these are two and seven. The third band is orange, which means that the first two digits must be multiplied by one thousand in order to give the value in ohms.

This gives 27 x 1000 and an answer of 27,000 ohms (27 kilohms (27k)). The color of the fourth band is gold, and the resistor therefore has a tolerance rating of five percent.

PREFERRED VALUES

Resistors are normally available in what is called the "E24" series of values. The basic E24 series of values is listed in Table 2, but values ten times higher, a hundred times higher, etc. are also available, up to a normal maximum of 10 megohms (10M). Values one tenth and one hundredth of the basic values are also available, but are relatively difficult to obtain.

This range of values might look rather random at first glance, but each value is roughly ten percent higher than the previous value in the series. Together with the inclusion of the same values in various decades, this means that one of these "preferred" values will always be close to the required value for a resistor. In fact the ideal value calculated by a circuit designer should never be more than about five percent away from a preferred value.

Most resistors are available in the full E24 series, but some are only available in the E12 series, which is every other value in the E24 series (1·0, 1·2, 1·5, etc.). Most electronic projects only use resistors having values from the E12 series.

BUNCH OF FIVES

Rather unhelpfully, many of the resistors now sold to amateur users have five band codes. These operate in the manner shown in Fig.2. The first of these is quite easy to use because the first four bands give the value and tolerance rating in the normal way. The additional fifth band shows the temperature coefficient of the component, which is not something that is normally of any relevance. If the fifth band is ignored, the other four give the value and tolerance rating in the usual fashion.

The second form of five band coding is probably the more common one, and is slightly more difficult to deal with. Again, it is not that far removed from the four-band method.

The first two bands indicate the first two digits of the value, and the last two bands provide the multiplier and the tolerance rating. The difference is that an additional middle band is used to indicate the third digit of the value.

This method of coding can handle non-standard values such as 26·7k, but as these are not used in amateur electronics this is irrelevant to the electronics enthusiast. The normal four-band method of coding is all that is needed.

Nevertheless, this form of five band coding does seem to be used on the resistors sold to amateur users. When applied to normal E24 values the third digit is always zero, and the third colored band is therefore black.

To compensate for this extra zero the multiplier value is reduced by a factor of ten. Taking our earlier 27k example, this would become *red–violet–black–red–gold*. This gives 270 x 100 = 27,000 ohms.

COMPOSITION

In component catalogs you will find resistors described as "carbon film" and "metal film" or "metal oxide". The simplest resistors are the carbon composition type, which are basically just pieces of carbon with an electrode attached to each end.

These have now been replaced by carbon film resistors, which consist of a former made from an insulating material having an electrode at each end. A film of carbon is deposited on the former, and the resistance value obtained depends on the thickness and the exact composition of the film. Carbon film resistors are adequate for most applications, and are the type normally specified in components lists.

Metal film resistors are the usual choice for more demanding applications. They are similar in construction to carbon film resistors, but the film is based on a metal oxide instead of carbon. Resistors of this type normally have close tolerances of two percent or better, and generate less electrical noise than any form of carbon resistor. Their values are also affected less by temperature changes and aging.

Metal oxide resistors are needed for some demanding applications, such as in critical stages of test equipment and in low noise audio preamplifiers. They can be used in place of carbon resistors for general use,

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but it makes sense to use cheaper carbon resistors in any application where they will suffice.

HIGH POWER

Some resistors do actually have the values written on the body using ordinary text characters, but in recent years this is something I have only encountered on higher power resistors. Most of the resistors used in electronic circuits have to dissipate very low power levels, and small resistors having ratings of about 0·25 watts are perfectly adequate.

Some circuits have the odd resistor or two that has to handle higher power ratings. Component lists normally indicate a suitable power rating for all the resistors anyway, but a suitable rating should certainly be given for any high power types.

It is very unusual for resistors having power ratings of more than about one watt (1W) to have the value marked using colored bands. The larger physical size of these resistors makes it possible to mark the value using text characters of reasonable size.

The value is invariably marked on the resistor in the same form that it appears on a circuit diagram. In other words, the letter used to indicate the unit of measurement is also used to denote the position of the decimal point. A value of 2·7k would be marked as “2k7”

Table 3

Letter	Tolerance
F	1%
G	2%
J	5%
K	10%
M	20%

and a value of 0·47 ohms would be marked as “0W47’’ (or “OR47”).

There will usually be other marks as well, some of which might simply be the makers name, a batch number or something of this type. Of more use, there will probably be a wattage rating and a letter to indicate the tolerance rating of the component. Table 3 shows the corresponding tolerance rating for each of the code letters used.

High power resistors have various compositions, but the *wirewound* variety is by far the most common. This consists of a coil of resistance wire wound around what is usually a ceramic former.

One slight problem with wirewound resistors is that the coil of wire also acts as an inductor, although most components of this type are constructed in a fashion that minimizes this problem. Even so, wirewound resistors are less than ideal for some applications, and if a different type is indicated in the components list it is advisable to use the specified type.

Very high power resistors have metal fins to help conduct heat from the component into the surrounding air (Fig.3). Many of these resistors also have to be mounted on a substantial piece of metal, which acts as a heatsink and provides further cooling. With resistors such as this, the article should give guidance on using the resistors, and this must be followed “to the letter”.

POTENTIOMETERS

The terms “potentiometer” and “variable resistor” tend to cause a certain amount of confusion. A potentiometer (“pot”)

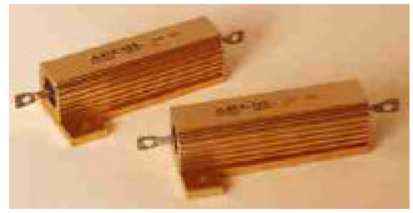

Fig.3. High power wirewound resistor in an aluminum heat dissipater.

has three terminals, and between two of these there is a fixed resistance. There is a variable resistance between these terminals and the third one.

A potentiometer consists of a track of carbon with a terminal at each end of the track. The third terminal connects to a wiper that can be moved along the track by means of a spindle.

There are also preset potentiometers that have no spindle, but can be adjusted using a screwdriver. With an open construction preset potentiometer the track, wiper, and terminals are all clearly visible (see Fig.4). The greater the amount of track between the wiper and one of the fixed terminals, the greater

Table 4

Letter	Potentiometer Type
A	Linear
B	Logarithmic
C	Anti-logarithmic

the resistance between them as well.

The normal way of using a potentiometer is with an input voltage across the track, and a variable output voltage is then available from the wiper (moving contact) and one of the track terminals. Strictly speaking, the components you buy are always potentiometers having three terminals, but in some applications it is a variable resistance that is

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required. It is then only necessary to use the wiper terminal and one of the track connections.

Potentiometers are available in three types, which are the linear (*lin*), logarithmic (*log*) and anti-logarithmic varieties. A linear potentiometer gives approximately equal resistance between the wiper and the two track terminals when it is at a central setting, as one would expect.

A logarithmic potentiometer produces vastly different resistances under the same conditions. So does an anti-logarithmic potentiometer, but with the high and low values the other way around.

When used as a volume control a linear potentiometer gives an odd control characteristic, with the volume seeming to jump to a high level when it is

Fig.4. "Open Track" preset potentiometer.

advanced slightly from zero. Further advancement then seems to have little effect. This is due to the way we perceive sound rather than a problem with the potentiometer.

When used as a volume control, a logarithmic potentiometer gives a much better control characteristic. Logarithmic potentiometers are used for little other than volume controls.

Anti-logarithmic controls are difficult to obtain and are only needed for a few specialist applications. If you use a potentiometer of the wrong type the circuit will still work, but the control will be awkward to use.

AS EASY AS ABC

The values of potentiometers are marked using text characters, together with the type "log", "lin" or "anti"). These days many potentiometers are marked with a code letter to indicate the type.

This works in the manner shown in Table 4. Note that potentiometers are only produced in a very limited range of values.

Go to next section

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DIGITAL FINGERPRINTING

Digital cameras can now not only assess vehicle speed limit violations, but also detect fingerprints on banknotes - Barry Fox reports.

Criminals beware. An adventurous local police force in the West of England is pioneering the use of electronic imaging to lift faint fingerprints from banknotes and check. The system relies on watermarking technology developed for electronic speed trap cameras but spurned by the Home Office. The mark stops lawyers discrediting fingerprint evidence by arguing that digital images can be easily doctored.

Three years ago Esther Neate, senior fingerprinting development officer at the Wiltshire Constabulary, persuaded the force to go out on a limb and replace the ageing film equipment in her lab with an all-digital system.

"The FBI and a few forces round the world are mixing film and digital technology, but we are first to replace film completely," says Neate.

Chemical Integrity

Prints from a sweaty finger are 95 percent water and five per cent salts, amino acids and fats. Suspect banknotes and checks are serially treated with 14 different chemicals such as ninhydrin, and a photograph taken at each stage because each chemical reacts with a different sweat component and destroys the previous reaction. By the end of the treatment, the paper is stained, toxic, and useless as evidence. So any case hangs on the quality and integrity of the photos.

High intensity white light is focussed on the print area by fiber optics, and the image captured on disc by a high resolution digital camera with 3648 x 4623 image sensor; 12-bit monochrome coding captures subtle grays in a 13 Megabyte file.

Because the image is in digital code, the lab can use Fourier Transform analysis to separate the regular pattern of banknote printing from the irregular fingerprint. Labs have tried to do this with film and color filters, but electronic analysis produces much clearer pictures.

An identifying watermark, with date, time and place, is embedded in the image using Veri-Data iDem software from British company Signum Technologies of Witney. The mark is invisible to the eye but can be detected by analysis of the image file. If even one pixel in the image is altered, it shows.

Speed Trapping

Signum developed VeriData for electronic speed traps, but in April '99 the Home Office approved the use of SVDD (Speed Violation Detection Deterrent) digital cameras as long as the images are securely encrypted or carried by the closed data networks used on motorways.

SVDD was tested on the M1 and M20, in Leicester and Kent and approved on 1 April 1999 for private data networks. Cameras use infrared flash to log the time taken for a car to travel a mile. They were catching 4000 a day but no summonses were issued. Now that the cameras are Type Approved the police and local councils can install them – but they are expensive.

Says Signum's Marketing Manager Alan Bartlett, *"The UK authorities are working on the principle that most motorists will not go to the expense of legally challenging a speeding fine. In the US people just shoot the speed cameras to pieces anyway. But 30 year jail sentences can hang on fingerprint evidence which will be challenged."*

The Wiltshire Constabulary will not identify individual cases that have relied on digitally recorded evidence. *"But for the last 18 months all cases this lab has handled have used the process,"* says Esther Neate.

Wiltshire's camera can work with a laptop PC running Windows NT, to capture fingerprints or footprints at the crime scene.

Police forces in Singapore, Turkey, Australia, New Zealand, Belgium and the US are now asking the fingerprinting laboratory in Devizes to help them set up similar systems.

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CORDLESS SOLDERING IRON

BS Manufacturing tell us that their latest soldering iron, the P100, sets a completely new standard by offering precision heating power in the form of a tiny pen-style tool. The P100 is 19cm long and weighs just 57g, delivering up to 120W output – double that of some competitive irons, allowing it to be used for heavy duty electrical work and silver soldering, in addition to precision electronics and model making applications.

The fuel used is liquid butane/propane gas, stored in the translucent handle. The tank can be refilled from a standard gas canister (cigarette lighter type). Typically each refill provides around 45 minutes of continuous use. Gas is ignited by means of a spark from a flint inside the tool's cap, with its flow regulated using a slider, allowing fine adjustment down to 20W.

A wide range of attachments for the P100 are offered, to configure it for soldering, hot knife cutting, slicing, heating, igniting, shrink wrapping, melting, shaping and other uses. A rich choice of tips for soldering/desoldering is available, from 4·8mm wedges to chisels and angles as small as 1mm.

The iron costs around 18 UK Pounds and may be purchased online (via the web site below), or from distributors.

For more information contact BS Manufacturing Ltd., Strawhall Industrial Estate, Carlow, Ireland.

Tel: +353 (0) 503-41340

Fax: +353 (0) 503-40363

Email: sales@vulkangt.com

Web: www.vulkangt.com

CELLPHONE DATA WAR

By Barry Fox

Rival British cellphone networks Orange and One-2-One have started a GSM data speed war that will replicate round the world. Most countries now use Europe's digital GSM system but email and Internet access, at 9·6Kbps, is painfully slow.

The completely new Universal Mobile Telecommunications System promises data rates up to 2Mbits/s, but will not be ready until 2002.

Orange recently launched a new service called High Speed Circuit Switched Data, which hikes the speed to 28·8Kbps. One-2-One will wait a year until different technology, called General Packet Radio Service, is ready. Both systems are authorized by ETSI, the European Telecommunications Standards Institute, but are not fully compatible.

HSCSD uses less error correction to increase the basic GSM data rate to 14·4Kbps, and then gangs channels together to give 28·8Kbps or higher.

GPRS works on the assumption that most users do not need constant data speed. A pool of capacity serves several users at the same time, with bits allocated as and when they are needed. One-2-One plans a GPRS service for September 2000, with speeds up to 56Kbps, rising to 112Kbps by 2001.

"HSCSD is a technology cul-de-sac" says Craig Tillotson, One-2-One's Director of Strategy. *"GPRS hardware will cope with HSCSD, but HSCSD hardware will not handle GPRS. And if Orange pass on the true cost to subscribers, HSCSD access will cost at least ten times as much as GPRS."*

"Not so", says Stuart Scott, Orange's Manager of Internet Products. *"We have not yet set tariffs, but our target is to add only a very small premium".*

Filter Software – Free!

Microchip, those ingenious PIC manufacturers, have told us that you can now download some filter design software from

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their web site, free! FilterLab is a software design tool that simplifies the design of active filter systems using opamps as analog filters. It provides full schematic diagrams of filter circuits with component values and display of the frequency response.

FilterLab supports the design of low-pass filters up to 8th order, with Chebyshev, Bessel, or Butterworth responses, from frequencies of 0·1Hz to 10MHz. Once the filter response has been identified, FilterLab generates Bode plots and the circuit diagram. It also generates a Spice model for time domain analysis, streamlining the design process.

To download Filterlab, access Microchip's site at: **www.microchip.com**

Power Lines and Health

The National Radiological Protection Board (NRPB) is to investigate recent claims that a causal link between power lines and human health can be established. It states that these claims need to be compared with the findings of the first paper from the UK Childhood Cancer Study (UKCCS) which shows no increased risk of childhood cancer associated with magnetic fields from the electricity supply. This definitive study, looking at actual cases of childhood cancer and controls, is the largest of its type in the world.

For more information, contact NRPB, Chilton, Didcot, Oxon OX11 0RQ, UK.

Tel: +44 (0) 1235-822744

Fax: +44 (0) 1235-822746

Web: **www.nrpb.org.uk**

PORTABLE POWER

"Run virtually anything in your car!" exclaims a Press Release from Merlin Equipment. Merlin's Cherokee unit simply plugs into a car's cigarette lighter and converts low voltage battery power to standard 230V AC mains power. A normal UK 13A socket on the unit allows direct connection to appliances.

The Cherokee 150 is capable of supplying up to 150 watts of power continuously. For appliances that require a surge of power (TVs for example), it can provide 300 watts instantaneously. The converter is overload, overheat and short-circuit protected. In the event of the input battery voltage dropping below 10·8V, the unit will cut out – ensuring that you can re-start your car's engine!

Merlin have a large range of other products designed for in-car, caravan or boat use.

For more details, contact Merlin Equipment, Dept EPE, Unit 1, Hithercroft Court, Lupton Road, Wallingford, Oxon OX10 9BT, UK.

Tel: +44 (0)1491-824333

Fax: +44 (0) 1491-824466

Email: sales@the-merlin-group.com

Web: www.the-merlin-group.com

Electronic Purse

One of the many documents that have come to us in connection with the Smart Card 2000 exhibition and conference (8-10 Feb 2000, Olympia, London), highlights the question *"Have Europe's banks invested millions developing a product no-one wants?".* The product referred to is the "electronic purse".

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Electronic purses have been the cherished goal of banks and other global organizations for around 10 years. Apparently, though, in many markets consumer feedback indicates they are not a viable proposition.

The concept of a cash-less society is proving difficult for the consumer to accept. If the public is not ecstatic about the concept, neither are many of Europe's bankers who are facing losses of up to two euros per purse card per annum. In some countries the costs of persuading the customer to load and use the card exceed incomes by several times.

So will we be jingling the coins in our pockets in 10 years time? As we go to press, such matters are due to be discussed by delegates at the conference.

Go to next section

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Readout

John Becker ***addresses some of the general points readers have raised. Have you anything interesting to say? Email us at editor@epemag.com!***

WIN A DIGITAL MULTIMETER

The DMT-1010 is a 3 1/2 digit pocket-sized LCD multi-meter which measures a.c. and d.c. voltage, d.c. current, and resistance. It can also test diodes and bipolar transistors.

Every month we will give a DMT-1010 Digital Multimeter to the author of the best *Readout* letter.

* LETTER OF THE MONTH *

A-LIVE-A-LIVE-OH!

Dear EPE,

A friend recently drew my attention to the current series you are running on Oscillators (since July '99). Having obtained the September issue, I sent for the previous issues. What interesting reading they make!

I have been pleasantly surprised by the exchange of information with readers in *Readout*, and the informative level of *Circuit Surgery*.

Arthur Lawrance
via the Net

It is an interesting fact that, despite attempts at standardization, English continues to evolve and, irrespective of "official" definitions, the perceived meaning of many words changes amongst the general population. There are many cases, too, where words have acquired different meanings depending on the context in which they are used.

It's worth remembering (or is it?!) what Alice's Wonderland friend Humpty-Dumpty said (in a rather scornful tone), "When I use a word it means just what I choose it to mean – neither more nor less"!

TEACH-INS PLUS EPE ONLINE

Dear EPE,

Thank you for not only the new *Teach-In 2000* series, but for the *Teach-In 1998* series as well. I credit knowledge gained from that for helping to secure a new job. Many companies are now giving a written skills test for technical positions and I would not have been able to pass the electronic and digital portions without your magazine. (My experience is in hydraulic and pneumatic systems.) The series was so well written, I learned enough basic electronics as well as digital to be hired.

I have since completed a well-known correspondence course in basic electronics for which my employer will reimburse me. I found your *Teach-In* series to be better written and more understandable than theirs. I also wish they had been able to provide the interactive software I downloaded for the *Teach-In 2000* series. It is always useful to reinforce what you have read with practice.

I have subscribed to the *On-line* version of your magazine and am looking forward to every issue. I have a few suggestions which I would like to see if possible.

I enjoyed the PDF files being separate files so that I could save the Teach-In 2000 from the Nov '99 issue to a floppy disk to view it at work on breaks and between service calls. (Remember the "paperless office" hype?). I am not able to do that with the Dec '99 issue. The only way to carry the information with me now is to print those pages out as the whole file is over 3MB. I hope you have plans to make the complete series and the previous *Teach-In* series available for purchase via the Internet as well. This would be most helpful to readers like myself in Macon, USA, whose only source for EPE is one bookstore which stocks four copies. I missed some of the PIC Tutorial because it was sold out.

Thanks for a great publication.

Alan Craig
Macon, Georgia, USA

Alan E-mailed his comments to our On-Line Editor Alan Winstanley, who E-mailed back:

We're really pleased to hear that Teach-In 98 *was of benefit to you, your compliments are much appreciated. Writing that series was hard work! We tried to mix together the essential theory along with some practical work. It was also difficult to co-*

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ordinate the material originating from four writers, to a very tight monthly deadline. The advent of digital cameras helped a lot.

The development and production time for Teach-In 98 *was shorter than that of* Teach-In 2000*, which has been in preparation for at least a year. There has therefore been much more time available to develop the* Teach-In 2000 *programs (It hasn't felt like it! JB), and its author John Becker is very skilled at producing QBasic electronics demo or test and measurement software.*

It is possible to buy photostats of any out-of-print EPE *Back Issue articles direct from the UK. These can be ordered via our secure server, accessible from the* EPE *web site at* **www.epemag.wimborne.co.uk**

Alan W also forwarded Alan C's queries on EPE Online *to its Editors Max and Alvin in Alabama, USA, from whence the electronic version is served out. Max responded:*

Thank you for your kind comments – it's always great to receive positive feedback. Sorry to hear that you would prefer to receive the Online magazine as multiple small PDFs. In fact, the main reason we decided to move to a single large PDF is that a lot of readers requested it that way (to make it easier to print out the entire issue in one go). However, you will be happy to know that once the Teach-In 2000 *series is finished, we are planning on offering the whole series on a single CD (actually a mini-CD that would fit into your wallet, so that you can easily read the articles whilst on the road).*

Furthermore, we're also planning on offering the entire set of EPE *1999 issues on these mini-CDs for ease of reference. Watch our web page at* **www.epemag.com** *for more details in the near future.*

PERSEVERENCE

Dear EPE,

I have had the *PIC Electric project* (Feb-Mar '96) hanging around for some time, and much to my irritation I have been unable to resolve a problem with it: the LED display continually shows flashing FFFF. The middle FF are fairly stable, but the outer two FF segments are dimmer and flash in a more pronounced fashion.

The circuitry has been constructed on PCBs purchased from you, using recommended components obtained through RS. I have checked connections and component layout and can find no problem with these. I have tried down-loading the program for the PIC a number of times, from a '486 66MHz PC. Using both the on-board components, *Simple PIC Programmer* and also the *PICtutor* board, I always end with the same results. Adjustment via the calibration buttons appears to do little. The +15V, –15V, +5V and TP7 check out OK. The A-D reference voltage has been adjusted as advised. Please could you offer some suggestions?

Steve Gooch
via the Net

I wondered if Steve had a power supply regulation problem, the rectified output of REC1 not providing sufficient voltage when the display has many digits active. This could affect synchronization and indeed the correct operation of the PIC. Making this suggestion to Steve, he later replied:

Thanks for your suggestion. The problem was with the PIC programming. Why, remains a mystery, data transmission speed? A preprogrammed chip from Magenta cured all, however. Thanks for the excellent magazine – and the back-up support.

PIC16F877 PROBLEM SOLVED

Here's another tale with a happy ending. First the problem:

Dear EPE,

Many thanks for the *PIC16F87x Mini Tutorial* (Oct '99). It was just what the doctor ordered, the inclusion of the Basic program was a masterstroke, my attempts to calculate baud rates had produced some improbable results, most of which would not have fitted into an 8-bit register.

However, I am experiencing difficulties re-programming a PIC16F877. I've built a board along the lines of your *Data Logger* (Aug-Sept '99), minus provision for EEPROMs, and connected it to my *EPE PIC Tutorial* (Mar-May '98) board and all went well. I ran the input port test program of Toolkit Mk2 (May-Jun '99), all voltages present and correct, plugged in my '877 and compiled and programmed TKTEST4 into the PIC. It ran and the LEDs flashed.

I then compiled (with no errors) my own program (well actually most of it was yours from Mini Tut) intended to initialize the USART with a baud rate of

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31.250kHz and loop 10101010 to give a nice square wave out of the port. I re-configured the PIC and then programmed it with my own program. Nothing appeared to be working, so I assumed that there was a problem with my program and re-loaded TKTEST4. Nothing happened, the PIC appeared dead. It seemed impossible to program it now. In case the PIC had developed a fault I plugged in another. TKTEST4 went straight in and ran. I then attempted with my own program again and I have exactly the same problem i.e. I cannot re-load TKTEST4 successfully.

I have thoroughly checked my board, PIC Tutorial board, etc. and can see no dry joints. I have checked the clock with an oscilloscope and the 4MHz clock is running, I have re-checked all voltages with the input port test program of *Toolkit Mk2* again and all voltages are present and correct, the 12V programming voltage switches between 12V and 5V as it should.

Derek Johnson
via the Net

That, then, is the outline of Derek's PIC problem, and he had obviously taken the correct steps in trying to determine the cause of the problem. The only thing that occurred to me was that it might be a PIC configuration problem – the settings having become corrupted in some way. I suggested such to Derek and recommended that he reconfigured as I described in Mini Tut.

Then comes the following reply back from Derek a couple of weeks later:

Have cured my problem! – by accidentally re-compiling TKTEST1 and loading it. It ran straight away. The problem with my program was due to having already defined PAGE1 and PAGE0 in the header. I then re-equated them to suit the SETBAUD routine in your Mini Tut. I assumed that it would be OK to use either routine, to select pages. Apparently not. After removing the equates for RP0 and RP1 from the header, the program ran.

Many thanks for your concern.

An interesting situation and solution – from which all us PIC programmers should learn a lesson!

TASM, MPASM MEANS SPASM

Dear EPE,

Recently I got hold of the *Simple PIC Programmer* as featured in *EPE* Feb '96. Once built it has all worked fine and has spurred me on to delve deeper into PIC programming, However, I would appreciate it if you could just clear up a couple of things that are driving me bonkers.

Firstly, the kit came with TASM. I assume that TASM is a forerunner of MPASM which I see and hear about wherever I go, and a specially written (guessing again) program called SEND.EXE. The prog is compiled with TASM and downloaded to the chip via the parallel port, all well and good.

Next I decided to get "EASYPic'n" to start learning. This is where it's all got a bit cloudy. EASYpic'n writes out the code ready to be compiled by MPASM. Undeterred by this I tried to use TASM instead (it's all I have!). Of course doing this throws up lots of errors and it takes a while to sort them out. At first this wasn't too bad, but as the progs move on its all getting a bit too much.

Now, I did download MPASM from Microchip's website and thought that would be it. (Ha, as if!) Of course MPASM converts my .ASM files to .HEX files. But when it comes to downloading to the chip, SEND.EXE needs to see .OBJ files. (Dare I ask what the difference is?) which is fine with TASM but no good with the hex files of MPASM. So what do I do with these hex files?

Next I downloaded MPLAB from Microchip. This is fine and I could probably get used to that. The thing is I'm not sure if that has something built in that will do something with the hex files and then download them. Maybe its Picstart Plus.

Any reference to programming the chip seems to refer to serial connection, and guess what – my TASM thingy plugs into the parallel port. Is my kit a bit of a dinosaur? How do I get my MPASM generated hex files to the chip? Do I now need a serial programmer instead? (I bet this is where free downloads end.)

Is there another *EPE* project that gets around these problems.

Mick Tinker
via the Net

Such confusion Mick! First let me say that you seem not to have been a regular reader of EPE, *otherwise your knowledge of PIC programming requirements and techniques would have increased through reading the several articles that we have published on the subject since*

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the Simple PIC Programmer*.*

In particular you should read the PIC Tutorial *series of Mar-May '98 (which discusses PIC programming at some length),* PIC Toolkit Mk1 *of July 98 (which discusses not only programming but also the differences between MPASM and TASM),* PIC Toolkit Mk2 *of May-June '99 (which is a much enhanced version of the Mk1 and has many of the features you obviously have need for, including the ability to translate between MPASM and TASM – it also allows the newer PIC16F87x series to be programmed, as well as the '84 series).*

We strongly recommend that you, and other readers in a similar position, should read these articles, which I am sure will clear up a fair number of your problems. I would comment, though, that as you have MPLAB you should make an in-depth attempt to get to know it, and to also obtain the other hardware associated with it. As good as Toolkit Mk2 *is, it does not cover the full range of PICs that are manufactured, whereas Microchip's hardware/software suites are designed to do so (after all, Microchip are the manufacturers of the PICs and so provide a full backup for their use in industry). Rather than discuss it all further here, do read the above-mentioned articles, available as back issues (or photocopies in some cases) from the* EPE *Editorial office.*

FLAWED PIRACY-PROOFING?

Dear EPE,

I found the *Pirate-Proof CDs* (News, Dec '99) interesting but flawed. Have the people at C-Dilla forgotten that a computer comes with an Audio Line-in and some more expensive sound cards have digital inputs, and certain CD Players have digital outputs? So if a CD player disregarded the false error correction code would the false code be sent through the digital outputs? (Hmm, I wonder).

But that aside, pirates would just sample from a CD player's audio outputs to a PC's audio inputs, and using a good PC sampler, save on to a hard drive track by track. After doing so they could (without the false code) be put on a CDR disk and then copied as many times as they liked. All in the time it takes to play a regular CD, so it seems the pirates will still be one step ahead, and that it just merely slows them down.

I think true anti-piracy will come when CD media is old hat (I predict in about 10-15 years), and solid state memory sticks or cards are the norm. Using encryption and digital ID tags, the consumer when buying music from a store would have his ID put onto the card, this ID would come from the manufacturer of the card player and would be unique, therefore not allowing it to be played on any other player even if copied.

Darren Portsmouth
via the Net

An interesting point, Darren, and one I am not qualified to comment on. Any readers care to comment further?

PIC vs AVR ETC

Dear EPE

PICs are definitely excellent microcontrollers, but it does not mean they are the only microcontrollers. There are other good microcontrollers like Atmel AVR or Scenix SX. By using only PICs you are limiting your magazine's resources. Some good projects with other microcontrollers will definitely open your magazine to a much wider audience.

I am not saying to throw away the PIC, it should be included, as it is very good for first time programmers, and a lot of your loyals also use PICs, but loyals like myself feel that we should not be confined to a single subject but rather explore all the possibilities.

Let me tell you what happened to me, I am a student and my professor gave an assignment, to design a data logger but to design it from any other microcontroller except PICs. None of my colleagues along with me were able to do that. We had to hear a long lecture on how we have gotten used to spoon-feeding, and had confined all our attention on a single topic. After graduating and getting a job we might be asked by our superiors to design a project from Atmel AVR, then what will we do?

Ziyad Saeed
via the Net

Editor Mike Kenward replied directly to Ziyad:

I can understand that as a student you will need to learn about other microcontrollers, but you should realize that for the type of projects we publish the PIC is usually the best and easiest solution.

We have published projects for the Atmel AVR microcontrollers, but few readers were interested. Whilst we do publish a range of educational items we cannot undertake to teach you about all the subjects you will undertake – sometimes you will

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need to find resources elsewhere.

To which I will add my own comment that I was personally very disappointed that the AVRs did not receive the reader response I had hoped for. I had felt that we should actively demonstrate that microcontrollers other than PICs were in commercial use and I was quite prepared to learn about them for myself and on behalf of you all! But, as so few readers have expressed an interest in AVRs, I too shall stick with PICs, which I must add, are not only "good for first time programmers", but are widely used by professional designers in industry.

VOLTAGE MONITOR

Dear EPE,

I am writing in regard to the *Voltage Monitor Starter Project* in the Feb '00 issue. Since I am a beginner and am following the *Teach-In 2000 series*, I thought that this would be an excellent project to build and use to ensure that the voltage level of the battery I am using when doing the practical experiments does not fall below a critical level.

You give very clear and easy-to-follow instructions for determining threshold voltages of the detectors when using the device to monitor batteries of voltages different to 12V. But what are these threshold voltages for a 6V battery? I would assume the upper threshold level to be 6V, but I have no idea what the lower one should be. I would be most grateful if you could recommend to me suitable threshold voltages, bearing in mind that the project is to be used in conjunction with the power supply for your *Teach-In* series.

I would like to say that I find the *Teach-In* series excellent. It explains concepts in a clear, thorough and practical way, and I have really enjoyed learning through it.

John Thornton
Sunderland

The Teach-In *circuits should function even with voltage levels well below 5V, even as low as 4V. When new, your 6V battery will probably deliver about 6·5V. I would probably regard 5·5V as being the level at which I would replace the battery, and so set one threshold for a little above that, and another for about 6V as advance warning that "fuel" is beginning to get a bit low. But in many ways, it's a somewhat arbitrary matter since the amount of current being consumed will determine what may be regarded as a reasonable life expectancy for the power remaining in the battery.*

It's like with car driving: my fuel light comes on when the tank is down to a quarter full. It is typically a 500 mile tank and so I know that I probably still have well over a hundred miles before having to walk! A hundred miles on the motorway is less than two hours of fuel remaining. Driving locally to the shops and back, the same fuel probably represents several days.

If you really feel in danger of "running out", keep a back-up fuel supply available, in your case keep another battery handy. I compliment you, though, on your initiative in this matter. Building the Voltage Monitor *will not only prove to be useful constructional experience, but using it will also help reinforce your concept of electronic power consumption.*

FTP PLUS TI2K

Dear EPE,

In *Readout* it seems some folks have a problem downloading from the FTP site, or they are getting corrupted code. I always use WS_FTP, which is a free shareware FTP program. It's very easy to use for both down and up loading!

I have downloaded the *Teach-In 2000* software and have to say I like it, it will prove very useful. The pots screen is useful and the cap-resistor time constants, can't wait to see how you convert the printer port to a frequency counter! What I would like to see added is a 555 timer time-freq calculator and basic opamp configuration with gain calc, etc.

Mel Saunders
via the Net

Hopefully, you should know by now – details were given in Feb '00 issue, easy isn't it?! Sorry to disappoint, though, I'm not covering 555s in TI2K. The aim of the series is to achieve a broader sweep without getting into specific named devices. Besides which, there's been enough published on 555s to fill the British Library twice over (much of it originating in EPE) – I've no wish to add to the glut!

Go to next section

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Shop Talk

with DAVID BARRINGTON

Some Component Suppliers for EPE Online Constructional Articles

Antex
Web: **www.antex.co.uk**

Bull Electrical (UK)
Tel: +44 (0) 1273-203500
Email: **sales@bull-electrical.com**
Web: **www.bullnet.co.uk**

CPC Preston (UK)
Tel: +44 (0) 1772-654455

EPE Online Store and Library
Web: **www.epemag.com**

Electromail (UK)
Tel: +44 (0) 1536-204555

ESR (UK)
Tel: +44 (0) 191-2514363
Fax: +44 (0) 191-2522296
Email: **sales@esr.co.uk**
Web: **www.esr.co.uk**

Farnell (UK)
Tel: +44 (0) 113-263-6311
Web: **www.farnell.com**

Gothic Crellon (UK)
Tel: +44 (0) 1743-788878

Greenweld (UK)
Fax: +44 (0) 1992-613020
Email: **greenweld@aol.com**
Web: **www.greenweld.co.uk**

Maplin (UK)
Web: **www.maplin.co.uk**

Magenta Electronics (UK)
Tel: +44 (0) 1283-565435
Email: **sales@magenta2000.co.uk**
Web: **www.magenta2000.co.uk**

Microchip
Web: **www.microchip.com**

Rapid Electronics (UK)
Tel: +44 (0) 1206-751166

RF Solutions (UK)
Tel: +44 (0) 1273-488880
Web: **www.rfsolution.co.uk**

RS (Radio Spares) (UK)
Web: **www.rswww.com**

Speak & Co. Ltd.
Tel: +44 (0) 1873-811281

EPE ICEbreaker

Apart from the specially programmed PIC16F877 microcontroller chip, most of the other components needed to construct the *EPE ICEbreaker* project are fairly common items. The "firmware" program in the chip is loaded and copy-protected (in the upper half of the 8K program memory) and is not available in any other way – you must purchase the preprogrammed PIC chip to build this project.

We have reached a special agreement whereby we are able to offer a ready-programmed, 20MHz version, PIC16F877 chip together with a floppy disk containing the *ICEbreaker* software and the printed circuit board (code 7000257) -- see the *EPE Online Store* at **www.epemag.com**

Also, the *ICEbreaker* software, including the simple test program and demo programs, is available for free download from the *EPE Online Library* at **www.epemag.com**

A special package has been put together by Magenta Electronics, which contains the following: preprogrammed 16F877 (20MHz version), printed circuit board, solderless breadboard, LCD display module, floppy disk, BT47 relay, 9-way PC serial lead (25-way extra), and all other components. They have even included a low-voltage stepper motor and UK mains adapter, "plug" type, power supply.

All this for just 34.99 UK Pounds plus 3 UK Pounds post and packing. For full details contact Magenta Electronics

2000.co.uk or E-mail: sales@magenta2000.co.uk.

Finally, we understand that some overseas readers (particularly in USA) may have difficulty in obtaining the ZTX transistor. The designer informs us that most general purpose *npn* types rated at 1A 60V should work (though not tried) in this set-up.

High Performance Regenerative Receiver

Some of the components needed for the *High Performance Regenerative Receiver* may be hard to track down. We have not included the Jackson type tuning capacitors in our pricing for this project, as it will depend on the condition and "newness" of these variables. We suggest you shop around for these items as they could add as much as 30 UK pounds, or nearly double the price, of this Receiver. Try Bull Electrical or J&N Factors (Tel: +44 (0) 1444-881965), who may be able to offer a good price, if they still stock them. You can also try Mainline Surplus Sales (Tel: +44 (0) 870-241-0810).

We found that some of the type numbers quoted for the TOKO tuning range coils did not tally with our information and could have caused real problems. However, thanks to

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the designer's, Raymond Haig, efforts in double-checking with the TOKO suppliers, we now have the correct type numbers.

The TOKO coil numbers and ranges used in the Receiver have been set out in a table (next month) and were purchased from Bonex Ltd (Tel: +44 (0) 1753-549502). Type numbers and order codes are as follows: CAN1A350EK, 380-350; RWO6A7752EK, 357-752; RWR331208NO, 351-208; 154FN8A6438EK, 356-438; KANK3426R, 363-426; KANK3337R, 363-337; MKXNAK3428R, 363-767.

The rest of the components for this project should be widely stocked. The three Receiver printed circuit boards are available as a set and are obtainable from the *EPE Online Store* at **www.epemag.com**

We could not close without saying that the author has produced a really "professional" Regenerative Receiver – almost a piece of nostalgic art!

Parking Warning System

A few dedicated parts are called up for the *Parking Warning System* and may not be obtainable from your usual local component stockist. The PIC260435 infrared sensor/ amplifier/demodulator came from Farnell, code 139-877. (This device has nothing to do with PIC microcontrollers.)

Turning to the HT12B or HT12A encoder and the HT12D decoder ICs, these caused considerable sourcing problems last time they were used in a published design. At that time, they appeared in a well-known company's catalog, but, in fact, they had discontinued stocking them. To solve this problem FML Electronics (Tel: +44 (0) 1677-425840) purchased some specially and, at the time of going to press, we understand they still have stocks.

The rest of the components, including the ceramic resonator, should be readily available items. Just one point, specify the L suffix when ordering the BC184L general-purpose transistor, because other types have differing pinouts to this one.

The single-sided printed circuit board is available from the *EPE Online Store* (code 7000258) at **www.epemag.com**

Automatic Train Signal

All parts, including the LF351N IC, for the *Automatic Train Signal*, this month's "starter project", should be stocked by our regular components advertisers. The choice of LEDs, 3mm or 5mm, will depend on gauge and size of your model railway layout. The LED current is not very high, so "high brightness" types are preferable.

Teach-In 2000

No additional components are called for in this month's installment of the *Teach-In 2000* series. For details of special packs readers should contact:

ESR Electronic Components – Hardware/Tools and Components Pack.

Magenta Electronics – Multimeter and components, Kit 879.

FML Electronics (Tel +44 (0) 1677-425840) – Basic component sets.

N. R. Bardwell (Tel +44 (0) 114 255-2886) – Digital Multimeter special offer.

PLEASE TAKE NOTE:
Scratch Blanker Jan '00

We have been informed that the MN3004 delay-line and the MN3101 clock generator ICs called for in the Scratch Blanker are no longer produced or stocked by Maplin. However we understand that Sky Electronics (Tel +44 (0) 20-8450-0995) have some.

Go to next section

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