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Next Month

EPE MOODLOOP

Various ways of encouraging the brain to generate specific electrical frequencies exist, one of which is exposure to a suitable alternating magnetic field. Opinions on how this works vary, but one likely method seems quite simple. An alternating magnetic field induces electrical currents in conductive material within range and brain tissue is such a conductor. It seems likely that the production of weak currents of suitable frequency within the brain will either tend to produce the desired mental state directly, or it may do so by encouraging the brain to "synchronise" to the frequency. Either way, the effect is one many people find worthwhile as shown by the interest in the two projects published so far in *EPE Online*. Both of these produce tiny localized magnetic fields. This one represents an attempt to increase the effect by delivering a much larger current into an inductive loop system which may be placed right around a small room (or around a bed in the case of insomnia!) to permeate a whole area with the desired field. Roughly speaking, it can saturate an area of up to four meters square with a field of intensity equal to that of one of the previous designs at a range of about three centimeters. This should be sufficient for the most ardent enthusiast of the system.

TOP TENNERS

This short collection of projects, some useful, some instructive and some amusing, can be made for around the ten UK pounds mark. The estimated cost does not include an enclosure, for many of them work just as well as an open board.

All of the projects are built on stripboard, and have been designed to fit on to boards of standard dimensions. All of the projects are battery-powered, so are safe to build.

DOOR PROTECTOR

Our first *Top Tenner* is a simple Door Protector. Even if you already have a system installed in your home or workplace, there is likely to be a use for this project. With any security system, or even with none, it is important that all doors and windows should be protected by bolts, bars, grids, or other physical means. Unfortunately, there is nearly always one weak point. This is the Exit Door, the door by which you normally leave the house when you are going out. This unit will provide timed entry and exit whilst protecting this or any other door or window.

HANDY AMP

This easy to build "bench" amplifier has an in-built loudspeaker, it also has the facility for connecting personal stereo type headphones or an external loudspeaker. it will accept both high-level and low-level input devices. Magnetic record player cartridges and dynamic microphones provide a low-level output while the "line output" socket fitted to many pieces of consumer equipment (such as compact disc players and video recorders) provide a high level.

Many readers will, no doubt, wish to construct the amplifier for experimental and test purposes. However, it could have a variety of other applications. Examples include a small practice amplifier for electronic musical instruments and as the basis for an intercom or toys and games. Being battery-operated, it may be set up outdoors and, with just a microphone (possibly with an extension lead) and a pair of headphones connected, it could be used to listen to wildlife etc.

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Editorial

ROUGH MEASUREMENTS

Measuring a change in capacitance of 10^{-18}F or a movement of 0·2 angstroms – about a tenth of an atomic diameter – in a hobbyist project seems to be next to impossible and certainly unthinkable a year or so ago. But with the development of specialist ICs such technology is now available to all. Why would we want to measure such small valves, well if you use a mass of just 0·1 micrograms to measure g-force then it is necessary to record movements of this nature.

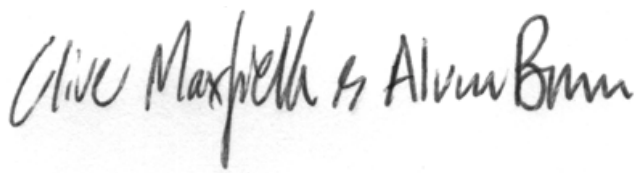
An IC with a two micrometre beam etched into it, along with the necessary detector electronics, forms the basis of our *g-Meter* project this month. When you realize that the whole thing, including the interconnections, is housed in a plastic package measuring just 10mm by 8mm you begin to realize just how far technology has advanced in what was previously an electromechanical device – we suppose it still is, even though it is now etched into a single silicon chip.

Devices like this are what keep our hobby interesting. One small chip plus a handful of passive devices and some form of readout and you have a fascinating, highly sensitive piece of equipment whose output can also be fed to a data logger or computer for analysis and recording.

When you realize that what you are using is right at the forefront of technology and you can buy this for less than 20 UK pounds it seems even more amazing. Gone are the days of weights on pendulums or inside bolt-on steel housings, now you can stick your accelerometer on with tape.

BLASÉ

We guess we should not be too surprised since we just accept that a Pentium chip contains seven million active devices, but it always seems to us that miniaturization of mechanical items of this nature is somehow a greater achievement. Maybe it's because we are so used to electronics getting smaller and smaller that we simply accept it, but find it harder to believe that a pump, gearbox or mechanical beam can be miniaturized in the same way.



Constructional Project

CAMERA SHUTTER TIMER

by ROBERT PENFOLD

An easy-to-build project that will check your camera shutter speeds. Four switched ranges up to: 5ms; 50ms; 500ms and 5 seconds.

Although digital cameras have been progressing rapidly in recent years, and most of the photographs in this magazine are now produced without the aid of film, most people are still using traditional cameras. It seems likely that they will continue to do so for some years yet.

The quality of the finished result with traditional photography is dependent on a number of factors. One of these is the accuracy of the shutter, which is particularly important when using certain types of film. There is very little exposure latitude with any form of transparency film, and also with certain negative films.

Modern SLR cameras mostly have electronically timed shutters, and in terms of accuracy they are generally superior to the purely mechanically shutters of older designs. Electronically timed shutters are also less prone to creeping out of adjustment over a period of time, but things can obviously go awry with shutters of either variety.

ON TIME

It is not essential to use a complex digital timer to test camera shutters, and a very basic analogue timer circuit is capable of providing accurate measurements in this application. The simple design featured here has four measuring ranges having full-scale values of 5ms, 50ms, 500ms, and 5 seconds. It can therefore be used to measure the full range of speeds covered by most cameras.

Some of the more modern cameras have manual shutter speeds of up to around 30 seconds or so, which takes the longer shutter speeds beyond the maximum range of this unit.

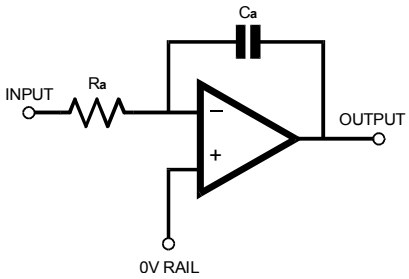


Fig.1. The basic integrator circuit.

However, these longer shutter times of around 8 seconds to a minute are easily tested using a stopwatch, and do not really need a shutter timer.

Although this unit is primarily designed for testing shutters, it should be possible to modify it for use in some other automatic timing applications. The light level on a sensor going above a certain threshold level activates the timer, but it can also be controlled by switch contacts.

INTEGRATOR

The circuit is based on an operational amplifier (opamp) connected as an integrator. The basic integrator circuit is shown in Fig.1. Like most basic operational amplifier building blocks an integrator requires dual (positive and negative) supply rails with a central (zero volt) earth rail. The inputs and outputs can therefore have negative as well as positive voltage levels.

An operational amplifier amplifies the voltage difference

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at its two inputs, and the output voltage is positive if the non-inverting (+) input is at the higher potential. The output voltage is negative if the inverting (–) input is at the higher voltage. The voltage gain is extremely high at DC and low frequencies, with a figure of around 200,000 being unexceptional.

Under standby conditions, the non-inverting (+) input is biased to the 0V rail, and there is no charge on capacitor *C*a. A negative feedback action stabilizes the inverting input at the 0V bias level fed to the non-inverting input.

If the output was at a positive potential, the coupling through *C*a (which has no charge voltage) would take the inverting input positive, unbalancing the input voltages and taking the output negative. With the output at a negative voltage the feedback through *C*a again unbalances the input levels, and this time sends the output positive. Any drift in the output voltage is therefore corrected by the feedback.

With a real world opamp the output will not be stabilized at precisely 0V, since the gain of the amplifier is very high rather than infinite. Also, imperfections in the opamp's circuit can produce small offset voltages at the output, but in practice any errors are normally very small.

ON CHARGE

So far we have only considered the circuit with the input "floating" or at 0V. Suppose that the input is taken a few volts positive. Capacitor *C*a then charges through resistor *R*a, and the voltage at the inverting input starts to rise.

This sends the output

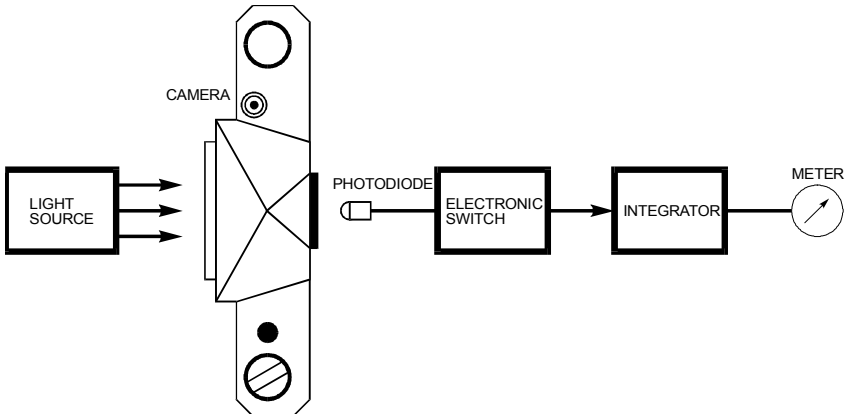
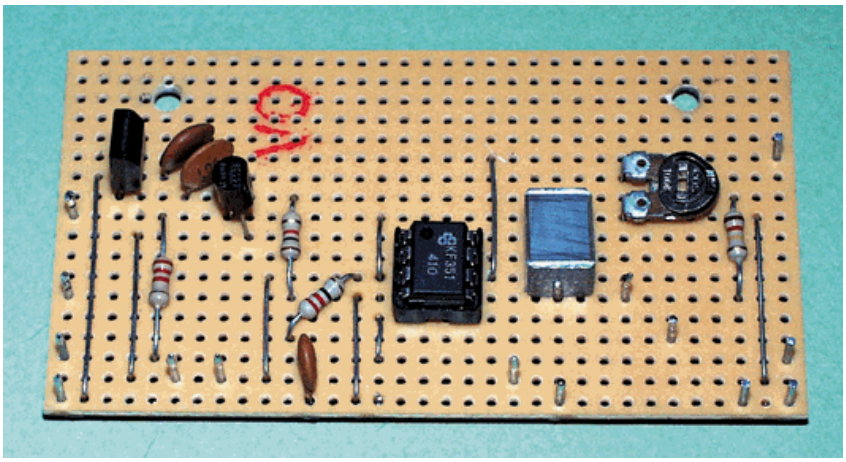


Fig.2. Block schematic diagram for the Camera Shutter Timer.



COMPONENTS

Resistors

R1 1k
R2 2k2
R3 2k7
R4 27k
R5 270k
R6 2M7
(0.6W 1% metal film)
R7 22 ohms
R8 120k

All 0.25W 5% carbon film except where noted

Potentiometers

VR1 220k rotary carbon (linear)
VR2 100k miniature carbon preset, horizontal

Capacitors

C1, C2, C4 100n disc ceramic (3 off)
C3 1u polyester, 10mm lead spacing

See also the SHOP TALK Page!

Semiconductors

D1 SFH309/5 phototransistor or other small phototransistor/diode (see text)
TR1 BC559 *pnp* transistor
IC1 78L05 +5V 100mA voltage regulator
IC2 LF351N biFET opamp

Miscellaneous

S1 4-way 3-pole rotary switch (only one pole used)
S2 pushbutton switch, push-to make release-to-break
S3 d.p.s.t. miniature toggle or rotary switch
ME1 50uA FSD moving coil panel meter
B1, B2 9V batteries, PP3 size (2 off)

Metal insrument case, size about 200mm wide; 0.1 inch matrix stripboard having 33 holes by 18 strips; 8-pin DIL socket; battery connector (2 off); control knob (3 off); multistrand connecting wire; screened lead; single-ended solder pins;

Approx. Cost Guidance Only ***(Excluding meter, case, batts)*** **$19**

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negative in order to keep the inverting input at 0V. As *C*a charges, the inverting input remains at 0V and the output of the circuit goes steadily more negative.

The important point to note here is that the voltage across resistor *R*a remains constant, and is equal to the input voltage. The current flow through *R*a, and therefore the charge current for *C*a, is also constant.

If a capacitor is simply charged from a resistor via a voltage source, the voltage rises quickly initially, but then gradually slows down. This is due to the fact that there is initially the full voltage across the resistor, giving a high charge current. As the voltage across the capacitor rises, the voltage across the resistor falls, giving an ever-decreasing charge rate.

The constant current flow into *C*a results in the output of the circuit going negative at a linear rate. If the output is at –1V after one second, it will be at –2V after two seconds, –3V after three seconds, and so on.

An integrator is therefore ideal as the basis of a simple timer. It is just a matter of using a voltmeter circuit at the output and adjusting the scaling so that the meter readings are easily converted into times.

SPEED AND SIZE

The block diagram of Fig.2 shows the general scheme of things used in the *Camera Shutter Timer* project. The integrator drives a moving coil panel meter, with the later directly indicating shutter timers over the four ranges stated previously. Using four input resistors, giving four different charge rates for the capacitor, provides the four ranges.

The integrator is driven from a photodiode or a phototransistor via an electronic switch. It is essential to use a photocell that has a fast response time since most cameras have a faster shutter time of one millisecond or less. Photo-resistors are too slow, but phototransistors and photodiodes have suitably fast response times.

In theory there is some advantage in using a photodiode due to its faster response time. In practice a photodiode seems to provide little improvement in accuracy in this application. Also, a photodiode has the drawback of being far less sensitive than a phototransistor. This design incorporates a simple transistor switching stage to ensure that the integrator receives a proper switching signal whether a photo-diode or a phototransistor is used.

On the face of it, the size of the sensor is unimportant, but in this application it is a case of "small is beautiful". The design of mechanical shutters has to take into account the fact that it takes a certain amount of time for the shutter to open and close.

At the slow speeds this factor does not matter because the opening and closing times are very short relative to the shutter time. At the fastest shutter speeds the opening and closing times can actually be longer than the nominal shutter speed. This may seem to be impossible, but all becomes clear when the action of a focal-plane shutter is examined.

CURTAIN CALL

There are two shutter curtains that are made from metal or rubberized cloth. One of the curtains blocks light from the film until the shutter is fired, and then it slides out of the way to one side to expose the film. After the appropriate time, the second curtain moves across the film gate and blocks light from reaching the film again. The two curtains are then pulled back to their original positions, and they move together in such away that light is always blocked from the film. The shutter is then ready to operate again.

As it takes several milliseconds for each curtain to traverse the film gate, the only way of achieving fast shutter speeds is to start the second shutter curtain before the first one has completely moved out of the way. This effectively gives a slit that travels across the film, exposing it a bit at a time. The faster the shutter speed, the narrower the slit is made. Although it may take something like 10 milliseconds for the shutter to complete an exposure, by making the slit narrow enough each part of the film can be exposed for a millisecond or even less.

Here we are measuring the shutter time by having a light source in front of the shutter, and the sensor positioned behind it and quite close to the film plane, see Fig.2. The unit responds to the pulse of light produced when the shutter is fired. If the sensor has a large diameter its size effectively increases the size of the slit when the shutter is used at fast speeds, giving elongated shutter timings. For this type of measurement the sensor would ideally be only a fraction of a millimeter in diameter, but it also needs to be reasonably sensitive.

In practice a diameter of about one millimeter is a good compromise. Photodiodes and phototransistors as small as this seem to be unobtainable these days, but a larger device is easily masked to produce an effective diameter of about one millimeter.

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CIRCUIT OPERATION

The full circuit diagram for the *Camera Shutter Timer* is shown in Fig.3. Operational amplifier IC2 is used in the integrator mode, and capacitor C3 is the integration capacitor. Resistors R3 to R6 are the input Range resistors, and the required resistor is selected using Range switch S1.

Meter ME1 is driven from the output of IC2 (pin 6) via the series resistance of R8 and calibration preset potentiometer VR2. Operating Reset switch S2 discharges capacitor C3 through current limiter resistor R7 so that the meter is zeroed and a new reading can be taken. Resistor R7 prevents excessive discharge currents that would otherwise shorten the operating life of switch S2.

Under dark conditions, photodiode D1 operates much like any other semiconductor diode. When reverse biased, as it is here, only a minute leakage current flows. Under bright conditions the leakage level increases, and the leakage current is roughly proportional to the received light level.

If the leakage current is high enough, transistor TR1 is biased into conduction and it applies +5V to the input of the integrator. In practice, sensitivity or Level control VR1 is adjusted so that TR1 is switched off when the shutter is closed, and turned on when the shutter is open. Potentiometer VR1 enables the unit to function properly under a wide range of ambient light levels.

Operation using a phototransistor is much the same, and Fig.3 shows the correct method of connection for a component of this type. Under dark conditions the collector (c) to emitter (e) leakage current is the low level associated with ordinary silicon transistors, but at high light intensities it rises to a milliamp or more. This again gives the required on/off switching action from TR1.

It is important that the integrator is fed with a stable input potential since any changes in this voltage will alter the charge current of the integration capacitor and degrade the accuracy of the unit. A monolithic voltage regulator (IC1) is therefore used to produce a well-stabilized +5V supply for the input circuitry.

The integrator, IC2, does not require a stabilized supply and is powered direct from two small (PP3 size) 9V batteries. The current consumption is only a few milliamps from each supply rail.

CONSTRUCTION

Most of the components are assembled on a piece of stripboard that has 33 holes by 18 copper strips. The component layout, interwiring and details of the breaks required in the underside copper strips are shown in Fig.4.

Construction of the board follows along normal lines, with a board being trimmed down to the correct size using a hacksaw, the two 3mm diameter mounting holes then being drilled, after which the 12 breaks in the copper strips are cut. The breaks can be made using a handheld twist drill bit of about 5mm diameter or so. The board is now ready for the components and link wires to be added. The LF351N specified for IC2 is not a static-sensitive component, but it is still a good idea to use a holder for this component. Do not overlook any of the eight link wires.

The shorter links can be made from the wire trimmed from resistors, but some 22s.w.g. or 24s.w.g. tinned copper wire is needed for the longer links. At this stage only fit single-sided solder pins to the board at the positions where connections to the meter, controls, etc. will eventually be made.

BOXING-UP

When choosing a case for this project, bear in mind that a fair amount of front panel space is required for the meter and four controls. This precludes the use of small and most medium size cases. A metal instrument case about 200mm or so wide is probably the best choice and was used for the prototype, but one of the larger plastic boxes would also be suitable.

The exact component layout used is not important from the electrical point of view, since the circuit operates at DC and is not prone to problems with stray feedback or noise pick up. However, try to use a sensible layout that makes the unit easy to use.

PANEL METER

Fitting the meter on the front panel is potentially difficult, as it requires a large round mounting hole. This is 38mm in diameter for most of the smaller meters, but it is clearly advisable to check this before cutting the hole.

The quickest way of making this cutout is to use a hole-cutter of the appropriate diameter, or to use one of the adjustable cutters that are available from most do-it-yourself superstores. Alternatively, cutting carefully using a coping saw, Abrafile, or any similar tool will produce the

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cutout, albeit rather slowly.

Four 3mm diameter mounting holes are required for the threaded rods built into the meter. These are normally at the corners of a square having 32mm sides and the same center as the main mounting hole. Again, it is advisable to make some measurements on the meter itself to check its mounting arrangements prior to drilling any holes.

Finished unit showing front panel layout and lettering. Note the phototransistor/diode light sensor is attached to the free end of the screened cable.

LIGHT SENSOR

Photodiode D1 can be connected to the main unit via a two-way plug and socket such as a 3·5mm jack type, but it is cheaper and easier to simply hard wire it to the circuit board. A hole for the connecting cable must be drilled in the case, and the hole should be fitted with a grommet to protect the cable if the case is a metal type.

A piece of two-way cable about 0·5 meters long is used to connect light sensor D1 to the circuit board, and low cost screened cable is probably the best choice. Use the outer braiding to connect the anode (or emitter) to the 0V rail, and the inner lead to connect the cathode (or collector) to resistor R2.

The unit worked when tried with various photodiodes and phototransistors, but as explained previously, results will be more accurate at faster shutter speeds if a sensor having a diameter of 3mm or less is used. Results will be even better if the sensor is masked down to a diameter of about one millimeter, and the easiest way of doing this is to

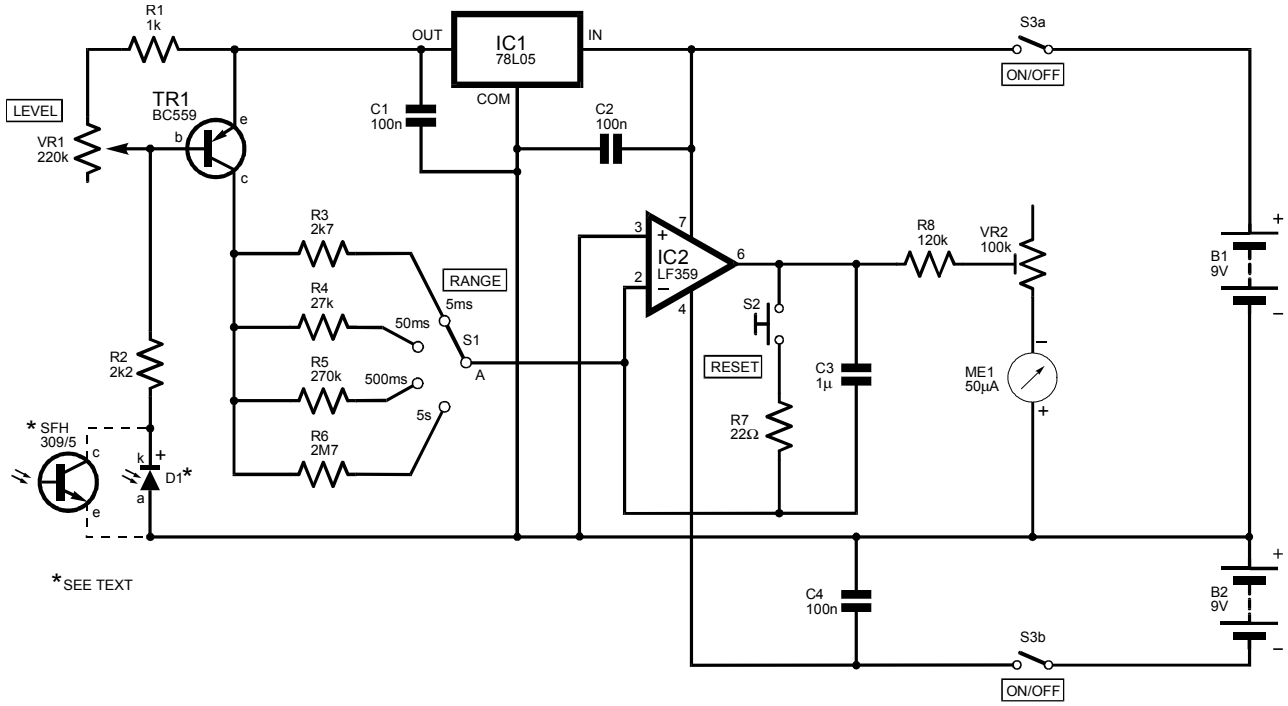

Fig.3. Complete circuit diagram for the Camera Shutter Timer. Note S3 is a "ganged" double-pole switch.

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apply a ring of black paint around the front of the diode.

FINAL ASSEMBLY

The circuit board is mounted on the base panel of the case, well towards the right-hand side, as viewed from the rear, so that there is sufficient space for the batteries to its left, see photograph. Mounting bolts are preferable to plastic stand-offs when using stripboard, and both 6BA and metric M3 bolts are suitable. Include spacers at least 6mm long to hold the underside of the board well clear of the case.

All the hard wiring is included in Fig.4 and is largely straightforward. Be careful to connect meter ME1 and the two battery connectors with the correct polarity. If sensor D1 has a standard light-emitting diode (LED) style case, the shorter leadout wire will be the cathode or the collector. For diodes having other case styles the manufacturer's or retailer's literature should be consulted.

The base terminal is not normally accessible on small phototransistors, but if there is a base lead it is simply ignored.

The four range resistors (R3 to R6) should be mounted directly on the rotary Range selector switch S1. It is best to solder the resistors on the switch tags before it is fitted in the case front panel.

Try to complete the soldering fairly swiftly so that the resistors do not overheat. It takes quite a lot of heat to destroy them, but relatively small amounts to impair their accuracy.

Table 1: Equivalent times in milliseconds for shutter speeds.

Marked Speed	Equivalent in ms
1/4000	0.25
1/2000	0.5
1/1000	1
1/500	2
1/250	3
1/125	8
1/60	16.66
1/30	33.33
1/15	66.66
1/8	125
1/4	250
1/2	500
1	1000

CALIBRATION AND TESTING

Start calibration/ testing with Range switch S1 set to the five-second range (R6 switched into circuit) and preset VR2 adjusted to roughly middle setting. When the unit is

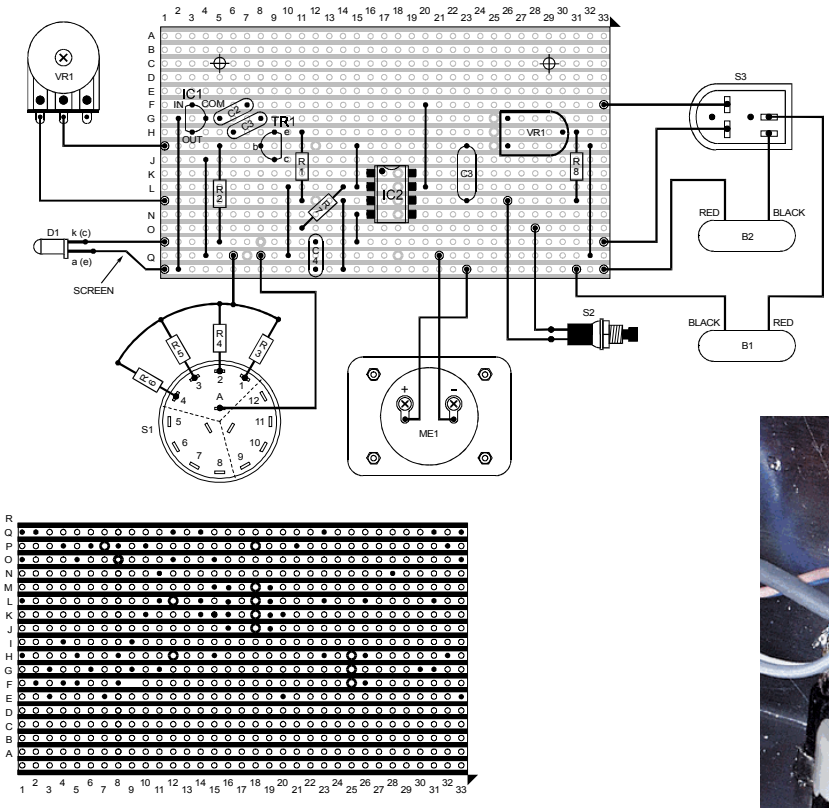

Fig.4. Camera Shutter Timer stripboard component layout, inter-wiring and details of breaks required in the underside copper strips. (Right) Mounting the Range resistors directly on the switch tags before it is fitted in the case will help with the final wiring.

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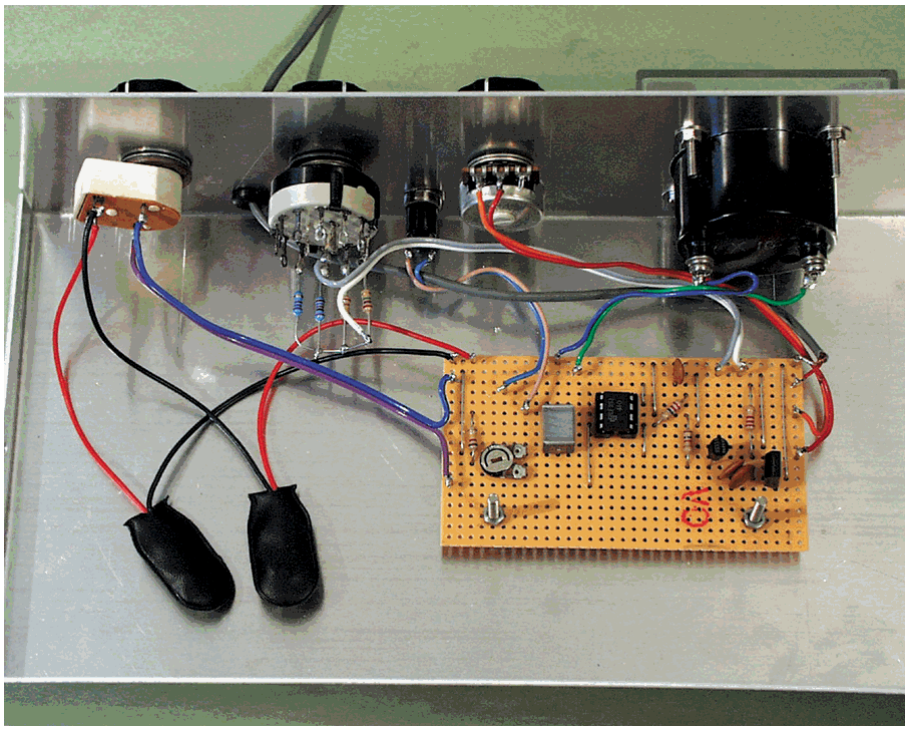

Layout of components inside the prototype metal case. The circuit board is bolted to one side of the case to make space for the batteries. The board should be bolted on 6mm spacers to keep the copper underside well clear of the metal case.

first switched on the meter ME1 may read other than zero, but briefly pressing pushswitch S2 should zero the meter.

With the sensor (D1) aimed towards a light source, which can simply be bright daylight coming through a window or light from a table lamp, the meter reading should slowly advance. However, it may require some adjustment to Level control VR1 before this happens. Clockwise adjustment of VR1 reduces the light level needed to activate the unit. If the sensor is a photodiode a reasonably strong light source will be required.

With a little trial and error it should be possible to find a setting that results in the meter reading advancing when the sensor is aimed towards the light source, and stopping when it is not. If the unit seems to be malfunctioning in any way, switch off immediately and recheck the entire wiring, etc.

It might be possible to check automatic exposure times with some cameras, but the unit was only designed to check manual speeds. Obviously the timer is only usable with cameras that have removable or hinged backs, which means the vast majority of 35mm models.

The main exceptions are some of the older Leica models and copies of these such as the early Fed and Zorki cameras. The timer was not designed to test “”leaf” shutters, but it seemed to work quite well when used with shutters for large format lenses and when tried with some “golden oldies”, such as an Agfa Rangefinder model.

Testing is easier if the lens is removed from the camera, but it is possible to make accurate measurements with cameras that have fixed lenses. A large light source such as a window is then preferable. This minimizes any dark areas where there will be insufficient light to activate the sensor.

Results are best with the sensor positioned quite close to the shutter curtains, but great care must be taken to avoid getting the sensor in contact with any part of the shutter. These days the cost of having damaged shutters repaired is so high that the sums involved are higher than the value of the repaired cameras. Therefore, it is better to err on the side of caution and have a gap of several millimeters between the shutter and the sensor.

The best way of calibrating the unit is to use a recently manufactured or serviced camera as the calibration source. Set the timer to the 500-millisecond range and the camera for a shutter speed of 0·5 seconds (500 milliseconds).

Press Reset switch S2 to zero the meter, take a reading, and then adjust preset VR2 for precisely full-scale reading on the meter. In the absence of a suitably reliable camera, calibrate the unit on the five-second range using the camera set to “bulb” or “B”, and a stopwatch to help generate a five second shutter time.

The 0 to 50 scaling of the specified meter produces readings that are easily converted into shutter times, and it is not worthwhile doing any recalibration. Cameras use shutter times expressed as fractions of a second rather than in milliseconds, which slightly complicates matters. However, Table 1 shows the equivalent

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times in milliseconds for the standard shutter speeds.

IN USE

It is only fair to point out that the generally accepted camera standards allow for quite large margins of error, especially on the faster shutter speeds. An error of something like +50 percent is clearly not good, but it does not indicate a faulty shutter, just one having mediocre accuracy.

With older cameras do not be surprised if checking the same shutter setting produces a fairly wide range of times. Unless the variations are very wide this does not indicate that the shutter is faulty, but it does suggest that it is long overdue for cleaning and recalibration.

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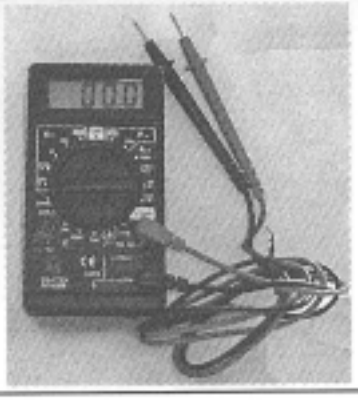

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Constructional Project

POCKET g-METER by BILL MOONEY

Uses a space-age chip to tell you how much g-force you are experiencing.

This portable accelerometer will tell you the g-force you experience when you break hard in your car, when you ride in a lift, or at the fairground. It is based on a tiny polysilicon micromachined sensor etched onto an integrated circuit. The earth's gravity is used as a reference standard.

As described, this is an experimental project designed as a simple introduction to the world of acceleration. The g-Meter output is in the form of a 10-segment bargraph type display, but for more accurate measurement or signal processing an output socket is provided.

ACCELEROMETERS

There are many ways of measuring acceleration involving various piezoelectric, resistive, or inductive devices, but the new micromachined silicon sensors represents a considerable advance. The ADXL105 from Analog Devices is of this type and

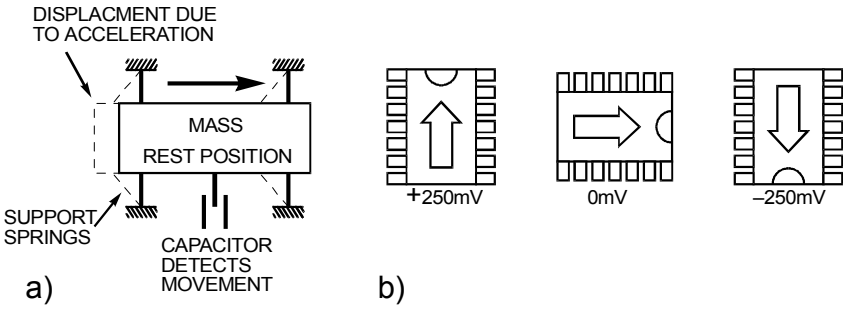

Fig.1. (a) Operating principle of the internal "beam" movement sensor and (b) influence of Earth's gravity.

the surface mount package contains all the driver circuitry to make a very effective accelerometer.

The sensor is a tiny, two micrometer, beam etched onto an integrated circuit along with the detector electronics. The sensor is, in fact, a beam of polysilicon held at four points by supports of the same material, see Fig.1a. The supports can flex and so act as springs.

Inertia resulting from the mass of the beam is the basis of the detection system. If the supporting integrated circuit is moved this mass tries to stay where it is. Any acceleration therefore causes the mass to move in proportion. On reaching constant velocity or if stationary, the beam returns to its rest position.

A small differential capacitor attached to the side of the beam is unbalanced by its displacement. This unbalance results in an on-board 200kHz clock signal reaching the

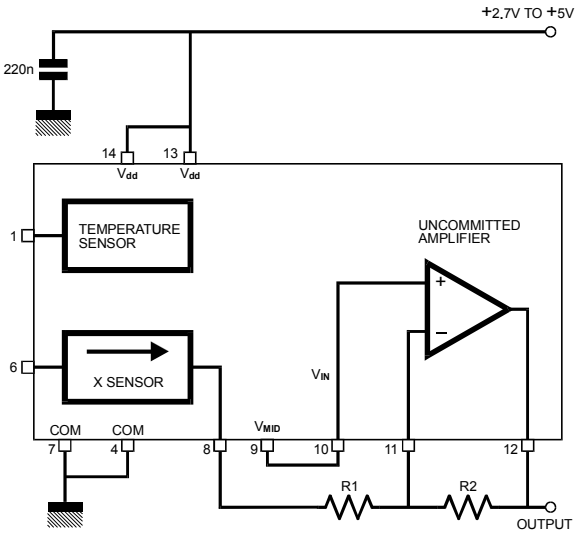

Fig.2. internal functional circuit of the ADXL105. Gain is set by values of external resistors R1 and R2.

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demodulator which produces an output voltage representing acceleration.

SENSITIVITY

Originally developed specially for space research projects, micromachined accelerometers are very tough and will withstand the huge acceleration experienced by rockets. The sensing beam has a mass of 0·1 microgram and its movement can be detected down to 0·2 angstroms or about a tenth of an atomic diameter. The beam displacement-sensing capacitor is a minute 0·1pF and a change of 1aF (1 ato farad is 10^{-18}F) can be detected; real space-age stuff! The ADXL105 accelerometers, as used in this project, can detect "g" down to a couple of milli-g at frequencies from DC to above 20kHz. A particular advantage for the g-Meter is the ease of calibration. Simply turn the chip on either end to detect +1g or –1g as it senses the earth's gravity. This is a very stable reference with a value of 9·80600 m.sec^{-2} at 45° latitude.

Devices like the ADXL105 can be used for tilt and inclination measurement as well as shock and vibration studies.

COMPONENTS

Resistors
- R1 100k
- R2 220k
- R3, R4 56k (2 off)
- R5 2k2

All surface mount devices (SMD), case size 1206

Potentiometer
- VR1 10k ceramic "knob pot" (linear)

Capacitors
- C1 200n ceramic chip, case size 1206
- C2 82n ceramic chip, case size 1206
- C3 100u tantalum, 4V

See also the SHOP TALK Page!

Semiconductors
- D1 to D9 3mm green LED (9 off)
- D10 3mm red LED
- IC1 ADXL105JQC (or AQC) micro-machined sensor (SMD)
- IC2 LM3914N linear bargraph LED driver

Miscellaneous
- S1, S2 s.p.d.t. miniature slide switches 15mm fixing center (2 off)
- SK1 phono socket, chassis mounting
- B1 3V battery pack (2 x AA cells with holder)

PCB available from the *EPE Online Store* at **www.epemag.com** (code 7000269); plastic box, size 75mm x 51mm x 28mm;

Approx. Cost Guidance Only ***(Excluding batts)*** **$56**

Multi-axis devices can be used to offset the effect of tilt, which appears as an acceleration to the sensor.

The ADXL105 single axis device was chosen for this simple project. The effect of the Earth's gravity on the output at pin 8 is shown in Fig.1b. The internal functional circuit for the IC is shown in Fig.2.

The signal from the detector has a magnitude of 250mV/g and is centered on the mid-rail voltage. An uncommitted on-board amplifier is provided for signal level adjustment and filtering. The gain is set by the selection of resistor R1 and R2 values and a variety of filtering options are possible by the addition of capacitors to the opamp feedback circuitry.

CIRCUIT DETAILS

The g-Meter is a simple experimental circuit intended to give an insight into the scope of acceleration measurement. It consists of an ADXL105 sensor directly coupled to a simple 10-segment light-emitting diode

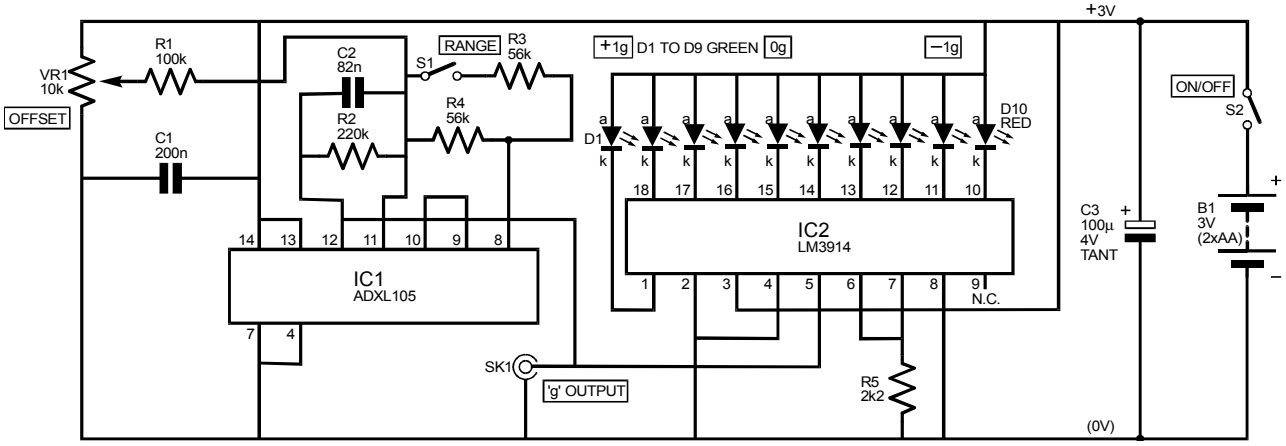

Fig.3. Complete circuit diagram for the Pocket g-Meter.

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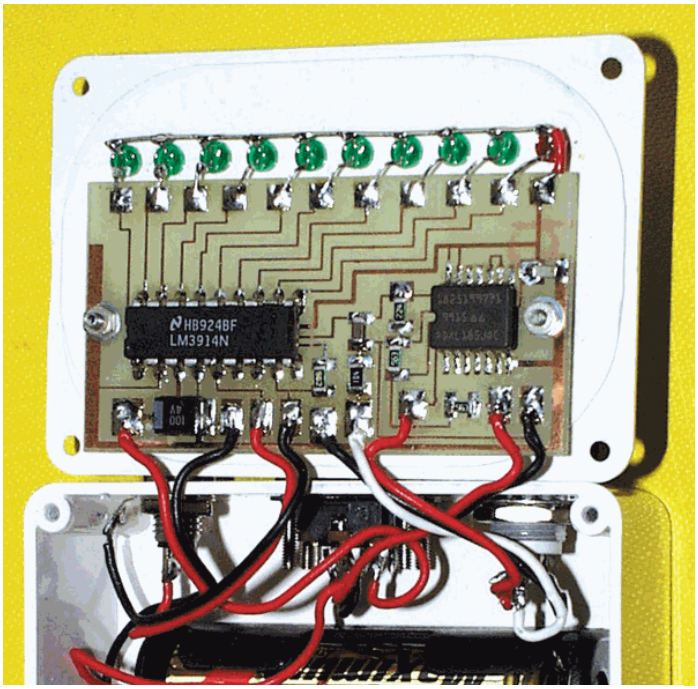


Larger-than-life view showing the tiny surface-mount components mounted on the PCB.

(LED) bargraph type display.

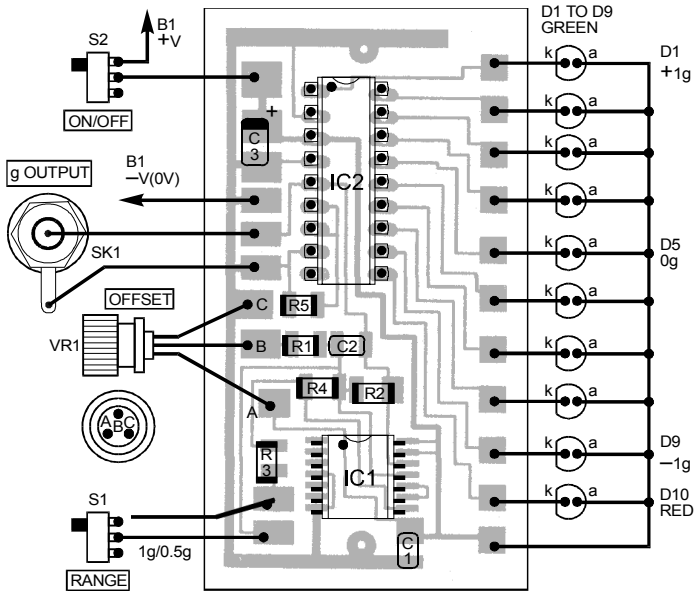
Both the LM3914 LED driver and the ADXL105 sensor will work down to 2·7V (unlike the now obsolete ADXL05 which needs 5V). The circuit can therefore be run from two AA cells.

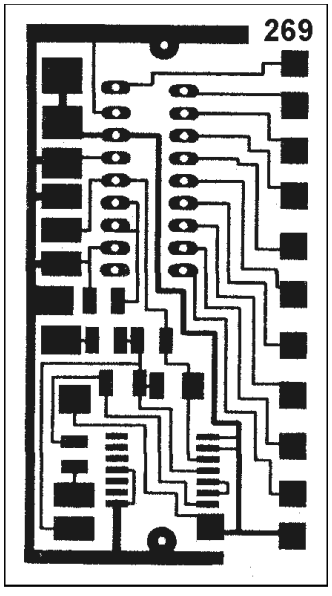
The full circuit diagram of the Pocket g-Meter is shown in Fig.3. The signal from the detector of IC1 appears at pin 8. This is coupled directly to the uncommitted amplifier which is wired for a gain of 4x or 8x corresponding to a 2g or 1g range, which is selectable by switch S1. A very rudimentary filter consisting of capacitor C2 limits the device to a frequency response of a few Hertz (Hz) to suit this application.

The LM3914 linear LED driver, IC2, is operated in dot mode for lowest current drain. It requires an input of 0V to 1·3V for full scale operation. Therefore, the mid-rail based output from the sensor must be offset as required.

Potentiometer VR1 allows the zero-g position to be conveniently placed at LED D1, D10 or D5 with the sensor chip in any orientation. This is a most useful feature of the design and makes the g-Meter a very versatile instrument. The amplified and filtered output is made available through phono socket SK1.

In the prototype, all LEDs





PCB DIMENSIONS: 37 x 67mm / 1.45 x 2.65 in

Fig.4. Printed circuit board component layout, interwiring and (approximately) full-size underside copper foil master. Note that IC2 is also soldered to the topside tracks of this surface-mount hybrid board.

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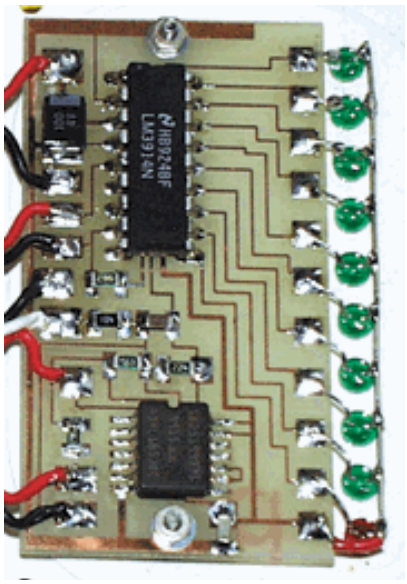


Finished circuit board bolted to the rear of the case kid.

are green except D10, which is red. This allows D5 to be set as zero g with four equal steps above and below this point. This LED also behaves differently in that higher voltage inputs leave it on so it acts as a useful indicator. Resistor R5 controls the LED brightness and can be changed at the expense of battery life.

CONSTRUCTION

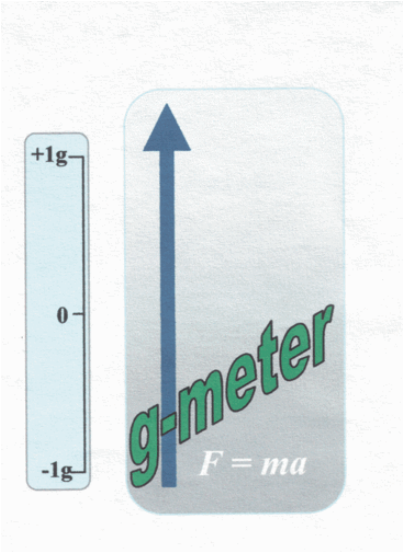
This project is a hybrid circuit in that the LM3914 LED driver, IC2, is a "standard" dual-in-line (DIL) format device. This is soldered on the upper copper track side of the printed circuit board (PCB) just like the surface mount devices. About half of the components fit on a single-sided printed circuit board (PCB).

The component layout on the surface mount circuit board (copper pads topside), together with the interwiring and (approximately) full size copper foil master, is shown in Fig.4. This PCB is available from the *EPE Online Store* (code 7000269) at **www.epemag.com**. If you are producing your own PCB, remember that track and components are on the same side so there is no need for the usual mask inversions.

The layout of the whole instrument is designed to cater for the "sense" of movement. So that a forward movement of the g-Meter, as you look at it, results in successive LEDs lighting up in the direction of movement, see photographs. Because of the inversion of the signal by the uncommitted amplifier in IC1, this means that LED D10 lights first, reaching D1 at maximum acceleration in this direction.

Similarly, the Offset potentiometer VR1 is wired so that a clockwise rotation "pushes" the lit LED towards D1. Thus the whole instrument is intuitive in operation.

The LED driver IC1 should be soldered in last because its pins protrude through the PCB and the board will not rest flat on the work surface. This would get in the way of the surface mount soldering process making it



Completed g-Meter showing the side-mounted components.

even more awkward in "positioning" these components.

Placing the chip components is just a matter of soldering one end first whilst holding it in place with tweezers. The free end can then be soldered with ease.

Aim to use minimal solder. This is not just to make the project look neat but results in a more flexible connection and less stress is transferred to the chip. This is particularly important for the higher value ceramic chip capacitors like C1 and C2, which are a little more delicate.

CASE PREPARATION

Before mounting the LEDs on the PCB and bolting the board to the lid of the case, the two halves of the project box should be prepared. Taking the bottom half, one side panel of the case should be carefully marked and drilled to take the phono socket SK1, the two slider switches and the miniature potentiometer VR1.

The two slide switches will need careful attention and the rectangular cutouts should be made first. The best way to do

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this is to mark the cutout for the lower switch, on the outside of the case, with a pencil or Biro and drill holes in the four corners, fractionally inside the marks.

Next, drill a series of holes along the guide marks to join up with the corner ones. The edges of the resulting cutout should be smoothed down with a fine file.

Now offer up the switch to the cutout so that the slider knob protrudes into the case from the outside. Mark the two fixing hole positions, remove the switch and drill the holes.

Repeat the procedure for the other switch and mount them in the case together with the other off-board components. You can, if you wish, solder leads on these components at this stage for later wiring to the PCB. If you do, make the leads sufficiently long enough to allow the lid of the case to be fully opened for battery changing.

Having completed this operation, the lower half of the box can be put to one side for later. Now for the case lid and final assembly.

FINAL ASSEMBLY

In the prototype, the 3mm LEDs protrude through 3mm holes in the lid of the project box. A sharp drill and a little skill should produce a push fit and no glue will be needed. Take care to drill the LED holes evenly spaced (6mm between centers) and in as straight a line as possible for best visual effect.

All the anode (a) leads are connected to the positive voltage line by a short length of stripped solid-core connecting wire. This is connected to the last copper pad in the line of LED connections, as indicated in Fig.4.

All the off-board controls and output socket SK1 are wired up using fine futaba wire as used for model control/servo work. It has a very flexible multistrand core and comes as a 3-way ribbon. You can, of course, use standard multistrand wire if you wish.

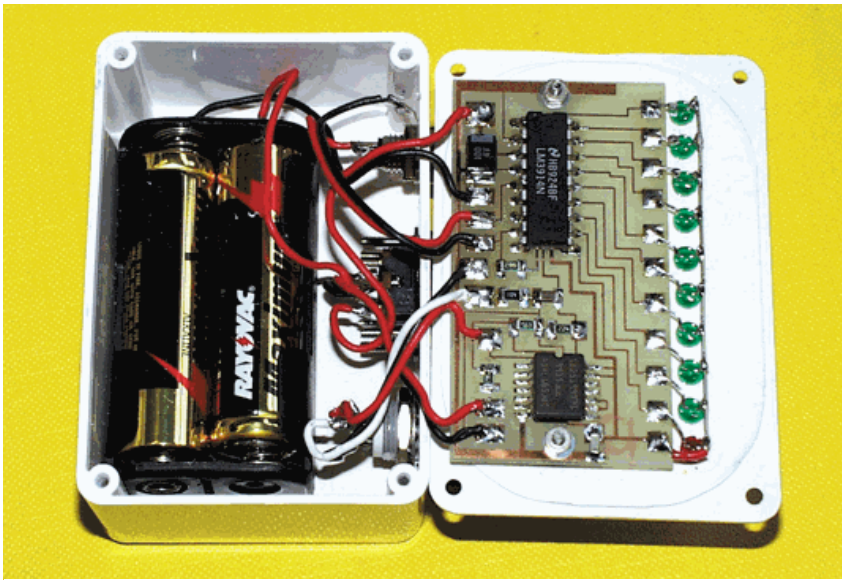
The cathode (k) lead of each LED (D1 to D10) is bent over to reach the appropriate copper pad on the PCB and soldered in place. This method is less critical than mounting the LEDs directly on the PCB.

There is little room for misalignment of the surface mount ADXL105 sensor IC as the pads are quite small, but the axis should be lined up as accurately as possible with the long axis of the PCB. The circuit board is held in place with two 2mm countersunk bolts, with extra nuts to form spacers between case lid and PCB.

For extended frequency application and if the ADXL105 were to be pushed to its full potential the mounting method would need further consideration. But the method shown is perfectly satisfactory for this low frequency application.

Finally, the LM3914 is added and its pins are soldered on the topside of the board along with the SM chips. This is perfectly in order for the DIL package which is frequently used on double-sided circuits. It is worthwhile removing the protruding leads from the reverse side of the board with a side cutter.

Returning now to the bottom half of the box, the off-board components should now be wired to the lid-mounted PCB. Give the board and wiring a final check and screw the two halves



Interwiring to the off-board components. Note the "common" connection to the LED anodes and the careful positioning of the battery holder.

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of the box together. All that remains is to produce a paper/card "scale" similar to the one shown in the photographs and the unit is ready for use.

CALIBRATION

The g-Meter does not require calibration and setting it up is just a matter of checking the current consumption and adjusting the Off-set control VR1 to get the active LED on scale. The drain current should be about 5mA with no LEDs alight and about 10mA with a LED on.

A few initial checks using gravity as a reference will be worthwhile to show correct operation and demonstrate how the scale can be used.

FEEL THE FORCE

First set the range to ±1g. Then hold the g-Meter flat or rest it on a horizontal surface and, using the Offset control, adjust the position of the "on" l.e.d. to the mid position. If D5 is used as the 0g position this gives four steps to +1g and four steps to –1g.

Now turn the g-Meter to the vertical position with the arrow pointing upwards. The internal ADXL105 IC1 is now on end with pin 1 uppermost. The indicator LED should travel up the scale to the +1g position stopping with LED D1 active. This is now registering the force of gravity. Standing the device on the other end, reversing the arrow direction should result in a –1g indication.

If the offset is adjusted to indicate –1g with the g-Meter horizontal it will now cover the range of 0g to +2g. As a check, stand it on end and the active LED should reach mid-scale, which now means +1g.

Setting the range switch to the ±0·5g will drive the indicator off-scale with the meter on either end. This range can be checked by setting the indicator to –1g, LED D10 in the horizontal orientation. Then by turning the meter end-on the indicator should travel full scale to D1 covering a range of 0g to 1g.

By such manipulation a variety of operating modes can be set to suit a particular type of measurement.

A few simple experiments can now be performed. Set the range to 0 to 2g and hold the box tightly in the vertical orientation whilst jumping on the spot. A small jump will generate +0·75 to 2g. A big jump may drive the meter off scale.

But an indication of the g-force can still be gleaned from this versatile device. Simply hold it at about 60 degrees to the vertical and after resetting the off-set to the position marked –1g (LED10) you now have at a range of about 0 to 4g. Can you drive your body skyward at 4g?

Whilst sitting on a swivel chair swing around in an arc with the meter held horizontal and pointing along the radius of movement. Which way does the g-force register and why?

Monitoring the accelerations experienced during driving is revealing. A slight easing of the foot from the accelerator pedal results in surprisingly rapid deceleration due to engine breaking. Hard breaking, rapid take-off from traffic lights and excursions over hump-back bridges also produce interesting g-forces.

Too much of this in-car work can result in unwanted large deceleration so be careful or get a chauffeur. A safer way to experience smooth acceleration is by travelling in lifts but here again there can be arresting dangers. Fairgrounds also generate a wide range of acceleration experiences.

WHAT IS "g"

Before all this is understood, it is necessary to explain speed and velocity. Speed is simply the average velocity over a journey and is not very useful in physics. Velocity describes the rate at which distance is covered with time and is measured in meters per second.

Velocity is always in a straight line. Any change in velocity is achieved by applying a force to the body when it will slow down or speed up, i.e. will decelerate or accelerate. So acceleration is the rate of change in velocity, and as the units of velocity are meters per second, then acceleration is meters per second per second or m. sec^{-2}

To understand "g" we need to invoke Newton who discovered that any two masses, like you and the earth for example, experience a force of attraction called gravity. At the earth's surface this force is the same as you would feel if you were accelerated at 9·81metres sec^{-2} and is therefore given its special title of 1g.

Although acceleration is measured and mostly quoted in meters per sec^{-2} in many cases it is more meaningful to quote it in g. Acceleration (a), force (F) and mass (m) are all tied together in Newton's apparently simple relationship:

$$F = ma$$

With this we can calculate the acceleration which will be produced by the application of a particular force. A good example

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is a falling apple. It weighs about 100g (its mass, m) and whilst it drops from the tree it will accelerate at 1g or 9·81m. sec^{-2} (a) so that the force (F) on the apple is obtained by multiplying its mass by its acceleration.

To get the units correct the mass is measured in kilograms, in this case 0·1kg. So that the force is 0·1 x 9·81 which gives F as 9·81kg.m. sec^{-2} and this happens to be about 1 Newton of force.

To sum up, it is acceleration coupled with mass that is meaningful to us as this describes the force we feel. A jumping flea can generate huge acceleration without problems whereas the same acceleration would be very uncomfortable for a human.

The ADXL105 is used for earthquake detection, in particular for automatic gas cut-off. It will register vibrations very effectively and looking at the output on an oscilloscope can be very informative. Wooden floors are not as solid as they feel, but lets hope you don't get a chance to register an earthquake.

The g-Meter, used for tilt detection will quickly show just how effective even a low cost spirit level can be. It is surprising what can be done with this single axis detector and it shows how useful a multi-axis device might be.

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Constructional Project

PIC-GEN FREQUENCY GENERATOR/ COUNTER

by JOHN BECKER

Add even more versatility to your workshop facilities.

Combining the sophisticated features of a Maxim MAX038 waveform generator and a PIC16F877 microcontroller has resulted in a highly versatile and inexpensive workshop tool whose facilities have hitherto been unattainable without considerable design complexity.

The MAX038 is a high-frequency precision function generator whose output is selectable to produce triangle, sine and square waveforms, within a wide operating frequency span of 0·1Hz to over 10MHz, split in the PIC-Gen as eight overlapping frequency ranges. Range and waveform selection are performed by the PIC16F877 in response to pushbutton switch controls. Frequency is fully variable within the selected range by means of a front panel control potentiometer.

An alphanumeric liquid crystal module displays the frequency and range information.

Four frequency outputs are provided:

- o) Direct output at ±1V peak-to-peak
- o) AC coupled output, fully variable between zero and 4V peak-to-peak
- o) Pulse output, 0V to 5V logic level
- o) 3·2768MHz fixed frequency, 0V to 5V logic level

The PIC is also used as a frequency counter, switch selectable to monitor the frequency generated by the MAX038, or from an external source in conjunction with a pre-conditioning waveform shaper and frequency divider. Two external signal inputs are provided: one for 0V to 5V logic level waveforms, the other for AC waveforms having a peak-to-peak swing of between about 2V to 5V. The prototype can monitor frequencies in excess of 40MHz.

MAX038 FUNCTION GENERATOR

In *EPE* September '96, Andy Flind first introduced readers to the merits of the then newly introduced MAX038 waveform generator, in a special feature article of the same name. He followed it up with a full constructional article, the *10MHz Function Generator*, in October '96.

Prior to the introduction of the MAX038, arguably the main contender for the most widely used function generator was the 8038, manufactured by various companies under different prefix codings, such as ICL8038 and XR8038, for instance.

The 8038 is still widely used but it has limitations in the maximum frequency that can be generated. The range is typically 0·001Hz to 100kHz.

The MAX038, however, is stated to have an upper frequency limit of at least 20MHz, and possibly around 40MHz. It has to be said, though, that attaining such high frequencies requires printed circuit board design and construction techniques normally found only in commercial manufacturing establishments.

The upper frequency limit of the device is dependent not only on very accurate control of the current flowing into its frequency setting inputs, but also on the capacitance associated with them. Maxim state in their data sheet, for instance, that the

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specified upper frequency limit is achieved when the timing capacitance is less than or equal to 15pF and the control current is 500uA.

Unfortunately, on a PCB designed for successful assembly by the average hobbyist, the capacitance between the MAX038, other components and the tracks is likely to prevent the maximum frequency from being reached. The prototype PIC-Gen described here achieves a maximum of just over 10MHz.

PIC-GEN CONCEPT

Considering how the MAX038 might be put under semi-automatic control as part of a frequency generator and counter system, the author recognized that a PIC16F877 microcontroller might provide the key. This device has five input-output ports which, it seemed, could possibly provide automated switching of the frequency range capacitors, selection of the waveform shape, offer frequency counting and provide an output to a liquid crystal display.

Doing a basic mock-up on stripboard coupled to a PIC roughly programmed to perform the bare essentials proved the viability of the idea. The concept was then given full flesh and bones to become the design whose circuit diagram is given in Fig.1.

The MAX038 function generator is shown as IC2. It will be seen that half the pins are grounded and from some of their notations it will probably be (correctly) deduced that the device has more functions than are used here. For information about the device's full range of functions, see its data sheet (details later) or Andy Flind's Sept/Oct '96 articles.

In the PIC-Gen design, the controls used are those that set frequency and waveform shape. The eight frequency ranges are set according to the capacitance value connected to the device's C OSC pin. Fine tuning of the frequency is performed by varying the current provided by potentiometer VR1 to the I IN pin.

Resistor R2 limits the maximum current that can flow, while R1 sets the minimum current.

FREQUENCY SELECTION

Eight capacitors are used to set the frequency ranges, C11 to C18. These are commonly connected at one end to the C OSC pin (5). Capacitors C12 to C18 have their other ends connected individually to port pins of the PIC microcontroller, IC5. For PCB layout convenience these pins were chosen to be RB1 to RB5, RD6 and RD7. Capacitor C11 is permanently connected to the 0V line.

Normally, the above seven pins are set as inputs to the PIC. In this condition, they are effectively held in an open-circuit state, the PIC inputs having a very high impedance. As such, the MAX038 ignores those capacitors.

To bring one of the seven port controlled capacitors into circuit, the PIC has the appropriate pin set as an output held at logic 0 (0V). With a higher capacitance value selected, so the lower the output frequency from IC2.

For the highest frequency range, capacitor C11 is the controlling component. Note, though, that its nominal value of 10pF will be seen by the MAX038 as a value higher than this due to the (unpredictable) capacitance of the circuit in proximity to the C OSC pin. Capacitor C11 could be omitted if you want to try increasing the maximum frequency attainable.

Pushbutton switches S1 and S2 cause the PIC to step the frequency range down or up (respectively) on a continuous 8-step loop.

Nominally, the capacitor values have been chosen to provide a factor of ten difference between each step. Normal manufacturing tolerances apply to these values, especially with the electrolytic capacitors.

Potentiometer VR1 provides a frequency control range of about 1 to 50. For example, if the minimum current flow through VR1 and R2 causes a frequency of 1kHz, then maximum current flow will cause 50kHz to be generated. The range may be shortened by increasing the value of R1, although this will raise the lowest frequency that can be attained.

WAVEFORM SELECTION

PIC-Gen provides selection of three waveform shapes, Sine, Triangle and Square.

Selection is made according to the binary code placed on the MAX038's A0 and A1 inputs. The code is controlled by the PIC, via its RB6 and RB7 pins, as follows:

A1	A0	WAVEFORM
0	0	Square
0	1	Triangle
1	x	Sine

where x = don't care

Pushbutton switch S4 causes the PIC to step through the three waveform codes on a repeating

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Typical LCD display showing that a square wave is being generated and that a frequency count of 3,706,286Hz has been read on range 7 during the normal 1-second sampling period.

cycle.

The selected waveform is output at IC2 pin OUT and has a fixed amplitude of ±1V, symmetrical about 0V. The output has a very low impedance (typically 0·1Ω) and can be used directly via socket SK5.

The same waveform is amplified by the non-inverting opamp circuit around IC3a. The gain is set at x2, resulting in an output swing of ±2V. Capacitor C3 provides DC isolation of the output and potentiometer VR2 provides full control over the amplitude output at socket SK3, from zero to maximum.

It should be noted that the TL082 used as IC3a does not permit the full frequency rage of the MAX038 to be amplified and output. In the prototype, a maximum of about 1MHz is experienced, after which the amplitude progressively falls. Other opamps which have higher frequency capabilities are available but no recommendation is offered on this point.

Readers should be aware that whilst some opamps may seem to offer very high frequency capabilities according their data sheets, other factors (also quoted) can affect the range and must be taken into account.

FREQUENCY COUNTER

Whilst a PIC can be programmed to act as a frequency counter simply by monitoring one input pin, the maximum frequency that can be monitored by this method is severely limited. To enable very high frequency signals to be counted by the PIC-Gen, a pre-counter is used and the output from that is monitored at regular, but slower intervals.

The pre-counter is IC6, a 74HC4040 12-stage ripple counter. Its outputs are fed into PIC pins RC0 to RC7 and RD0 to RD3. It will be seen in Fig.1 that the PIC's pin order use relative to the output pin order of the counter does not match. This is intentional to simplify the PCB design, allowing software to interpret the input values as correct binary numbers.

Note that IC6's Q12 output is the final one in its counting sequence. This changes state at 1/4096 of the input frequency and even at high input rates the PIC is able to monitor this pin. Each time the pin changes state, the PIC registers the fact and increments an internal counter.

At regular intervals, selectable for one or ten seconds by switch S3 (Sample Time), the full 12-pin sequence of IC6's outputs is read and a frequency value calculated according to this value and that of the internal counter. Once the reading has been taken, the internal and IC6 counters are reset (the latter via PIC pin RD4) prior to the next batch of counting.

Frequencies in excess of 40MHz have been recorded on the author's prototype.

FREQUENCY INPUT

There are three sources from which the signal to be counted can be input, as described presently. All three finally arrive at counter IC6 via the Schmitt trigger NAND gate IC7a. Immediately prior to reading the contents of IC6, the PIC sets pin RD5 low, so turning off gate IC7a and preventing further input signals from

PIC-Gen front panel. The waveform button is bottom far right. The switch marked "pulse" (top right) is the on/off switch in the final model.

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reaching the counter. This allows the ripple-nature of the counter to stabilize (ripple through) at the correct count value. Software introduces a slight delay between closing the gate and taking the reading.

Logic level signals (nominally 0V to 5V) are input to the PIC-Gen via socket SK1 (Logic Input), switch S5 selecting their routing to gate IC7a and the counter. Signals having other voltage ranges, either above or below the 0V/5V range should not be input to socket SK1. Those having lesser swings may not trigger gate IC7a, those having swings greater than about 6V could kill it.

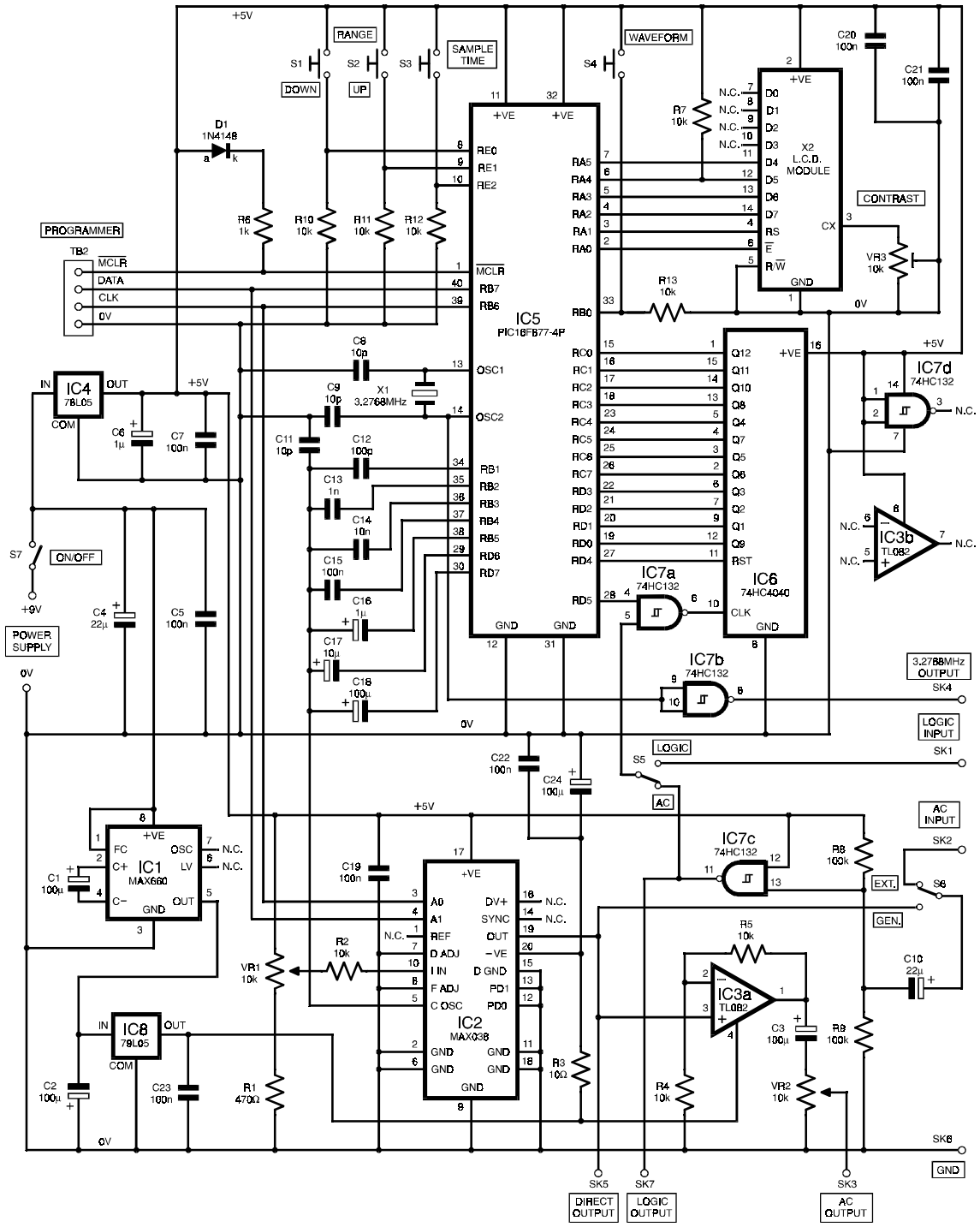

Fig.1. Full circuit diagram for the PIC-Gen Frequency generator and Counter.

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Signals which are analog or digital and have a swing range less than 5V, but greater than about 2V to 2·5V, are input via socket SK2 (AC Input). Switch S6 selects their routing to the pre-conditioning circuit around IC7c. This is another Schmitt trigger NAND gate, having one input (pin 13) held biassed at a mid-power line level (2·5V) by the potential divider formed by resistors R8 and R9. The other input (pin 12) is held at +5V.

The input signal is AC coupled via C10 to the biased input of the gate. Providing the input signal's peak-to-peak range is greater than the gate's hysteresis value (which varies slightly between individual devices), so the gate will be triggered.

The output of this gate is also fed to switch S5, which routes it to the counter via IC7a when selected.

Because the main output signal from the MAX038 has a peak-to-peak swing of ±1V, it too has to be pre-conditioned via IC7c before its frequency can be counted, the routing also being selected by switches S6 and S5, respectively.

LOGIC OUTPUT

The output from IC7c is additionally fed to socket SK7 allowing, for example, the frequency generated by the MAX038 to be used as a 5V square wave (irrespective of which waveform is being generated), or for the a.c. signal to be converted to 5V pulses (whose width depends on the nature of the signal).

Whilst the MAX038 has its own 5V square wave available at the SYNC pin (when pin +DV is held high), it was found that instability occurred when this was generated (as cautioned in Maxim's data sheet). Consequently, the option to use this output has been dropped from the published PIC-Gen (although the connection tracks on the PCB have been retained).

This display shows a sine wave is being generated and a frequency of 25,124Hz has been registered via range 4.

3·2768MHz OUTPUT

The PIC is run at a frequency of 3·2768MHz, as set by crystal X1. Although this frequency can be tapped directly from PIC pin OSC2, it was deemed better to buffer it via gate IC7b before releasing it to the outside world through socket SK4. The output is a 5V square wave.

DISPLAY MODULE

As is common with so many recent *EPE Online* PIC projects, an alphanumeric liquid crystal display (LCD) is used. This shows the frequency count and sampling rate, plus the generated waveform selected and its frequency range (as a number between 0 and 7, where 0 is the lower frequency range). The information displayed takes a form similar to:

SINE 25124Hz

Range4 Time1 sec

where:

- o) Line 1 left: waveform selected (sine, triangle or square).
- o) Line 1 mid/right: frequency value.
- o) Line 2 left: frequency range selected (8 choices).
- o) Line 2 mid/right: sampling range selected (2 choices).

The LCD is shown as X2 in Fig.1. It is under standard 4-bit control, but whereas many PIC projects control it via PIC Port B, here it is controlled via Port A (RA0 to RA5). Apart from the change of PIC port register number, the software routine that drives the LCD is the author's usual "library" routine.

It is worth noting, though, that because Port A RA4 is an open-collector pin, resistor R7 has to be used to bias it high in order to correctly control LCD pin D5.

The LCD screen contrast is adjustable by preset VR3.

POWER SUPPLY

It is intended that the PIC-Gen should be powered at 9V, either from a 9V battery or a 9V mains power supply (in fact, input supply voltages between about 7V and 12V are acceptable). Regulator IC5 drops and stabilizes the input supply at 5V. This powers IC3, IC5 to IC7, and the LCD. These devices must not be powered

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COMPONENTS

See also the SHOP TALK Page!

Resistors
R1 470 ohms
R2, R4, R5, R7, R10 to R13 10k (8 off)
R3 10 ohms
R6 1k
R8, R9 100k (2 off)

Potentiometers
VR1 10k panel mounting rotary or multi-turn linear (see text)
VR2 10k panel mounting rotary lin.
VR3 10k miniature preset, round

Capacitors
C1 to C3, C18 to C24 100u radial electrolytic, 16V (5 off)
C4, C10 22u radial electrolytic, 10V (2 off)
C5, C7, C15, C19 to C23 100n ceramic disk, 5mm pitch (8 off)
C6, C16 1u radial electrolytic, 10V (2 off)
C8, C9, C11 10p ceramic disk, 5mm pitch (3 off)
C12 100p ceramic disk, 5mm pitch
C13 1n ceramic disk, 5mm pitch
C14 10n ceramic disk, 5mm pitch
C17 10u radial electrolytic, 10V

Semiconductors
D1 1N4148 signal diode
IC1 MAX660 DC-to-DC converter
IC2 MAX038 function generator
IC3 TL082 dual opamp
IC4 78L05 +5V voltage regulator
IC5 PIC16F877-4P microcontroller (pre-programmed -- see text)
IC6 74HC4040 12-stage binary ripple counter
IC7 74HC132 quad dual-input Schmitt NAND gate
IC8 79L05 -5V voltage regulator

Miscellaneous
S1 to S4 s.p. push-to-make switch (4 off)
S5 to S7 s.p.d.t. miniature toggle switch (3 off)
X1 3.2768MHz crystal
X2 2-line 16-character (per line) LCD module (see text)

PCB available from the *EPE Online Store* (code 7000268) at **www.epemag.com**.
knob (2 off); 8-pin DIL socket (2 off); 14-pin DIL socket; 16-pin DIL socket; 20-pin DIL socket; 40-pin DIL socket; 1mm pin header strips (see text); 1mm terminal pins;
2mm socket (7 off, various colors) (or sockets to suit other equipment); plastic case,
205mm x 108mm x 57mm; plastic feet for case (4 off); PCB mounting supports (4 off); PP3 battery and clip, or socket to suit external power supply (see text);

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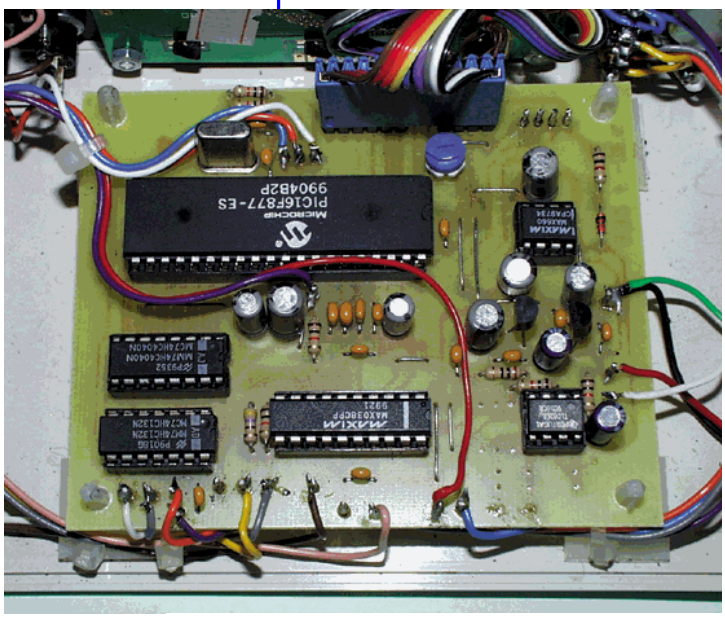

Completed prototype PCB. Differs slightly from final model.

within the PIC-Gen circuit at any other voltages (normal power supply tolerances apply).

The 5V supply is also used by the MAX038, but this device additionally requires a supply of –5V. A double-staged circuit is used for this purpose, based around IC1 and IC8.

IC1 is a MAX660 voltage converter, used here to generate a negative voltage of the same (inverse) magnitude as the voltage at which it is powered. In this instance, the 9V supply is inverted to become –9V.

The MAX660 has a much greater output load capability than the more familiar ICL7660 (and similar) devices, typically about 100mA as compared with 20mA. ONLY the MAX660 should be used in the PIC-Gen.

It had been expected that the MAX660 could have been powered by the 5V regulated supply from IC4, producing –5V as a result. However, the first test model of the PIC-Gen showed significant instability in the frequency generated when this method was used. Investigation showed that the ripple frequency output by the MAX660 could not be dampened sufficiently to prevent it from modulating the MAX038 frequency output.

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Consequently, it was found necessary to first generate –9V and then to regulate and stabilize it down to –5V using IC8, a negative voltage regulator. Further smoothing is given by the use of resistor R3 and capacitors C23 and C24.

A small instability remains, believed to be due to the MAX066's square wave oscillator radiating into other parts of the circuit (an oscilloscope probe on a range of 10mV just picks up the signal when held near to the device). The instability is principally noticeable at higher MAX038 frequencies.

PROGRAMMING CONNECTIONS

As is customary with the author's recent PIC projects, the PIC device used in this circuit can be programmed in-situ on the printed circuit board. The usual four connections are provided, ~MCLR (Vpp), DATA, CLK, and 0V, accessible via connector TB2, whose connections are in the same now-familiar order. Diode D1 and resistor R6 are part of the required control configuration. The *EPE PIC Toolkit Mk2* (May/June '99) is an ideal programmer to use.

MISCELLANY

Resistors R10 to R13 are pull-down resistors to appropriately bias the respective PIC input pins when switches S1 to S4 are not pressed. NAND gate IC7d has its inputs biassed to a power line (+5V in this case) as is required for unused CMOS gates. Opamp IC3b had been intended for use as an external analog input amplifier, but it was decided that the configuration around IC7c provided cleaner signal control, and at a far higher frequency.

If users need to frequency-count signals having a peak-to-peak value less than about 2V, they should pre-amplify them first.

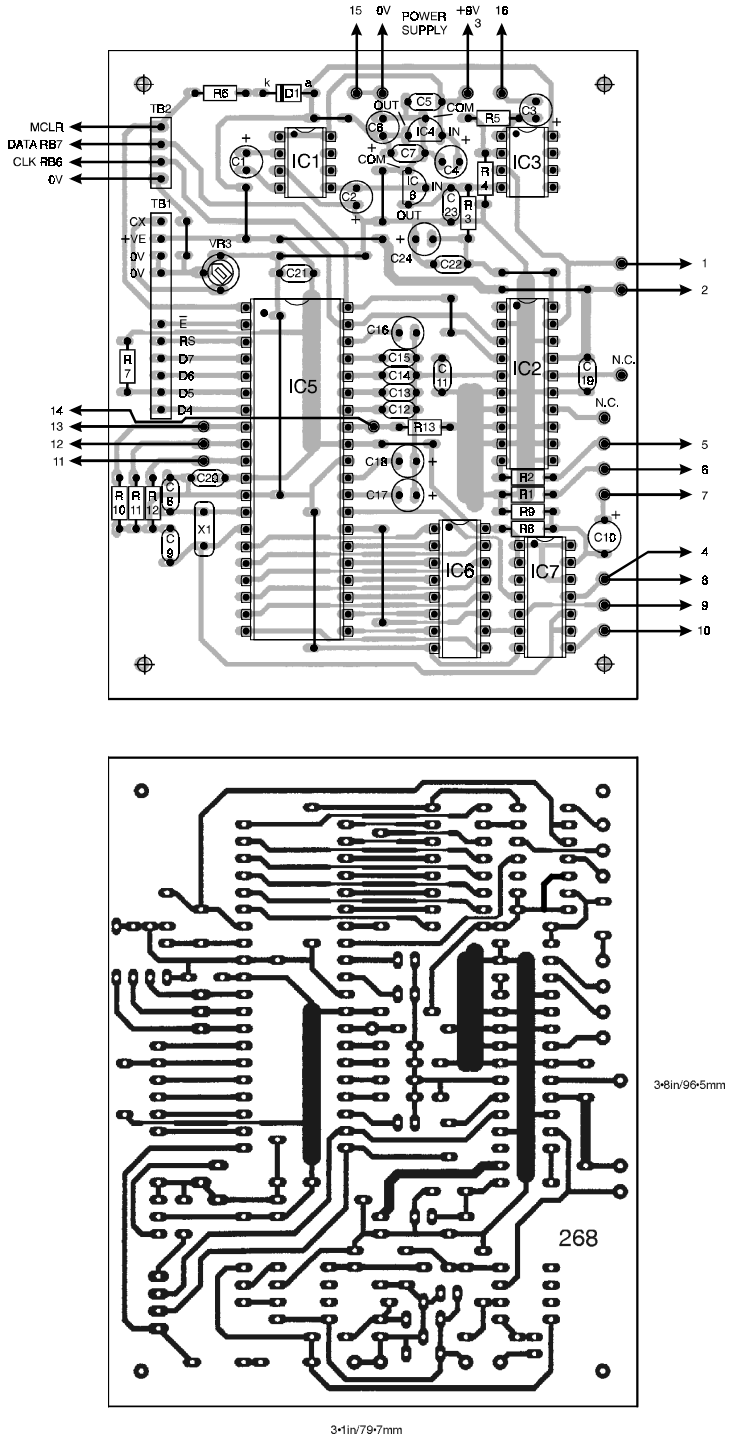

Fig.2. PIC-Gen PCB component layout and (approximately) full-size copper foil master pattern. The numbers at the ends of the lead-off wires should terminate at identical points on the front panel (Fig.3).

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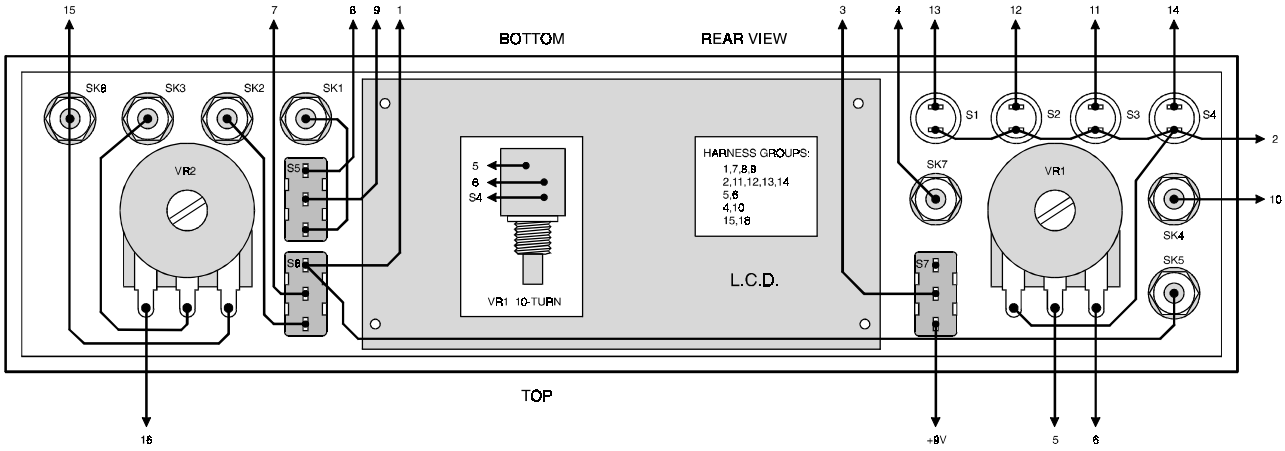


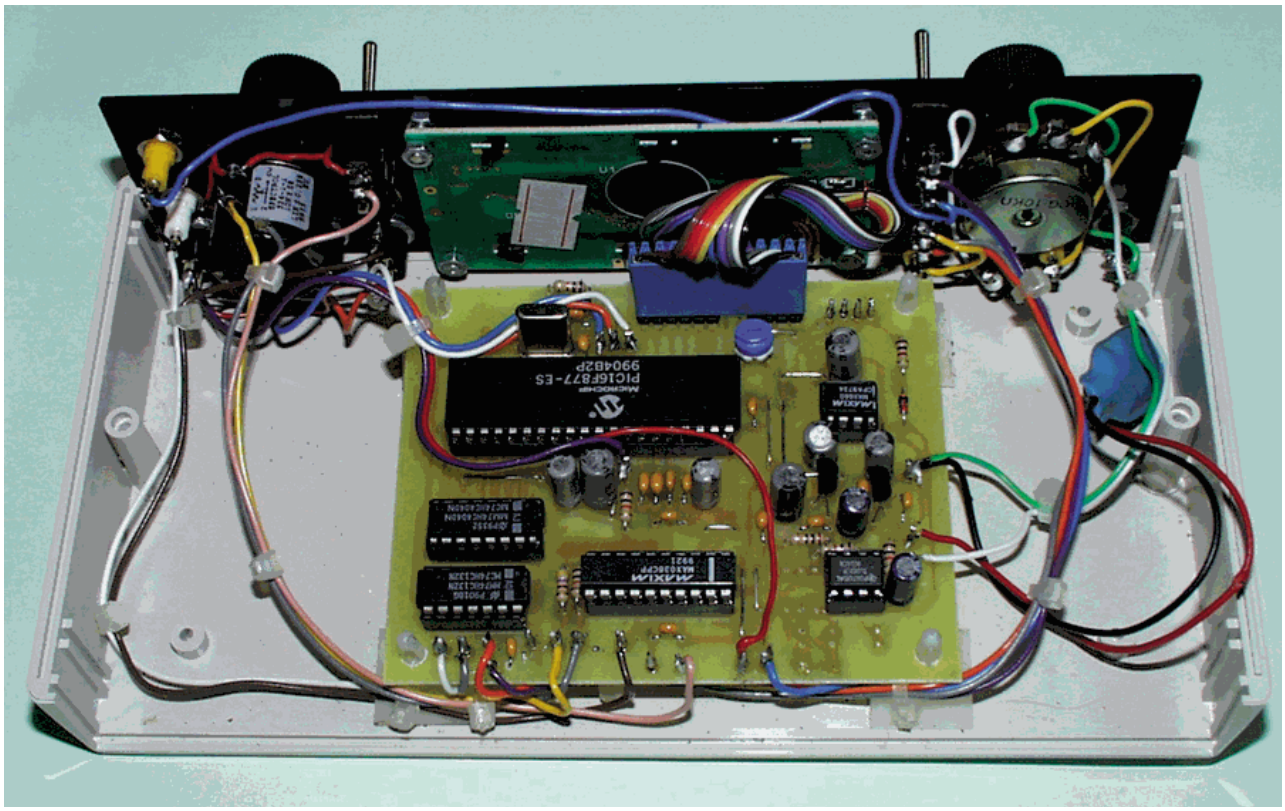
Fig.3. Layout and wiring to the front panel (full size) mounted components. The inset panels show wiring to a multiturn pot and suggested wire groupings.

Only the HC versions of IC6 and IC7 should be used (74HC4040 and 74HC132). These are typically capable of handling signals in excess of 40MHz. The "standard" CMOS 4040 counter is far too slow to be usable in this circuit. The use of a 74LS132 should allow lesser amplitude external signals to be input to the frequency counter, typically having a peak-to-peak swing of about 0·8V, although this has not been tried.

Numerous smoothing capacitors are used throughout the circuit at strategic points on the PCB.

CONSTRUCTION

Details of the component and track layouts for the PIC-



Layout of components and wiring inside the case of the completed prototype PIC-Gen. There are very minor differences between this and the final wiring diagrams. Note the various wiring "looms".

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Gen PCB are shown in Fig.2. This board is available from the *EPE Online Store* (code 7000268) at **www.epemag.com**

The author's preferred assembly is in order of link wires (some go under IC positions), IC sockets, resistors, diode, small capacitors, and remaining components in ascending order of size. Do not insert the DIL (dual-in-line) ICs at this stage.

Ensure that all polarized components are orientated as shown in Fig.2.

Pin-header strips were used for terminal groups TB1 and TB2. The order of these connections is identical to that used in the author's recent PIC projects. Details of the source for the LCD module complete with matching connector are given on this month's *Shoptalk* page.

The prototype PIC-Gen is housed in a plastic case measuring 205mm x 108mm x 57mm. The layout and interwiring of the off-board components on the rear of the case's front panel are shown in Fig.3. The illustration is to scale. (Note that the photographs show slightly different panel wiring to that in Fig.3.)

A choice of frequency control potentiometer is offered. The illustration in Fig.3 shows the connections for VR1 as a standard single-turn carbon rotary potentiometer. The inset shows the typical connections for a multiturn (10-turn in the prototype) wirewound potentiometer.

The standard pot is the least expensive choice but does not allow the same degree of frequency setting precision as the more-expensive multiturn pot.

To minimize the possibility of signals interacting with each other through the interwiring, several "harness" groups were used, keeping potentially interactive signal paths apart as seemed reasonable. The groups can be seen in the photograph, and they are itemized by connection number in the second insert of Fig.3.

Several cable ties are used to keep each group separately harnessed.

When the sampling rate change switch is pressed, the word "counting" is displayed until the first new count has been completed. In this instance a 10-second sampling rate has been selected.

Table 1: PIC16F877 configuration bits.

CP1	CP0	DBG	NIL	WRT	CPD	LVP	BOR	CP1	CP0	POR	WDT	OS1	OS0
1	1	1	1	1	1	0	0	1	1	0	0	0	1

CHECK-OUT

During the checking-out of the circuit, power should always be switched off before inserting ICs or making other alterations. Switch off immediately if the circuit does not behave as expected, rechecking your assembly for errors.

Assuming that you have thoroughly checked that you have not made assembly or soldering errors, the first check should be with the LCD and all ICs omitted except the two regulators IC4 and IC8.

With power applied, check that +5V is present at the output of IC4 and at strategic points around the PCB (referring to both Fig.1 and Fig.2).

Insert the negative voltage converter IC1 and check that a negative voltage equivalent to the applied power supply is present at it's output (i.e. –9V for a +9V supply). Check that –5V is present at the output of regulator IC8 and at the pin 20 position of the socket for IC2.

If all is satisfactory, the remaining ICs and the LCD can be inserted. Only one LCD line will be active until the PIC is running. Adjust preset VR3 until the active pixels are seen as slightly darkened rectangles, or the displayed text is clearly visible if the PIC is running.

If not already programmed, the PIC can have its program downloaded to it on the PIC-Gen board from a suitable PIC programmer, connecting the programmer via pin header TB2.

The PIC configuration (initialization) required is the *PIC Toolkit Mk2* default as shown in Table 1.

Once programmed, the PIC should immediately start running and a set of data similar to that previously discussed should be seen. Set switches S5 and S6 so that the frequency being generated by IC2 is being monitored. Observe the results when different waveforms, frequency ranges and sampling rates are selected using

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switches S1 to S4 and with the frequency control potentiometer VR1 at various settings.

If you have an oscilloscope, monitor the waveforms output at all settings and from all panel outputs. Additionally check the two inputs, using an external signal generator. Outputs Out Direct and AC Out should only be fed into the AC Input (do not feed them into the Logic Input because of their negative-going content).

(You may prefer to insert a 1k resistor between socket SK1 and switch S5 to minimize the risk of IC7a becoming distressed by negative-going or over-voltage signals.)

Once fully checked, the PIC-Gen is ready to be put into general workshop use.

RESOURCES

The software for the PIC-Gen is available for free downloaded from the *EPE* Obline library at **www.epemag.com**. The program is written in TASM.

Data sheets for the MAX038 and MAX660 can be downloaded from Maxim's web site at **www.maxim-ic.com**

Data sheets for the PIC16F877 (and other PIC products) can be downloaded from Microchip's web site at **www.microchip.com**

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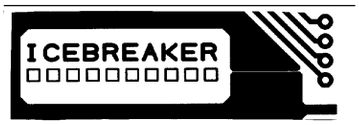

SEE ICEBREAK AD PAGE 367

★ TENS UNIT ★

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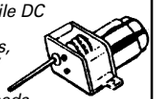

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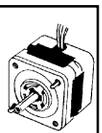

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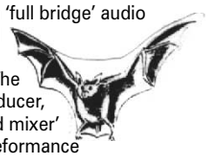

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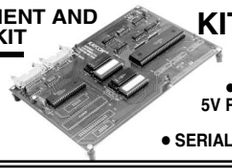

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As featured in *EPE* and now published as Teach-In 7. All parts are supplied by Magenta. *Teach-In 7* is £3.95 from us or *EPE*
Full Mini Lab Kit – £119.95 – Power supply extra – £22.55
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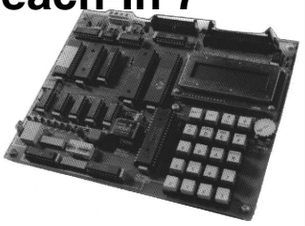

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Ingenuity is our regular round-up of readers' own circuits. We pay between $16 and $80 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. 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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Multi-Purpose AC Detector/Switch – Dig Those Fields

The circuit diagram shown in Fig. 1 has potential uses as an AC Field Detector, a touch alarm trigger, or as a touch-on touch-off switch. The first stage of the circuit, based upon opamp IC1a, serves as a sensitive AC field detector with a range of a few meters.

If an optional coil L1 is connected as a sensor (a loudspeaker coil is fairly effective), piezo disc X1 will emit a Geiger-counter-like sound in the presence of an AC field as one moves through the home. With the correct setting of potentiometers VR1 and VR2, the device may be used to detect hidden AC wiring.

As an Alarm Trigger, almost any metal object may be attached to the circuit as a sensor – a door knob, a toaster, or that precious can of premium beer. Static sensitive materials may also be found to work (e.g. a synthetic tablecloth). With switch S1 closed, relay contacts RLA1

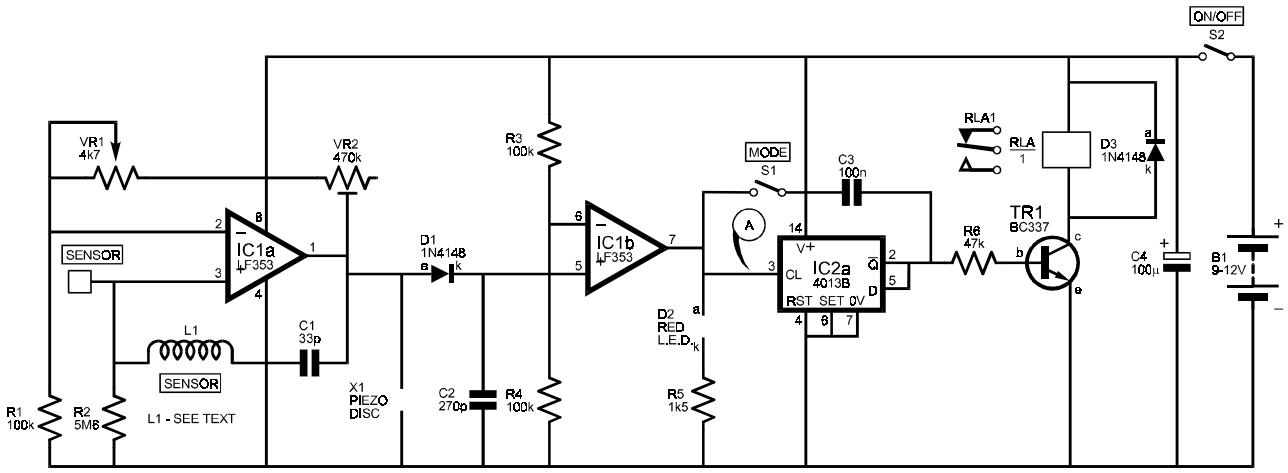

Fig.1. Circuit diagram for the Multi-Purpose AC Detector/Touch Switch.

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momentarily close and open again when the sensor is touched, thus serving as a trigger. When S1 is open, the circuit acts as a sensitive and reliable Touch-On Touch-Off switch.

Opamp IC1a is wired as an oscillator, carefully tuned by VR1 and VR2 so that it is just reluctant to oscillate. The value of resistor R2 is high, so that IC1a is sensitive to stray pick-up by the sensor, which biases the oscillator into operation. IC1b is wired as a simple comparator, which detects a rise in voltage in capacitor C2 and provides a clear logic high or low output at point 'A'.

The main function of flip-flop IC2a is to prevent the circuit from re-triggering itself through stray pick-up from the relay. IC2a masks such pick-up for a fraction of a second when the relay switches. It also serves to select trigger or touch-on/touch-off modes through switch S1.

Piezoelectric disc X1 is included to monitor whether IC1a is breaking into oscillation. Light-emitting diode D2 indicates when IC1b goes high. Note that the circuit is obviously dependent on the electromagnetic field generated by the AC mains, and will only operate in the vicinity of AC wiring or appliances. It should operate successfully in most (though perhaps not all) positions in the home.

Although the circuit is sensitive, there is virtually no spurious triggering, all leads should be kept short. With a large 9V PP9 battery, the detector/trigger/switch will remain on standby for up to 2 months. A connection may be taken from point 'A' to most CMOS logic inputs.

Rev. Thos. Scarborough
Fresnaye, Cape Town
South Africa

Versatile Car Interior Light Delay – Light Work

Many cars manufactured these days include an interior light ("dome light" in the USA) delay unit as a standard feature, but the circuit diagram of Fig. 2 was devised to fit an older vehicle without one. The unit uses a 555 timer in its astable mode and a useful automatic cancel feature is also included.

On opening a car door, relay RLA is energized via diode D4 which grounds the relay coil to the car chassis (0V) through the normally-closed door pillar switch. The interior light remains on for as long as the door remains open. The Reset (pin 4) on timer IC1 is grounded until the door is closed, when it goes to +12V via resistor R3, so the timing cycle starts.

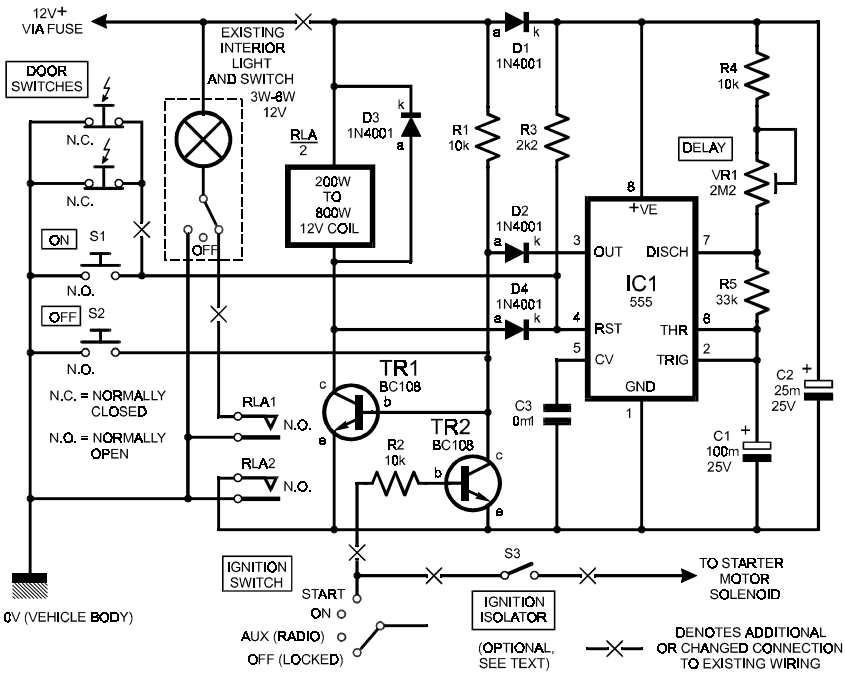

Fig.2. Circuit diagram for a Versatile Car interior Light Delay. (Be aware that altering the vehicle wiring may invalidate any warranty – check first.)

The relay is now "latched on" via contacts RLA2, the supply to the 0V side of its coil now being maintained by transistor TR1 which itself is kept in the conducting state by resistor R1. After a pre-set interval (usually 1 to 3 minutes is about right), determined by the RC network on IC1, the output at pin 3 goes low, which turns off TR1, causing the relay to unlatch and switch off the interior light. A fairly long ON period can be used to allow time for the pre-driving-off activities of fastening seat belts, loading audio cassettes or CDs, or applying make-up!

Run-On

The problem of the light staying on after driving off is overcome by transistor TR2 which conducts as soon as the starter is operated, so switching off TR1 and the relay as before. The addition of pushbutton switches S1 and S2 as indepen-

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dent On and Off switches allows the light to be operated with the engine running which is useful if the driver needs to stop briefly to look at directions for example, or to switch off the light after allowing a passenger to get in or out of the vehicle.

By threading the extra wires down the same route as the existing wiring to the light (usually down a door pillar) and the use of appropriate male, female and piggy-back spade connectors, the unit can be installed without cutting existing wiring to the light. The only additional connections required are an Earth to the vehicle body and a "Scotch-lok" splice to the starter feed from the ignition switch.

Although not part of the timer circuit, a loop of suitable wire could be added while the starter switch is exposed, fitted with a concealed switch (S3) to provide added security against the vehicle being started by an unauthorized key holder.

Andrew R.G.Calder
Leigh, Lancs, UK

Musical Chip Amplifier – Loud and Clear

Musical greeting cards incorporate a "chip-on-board" (COB) device which plays a tune through a piezo disc when the card is opened. The card actually acts as a resonator, which contributes considerably to the volume of the tune.

The circuit diagram shown in Fig. 3a is a simple amplifier, which will allow a musical chip to be played over a conventional loudspeaker instead. It was found that the chip would run from 4·5V (three button cells), hence it was felt worth constructing a simple bridge amplifier to try to double the voltage swing across the loudspeaker coil. It was constructed using parts to hand and none of the transistor types are critical, neither is the loudspeaker type.

Some circuits require a pull-up or pull-down resistor on the output of the chip. If so, this provides an opportunity to add a peaking inductor to increase the voltage swing still further. A "ringing choke" (L1) load can be added (see Fig. 3b), which could perhaps be sufficient to drive a logic-compatible MOSFET transistor, which has a gate optimized for a +5V drive signal (e.g. BSS98, ZVN4206, 2SK940 etc.). The inductor L1 should have as large a value as possible, using trial and error.

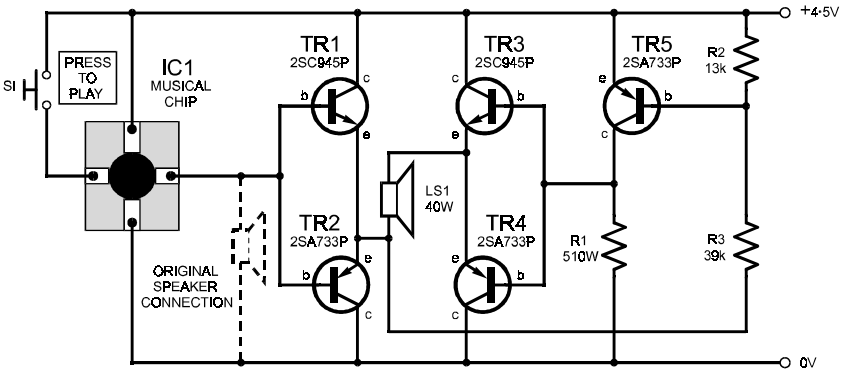

Fig.3a. Simple "greeting card" Musical Chip Amplifier circuit diagram.

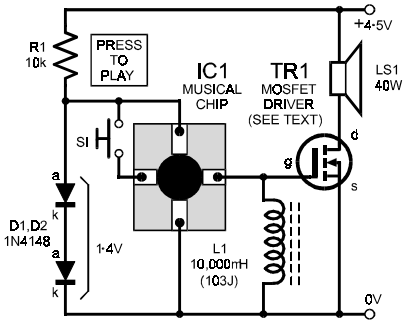

Fig.3b. using an inductor L1 to increase the output voltage.

I. Field,
Letchworth, Herts, UK

Narrow SCSI Active Terminator – Cheaper Solution

If you are using more than one SCSI device in your home PC, you will probably be aware that terminating the SCSI bus is essential to ensure reliable communication across the Bus. In my own experience with SCSI, I have found that "active" terminators are the better ones to use, but such devices are often expensive for what they are.

The circuit diagram of Fig. 4 shows how to construct an Active Terminator for an 8-Bit SCSI Bus (Narrow SCSI). Note the terminator is for Single-Ended SCSI only, not the differential SCSI Host Adapters.

As can be seen, the design is very straightforward, and uses the simple Zener regulation method to hold the SCSI signals at about 3·3V (the inactive state). The 220 ohm pull-up resistors limit the current to about 25mA when the SCSI signals

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become active and fall to ground.

The IDC plug used in the main diagram shows the connections for an internal terminator and the Centronics plug in diagram Fig.5 shows the connections for an external terminator often used with Scanners and other peripherals.

Paul Entwistle
Bolton, Lancs, UK

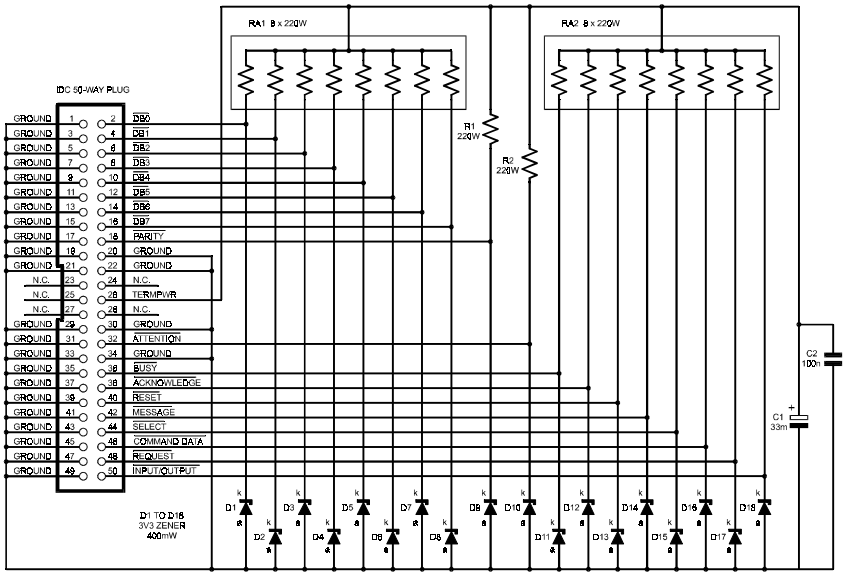

Fig.4. Circuit diagram for an 8-bit Narrow SCSI Active Terminator. The terminator is for Single-Ended SCSI only, not the differential SCSI Host adapters.

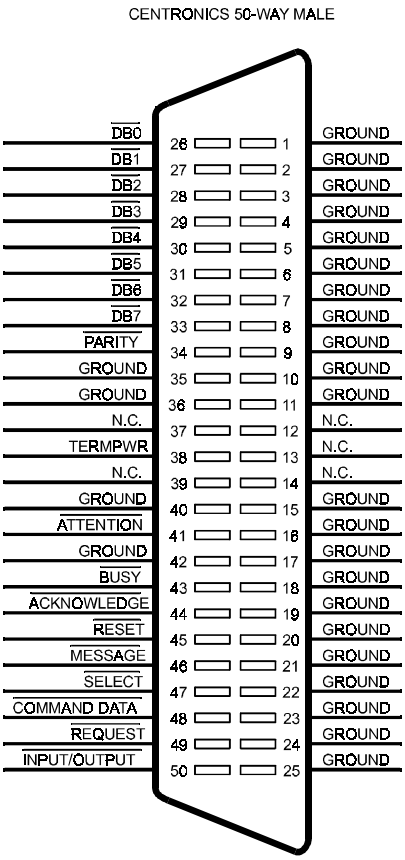

Fig.5 (right). Connection details for a Centronics 50-way male plug external terminator.

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ATMOSPHERIC ELECTRICITY DETECTOR by KEITH GARWELL - PART 2

Investigate Nature's power-house with this intriguing experimental design.

Last month we dealt with the Meter Interface Buffer and Dual-Voltage Power Supply circuits together with suggested stripboard constructional details. We conclude this month with meter switching, module interconnections and probe details.

SYSTEM METERING

Moving coil meters are the favorite for this application as they show more clearly the activity that is taking place. Digital voltmeters (DVMs) are fine in some respects but when the voltage is changing rapidly (as it often is in this caper) the digits just whirl about and it can be very difficult to make head or tail of them.

A pair of moving coil meters are required with a full scale of 0·1 milliamps. These are usually around 1000 ohms or less in resistance, which is small enough to be ignored for this exercise. The scale will normally be marked with 0 to 10 with 0·2 intervals.

Meter ME1 in Fig.8 is used with a 10 volt scale to show the output of the high resistance meter and is provided with a center zero facility, and a reversing facility. Included along with the meter and its switches is a 2-cell AA size battery pack which is switched into effect by S2 to give half scale deflection i.e. center zero. Preset VR2 is used to adjust the reading to 5, the half-way mark.

This means that the meter unit's output of +5V or –5V can be read and is very helpful when trying to back off the plate voltage with the high voltage supply. When voltages of greater than 5V are present at the meter output, S2 can be turned off so that the full range (10V) of the meter is available. Switch S1 is used to reverse the meter connections if necessary.

Meter ME2 is also a 0·1 milliamp meter which is used to measure the high voltage supply output. It is very helpful if this meter is marked 0 to 3, and there are some meters about which have two scales 0 to 10 and 0 to 3. The alternative is to do the arithmetic, i.e. multiply the reading by 30 if it is calibrated 0 to 10.

It is entirely up to the user how the "metering" is arranged. In the prototype, the meters are separate, but it could be more convenient to build them into a

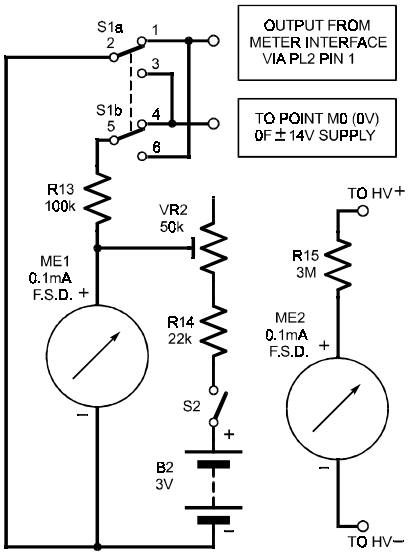

Fig.8. Circuit diagram for the twin meters.

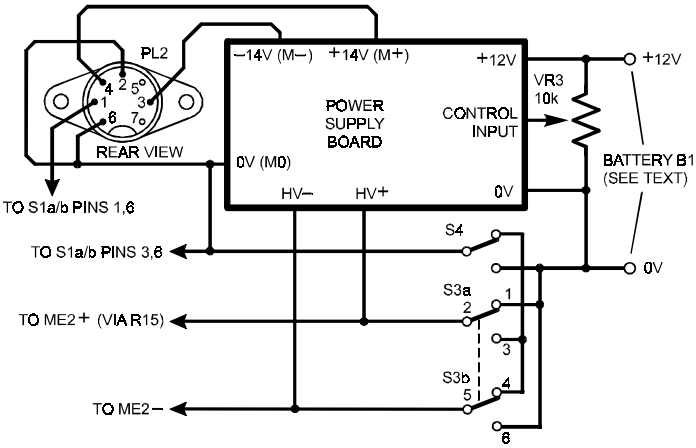

Fig.9. Schematic illustrating the connections distributed from the power supply.

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dedicated unit. It depends whether you have other uses for them, and they do require the largest capital outlay of the whole project.

INTERCONNECTIONS

So far we have discussed the various units in isolation, and they must be brought together to implement Fig.1 (last month).

The interconnections between the various system components are shown in Fig.9. There are three controls, an on/off switch (S4) and a reversing switch (S3) to change the potentials of the high voltage supply, plus a rotary control (VR3) to adjust the voltage supplied to the monitoring system. There are also the two moving coil meters, ME1 and ME2, connected as shown earlier in Fig.8.

Switches S3 and S4 must be rated at least at 250V AC. The current involved is only a few microamps.

A 6-way cable (low voltage) with a 7-pin DIN plug at either end connects this unit with the meter interface unit and needs to be long enough to enable the user to be well away from the plate when it is being used for atmospheric measurements, 15 meters for example.

It must be pointed out that the sensitivity of the meter unit allows it to detect the static on the author's clothes at 10 meters, and don't try using the unit if there's any washing hanging on the line – the pinging noise made by the meter becomes quite audible! Arrange to share the good days with wife and family!

The author has not tried screening the system between himself and the probe (he doesn't think he's really cut out to be the monkey in the cage!), but he has noticed that walls seem to provide protection, whether glazed or brick.

The 0V line of the 12V power supply source and the case **MUST BE CONNECTED TO GROUND**. If the 12V supply is derived from a mains power supply rather than a battery, then the mains earth will be sufficient, but check that there is no significant voltage between this and true ground. If a battery is being used for the 12V supply then an earth connection must be made to the 0V line. If no other is available an earth spike must be used, driven into the ground beside the unit. DO NOT earth the 0V line of the ±14V supply.

CONSTRUCTION

An aluminum box about 120mm x 120mm x 50mm deep was used for the prototype power supply, its controls and connectors.

The panel layout is open to the constructor's preference and no layout is offered. In the prototype the connectors are at the top of the panel and the controls below.

For a portable unit perhaps a 12V lead acid battery, meters and the dual supply should all be in the same box, with just the controls and the 7-pin DIN connector to connect to the meter circuit showing, plus some means of easily removing the battery (or connecting to it) for charging.

Sealed versions of lead acid batteries are available which can be mounted in any position. A whole range is available from about 0·5Ah upwards (YUASA range). If such a battery is used, it must be provided with a suitably rated fuse (100mA) as they are capable of very high currents under fault conditions.

The author has two separate power supplies available, a mains only unit, and a battery powered unit which can also be connected to the mains (the latter is effectively a no-break 12V supply), with the option for supplying 12V at 100mA or 500mA.

There are various aluminum boxes available and one convenient form is a two-part unit where the top (lid) is formed into a U-section and fits over the base, which has sides formed and an edging with fixing holes to fasten the top. One of these was used for the meter unit, and another for the high voltage power supply and controls.

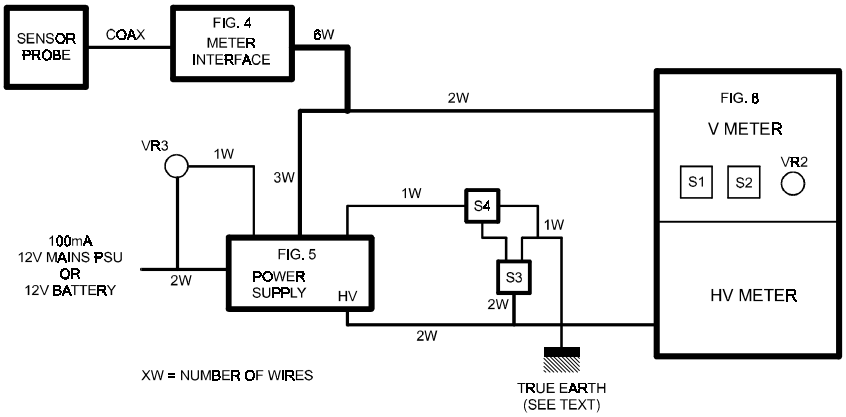

Fig.10. Block diagram illustrating the cabled interconnections between the various units.

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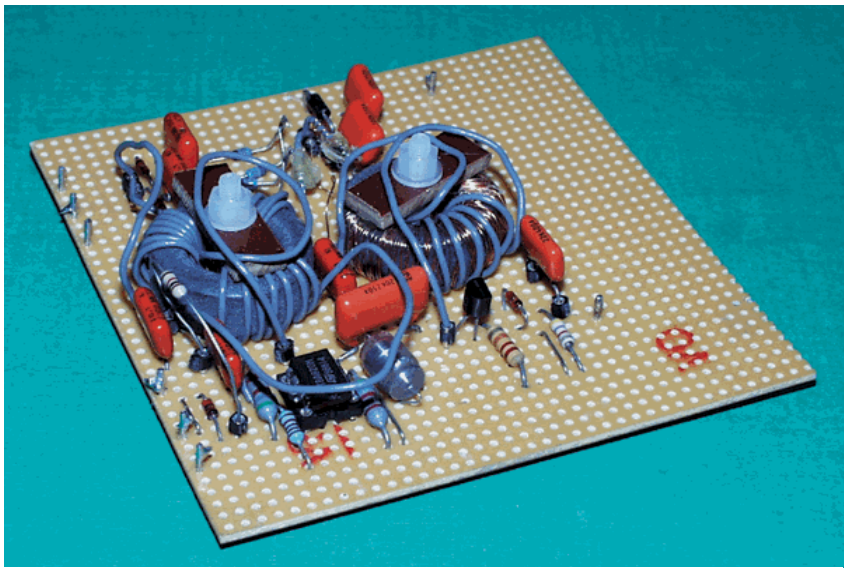

Close up details of the constructed power supply board.

However you decide to house it, once the building work is finished it is time for testing. Thoroughly check all connections, particularly the 0V line. At this stage don't connect the meter unit or its cable.

It is recommended that a regulated and current-protected (at about 100mA) 12V power supply should be used while testing the units.

With power switched on, the output of the high voltage meter should be adjustable (using VR3) between about 0V and 300V. Note that 0V might not be reached and that the minimum might be nearer to 5V.

If this is OK so far, check the low voltage (nominally ±14V) outputs at pins 2, 3 and 4 of the 7-pin connector SK2.

Fit the two AA cells to the low voltage meter ME1 and switch on S2. Adjust VR2 to give exactly half scale (5V).

Connect the meter interface unit and open the case just enough to get at its off-set balance adjustment preset VR1 and adjust it to give zero output, i.e. the meter needle on the 5V mark. Refit the cover.

Now fit the short coaxial connector with about 6cm of coax cable attached to it, and a crocodile clip at the far end of the cable. The screening is removed for about 30mm to allow the clip to be fitted.

The meter needle should wander back and forth as you move around the unit. The next step is to check the calibration, which requires another meter, preferably a DVM, and two or three test voltages of between 0V and 5V. The latter can be achieved by using three single cells or a battery with a potentiometer across it.

By this means apply voltages between the meter unit input and the 0V line of the 12V supply. Check on both polarities and on the agreement between meter ME1 and the DVM. Don't be surprised by slight irregularities, moving coil meters are not perfect.

To make checks above 5V up to 10V, the meter's center zero will have to be switched off and the full scale used.

If this is OK, you can now prepare the probes.

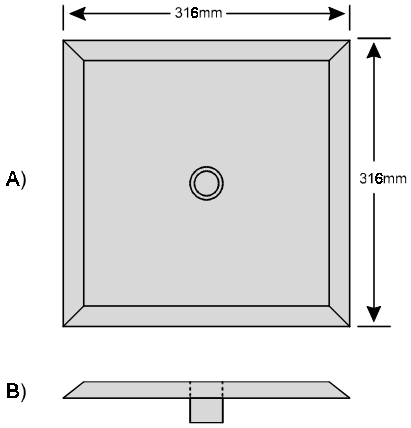

Fig.11. Details of the suggested sensor probe plate.

PROBES

The probe suggested in Fig.1 last month is the author's principal tool. As the illustration suggests, it is nothing more than a piece of aluminum 316mm square, which gives one tenth of a square meter in area.

The corners are just nicked with tin snips or a fine saw from the corner towards the center for about a centimeter and then the four edges are just dressed down a little way. This both stiffens the plate and prevents it fluttering in the wind, see Fig.11.

It is supported on 41mm, outside diameter, standard plastic waste pipe and connector, both obtainable at any DIY store.

The connector was first cut in half, the sealing rings removed, and then glued to the center of the metal plate using hot-melt glue. The pipe was then pushed into the connector.

In a very similar way, the base for the pipe was made from a piece of chipboard, 380mm x 280mm x 20mm. This was just a scrap found in the workshop and its thickness makes it heavy enough to be a firm support. Screwed to the

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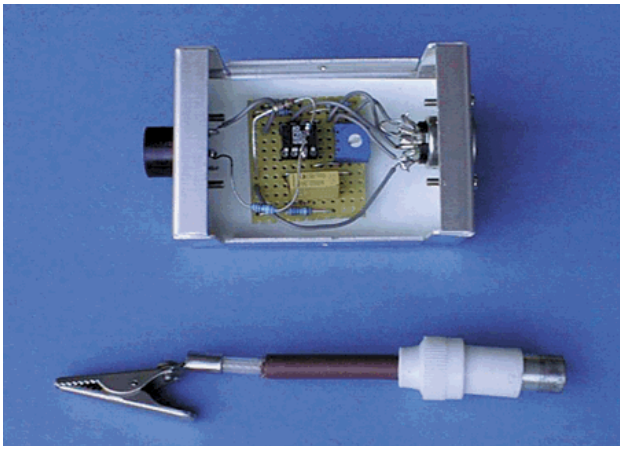
Meter interface unit connected to the sensor probe plate.



Details of the meter interface unit and the interconnecting probe clip.

center of this is a "socket" made from another scrap of wood about 100mm x 100mm x 45mm.

A 41mm diameter hole was drilled into this block, which was then screwed to the chipboard. It provides a firm fit when the pipe is pushed in and there is no tendency to wobble.

The pipe can be cut to length as required – the "standard" length is one meter, the length used for reference readings, but experiments may require alternative lengths of perhaps 0·5 and 1·5 meters.

Connection between the plate and the meter unit is made by means of the short length of coaxial cable with its plug at one end and a crocodile clip at the other, the latter clips on to a small screw on the underside of the plate.

This arrangement works well and the pieces (plate, pipe and base) need only to be connected together as and when required. Several lengths of pipe allow measurements to be taken at different heights.

The author's prototype single-plate atmospheric detection platform

ALTERNATIVE SUPPORT

The simple arrangement described has two shortcomings. A change in height requires a change in the supporting pipe and, as the values being measured can change quite quickly, it would be nice to be able to change the height quickly.

Secondly, it is necessary to be aware of the possibility of condensation on the surfaces of the pipe. On one occasion when the readings didn't make sense it was realized that condensation was taking place. A quick wave of a hair drier warmed the pipe enough to stop the condensation, but the readings were still nonsense. It eventually became apparent that condensation was taking place on the inside of the pipe as well!

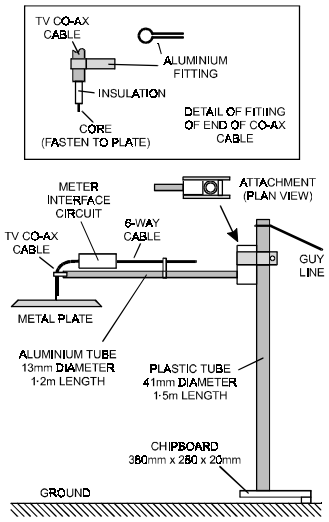


Fig.12. Alternative sensor plate support construction.

In a sense, these are trivial problems, one of which only occurs when it's cold and damp, but it was still thought desirable to avoid the support problem altogether. As a consequence, the arrangement shown in Fig.12 was invented.

No support is used as the

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plate is suspended and can be raised or lowered by shortening or lengthening the guy line when the whole affair tips backwards or forwards on its foot. It all works like a charm – until there is a breeze when the plate waves around like a mad thing! So do the meter needles!

Ah well, there are times when you can't win them all, but it otherwise does the job it's meant to. Do any readers have any bright ideas to steady the plate?

We will be happy to published any feedback from readers through our Readout *column. Ed.*

AUTHOR'S WEB SITE

This equipment is referred to on the author's web site under Atmospheric Electricity, and which is kept updated with developments:

http://members.tripod.co.uk/GarwellK

The author would also be pleased hear from you via his E-mail address at: **kgarwell@hotmail.com**

There are many other sites dealing with Atmospheric Electricity which are well worth a browse – in particular the meteorological site at Reading University: **www.met.reading.a.c.uk**

The UK Meteorological Office site is at **www.meto.gov.uk**

The equivalent US site (National Oceanic and Atmospheric administration) is at **www.noaa.gov**

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● **PC CONTROLLED RELAY BOARD** Convert any 286 upward PC into a dedicated automatic controller to independently turn on/off up to eight lights, motors & other devices around the home, office, laboratory or factory using 8 240VAC/12A onboard relays. DOS utilities, sample test program, full-featured Windows utility & all components (except cable) provided. 12VDC. PCB 70x200mm. **3074KT £29.95**

● **2 CHANNEL UHF RELAY SWITCH** Contains the same transmitter/receiver pair as 30A15 below plus the components and PCB to control two 240VAC/10A relays (also supplied). Ultra bright LEDs used to indicate relay status. **3082KT £26.95**

● **TRANSMITTER RECEIVER PAIR** 2-button keyfob style 300-375MHz Tx with 30m range. Receiver encoder module with matched decoder IC. Components must be built into a circuit like kit 3082 above. **30A15 £13.95**

● **TELEPHONE LINE RELAY SWITCH** Turn on/off 4 relays over your phone line from anywhere in the world. 4-digit security code. Line protection circuitry built-in (non-approved). PCB 78x105mm. **3086KT £39.95**

● **PC DATA ACQUISITION/CONTROL UNIT** Use your PC to monitor physical variables (e.g. pressure, temperature, light, weight, switch state, movement, relays, etc.), process the information & use results to control physical devices like motors, sirens, relays, servo & stepper motors. Inputs: 16 digital & 11 analogue. Outputs: 8 digital & 1 analogue. Plastic case with printed front/rear panels, software utilities, programming examples & all components (except sensors & cable) provided. 12VDC. **3093KT £79.95**

● **PIC 16C71 FOUR SERVO MOTOR DRIVER** Simultaneously control up to 4 servo motors. Software & all components (except servos/control pots) supplied. 5VDC. PCB 50x70mm. **3102KT £14.95**

● **PC SERIAL PORT ISOLATED I/O BOARD** Provides eight 240VAC/10A relay outputs & 4 optically isolated inputs. Designed for use in various control & sensing applications e.g. load switching, external switch input sensing, contact closure & external voltage sensing. Controlled via serial port & a terminal emulator program (built into Windows). Can be used with ANY computer/operating system. Plastic case with printed front/rear panels & all components (except cable) provided. **3108KT £49.95**

● **UNIPOLAR STEPPER MOTOR DRIVER** for any 5/6/8 lead motor. Fast/slow & single step rates. Direction control & on/off switch. Wave, 2-phase & half-wave step modes. 4 LED indicators. PCB 50x65mm. **3109KT £14.95**

● **PC CONTROLLED STEPPER MOTOR DRIVER** Control two unipolar stepper motors (3A max. each) via PC printer port. Wave, 2-phase & half-wave step modes. Software accepts 4 digital inputs from external switches & will single step motors. PCB fits in D-shell case provided. **3113KT £16.95**

● **12-BIT PC DATA ACQUISITION/CONTROL UNIT** Similar to kit 3093 above but uses a 12 bit Analogue-to-Digital Converter (ADC) with internal analogue multiplexor. Reads 8 single ended channels or 4 differential inputs or a mixture of both. Analogue inputs read 0-4V. Four TTL/CMOS compatible digital input/outputs. ADC conversion time <10uS. Software (C, QB & Win), extended D shell case & all components (except sensors & cable) provided. **3118KT £47.95**

● **LIQUID LEVEL SENSOR/RAIN ALARM** Will indicate fluid levels or simply the presence of fluid. Relay output to control a pump to add/remove water when it reaches a certain level. **1080KT £6.95**

● **UNIVERSAL TIMER** Seven crystal controlled timing operations in steps of 0.1s from 0.1-6553.6s or 1 second steps from 0.1-65536s. Allows 4 signal input types from push button to electrically isolated voltage switching sources. On-board relay will switch 240V/5A. Box, software & all components provided. PCB 56 x 97mm. **3054KT £24.95**

● **LED DICE** Classic intro to electronics & circuit analysis. 7 LED's simulate dice roll, slow down & land on a number at random. 555 IC circuit. **3003KT £7.95**

● **STAIRWAY TO HEAVEN** Tests hand-eye co-ordination. Press switch when green segment of LED lights to climb the stairway - miss & start again! Good intro to several basic circuits. **3005KT £7.95**

● **ROULETTE LED** 'Ball' spins round the wheel, slows down & drops into a slot. 10 LED's. Good intro to CMOS decade counters & Op-Amps. **3006KT £9.95**

● **DUAL LED DICE** PIC 16C54 circuit performs similar function to 3003KT above but two dice. Good intro to micro-controllers. **3071KT £11.95**

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● **LED FLASHER 2** Similar to above but flash in sequence or randomly. Ideal for model railways. **3052MKT £4.50**

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● **20 MHz FUNCTION GENERATOR** Square, triangular and sine waveform up to 20MHz over 3 ranges using 'coarse' and 'fine' frequency adjustment controls. Adjustable output from 0-2V p-p. A TTL output is also provided for connection to a frequency meter. Uses MAX038 IC. Plastic case with printed front/rear panels & all components provided. 7-12VAC. **3101KT £49.95**

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Circuit Surgery

by ALAN WINSTANLEY & IAN BELL

Our ever-helpful team of circuit surgeons check out a CMOS D-type latch and offer suggestions for a low-voltage monitor circuit.

CHECKING THE CHIPS

Our thanks to **Mr. D. Lee** of Birkenhead, Cheshire, UK, who wrote asking for help in testing 4042 logic devices. Mr. Lee says that he needs a simple test circuit to "fully auto-test the logic outputs" of the 4042. He has previously built circuits to test basic gates, but testing the 4042 presents a more difficult case.

We're not sure how feasible it is to custom-build a tester dedicated to a specific chip, however our first port of call has to be the Philips Semiconductor web site to fetch a data sheet, so point your web browser at **www.semiconductors.com/products/** then do a search for "4042". Data sheets are published in Adobe Acrobat format (PDF file types) which can be read and printed using the free Adobe Acrobat Reader from **www.adobe.com**

Data sheets often include function diagrams of the chip and Philips' data is helpful as always. The 4042 is a CMOS level-sensitive quad D-latch, with complementary outputs and a clock input with selectable polarity.

Basically speaking, a D-Latch (or Data latch) is a circuit that "remembers" (latches) data when a suitable clock pulse comes along. The data (0 or 1) presented to the latch's D-input is written to the latch's Q output, and the latch stays in that condition until another suitable clock signal is delivered. The Q complementary output is just the inverse of Q.

The clock signals for all four latches are connected via an exclusive-NOR function (XNOR) which has two inputs. These inputs can be interpreted as the clock (C) and polarity control (P) for the clock (see Fig. 1a). Philips' 4042 data sheet describes them as Enable 0 (E0) and Enable 1 (E1). In fact the data sheet includes a function table (Table 1) which outlines the logical operation of this chip.

Looking in more detail at the circuit for an individual latch, see Fig 1b, the four latches each have a positive level sensitive clock labeled CP. When CP is high data is transferred from the D input to the Q and Q outputs of each latch, and when the clock goes low the state on the Q and Q output at that time is memorized or latched.

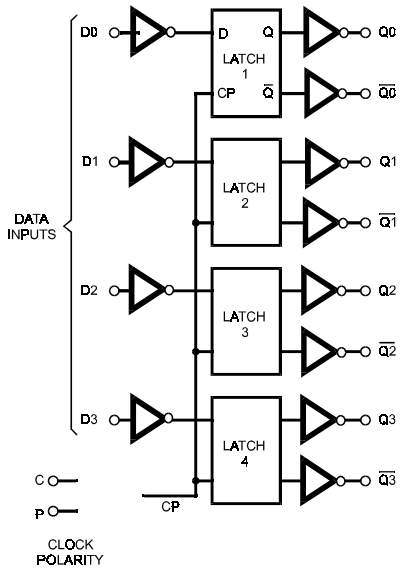

Fig.1a. Internal logic diagram for the HEF4042 (Philips Semi). Note the CP signal cannot be accessed externally.

Table 1: Logic operation of the 4042.

E0	E1	Output Qn
L	L	Dn
L	H	Latched
H	L	Latched
H	H	Dn

(H = high, L = low)

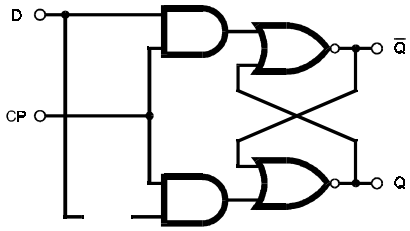

Fig.1b. Circuit for an individual latch.

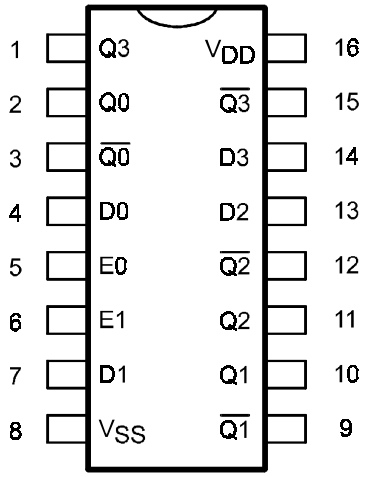

Fig.1c. Pinout details for the 4042B.

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TEST THIS OUT

To test the logic function of the latch, we would need to check that the output could follow the input to both 0 and 1 with CP high, and when CP was taken low both a 1 and a 0 could be latched without a subsequent change on D changing the stored value.

In practice, the CP line is not accessible externally as it is driven from the C and P signals (pins 5 and 6) via the XNOR gate. We can hold P at one state and fully test the latches, after which all we have to do is check that the C signal still gets through to the CP with P in its opposite state (it is not necessary to fully test the latches twice).

A sequence of inputs that should achieve our purpose is shown in Fig.2, together with the expected output from Q (also Q should always be the complement or opposite state of Q) and the state of the internal clock signal CP (we cannot access this but it is drawn to help show circuit operation).

The test sequence works as follows. First the transmission of a 1 with CP high is checked (T1), then the 1 is latched (L1) and D is changed to check that the 1 has actually latched (C1). This is repeated for a 0 (T0, L0, C0). The value of P is changed and the T1, L1, C1 sequence is repeated to check that C still gets through to CP.

How do we automate the process? We need a circuit to generate the sequence on P and C and also check that the output from Q is correct, which means we need to generate the expected sequence from Q and Q too. There are a number of ways of doing this. We could program a microcontroller

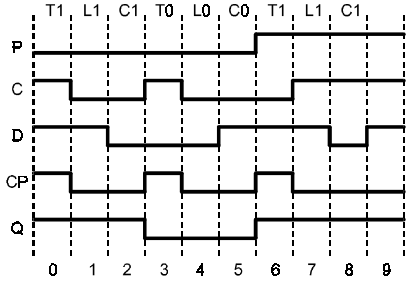

Fig.2. Possible 4042 test sequence (see text).

device such as a PIC to generate the C and P sequences and check the sequence on Q and Q. This may be a good option for someone who is familiar with a particular microcontroller and has all the kit and software ready to use.

IN SEQUENCE

An alternative is to build a sequence generator from basic logic. One way of doing this is to build a counter that goes through ten states: a synchronous binary up-counter which is synchronously reset to 0 from state 9 is probably the best choice.

The outputs of the counter (Q3, Q2, Q1, Q0) can then be decoded using combinational logic to give the required sequences. For example, the sequence on P is obtained using the function P = Q3 OR (Q2 AND Q1), which requires an AND gate and an OR gate. These circuits can be built with ordinary discrete logic gates designed by using K-maps (as described in our series *Teach-In '98 – An Introduction to Digital Electronics*).

To check the output we could use a logic comparator connected to the Q and Q outputs and to the Q and Q sequence logic derived from the counter's outputs. If the device under test is OK then the comparator outputs will always indicate "equals". The comparator output should be sampled by the counter clock (i.e. stored in a flip-flop using the counter clock) to prevent any variations in timing between the 4042's output and the test sequence generator from indicating false "not equals" states from the comparator.

A third possibility for implementing the tester is to program an EPROM with the test input and expected output sequences stored in consecutive memory locations (one EPROM data bit per device under test I/O pin). The EPROM's address bits would be connected to a counter that would step the EPROM through the addresses containing the test sequence.

As with the previous suggestion a logic comparator would be used to compare the expected and actual output sequences. This approach could also be extended to test devices other than the 4042, spare address lines could be used to select which sequence the counter ran through.

ADVANCED OPTIONS

A more sophisticated version of this approach would be to use a RAM or E2PROM which could be loaded with a test sequence from a PC using, say a serial port, allowing a large number of test sequences to be defined and stored on the PC and downloaded to the tester when required..

The previous discussion has overlooked an important point – what is meant by "fully test''? We have only considered one latch (to keep things simple) and

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it would seem at first that we could supply the same sequence to all the D inputs to check the latches in parallel. This would let us detect a significant number of faults – for example if one of the Q outputs was open-circuit we would not observe the expected sequence on it.

However, if we apply the same sequence to all the D inputs then all the latches are doing the same thing and short circuits between equivalent points in any two latches would not be detected. We could get around this by running the sequence more than once with different values on adjacent D inputs, but the best way to do this may depend on knowledge of the structure of the chips (i.e. which latches, and latch I/O pins are next to one another and thus more likely to short).

The problem of short circuits gives us some hint of the difficulty of testing circuits. In general, although we can perform simple tests to prove the logic of the latches is operating, it would be difficult to prove that the device had been "fully tested" – tested for what faults? Shorts? Opens? Defects in the oxide of the MOS transistors causing increased leakage? *IMB.*

LOW VOLTAGE DETECTOR

I am a 16 year old student designing an intercom. I'd like to attach a low battery indicator to a 9V battery for use with my project, but I can't find any schematics. Is it possible to build a low battery indicator with the ICL8211 chip? ***Adam*** *via email.*

I think the 8211/8212 low voltage detectors originated

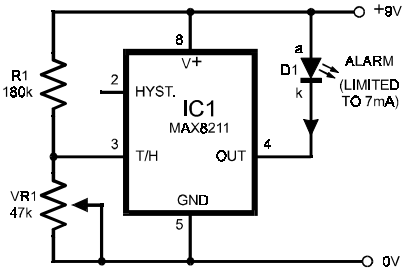

Fig.3a. Low voltage alarm using the MAX8211 to drive a LED.

from Harris, who sold their semiconductor business to Intersil. This company used to manufacturer a bipolar version, the ICL 8211/8212. Maxim also produce CMOS versions, namely the MAX8211/8212.

The overall chip design has been around a good 20 years, and although Intersil flagged them as obsolete there should be plenty around. Let's narrow down our options and look at the Maxim version. Data sheets for the CMOS type can be obtained from Maxim's web site (**www.maxim-ic.com**).

Both the MAX8211 and MAX8212 contain a 1·15V reference, a comparator, an open-drain *n*-channel output transistor and an open-drain p-channel transistor on the hysteresis pin. The chips operate in a manner opposite to each other. The 8211 output transistor turns on when the input voltage is less than the threshold or reference voltage. Its output (pin 4) goes low and sinks up to 7mA.

However, the 8212 output turns on (goes low) when the input is greater than the threshold. Note that the 8212's output is not current limited, and can sink typically 35mA. The chips are handy for under-voltage or over-voltage detection, back-up battery switching, microprocessor monitoring etc., noting that the CMOS chips typically consume a meager 5uA, so their impact on battery life is negligible.

To answer your questions, Adam, a low voltage alarm can readily be constructed using the MAX8211 which will operate with any supply from +2V to +16·6V. Since its output is current limited it can drive a light-emitting diode (LED) directly, see Fig.3a.

The chip monitors the power supply rail by comparing the voltage at the threshold pin against the internal reference. When pin 3 is less than 1·15V, pin 4 goes low, current sinks into it and illuminates the LED. (consider a high-efficiency type). The potential divider R1/VR1 was set for 50uA maximum. The trimmer resistor adjusts the set-point.

The hysteresis feature was unused in this example, which means that the switching point will be very sensitive. The LED may flash or jitter when the chip is at its threshold. The addition of hysteresis introduces a difference in the switching points which allows for two switching levels (high and low). This can be accomplished using a third resistor shown in circuit diagram Fig.3b.

Note that this arrangement is only suited if detecting a drop in the supply rail, i.e. when the supply voltage is the same as that powering the 8211. To calculate the resistor values, firstly decide on the desired hysteresis voltage – the difference between the upper and the lower switching points, say 75mV. Then decide on a value for resistor R3, anything up to 10M should do. In this example, 750k (kilohms) was assumed. Choose the alarm

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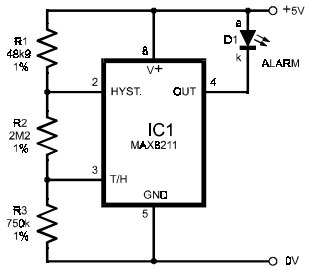

Fig.3b. A logic level alarm which monitors a 5V logic supply. Note the addition of hysterisis using resistor R2.

voltage level (4·5V here).

The hysteresis resistor R2 is calculated using:

$$R2 = R3 \times (V_{low} - 1.15V) / 1.15V = 2M2$$

Lastly resistor R1 is calculated using:

$$R3 \times (V_{hyst} / 1.15V) = 48k9$$

This circuit is designed to monitor a +5V logic supply, with an alarm output when the rail drops below +4·5V. The 75mV hysteresis ensures that the alarm will not be for ever triggering when the 8211 is hovering around the threshold point. I'm sure the circuit can be adapted as needed. The ICL821x and MAX821x are listed by Farnell. *ARW.*

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Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

According to the old proverb "you should not judge a book by its cover", but it is a fact of life that people will judge your completed electronic projects by the standard of their external finish rather than the quality of the circuit boards and wiring.

It is probably fair to say that most constructors, even if they were primarily interested in the electronics rather than the mechanical side of construction, would prefer to produce neat looking projects. Few will be satisfied with perpetually churning out projects that look as if they have just had a nasty accident.

It takes more money and often quite a lot of additional time to put the finishing touches to the exterior of a project, but it is likely to be time well spent.

THE RUB-OFF

You can put a great deal of time and effort into the exterior finish of a project, but without some neat legends for the controls you will not get that professional look.

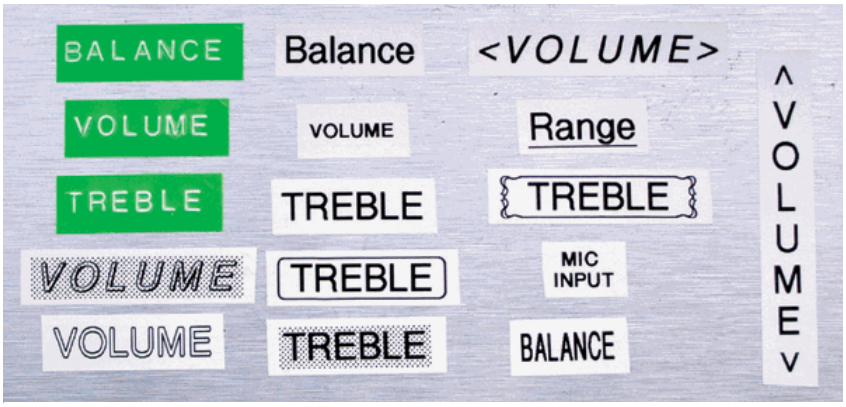

Fig.2. Some example labels produced using a Brother PT75 labeler. The three at the top left-hand corner were produced using a Dymo Mini.

Even if you are not worried about the appearance of your projects, it is still a good idea to clearly label the controls and sockets. Having just finished the project you can probably remember the function of every control and socket, but you might find the going more difficult when returning to the project at some later date.

Fig.1. An electronic labeling machine (left) and (right) a simple mechanical type which produces embossed lettering, self-adhesive labels.

Also, it pays to bear in mind that others may need to use the device. With no labels to indicate the functions of the controls, operating the gadget becomes a matter of trial and error.

In the past the standard method of producing panel legends was to use rub-on transfers. These days there are a number of alternatives that are quicker, easier, and tougher. Rub-on transfers can produce some first class results, but even in the hands of experienced users they are slow to use and getting neat results is not particularly easy.

Probably their biggest drawback is their lack of durability. They rub-on easily enough, but they rub off again just as easily. Lacquers and varnishes can render them less vulnerable, but are usually something less than 100 percent effective.

Obtaining the smaller sizes is also more difficult than it used to be, presumably due to a drop in demand as other labeling methods have become more popular. Rub-on transfers remain a perfectly valid approach to panel legends, but here we will concentrate on the other options.

CHEAP AND CHEERFUL

The quickest and easiest method of adding legends is to use a labeling machine. The least expensive of these are the Dymo labelers (Fig.1), which are purely mechanical devices that produce embossed lettering on

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self-adhesive tapes.

These labelers cost only a few pounds each complete with one tape, and are available from the larger stationers. Tapes of various colors are available, and this is a very inexpensive means of making labels.

To produce a label you dial up the letters one by one, operating a simple lever system to put each letter onto the tape. Once the label is finished it is cut from the tape using the built-in cutter.

Unfortunately, the finished labels tend to have a "cheap and cheerful" look, and even if you are very careful in their preparation they do not look very professional. Another slight problem is that the tapes are quite wide at about 9mm, which makes the labels too large for some projects. However, if you simply wish to add some labels as quickly, easily, and cheaply as possible, a simple labeler of this type has no competition.

HI-TECH LABELS

Electronic labeling machines have been in existence for many years now, but they used to be prohibitively expensive for occasional amateur use. In common with most electronic goods, they have been subject to steady price reductions in recent years, and the cheaper units are now starting to "put the squeeze" on mechanical labeling machines.

The simpler electronic units from Dymo, Brother, and probably some other manufacturers, are available for less than 20 UK pounds complete with one tape. They are occasionally put on special offer at about half that price.

In the Brother PT75 electronic labeler, shown in Fig.1, letters are entered on a form of

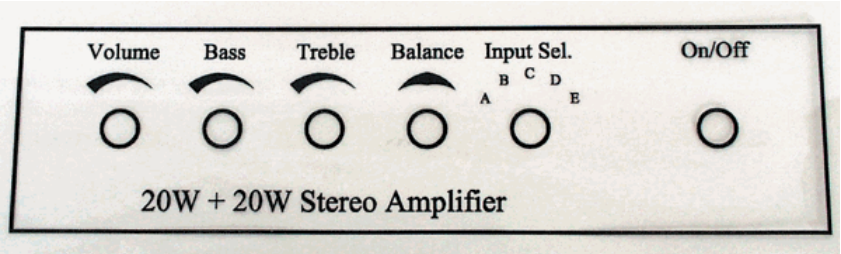

Fig.3. A front panel overlay produced using a PC and a laser printer. The printing is on the underside of a transparent sheet.

QWERTY keyboard and there is a small liquid crystal display so that you can check that words have been entered correctly. Upper and lower case letters are available, together with numbers and a full range of punctuation marks and symbols. Additionally, there is a limited choice of text sizes and styles, and it is also possible to underline words or have them within a frame.

The labels are produced using some form of thermal printer technology, and the quality of results from even the cheaper labelers is certainly very impressive. The results obtained from a Brother PT75 labeling machine can be seen in Fig.2, and they are at least as good as those produced using rub-on transfers. The three labels in the top left hand corner were produced using a Dymo Mini (mechanical) labeling machine, and are clearly not in the same league.

Operating an electronic labeling machine is extremely simple. Having set the text size, etc., it is just a matter of typing in the required word, pressing the Print button, and then pressing a lever to cut off the completed label once it has been printed.

In common with mechanical labelers, one slight drawback of the electronic units is the width of the tapes, which is either 9mm or 12mm. However, the 9mm type is well suited to most projects, and there is usually an option to print in small text if necessary. Text from the PT75 is normally a little over four millimeters high, but it can be reduced to half this if desired. With the aid of a sharp modeling knife or scalpel and a metal ruler it is possible to trim labels having small letters so that they will fit into quite small spaces.

Electronic labeling machines are somewhat more costly than the mechanical variety, but their greater versatility and higher quality results seem to more than justify the extra cost. It is worth bearing in mind that both types of labeler are also suitable for general labeling around the home or office.

SELF CENTERED

Using labels gives less neat results than applying lettering directly on to a panel one letter at a time, but with many modern cases labels are a more practical approach. With many contemporary cases the front panel is not removable, making access to the panel very awkward. The one letter at a time approach can then be very tricky indeed.

When using labels you still need to be careful to get the words properly centered above controls and sockets, and to make sure they are not on a slant. If the lettering uses pro-

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portional spacing, and the electronic labeling machines normally do, you have to be careful when determining the center of a word.

For example, on the face of it the center of the word "balance" is in the middle of the second "a". However, with proportional spacing the "l" is allotted less space than the other letters in this word, pushing the center slightly to the right of this.

The only sure way to determine the center of the label is to measure it. You can then lightly mark lines on the panel to help keep the labels on the level, and to indicate the center point for each label. The labels can then be carefully positioned on these marks, preferably just covering up the marks so that the problem of removing them is avoided.

Alternatively, if you are good at this type of thing you can simply position the labels "by eye". When designing front panel layouts and fitting labels it is the design that looks the best that is right, and not the one that is mathematically perfect.

The adhesive on labels from either type of labeling machine is usually quite strong, so it is not possible to slide the labels into position once they are even partially stuck to the panel. If a mistake is made it is often possible to carefully peel the offending label from the panel and reposition it, but doing this more than once will probably damage it. Fortunately, making a replacement should only take a few seconds and cost less than 0·1 pence!

Experience suggests that the best method of positioning is to place the label on the end of a metal or plastic rod about 150mm or so in length. This acts as a handle that makes positioning of the label much less fiddly. Having maneuvered the label precisely into position it can be pressed down onto the panel.

With this method the labels can be fitted into otherwise inaccessible places. They can even be added with the controls in place on the panel and the control knobs fitted.

Both types of label seem to be quite durable and do not need to be protected with lacquer or varnish. Be careful with your choice if you should decide to apply a protective coating, Some varnishes and lacquers will attack the labels, so it is advisable to make a test on a dummy label before progressing to the "real thing''.

PC LABELS

Many people these days own or have access to a PC and a printer. As we have pointed out in the past, this combination can print excellent labels at quite low cost. The quality of the labels clearly depends on the capabilities of the printer used, but any modern inkjet or laser printer should produce "crisp" text characters.

A laser printer seems to produce more durable labels, which are waterproof and can be printed on a wider range of media. Inkjet printers have the advantage of being able to produce multi-colored labels if desired.

A modern word processor enables lettering to be produced in a wide range of fonts and sizes, as does any desktop publishing program and most drawing programs. If you have a PC you almost certainly have some software that can produce labels. Even the humble Wordpad word processor supplied with Windows 95 and 98 is capable of the full range of Windows fonts and text sizes.

Some of the standard Windows fonts are actually sets of symbols. Most of these are of little use in an electronic context, but it is worthwhile looking through the symbols for something useful.

Try going through the Vacation and Wingdings fonts. The Arial font is a good choice if you require a simple font that will produce neat looking labels. There are plenty of fonts to choose from if you prefer fancy lettering styles. Many of the standard fonts look slightly "heavy" when used for panel legends, but some of the fonts are also available in light versions.

The simple way of handling computer generated labels is to produce a page containing the required words, print it out, cut out the labels using a sharp knife and a cutting edge, and then glue them to the panel. Any general-purpose adhesive should be suitable, but do not use so much that it soaks into the labels and ruins them.

Double-sided adhesive tape is also suitable, and avoids any risk of the adhesive soaking into the labels. Stick the tape in place behind the labels prior to trimming them down to size. That way the tape is trimmed down to size at the same time, and is always a perfect match.

It can be a bit difficult to get the backing paper away from the tape when doing things this way, but it can usually be prized free without damaging the label. It is also a good idea to print some extra labels to allow for casualties.

You can also print the labels in various sizes. If you then find

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that your original choice looks slightly too large or too small once in place, another size can be tried. It is possible to get a large number of labels onto an A4 size sheet, and the cost per label is negligible, so wastage is not a problem.

UP-MARKET

The more up-market approach to computer generated labels is to produce a complete overlay for the front panel. Modern wordprocessors, etc. have onscreen rulers that enable lettering to be positioned accurately on the page. With drawing programs you can add custom symbols and other graphics as well.

For the ultimate in durability the panel design should be printed as a mirror image on transparent film. When viewed from the "wrong" side the image is the right way round (Fig.3), and the lettering is protected by the transparent film.

Scotch "Spraymount" is suitable for fixing most transparent films to most types of front panel. Whatever adhesive you use it is advisable to make tests to ensure that it will not attack the film, or the panel if the case is a plastic type.

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Net Work

By Alan Winstanley

FRIED SPAM

SPAM stands for *Supply Pressed American Meat*, a familiar tinned meat (yum) dating back over 60 years, but thanks to the Internet it also implies another form of import which is unwelcome by almost every Internet user. The past few months have seen a major resurgence in the level of unsolicited commercial email (UCE) or "spam'' being received at my regular E-mail address.

Recently, a number of Internet users including myself have faced a real barrage of spam, in my case 30 or more per day at times. The spam is actually a Reject message sent to my default "postmaster" address. By checking a typical Reject message, it's possible to see what's really going on. An abbreviated header and message appears below:

——— Here is your List of Failed Recipients ———

<xxxxxxx@xxx.net>

———— Here Is Your Returned Mail ————

Received: FROM mail-gw.datawld.com BY vs.mail.xxx.net ; Wed Apr 12 08:47:22 2000

Wed, 12 Apr 2000 07:58:08 -0400

Received: from ppp-xx.tnt-1.hou.smartworld.net (HELO orl2786xN?) (xx.xx.xx.xx) by xxxxx.xxxxxxx.educ.xxxxxxxx.xx with SMTP; 28 Aug 1999 02:23:13 - 0000

DATE: 12 Apr 00 7:32:06 AM

FROM: AiVs85TN4@epemag.demon.co.uk

Message-ID: <402WavWnR1A1x4s3Vz>

SUBJECT: COMPLETE ONLINE BUSINESS!!!

Build a residual income from time you spend on the Internet placing FREE advertisements like this. Successful Internet company wants you to help them market their products and services online. To Register with the program and to begin receiving instructions, simply reply to this email and type your first and last name. mailto:xxxxxxx to be removed from this list

mailto:xxxxxxx@england.com?subject=remove

Many more examples of these messages started flooding in to my mailbox. This is because my domain had been forged as the original sender (see the FROM: line) by the spammer, who then proceeded to mail out thousands, if not millions, of similar messages in my name. Any messages which could not be delivered would be "rejected" and sent back to its "sender" (me).

Spammers often use "open relays" – third party mail servers which inadvertently allow spammers to use them from anywhere in the world in order to mail spam to its intended victims. By examining another Reject header very closely, an open relay at the University of Victoria, Canada, was found which was promptly reconfigured to close it. All of this policework takes time and effort though, and it often needs an expert to analyze the headers fully. The ORBS (Open Relay Behaviour-modification System) at **www.orbs.org** is a voluntary organization which provides online resources to help combat abuse of insecure mailservers by spammers.

HEADING FOR HOME

Looking further into the header, the interesting part is the line:

Received: from ppp-xx.tnt-1.hou.smartworld.net (HELO orl2786xN?).

Every forged Reject message contained a similar line, which starts to reveal the true identity of the spammer: it's a dial-up (PPP account) user of an American ISP called SmartWorld, who told me they were filing a lawsuit against the user.

Spam on this scale is bad for everyone: the huge volume of UCE damages the relationship between the originating ISP and its bandwidth provider, and it causes support problems for everyone concerned, including Demon Internet and SmartWorld. It blocks my email, and obscures genuine e-mails which get lost amongst the volume of UCE.

Unwanted spam places the burden of cost on everyone except the sender. It causes direct costs to be incurred in terms of

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wasted time, lost productivity and Internet access costs. In this case it also made my domain appear to be responsible for sending the spam.

These Reject messages were unremitting for several months and the sheer volume forced me to re-configure my email client. It was noticeable that almost always, the Reject messages had my genuine host name but the user name was randomized to bypass mail filters. In the above example, it was mailed to **AiVs85TN4@epemag.demon.co.uk**

My main Turnpike 5.0 mail software was reconfigured to only accept emails addressed to recognized email user names (e.g. **alan@epemag.demon.co.uk**); sure enough, Turnpike immediately began to report that messages were being rejected from my mailbox, meaning that at long last, I was starting to get my revenge. There is no problem in rejecting mail in this way, as it will hopefully get routed to a "bit-bucket" where the message will be scrapped.

Interestingly, the spam stopped just a few days later, although whether this was because the spammer finally took the hint, or whether he had been closed down, is unclear. However at the time of writing, complaints are appearing in Demon newsgroups of yet another forged UCE campaign starting up.

HOW TO FRY SPAM

There are some lessons to be learned from extreme cases like this. Learn to use the mail filter rules of your software. I use Microsoft Outlook Express 5.0 on my laptop, which is configured only to allow mail addressed to my recognized E-mail addresses.

This can be done as follows: go **Tools/Message Rules/Mail**.

1) Select the Conditions for your rule: [tick Where the To line contains people].

2) Select the Actions for your rule: [tick Do Not download it from the server].

3) Rule Description: [configure Where the To line does not contain "alan" or "arw" or "user" or "postmaster"]. Here, edit the rule's options then click the Options button in the "Select People" dialog box, to further customize the rule:

   – Apply Rule if Message does not contain the people below, and
   – Apply Rule if Message matches any one of the people below.

So if the To: line does not contain "alan" or "arw" or "user" or "postmaster" it will not be downloaded from the server.

Microsoft Outlook Express 5 arrives with Microsoft Internet Explorer 5. Its filter rules look complicated but they are written in plain English and are quite easy to use, but you will need to refine the rules over time. Test the filters by sending E-mailing to yourself.

It is worth reminding readers that **under no circumstances** should you ever reply to any email address contained in any spam message unless it's a genuine mailing which you subscribed to. Never email to ask them to stop, and never reply to the Remove-me address. Replying confirms your address is valid, making it a prized commodity amongst spammers (and worth more money).

You can also help combat UCE by forwarding examples (with headers) to the originating ISP (e.g. SmartWorld). They usually have an **abuse@** E-mail address so send it there, along with your polite comments. Remember you are dealing with tech support people at the other end who may be inundated with problems similar to yours, so keep your complaint reasonable.

My E-mail address is **alan@epemag.demon.co.uk** and you can check my web site at **http://homepages.tcp.co.uk/~alanwin**. See you next month.

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Special Review

PIC DR DAG REVIEWED

Robert meets DrDAQ and finds that apart from professional use he has enormous play value for the electronics hobbyist, and is eminently suited for anyone looking for an easy, inexpensive way into computer interfacing.

Pico Technology is a company that is best known for its PicoScope interfaces, which turn practically any PC into a storage oscilloscope. In fact the current software provides several additional functions such as frequency measurement and spectrum analysis.

The DrDAQ unit reviewed here could be regarded as a greatly simplified version of the PicoScopes. It is an analog-to-digital converter that connects to the parallel port of a PC, but it has a relatively slow maximum sampling rate of 10kHz to 15kHz, depending on the speed of the PC used. The interface has no built-in memory, but with such a modest maximum sampling frequency the PCs memory can be used if storage facilities are required.

Although high-speed sampling is not possible, this interface is still adequate for many purposes, such as measuring temperature, light levels, pH, etc. It can also be used for sampling audio frequency signals, albeit with a somewhat limited bandwidth.

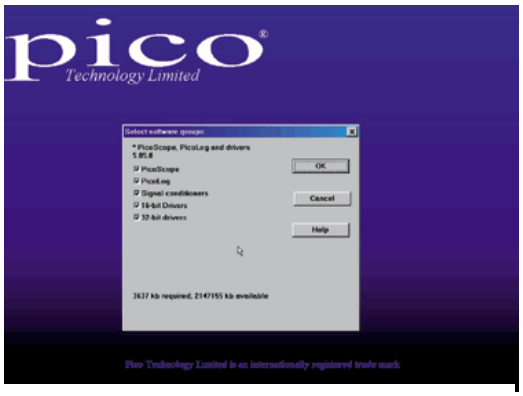

Fig.1. There are various installation software options to choose from.

GETTING CONNECTED

DrDAQ is primarily aimed at educational establishments, but it would also seem to be a worthwhile proposition for professional electronic engineers. At a VAT exclusive price of 59 UK pounds for the basic version, it is within the budget of many electronics hobbyists as well. The basic version comprises the interface and a parallel port connecting cable, plus two programs and the necessary drivers.

No power supply unit or batteries are required, because the interface taps off the small amount of power it requires from the parallel port. Consequently, getting the interface ready for use is just a matter of connecting one end of the supplied cable to the interface and the other to the parallel port of the PC. There is no through-port connector on the interface, so it will either require its own parallel port or a switching unit will be required to enable one port to operate with either the interface or a printer.

The interface unit is an uncased printed circuit board that seems to have most of the components on the underside, where they are hidden by a foam covering that ensures the unit will not scratch tabletops. On top of the board (Fig.2) there is the parallel port connector at one end, and three sockets plus a microphone at the other.

The built-in microphone enables sound waveforms to be displayed and sound levels to be measured. One of the input sockets is a BNC type that is

Fig.2. The uncased DrDAQ circuit board showing the parallel port connector, three sockets plus microphone. The underside components are hidden by a

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Channel	Range	Resolution	Accuracy
Sound Waveform	+/-100	0.3	--
Sound Level	55-100dBA	1dBA	5dBA
Voltage	0-5V	5mV	3% of FSD
Resistance	0-1M	100 ohms at 10k 400 ohms at 100k	2% at 100k
pH	0-14	0.02pH	Calibration dependent
Temperature	0-70C	0.1 at 25C	2 at 25C
Light	0-100	0.1	--

intended for use with a standard pH sensor. The other two are telephone style connectors that are intended for use with temperature sensors, etc.

There is also a light-emitting diode (LED) indicator and a 4-way connector block that provides a ground terminal, a digital output, and voltage plus resistance inputs. The LED and the output can be set to operate at a given threshold level so that they can be used in alarm and control applications.

Last and by no means least, there is a photo-resistor light sensor and a semiconductor temperature sensor. With three integral sensors the interface is clearly useful for a variety of experiments and applications even without any external sensors added.

SOFTWARE

The review unit came complete with three floppy discs containing the software, but the production units will have the software on CD-ROM. The software is compatible with Windows 3.1, 95, 98, 2000, and NT. Under Windows 98, the software loaded without any difficulty and the installation process follows along normal Windows lines. There are various installation options to select, such as choosing the programs you wish to install

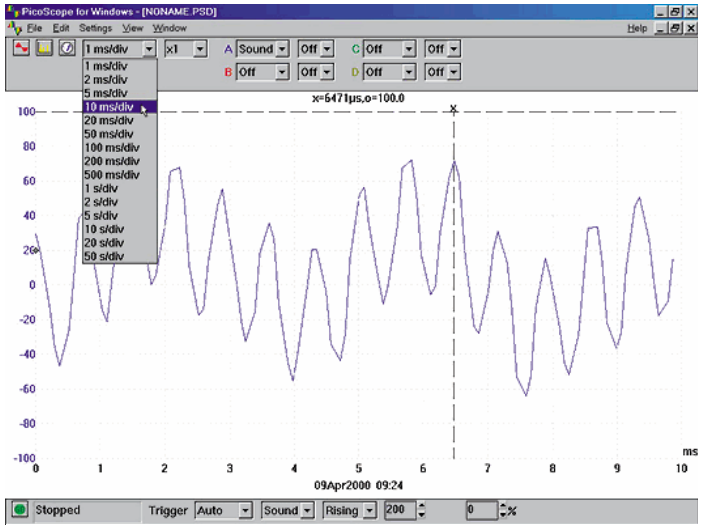

Fig.3. Selecting the PicoScope option lets you view audio waveforms or show temperature data.

(Fig.1), but simply selecting the defaults is all that will normally be required.

There are two applications programs provided, called PicoScope and PicoLog. PicoScope provides an oscilloscope style display and is used to display data gathered over a relatively short period, whereas PicoLog is primarily for gathering data over much longer time-spans.

PicoScope is therefore used for such things as viewing audio waveforms (Fig.3) or showing temperature data from experiments that produce rapid changes in temperature. PicoLog is used for an application such as logging weather data over a period of days.

PICOSCOPE

Starting with PicoScope, this is very similar to the software supplied with the Pico range of storage oscilloscope interfaces, but some concessions have to be made to the slower sampling rate of

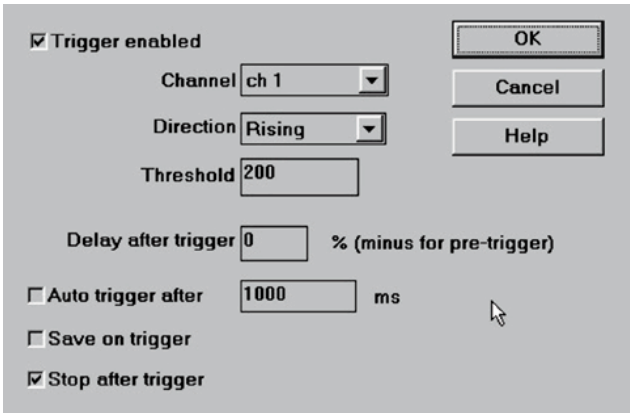

Fig.4. Trigger dialog box. Trigger options are: none (free running); auto; repeat and single, with adjustable trigger level.

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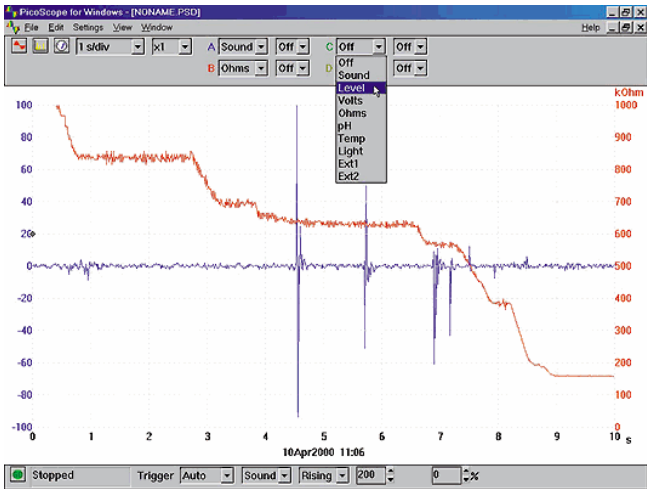

Fig.5. Using just two of the possible four traces (channels) can make it easier to follow what's happening.

DrDAQ. Accordingly, the fastest sweep rate is 1ms per division, but at the other end of the range the slowest rate is a generous 50s per division. A panel having a pop-down menu enables sweep rates to be selected, and the times are in the usual 1-2-5-10 progression, as can be seen in Fig.3.

The same method is used to select a multiplication factor from 1 to 200, and this enables part of the waveform to be viewed in detail. Of course, high multiplication factors are only a practical proposition at the slower sweep rates where there are enough samples taken to permit a magnified view.

Most things can be handled by the on-screen controls, but there are the usual pop-down menus and dialog boxes as well. For example, the Trigger dialog box is shown in Fig.4. The basic trigger options are none (free running), auto, repeat, and single, with a fully adjustable trigger level. The dialog box offers further options such as a preset delay, triggering on the rising of falling edge of a signal, and the channel used as the trigger source.

There are four channels available, and each one can be used to measure Sound (waveform or level), Volts, Ohms, pH, Temperature, Light, or one of the external inputs. It is possible to have all four channels operating simultaneously, with each trace drawn in a different color. However, results are easier to follow with just two traces, see Fig.5.

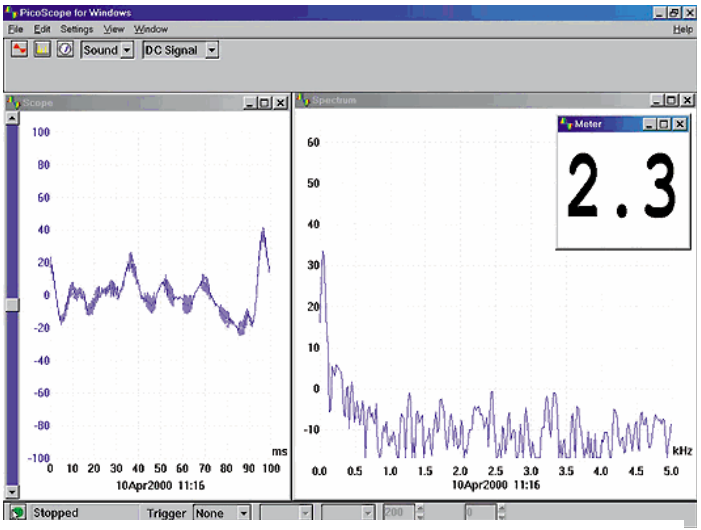

Fig.6. You can have two oscilloscopes in operation simultaneously or, as here, three windows each operating in a different mode.

The three buttons towards the top left-hand corner of the screen enable the required function to be selected. By default the program starts in oscilloscope mode, but the buttons enable oscilloscope, spectrum analyzer, and voltmeter functions to be selected.

Operating a button does not switch the current window to a new operating mode, but instead launches a new window. You can therefore have something like two oscilloscopes in operation simultaneously, or three windows with each one operating in a different mode (Fig.6). For this type of thing it is obviously advantageous to use a large monitor running at high resolution. The voltmeter and analyzer features are useful, but the abilities of the latter are severely restricted by the relatively low sampling rate.

The program has facilities for printing traces, etc. to any Windows compatible printer, and data can be saved to disk and exported via the clipboard. The clipboard enables data to be exported in graph form or as a text file containing a list of readings. There are various set-up options that provide control over the screen colors, maximum number of screen updates per second, and various other factors.

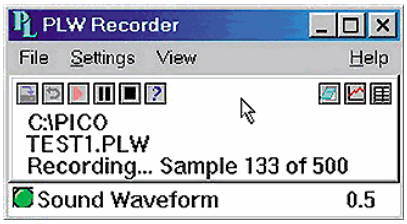

Fig.7. Setting up and selecting the record program.

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PICOLOG

By its nature, PicoLog is somewhat less straightforward to use. There are actually two programs, which are the recorder and the player. However, the recording program also has playback facilities, and is possible to log and analyze data without resorting to the playback program. We will only consider the recording program here. The playback facilities of the playback program seem to be much the same as those of the recording program.

A certain amount of setting up is required before the recorder is ready to do anything useful, and the software includes a "guided tour" that helps to get you started. The first task is to run the recorder (Fig.7) and then select a filename for the new data to be saved under. Then the Settings menu plus some dialog boxes are used to set such things as the rate at which data will be read, the maximum number of samples to be taken, threshold levels for the LED and digital output (where required), and the channel to be used.

Once the preliminaries have been completed the data logging can commence, and there are tape recorder style control buttons just beneath the main menu. These provide re-record, record, pause/resume, and stop functions.

The three control buttons on the other side of the screen are used to view data. The first button just brings up a simple text editor that can be used for notes. The other two buttons bring up the data as a table of results or a graph (Fig.8). There are various control buttons in the graph window that permit part of the graph to be expanded and viewed in detail, the graph to be printed or copied to the clipboard, and so on.

OPTIONAL EXTRAS

In addition to the standard kit, Pico offer a deluxe version that also includes two temperature sensors and one pH type. One sensor of each type is shown in Fig.10. The interface is apparently compatible with any standard pH sensor. The deluxe version costs 99 UK pounds plus V.A.T.

With PicoScope set to read the appropriate sensor or sensors it is possible to have a straightforward readout of temperature or pH values, and (or) a graph showing how the data changes over a period of time (Fig.9). The temperature sensors cover a range of –10°C to +105°C, and pH is measured over a range of 0 to 14.

Probably most professional users and experimenters will opt for the standard kit, but the deluxe kit seems to be a good choice for educational users.

CONCLUSION

The interface board is well built and getting it "up and running" is about as simple as it possibly could be. With built-in sensors the unit can be used for some simple experiments straight away. The price is good but not especially low for what is really a fairly simple interface, but the inclusion of the PicoScope and PicoLog software makes both the standard and deluxe kits very good value for money.

Both programs are sophisticated enough to be genuinely useful, but are still reasonably easy to use. It is only fair to point out that the programs reviewed here are beta versions that still have a few bugs and omissions, but this should all be sorted out by the time this review is published.

As pointed out previously, DrDAQ is primarily aimed at educational establishments, and it can certainly be recommended to those involved in teaching computer interfacing,

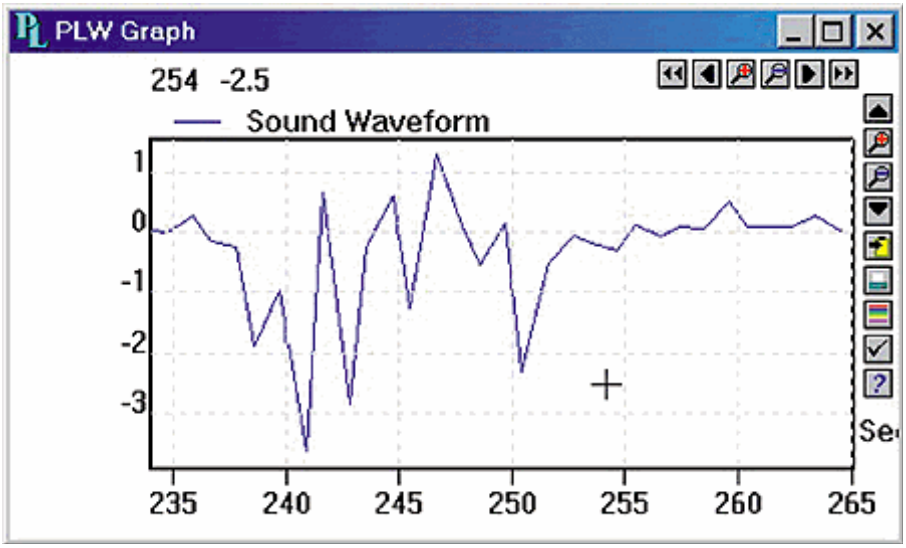

Fig.8. Test result sound waveform graph. Various control buttons in the graph window allow it to be enlarged, printed or sent to "clipboard".

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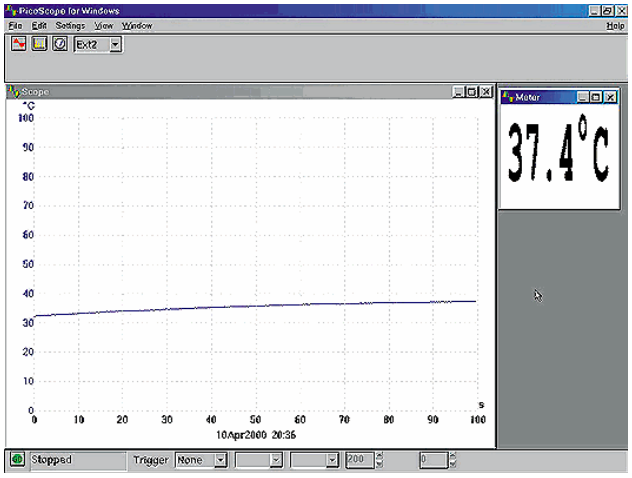


Fig.9. Graph showing how the temperature data changes over a period of time.

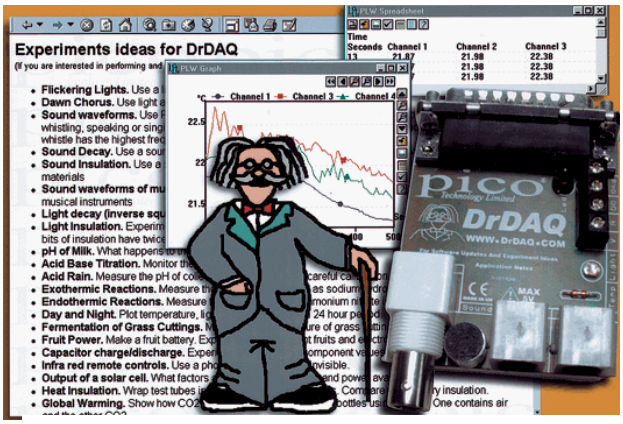
Fig.10. The two types of sensors: left, temperature sensor and right, pH sensor. Both types can be purchased separately.

or wishing to use computer based equipment when demonstrating appropriate scientific experiments. Incidentally, the Pico Technologies web site has details of numerous experiments that can be carried out using DrDAQ, and this information will be included on the CD-ROM included with the kits.

DrDAQ is also suitable for professional users requiring an inexpensive but effective analogue-to-digital converter, but only if they do not require high sampling rates. The DrDAQ kits have enormous play value for the electronics hobbyist, and are eminently suitable for anyone looking for an inexpensive and easy way into computer interfacing.

The DrDAQ standard kit costs 79.90 UK pounds (59.00 plus 9.00 for delivery within Europe, and VAT). The all-inclusive price for the kit with two temperature sensors and one pH sensor is 126.90 pounds, or 103.40 pounds with two temperature sensors but no pH type. Both types of sensor are available separately.

For more information contact Pico Technology Ltd., Dept EPE, The Mill House, Cambridge Street, St. Neots, Cambridgeshire, PE19 1QB, UK. Tel. +44 (0)



Some of DrDAQ's possible experiments.

1480-396395, Fax +44 (0) 1480-396296, Email **post@picotech.com**. Also, additional information and demonstration software, etc. is available from the Pico web sites at **www.picotech.com** and **www.drdaq.com**

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New Technology Updates

CAPACITOR SIZE AND STORAGE ABILITY ARE BEING DRAMATICALLY INFLUENCED BY AEROGEL FOAM TECHNOLOGY. IAN POOLE REPORTS.

Like many other areas of electronics, capacitor technology is being developed and as a result existing capacitor types are being greatly improved, and in other areas new types of capacitor are appearing. It is only necessary to look at a printed circuit board today to see the very small surface mount capacitors that are in widespread use.

Years ago all capacitors were leaded and very much larger. Now with the widespread use of surface mount technology capacitors are very much smaller. To achieve this has given capacitor developers some significant challenges. It has been necessary to squeeze very high levels of capacitance into minute packages and this has required new types of dielectric to be developed.

Whilst surface mount technology has been a major driver in pushing forward many developments in capacitor technology it is not the only one. Higher voltages, greater reliability and new applications have also played a major part.

POWER STORAGE

One such application is for a capacitor that is able to be charged up when a unit is under power and hold its charge to enable a memory to hold its data or for another device to operate if there is a power failure.

Rechargeable batteries do not always perform particularly well under these circumstances, and capacitors are an alternative. However they need to have very high levels of capacitance if they are to undertaken this function correctly.

Another application for high value capacitors is to store charge to enable high current pulses to be generated. Under these conditions the current pulses may damage the battery, if this is the source of the power, especially if the pulses are required frequently over a period of time, or the battery may not be able to supply the pulse satisfactorily.

Whilst the battery may be able to deliver the required power over a longer period of time, the high current pulse requirement means that a larger battery needs to be used, and space or weight constraints may preclude this. Unfortunately it often happens that both size and weight are of paramount importance in today's equipment.

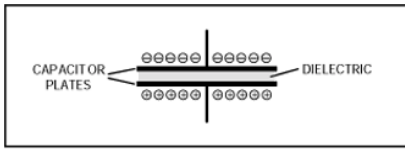

Fig.1. Representation of a "standard" capacitor.

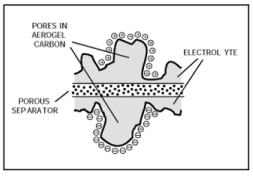

Fig.2. How charge is stored in an aerogel foam capacitor.

SUPERCAP

In applications such as these a new breed of capacitor known as *supercapacitors* or *supercaps* are being used. Although these components have been around for a while, new developments are improving their performance so that they can meet the demands being made on them.

In areas where the capacitors are used to supply current pulses, one of the most important attributes of the capacitor, apart from capacitance and working voltage is the equivalent series resistance (ESR). This is effectively the internal resistance of the capacitor, and if it is high it will tend to limit the current capability.

Cooper Electronic Technologies have developed a new type of supercap that achieves significant reductions in ESR when compared to other similar capacitors. This enables it to fulfil its role more efficiently than before.

The new capacitor is known as the PowerStor Aerogel capacitor. It is what is termed a double layer capacitor and has electrodes formed from a material called carbon aerogel foam. This foam gives a high electrical conductivity as well as providing a controlled ultra-fine pore size and it provides a high useable surface area for double layer formation.

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CONSTRUCTION

The construction of the new capacitor bears many similarities to both Lithium Ion batteries and to electrolytic capacitors (see Fig.1). A porous separator is placed between the two electrodes. This sandwich is rolled up and then inserted into a can. Electrolyte is then added and absorbed by the separator. The can is sealed and the electrodes added to the electrodes that protrude from it.

The electrodes are formed from the carbon aerogel foam. The charge is stored in this as shown in Fig.2. Here it can be seen that the porous nature of the foam gives a significant increase in the surface area that allows much greater levels of charge storage than would normally be possible with a conventionally manufactured supercap.

RESULTS

The chief advantage of the new material is that it provides a very low level of ESR. Typically it can give a value of only 15 milliohms for a 10 farad capacitor, whereas a comparable part made by more traditional means might have a value of 200 milliohms. Although these values may appear to be insignificant for normal electronics applications they are crucial when high levels of pulse current are required.

In addition to the low level of ESR the new capacitor has a low level of leakage, and this is particularly useful in applications where the capacitor has to hold its charge over any length of time.

In addition to supplying pulse currents, supercaps can be used to provide power in other areas where the current requirement is more even. Often rechargeable cells are used in this function, but they have a number of disadvantages.

Firstly they have a limited life. The quoted life of a cell varies from one type to the next and may be a few hundred charge–discharge cycles. With each cycle their maximum capacity is slightly reduced. Capacitors are able to undergo many thousands of charge–discharge cycles with no degradation in performance. Also they do not require the very careful charging methods that are required by many types of secondary cell.

The capacitors also have advantages over other large capacitance components. When compared to electrolytics, the supercap has a far greater capacitance for a given volume, and its leakage is very much less.

All of these attributes make it an ideal choice for applications where a “hold up” current is required. Here the capacitor can supply a small current of a few microamps or milliamps for a few hours or days, to keep a circuit operational after the main power has been removed. Typically a memory circuit or a clock may be required to remain operational under such circumstances. In these circuits the very high capacitance rather than the low ESR is the main requirement. The PowerStor supercap operates well under these conditions.

FUTURE

In view of the very high capacitance and low volume of these components, it is hardly surprising to note that the working voltages are relatively low. Components in this range are available with a working voltage up to 2·75V. However, the company expects to introduce a component with a working voltage of 5·5V.

Further information can be obtained from the Cooper Electronics Technologies website at **www.radio-electronics.com**

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TEACH-IN 2000

PART PART 9 – Transistors

by John Becker

With eight parts of our Teach-In 2000 series complete, we trust that you are gaining a good grasp of what makes electronic circuits function. We have covered various passive components, examined logic gate devices and other digital integrated circuits. You have also assembled and have been using a computer interface, which has allowed you to examine various waveforms generated by your experimental circuits.

In the last two parts it has been opamps that have been covered, allowing you to amplify and otherwise manipulate analog electrical signals. This month it is transistors we examine. These are not only the fundamental building blocks of any integrated circuit, but are still used as individual devices in many circuit designs. At the simplest level of understanding, they are not hard to use in a variety of ways.

At the heart of each active integrated circuit (IC) you have been using so far, whether it has been a digital inverter, logic gate, counter or opamp, is a collection of transistors, cleverly interconnected during manufacture to perform the function required. The same holds true for all the ICs you could encounter in any of today's electronic equipment.

The 74HC14 Schmitt trigger inverter you have made great use of through much of this *Teach-In* series has 60 transistors. The Pentium microprocessor in a modern computer has in excess of seven million!

Despite the multitude of ways in which many transistors can be connected together in single packages, transistors continue to find use as individual components in a variety of more simple circuits. It is appropriate, therefore, that you now dig into your components bag and pull one out for closer examination!

One marked BC549 is what you need (or the 2N3704 if you live State-side and could not get hold of the European type numbers from your local stockist – also see Panel 9.1). It looks like the three small devices at the bottom center of Photo 9.2.

As with opamps, we'll first run through a few experiments using this transistor, and then we'll don our Tutorial togas and discuss what you've found.

BASIC BITS FIRST

Strip out any components currently inhabiting your breadboard between columns 16 and 36, temporarily remove oscillator capacitor C1, but otherwise leave the oscillator and computer interface circuits intact. Then assemble the breadboard layout shown in Fig.9.1, referring to Fig.9.2 for the component values and the equivalent circuit diagram. The transistor is referred to as component number TR1.

Ensure that you plug in the transistor so that its shape matches the outline in Fig.9.1, noting the different outline orientation for the 2N3704 at the bottom of the figure. Like so many electronic components, transistors are very conscious about correct power supply polarities.

Indeed, we'll briefly digress and point out Fig.9.3b and Fig.9.3c. The former shows the pinouts (legouts?) for the BC549 and the 2N3704, as though looking at an angled view of the top of the transistor. Fig.9.3c shows them from underneath, which is the way most data sheets show them.

Whereas ICs have numbers allocated to their pins, transistor legs or pins are referred to by letters. Those for the type of transistor you're using now are lettered *c*, *b* and *e*, the letters standing for collector, base and emitter. You will see the same letters drawn within TR1 in Fig.9.1.

The circuit diagram symbol for this transistor, in Fig.9.3a, shows the same letters next to the schematic legs, note the ar-

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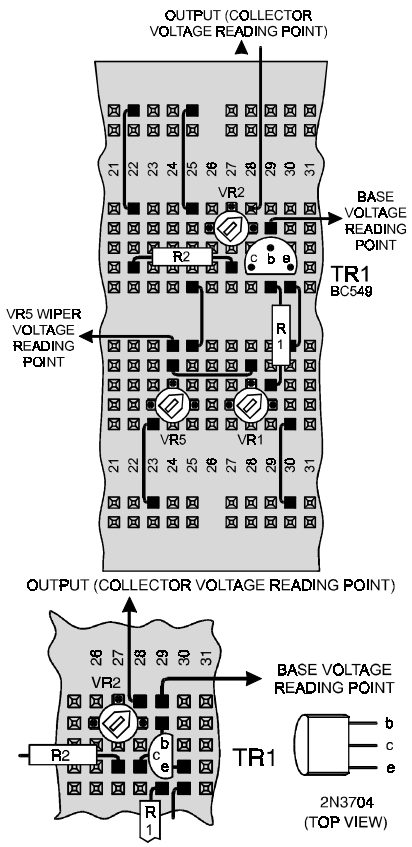

Fig.9.1. Breadboard layout for the first transistor experiment. Note the different orientation for TR1 depending on whether it is of type BC549 or 2N3704.

row, which indicates current flow direction. We'll say more on all this by-and-by.

DISCOVERY TIME

Before connecting your battery, and referring to Fig.9.1, set the preset wipers as follows: VR1 and VR2 midway, VR5 fully anticlockwise (wiper to 0V). Connect your multimeter between the point marked "Output" and the negative (0V) terminal of your battery. Set the meter for a DC range suited to monitoring up to 6V. Connect power to the breadboard in the same positions as in previous parts of Teach-In.

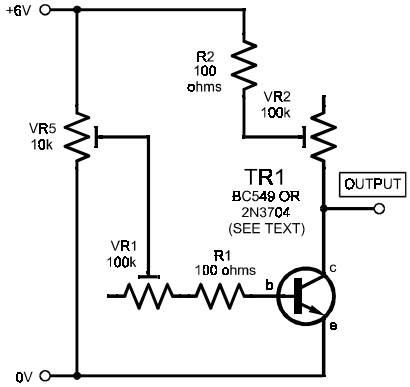

Fig.9.2. Circuit diagram for the first transistor experiment

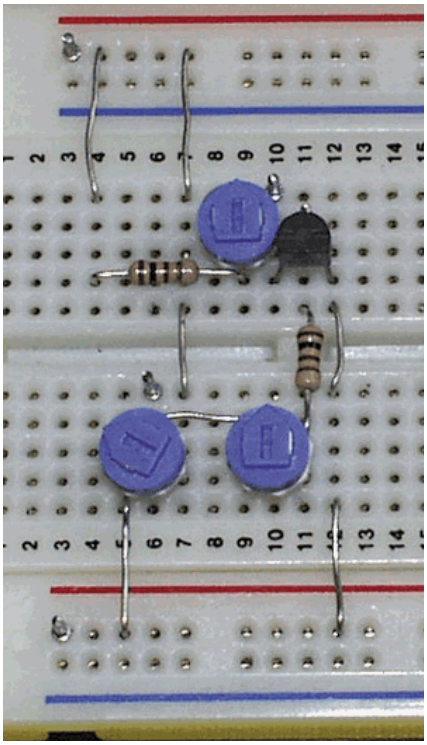

Photo 9.1. Detail of the breadboard using a BC549 transistor. Ignore column numbers.

Note the voltage reading you get at "Output" (the connection to TR1's collector, notated as "c"), it should be virtually the same as the voltage being delivered by your battery, about 6V or so. (It would be a good idea to check your battery as well – if it's delivering nearer to 5·5V, it's time to change it!)

Very slowly rotate the wiper

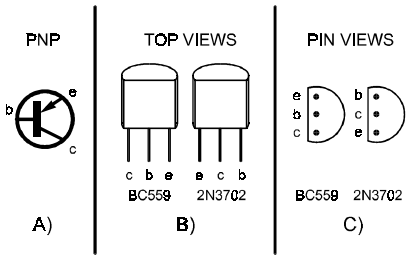

Fig.9.3. Symbol for an npn *transistor, plus pinouts for BC549 and 2N3704.*

of VR5 clockwise, while watching the meter. As the rotation gets to about one-tenth of full rotation, the voltage reading on the meter should begin to fall. There will come a point, not long after the wiper has passed the one-tenth position, that the voltage will read as 0V. It will remain at that level however far you now rotate the wiper towards the 6V end.

Rotate VR5's wiper anticlockwise until the meter reading just ceases to be at 0V. Disconnect the meter and read the voltages at VR5's wiper and at the transistor pin marked "b" (base). Make a note of these values.

Return the meter to reading the collector voltage. Continue rotating VR5's wiper anticlockwise until the meter reads just under the maximum power supply voltage. Again make a note of the voltage at VR5's wiper and at TR1's base.

Slightly rotate VR5 back a bit until the collector voltage reads about 3V (half the battery supply). The position is very sensitive. Once more note the wiper and base voltages.

Now, equally slowly, adjust VR2's wiper, first fully anticlockwise (maximum resistance between it and resistor R2), and then fully clockwise (minimum resistance between it and R2).

In the first instance, increasing the resistance will be accompanied by a reduction in the voltage at the collector, perhaps right

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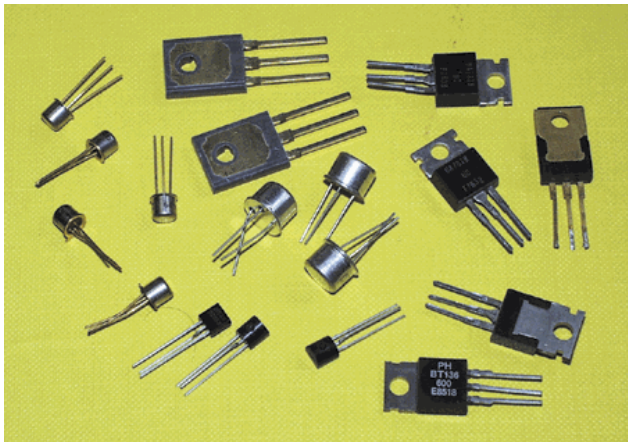

Photo 9.2. A selection of transistors and other related components. Many other case styles exist.

down to 0V. In the opposite direction the voltage will rise, back close to the power supply level, but possibly a little below it. Make a note of the voltage readings at TR1's collector and base when VR2's wiper is at the extreme ends of its travel.

Again return VR2's wiper to the position at which the meter reading is about 3V.

Preset VR1 is the next to adjust. Take a reading of TR1's base voltage before doing so. Maximum resistance between VR1's wiper (fully anticlockwise) and resistor R1 should result in an increase in the collector voltage reading; note it and the base voltage. Minimum resistance will probably decrease the collector voltage, perhaps even as far as 0V; again note it, and that at the base.

NOTED RESULTS

Cogs are probably turning in your brain right now, wondering about the meter readings you've noted down. Do they follow a pattern? If so, it's not a pattern such as you would have seen when examining the output of an opamp in response to voltage changes on its input, as we asked you to do in Part 7.

In the opamp experiments, within range limits discussed in that Tutorial, the results showed linear responses between the input and output voltages, even though amplification occurred.

What you should find studying your transistor voltage readings is that (within about 0·1V of the voltages we quote):

a) with VR5's wiper voltage below about 0·6V (minimum bias voltage level), the collector voltage remained close to 6V, irrespective of the settings of VR1 and VR2.

b) with VR5's wiper above about 0·7V (maximum bias voltage level), the collector voltage would not decrease below a certain level, that level being dependent on the setting of VR1 and VR2.

c) with VR5's wiper set about half-way between the minimum and maximum bias voltage readings you made (midway bias), the collector voltage could be set for varying levels, but again dependent of the settings of VR1 and VR2.

d) the voltage at TR1's base never exceeded a voltage of about 0·7V, irrespective of how high the voltage at VR5's wiper became.

e) with VR5's wiper set for midway bias and VR1 set midway, increasing the resistance of VR2 (collector resistance) decreased the collector voltage, and vice versa.

f) with VR5's wiper set for midway bias and VR2 set midway, increasing the resistance of VR1 (base resistance) increased the collector voltage, and vice versa.

g) You may well have found that, whereas we state minimum and maximum bias voltage levels of 0·6V and 0·7V, your observed readings may be different, e.g. minimum of 0·5V and maximum of 0·6V.

From these facts, and the knowledge you've gained in earlier parts of this series, you should now be able to deduce that:

h) a change in current flowing through VR2 must occur in order to comply with the observed fact that its collector voltage can be changed depending on the settings of one or more resistances (VR1 and VR5).

i) a change in current flowing through VR1 must occur since the base voltage can never exceed about 0·7V, even though the voltage supplied by VR5 can be raised well above 0·7V.

j) when the base voltage is below about 0·6V, the voltage at the wiper of VR5 has the same value.

k) from (j), there is no current flowing through VR1 when the base voltage is below about 0·6V.

l) when no current is flowing through VR1, no current flows through VR2.

m) your min/max bias voltage range may be below that which we state (or even a bit above).

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RAW NATURE

Two basic facts about transistors emerge from these observations:

1) a minimum base voltage (in the region of about 0·6V) must exist before current will flow through the base resistance.
2) the current flowing through the base resistance determines the current flowing through the collector resistance.

In essence, the second fact sums up the entire nature of a transistor. It is a *current amplifier*, purely and simply. The fact that you have observed *voltage* changes in respect of *current* changes is a by-product of current amplification.

Typically, for the tran- sist or type you are using now, the current amplification (gain) might be about 100, thus 1mA flowing into the base would cause a current of 100mA to flow into the collector (assuming the resistance through which it flows will allow this amount of current flow).

GAIN TERMINOLOGY

There are two "official" terms given to a transistor's gain factor: h_{FE} and h_{fe}. The former refers to large signal (DC) forward current gain, and the second to small signal (AC) forward current gain. However, the complexities of the difference are outside the scope of what we want to demonstrate. It is h_{fe} which is quoted in most data sheets and catalogs and is the value which we shall use here (even though purists may at times regard its use as an oversimplification).

Whenever you see h_{fe} stated for a transistor type, the value given is the *expected* gain provided by a *typical* transistor of that type. However, as with other component values, the gain is subject to a tolerance factor. The BC549 has a quoted h_{fe} range of 110 to 800. The 2N3704 has a range of 100 to 300.

CURRENT FLOW

You are no doubt wondering about where the current flows, the answer is simple. Base current flows into the base and out through the transistor's third leg, the emitter (e), but it does not flow through the collector. The collector current flows through the transistor and also out through the emitter (but not through the base). The total current flowing out through the emitter is thus the total of the base and collector currents.

The fact that a minimum bias voltage is required before current amplification can occur is something of a stumbling block, however. The problem is that the region is very narrow

PANEL 9.1 – IDENTYFYING TRANSISTORS

The American labeling system for transistor identification uses the prefix '2N' followed by four numbers. The European system for labeling standard transistors consists basically of two letters followed by three numbers. Transistors for special applications are identified by three letters and two numbers.

The first letter indicates the material from which the transistor is made:

A = germanium
B = silicon

The second letter indicates the typical area of use:

C = low power, low frequency
D = power, for low frequency
F = low power for high frequency
L = power for high frequency
P = phototransistor
S = switching transistor for low power
U = switching transistor for high power

The third letter, where included, does not generally have any particular significance, apart from manufacturer's identification. There is no coding used to indicate whether a transistor is an *npn* or *pnp* type, or whether it is bipolar or field effect, etc. (see Panel 9.3).

Bipolar transistors may also have a letter which follows the number, such as A, B, C or L. Letters A, B and C indicate the maximum amount of gain (amplification) which can be expected from a bipolar transistor, it is usually quoted in data sheets as a range within which the gain can be.

Suffix C indicates a gain greater than that for suffix B, which in turn is greater than for suffix A. Transistors without a suffix can have a gain anywhere between the extremes. Suffix L is not a gain code, it is a pinout orientation code.

Transistor specifications cannot be identified through the type number. These facts can only be identified from data sheets and catalogs.

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between the bias voltage just about causing current to flow through the collector (causing the transistor to begin to conduct or turn-on), and it allowing maximum current to flow. The range is also somewhat unpredictable, from three points of view.

First, the actual voltages concerned vary slightly, not only between transistors of different types, but also between individuals of the same type.

Second, the current flowing between the base and emitter is not just a product of that being allowed through by the base resistance, it is subject to a more fundamental fact of nature. Here, though, we are in danger of now peering into the awesome abyss, which holds the fundamental secrets of the universe, life and everything!

So we'll avoid that route and its discussion of electrons, holes and carriers and the like. Sufficient to say that at very small values of bias applied to transistor's base, the current flowing between the base and emitter has an essentially unpredictable value, and can change exponentially in respect of minute linear increases in bias voltage. The graph in Fig.9.4 illustrates this.

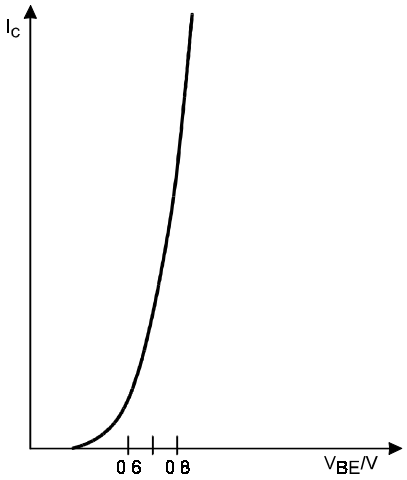

Fig.9.4. Variation of transistor base-emitter current with changes in base voltage.

TAMING BEHAVIOUR

Happily for us all (and the electronics industry), there comes a point once the bias has risen sufficiently high into the "turn-on" region, that further increases of current flow into the base-emitter path (junction) are responded to by linear increases in the current flow through the collector-emitter path, but amplified by the gain factor of the transistor.

Thus, in order to tame a transistor's behavior, it is only necessary to set up a basic bias voltage on its base, somewhere between the minimum and maximum turn-on levels, and then further changes in bias current will be responded to as linear current gain through the collector-emitter path.

Of course, once we have predictable current gain, we can think about what values of resistance in the collector path can be used to produce voltage changes in respect of current changes on the base. Which is where Ohm's Law comes in handy again: V = I x R.

The third problem to be considered about the circuit in Fig.9.2 is one we have mentioned several times throughout this series – temperature. The characteristics of a transistor are heavily dependent on its temperature. For example, the current flow into its base-emitter junction is likely to rise as the temperature rises, either due to the temperature of the transistor's surroundings, or due to internal heating caused by the current flowing through the collector-emitter path.

In both cases, the result is that the increased current flow through the transistor will cause the voltage at the junction of the collector and its resistor to fall.

In extreme circumstances, particularly when there is no limiting resistor in the collector path, a situation known as thermal run-away can develop, in which the increased current flow causes increased heating, which causes yet further increases in current flow, and so on until the transistor gets so hot that it dies.

You can prove that a transistor's response is temperature dependent (without endangering it) in a very simple experiment:

Still referring to the circuit on your breadboard, first set VR5's wiper so that the collector voltage is a little below the power line maximum. Now warm your thumb and first finger against the side of a hot tea cup (or coffee cup if you prefer!). Then grip the transistor's plastic body to transfer heat to it. Observe the meter while doing so. The collector voltage will be seen to progressively fall as the transistor gets warmer.

Remove your fingers once you've seen the principle, whereupon the transistor will start to cool, allowing the collector voltage to rise again.

When you get a moment, see if you can plot graphs of the rate at which the collector voltage changes with time and temperature.

DEMO PROGRAM

Time to bring our virtual guns into action – from the main program menu select *Transistors – Menu*.

On selecting this option, you will be presented with a sub-option menu, devoted to the transistor demos. As part of this screen is a text which briefly reminds you that some transistor responses can be a bit unpredictable, and that the demos are just generalized guides to their

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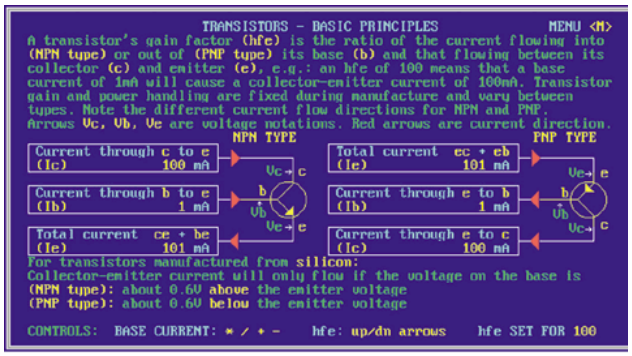

Photo 9.3. Interactive demo screen which illustrates the basic transistor principle.

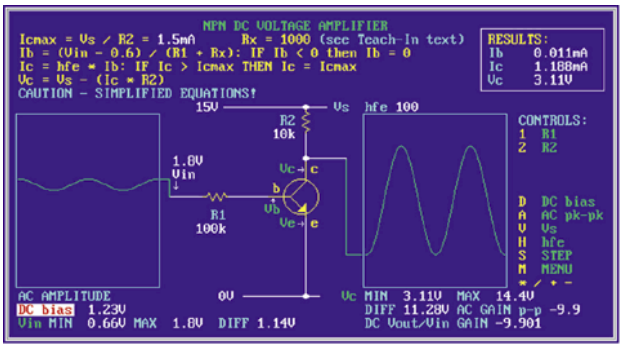

Photo 9.4. Interactive demo screen which illustrates DC voltage amplification.

behavior.

Selecting the first option, *Transistors – Principle*, reveals another screen which shows you a theoretical transistor's response to varying levels of input current (see Photo 9.3).

You will quickly spot, though, that there are two transistor outlines, not one. The reason is that the transistor you are using now has a mirror-image "twin". Yours is known as an *npn* type and as such has its collector and emitter connected across the power lines as shown in Fig.9.2 and implied on the left of the screen display.

The second transistor is known as a *pnp* type and functions with an opposite polarity to an *npn*, the emitter nearest to the positive line, collector nearest to the lower voltage (e.g. 0V) line. This is illustrated in the right-hand screen outline. Both transistor types belong to a general family known as bipolar. It is a term that describes the manufacturing process.

Although most of our discussions are concerned with *npn* types, later we shall briefly describe and ask you to explore an example of a *pnp* type in operation. Basically, a *pnp* transistor is used the "other way up", and is biased accordingly.

The Principles screen dislay

PANEL 9.2 – BIPOLAR TRANSISTOR ABBREVIATIONS

When you examine the data sheets or catalog details for bipolar transistors, you are likely to find a large number of columns and abbreviations describing each transistor's characteristics. Until you are more fully knowledgeable about other aspects of electronics, you can usually ignore most of them, with the following exceptions:

- o) Type – *npn* or *pnp*
- o) Material – Silicon or germanium (silicon transistors are far more widely used than germanium, the latter having become largely obsolete). The transistors used in this *Teach-In* are made from silicon.
- o) Pinout – The order in which the transistor's pins are arranged.
- o) $h_{fe(typ)}$ – Gain (amplification factor), usually specified as a typical range within which the actual gain could be, and often quoted in relation to a specified current at which that gain occurs.
- o) $V_{CEO(max)}$ – Voltage maximum which can be applied between the collector and the emitter.
- o) $IC_{(max)}$ – Current maximum which can safely be allowed to flow through the collector/emitter path.
- o) P_{TOT} – Power total which the transistor can handle, the product of the voltage across the collector and emitter and the current flowing between them.
- o) $f_{t(typ)}$ – Frequency up to which the transistor can typically operate before signal degradation occurs.

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is interactive, use the control keys stated.

NPN DC AMPLIFIER DEMO

Sub-menu option two, *NPN DC Voltage Amplifier*, illustrates a simple form of the circuit you have been experimenting with. It has been stripped to just two resistors, base and collector, plus a variable DC base bias voltage (see Photo 9.4).

We mentioned a few paragraphs earlier that transistors can die if too much current flows through them. This is why in addition to presets VR1 and VR2 in Fig.9.2, we also have fixed resistors R1 and R2. The purpose of these is to limit the maximum current which you can cause to flow through the transistor, and so avoid killing it through carelessness.

With the demo screens there is no chance of you killing the virtual transistors. You can stick as much voltage or current through them as you wish!

On entry to this demo, the bias voltage is set just below a theoretical turn-on voltage of 0·6V (at 0·56V). There are a number of control options allowing principal factors to be changed, including the ability to use either a steady DC voltage or a sine wave as the input voltage. All control options are itemized on screen, as usual.

To bring in the sine wave input, first press <A> to highlight AC Amplitude. Then press the <*> key a few times to increase the waveform's amplitude. At low amplitudes you won't see it as a sine wave because of the screen resolution, but the calculations which are performed assume that it is sinusoidal.

Note how the output shape of the amplified waveform is very sensitive to both base and collector currents. It will frequently show the same "clipping" characteristics that you encountered when examining opamps.

In a real life situation, transistors used in the manner demonstrated now are extremely difficult to bias so that the output waveform retains the shape of the original. The response is also very dependent on temperature.

Where this circuit finds considerable use, though, is as a switch. The voltage at the collector is very easy to be caused to swing between the two extremes of fully on or off in response to an input voltage swinging above and below the 0·6V turn-on threshold.

Two particular applications for this are in raising a low amplitude input waveform to a maximum power line level swing, and in switching on and off such hardware as relays. In the latter case the relay coil (electromagnet) is used in place of resistor R2 (sorry, but relays will not be examined in this Teach-In series).

CALCULATIONS

Be aware that the controlling program which simulates the transistor's response is only a simple model of what actually happens in a real transistor. For example, the base bias voltage range we discussed earlier is not allowed for, the "turn-on" bias being taken as exactly 0·6V. Neither has the varying current-dependent base-emitter resistance been simulated. It has been taken as a fixed value of 1000 ohms. In real life, the actually value can be vastly different.

However, we have not provided these demos as design tools, there are many excellent commercial software programs which provide such facilities. We are simply demonstrating the most elementary characteristics of transistors.

Listing 9.1

```
10 Icmax = Vs / R2
20 Rx = 1000
30 Ib = (Vin - 0.6) / (R1 + Rx)
40 IF Ib < 0 THEN Ib = 0
50 Ic = hfe * Ib
60 IF Ic > Icmax THEN Ic = Icmax
70 Vc = Vs - (Ic * R2)
```

At the top of the screen are shown the command lines which are used within the full QuickBASIC program to perform the calculations whose results you see displayed, as repeated in Listing 9.1 (but with line numbers to aid our description of it).

The program performs the interpretation of the basic simple formula:

Vc = Vs – (Ib x gain x R2)

where:

Vc = collector voltage

Vs = positive power line voltage

Ib = base bias current

Let's quickly run through the command lines:

10. The maximum current (Icmax) which can flow through the transistor is limited by the value of resistor R2 in relation to the power supply voltage, Vs.
20. Rx represents the base-emitter resistance referred to a moment ago, and is set for a nominal value of 1000 ohms.
30. Ib represents the current flowing into the base. This is determined by the input voltage (Vin) minus the 0·6V transistor turn-on voltage, divided by the total value of the base input resistance, consisting of R1 plus the base-emitter resistance Rx.

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The basic formula here, as you will recognize, is I = V / R (Ohm's Law).

40. Purely for the program's benefit, current into the base is not allowed to fall below zero.
50. The basic collector current (Ic) that can flow, without the presence of R2, is the base current (Ib) multiplied by the transistor's supposed gain.
60. For the program's benefit, if the calculation result is greater than resistor R2 can allow (Icmax), the result is limited to that value.
70. The current (Ic) flowing through R2 and the collector determines the voltage that appears at the collector (Vc). This is calculated by multiplying Ic by R2 and subtracting the answer from the supply voltage, Vs.

At the top right of the screen are shown the intermediate results for Ib, Ic and Vc. They are those for the immediate value of Vin, as shown to the left of R1.

In the full program the calculations are repeatedly made for each voltage value being supplied to resistor R1, and plotted on screen as the output.

It is important to note that the actual overall gain (amplification) given to a voltage or current, steady or varying, is not necessarily the same as the transistor's quoted gain value. It is limited by the collector resistance and whether or not the output signal becomes clipped.

Incidentally, when the input current causes the collector voltage to fall to the same voltage as on the emitter (in this case 0V), the transistor is said to be

PANEL 9.3 TRANSISTOR TYPES

Bipolar transistors

The simplest type of transistor is known as a *bipolar* transistor and it has three connections, referred to as the *base*, *emitter* and *collector* (usually abbreviated to *b*, *e*, *c*).

There are two fundamental types of bipolar transistor, *npn* (think of it as negative-positive-negative) and *pnp* (think of it as positive-negative-positive). These terms describe the internal construction polarity between the junctions of collector, base and emitter.

Current through a transistor's principal terminals, the collector and the emitter, should only be allowed to flow in one direction: from collector to emitter for *npn*, from emitter to collector for *pnp*.

For silicon *npn* transistors, base current must be supplied at a minimum voltage level of around 0·6V above the voltage at the emitter before it will "turn-on". For silicon *pnp* transistors, the turn-on voltage is about 0·6V below the emitter voltage.

For germanium transistors (now seldom encountered), the voltage differential is about 0·3V.

This differential can sometimes make transistors easy to check in circuit: if the voltage differential between the base and emitter is ever well above the "normal" level, the transistor is dead.

Field effect transistors

Field effect transistors (FETs) do not require current flow in order to be "turned on". Instead, this control occurs in response simply to the presence of a voltage (electrical field) on their control electrode (pin), the value of the voltage determining the amount of current which can flow through the transistor's main path. (There will be a small amount of control current consumed, but it will be so extremely small that it can essentially be discounted.)

FETs have three terminals, *gate*, *source* and *drain*, which are the equivalent of the bipolar base, emitter and collector, respectively. (In this context, the term gate should not be confused with a gate as used in logic circuits.)

They are available as two basic types, known as *n*-channel and *p*-channel. They are (usually) as conscious of their electrical orientation in respect to power line polarities as bipolar transistors.

Darlington transistors

Darlington is the name given to a configuration of two transistors connected as shown in Fig.9.5 (upper right), and combined in the same package. The first transistor has high gain characteristics, while the second is capable of passing high currents.

Because there are two base-to-emitter junctions in series, the turn-on voltage for a Darlington is twice that of a single bipolar transistor, i.e. about 1·2V to 1·4V.

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PANEL 9.3 TRANSISTOR TYPES cont

Phototransistors

Phototransistors conduct current when exposed to light. They belong to the optoelectronics class of components. Other members of the category include any device that responds to light falling on it, or emits light, or displays information in a controllable manner. Examples of the latter two groups are light emitting diodes (LEDs) and liquid crystal displays (LCDs).

Thyristors, triacs and diacs

Thyristors, triacs and diacs are three of the principal components in the area of power electronics, where the switching of large currents and high voltages is involved. However, they can only block and conduct current, they cannot be used to amplify it. Strictly speaking they are not classified as transistors.

Thyristors can be used to control AC or DC power; triacs and diacs are principally intended for AC power control.

Thyristors and triacs are manufactured for switching currents which can range from a few hundreds of milliamps to several thousand amps and to voltages well over 1000V.

Unijunction transistors

A unijunction (UJT) or filamentary transistor has two bases, B1 and B2, and an emitter. It is principally used in thyristor and triac firing circuits.

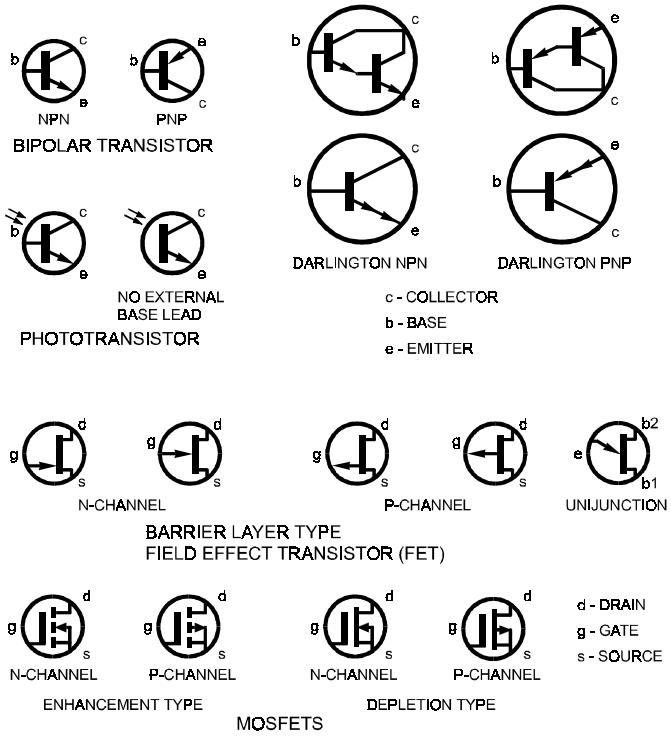

Fig.9.5. Circuit symbols for the various forms of transistor types.

saturated.

As previously said, if you press <A> and then the <*> or <+> keys you can cause a waveform to be input to TR1 via VR1. For the most part the output will be seen to be an amplified, but inverted, version of the input but with clipping on its upper peaks. This can be adjusted by changing the DC bias voltage (use <D> and then the <* / + –> keys).

Experiment with this for a while, also changing the values for R1, R2, h_{fe} and the power supply voltage. You will find that, whilst the shape of the waveform can be made to follow the input more adequately, it is not easy to select the right combination of the changeable parameters.

What is much easier, though, is to set high gain values and achieve full maximum to minimum output voltage swings. This bears out our previous statement that this circuit is more suited to switching rather than waveform amplification.

IMPROVED AMPLIFIER

If you were to connect the triangle waveform from IC1a pin 1 (see previous parts of Teach-In) to transistor TR1 on your breadboard via preset VR1, with preset VR5 removed, you would find that the collector voltage would always be at 0V (fully saturated). The voltage from IC1a pin 1 never falls below 0·6V and so always keeps TR1 turned on.

As with the opamp circuit, though, we can isolate the transistor from the DC influence of the oscillator. Basically, this is again done by inserting a capacitor (call it C1) between the oscillator and the input to the amplifier (TR1 base, in this case), see

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Fig.9.6.

On the breadboard layout (Fig.9.7) we have also included an opamp buffer (not shown in Fig.9.6) between IC1a pin 1 and this capacitor, to prevent "loading the oscillator" (as discussed in Part 7). On its own, C1 might still not allow the input waveform voltage to swing adequately above and below the nominal 0·6V threshold. The signal level might cause TR1 to operate in its principally unpredictable bias region, in which the base-emitter resistance can vary greatly (as previously discussed).

What we can do, though, is to add an extra and greater fixed current flow into the base, which is just right to ensure that TR1 is primarily biased to operate in its more linear region. In this way, the incoming signal via C1, even if it is only very small, will cause the collector voltage swing to become a more faithfully amplified version of the input waveform.

EASIER BIASING

In this circuit, the bias setting using VR5 is also far less critical. The reason is that we have introduced resistance into the emitter path, using VR3 and R3.

The addition of emitter resistance creates two new situations. First, it allows a signal to be output at the emitter. Secondly, it raises the effective resistance between the base and emitter, so reducing the load that the preceding circuit experiences through its connection to the transistor's base. The transistor circuit is now said to have a higher input impedance.

An important point about the signal output at the emitter is that it does not provide an amplified signal. The output voltage

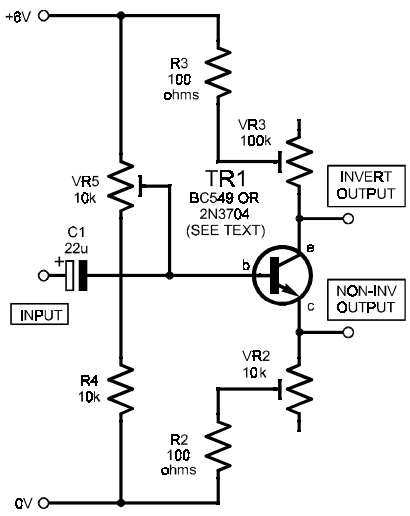

Fig.9.6. Circuit diagram for the AC coupled phase-split amplifier.

level will always have the same amplitude (minus a DC shift of 0·6V) as that being input, provided the latter never falls below the transistor's 0·6V turn-on voltage differential between base and emitter.

A second attribute, which follows on from this, is that the signal level is always the "same way up" as the original (as you were able to achieve with the non-inverting opamp configuration). The output is said to have the same phase as the input. In some respects, the emitter output can be regarded as the transistor equivalent of an opamp buffer.

Even though the emitter output is not amplified, the signal at the collector is still capable of being amplified according to the choice of collector resistance. It continues to be an inversion of the original, i.e. having an opposite phase.

PHASE-SPLIT AMPLIFIER

Because the circuit produces two signals of opposite phases it is sometimes known

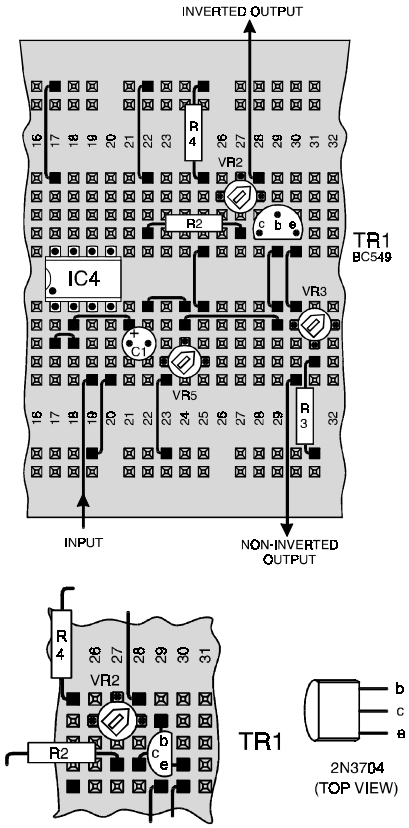

Fig.9.7. Breadboard layout for the circuit in Fig.9.6. Again note the different transistor orientation if using a 2N3704 instead of a BC549.

as a phase-splitter. This term is especially relevant when the gain is set so that the amplitude of the collector signal is the same as that at the emitter. Such a circuit is invaluable in a number of situations, one of which is in audio circuits if "push-pull" power amplification is required (offering greater power handling efficiency).

Before examining the breadboard setup of the phase-split configuration, let's again look at a computer demo. Select submenu option NPN Phase-Split Amplifier (see Photo 9.6).

When you experiment with the demo circuit, it will become obvious why the base bias setting is far less critical in this cir-

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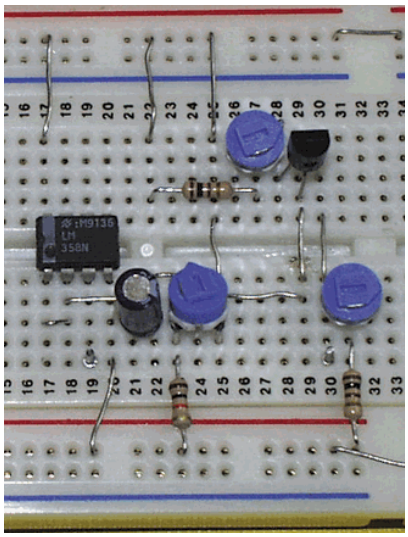

Photo 9.5. Detail of the breadboard using a BC549 transistor.

cuit. Whereas previously the bias had to be set precisely within the 0·6V region, we now have a situation in which a base bias voltage in excess of the nominal 0·6V will appear at the emitter, minus 0·6V. The emitter resistance "takes up the slack", so to speak.

This circuit is only for use with AC coupled input signals (the bias setting resistors would simply impose a greater load on a DC coupled circuit without actually providing the required bias).

When choosing the values for the potential divider R4 and VR5, we select them so that, in the absence of an input signal, the collector voltage sits at about the midway power line level, and the emitter voltage is just above 0V.

This ensures that the collector output waveform can swing evenly, and that the emitter output waveform never "bottoms-out" (never reaches 0V).

A further and really important point about this circuit is that the signal gain at the collector is, to all intents and purposes, *independent of the transistor's own gain factor.*

With this configuration, the actual gain applied to any waveform is simply defined by the formula:

gain = R2 / R3

This is not to say that h_{fe} is unimportant, it isn't. It plays a part in the impedance that the incoming signal's source sees, and in determining the bias voltage at the base, and hence the voltage at the emitter. However, in most circuits, the input impedance imposed by the biasing resistors will be lower than the effective base-emitter resistance and the latter can have less significance.

DEMO CALCULATIONS

In the control program for this circuit, the appropriate section of which is shown at the top of the screen, a lot of commands are required to produce a reasonable model of what happens.

First, the resistance (Rx) between the transistor base and emitter has been redefined to bring h_{fe} and the value of R3 into play. Again an assumption has been made about it having a predictable value which, as we have said before, is not necessarily the case in a real transistor.

For the sake of this demo, we have defined Rx as:

$Rx = R3 \times h_{fe} \times 100$

With R3 in play, but having the effective value Rx, the voltage at the base is set by the potential divider in which R4 is the upper part, and the lower part (Rb) comprising R5 in parallel with Rx.

Using the resistors in parallel formula (see Part 1):

$Rb = 1 / ((1 / R5) + (1 / Rx))$

Therefore the base voltage (Vb), in the absence of an input signal, is defined by using the potential divider formula, as:

$Vb = Vs \times (Rb / (R4 + Rb))$

Because there is a (nominal) voltage drop of 0·6V between the base and emitter, the emitter voltage (Ve) is thus Vb – 0·6 (providing, of course Vb is greater than 0·6V, if it's not then Ve = 0V).

The collector voltage (Vc) is then defined as:

$Vc = Vs - ((Vb - 0{\cdot}6) \times (R2 / R3))$

To establish the collector and emitter voltages when a waveform is applied via capacitor C1, its instantaneous value (Vin) is simply added to the value of the base voltage (Vb) in the equation defining Vb.

EXCESS INPUT VALUES

A curious fact is worth highlighting about the relationship between the collector and emitter voltages. It must be obvious that the collector voltage can never go below that on the emit-

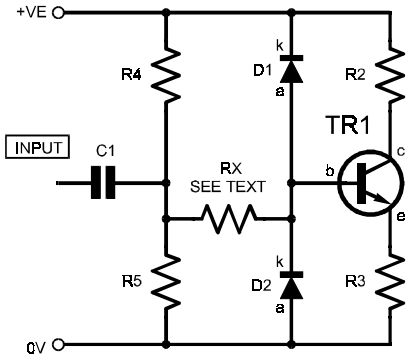

Fig.9.8 Using diodes to protect a transistor from excess input voltage

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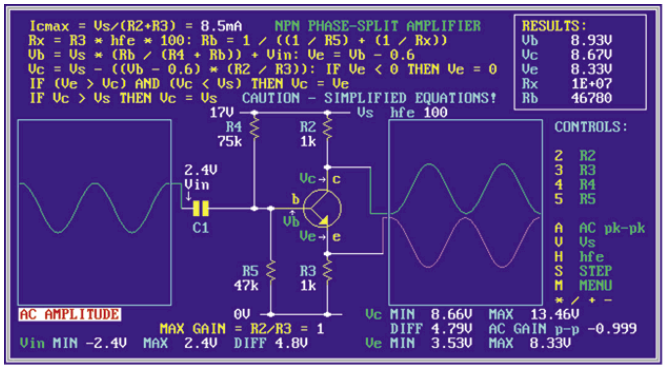

Photo 9.6. Screen dump of the interactive npn *Phase-Split Amplifier demo.*

ter, since the current flows through the collector to the emitter.

By the same token, one might expect that the emitter voltage will always be less than or equal to the collector voltage. Not necessarily so, as you can illustrate via your screen demo presently (using a very high input amplitude).

Suppose that the incoming signal has a positive peak value which exceeds the calculated collector voltage by at least 0·6V. The collector voltage cannot fall to its expected value, it can only fall to the same level as on the emitter. Consequently, the collector voltage waveform will take on an unexpected shape (see Photo 9.7).

The collector voltage begins to fall in the usual way as the input voltage starts to rise. Then, as the input level continues to increase, the collector and emitter voltages become equal. Further increases in the input voltage now cause the emitter voltage to rise higher still, and the collector voltage is also forced to rise.

In extreme circumstances, where the peak input voltage level exceeds the power line voltage supplying the transistor, the emitter voltage can actually rise above the supply voltage, although the collector cannot exceed it, the internal nature of the transistor preventing it.

To prevent the latter from happening, a diode (D1 in Fig.9.8) can be connected in parallel with R4, cathode (k) on the positive power line, anode (a) on the base of TR1.

A related problem exists if the input voltage level falls greatly such that a negative voltage appears on the transistor base. Whilst the transistor can withstand a certain amount of reverse bias (base less positive than the emitter) there are limits as stated in transistor data sheets. If these are exceeded, the transistor could die.

Another diode (D2 in Fig.9.8) can prevent this, using it in parallel with R5, anode on 0V, cathode on the base of TR1.

In both cases, excess voltage flows through the diode to or from the relevant power line. The voltage drop across each diode is about 0·7V (as discussed in Part 4) and the voltage on the base is limited to within ±0·7V of the power lines.

You are more likely to encounter circuits which use the negative-limiting diode (that across R5), rather a diode across R4. (CMOS integrated circuits have voltage limiting diodes between their inputs and the internal power connections to "short out" such excess voltages).

Note that the diode must be capable of handling the currents that are likely to flow in excess input voltage situations. In most cases, though, a diode such as the 1N4148 type you have been using in the oscillator circuit will provide adequate protection.

Also be aware that the diodes will place a load on the signal source if they are caused to conduct. In some cases it

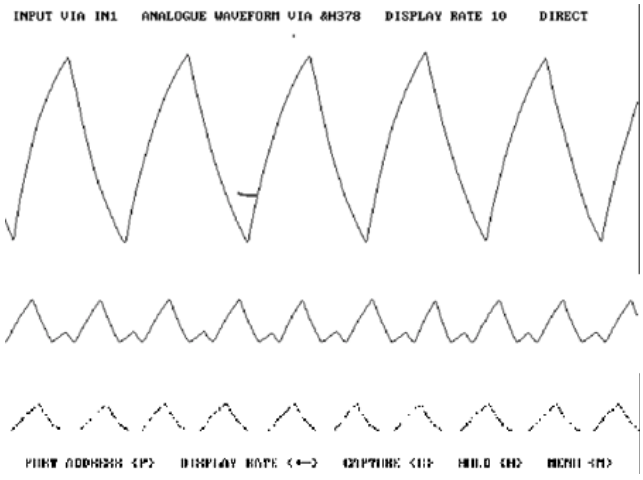

Photo 9.7. Composite screen dump of three transistor-amplified waveforms as monitored at the collector. Top, evenly amplified using correct base biasing. Middle, lower part of waveform distorted by emitter voltage rising too high. Bottom, base bias too low causing waveform to saturate ("bottom-out").

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PANEL 9.4 – CALCULATING RESISTORS

When deciding which range of resistor values to choose from in an amplifying circuit, the first matter you should consider is what load is going to be placed on the collector output by the circuit into which it feeds.

The resistance of the load forms a potential divider with the collector resistor R2 as its upper part. The voltage output at the collector can only ever have a maximum of the potential divider voltage. As discussed in other parts (e.g. Part 1), the load should have a resistance at least 10 times greater than the resistance of the significant divider arm, i.e. R2 should be at least 10 times less than the minimum load resistance.

Once R2's value is known, the other resistor values can be chosen to achieve the optimum biasing as discussed. Should doubt exist about any current requirements, assume a worst case condition and calculate accordingly. It is always better to have more current capability available than is likely to be consumed.

Always ensure that the components you use are capable of handling the currents and wattages required. Err on the side of caution in all cases and don't allow components to exceed their limits. Manufacturers' data sheets quote component limits and other parameters.

may be desirable to have a current-limiting resistor between them and the source (e.g. Rx as in Fig.9.8).

When you have assembled the split-phase circuit layout of Fig.9.7, experiment with the presets and observe the results on your computer (Analog Input Waveform Display) and meter.

NPN AC AMPLIFIER DEMO

A shortened version of the phase splitter which is well suited to AC coupled signal switching is demonstrated in the sub-menu selection NPN AC Voltage Amplifier. In it, the emitter is taken direct to the 0V line. We shall not discuss this demo, but let you explore it at your leisure.

TRANSISTOR BUFFER

We have commented on the emitter voltage retaining the same phase and amplitude as the signal on the base. What may not be immediately apparent is that the current available at the emitter is related not only to the resistance in the collector emitter path (R2 + R3 as in photo 9.6), but to the current gain provided by the transistor.

If we remove resistor R2, the total current flowing into R3 is the current flowing into the base times the gain (h_{fe}) of the transistor. The maximum current that can be allowed to flow into R3 is only limited by what the transistor can safely handle. In the case of the BC549, this is a maximum of 100mA; the 2N3704 can handle 800mA.

However, the "safely" term must also take in account the heat which will be generated within the transistor when that current flows, in other words, the wattage limits of the transistor must also be considered. The limits for the BC549 and 2N3704 are 625mW and 360mW respectively.

Note that more heat will be generated when the transistor is only *partly* turned on, rather than when it is fully turned off or fully turned on. This is due to the transistor offering resistance to the current flow when it is only partly turned on.

Recalling the derivative of Ohm's Law from Part 3, which states that P = I x V, where P is the power in watts, you measure the voltage drop between the transistor's collector and emitter, and the current flowing into the collector. From this you can calculate whether the transistor is safely operating within its current and wattage limits.

Another test that can sometimes be useful (if not very scientific), is to feel the transistor between your fingers. If it feels hot, then it is probably *too* hot, and the current flow should be reduced. With power transistors (those designed to handle high currents), metal *heatsinks* can be clipped or bolted to them to dissipate excess heat. That is another story, though, beyond the scope of this series.

The benefit of a transistor configured in this mode, known as *emitter-follower* mode, is that it can be used as a buffer to increase the impedance (resistance) seen by a preceding circuit, allowing the current-amplified signal to drive (feed into) a much lower resistance.

The mode can be used for AC and DC coupled signals.

CURRENT AMP DEMO

The demo program *NPN DC Current Amplifier* shows a simple circuit for a DC coupled emitter follower (with the collector resistor R2 omitted).

In the demo, emitter resistor R3 represents the resistance of the load (e.g. next circuit) into

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which the amplified current can be fed. The use of base resistor R1 is not always necessary.

The maximum current that *can* flow through R3 is expressed according to Ohm's Law, I = V / R

With R1 omitted, the current (Ie) which will flow through R3 is:

I = (Vb – 0.6) / R3 or

I = Ve / R3

For the demo calculations and with R1 included, Vb is calculated using the potential divider formula:

Vb = Vin x (Rx / (R1 + Rx))

where Rx = R3 x h_{fe} x 100 (using the same assumption as discussed earlier)

The program's calculation commands and intermediate results are again shown at the top of the screen.

Experiment with the program's options, and then return to your breadboard layout in Fig.9.6 for of the Split-Phase circuit and experiment there, concentrating on the emitter voltage when the collector resistance VR2 is at its minimum. If you wish, replace R2 and VR2 by a wire link between the collector and the positive line, but retain R3 and VR3 in the emitter path as a safety measure.

NEXT MONTH

In Part 10 we examine the theory of power supplies, including those operated from the AC mains. However, we shall not ask you to actually plug anything into the mains (other than your computer as usual!).

TEACH-IN 2000 – EXPERIMENTAL 9

As this month's first experimental suggestion, insert LEDs (light emitting diodes) into the emitter and collector paths in your breadboard assembly of Fig.9.7 from the Tutorial. Each should be placed between the relevant power line and existing 100 ohm resistor. An extra link wire will be needed for each of them.

Discover how the LEDs can give an indication of the transistor's response to different choices of circuit gain and signal bias.

Remember that a LED requires a voltage drop across it of about 2V. If the LED is placed between the emitter and 0V, how does this affect the base bias voltage required to turn it on?

Can you have LEDs in both the collector and emitter paths at the same time?

BUZZER CONTROL

Experiment with placing the active buzzer (one of the components you were advised to obtain in Part 1) into the collector and emitter paths, in place of the LEDs. Allow the oscillator frequency setting to vary the rate at which the buzzer is turned on and off. Which position of the buzzer produces the best response, in the collector or emitter path?

Reinstate diodes D2 and D3 in the oscillator circuit (see Part 4, Fig.4.1) and experiment with different ramp waveform settings, discovering how the buzzer's on-to-off periods can be changed. Try different values for the oscillator's capacitor C1.

AUDIO OUTPUT

If you insert your headphones into the collector or emitter paths (LEDs and buzzer removed), you can hear the frequency generated by the oscillator around IC1a. How does the base bias voltage setting affect not only the volume of the sound but also its quality?

Also try inserting a volume control preset between the transistor's input capacitor C1 and its base, referring to the circuit diagram shown in Part 8, Fig.8.13.

Next remove oscillator diodes D2 and D3 again, and replace D3 with a 100 ohm resistor.

Running the Computer as Frequency Counter program, connect the output of IC1a pin 2 to one of the computer interface inputs. Discover the range of frequencies that you can hear through the headphones. Use different values of oscillator capacitor C1 and settings for its preset VR1.

MIC AND SENSORS

With the opamps discussion last month, we explained how an electret microphone, a light sensor (LDR) and a heat sensor (thermistor) could be used with an opamp circuit.

We believe that now having worked your way through eight Tutorials, your confidence will be such that you can experiment

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with finding out how all three devices can be used with a transistor amplifier. With your headphones still in use, start off by putting the microphone into circuit.

Then, with headphones removed, experiment with the two sensors, monitor the response on your meter and the computer's waveform display program.

PNP CONVERSION

Now for another challenge (or more)!

Our discussions and demos in this month's Tutorial were all associated with transistors of the type thaty we referred to as *npn*. We mentioned that an "upside-down" version of this transistor type exists, that known as *pnp*.

With a *pnp* transistor, current flows from the emitter into collector, and from the emitter into the base. When the difference in the base bias and emitter voltages is less than 0·6V, the transistor is turned-off. A bias voltage difference greater than this turns the transistor on.

When turned on, the current flowing through the emitter-base path causes a current to flow through the emitter-collector path, amplified by the gain (h_{fe}) of the transistor. Apart from the different current flow directions, *pnp* and *npn* transistors behave identically.

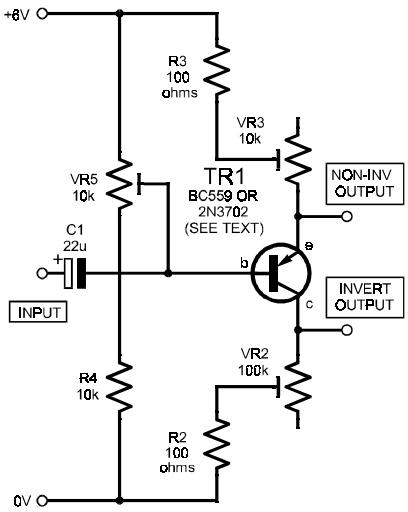


Fig.9.9. Circuit diagram for a pnp *Phase-split amplifier.*

In Fig.9.9 is shown the *pnp* equivalent of the *npn* phase-splitting circuit of Tutorial Fig.9.6. Compare the two circuits and observe how all component positions have been swapped between top and bottom to match the reverse emitter and collector positions. Their values, though, are identical for each circuit.

The *pnp* transistor you require from your bag is marked either BC559 or 2N3702.

The breadboard layout for the circuit of Fig.9.9 is given in Fig.9.10. Reassemble the board

PANEL 9.5 – PRINTER PORT PROBLEM

A few readers have experienced problems regarding the voltages obtained when their demo PCB is coupled to the computer via the Centronics printer port cable, in some cases experiencing negative voltages.

It appears as though there are at least three different wiring arrangements for Centronics cables, even though the fittings at each end are the same:

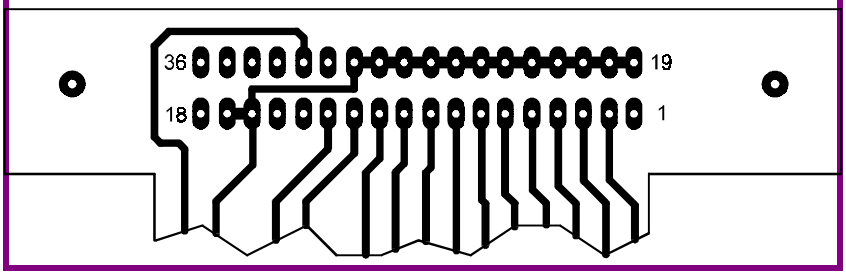
- o) Type 1 – No pins connected to ground, but case connected to ground.
- o) Type 2 – One pin only connected to ground.
- o) Type 3 – At least five pins connected to ground.

We were totally unaware that PC to Centronics printer port cables might differ. We have numerous such cables and all work interchangeably and we have never had to specify a particular type when purchasing new ones. It had been assumed that IBM PC-compatible computers would all be identically compatible in respect of parallel printer port connections.

The IBM data we have states that Centronics parallel printer connectors have 0V (ground) at the following pins: 16, 17, 19 to 30 and 33. The *Teach-In* interface board was designed to minimize the number of soldered connections that inexperienced constructors would have to make.

Consequently, only one 0V connection was incorporated, that being the one at the "front" of the connector.

Readers who are having problems which might be attributable to the printer port connection should try connecting all the 0V pins to the 0V pin already in use on the *Teach-In* board, as shown below. Solder connecting wire between all the 0V pins, ensuring that it is insulated against connecting to other pins.



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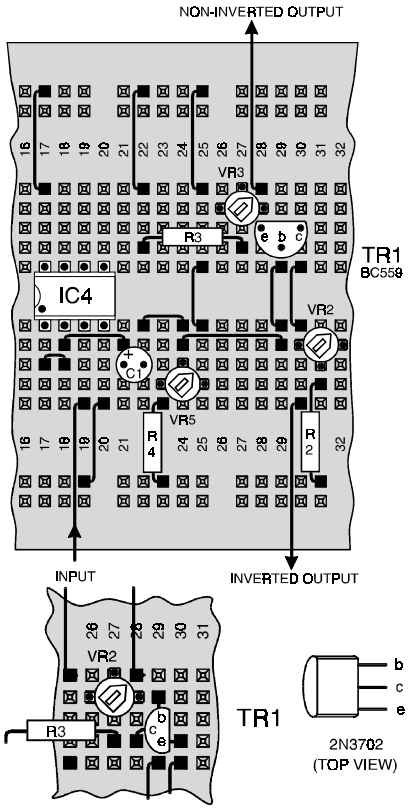

Fig.9.10. Breadboard layout for the circuit in Fig.9.9, again with choice of transistor.

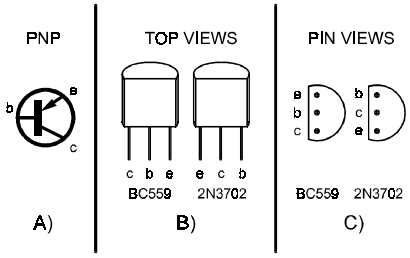

Fig.9.11 Symbol for a pnp *transistor plus pinouts for BC559 and 2N3702.*

to match this layout and perform the same experiments as you did for its *npn* counterpart. Use your meter and computer display to observe the results.

You might also care to experiment with the LEDs, buzzer and headphones insertion as you did for the *npn* circuit.

When you've spent a while at this, turn your attention back to Fig.9.1 and Fig.9.2. Reconstruct the breadboard in Fig.9.1 for use with the *pnp* transistor. It will help if you first redraw Fig.9.2 as a *pnp* circuit diagram.

Again check out your results on the meter and computer display.

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3G AND UMTS MOBILES

The new 3G mobile networks will offer higher data rate exchanges. Barry Fox looks at the figures.

The UK's recent 3G frequency auction was the first in the world, and earned the Treasury about 22·5 billion UK pounds. BT/Cellnet paid 4bn, Vodafone 6bn, Orange 4bn, One2One 4bn, and TIW of Canada 4·4bn. All the licensees must now pay a similar amount to build new networks.

The Isle of Man should provide a dry run, with the first service, promised by British Telecom (BT) and its subsidiary Manx Telecom, due to launch next year, a year ahead of the UK.

Frequency Limits

3G, third generation mobiles, will use the UMTS or Universal Mobile Telecommunications System, which is now an international standard, on higher frequencies than current systems (1900-1980, 2010-2025, 2110-2170 MHz). This allows for data rates of up to 2Mbits/sec.

But the actual data speeds on offer will usually be far lower, because of error correction overheads; 144Kbps for full mobility applications over wide areas; 384Kbps for limited mobility applications with 2Mbps used only for low mobility applications in very small cells.

The issue is further complicated because the licenses are for different amounts of spectrum, which will limit the bandwidth the operators can offer. New entrant TIW gets License A and a better chance of competing with existing operators who already have GSM 900 or DCS 1800 spectrum. TIW's License A is two times 15MHz paired plus 5MHz unpaired, License B is two times 15MHz paired and no unpaired, Licenses C to E are two times 10MHz paired plus 5MHz unpaired.

Paired Spectrum

"Paired spectrum" means that a slice of frequencies is set aside for the base station to use for transmission and another slice for reception, as with existing cellphones. Paired spectrum will be used with W-CDMA, wideband code division multiple access. This is a spread spectrum system where all users use the whole band, but their signals are digitally labeled.

Unpaired spectrum must be used for time division duplex (TDD) mode of CDMA working; a single frequency is used for both receive and transmit. This is how the digital cordless phone

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systems CT2 and DECT work. A chunk of data is transmitted, then a chunk received, then a chunk transmitted, and so on. The mobile stitches them together.

Although existing GSM/DCS1800 cellphone services run only at painfully slow 9·6Kbps (compared to 33·6Kbps or 56Kbps from a fixed line modem) there are two ways to accelerate GSM and DCS1800 data links. The irony is that the current operators are already working on this.

System Services

Last year, Orange was promising to launch a new service for Christmas called High Speed Circuit Switched Data, which hikes the speed to 28·8Kbps.

Rivals One2One, Cellnet and Vodafone were, however, waiting a year for completely different technology, called General Packet Radio Service.

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. Services are promised for September 2000, with speeds up to 56Kbps, rising to 112Kbps by 2001.

In March 2000 Vodafone claimed the "first public GPRS demonstration" at a trade exhibition in Birmingham, while BT announced GPRS roaming trials with AT&T in the UK, USA, Hong Kong and Taiwan.

Orange has been mysteriously quiet on HSCSD and in late April admitted that the Christmas service had still not been launched. According to Orange all the network modifications were in place by the end of 1999, but Nokia failed to deliver the PCMCIA cards that will plug into a laptop PC and connect to a phone.

In practice the difference between 144Kbps for 3G and 112Kbps for GPRS/GSM may not make much difference, because the limiting factor is more likely to be Internet congestion. MPEG-4 video will be possible at either speed. The key issue will be cost per minute on line and this will be controlled by the four existing cellphone operators and a newcomer crippled by high license and start up costs.

3G looks most unlikely to be cheap.

MOBILE PHONE EARPIECE SAFETY QUESTIONED

Which? discovers hands-free earpieces might _increase_ alleged radiation hazards. Barry Fox reports.

The recent auction of frequencies for third generation mobiles coincided with fresh questions on cellphone safety. While testing cellphone shields *Which?* also tested a couple of the hands-free earpieces (from BT Cellnet and Carphone Warehouse) that people use, either for convenience, to make driving safer, or in the fond belief that they protect the head from radiation. The results were so surprising that *Which?* did the tests again.

The connecting cords acted as vertical aerials, channeling three times as much radiation into the head. Holding the phone out sideways, so that the cord is horizontal, kills the radiation.

Whose Responsibility?

The BT Cellnet headset is not made by Cellnet. But that's no excuse. If anyone else started selling products marked BT Cellnet or Carphone Warehouse they could very soon expect to hear from the companies' lawyers.

This divided responsibility is the crux of the problem. If one company made both the phone and the headset we could hope that they had used filters to stop the radio signal going up the audio lead, and screened the lead to stop it radiating. As things stand responsibility is split.

Very possibly there are other kits that don't radiate. But so far no-one has spoken out with a test-based reassurance.

Graeme Jacobs, Editor of *Which?*, is very blunt about phone shields, too. "The ones looked at don't help, so if you're thinking of buying one, don't waste your money".

Testing the Allegation

Which? reminds that there is no scientific evidence that cellphones are dangerous. If they are, it will take years to prove. It will be even more difficult to reassure that there is no risk. Negatives are well-nigh impossible to prove.

The cellphone manufacturers have yet to take the blind-

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ingly obvious and easy step of putting the aerial on the bottom of the phone so that is in free space in front of the jaw, not flat against the head. Inverse square law would then drastically reduce the strength of the signal reaching the body.

BLUETOOTH BITES

Many moons ago we reported on how Bluetooth would provide a revolutionary standard for short-range wireless communication which is intended to replace cables connecting PCs to peripherals. Founded by global technology leaders, Bluetooth is supported by over 1000 organizations. Ericsson estimate that before the year 2002, Bluetooth will be a built-in feature in more than 100 million mobile phones and many millions of other communications devices. Bluetooth is effective over a 10 meter distance and line of sight is not required.

Brain Boxes have now launched and demonstrated the world's first working PCMCIA Type 2 Bluetooth module at the recent CeBIT 2000 fair in Hanover. The product becomes available in commercial volumes by June 2000. Amongst the other Bluetooth products to be launched will be a printer port to Bluetooth box, with support available in all Windows operating systems.

For more information contact Brain Boxes Ltd., Dept EPE, Unit 3c, Wavertree Boulevard South, Wavertree Technology Park, Liverpool L7 9PF, UK.

Tel: +44 (0) 151-220-2500

Fax: +44 (0) 151-252-0446

E-mail sales@brainboxes.com

Web: www.brainboxes.com

NEC Boosts Scotland

The NEC Corporation will this year invest a further 60 million UK pounds in its subsidiary NEC Semiconductors (UK) Ltd in Scotland. The additional investment will go towards further strengthening the Scottish plant as a global production centre in NEC's electron device business.

The plant will be upgraded to use leading-edge 0·18 micron process technology, producing around 27,000 wafers a month.

For more information browse **www.nec-global.com**

UK and the Comet

The Surrey Space Centre, part of the University of Surrey, has won a contract to manufacture the attitude control momentum wheel for the *Rosetta Lander* mission to be launched in 2004. The *Rosetta* spacecraft will rendezvous with comet 46P/Wirtanen nine years later, mapping its surface in fine detail and land a package of instruments on its surface.

For more information browse **www.sstl.co.uk**

B.A.E.C.

Again we are given the opportunity to publicize that renowned institution, the British Amateur Electronics Club (B.A.E.C.), with the arrival of their latest newsletter (No 135, April 2000).

One of the benefits of belonging to B.A.E.C., Chairman and Editor George Burton reminds us in his Editorial, is that the Club has a library of several hundred books (mostly paperback) which are available on loan for the cost of the return postage. The newsletter itemizes the books available.

The newsletter also has its usual offerings of tips and ideas for the electronics enthusiast. We've said it many times, but we have no hesitation in saying again that if you want to belong to a worthwhile Club that encourages interest in electronics, then consider joining the B.A.E.C.

For more information, contact the Hon. Secretary, Martyn Moses, 5 Park View, Cwmaman, Aberdare, Mid Glam CF44 6PP, UK.

Tel: +44 (0) 1685-879025

Email: MP-MOSES@compuserve.com

Web: members.tripod/~dledgard/baec.htm

FARNELL WEB SITE

Leading distributor Farnell has recently launched an all new e-commerce web site. Available to anyone with Internet access, the site combines an intuitive user interface with sophisticated searching facilities to deliver what Farnell describe as "unrivalled access" to their 100,000-plus branded products and services.

Farnell has built extensive product search facilities into the site and combined this with a convenient "shopping basket" system for order assembly. There is seamless hyperlinking to over 750 Farnell supplier web sites making available a vast array of additional details on products.

The new web site complements Farnell's 6-book paper catalog by providing an alternative means of obtaining products and information 24 hours day, 365 days a year. A CD-ROM version is also available.

Tel: +44 (0) 870-1200-200

Web: www.farnell.com/uk

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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 *

SELLING IDEAS AND INVENTIONS

Dear EPE,

I was saddened but maybe not surprised to read Jim Delaney's letter (Readout May '00) regarding the reception he had from various companies and individuals when trying to sell his inventions. From two years of earning a living from doing just this I can understand how tough it appears. On the bright side there are ways of approaching this that might be more likely to bring success, or at least won't leave you feeling as downcast when another rejection letter hits the mat, or worse still, nothing hits the mat. They are summarized in ten golden rules, plus an eleventh platinum that is probably the most important.

Ten (+1) Golden Rules for selling ideas:

1) Develop any ideas you have informally, to see how "logical" they are: only ever spend significant money and time on ideas where you know it satisfies a current need which is not being filled, or filled badly at the present time.
2) Only concentrate on things people are likely to spend money on; a remote control integrated into a coffee table is probably useful to somebody but nobody is ever likely to buy one. If it is to business then it's likely that products that save money will succeed. If its aimed at consumers, then things like fashion, labor saving features, etc. are often important.
3) Research your target companies (customers) VERY, VERY carefully. Understand their current product line, work out a logical fit for your invention in their current product range. If you can't see where your product fits, they're probably the wrong company.
4) Work out who their competitors are (this is becoming progressively easier with the Internet). If the first company turns you down, approach their competitors armed with a more complete case using the experience of your prior conversations
5) Never send open letters addressed as "Dear Sir" etc. Find the exact names and job titles of both management and the plebs who do the work and decide who might be best to contact. People in sales are the easiest to find (for obvious reasons) but often the hardest to make any progress with. Try to get them to give you a name of a technical contact.

   Always try and speak to people on the phone and begin the conversation by saying that you "need advice" on a new product idea rather than trying to sell it to them in the first 10 seconds. If nothing else these conversations will often give you high quality market research data. Try to strike up a rapport with the person on the other end of the phone, after all they're human too, and will often respond positively if you're friendly and amiable. Practice on your bank manager.
6) Be prepared and plan realistically for failure; if you go into a meeting deciding the color of the Porsche you'll buy with the proceeds from selling your idea, you're doomed to disappointment. This can de-motivate you just at the time you need to be at your most productive.
7) If you do manage to sell your idea, understand that it might be many months or even years before you see any cash from the sale of a product based on your tech-

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nology. How will you feed and clothe yourself in the meantime?

8) Have plenty of ideas on the go at any one time; truly inventive people have hundreds of ideas, some good, most not so good. Be objective at every stage of the development as to how useful an idea is. Concentrate on the wheat and not the chaff, but never discard anything as you can never tell how circumstances might change in favor of a particular idea. If ideas are left to their own devices, they often seem to develop and improve of their own accord.

9) Ideas often run out of steam; sometimes you've done as much as you can think of developing and selling an idea, and you literally can't think of anything else to do. Often a good strategy is to stop and "park it" and get on with something more promising. Doing this isn't giving in to failure, it's pragmatism taking over. As above, a parked idea can spring back into life for any number of reasons; you might be surprised how different things look after a few months' break.

10) Don't be tempted to file patents on every idea you have at the time you have it (you'll soon run out of money!). Develop ideas privately until you can convince yourself of their worth, and then file (be careful of disclosure to anybody during this period). Good patent agents will never give an opinion as to the worth or otherwise of an idea, they assume you have done that and that's why you are patenting it.

11) ***MOST IMPORTANT*** Don't give up your day job; at least try not to until you can see money generated by your invention being paid into your bank account.

Julian White
via the Net

Thank you Julian, we believe quite a few readers will benefit from this advice.
The UK Government also offers the following web sites for further guidance:

The Patent Office:
www.patent.gov.uk
NESTA: **www.nesta.org.uk**
Business Link:
www.businesslink.co.uk
DTI Innovation Unit:
www.innovation.gov.uk
Institute of Patentees and Inventors:
www.invent.org.uk

HISTORY

Dear EPE,

Just a little note to say thank you for the many years that the mag has been going. The value for money has never been greater than it is today. I have a copy of Practical Electronics from Nov 1971, one of the few older ones that I have left.

From 20p in those days, to 2.65 UK pounds, the magazine is worth every penny.

Andrew Allen
via the Net

Thanks Andrew, we appreciate your kind note, and long term support.

SCOPE CHOICE (1)

Dear EPE,

Regarding the Scope Choice question by **R.J. Spratt** in *Readout April 2000* issue, I read this letter and the corresponding answer and thought that perhaps I could add a little information on virtual scopes on PCs, and whether an old '386 could cope.

From 1995 to '97 my job involved designing software for data acquisition and control using PCs (I don't think the field will have changed much in the last three or four years). To say it shortly, it is possible to have data acquisition, and thus a virtual scope, on a '386 computer (or even less), at least using plain old DOS. The problem is whether you can get it at an affordable price, and that almost nobody programs for DOS nowadays.

There are three main ways to do data acquisition with a PC that I know of:

1) Directly with an unbuffered internal card. The card does one A/D conversion, then the computer reads the data (1 or 2 bytes). The speed limit here is the bus or interface used. In the case of the ISA bus (the old 8-bit for PCs, and perhaps the 16-bit expanded version for ATs) the limit was 100K samples per second using DMA transfer. I couldn't find a faster card of this type; but even a 30Ks/s card had a price of around 400 euros (clones were cheaper). Much better cards, PCI bus version from a well known manufacturer could cost 3000 euros. And, yes, we used them on the now old '386, running plain DOS, at perhaps 20Ks/s. For Windows you need much better computers, as it is slower in general.

2) Buffered type internal card. These have a local memory,

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used to store a number of conversions (running unattended by the main CPU) till the computer reads all the samples in one operation. I saw a prototype, two 8-bit channels running perhaps at 1Ms/s on a 10MHz 8086 PC, around 1990. The snag is that acquisition is not continuous if the sampling speed is faster than what the computer bus can handle; but for a scope displaying continuous periodic signals, it is usually OK.

3) An external box, connected to the serial or parallel port (or another dedicated port, e.g. GPIB), buffered or unbuffered (even a real scope connected to the PC could be grouped here). The limits are similar to the above said cases. There are little ones advertised in your magazine (Pico ADC200 and 216, but I have not used them personally) which claim to sample at 100Ms/s, storing the 8-bit samples on a 32Kb internal memory (that means 0·16ms total time for two channels). I find 8-bit insufficient for serious work, other than seeing the shape: I prefer 12-bit minimum, but then the sampling rate goes down to 3Ms/s, and I do not find them very cheap then. They supply DOS based software, so perhaps it will work OK on the '386 computer.

The card I used most was a PClab 812PG from Advantech, old technology even on Win95, and expensive at 400 euros (local Spanish price). There were clones at nearly half that cost, and much better cards from National Semiconductor for 3000 euros and more.

Carlos Robinson
Spain, via the Net

Thank you for your useful contribution.

SCOPE CHOICE (2)

Dear EPE,

As a Solatron CD1400 user myself (*Readout April '00*), I am aware of the transformer problem, the second one that blew-up is still in my possession just in case I ever find the time to repair it!

What I had originally considered was replacing the circuitry used to generate the EHT and focus potentials and it occurred to me that the line timebase section from a B&W portable TV might do the job. Typically, the EHT in one of these units is around 12kV. The fact that this is three times the value required may not be a problem.

A well-known fact in my trade, not so widely appreciated elsewhere, is that in the CRT horizontal drive timebase the scanning coils are the primary inductive component in the resonant system. With these disconnected, the EHT voltage will fall dramatically. From this point it is possible to "tune" the primary inductance of the flyback transformer by experimenting with different values of flyback tuning capacitor. This component is directly across the collector/emitter pins of the line output transistors and usually has a value of several nanofarads and a voltage rating of at least 400V. Don't try this with a color chassis.

There are several reasons why I did not proceed with this plan. The first being the limited space inside the CD1400 casing, also the need to accurately determine the final EHT voltage. This was not so much for safety reasons – the low power flyback generator is "harmless" compared to the Cockroft and Walton voltage multiplier fed by a mains transformer winding which, typical with many oscilloscope designs, will be between 750V and 1000V and capable of supplying several hundred milliamps from the winding, and at least a lethal number of milliamps from the multiplier!

The concern over voltage regulation stems from the fact that increasing the EHT increases the electron beam current – this results in greater deflection energy requirement to deflect the spot. The EHT is just as much a calibrated specification as the attenuator trimmers and timebase oscillator presets!

The most compelling reason for abandoning these plans was the fact that a visit to the local council tip produced an Advance OS2000R that was much easier to repair!

Such Civil Amenity Sites are usually contracted out to private operators by the Environmental Health division of local authorities. In my experience, it is possible to "haggle" for discarded items. Oscilloscopes, computers and an unexpected diversity of electronic equipment form a "not infrequent" part of the treasure trove!

I. Field
Letchworth, Herts, UK

We wonder just how many readers these days are familiar with working on high voltage electronic equipment. Personally I learned much of my early electronics only through figuring out how to repair defunct TVs purchased for about five shillings (25p in today's currency) from local markets. It also taught me to respect the charge held on capacitors even when the mains

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power is switched off!

Perhaps we now "molly-coddle" readers too much by stressing the dangers of AC mains voltages and the like. But then most of electronics these days is only powered at low DC voltages. Gone are the days when most of what the hobbyist electronics magazines published was thermionic valve-based and as such often required voltages well into the several hundreds.

None-the-less, Mr Field's observations may provide excellent food for thought for the adventurous amongst you should your local "tip" not prove to be a viable materials source (and it has to be said that many are prohibited from allowing the public to acquire materials from their sites, especially electrical goods).

QBASIC ETC

Dear EPE,

There is from time to time discussion in EPE about what can be used to replace GW and QBasic at a reasonable cost. I have come across a product called Envelope Engine on the web. It was intended as a rival to Visual Basic. Although the project was abandoned the product has been made available as Freeware and can be downloaded as a self-extracting file from:

www.winsite.com/info/pc/win95/programr/envlpl4.exe

It will only run on Win 95 or later, but it is complete, is based on Basic, and its free. Thought this might be of use to readers.

Bob Allan
via the Net

Thanks Bob. We have to comment, though, that whilst individual readers may find this program to be beneficial, as a magazine we can really only "take on board" programming languages and dialects which the majority of the readers use or have access to. In terms of Basic, this really brings us to only supporting QBasic, QuickBASIC, Visual Basic and Delphi (the latter Robert Penfold has been discussing in several of his recent Interface columns).

I have previously commented that QBasic and QuickBASIC are no longer available commercially, but that it is supposedly possible to download them from some private Internet sites (details not known). However, we have recently been informed by Alan S. Raistrick via E-mail that (unknown to us):

"…it is included on every CD-ROM with Windows 95 and 98. Do a search on the CD-ROM using Windows Explorer Tools/Find/Files or Folders and there it is…"

We invite all of you who use Win 95 and 98 to check your CD-ROMS on this point and to inundate us with replies (my Win 95 CD-ROM does include QBasic). It is immensely important that we get to the bottom of the apparent Basic problem. I for one have tried getting into Visual Basic but have not yet got on too well with it – it does not seem as instinctive as the other many languages and dialects I use. Delphi I have not yet tried, though Robert has been encouraging me to think about it.

MORE BASIC

Dear EPE,

Several years ago I developed a "machine" in my spare time and used the ZX Spectrum (16K) computer to do all the calculations and control the "machine".

I wrote a program (approx 5000 instructions) in Basic using a lot of the ZX functions. I also used designs similar to those shown in Mike Tooley's Electronic Circuit Book to input and output analog information via the ZX printer port.

I am about to purchase a "proper" computer, with Windows 98 software so my granddaughter can use the Internet. I would also like to write programs on it in Basic and, being a simple soul, imagined that I could get a CD-ROM to program the computer in Basic with at least all the functions of the ZX.

I have made several enquiries with computer manufacturers and Microsoft, but I have not found anyone, so far, who can supply anything to meet these requirements. Can you advise me of a suitable supplier.

May I say how much I enjoy reading EPE each month and have been a regular subscriber for many, many years.

Peter Gardner
Pucklechurch, Bristol

I refer the honorable gentleman to the reply I gave a few moments ago (to mimic Maggie – remember her?)

PIC NOP TRICK

Dear EPE,

I am new to the PIC game so my trick may well be old news. It concerns the OTP (One Time Programmable) chips. In my case it was the PIC16C773SP. The trick is about multiple programming of those chips. Providing that your program size is less that half the program memory size and you are not using interrupts and, with some exceptions, the configuration bits have been set correctly the first time, you can re-

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program the chip by overwriting the programmed memory area with the NOP instruction and shifting the entry point to a new location.

I guess there is no need to explain that programming an EPROM memory is about writing 0s in specific bit positions and the NOP instruction is all 0s. So all you have to do is insert enough NOP instructions at the beginning of your new program to overwrite the old one. The cost obviously is a number of clock cycles when the chip is doing nothing (NOP) but only when the program starts to run and the extra program memory used which would have been lost in any case.

There is no need to type several hundred NOP instructions either. Just work out how much space your faulty program takes up and use the FILL directive. Using the MPLAB dialect it could look like this, assuming the original faulty program size was 0x200 (512 words):

;New **ORG 0X00 FILL 0,0x200** ;puts 0s (NOP) in the first 512 program memory locations

GOTO Start

;Old ORG 0X00

GOTO Start

Peter Malczyk
Cape Town, South Africa

The OTP PIC chips are not components that I have had occasion to use. The reprogrammable EEPROM PIC16x84 and PIC16F87x devices are far too useful when developing a design for publication and which some readers may wish to ultimately amend to suit their own particular needs. With the very rare exception, it seems preferable for us to avoid OTP devices, even though their unit cost can be lower.

However, we recognize that some of you will be taking the OTP route and are using PICs that are only available with that structure. As a designer who used EPROM memories until a few years ago (until PICs enabled me to move away from 6502 microprocessor-based designs), I can recommend Peter's technique.

With the EPROMs, although they can be erased using UV light, it was not necessarily convenient to take time out to erase them (as I recall it took 10 to 15 minutes a time). For each successive change to EPROM code, I would start the new code at an address just a few bytes beyond where the previous code version had ended, writing zeros into the foregoing addresses, and making a note of the end address of the new code, so that the process could be repeated.

In this way it was possible to make maximum use of the EPROM chip before having to erase it. With some codes it was possible to have many version updates before the space ran out.

MISSING LINK

Dear EPE,

I experience "Unforeseen DOS Error 75" when I run **tk.bat** of PIC Toolkit Mk2. It worked fine on previous attempts. Any ideas?

Hennie R van Rensburg
South Africa, via the Net

To which I replied via E-mail: "Error 75 is path/file Access Error. Check that you are not trying to access a non-existent file or folder." And Hennie came back with:

Thanks for the help!

Next time I will read the installation instructions more carefully! It's working like a charm!

Best regards and thanks for the Great Magazine, Hennie.

There's a public lesson here for a few other readers – I like to think that the instructions I write are going to be followed! T'aint always so – some of you don't from time to time!

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Shop Talk

with DAVID BARRINGTON

Some Component Suppliers for EPE Online Constructional Articles

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

Electrovalue (UK)
Tel: +44 (0) 1784-433604
E-mail: **evalue@compuserve.com**

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

Pocket g-Meter

It's not everyday we have to find a source for such an up-to-date specialized chip as that used in the Pocket g-Meter project. But thanks to the guidance of Bill Mooney, the designer, we have managed to crack it and come up with a "one-off" source.

The Analog Devices' ADXL105JQC surface mount micromachined sensor chip is available from Thame Components Ltd, Dept EPE, Thame Park Road, Thame, Oxfordshire, OX9 3UQ, UK (Tel: +44 (0) 1844-261188 or Web: **www.impact.uk.memec.com**). It will cost you around 16.14 UK pounds plus a postage and handling charge of about 4.50 pounds. Another possibility is Avnet Macro Direct (Tel: +44 (0) 1628-606000 or **www.avnetmacro.co.uk**), although they were not so forthcoming with information.

The miniature ceramic "knob pot" came from Farnell Electronic Components (code 350-655). Most of our component advertisers now carry stocks of general surface mount devices. Note that the LM3914N bargraph LED driver IC is a standard 18-pin DIL format device.

There are plenty of really small plastic boxes around and readers should have no problems in finding one to suit this project. We suggest you go for one slightly larger than that shown as the components are certainly packed tightly in the prototype model. The small "hybrid" printed circuit board (copper pads on component side) is available from the *EPE Online Store* (code 7000269).

Probably the biggest problem constructors are going to encounter is the one of soldering the surface mount components to the small PCB. We suggest readers check out Bill Mooney's web site at **www.billssmd.mcmail.com**, where a host of information on surface mount will be found, including details on soldering.

PIC-Gen Frequency Generator/Counter

Several components need highlighting when purchasing parts for the PIC-Gen Frequency Generator/Counter project. This applies particularly to the ICs.

Both the Maxim MAX660 voltage converter and the MAX038 function generator chips were ordered through Electromail, the RS mail order outlet. The MAX660 carries the order code of 265-055 and the MAX0388 code 810-396. For those interested, Maxim's web

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site is at: **www.maxim-ic.com**.

The MAX660 converter is claimed to have a greater output load capability than similar devices and should be the only one used in this project. Also, the author advises that the HC versions of the 74xx4040 (IC6) and the 74xx132 (IC7) should be the only ones used in this circuit. The standard CMOS 4040 counter is too slow and although the LS132 voltage converter version should work it has not been tried in the model.

The neat plastic case, with plastic removable front and rear panels, is from a new range introduced by RS and available from the first mentioned company, code 239-7413. Multi-turn potentiometers are "off-the-shelf" items and the most popular range seems to be from around 10-turns to about 20-turns.

The alphanumeric 2-line 16-character per line liquid crystal display module used in the prototype was originally purchased from Magenta Electronics. This comes complete with a connector and is one we would recommend. Other component suppliers will no doubt be able to offer something similar.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-4P can be purchased from Magenta (see above) for the inclusive price of 10 UK pounds (overseas readers add 1 pound for postage). Software for the PIC-Gen is available for free download from the *EPE Online Library*. The software is written in TASM.

The printed circuit board is available from the *EPE Online Store* (code 7000268).

Camera Shutter Timer

This month's Starter Project is a low-cost Camera Shutter Timer and we cannot picture any component buying problems.

If you decide to use a phototransistor and wish to use the 3mm SFH309 type listed, this came from Maplin, code CY86T. However, the circuit has been designed to work equally as well with most photodiodes or phototransistors.

Judging from photos of the prototype, the 50uA moving coil meter is one from the 2·5 class range. Another one with similar characteristics and dimensions, 51mm (2in.) by 45mm (1.75in.), is the MU38 series. Both types should be widely stocked.

If you use a different case to the one shown, such as an all--plastic type, keep in mind that you will need plenty of space on the front panel for the controls and meter.

Atmospheric Electricity Detector – Part 2

We have received no further feedback regarding the availability or any alternatives to the Siemens B6429 series of toroid ferrite ring cores called for in the Atmospheric Electricity Detector. These were purchased from ElectroValve (**evalve@compuserve.com**) – quote full code B64290K618X830 when ordering.

The choice of meters is left to the individual constructor, but most of our component suppliers should be able to help. Also note the author advises that switches S3 and S4 must be rated at least 250V AC.

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.

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