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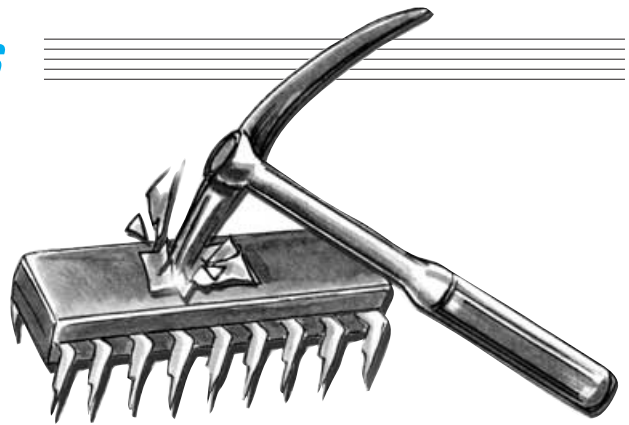
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PICAXE PROJECTS



MAX HORSEY

Part 2 – Temperature Sensor, Voltage Sensor, VU Indicator

Using the PICAXE system, you do not need specialised equipment or knowledge to program the PIC microcontrollers used in these designs.

LAST month we described three projects based on the PICAXE-18, a microcontroller based on the PIC16F627 device but which is programmed by using a version of BASIC via a serial link connected to your PC-compatible computer. The projects were an Egg Timer, Dice Machine and a Quiz Game Monitor and used the PICAXE's digital options. This month we describe three applications which employ this device's analogue inputs:

- Temperature Sensor

- Voltage Sensor
- VU Indicator

Details of obtaining the devices and their software are given later.

GENERAL CIRCUITRY

The general purpose circuit diagram for all nine designs in this three-part series, is repeated here from Part 1, in Fig.1. Each of the circuits to be described is a variant of that shown in this figure, and just the essential changes are shown as separate diagrams.

In the circuits to be described, push-button (push-to-make) switches S2, S3 and S5 are omitted, and pin RA0/AN0 (IC1 pin 17) is used as an analogue signal input. In other applications, pins RA1/AN1 and RA2/AN2 of the PICAXE-18 can also be used as analogue inputs.

With the BASIC dialect used by the PICAXE-18, the command `readadc 0,b0`, is all that is required to configure RA0/AN0 as an input to read an analogue voltage. The zero (0) in this case refers to RA0/AN0, to read from another analogue

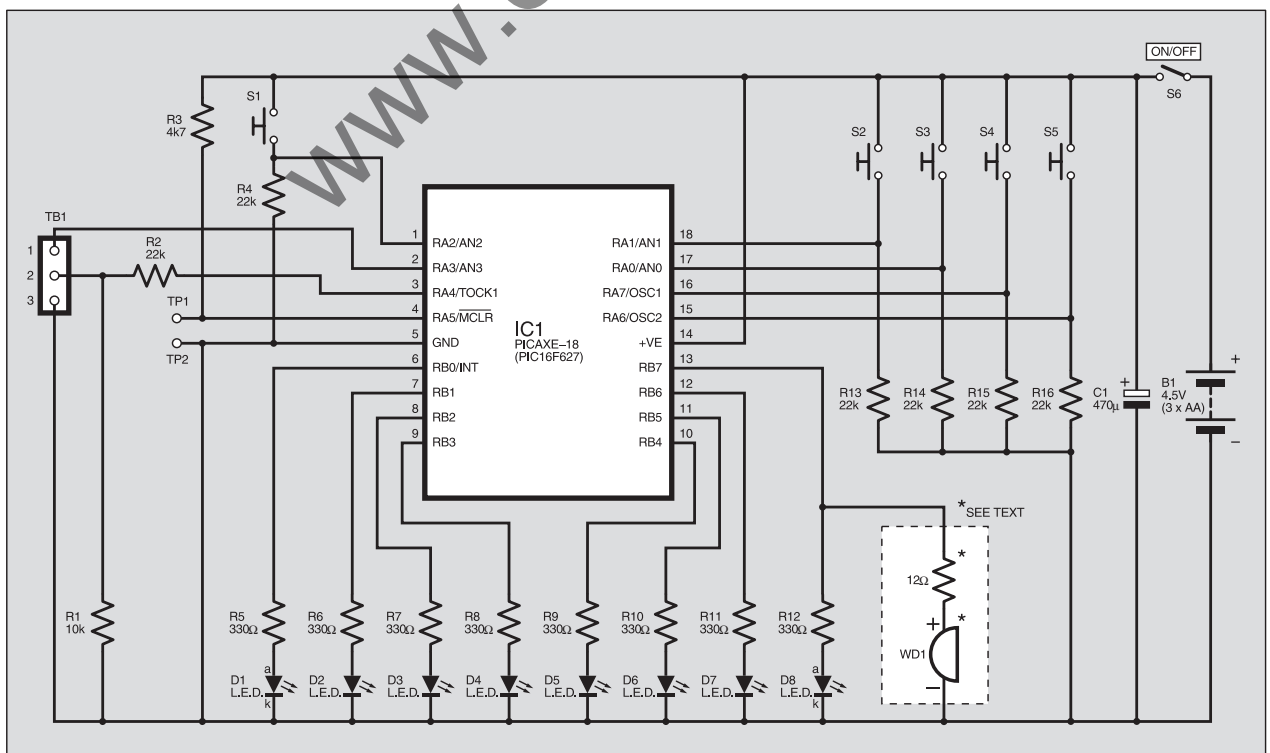


Fig.1. General circuit diagram for all the designs in this PICAXE series of projects.

pin, the number of that input would be substituted for it. For example, to read from RA1/AN1, the command would be **readadc 1,b0**. The variable **b0** is that into which the analogue value is placed.

The PIC16F627 itself (i.e. *not* the PICAXE-18) offers low-resolution analogue readings ranging from 0 to 255 as the voltage at the analogue pin rises from 0V to 5V. However, the PICAXE-18 version of the PIC16F627 can only return values from 0 to 160 in 16 discrete steps. Hence, on a 5V supply, only voltages from 0V to 3.3V can be measured; voltages between 3.3V and 5V will all return a value of 160.

The projects may be powered by batteries (e.g. 3 × AA size cells, although the option to use a 12V battery is described), or by a 5V mains adaptor. Note that the latter *must be a regulated type* since non-regulated adaptors often produce much higher voltages than expected.

TEMPERATURE SENSOR – FISH TANK MONITOR

In the Temperature Sensor – Fish Tank Monitor design, apart from switches S2, S3 and S5 having been omitted, switch S4 now becomes a toggle switch. Its role will be discussed shortly. Resistor R14 is replaced by a negative temperature coefficient (*n.t.c.*) thermistor having a value of

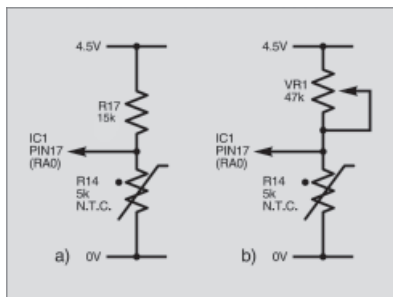


Fig.2. Two possible minor changes to allow temperature sensing.



Line-up of this month's three demonstration modules: ● Temperature Sensor – Fish Tank Monitor ● VU Indicator – Volume Level Display ● Voltage Sensor – Battery Tester.

about five kilohms (5kΩ) at room temperature, see Fig.2a.

As the temperature increases, the resistance of the thermistor falls, causing the voltage at pin RA0/AN0 of the PICAXE-18 to fall, and so causing the value of the resulting analogue reading to fall as well.

Switch S3 is replaced by a 12kΩ resistor, R17. The value was chosen so that temperatures from a little below to some way above “normal” room temperature can be indicated. If preferred, R17 could be changed to a potentiometer (VR1) used as a variable resistor. A value of, say, 47kΩ would allow a wider range of temperatures to be accommodated. This change is shown in Fig.2b.

L.E.D. DOT/BAR MODE

In the context of the l.e.d.s (light emitting diodes) used in this series, Dot Mode means that only a single l.e.d. lights at any one time. Bar Mode is when two or more l.e.d.s in a chained sequence light up,

forming a bar effect. This is the most common form of display but the program includes both modes of operation, selected by using toggle switch S4 (if used).

If S4 is omitted, the display will always be in Dot Mode (do *not* omit resistor R15, though). If you wish to set the circuit permanently to Bar Mode, fit a wire link in place of S4 so that pin 16 (RA7) is always held at logic 1 (high), in which case R15 can be omitted, although it can be retained if preferred.

As was done in the *Egg Timer* last month, i.e.d. D8 could be replaced by a buzzer (WD1), with the value of resistor R12 being changed to 12Ω. In this case potentiometer VR1 could be set so that the circuit provides an audible warning if the temperature rises above a certain level.

If a small buzzer (low current) is used, it may be driven directly from the designated PICAXE-18 output in addition to the l.e.d. Furthermore, if the circuit is set to Dot Mode, then separate buzzers could be

LISTING 1

```

'temperature sensor 'tem3'
'use 5k thermistor in place of resistor and 12k resistor or 47k
variable in place of switch
'for Dot Mode make in7 low, for Bar Mode make in7 high
start: readadc 0,b0
      'put the analogue value at
      pin0 into b0
      'jump to appropriate display
      routine
      if b0>75 then one
      if b0>64 then two
      if b0>53 then three
      if b0>43 then four
      if b0>32 then five
      if b0>21 then six
      if b0>11 then seven
      let pins=%10000000
      'if b0 is less than 12, then
      make output 7 high (Dot
      Mode)
      'if input pin 7 is low, goto start
      'if input pin 7 is high, make all
      outputs high (Bar Mode)
      if pin7 = 0 then start
      let pins=%11111111
      goto start
one:   let pins=%00000001
      'make output 0 high (dot or
      Bar Mode)
      goto start
two:   let pins = %00000010
      'make output 1 high (Dot
      Mode)
      if pin7 = 0 then start
      let pins=%00000011
      'make output 0 & 1 high (Bar
      Mode)
      goto start
three: let pins=%00000100
      if pin7 = 0 then start
      let pins=%00000111
      goto start
four:  let pins=%00001000
      if pin7 = 0 then start
      let pins=%00001111
      goto start
five:  let pins=%00010000
      if pin7 = 0 then start
      let pins=%00011111
      goto start
six:   let pins=%00100000
      if pin7 = 0 then start
      let pins=%00111111
      goto start
seven: let pins=%01000000
      if pin7 = 0 then start
      let pins=%01111111
      goto start

```

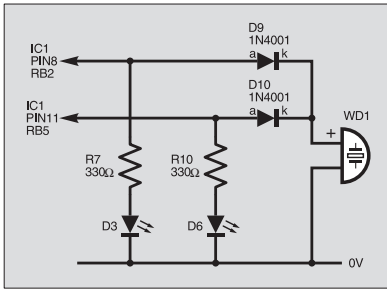


Fig.3. Adding diodes to selected IC1 outputs, such as RB2 and RB5, enables a single buzzer to be driven from several sources.

connected to any two outputs to provide over- and under-temperature warnings. Hence it would be possible to monitor the temperature of a fish tank, for example.

Another approach would be to add diodes to selected outputs so that a single buzzer could be used, but driven from several sources. An example is shown in Fig.3, in which outputs RB2 and RB5 are coupled via diodes D9 and D10 to jointly feed to the buzzer WD1. Resistors R7 and R10, and I.e.d.s D3 and D6 can be retained.

Note that the voltage change caused when a thermistor is employed is not linear. Hence it would be difficult to achieve accurate calibration over a wide range of temperatures. However, it is still possible to set two "safe" points as required for the fish tank monitor

either by selecting the appropriate outputs, or by changing the program.

TEMPERATURE PROGRAM

The BASIC source code for the Temperature Sensor program is shown in Listing 1. Comments following an apostrophe are ignored by the compiler. The line at the label **Start:** states **readadc 0,b0**. This command causes the PICAXE-18 to read the voltage at input RA0/AN0 and place the value in variable **b0**.

The next set of lines examine this value and jump to the appropriate command routine to turn on specific I.e.d.s. For example, outputting the command **let pins = %10000000** causes I.e.d. D8 to turn on. A "1" in any position will make the appropriate output go high.

The percentage sign tells the compiler that the number is in binary. The equivalent decimal number is 128 and so you could in fact replace the line with **let pins = 128**. However, the binary representation provides a better indication of which I.e.d.s are affected. Note that in the absence of a percentage sign, the compiler will assume that a decimal number is to be processed. Remember that binary codes are numbered from right to left, in order



Completed Temperature Sensor module. Note the thermistor mounted in a discarded ballpoint pen barrel.

of bit 0 to bit 7, with bit 0 controlling I.e.d. D1.

The program continually checks whether input RA7 is high or low, to determine whether to display in Bar Mode or Dot Mode. So the command line **if pin7 = 0 then start** causes the compiler to skip the Bar Mode display command, and so display in Dot Mode.

VOLTAGE SENSOR – BATTERY TESTER

A voltage sensing interface is illustrated in Fig.4. Extra care is required when connecting external voltages to the circuit. It is important, for example, to prevent the

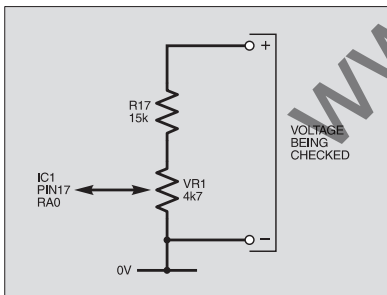


Fig.4. Circuit modification to give a voltage sensing interface. Adjusting VR1 will give a monitoring range of 0V to 8V d.c. on the eight I.e.d.s.

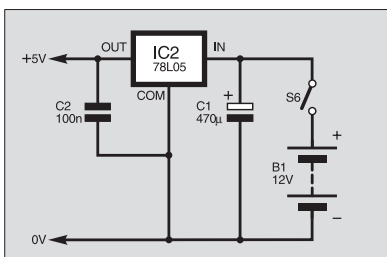


Fig.5. Adding a simple regulator circuit to give more accurate voltage detection.

voltage at the RA0/AN0 analogue input from rising above 5V d.c., or falling below 0V.

In fact, for the reasons mentioned earlier, the highest voltage which can be measured is 3.3V. So the input voltage is attenuated by resistor R17 and potentiometer VR1. By adjusting VR1, voltages from 0V to 8V can be monitored and displayed on the eight I.e.d.s. A wider range is possible, although 0V to 12V, say, is more difficult to display on eight I.e.d.s! However, you could reduce the range to say 5V to 12V by changing the program.

If accurate voltage detection is required then the circuit should be driven from a reliable voltage supply, such as provided via a 5V regulator. Since only two additional components are required, as shown in Fig.5, i.e. +5V regulator IC2 and capacitor C2, it is worth adding this facility.

PROGRAM

The program is similar to the temperature display except that higher analogue values cause more I.e.d.s to be displayed. Provision for Bar Mode or Dot Mode has been included. Note that the commands **high 0**, **high 1**, **high 2** etc. have been used instead of **let pins = x**.

When only a single I.e.d. is required – as in Dot Mode – this method of switching an output high is more economical with memory space – something quite critical with PICAXE devices.



Completed prototype Voltage Sensor (Battery Tester). The I.e.d.s shown here are made up of three red (low), two yellow and three green lights.

VU INDICATOR – VOLUME LEVEL DISPLAY

The circuit diagram in Fig.6 shows the changes needed to produce a VU (Volume Units) Indicator circuit. This is ideally suited to sound level monitoring by connecting the circuit to the speaker or headphone output of an amplifier. The l.e.d.s indicate a relative volume level.

The circuit type is known as a “diode pump”. Capacitor C3 a.c. couples the analogue signal to the circuit, preventing any d.c. current flow between the two circuits. Diode D9 only allows positive going aspects of the signal to pass, and diode D10 prevents the output from C3 going below about 0.7V. The effect is that the output from D10 is effectively twice the value of the basic positive-going waveform from the amplifier (less the voltage drops across the diodes).

The output from diode D9 causes capacitor C4 to charge up to a level representing the output level from the amplifier. This voltage is then monitored in the same way as before. It is essential that resistor R17 should be retained to minimise the risk of damage to the PICAXE chip in the event of the signal voltage rising too high. Its value may be reduced from the 15k Ω shown, but it is best not to reduce it below about 1k Ω for fear of PICAXE damage.

It is worth noting that you should NOT connect the circuit in Fig.4 direct to the amplifier output since this is likely to contain negative-going waveforms, which if received by the PICAXE chip could cause irreparable damage if the condition is sustained, even though the device has a certain amount of internal voltage and current limiting.

The value of capacitor C3 is not critical, and smaller values will tend to limit bass frequencies – a little experimentation may be helpful.

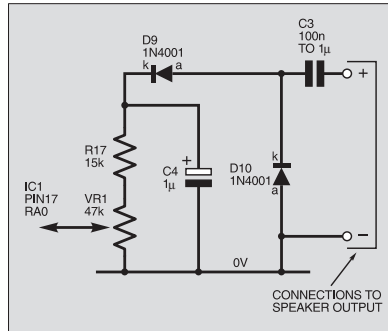


Fig.6. Adding a “diode pump” circuit to produce a simple VU Indicator.

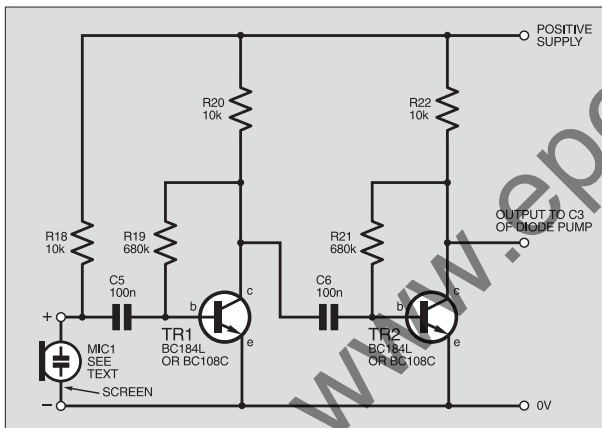


Fig.7. Optional two-transistor microphone amplifier circuit diagram for monitoring microphone outputs.

MICROPHONE INPUT

You may wish to experiment with monitoring the output from a microphone. As the output from a microphone is much lower than required for the circuit to respond adequately, some amplification is necessary. Simple microphone amplifiers can be easily made around op.amps such as the type 741 and various designs have been published.

A very simple but extremely effective amplifier, though, can be made based on two transistors, such as types BC108C or BC184L and a suitable arrangement is shown in Fig.7. In fact, any pair of *npn* transistors with gains of 250 to 400 should work, though you may need to experiment with the resistor values a little for best results.

The capacitor values are not critical and any value between 100nF and 1 μ F will work well. The capacitors should be non-polarised and electrolytic types are best avoided.

Note that the circuit is intended for use with an electret microphone (MIC1). These inexpensive devices are very small and provide excellent results. Resistor R18 provides power for the microphone. If you wish to try a dynamic microphone instead of an electret, then omit R18. In tests, cheap loudspeakers and headphones also provided good results when used as microphones and with R18 omitted.

COMPONENTS

Resistors

R1	10k
R2, R4, R13, R15, R16	22k (5 off)
R3	4k7
R5 to R11	330 Ω (7 off)
R12	12 Ω or 330 Ω (see text)
R14	5k n.t.c. thermistor (see text)
R17	15k (see text)
R18, R20, R22	10k (3 off) (see text)
R19, R21	680k (2 off) (see text)

All 0.25W 5% carbon film, except R14.

Potentiometer

VR1	4k7 or 47k rotary carbon, panel mounting, linear (see text)
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Capacitor

C1	470 μ , radial elect. 16V
C2	100n ceramic or polyester layer (see text)
C3	100n to 1 μ ceramic or polyester layer (see text)
C4	1 μ radial elect. 16V (see text)
C5, C6	100n ceramic or polyester layer (2 off) (see text)

Semiconductors

D1 to D8	red l.e.d. (or other colours – see text) and mounting clips (8 off)
D9, D10	1N4001 rectifier diode (see text) (2 off)
TR1, TR2	BC184L or BC108C (2 off) (see text)
IC1	PICAXE-18 microcontroller (see text)
IC2	78L05 +5V voltage regulator (see text)

Miscellaneous

B1	4.5V battery (3 x AA) and clip (see text)
S1 to S5	min. s.p. push-to-make switch (not used – see text)
S6	min. s.p.s.t. toggle switch
TB1	3-pin serial connector (shrouded 3-pin header (see text))
TP1, TP2	(see text)
WD1	active buzzer, 5V
MIC1	electret microphone insert (see text)

Printed circuit board, available from the *EPE PCB Service*, code 373 (one for each design – see text); 18-pin i.c. socket (one for each p.c.b.); plastic case 140mm x 80mm x 30mm approx (one per p.c.b.); p.c.b. supports (4 off per p.c.b.); knob for VR1 (see text); stripboard, 18 holes x 10 strips (see text); stripboard, 9 holes x 3 strips (see text); 1mm terminal pins; connecting wires; solder, etc.

Approx. Cost
Guidance Only

£20
excl. case & batts.

PROGRAM

The program is similar to that for the Voltage Sensor, except that a For-Next loop is used to sample the analogue value 20 times, taking a peak value as it loops.

This provides a more stable display. There is no provision for Dot Mode display, although this could be added to the program if desired.

CONSTRUCTION - GENERAL NOTES

Each project is built on the same printed circuit board (p.c.b.) that was presented in Part 1 of the series last month, shown there as Fig.2. This board is available from the *EPE PCB Service*, code 373. The individual component positioning and wiring details for the projects discussed here in Part 2 are shown separately.

Check the component list for the particular project being constructed, and fit only the required parts. Note that resistors R1 and R2, and connector TB1 are only required if you intend to program the PICAXE in-circuit. Serial connector TB1 must be inserted the correct way round, with the plastic tongue nearer the line of l.e.d.s, as shown in the p.c.b. layouts. Electrolytic capacitor C1 must also be fitted the correct way round.

The l.e.d.s have a common cathode (k) and so only one wire is required for all the cathodes, as shown in their component layout diagrams. The l.e.d.s should be fitted into the drilled case before connecting wires to them.

As discussed in Part 1, solder pins TP1 and TP2 are not essential, but may be useful if the PICAXE crashes. Shorting the two pins together causes the PICAXE program to restart from the beginning. Switching off the power supply should

TEMPERATURE SENSOR - FISH TANK MONITOR

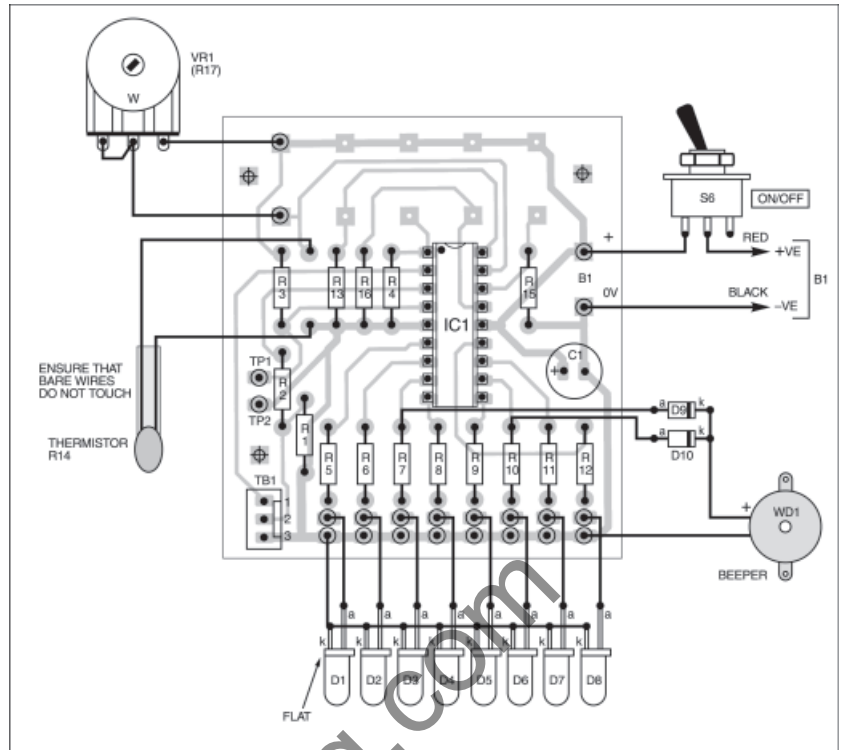


Fig.8. Multiboard component layout and wiring for the Temperature Sensor. As it stands, with switch S4 omitted, this arrangement will give Dot Mode (single l.e.d.) display.

defeat a crash, but on rare occasions with the PICAXE-18 it is useful to be able to reset the system directly.

When assembly has been completed and thoroughly checked, insert the PICAXE-18

chip and program it from the PC using the serial link. Part 1 discussed the programming of PICAXE-18 devices and how PIC16F627 devices could be used instead of them, and readers are referred to that for more information. Pre-programmed PICAXE-18s are available as stated in this month's *Shoptalk*, which also gives information on obtaining the software itself.

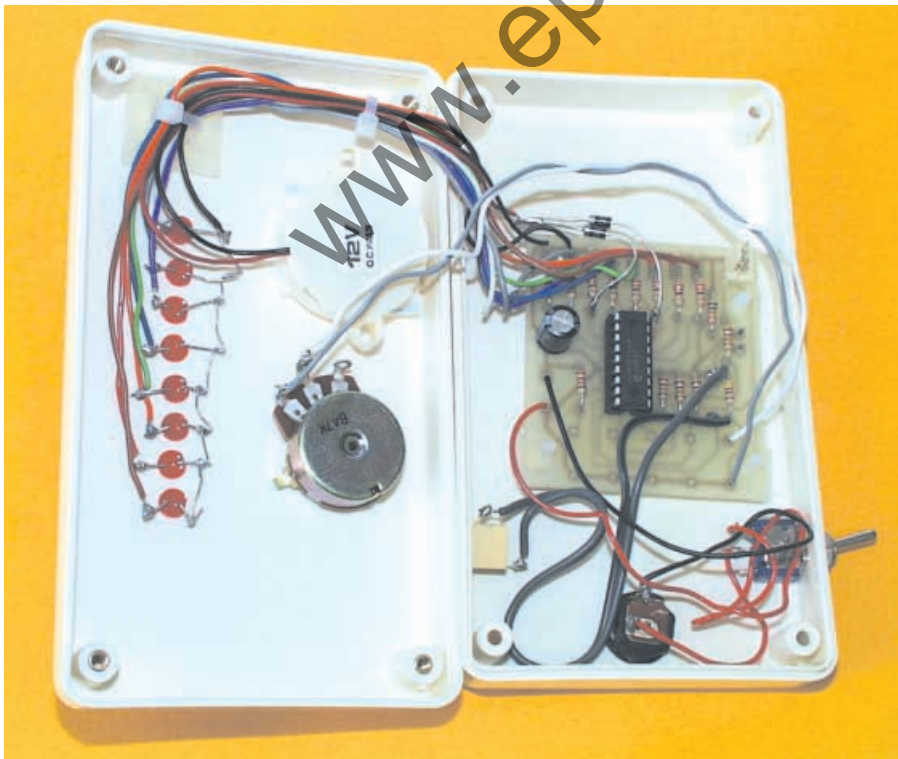
TEMPERATURE SENSOR

The diagram in Fig.8 shows the component layout for the Temperature Sensor based on Fig.2 and Fig.3, for monitoring both high and low temperatures. Since the circuit must always work in Dot Mode, switch S4 is omitted. Potentiometer VR1 has been included, since adjustments are almost certainly required.

Diodes D9 and D10 are connected to the ends of resistors R7 and R10 respectively, either on the component side, or on the copper side of the p.c.b.

If the project is to be used to check air temperature, the thermistor (R14) could be mounted at the end of a pair of leads. Single-core screened cable provides a neat solution.

If the thermistor is to be placed in water then it must be suitably housed to prevent water, as in a fish tank, touching its leads. For example, a glass tube could be employed, or the plastic case of an old ballpoint pen – take care to block any air holes. A suitable filler or glue may be used to retain and seal the thermistor.



General layout of components inside the prototype Temperature Sensor case. A power input socket is mounted on the case bottom and a jack socket for the thermistor on one side panel.

VOLTAGE SENSOR

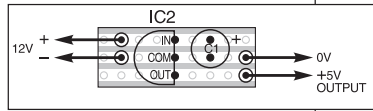
The component layout details for the Voltage Sensor are shown in Fig.9.

As stated earlier, the display will vary with the supply voltage as well as the voltage being sensed, hence for accurate readings a voltage regulator should be employed here.

If a voltage regulator circuit, such as discussed earlier (Fig.5) is to be used, it can be constructed on a small piece of stripboard, as shown in Fig.10.

Capacitor C2 is fitted to the multiboard p.c.b. in the position occupied by C1 in the previous circuits. Ensure that C1 and IC2 are fitted the correct way round.

Fig.10. Stripboard voltage regulator (see text).



Note that the circuit will only function correctly if the battery voltage is above about +7V. If it falls below this level, the output from the regulator will fall below 5V and the l.e.d.s may start flashing randomly!

VU INDICATOR

The VU Indicator component layout details are shown in Fig.11. Diode D10 and resistor R17 are soldered directly onto the potentiometer VR1 tabs as indicated, and C3 is soldered to the junction between the diodes and then connected to the sound source using any technique suited to it, e.g. via a jack socket perhaps.

VU INDICATOR - VOLUME LEVEL DISPLAY

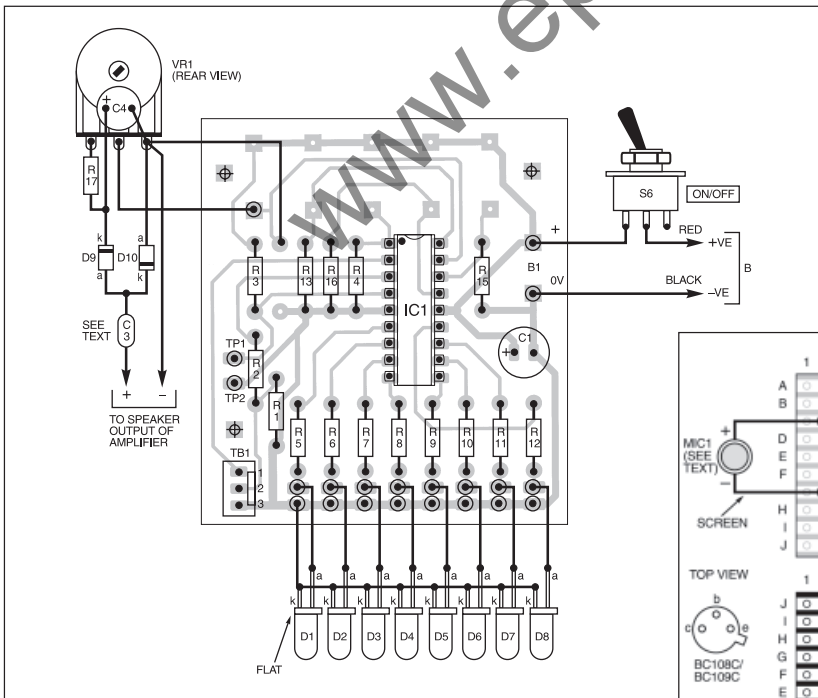
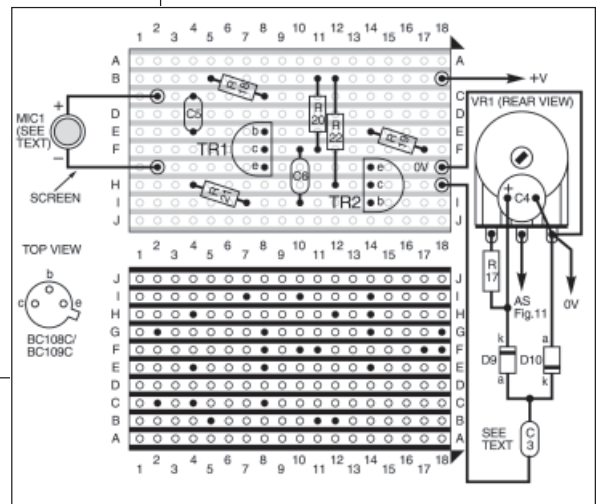


Fig.11 (above). Component layout and interwiring for the VU Indicator.

Fig.12 (right). Stripboard component and interwiring details for the two-transistor microphone amplifier circuit (Fig.7).



VOLTAGE SENSOR - BATTERY TESTER

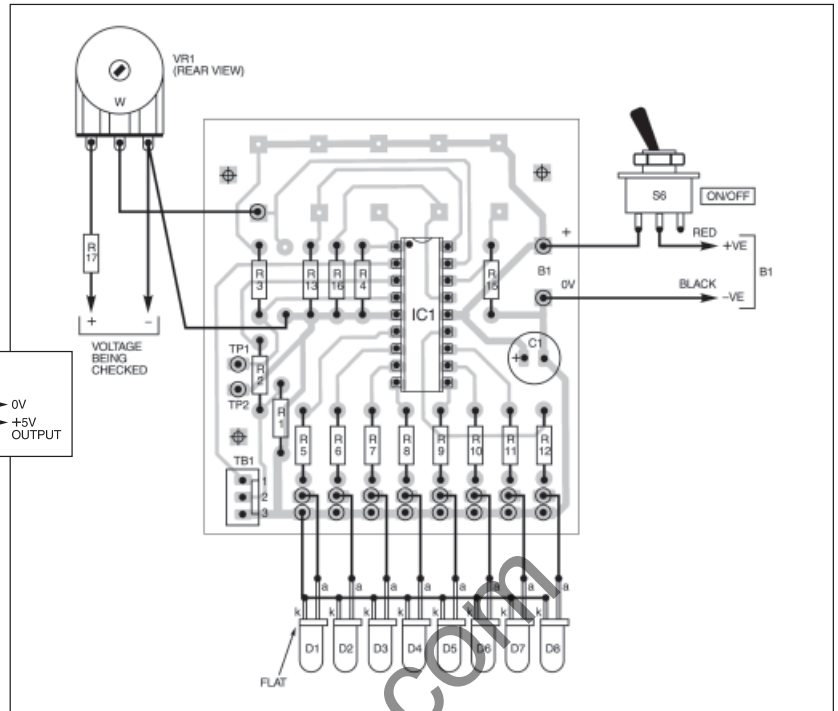


Fig.9. Component layout and wiring for the Voltage Sensor.

Ensure that the diodes are fitted the correct way round.

The potentiometer VR1 provides a firm support since it is fastened to the case. Capacitor C3 should be non-electrolytic

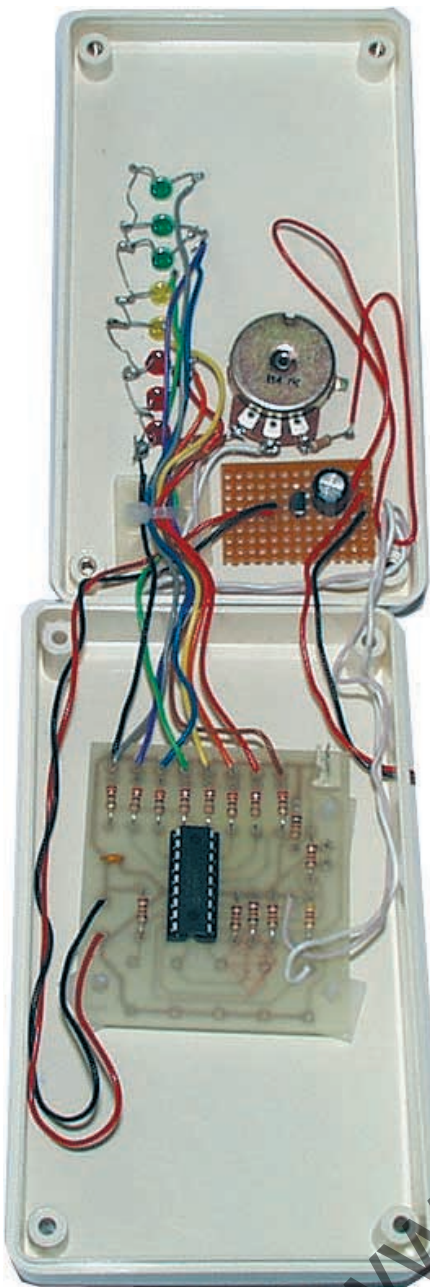
(e.g. ceramic disc or polyester layer) and may be fitted either way round.

MICROPHONE AMPLIFIER

The two-transistor microphone amplifier circuit is constructed on stripboard as shown in Fig.12. Remember to omit R18 if a dynamic microphone is employed instead of the electret type suggested. Assuming that an electret type is used, you will need to check its polarity when connecting it to the stripboard.

The transistor pin connections shown are for type BC184L, the top view pinouts for a BC108C/BC109C type transistor are shown separately in Fig.12. Ensure that the correct pinouts are used.

The leads of capacitor C6 must be spread out slightly to fit the tracks as shown.



Component positioning inside the two halves of the Voltage Sensor case.

CASING

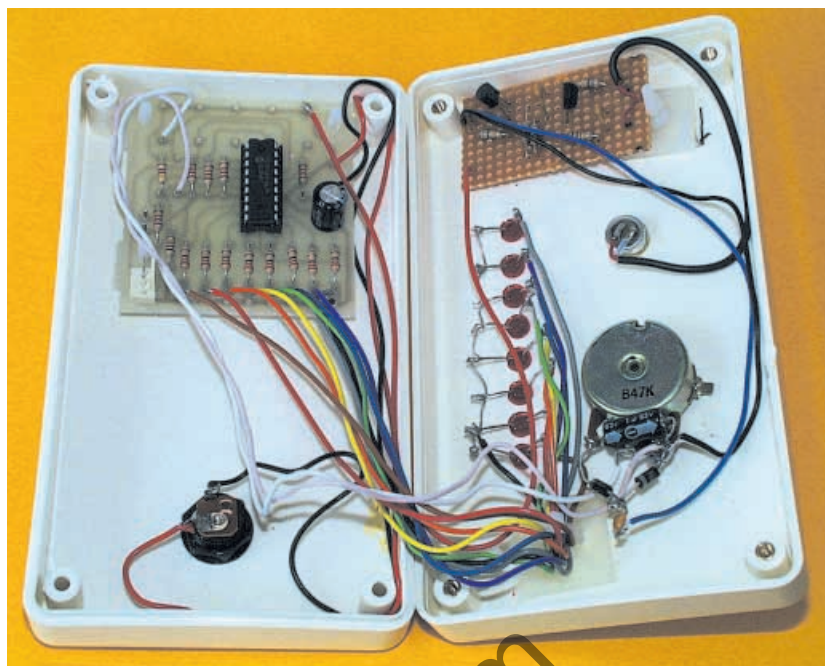
As with last month's projects, all three described here were mounted in plastic cases, measuring approximately 140mm x 80mm x 30mm, and drilled as required and shown in the photographs.

Begin by marking and drilling the holes required for the l.e.d.s. Additional holes are required for the thermistor, optional voltage-monitoring and sound inputs, and an external power source, as appropriate.

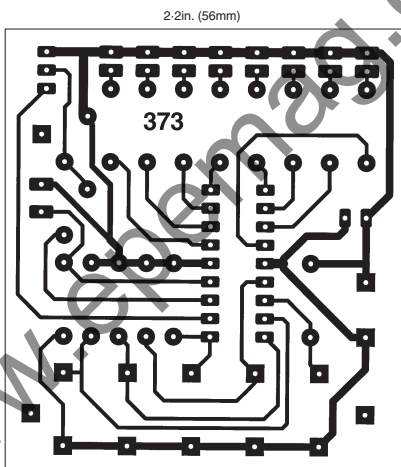
Each project has an optional potentiometer (VR1), and if this is required a suitable hole must be made for its mounting bush. The p.c.b. should be secured using p.c.b. supports, of which self-adhesive types are suggested.

PROGRAMMING AND TESTING

As discussed last month, there are two ways of obtaining a programmed



Completed VU Indicator unit showing the general layout of components inside the case. The miniature electret microphone is mounted just above the control potentiometer.



Multiboard full-size copper foil master pattern. (This board is available from the EPE PCB Service).

PICAXE-18 device. The preferred technique is to program it yourself while in-circuit using the PICAXE software, as this allows you to experiment with the BASIC program code and repeatedly reprogram the device with each code version. They can, though, be bought ready-programmed as stated in this month's *Shoptalk*.

Since a PICAXE-18 device is a specially modified version of the PIC16F627 microcontroller, produced by Revolution Education, there is a third programming option. For this you need standard PIC programming facilities to program the PIC16F627 using the hex code that is available for this series of designs.

To test a circuit, switch on the power supply and then, as appropriate, warm the thermistor or apply a voltage or sound signal. Adjust control VR1 until the l.e.d.s. light accordingly, either in Dot Mode or Bar Mode, depending on the circuit's function.

For general information on programming PICAXE devices and checking their in-circuit behaviour, refer to Part 1, last month.

RESOURCES

Preprogrammed HEX versions of the PICs for these designs can be obtained (*mail order only*) from: M. P. Horsey, Electronics Dept., Radley College, Abingdon, Oxon. OX14 2HR. The price is £5.90 per PIC, including postage (overseas add £1 p&p). Specify the project for which the PIC is required. Enclose a cheque payable to Radley College.

Software for these three designs and for Parts 1 and 3 of the series, (except the PICAXE programming software) is available on 3.5in disk (*EPE Disk 5*), for which a nominal handling charge applies, from the Editorial office (see the *PCB Service* page). It is also available for free download from the *EPE* ftp site.

PICAXE programming software can be obtained from: Tech-Supplies, Dept. *EPE*, 4 Old Dairy Business Centre, Melcombe Road, Bath, BS2 3LR.

The telephone number of Revolution Education is: 01225 340563, and their web site is at: www.rev-ed.co.uk.

Next month: In the third and final part of this series three *Chaser Lights* circuits are presented.

