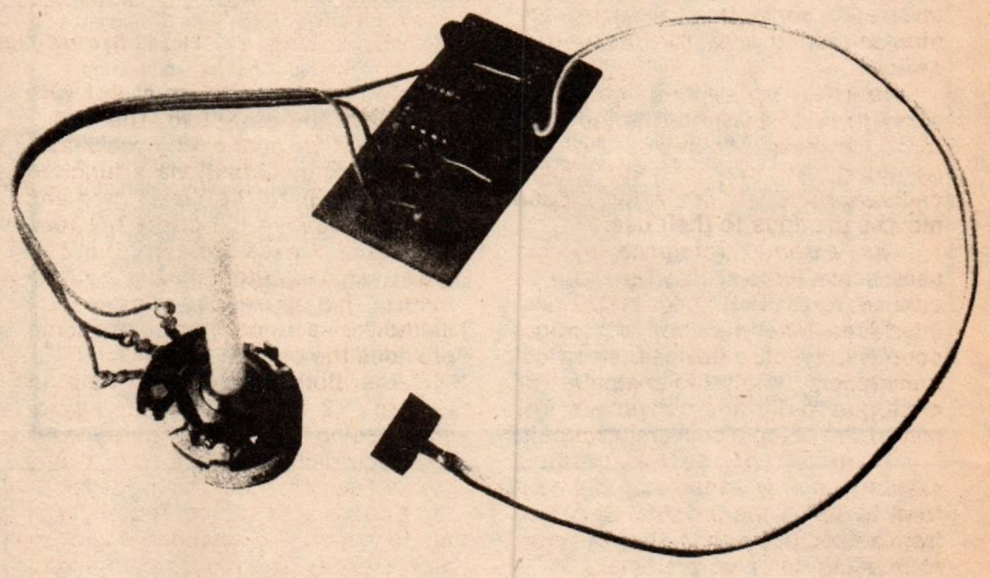
Multipurpose PCB

PROJECT

HEAT LIGHT CONTROLLER

In the dark or frozen out? Don't be with the ETI switching unit, designed for porch lights or thermostatic control. Design by Andy Elam. Development by Dave Bradshaw.



ONE OF the main uses of electronics is in control systems. The design we describe here can be used either to control a porch light, so that it comes on when it gets dark, or to act as a thermostat. It's possible to adapt this circuit to other uses as well, provided you have a transducer that varies its resistance with the controlled parameter. So, for example, you could use the same circuit with a level sensor and a relay-controlled valve to keep the water level constant in a storage tank.

If the circuit is used as a thermostat, the transducer should be a thermistor with a negative temperature coefficient and a range of operation covering the temperature you want to control. The values chosen for the circuit should work with most thermistors, but if you have problems you can alter the value of R2 to compensate — it should be within a factor of three or so of the thermistor resistance at control temperature.

How heavy a load can be switched depends on the relay contacts; if you don't use a relay that's up to the job it won't last very long. It is particularly important to use a suitable relay if you want to control a line-powered appliance. And take great care to ensure that the electronics is well separated from the line. Using a more meaty transistor for Q1 (and adjusting R5 and R6 for a correspondingly higher base current) will make it possible to drive a fairly hefty relay, though it must have a 12 V coil.

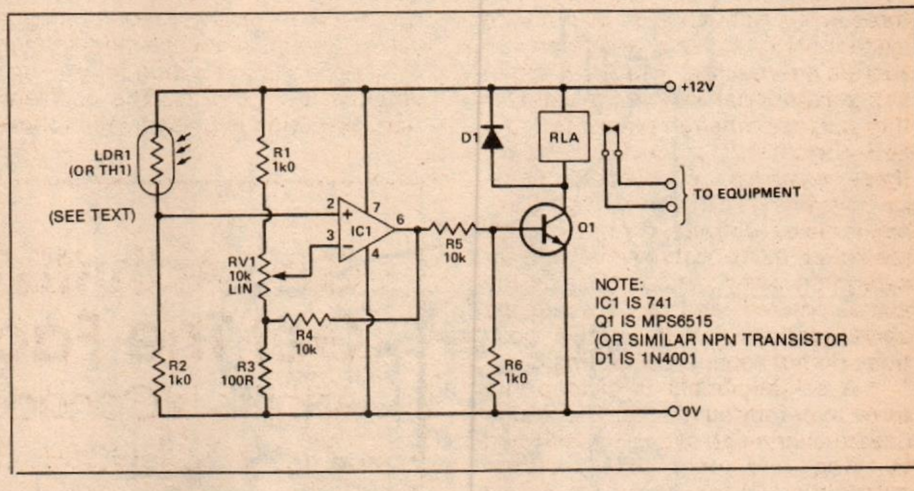


Fig. 1 Circuit diagram of porch light controller or thermostat.

Construction

Assembly of the components on to the PCB should be straightforward provided the overlay shown is carefully followed. We suggest using Vero pins for the wiring connections and these should be attached first. Next solder in the resistors, then all the other components. Be sure to get the connections of D1 the correct way around and note that the connections of Q1 will vary depending on what type of transistor you use — it may be necessary to bend the leads to get the transistor to fit if you don't use the one we specify.

Once you've built the circuit, you can check it's working correctly by connecting the power and adjusting RV1. If it is working, the relay will switch on and off as you move the wiper of RV1 from one end of the track to the other.

Next install the transducer in position, and then set RV1 so that the relay energises at the desired light level or temperature. However, the LDR shouldn't be illuminated by the porch light it's controlling, or you'll get oscillation which isn't the effect we're looking for!

HOW IT WORKS

The only difference between the circuit used as a porch light controller and as a thermostat is the transducer used — the operation of the circuit in sensing the change of resistance of the LDR or thermistor is identical. For the LDR, the resistance increases as the light falling on the sensitive surface lessens. If you use a thermistor with a negative temperature coefficient, as we suggest for the thermostat, then its resistance increases as the temperature falls. So in both cases, the circuit should turn on the relay as the resistance of the transducer increases.

The transducer chosen is used with a 1k0 resistor to create a potential divider at the inverting (−) input of the op-amp, so that the potential seen at the input is dependent on either the light or the temperature. There is another potential divider supplying the non-inverting (+) input, but in this case the input voltage is determined solely by the position of the potentiometer slider (neglecting supply variations).

Differential op-amps have the property of amplifying the voltage difference between the inverting and non-inverting inputs. Without negative feedback, the internal DC gain of 100 dB (x100,000) is obtained. This means that whenever the inverting input voltage is greater than the non-inverting input voltage, the output of the op-amp goes to its minimum — a volt or two above 0V. If the non-inverting in put voltage exceeds the inverting input voltage, the output rises to nearly +12V.

The effect of R3 and R4 is to introduce very limited positive feedback, and so hysteresis (not to be confused with hysteria, which is an effect widely found amongst ETI editorial staff). The op-amp with switch on at one light level (or temperature) and go off at a slightly higher one. This is to provide clean switching, with no flickering on and off of the controlled light or heater.

Q1 is driven via R5 and R6, and in turn drives the relay. R5 is necessary to limit the base current of the transistor; R6 prevents the minimum (off) output of the op-amp from turning Q1 on. D1 protects Q1 against any back-EMF generated by the relay coil.

Transposing the transducer (LDR1 or TH1) with R2 will have the effect of reversing the switching action of the circuit, ie the light will go off as daylight fades.

PARTS LIST

Resistors (all ¼W, 5%)	
R1,2,6	1k0
R3	100R
R4,5	10k
Potentiometer	
RV1	10k linear
Semiconductors	
IC1	741
Q1	MPS6515 (or any other general purpose NPN transistor)
D1	1N4001
Miscellaneous	
LDR1	ORP12 or Radio Shack 276-116 or
TH1	thermistor — see text
RLA	12V relay, minimum coil resistance 100R; see text
PCB	

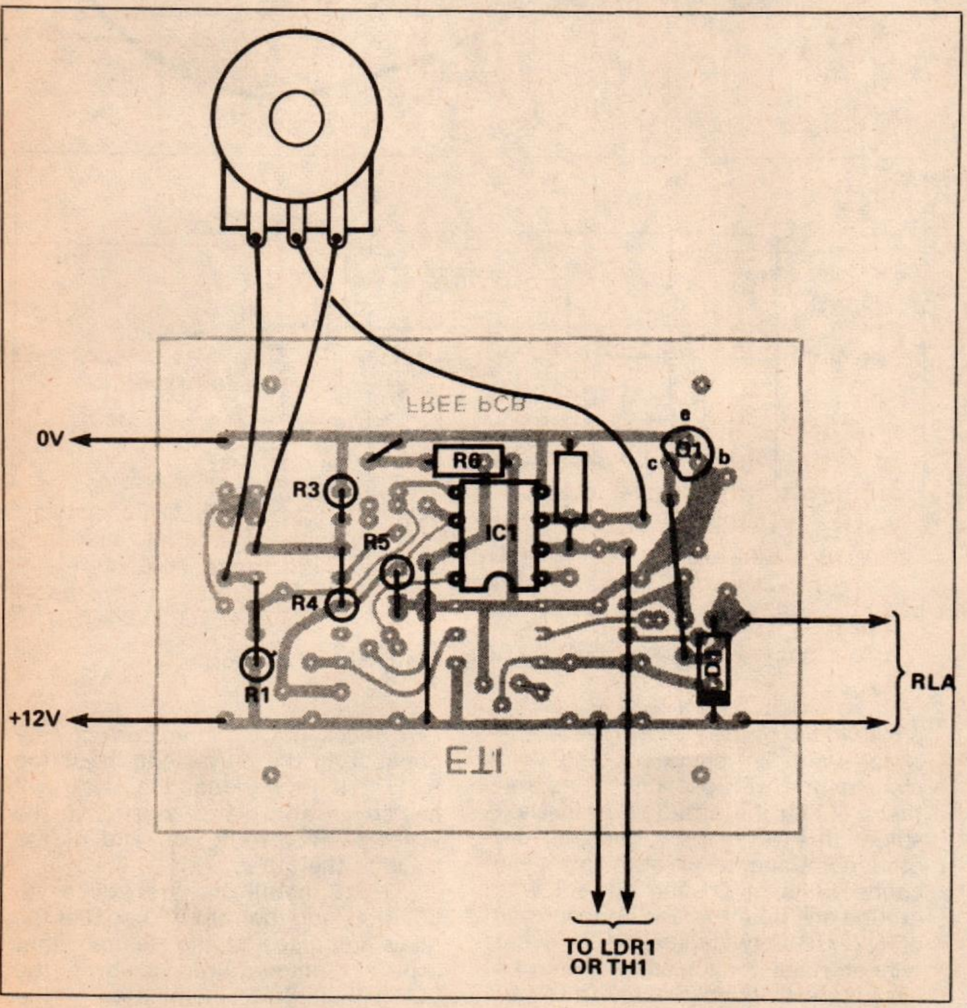


Fig. 2 Component overlay. Note that LDR1 (or TH1), RV1 and RLA are mounted off the board.

IF STRIP TESTER

You're listening to The News when the radio goes dead; if you're one of the few people in the country who wouldn't regard this as a blessing, here's a simple little circuit to help you to find the fault. Design and development by Andy Elam.

THE IF strip tester is a very useful and simple-to-build piece of test equipment. The purpose of it is to inject a signal onto an AM radio's IF strip and determine where a fault might be — the test waveform used is a 455 kHz signal modulated by 1.5 kHz. The probe should be first connected to the radio's ground rail with the croc-clip; the point of the probe should be touched onto various points along the IF strip while the radio is switched on. If the section works the radio will demodulate the signal and give a 1.5 kHz tone through the loudspeaker. When no signal is output the fault must lie after that point in the circuit.

Construction

A suitable probe can be constructed from an old ball-point pen case with a piece of 50R co-ax cable. The refill should be removed from the pen, along with the end-cap. Strip 9" from the end of the cable and insert this into the pen, forcing the sleeve of the cable into the end of the pen. This may be glued (if necessary) with an epoxy adhesive. Then strip the shield of the cable back to the top of the pen, tin the end and insulate it with a piece of plastic sleeving. The end should be soldered to an insulated croc-clip. The inner core should be cut back to about 1 cm and stripped to the end of the pen. The tip may now be tinned and gently filed away to form a point. Strip the other end, tin the cable and solder it to the board when this is completed.

The board should be constructed as shown in the component overlay. Once complete, the output may be tested with a scope. The faster frequency seen should have a period of approximately 2.2uS. If this is less than 2.1 uS or greater than 2.3 uS a 1k0 variable resistor may be connected in place of R3. Once the correct frequency is obtained, the potentiometer should be removed and measured on a multimeter. The closest preferred value should then be used to replace R3.

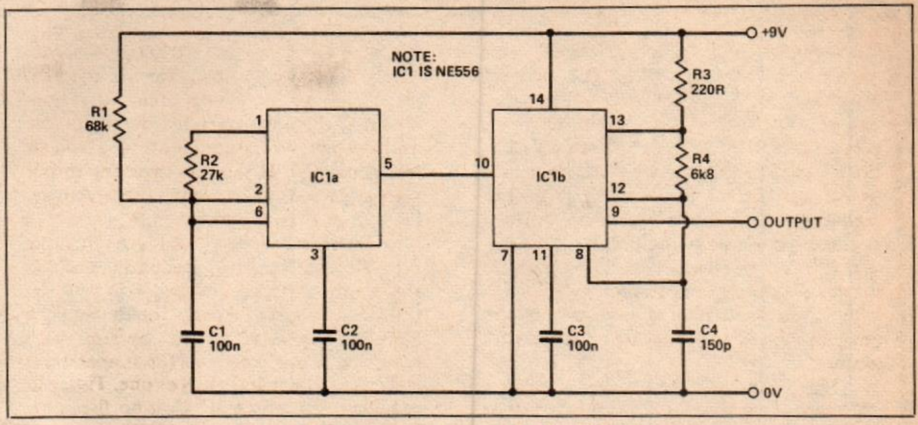


Fig. 1 Circuit diagram of the 1F strip tester.

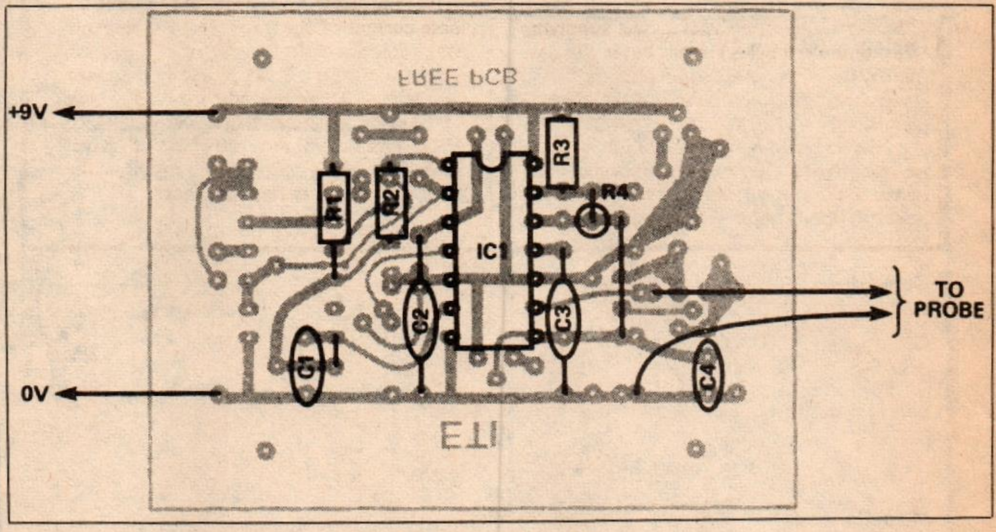


Fig. 2 Component overlay.

PARTS LIST

Resistors (all ¼W, 5%)	
R1	68k
R2	27k
R3	220R
R4	6k8
Capacitors	
C1,2,3	100n ceramic
C4	150p ceramic
Semiconductors	
IC1	NE556
Miscellaneous	
PCB; test probe (ball point pen, 1m solid inner core 50R coax cable).	

HOW IT WORKS

The circuit uses a dual 555-type timer chip, the NE556, and it's very similar in action to the doorbell circuit. The first section, built around IC1a, is a 1.5 kHz square wave generator. This is set by the time constant of R1, R2 and C1. Pin 5 is the output, which is sent to the reset pin of the next astable. This section sgenerates a rectangular (not quite square) signal, at around 455 kHz modulated by the 1.5 kHz square wave from IC1a.

ELECTRONIC DOORBELL

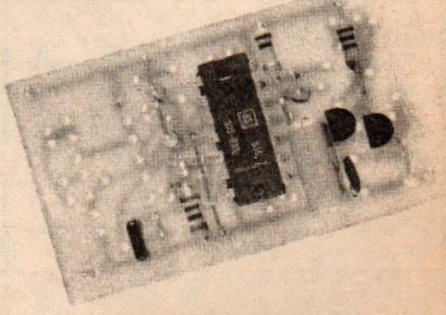
If he'd had this project instead of the bells, Quasimodo wouldn't have gone deaf; let your visitors announce themselves with a gentle warbling. Design and development by Andy Elam.

This circuit is a simple but useful device which may be used for many applications as well as the intended doorbell. No problems should be encountered with the construction of this project if the overlay diagrams are closely followed. The push-button may be a standard bell-push. However, if you use an illuminated bell-push, you'll have to use a line-powered supply and reduce the value of R3 to around a few tens of ohms — you'll have to experiment to get a suitable value, because it will depend on the bulb in the bell-push. Should you want to change either of the frequencies the CR networks may be adjusted to suit. The frequency of oscillation of IC1a is given by:

$$\frac{1.44}{(R1 + 2R2) \times C1}$$

(R1 and R2 in ohms; C1 is farads).

Other variations may also be obtained with some ingenuity — try varying the signal fed to the second astable as well as the two repeat and tone frequencies.



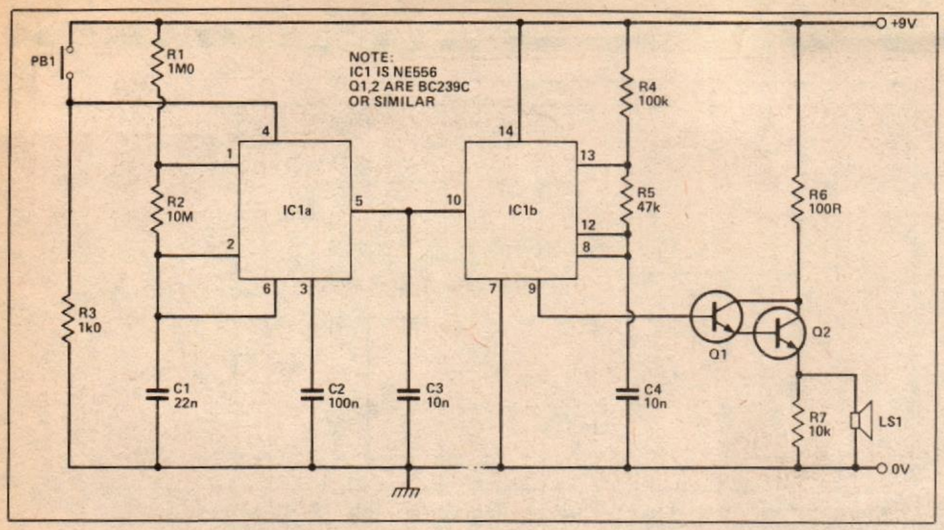


Fig. 1 Circuit diagram of doorbell.

PARTS LIST

Resistors (all ¼ W, 5%)	
R1	1M0
R2	10M
R3	1k0
R4	100k
R5	47k
R6	100R
R7	10k
Capacitors	
C1	22n ceramic
C2	100n ceramic
C3,4	10n ceramic
Semiconductors	
IC1	NE556
Q1,2	MPS6515 or similar
Miscellaneous	
LS1	8R miniature loudspeaker
PB1	push-to-make switch
PCB	

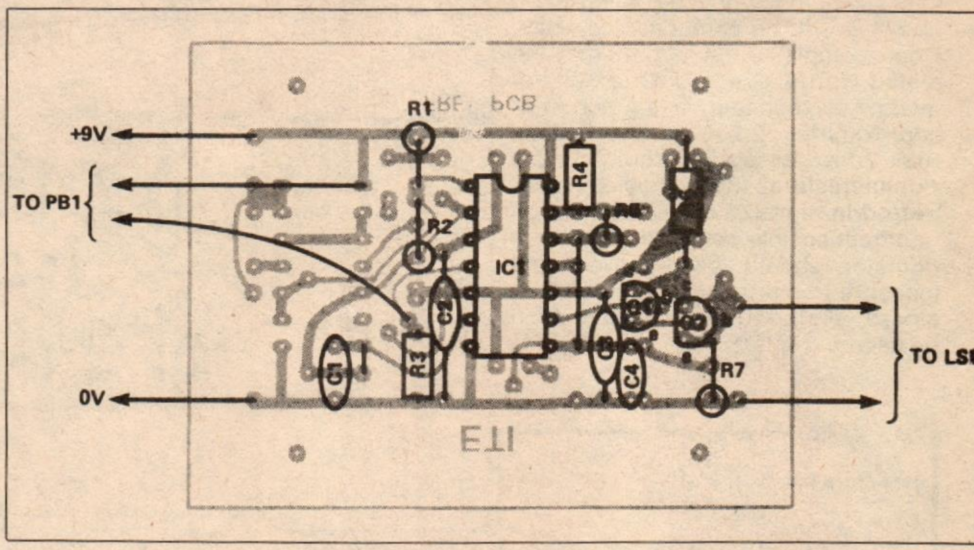


Fig. 2 Component overlay.

HOW IT WORKS

The circuit functions in a similar way to the IF strip tester. A 556 is used to provide two 555-type timers, connected here as astable multivibrators with unequal on and off periods. The first of these provides the lower, modulating frequency which gives the repeat rate. The second astable gives the higher frequency, ie the tone. Thus when the push-button is pressed the tone is generated and modulated on and off at the repeating frequency.

Until PB1 is pushed to make, the reset input of IC1a is held low by R3; this ensures that the output of IC1a (pin 5) is held low, so that the reset input (pin 10) and hence the output (pin 9) of IC1b are also held low. When PB1 makes, IC1a oscillates at a frequency determined by R1, R2, and C1 — with the values shown this is about 3 Hz. IC1b will oscillate at a frequency determined by R4, R5 and C4 (about 750 Hz) only while its reset input is high, hence producing the modulated tone.

The Darlington pair, Q1 and Q2, are used to provide sufficient current to drive LS1.

TOUCH SWITCH

Get a touching feeling with our CMOS touch switch. Design and development by Andy Elam.

THIS CIRCUIT uses CMOS technology to provide a time delay switch, suitable for use in situations where you don't want to leave a light on all night. This is very useful for those of us fortunate (?) enough to be blessed with kids. The circuit can control line-powered lighting with a suitable relay.

A time latch switch is built around a micropower CMOS IC. In the quiescent state, this IC will consume less than one microamp from the supply. The IC employed is a quad two-input NAND gate, the 4011.

Construction

This is very straightforward; the touch pads may be any type of metal connections which will not corrode or oxidise, mounted on a good insulator such as a plastic sheet. Two screw heads could be used. If the time cons-

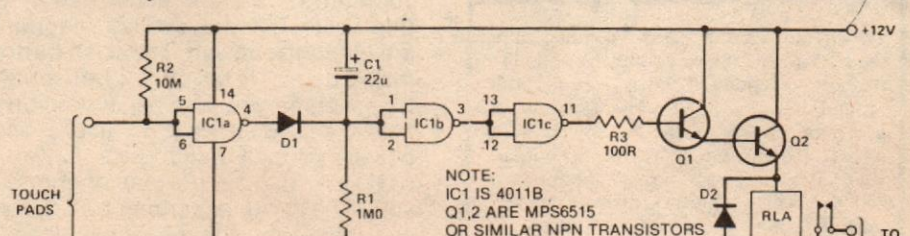


Fig. 1 Circuit diagram of touch switch.

Continued on page 25

Continued from page 22

HOW IT WORKS

When the circuit is waiting for a touch the input to the first gate, IC1a, is pulled high via the 10M resistor. So the output of IC1a is low, the input to the Darlington pair is low and the transistors do not conduct or draw any significant current.

When the contacts are bridged by the relatively low resistance of the skin, the input of IC1a is pulled low, and this leads to all the other gates switching their states. Thus, the negative plate of C1 rises to around +12V. After skin contact is removed, the first gate will resume its quiescent state, with input high and output low. R1 gradually recharges C1, so that the negative plate voltage drops (the input impedance of IC1b can be neglected because it's very high). With a 22uF and 1M0 resistor combination approximately 8 seconds elapses before the input to IC1b goes low enough for the Darlington pair to be turned off via IC1c.

This means that the relay coil will be energised for abou the duration of the RC time-constant. The relay isn't necessary if a 1V4 voltage drop from the supply is tolerable for a circuit. However, the current available is limited by the two transistors' capability.

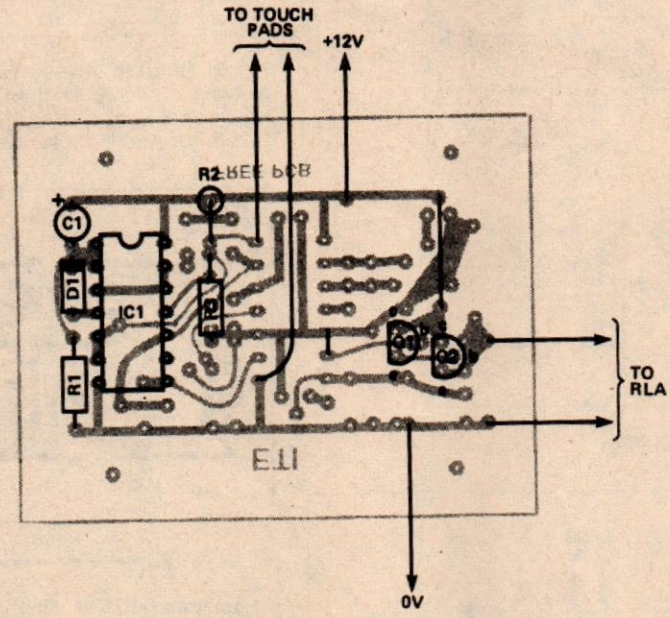


Fig. 2 Component overlay.

PARTS LIST

Resistors (all ¼W, 5%)	
R1	1M0
R2	10M
R3	100R
Capacitors	
C1	22u 16V tantalum
Semiconductors	
IC1	DC4011B
Q1,2	MPS6515 (or similar)
D1	1N4148
D2	1N4001
Miscellaneous	
RLA	12V relay, coil resistance greater than 185R
PCB	

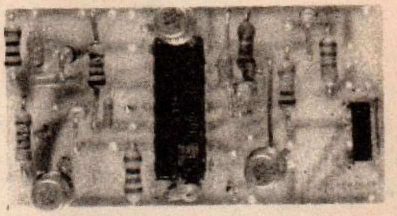
tant is too short a larger capacitor may be used, or a smaller capacitor to get a shorter time constant. The board is small enough to stick to the relay with some double-sided sticky pads if required.

SOUND TO LIGHT UNIT

Feel like flashing? Don't get arrested — build this sound-to-light unit instead! Design and development by Andy Elam.

THIS MINIATURE sound-to-light circuit uses an electronic element, the active filter, that, despite the trepidation some beginners may feel, has become a basic building block in electronics. The system takes the audio signal from a radio cassette player or other piece of audio equipment and lights up the corresponding light emitting diodes depending on the frequency components of the signal; using opto-coupled triacs, line-powered lighting can be controlled — more on this later.

The circuit should be constructed as shown in the overlay diagram with all the external connections made carefully. The input signal may be taken directly from the loudspeaker terminals of a radio or cassette player, or the output for an earpiece may be used providing the loudspeaker is not switched off. In use, RV1 can be adjusted to get most pleasing effect, with the lights flashing in time to the sound source.



HOW IT WORKS

Three types of filter must be used, one which passes low frequencies, one which passes the mid-band frequencies, and one which passes high frequencies. Thus, low-pass, band-pass and high-pass filters are needed.

The first element in the circuit is a level control and amplifier. The gain of the amplifier can be increased by increasing the value of R2, in order to provide sufficient signal to drive the filters. The circuit also privides a buffer between the sign-providing circuit and the filters.

IC1b provides the high-pass section, IC1c the band-pass and finally IC1d the low-pass. The high and low pass sections are actually passive filters, buffered by IC1b and IC1d respectively; the band-pass filter around IC1c is the only tru active filter. When a signal has enough low frequency elements the low-pass filter permits its output to saturate and this switches the LED on. Similarly, with mid and high frequency elements, the mid and high LEDs come on.

Substituting the LED with the control inputs of an opto-isolated triac (see Fig. 2) and reducing R13, 14 and 15 to 820R will enable you to control line-powered lights.

In Fig. 2 the circuit for one control channel only is shown: the other two will be identical. Note that all the circuit to the right of the optoisolator is at line potential: use extreme caution when connecting to the line and ensure that all components are enclosed within a grounded metal container or plastic box. If the common terminal of the line unit isn't grounded already, then you should connect it to ground as shown.

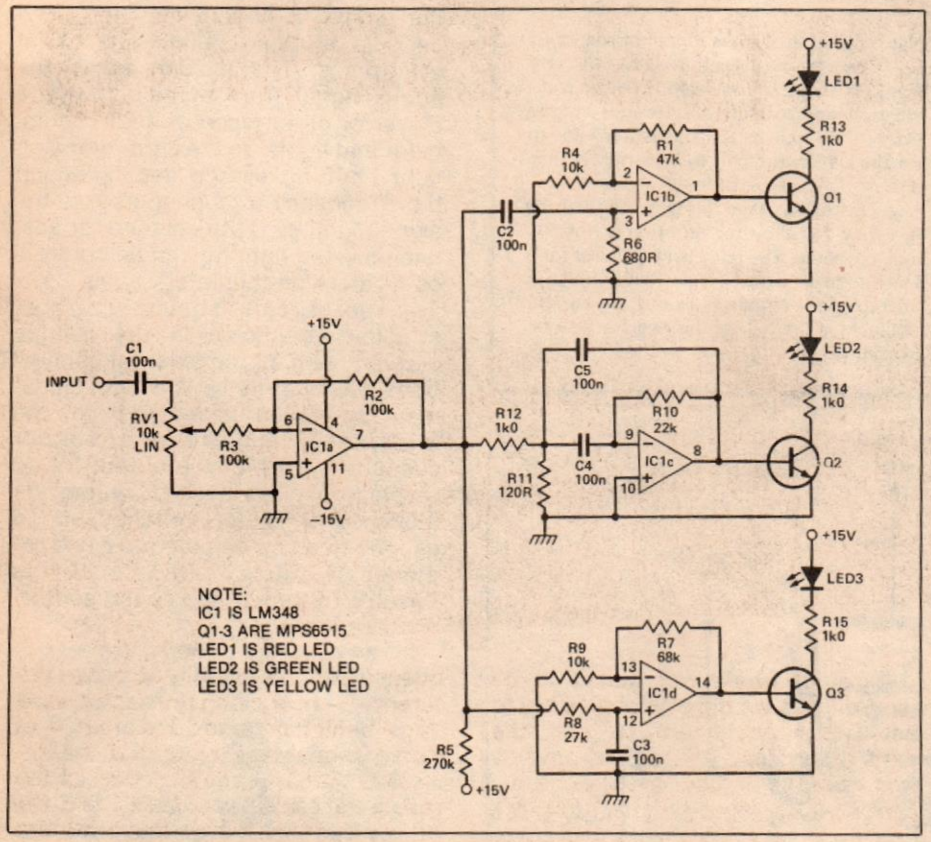


Fig. 1 Basic circuit diagram.

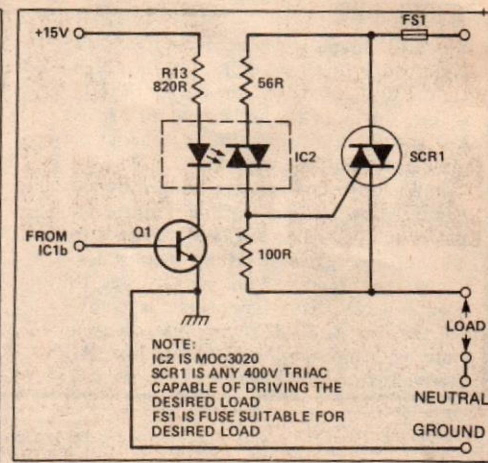
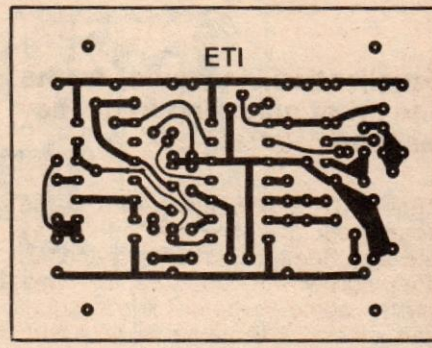


Fig. 2 Circuit to drive line-operated lights. Note: IC2 is MOC 3020, SCR1 is any 400V triac capable of driving the desired load, FS1 is fuse suitable for desired load.



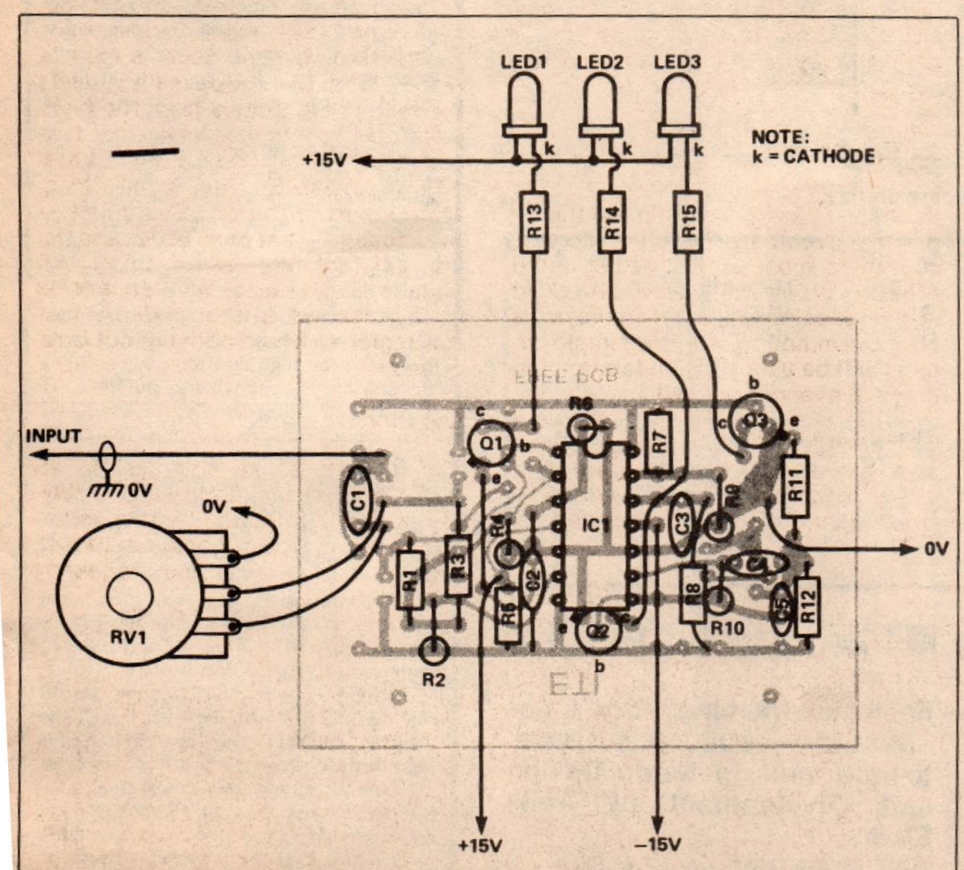


Fig. 3 Component overlay.

PARTS LIST

Resistors (all ¼ W, 5%)	
R1	47k
R2,3	100k
R4,9	10k
R5	270k
R6	680R
R7	68k
R8	27k
R10	22k
R11	120R
R12,13,14,15	1k0
Potentiometers	
RV1	10k linear
Capacitors	
C1-5	100n ceramic
Semiconductors	
IC1	LM348
LED1	any red LED
LED2	any green LED
LED3	any yellow LED
Miscellaneous	
PCB	

Linear Temperature To Frequency Transconducer

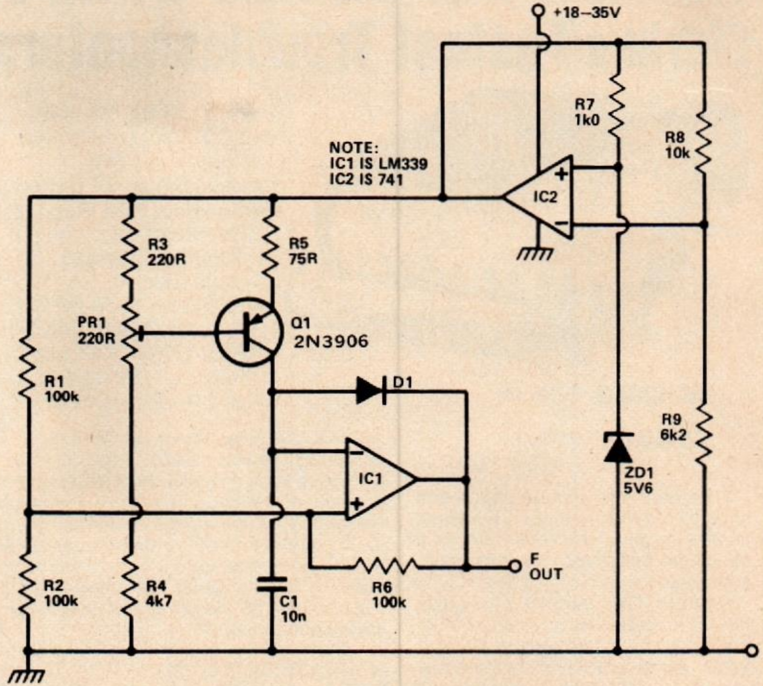
J.P. Macaulay

This circuit provides a linear increase of frequency of 10 Hz/°C over 0-100°C and can thus be used with logic systems, including microprocessors.

The heart of the system is the temperature probe Q1 whose Vbe changes at 2.2 mV/°C. Since this transistor is incorporated in a "constant" current source circuit it follows that a current proportional to temperature will be available to charge C1.

The circuit is powered via the temperature stable reference voltage supplied by the 741. Comparator IC1 is used as a Schmitt trigger, the output of which is used to discharge C1 via D1. To calibrate the circuit Q1 is immersed in boiling distilled water and PR1 adjusted to give 1 kHz output.

The prototype was found to be accurate to within 0.2°C.



Build a
Diode Temperature Probe

Low-cost sensor gives temperature reading on a DMM

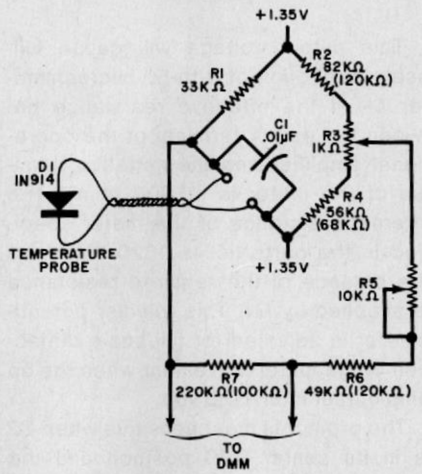


Fig. 1. Diode is one leg of a Wheatstone bridge connected to DMM.

IF YOU own a digital multimeter (DMM), it can be made to give temperature readings for a small expenditure in parts and effort. When a small forward bias is applied to a conventional silicon diode, the voltage drop across the diode junction changes at a rate of about 1.25-mV/°F (2.24-mV/°C). Thus, a low-cost and readily available diode such as the 1N914 can be used as a temperature probe.

The bridge circuit shown in Fig.1 works in conjunction with the sensor diode and a DMM on the 200-mV (low temperature) or 2-volt (high-temperature dc voltage ranges. The displayed digits are the temperature. Note that in Fig. 1, two values are shown for *R2*, *R4*, *R6*, and *R7*. The values in parenthesis are for Celsius operation, while the others are for Fahrenheit. Capacitor *C1* is used to bypass stray signals that may be picked up on the leads.

Construction. The circuit can be assembled on a small printed-circuit or perforated board. The small circles at *C1* indicate the need for a pc pad, or WireWrap pin to make the connections to the remote diode.

To make the temperature probe safe for liquid immersion, the arrangement shown in Fig. 2 is used. Preform a short length of vinyl tubing, fill it with epoxy, and "thread" it up the diode leads to make contact with the diode body. Allow the epoxy to thoroughly cure. If desired, a length of heat-shrink tubing may be used. In either case, leave a short length of diode lead exposed for soldering to the flexible cable.

Slide a short length of heat-shrink tubing over the covered diode leads, solder each diode lead to the flexible cable, and then fit the tubing over the solder joint. Shrink the tubing to make a tight fit.

PARTS LIST

C1—0.01-μF disc capacitor
D1—1N914 silicon diode
R1—33 kΩ, ½-W resistor
R2—82 kΩ (F) or 12 kΩ (C) ½-W resistor
R3—1-kΩ pc-mount potentiometer
R4—56 kΩ (F) or 68 kΩ (C) ½-W resistor
R5—10 kΩ pc-mount potentiometer
R6—49 kΩ (F) or 120 kΩ (C) ½-W resistor
Misc.—1.35-volt battery and holder, vinyl or heat-shrink tubing, flexible two-conductor cable, epoxy, solder, etc.

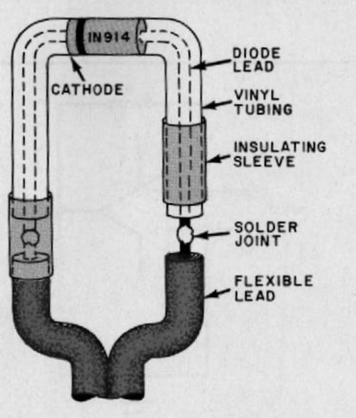


Fig. 2. To make probe immersible, vinyl tubing is added around leads.

Calibration. The resistance values for *R2-R4* and *R6-R7* are not critical, but their *ratios* are. Perform the following calibration tests before changing any resistance value.

Potentiometer *R3* balances the bridge to indicate 32°F (0°C) at this temperature. Potentiometer *R5* is used to reduce the 1.25 (2.24) mV/degree to exactly 1 mV/degree and is also used to set the upper range point.

With *R3* and *R5* at their center of rotation, immerse the diode probe in a container of finely shaved or crushed ice. Adjust *R3* to produce a DMM indication of 32 (°F) or 0 (°C). Place the DMM in the 2-volt dc range, immerse the probe in a container of boiling water, and adjust *R5* for a DMM indication of 212 (°F) or 100 (°C).

If you find that *R3* is at one end of its rotation, add a parallel resistor in the megohm range across either *R2* or *R4*, depending on the location of the wiper of *R3*. If *R5* is at one end of its rotation, add a parallel resistor (also in the megohm range) across *R6* or *R7*. If desired, a 10-turn trimmer potentiometer can be used for each of the fixed resistors and preset for the correct ratios.

Since the DMM will also indicate negative voltages, it will similarly indicate temperatures below those at which it is calibrated. Also, the diode can operate at temperatures above 212°F, which is about the limit for the plastic insulation used for the diode leads, so a plastic with a higher temperature rating can be used to liquid-proof the sensor. Or, without such protection, the sensor can be used for dry, or contact, temperature measurements. ◇

Measure Weak Direct Currents with the Sensitive Micro Meter

BY I. QUEEN

Low-cost op-amp system can measure solar-cell output and currents in other low-level circuits.

IF YOU PLAN to measure the output of a solar cell under low-light conditions, to work with micropower ICs, or otherwise experiment with weak-current circuits, you'll need a sensitive current meter. The Sensitive μ Meter presented here will allow you to measure direct currents as small as a fraction of a microampere. Moreover, it is not subject to the disadvantages associated with standard panel microammeters—high cost, fragile movements, and relatively high internal resistance.

The project employs an operational amplifier to increase the sensitivity and effectively decrease the input impedance of a moderately priced, readily available 0-to-50 microammeter. It has three switch-selected scales; 0 to 0.5 μ A; 0 to 5 μ A; and 0 to 50 μ A. The circuit can be powered by a supply furnishing as little as ±2 or +4 V, and can be constructed for about $15.

Circuit Operation. A simple circuit for current-measuring applications is shown in Fig. 1. When an input current *I* is applied to the inverting input of the op amp, an inverted output signal is generated by the op amp. If the gain of the operational amplifier is very high, we can consider that the entire input current flows through feedback resistor *R*. An output voltmeter *M*, which is calibrated in terms of *I*, measures the product *IR*. The voltage drop across the operational amplifier is practically zero (the output voltage divided by the op amp's open-loop gain).

The schematic of the Sensitive μ Meter is shown in Fig. 2. Switch *S2* selects the range and determines the feedback resistance of the stage. When the switch is in its center (off) position, the feedback resistance is *R3*, one megohm. An input current of 0.5 μ A will cause the output of the op amp to be 0.5 volt above ground when only *R3* is in the feedback loop.

This output voltage will cause full-scale deflection of 0-to-50-microammeter *M1* if the effective resistance between the output terminal of the operational amplifier and the negative terminal of the meter is 10,000 ohms. The internal resistance of the meter specified in the parts list is 1620 ohms, so the balance of the required resistance is supplied by *R4*. This trimmer potentiometer is adjusted for full-scale deflection of the meter movement when the op amp output is at +0.5 volt.

The project is most sensitive when *S2* is in its center (off) position and the feedback resistance is one megohm. In this operating mode, full-scale deflection of the meter corresponds to an input current of 0.5 μ A. Higher-current ranges are obtained by shunting *R3* with other resistors to lower the overall feedback resistance. This is accomplished by placing *S2* in one of its two other positions. When the range switch is placed in its 5 μ A position, the parallel combination of *R1* and *R3* causes the meter to deflect to full scale if the input current is five microamperes. Similarly, placing *S2* in its 50 μ A position shunts *R3* with *R2* and causes full-scale deflection of the meter movement when an input current of fifty microamperes exists.

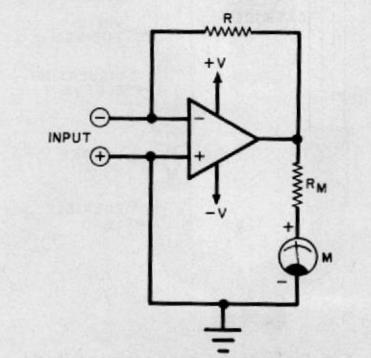


Fig. 1. Schematic of simple current-measuring circuit.

Two shorting switches are included in the circuit. Switch *S1* shorts the input of the project. It is used in conjunction with potentiometer *R5* to zero the meter movement. The other switch (*S3*) is used to short the terminals of *M1* when the meter is not being used. This minimizes mechanical shocks to the meter movement when the project is being transported. Diodes *D1* and *D2* protect the project from excessive input voltages. Jack *J2* provides access to *M1* so that the meter can be used in isolation from the rest of the project.

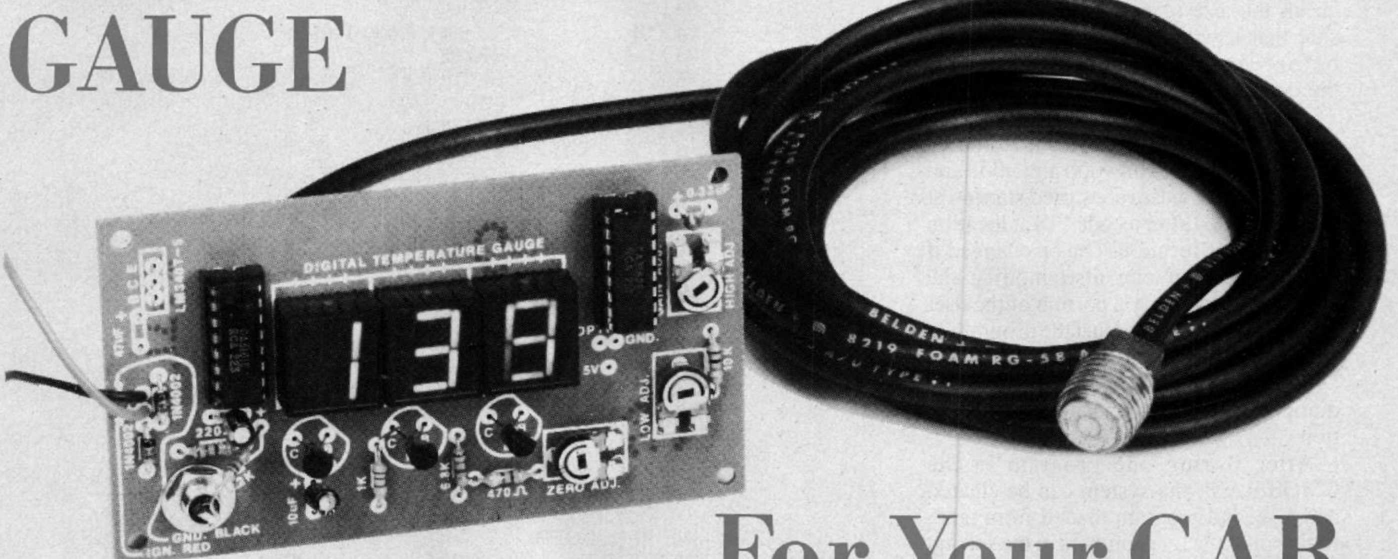
You might wonder why the circuit provides for a 0-to-50-microampere scale when meter movement, *M1*, covers this range on its own. The following exercise performed by the author will illustrate the need for such a scale. A solar cell was connected across input jack *J1* and illuminated so that the Sensitive μ Meter indicated a current of 50 μ A. The cell was then connected to *J2* and its output current measured using *M1* alone. It indicated a current of 1 μ A.

The reason for this discrepancy between the two readings is that *M1* presents a higher resistance to the solar cell when it is used independently than the project as a whole does. It is desirable to keep the internal impedance of a current-measuring instrument as low as possible. Thus, it is better to employ the project as a whole (as opposed to *M1* or a similar meter alone) in the measurement of currents up to 50 μ A.

There is another significant advantage to the use of the Sensitive μ Meter as opposed to a microammeter alone. Due to the clipping action of protective diodes *D1* and *D2*, the maximum output voltage of the op amp on any of the three ranges is

Digital TEMPERATURE GAUGE

FRED L. YOUNG, SR. and
FRED L. YOUNG. JR.



For Your CAR

This is the time of year when automobile engines start to overheat and leave angry motorists stranded by the roadside. This digital temperature gauge for your car will see to it that you're not one of them.

LAST MONTH WE DESCRIBED A DIGITAL voltmeter for your car (or other vehicle) based on the CA3161E and CA3162E IC's. This month we'll use the same IC's to build a digital thermometer that can be used to monitor your car's engine temperature, or in any of many other temperature-measurement applications.

The thermometer's circuit is similar in many respects to that of the voltmeter, and we suggest that you refer to the July 1983 issue of **Radio-Electronics** for a complete description of its operation.

A schematic of the thermometer is shown in Fig. 1. In essence, IC2, a CA3162E dual-slope, dual-rate analog-to-digital converter, translates an incoming analog signal (we'll discuss its source in a moment) into a digital BCD (*B*inary-*C*oded *D*ecimal) number. Then, IC2, a CA3161E, converts that number into signals that cause the segments of DISP1–DISP3 to light up in certain patterns to form numbers. The CA3161E is known as a BCD–7-segment decoder/driver. The power for the entire circuit is derived from IC1, a 340T-5 five-volt regulator.

The temperature probe itself is ridiculously simple—it's just a 1N4002 or 1N914 (1N4148) diode at the end of a piece of coaxial cable. Diodes (and other semiconductor junction-devices) have an unusual—but very useful—characteristic: the forward voltage across them drops as the temperature increases. In the case of diodes, the rate of change is about two millivolts per degree Fahrenheit. The rate of change is linear over a respectable temperature range, and this temperature gauge is accurate from well below zero up to 250°. All we have to do is apply a voltage to the diode and measure the forward voltage, which is then converted by the rest of the circuit into a temperature reading.

(One word of caution, though: If you ever have to change probes, the gauge will have to be recalibrated. While any diode you use will have the same rate of change, each will have a different "base point" from which it is referenced, and recalibration will be necessary to take that into account.)

Construction

Before you start mounting parts on the board, you should prepare the piece of red plastic that will protect the board and display. The plastic should be ⅛-inch thick and just a little larger in area than the circuit board. Place the plastic under the board and, with a sharp point, mark the position of the four mounting holes in the board on the plastic. Then, make a hole at each position for the 4-40 mounting hardware (drill a small pilot hole, and then carefully enlarge it; that way you won't crack the plastic). Temporarily set the plastic aside.

A foil pattern for the digital temperature-gauge circuit board is shown in Fig. 2. If you would rather purchase a ready-to-use board than make your own, see the Parts List for the supplier.

Techniques for PC-board construction were discussed in detail in the article the digital voltmeter, and if this is your first project, you will gain a lot by reading it before you start building.

Figure 3 shows a parts-placement diagram for the board. It's advisable to use sockets for IC2 and IC3; install them first, then the resistors, followed by the capacitors. Do not install IC2 or IC3 until after your initial board-checkout. When you mount the three 7-segment LED's, DISP1–DISP3, solder only two pins at opposite corners at first. That will permit you to adjust their positions fairly easily if you don't put them in straight the first time. Be sure that the ridges at the tops of the LED's face the way shown in the diagram. When you install jack J1, you may have to enlarge the hole in the board so it can fit through. Use a lockwasher on the foil side of board both to keep the jack

The CMOS RAM board allows you to store and merge programs or data quite easily—using machine-language routines resident in the DMOS memory. (You'll have to enter the two machine-code programs in Tables 12 and 13.)

The routine in Table 12 is used to dump a program from the BASIC system to the CMOS RAM. The contents of all memory (both programs and variables) from the start of user memory (16509) to the start of the display file is dumped. To check the size of the program (to make sure that it will fit in the CMOS RAM) before executing the routine, use the command "PRINT (PEEK 16396 + 256*PEEK 16397 − 16509)/1024; "K"." The number of bytes is stored by the routine in location 9000 and 9001 and the program and data are stored starting at location 9003 (after a code 118 at location 9002). Those locations can be changed if you wish. You can also modify the routine to dump only a portion of the user memory (for example, just the program or perhaps just the variables). The command "PRINT USR 8244" will execute the dump and respond with a 0 upon completion.

After storing one program in the CMOS RAM, the system can be cleared and a second program loaded from tape. Make all of the line numbers in the second program loaded from tape less than the lowest line number in the first BASIC program. Line numbers from the stored program should not be duplicated—the BASIC program in Table 14 can be used for renumbering. (It is also a good example of a program that might be useful to store in the system-transparent RAM.) Enter the command "IF USR 8269 = 0 THEN STOP." That is necessary to prevent the execution of the program after reloading.

The merge routine can also be used to store a BASIC program in the CMOS RAM. However, you must remember to enter a line like "1 REM" before moving the stored program back up to the system RAM. (You can delete it once it is back in the user memory.)

Free space

The amount of free space in memory is the "spare" memory between the top of the calculator stack and the bottom of the machine stack. (See page 128 of your manual.) The top of the calculator stack is stored as the system variable STKEND. The bottom of the machine stack is always pointed to by the Z80 register SP (stack pointer). The routine in Table 15 simply subtracts one from the other. To determine the amount of free memory in your system, enter the machine-code program in Table 15 and then enter the command "PRINT USR 8297." The result that you will see will be the number of free bytes.

As suggested in the introduction, there are many other routines like these that you can devise to expand the versatility of the Sinclair BASIC system. You might consider only partially populating the board with one HM6116P CMOS memory IC initially—even 2K of system-transparent memory is extremely useful. We've discussed several useful programs that can be stored in the nonvolatile RAM. But as you can see, the software does not occupy much of the space that is available.

Before we finish up, a word of caution: If you use this memory expansion along with the 16K RAM pack, be sure to use the programs we discussed earlier to save the contents of the 8K system-transparent region. As you are probably aware, the poor design of the Timex RAM pack connector can be the cause of frequent system crashes. While any crash is annoying, it is even worse in this case. It's bad enough to lose BASIC that is stored in the 16K RAM, but there is nothing more frustrating than having 8K of machine code that you stored in nonvolatile RAM overwritten by garbage. **R-E**

TABLE 12

Address	Data	Mnemonic
8244	17 125 64	LD DE (start of program area; 16509)
8247	42 12 64	LD HL (start of display file)
8250	183	OR A (clear carry flag)
8251	237 82	SBC HL, DE
8253	68 77	LD B, H and LD C, L
8255	33 40 35	LD HL (start of storage area; 9000)
8258	113	LD (HL), C
8259	35	INC HL
8260	112	LD (HL), B
8261	35	INC HL
8262	54 118	LD (HL), (code 118)
8264	35	INC HL
8265	235	EX DE, HL
8266	237 176	LDIR
8268	201	RETURN

TABLE 13

Address	Data	Mnemonic
8269	237 75 40 35	LD BC (size of progam)
8273	42 12 64	LD HL (start of display file)
8276	43	DEC HL
8277	197 229	PUSH BC; PUSH HL
8279	205 158 9	CALL routine at 2462 decimal
8282	209 193	POP DE; POP BC (note exchange)
8284	33 42 35	LD HL (start of storage area; 9002)
8287	237 176	LDIR
8289	201	RETURN

TABLE 14

```
9900 REM LINE RENUMBER
9905 PRINT "NOTE GOTO AND GOSUB ADDRESSES"
9910 PRINT
9915 PRINT "ENTER NUMBER FIRST LINE WILL BE"
9920 INPUT F
9925 PRINT
9930 PRINT "ENTER LINE INCREMENT"
9935 INPUT I
9940 PRINT
9945 LET N = 16509
9950 POKE N, INT (F/256)
9955 POKE N+1, F - 256*INT (F/256)
9960 REM POINT TO NEXT LINE
9965 LET N = N + PEEK (N+2) + 256*PEEK (N+3) + 4
9970 IF 256*PEEK N + PEEK (N+1) = 9900 THEN GOTO 9990
9975 LET F= F+I
9980 GOTO 9950
9990 PRINT "LAST LINE IS ";F;
```

TABLE 15

Address	Date	Mnemonic	
8297	33 0 0	LD HL, 00	Clear HL
8300	57	ADD HL, SP	Move SP to HL
8301	237 91 28 64	LD DE (Stkend)	
8305	237 82	SBC HL, DE	Carry flag already cleared
8307	68 77	LD B, H and LD C, L	
8309	201	RETURN	

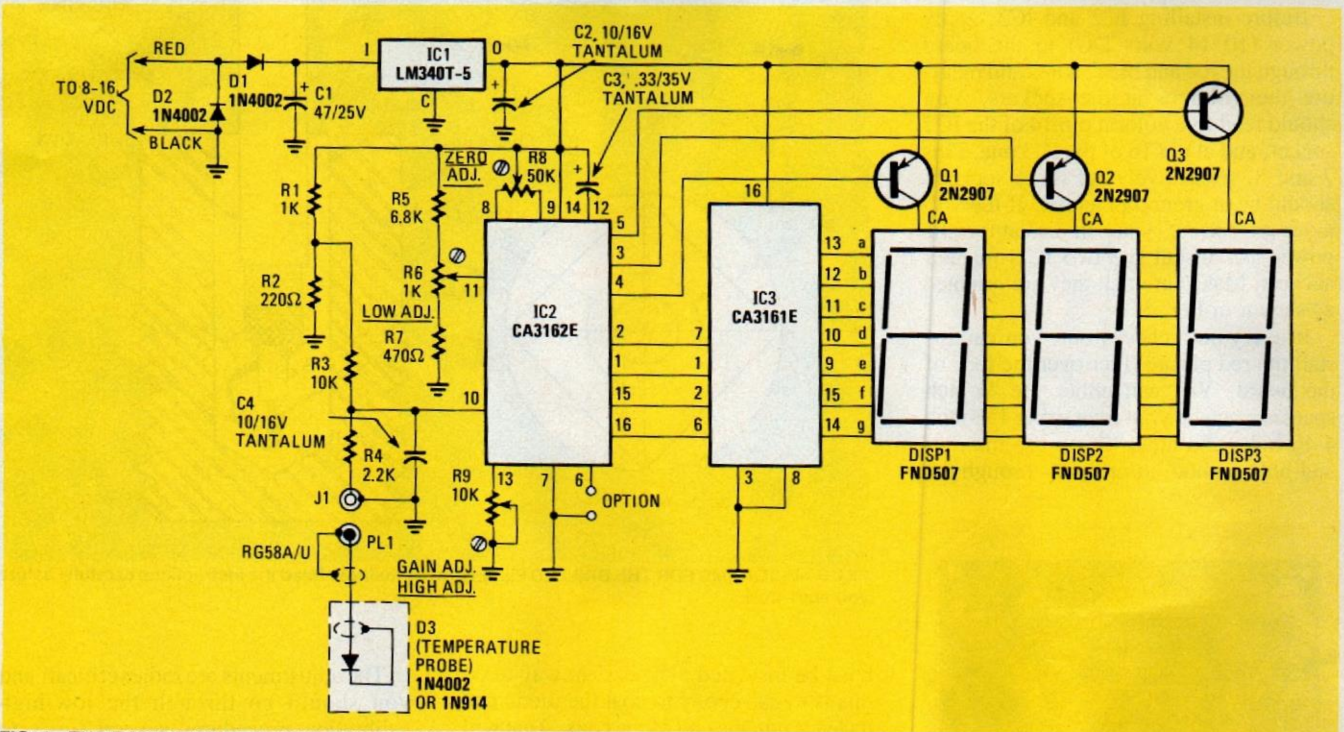


FIG. 1—THE BASIC DIGITAL TEMPERATURE GAUGE consists of a probe, an A/D converter (IC2), a 7-segment LED decoder/driver (IC3) and, of course, the display LED's themselves.

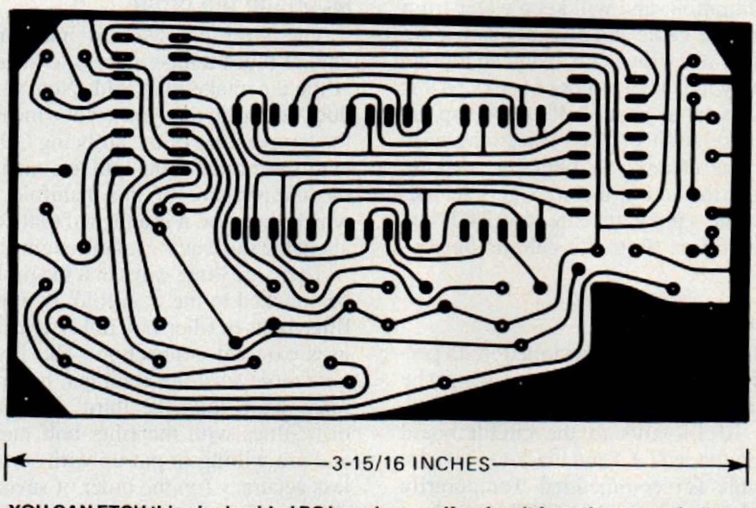


FIG. 2—YOU CAN ETCH this single-sided PC board yourself, or buy it from the source indicated in the Parts List.

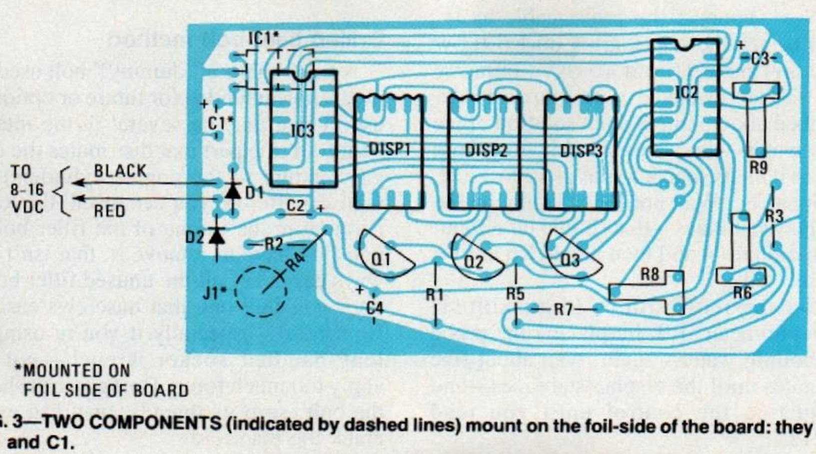


FIG. 3—TWO COMPONENTS (indicated by dashed lines) mount on the foil-side of the board: they are IC1 and C1.

from working loose and to make sure that it makes good electrical contact with the foil. Note that the "business end" of the jack is on the foil side of the board. Connect resistor R4 from the center lug of the jack to the board.

The last two components to be installed (except for the two IC's) are IC1 and C1. They should be mounted on the *foil side* of the board, as shown in Fig. 4. That is done to keep the total height of the component-side of the board down. Make sure that the regulator is arched over backward as shown, but that its case does not contact the board. (A piece of electrical tape on the board beneath the regulator to act as insulation will make sure of that!)

Finally, connect three-foot lengths of

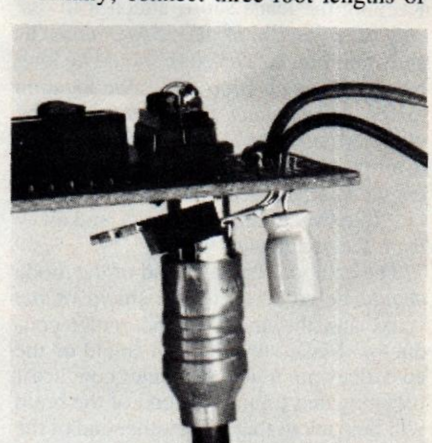


FIG. 4—BEND IC1 OVER BACKWARD on the bottom of the board as shown.

red and black wire to the points on the board indicated in Fig. 3; they will be used to provide power to the circuit.

Before installing IC2 and IC3, apply power (10–14 volts DC) to the board through the red and black wires and measure the voltages at the sockets. You should read five volts at pin 14 of the IC2 socket, and at pin 16 of the IC3 one. Pins 7 and 8, respectively, of those sockets, should be at ground potential. If the voltages are correct, you can disconnect the power and install the two IC's in their sockets. Make sure that they are oriented as shown in Fig. 5.

If everything checks out, you can install the red plastic filter over the face of the board. You can either use ¾-inch spacers or make your own using 1½-inch 4-40 bolts and nuts. If you use the nut-and-bolt method, insert bolts through the plastic, and secure them with nuts on the reverse side. Then screw a second nut onto each bolt, allowing ¾ inch of space between it and the first one. Insert the bolted-plastic assembly into the holes in the PC board, and secure it with four more nuts.

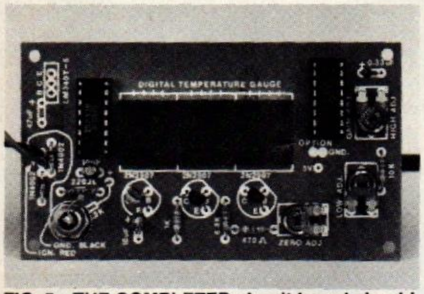


FIG. 5—THE COMPLETED circuit board should look like this. Note the mounting of J1 and how R4 is connected to it.

With that done, you are ready to build the temperature probe and calibrate unit.

Probe construction

The temperature probe, D3, can be a 1N4002, 1N914, or 1N4148 diode. Keeping the leads short, attach it to one end of a length of RG58A/U coax as shown in Fig. 6. The coax should be long enough to reach from the probe location to the point where the display will be mounted, and should have enough slack to allow it to be routed around areas of the engine compartment that get particularly hot, like the exhaust manifold, and away from the spark-plug wires.

The cathode (banded) end of the diode should be soldered to the shield of the coax, and the anode to the center conductor. Make sure that the shield of the coax does not touch the center conductor (twisting and tinning the end of the braid will help avoid that). The other end of the coax—the end that will be connected to the circuit board—should receive an RCA-type plug, PL1.

To avoid errors and contamination during the calibration, the probe assembly must be insulated. The easiest way to do this is to use epoxy to coat the diode and its leads *and* the end of the coax. That will prevent any current leakage when the probe is immersed in the water baths used for calibration, and will keep water from entering the cable and possibly damaging it. If you're extravagant, you can dip the assembly into a container of epoxy so it is coated as far as about half an inch up the outer insulation of the cable; otherwise smear the cement on liberally, making sure that the end of the coax gets sealed. Allow the epoxy to cure for 24 hours before you go on to the calibration procedure.

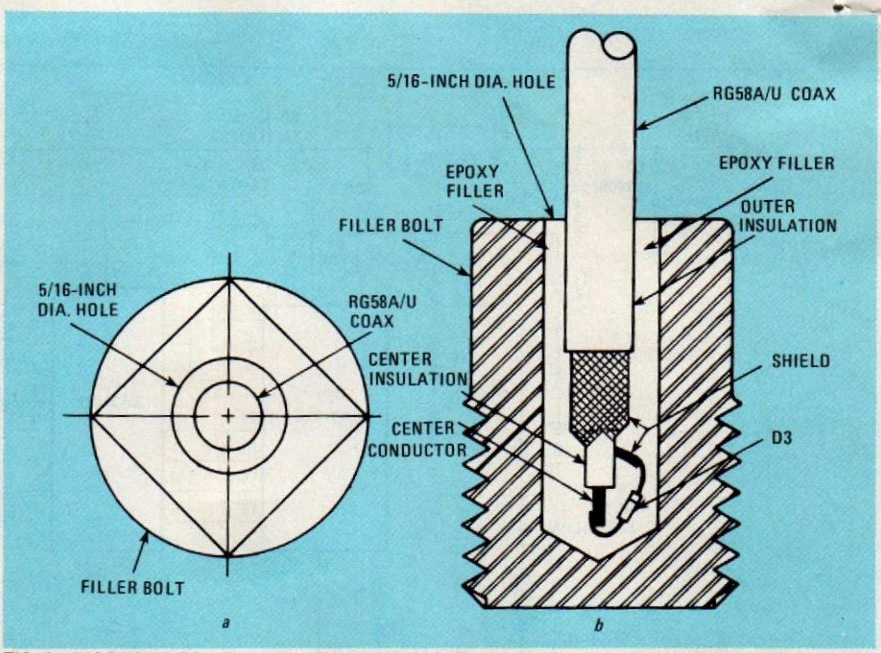


FIG. 6—DIAGRAMS FOR THE DRILLED FILLER-BOLT method. Read the instructions carefully before you start work.

Calibration

Before the probe is installed in its permanent location, the meter circuit must be calibrated. *Without the probe connected*, apply 10–14 volts to the circuit board through the red (+) and black (−) wires; 13.8 volts is recommended. Temporarily ground pins 10 and 11 of IC2 and adjust R8 (ZERO ADJUST) until the display reads "000." Then unground the two IC pins.

Next, connect the probe cable to J1, and center the wiper arms on R6 (LOW ADJUST) and R9 (HIGH ADJUST). Immerse the probe (insulated with epoxy as described above) into a plain solution of ice and water—the water should come from ice as it melts so that it is as close to 32° F. as it can be. Wait until the reading on the display stabilizes—that should take about five minutes—and then adjust R6 until it reads "032."

Set the HIGH ADJUST (GAIN ADJUST) potentiometer, R9, by placing the probe in boiling water—again, wait about five minutes until the display stabilizes—and adjusting the control until you read "212."

The adjustments are rather critical, and you should go through the low-high calibration procedures several times to eliminate as much error as you can.

Mounting the probe

The simplest way to measure the engine-block temperature is to measure it at the air-intake manifold. Note that that does not mean that you will be measuring the temperature of the air being fed to the engine—rather, you will be measuring the temperature of the manifold itself, which, because it is attached to it, will be about the same as that of the engine block.

There are three ways that the probe can be attached to the manifold: two involve filler-bolts or filler-bolt holes, and the last uses external connection. The first two give more accurate readings, but involve more work than the third. If you have difficulties with the filler-bolt methods, and are willing to put up with somewhat less accuracy (on the order of several degrees), then the external-connection method can be used. Study all the methods before you make your decision.

Drilled filler-bolt method

A filler bolt is a "dummy" bolt used to plug a hole intended for future or optional use. There may be several in the intake manifold (the part that distributes the air/gas mixture to the engine cylinders) of your car. Before you can install the temperature probe in one of the filler bolts, you first have to remove it; that isn't always easy. Try all the unused filler bolts until you find one that unscrews easily. Be careful—especially if you're using a long-handled socket wrench—not to apply too much force. Doing so can shear the bolt, strip its threads, or it can even crack the manifold.

PARTS LIST

All resistors ¼ watt, 5% unless otherwise indicated
R1—1000 ohms
R2—220 ohms
R3—10,000 ohms
R4—2200 ohms
R5—6800 ohms
R6—1000 ohms, trimmer potentiometer
R7—470 ohms
R8—50,000 ohms, trimmer potentiometer
R9—10,000 ohms, trimmer potentiometer
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C4—10 µF, 16 volts, tantalum or electrolytic
C3—0.33 µF, 35 volts, tantalum
Semiconductors
IC1—LM340T-5 (7805) positive 5-volt regulator
IC2—CA3162 dual-slope, dual-speed, A/D converter
IC3—CA3161 BCD-7-segment multiplexing decoder/driver
DISP1–DISP3—FND507 (FND510) 0.5-inch 7-segment LED, common anode
D1, D2—1N4002
D3—1N4002 or 1N914 (1N4148)
J1—RCA phono jack
PL1—RCA phono plug
Miscellaneous: PC board, RG58A/U coax, epoxy, etc.

The following are available from Digital World, PO Box 5508, Augusta, GA 30906: temperature gauge PC-board only, $7.50; temperature gauge PC board with schematic & diagrams, $8.50; IC2 and IC3, $12.00; PC board and IC1–IC3, $20.00; kit of all parts including coax (does not include plastic, solder or chassis), $32.50. The first two items (PC board and PC board with schematic & diagrams) are postpaid within the continental U.S.; all other items add $2.00 shipping & handling. APO, FPO, and other U.S. add $3.00. Canadians add $3.00 (please use U.S.-dollar money order). All others write for prices and shipping costs. Please allow 4 to 6 weeks for delivery.

Sometimes, applying some penetrating oil and allowing it to work overnight will allow you to remove a frozen- or rusted-in filler bolt with several light taps and the *gentle* application of force. If none of the bolts can be removed conveniently, you'll have to connect the probe externally, as described below.

With a bolt removed, use a drill press to drill a 5/16-inch hole in it from the outside to the inside (naturally). Refer again to Fig. 6 (The completed filler-bolt assembly is shown in Fig. 7). The hole should be deep enough to hold the diode and a "dab" of retaining epoxy, but must stop ⅛-inch short of the end of the bolt. If you drill through the end, you'll have to start over with another bolt; it might be a good idea for you to practice on a non-essential

FIG. 7—COMPLETED FILLER-BOLT probe with cable attached.

piece of material similar to the bolt first, to get a "feel" for the procedure.

Mix a batch of quick-setting epoxy and fill the hole half-full with it. You'll have to work fairly quickly—after five or ten minutes the epoxy starts to set and becomes difficult to work with.

Then insert the diode assembly into the epoxy in the hole in the bolt until it makes contact with the bottom of the bolt. Now slowly and gently pull on the coax to lift the diode until it is no longer in contact with the bolt. That's just to make sure that the probe will not short out to the bolt even if there's a defect in the probe's epoxy "insulation." A change in position of about ⅛-inch should be enough. Stop! Hold the probe in that position for at least ten minutes, until the epoxy has set enough to be firm.

When the epoxy has started to set, any excess that may have been forced out of the hole can be removed carefully. Allow the epoxy to cure for 24 hours at a temperature between 60° and 90°F. Finally, after the epoxy has cured, check the cable with an ohmmeter to make certain that the probe has not shorted to the bolt. Reinsert the bolt in the manifold, and proceed to the "Installation" section.

Filler-bolt hole method

If you are unable to remove any of the filler bolts, the probe can be inserted in an unused filler-bolt hole in the intake manifold. The hole should be cleaned thoroughly and any accumulated oil or rust removed—epoxy needs a clean surface to bond to and any foreign matter could prevent a solid adhesion and result in the probe's working loose and coming out.

Make sure the engine is cool—not only could you get burned otherwise, but some epoxies are flammable, and could catch fire if applied to a hot surface. The angle of the hole may present a problem in getting the epoxy in and keeping it in; it may be necessary to build up a shelf of wax around the lower rim of the hole to ensure that enough epoxy is retained to encapsulate the probe and to grip the probe-end of the coax securely.

Mix the epoxy and force an amount into the bottom of the hole by using a wooden dowel of about the same diameter as the hole. The hole should be filled completely to make certain that there's enough cement to hold the probe and cable. The rest of the procedure is essentially the same as that given for the "drilled filler-bolt" method: insert the probe so it's about ⅛ inch from the bottom of the hole and allow the epoxy to set and cure while using an ohmmeter to make sure that the probe doesn't short to the side or bottom of the hole. After the epoxy has cured, proceed to the "Installation" section.

External probe-attachment

If neither of the first two methods will work for you, then the probe can be epoxied to the outside of the intake manifold.

Clean the selected surface well so that the epoxy will bond firmly to it and mix some epoxy (do not mix it all; you'll need more shortly). Apply a coating about ⅛-inch thick to an area about 1½-inches square to form a mounting base. Let the cement harden for 20-30 minutes and then mix a second batch of epoxy. Tape the probe/coax assembly in place and use the second batch of epoxy to encapsulate it. Use your ohmmeter to make sure that the probe is not shorting out to the surface on which it's mounted. After the epoxy has cured, you may proceed to the "Installation" section.

Installation

The temperature gauge can be installed either in the dashboard of your car, or in a separate enclosure. The cable from the probe can be routed through a hole in the firewall; you can later seal the hole around the cable to keep dust, water, and fumes out of the car. Remember to plug the probe cable into the board—otherwise you'll go crazy trying to figure out why the gauge doesn't work.

A good place to obtain power for the gauge is from the same fuse terminal to which your car's radio is connected. The red wire should go there, and the black wire to the car's body (so there is a return to the negative post of the battery).

If you find that the operation of the gauge creates interference on your AM radio, there are several "fixes" you can try to get rid of it.

First, try connecting the gauge to a power source other than the radio's fuse. You can also try locating the gauge a distance away from the radio itself. Finally, if the circuit board is not in an enclosure, add one, made of metal and grounded; this solution is usually quite effective.

A last word of advice: Don't disconnect your present temperature gauge or warning light—it's always a good idea to have a backup!

The use of this gauge is not limited to your car, of course. You can use it to monitor the temperature inside your freezer, for example, or just as an electronic indoor or outdoor thermometer. However you use it, you'll find that its speed, accuracy, and readability make it a valuable instrument to have. **R-E**

NEW IDEAS

Ultrasonic pest repeller

PEST CONTROL HAS BEEN BROUGHT INTO the electronic age by the introduction of the ultrasonic insect repeller. That device is said to repel—not kill—unwanted flying and crawling pests by emitting ultrasonic sound waves that sweep between 65,000 and 25,000 hertz. The sound is apparently rather irritating to them.

I went shopping for one of those "miracle" devices but *I* was repelled—by their prices, which ranged from $49 to $69. Therefore I decided to design and build my own. The circuit I came up with, which should cost about $20 to build, is shown in Fig. 1.

The repeller is designed around a 556 dual timer. One half is operated as an astable multivibrator with an adjustable frequency of 1 to 3 Hz. The second half is also operated as an astable multivibrator but with a fixed free running frequency around 45,000 Hz. The 25–65 kHz sweep is accomplished by coupling the voltage across C2 (the timing capacitor for the first half of the 556) via Q1 to the control voltage terminal (pin 11) of the second half of the 556.

Transistor Q1 serves two purposes: it isolates the timing circuit of the first half of the 556 from pin 11 and it controls an LED indicator. When the first half is operating, timing capacitor C2 continually charges and discharges between ⅓ and ⅔ the supply voltage. Because the base of Q1 is tied to C2, the voltage across C2 will affect the operation of Q1. The voltage at the base of Q1 causes it to conduct, thereby turning on the LED and lowering the control voltage that is applied to pin 11. The lower control voltage causes the output frequency of that half of the timer to increase to around 65 kHz. As C2 is charged toward ⅔ volt, Q1 conducts less and less. That causes the intensity of the LED to decrease and the control voltage applied to pin 11 to increase, because Q1's emitter approaches +V. The increasing control voltage causes the output frequency to decrease from 65 kHz to 25 kHz. That sweep will take from 1 to ⅓ second depending on the setting of R1. Theory has it that periodic adjustment of the sweep rate will prevent the pests from developing an immunity to the sound.

The device that radiates the ultrasonic sound is a piezo tweeter. Radio Shack sells several models ranging in price from $9 to $15.

Because the output of the repeller is above the range of human hearing, it is difficult to determine whether it is operating properly. If S1 is closed, though, the output frequency is lowered so that it can be heard. The output of the piezo tweeter is intense so, if you get tired of the repeller, you can switch C4 permanently into the circuit and turn the repeller into one heck of an alarm.—*David L. Holmes*

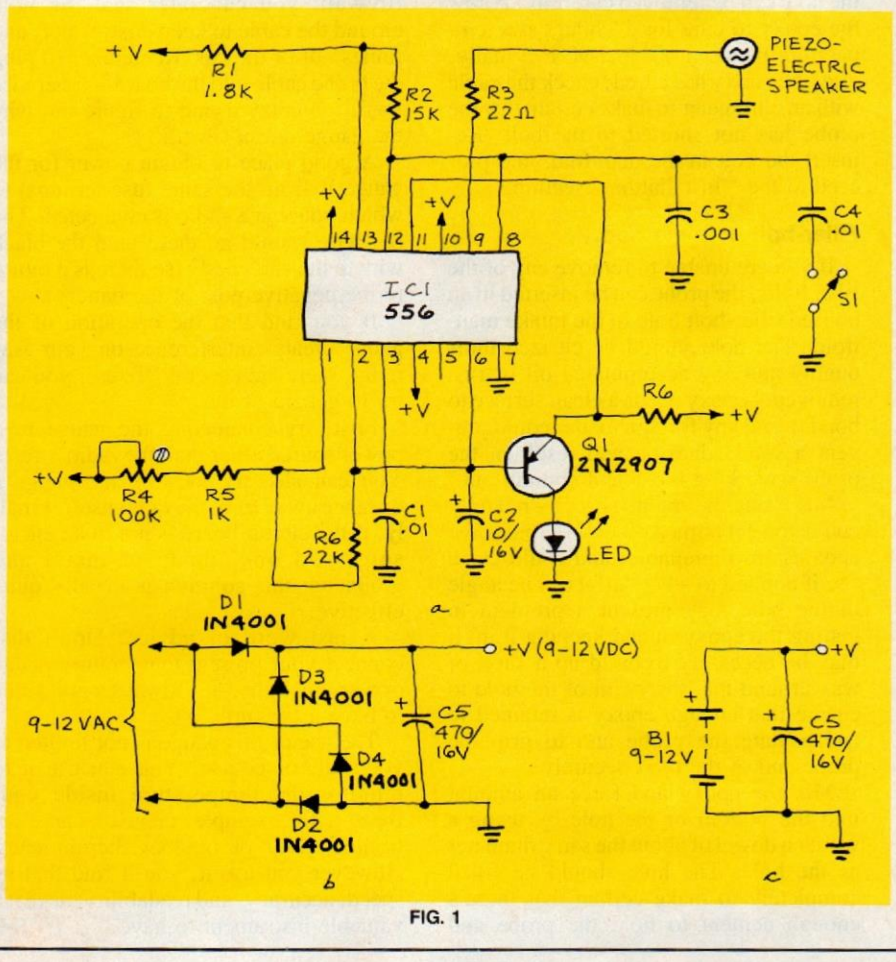


FIG. 1

NEW IDEAS

This column is devoted to new ideas, circuits, device applications, construction techniques, helpful hints, etc.

All published entries, upon publication, will earn $25. In addition, Panavise will donate their *model 333*—The Rapid Assembly Circuit Board Holder, having a retail price of $39.95. It features an eight-position rotating adjustment, indexing at 45-degree increments, and six positive lock positions in the vertical plane, giving you a full ten-inch height adjustment for comfortable working.

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STATE OF SOLID STATE

ROBERT F. SCOTT
SEMICONDUCTOR EDITOR

IC temperature sensors and more

TEMPERATURE SENSORS HAVE COME A long way since the invention of the mercury-bulb thermometer. In the past, electronic devices that indicated changes in temperature were often based on the principle that a device's resistance varies as temperature changes. That variable resistance would cause a change in voltage that could be sampled, scaled, and output in human-readable form. Thermocouples, for example, work according to such principles. But the latest in electronic temperature sensing is based on integrated-circuit technology.

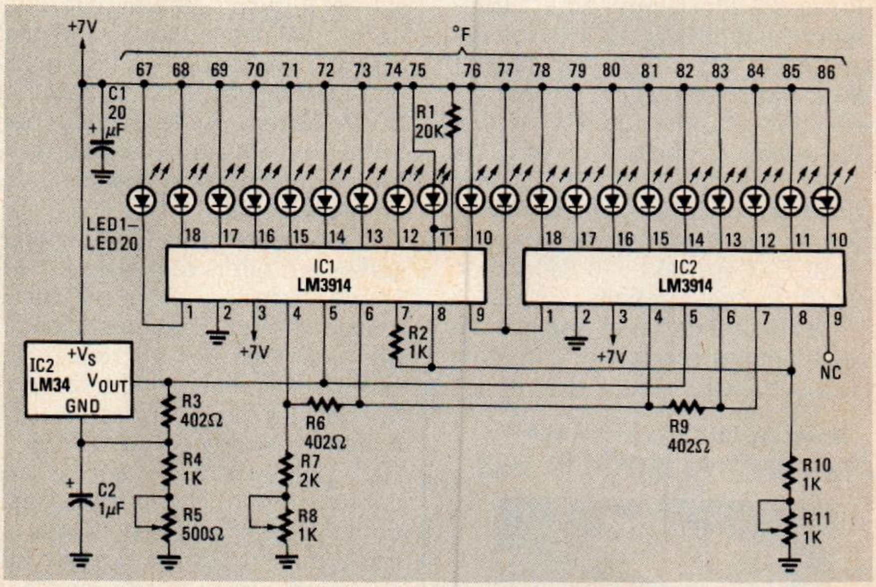


FIG. 2

National Semiconductor has introduced two new series of precision IC temperature sensors; each series consists of five different devices with different temperature ranges. In each device, output voltage is linearly proportional to temperature. The LM35 series is used for Celsius readings, and the LM34 series for Fahrenheit readings.

All devices in the series are trimmed and calibrated during manufacturing to provide high accuracy and linearity; hence the circuit designer need not provide either calibration or trimming. The LM35 series features accuracy of ±0.25-degree at room temperature, and ±0.75-degree over the full −55 to +150°C range. The accuracy of the Fahrenheit units is ±0.5-degree at room temperature, and ±1.5-degree over the −50°F to +300°F range. Those devices have one advantage over similar units calibrated in degrees Kelvin. It is unnecessary to subtract or to null out a large constant in order to obtain readings directly in either degrees Celsius or degrees Fahrenheit.

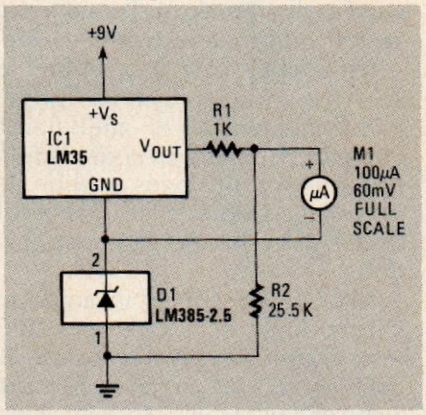


FIG. 1

All devices feature low output impedance, linear output, and precise inherent calibration, all of which make interfacing to readouts or control circuits especially easy. They can be powered by single-ended supplies ranging from +4 to +30 volts, or by split (plus and minus) supplies.

Quiescent current drain is very low. The LM35 series draws 56 μA from a 5- to 30-volt supply at 25°C. The LM34 series draws 75 μA. Self-heating due to thermal resistance is less than 0.1°C or 0.2°F in still air. Devices in the series measure temperatures ranging all the way from −55°C to +150°C (LM35, LM35A), and −50°F to +300°F (LM34, LM34A). Other models are available with more restricted ranges.

Thermal resistance of the LM35 in the TO-46 package is 400°C/W junction to ambient and 24°C/W junction to case. Thermal resistance in the TO-92 package is 180°C/W junction to ambient. The LM34 has a thermal resistance of 292°F/W junction to ambient, and 43°F/W junction to case in a TO-46 metal-can package. Thermal resistance is 324°F/W junction to ambient in the TO-92 plastic package.

All devices in the series produce a linear 10.0 mV/degree (°C or °F) output over the range of +2°C to +150°C for the LM35, and +5°F to +300°F for the LM34. Figure 1 shows the LM35 as an expanded-scale Fahrenheit thermometer with a +50°F to +80°F range.

Figure 2 shows the LM34 used as a bar-graph temperature display that displays temperatures ranging from +67 to +86°F. Two LM3914 bar-display LED drivers control twenty LED's. All fixed resistors are 1% or 2% film types. Adjust trimmer resistor R11 so that the voltage at pin 8 of IC3 is 3.525 volts; adjust R8 so that the voltage at pin 4 of IC2 is 2.725 volts; and adjust R5 so that the voltage at the output of IC1 is 0.085 volts + 40mV/°F × T_A (ambient temperature). For example, for an ambient temperature of +80°F, V = 0.085 + (0.04 × 80) = 0.085 + 3.2 = 3.285 volts.

The data sheets on these two device families come with complete specifications and a dozen or so practical circuit applications. Request copies from **National Semiconductor,** Public Relations, 2900 Semiconductor Drive, Santa Clara, CA 95051.

New transient suppressor

The *Surgector* is a new type of device capable of diverting dangerous transient energy away from sensitive electronic equipment like telephones, computers, and other types of equipment subject to sudden voltage surges.

The monolithic device is a thyristor whose gate region contains a special diffused section that functions as a Zener diode, and that also permits anode-voltage turn-on of the device. It is claimed that this feature provides high-speed protection not available with many transient-protection devices presently used.

Risetimes of transient voltage spikes are often very fast; for example, lightning often produces transients with risetimes exceeding 1000 volts per microsecond. Gas tubes and many other protective devices cannot act fast enough to limit the voltage across the protected circuits. The *Surgector* uses Zener action to clamp the voltage until the integral thyristor turns on and drops the voltage to a safe value. In most cases the peak voltage reaching the protected circuitry does not exceed 130% of normal operating voltage. For example, it is claimed that a lightning surge with a risetime of 1500 volts/μs is clipped at about 100 volts.

Presently, RCA offers four types of Surgector: the SGTO3U13, SGTO6U13, SGT23U13 (2-terminal devices), and the SGT10S10 (a 3-terminal device). The 2-terminal devices are available with voltage ratings of 30, 58, and 226 volts. Those ratings refer to the voltage that can be continuously applied without tripping the device.

When a high-voltage transient arrives, the Zener diode in the gate region of the SCR conducts, and that turns the SCR on. The transient is thereby clamped to the forward drop of the SCR so the protected circuitry cannot be damaged. After the transient has passed, and after normal circuit current has dropped below the holding current of the Surgector, the device turns off, and normal circuit operation resumes. The devices have holding currents above 100 mA, and that insures they will operate in average telecommunication circuits.

The SGT10S10 is unidirectional, and its third terminal allows the user to control the SCR's turn-on voltage. That voltage is normally 100 volts, but, by using external gate-control circuitry, voltages less than 100 can be used to trigger the device.

All devices in the SGT series are housed in modified TO-202 plastic packages, whose small size makes them ideal for telephone handsets and PBX's. However, the SGT devices' low cost and high speed also make them suitable for applications in computers, alarm systems, TV, aircraft electronics, and CATV. In 10,000-piece lots, the SGT03U13, -06U13, -23U13, and -10S10 are $0.58, $0.72, $1.06, and $0.85, respectively.—**RCA Solid State,** Route 202, Somerville, NJ 08876.

One-IC AM receiver

The ZN416E is the latest addition to Ferranti's line of single-IC AM broadcast-band receivers. Similar to the ZN415E in packaging and pin-out, the new device is a buffered-output version of the TO-92 style ZN414Z. A typical ZN416E delivers 120-mv RMS into a 64-ohm load.

Powered by a single 1.5-volt dry cell, the device may be used in a wide range of applications, including personal receivers, novelty radios, remote telephones, and radio-control circuits. The ZN416E, like others in its family, can be used as the IF-strip and detector of an AM superheterodyne receiver.

The ZN416E features a 150-kHz to 3.0-MHz input-frequency range, and it includes an RF amplifier, a detector, AGC and an audio amplifier. The output stages provide 18-dB voltage gain that is suitable for direct-drive headphone applications.

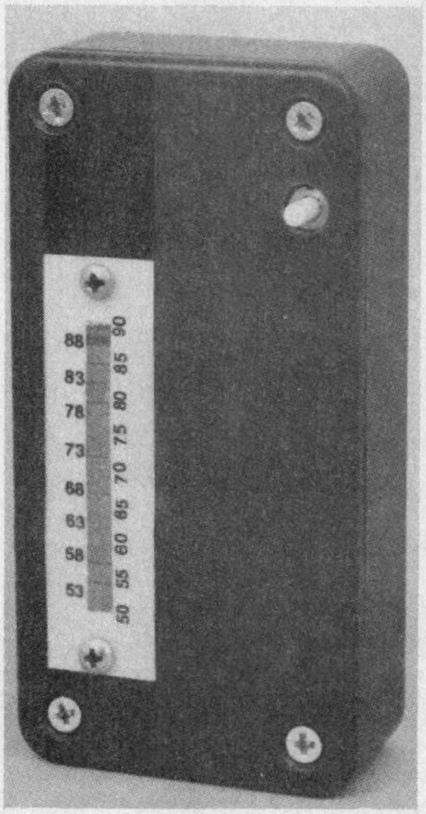
The ZN416E comes in an 8-pin DIP, operates over a 0°C to +70°C temperature range, and costs $1.12 each in lots of 10,000.—**Ferranti Semiconductors,** 87 Modular Ave., Commack, NY 11725. **R-E**

Electronic Thermometer

MARC SPIWAK, ASSOCIATE EDITOR

QUITE OFTEN, THE BEST KIND OF PROJECT to build is just a neat little gadget that you don't necessarily need, but one that will give you something to do without costing you an arm and a leg. That way, you don't have to rush the project in order to meet some deadline. And if you should run into any problems while trying to get your project to work, you won't be ready to kill your friends and family—and believe it or not, the fourth-most leading cause of death in this country is due to crazed electronics hobbyists who have wasted hundreds of dollars and hours on a dead-end project.

The project we are presenting, however, is one that you'll want to build. It is an electronic thermometer that displays a temperature range of 40 degrees Fahrenheit (or about 23 degrees Celsius) on a 16-LED bar-type display. It's easy to build, very inexpensive, and it is a great desktop-novelty item when it's finished. It's also so small that, with a little customizing, it can be made to fit, along with two small 6-volt batteries, inside a very small project case.



Here's something that you don't really need—but you'll probably want to build one, anyway!

Circuitry

As you can see from the schematic in Fig. 1, the heart of the electronic thermometer is IC1, a Siemens UAA170. That IC is really just a 16-LED driver. Depending on the level of the input voltage to pin 11, and how V_{REF}(min) and V_{REF}(max) (pins 12 and 13) are biased, one of the 16 LED's is illuminated.

The temperature-sensing ability of the circuit is made possible by R10, an NTC (*N*egative *T*emperature *C*o-efficient) thermistor. (A thermistor is a temperature-dependent resistor, and NTC means that as the temperature increases, the resistance decreases; PTC means that as the temperature increases, the resistance also increases.) As the ambient temperature increases, the thermistor's resistance, and consequently the input voltage to pin 11, decreases. The 16 LED's on the prototype display from about 50 to 90 degrees Fahrenheit, but you can calibrate the center temperature (the middle LED) via potentiometer R12.

The circuit also includes an LDR (*L*ight-*D*ependent *R*esistor), R11, that adjusts the display's brightness according to how much light is in the room. The LDR's resistance in bright light is about 350 ohms, and in total darkness its resistance approaches 200,000 ohms. When the prototype was tested, the photoresistor did its job too well. The display's brightness varied greatly between a very pleasant level and an excessively bright one. Thus, the light-dependent resistor was covered with a piece of tape so that the display will maintain the same low (pleasant) level of brightness and the batteries won't have to work so hard. However, because the LDR is in parallel with an 18K resistor (R1), the combined total resistance of those two components will never be more than 18K. Therefore, another alternative is to leave the LDR out of the circuit completely.

Components

The electronic thermometer can be built using parts that you gather individually, or purchased as a complete kit for $17.54 from the source listed in the Parts List. The kit includes the PC board and all components except a power supply, ON/OFF switch, and a case. While buying the kit is probably the easiest and cheapest way to build the project, you can also make your own PC board from the pattern in the PC-Service section of this magazine. You may even be able to get away with point-to-point wiring since it's such a simple circuit. Then, if you're lucky, your junkbox may contain all the parts you need except the IC.

The ON/OFF switch that was used in the prototype is a momentary push-button-type switch. A momentary switch was used because LED's are very power-hungry, and if the device were left on, the batteries wouldn't last very long. However, if you decide to build or buy a 12-volt DC power supply, or use a much larger battery pack, then it won't hurt a bit to leave the unit on all the time.

Construction

Begin building the project by installing all of the resistors on whatever PC board you're using, as shown in Fig. 2. Then, install the potentiometer R12, the thermistor R10, the light-dependent resistor R11, the IC socket, and lastly the LED's. Be sure to be very careful when spreading the leads of the LED's, because too much force will crack the LED in half. The kit includes 15 LED's of the same color, and one of a different color. You should install that single LED on the right-hand side of the board (above

R12 in the LED16 position) to indicate the maximum temperature on the display. (If you don't buy the kit, it's entirely up to you as far as the colors of the LED's are concerned.) Now just press IC1 into its socket.

After the board is completely assembled, you'll need some wire, an ON/OFF switch, and whatever you are using as a power supply. The prototype uses two 6-volt photo batteries (Eveready type A544 or equivalent)

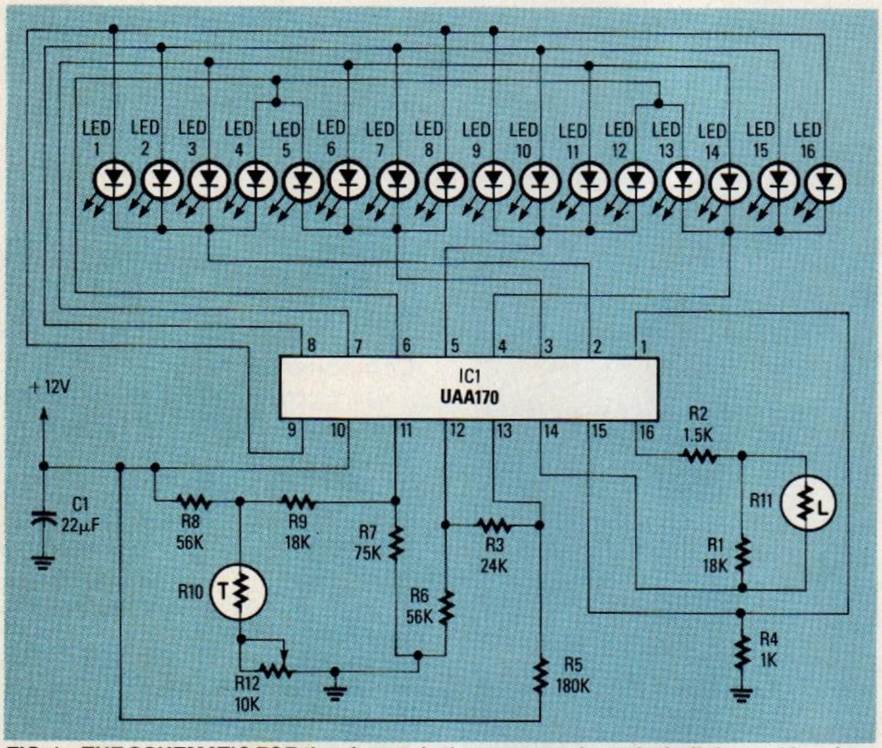


FIG. 1—THE SCHEMATIC FOR the electronic thermometer. It can be built from a kit or from separately purchased pieces on a PC board or perforated construction board.

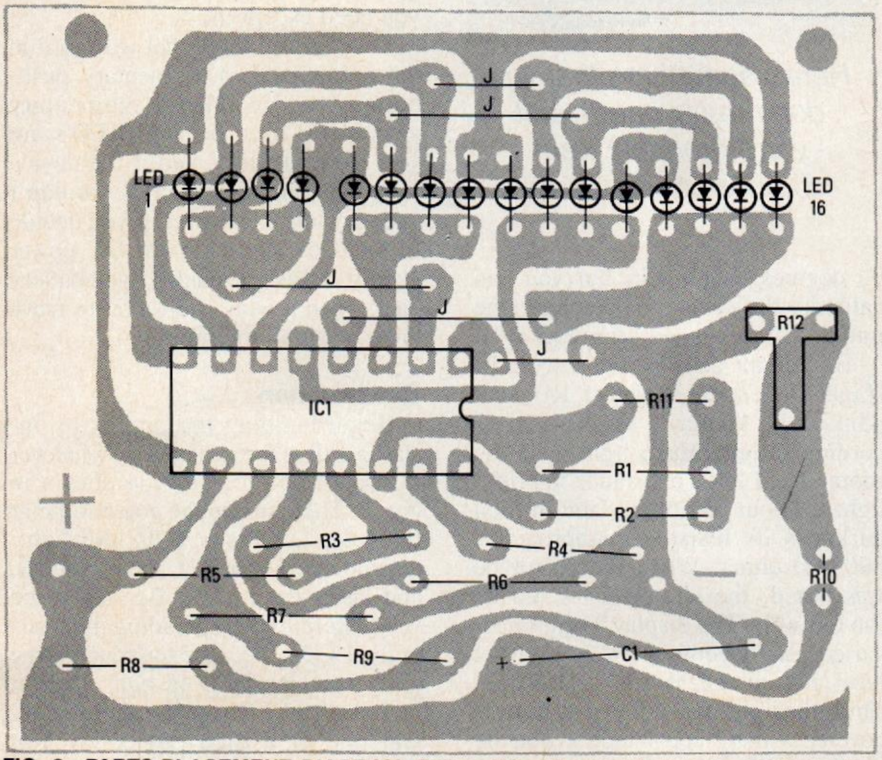


FIG. 2—PARTS-PLACEMENT DIAGRAM. Follow this when soldering the parts on the board supplied with the kit, or the one you can make from the pattern in PC Service.

taped together, with the positive side of one connected to the negative side of the other. They are held in place inside the case with a piece of double-sided tape. Depending on what size case you're planning to install the board in, cut and solder appropriate lengths of wire to the + and − terminals on the PC board. Then install S1 in series with the positive supply line and connect the leads to the batteries. (Depending on what type of switch you use, and how it's supposed to mount to the project case, you may have to install it in the case first, and then solder it in the circuit.)

Test and calibrate

By now you've probably already pressed the button to see if your thermometer is working—if not, do it now. At least one LED, or two right next to each other, should light up. (If nothing happens, check your soldering and the placement of the components—there can't be too much wrong with a circuit this simple!)

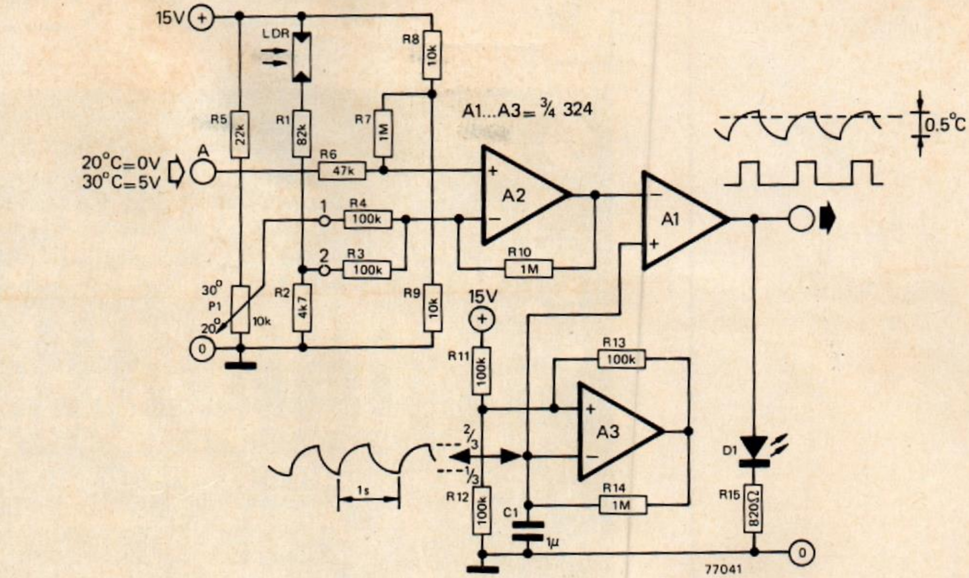
Once you are sure that your thermometer is working, you have to let it sit for about a half an hour. That's so the board can cool down to room temperature after all the soldering and handling. Try to let the board cool in a room that's at about 70 degrees—you'll have to get an ordinary thermometer, or look at your home thermostat's reading.

After the board's temperature has settled to about 70 degrees, adjust R12 so that the center LED (or one or two LED's higher or lower, depending on the exact room temperature) is illuminated. Now you should take a sheet of paper and draw 16 circles representing the 16 LED's on your display, and write a 70 next to the appropriate circle.

Place both the electronic thermometer and a regular thermometer inside a refrigerator for about ten minutes, and then remove them both. The temperature inside the refrigerator should be lower than 50 degrees, so the far-left LED should light up when the button is pressed. As soon as the next LED begins to light, check the temperature on the regular thermometer, and record it next to the appropriate circle on the sheet of paper. Then you can estimate what temperature the first LED should indicate. As the temperature continues to rise, keep on recording the readings until both thermometers once again

8

thermostat



Although primarily designed to keep the water in an aquarium at a constant temperature, this circuit is also suitable for a number of other applications.

The circuit described here represents only the control section of the thermostat. In addition a temperature sensor and a triac relay, which at periodic intervals supplies the heating element with voltage, are necessary to complete the thermostat proper. A simple temperature sensor is provided by the NTC sensor described elsewhere in this issue, or by the temperature-voltage converter in Elektor 5, July/August 1975. A suitable triac circuit which triggers at the zero-crossing point (i.e. when the load voltage and current are small, thus preventing interference and contact wear) is the solid state triac relay described in Elektor 11, March 1976, or, the 'solid state relay' described elsewhere in this issue.

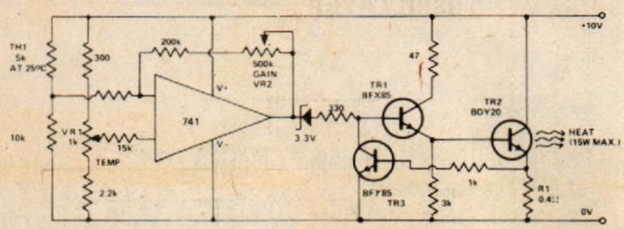
The thermostat functions as follows: the water temperature is measured by the sensor (the NTC or diode), which is fixed to the glass on the outside of the aquarium by insulating tape. Since only three amplifiers are needed for the control circuit of the thermostat, the remaining amplifier can be used to construct the NTC sensor. The voltage supplied by this circuit is compared in A2 with the preset value of P1 and the LDR, and then amplified by a factor of 10. The amplified voltage is then compared in A1 with the triangular voltage produced in A3. The result is a squarewave output voltage, which triggers the triac circuit for longer or shorter periods.

The desired reference temperature can be set by means of P1. The circuit also contains a second input which is sensitive to light. This has the effect of raising the reference voltage of the thermostat so that the aquarium is allowed to get warmer during the day. With the component values shown in the diagram, the increase in temperature (the size of which depends on R1 and R2) is approx. 2°C. The LDR may also be omitted if required.

The 15 V supply is not critical, and providing that it is properly smoothed it need not be stabilised. The current consumption for the circuit is 3 mA, which rises to 6 mA when light falls upon the LDR, and to 15 mA when the LED at the output lights up.

A certain amount of attention should be paid to the safety of the circuit; for this reason the NTC is placed on the outside of the tank, and the triac relay should be fitted with an opto-isolator so that there is no direct electrical connection between the input and the mains.

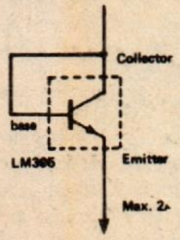
A SIMPLE TEMPERATURE-CONTROL SYSTEM



In electronics the need often arises to stabilise the temperature of critical sections of circuitry, such as master oscillators, log converters, and reference supplies. This circuit will control the temperature of a small mass of metal, such as a heat sink onto which critical components can be mounted, simply and efficiently.

The difference between a reference voltage set up on the temperature setting control VR1, and a voltage derived via thermistor TH1, is amplified by the op-amp, gain being set via VR2. This output voltage is applied to heater transistor TR2 via current amplifier TR1. ZD1 is essential for voltage-shifting since without it even the negative saturation voltage of the 741 would leave TR2 turned on. The current flowing in TR2 is limited to 1.5Amp by TR3, which shunts current from TR1 base if the voltage developed across R1 exceeds 0.6V. This arrangement leaves most of the supply voltage across TR2 and hence it is the only component dissipating significant heat.

SIMPLE CURRENT LIMITER



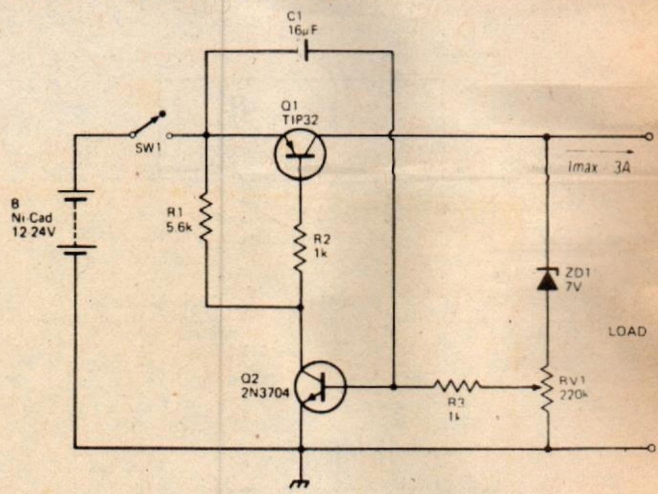
An extremely simple current limiter can be made using the new National Semiconductor LM395K. This looks like a power transistor, but is actually an IC which is fully protected against thermal overload and excessive current.

The device can be used in the circuit shown with a heat sink for limiting at just under 2A. No damage will occur if no heat sink is employed, but if the device gets really hot, the current will automatically fall to about 0.5A or less.

The case of the device is the emitter and *not* the collector as in a normal power transistor.

If the base is disconnected from the collector and is returned to the emitter, the device will be switched off.

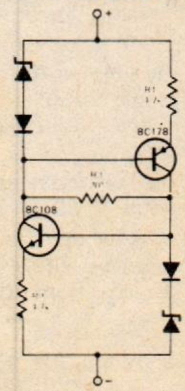
NI-CAD DISCHARGE LIMITER



Nickel-cadmium batteries should never be completely discharged as this leads to shortened life. The circuit shown may be used to disconnect the battery from the load when ever output voltage falls below a preset level.

In operation C1 charges through R1 and turns on Q2, the collector current of which flows through R2, turning Q1 on. Thus the battery is connected to the load. When the output voltage falls below a point set by RV1, Q2 turns off, Q1 turns off and further discharge of the battery is prevented.

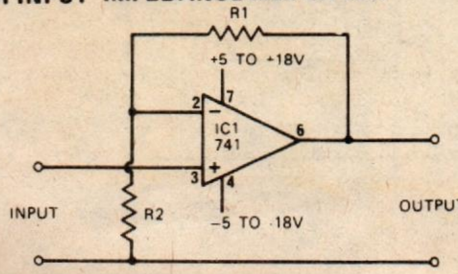
CONSTANT CURRENT SOURCE



This unique two terminal circuit can be used to define a constant current in the same manner as a Zener diode may be used to define a constant voltage.

The values of R1 and R2 shown are for a current of 1mA. Maximum applied voltage with transistors shown should be limited to 50 volts. Minimum should be at least 8 volts.

HIGH INPUT IMPEDANCE AMPLIFIER



The circuit shown, using one op- amp and two resistors has a high input impedance (500 nanoamps input current) and a gain which may be programmed by R1 and R2.

$$G = \frac{R1 + R2}{R2}$$

Thus for G = 1 R1 = 0, R2 is not used
for G = 100 R1 = 100k R2 = 1k.

The frequency response decreases with increasing gain, eg, for G = 1 the amplifier is flat to 800 kHz, for G = 100 the response drops to 6 kHz.

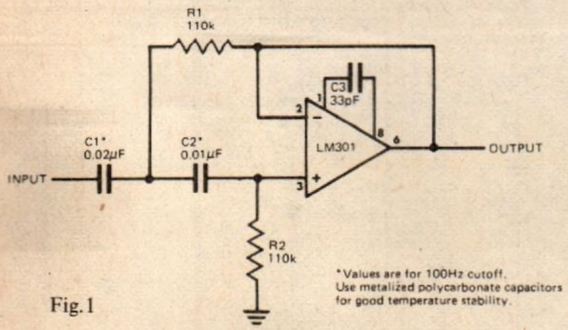


Fig.1

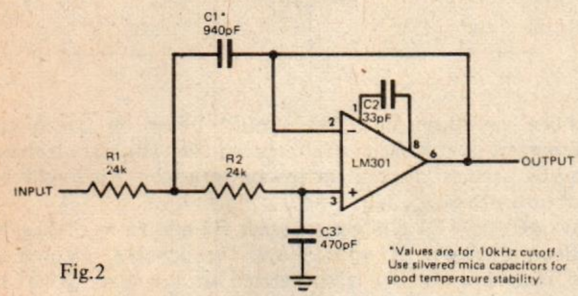


Fig.2

ACTIVE RC filters using operational amplifiers are increasingly being used to supplant LC filters because of the small size and ever-decreasing cost of integrated circuit operational amplifiers. Here are two useful general purpose circuits which may be readily incorporated into other circuitry where needed.

Figure 1 shows one of the simplest forms of filter, the low pass. The circuit has the same characteristic as two isolated RC filter sections with the additional advantage of a buffered low impedance output.

The attenuation is 12 dB per octave at twice the cut off frequency with an ultimate of 40 dB per decade.

There are two basic designs for this filter, the Butterworth (maximum flatness), and Linear Phase (minimum settling time for pulse input). The equations for the Butterworth design are:–

$$C_1 = \frac{R_1 + R_2}{\sqrt{2}\ R_1\ R_2\,\omega C}$$

and

$$C_2 = \frac{\sqrt{2}}{(R_1 + R_2)\,\omega C}$$

For the Linear Phase design simply substitute $\sqrt{3}$ for $\sqrt{2}$ in the above equations.

To make a high pass filter we merely substitute resistors for capacitors and capacitors for resistors, as shown in Fig. 2, and apply the same formulae.

HIGH INPUT IMPEDANCE AMPLIFIER

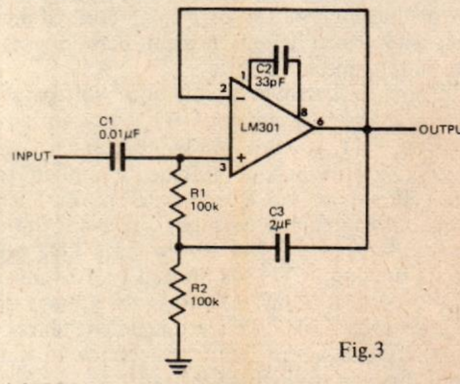


Fig.3

The LM301 may also be used to construct a simple high input-impedance ac amplifier as shown in Fig. 3. In this circuit even though the bias resistor is only 200 k, as required for good dc stability, the bootstrapping by C3 provides an input impedance of 12 M at 100 Hz increasing to 100 megohm at 1 kHz.

POSITIVE PEAK DETECTOR

A positive-peak detector having gain may be constructed using two LM301As as shown in Fig. 4.

The output is the peak voltage at the input amplified by the ratio (R1 + R2)/R2. Typical error is 2 (R1 + R2)/R2 millivolts.

If unity gain is required R2 is deleted. The combined resistance of R1 and R2 should be in the range of 10 to 100 k and the minimum load resistance 2.2 k. Where negative peak detection is required reverse the polarity of both IN914 diodes.

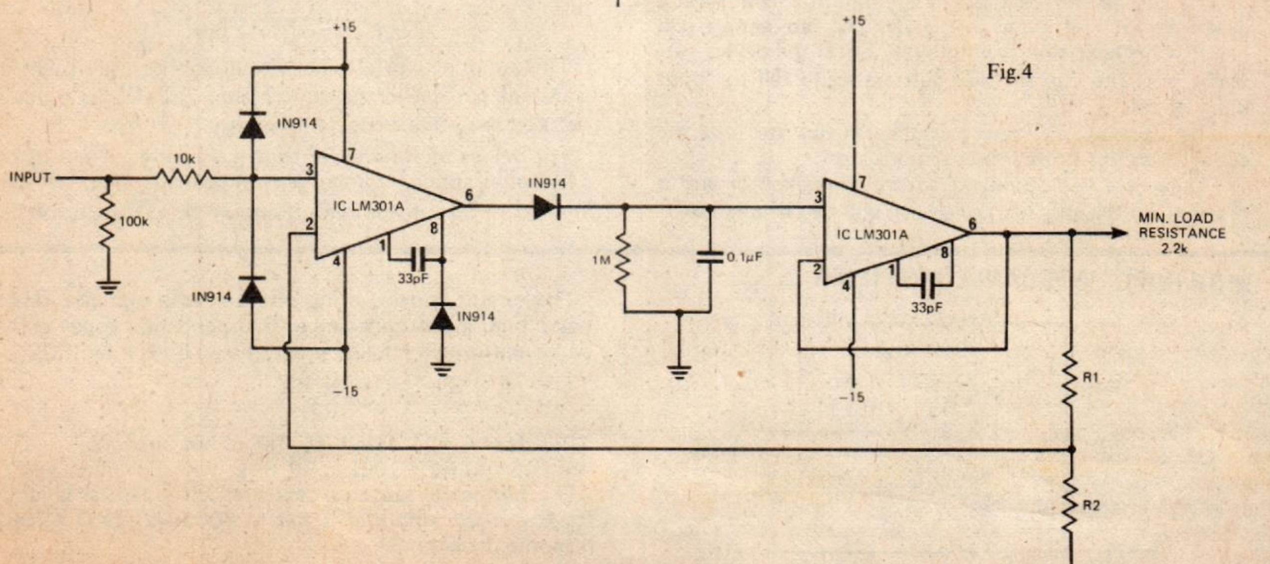


Fig.4

HIGH-LOSS POWER SUPPLY?

The low-loss power supply shown on page 42 of your February issue is potentially lethal! It is essential that the voltage rating of R_1 is not exceeded, as a failure could put mains voltage on the +12V terminal, having blown up the 470µF capacitor. This usually means that R_1 should be at least two resistors in series. Experience shows that carbon-composition resistors fail to any value – high or low. Carbon, metal-film and metal-oxide resistors almost always fail to a higher value, so should be used in this circuit.

Any mains-supplied circuit should have an appropriate fuse in the live line. A zener clamp (say 22V0) across the 0-12V output would be an additional safety factor. It should be hefty enough to carry sufficient current to blow the fuse in the case of other components failing (1.7 times rated current of the fuse).

Direct connexion of low-voltage equipment to the mains is always potentially dangerous and is best avoided.

R. Jenkins
Cheltenham,
Gloucestershire

COST-EFFECTIVE IGNITION

It is unfortunate that you have published another constructional article – Cooper's article on an electronic ignition system, March, 1982, p4 – which falls into the common trap of using device characteristics that are not specified by the manufacturer.

The devices in question are the 1N4000 series. These are low-frequency rectifiers, and the JEDEC specification to which their numerous manufacturers conform contains no information about their use at at high frequencies. While the devices used by Mr Cooper were evidently adequate, devices from another batch or from another manufacturer could be completely unusable at 15kHz. There is no shortage of devices designed and characterized for use at tv line frequency; for example, the 1N4933 would replace the 1N4001. If a 600V rating is considered sufficient for the s.c.r., D_2 and D_3 could be the BY299, an 800V, 2A fast device.

R. E. Pickvance
ITT Semiconductors
Foots Cray
Kent.

The author replies:

Mr Pickvance is quite wrong to say the article "falls into a trap", because I went to some lengths in the article to show why I used the 1N4000 series diodes and also included a graph to show their limitation, with the advice to use high-frequency diodes beyond 15kHz. Perhaps he hasn't read this part of the article?

Most of the reputable manufacturers (Motorola for instance) actually provide information on the frequency characteristics of the 1N4000 series although it isn't, strictly speaking part of the JEDEC specification. One firm devotes a whole page of its data sheet to this aspect (see enclosed photostat), so they clearly acknowledge that this diode is used at higher frequencies.

The main reason why I chose this diode is because it is readily available to the constructor. Although high-frequency diodes appear in manufacturers' catalogues, they are not available from suppliers such as Electrovalue, Maplin, Marshall's, or Semiconductor Supplies. Nowhere in these firms' catalogues are the 1N4933 or BY299 diodes to be found. To reinforce this point, I rang ITT's own main stockists, VSI (tel 0279-29666) and Nobel (tel 01-309-0500) and asked them to quote for the 1N4933 and BY299. Neither firm had any stocks of the 1N4933 or intended to stock it, and would not even quote a price. Neither firm had any stocks of the BY299, but Nobel did at least quote a delivery (6 to 8 weeks!) and a price of 17p. This latter firm, when they found out the application of the diode, went so far as to recommend the 1N4000 series as a substitute!

However, all the suppliers mentioned sell the 1N4000 series, and at a moderate cost, too – about 50p will buy all five diodes used in this circuit; and this brings me to my third point.

If the circuit were designed around specialized components instead of general-purpose components, the price would go through the roof, and the whole essence of this particular electronic ignition was that it could be paid for out of the savings on one year's motoring. If I uprated the diodes it would make even better sense to substitute the TIP3055 switching transistor, improve the transformer windings, select a military-grade capacitor for C_1 and specify a high-grade thyristor. This I would like to do, but there would be very little economic sense in it; it would no longer be cost-effective.

Finally, I suggest that Mr Pickvance reads *Wireless World* Letters to the Editor for Oct 1975 p.465, and June 1975 p.265 – and indeed anyone intent on criticism, before they put pen to company notepaper, would do well to read these letters.

HEATING-FUEL SAVER

Mr Ryder's central heating fuel saver is pretty obviously going to be cost effective but it does seem to be amenable a further cost-effective modification. This is to add a further thermistor to measure the indoor temperature and hence the temperature difference between inside and out which will better reflect the time needed to reach the desired temperature.

As it stands there is a distinct and obvious weakness in using the device with the popular time clocks providing a gap during the day, long for those at work and shorter for those staying at home. The lowest outdoor temperatures are almost always reached at night and the house has far longer to cool down, whilst during the day it is possible to have quite large solar gains to further diminish indoor temperature reduction. Therefore it obviously makes sense to respond to both temperatures.

What may be less obvious is that a linear type response is not really needed In cold weather the heating system loses more heat to the outside and thus take longer to warm inside, (in the extreme it cannot even reach the desired indoor temperature). If, as seems reasonable, non linearity can be a virtue it does seem feasible to replace R_s, the fixed resistor, with a combination of a thermistor and resistance. the actual choice of values may be made empirically if one has a fairly good idea of the characteristics of one's own heating system performance.

An allied device would be a "time extender" when switching off. The "off" time would be chosen to suit a warm day and the actual close-down would be later according to the temperature outside. One can usually tolerate a few degrees drop but this is a matter very much of personal feelings, and keenness to save fuel. With cast iron boilers and systems having a large water content there is also hot water left after the boiler stops which can be used if the pump is allowed to run longer. Thus two "time extenders" can be of value – one to let the boiler run longer in cold weather and the other a simple fixed "extender" to give about half an hour extra for the pump.

Having suggested that two thermistors are needed to measure the temperature difference it might be worth experimenting, when the time clock has no OFF period during the day, with a thermistor mounted indoors but near to a window so that it is exposed both to the outside and room temepratures. Quite obviously such a thermistor must not be exposed to the sun but the author's choice of a north facing window is unduly restrictive.

As probably 99% of domestic heating systems are just thrown together rather than designed to suit the actual house and the needs of its occupants, it is fairly safe to say that great precision in timing the heating will be uncalled for. The occupants will already suffer from wrongly sized or placed radiators and many other problems, so errors in timing of ± 15 minutes are unlikely to be noticed in terms of comfort.

L. Streatfield
Poole
Dorset

The author replies:

I am obliged to Mr Streatfield for his constructive remarks. If the thermometer facility is not required, then certainly an indoor thermistor could partly replace resistor R_s; or it might be used to modulate the 555 period, via pin 5. With a divide-by-two circuit (such as that of p. 66 *W.W.* Nov. 79) the a.m. and p.m. signals from the time-clock could be distinguished, and the operation modified to suit, for example by switching the 555 timing resistor. The difficulties lie not so much in meeting a particular set of requirements, as in defining the requirements, in the first place.

CARTRIDGE ALIGNMENT

When dealing with tone-arm geometry the tendency is to picture things as they are seen on the turntable and to always include the arc described by the stylus. If instead the stylus/cartridge assembly is imagined to be fixed and the turntable spindle itself moving about the arm pivot, the relative positions of stylus, spindle and pivot are as before but the facts are more clearly illustrated. More importantly, new facts reveal themselves.

Starting from a point representing the stylus, a perpendicular line – a datum line – from which tracking errors may be determined is drawn. Along this line the two zero tracking radii are marked. Through these points an arc with radius equal to the spindle-to-pivot distance is described from a point which, of course, represents the pivot. Any important platter radius may now be marked on the arc directly from the stylus point.

The diagram here is drawn considerably out of scale to avoid crowding. For the same reason lines have been omitted: in an endeavour to avoid confusion, points are symbolized by some letters not customarily employed.

Position of spindle when stylus is on:

outermost groove,	A
innermost,	B
intermediate radius of high error,	C
any radius (A B etc) included,	R
inner zero tracking radius	p
outer zero tracking radius	q

D, spindle to pivot dist. (arc radius)
L, stylus to pivot
O, offset angle
$L\text{-}D$=overhang=$\sqrt{D^2+pq}-D$
x, angle at R.

$$\sin=\frac{R^2+L^2-D^2}{2LR}=\frac{R^2+pq}{2LR}.$$

When this is applied to *p*,

$$\sin=\frac{p^2+pq}{2Lp}=\frac{p+q}{2L}=\sin O$$

Similarly with *q*. $((p+q)/2L=\sin O$ is clear from the diagram). When applied to C,

$$\sin=\frac{C^2+pq}{2LC}.$$

Now $\sqrt{pq}=C$ therefore $pq=C^2$ and

$$\frac{C^2+pq}{2LC}=\frac{2C^2}{2LC}=\frac{C}{L}=\sin x \text{ at } C.$$

To clarify this, it can be seen from the diagram that $C^2=L^2-D^2$. Now if we join point *q* to the pivot point, a triangle is completed one side of which is common to another triangle whose hypotenuse is *L*, because of this

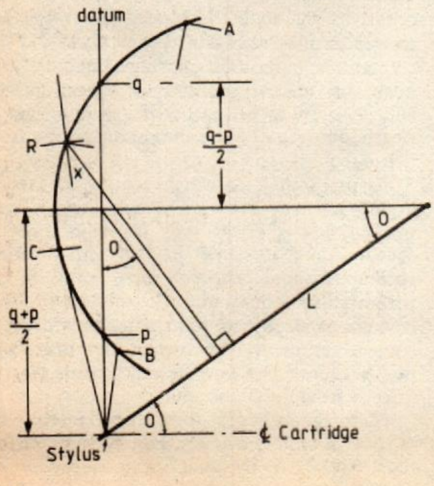
$$D^2-\left(\frac{q-p}{2}\right)^2=L^2-\left(\frac{p+q}{2}\right)^2,$$

therefore

$$L^2-D^2=\left(\frac{p+q}{2}\right)^2-\left(\frac{q-p}{2}\right)^2=pq.$$

(Quickly proved by substituting figures for *p* and *q*.)

It is useful to note that while the magnitude of the tracking errors (difference between *x* and *O*) depends on the values of *D* and *L*, their proportions depend on the zero tracking radii. When *p* and *q* are 66 and 121, for instance, the errors at *A* and *B* are 1.7 and 0.7 of that found at *C*. When *p* and *q* are 49 and 110, at *A* the error is double that found at *C*, while at *B* it is two thirds. If a diagram is drawn to scale showing only the arc, datum line and points *A*, *B* and *C* joined by straight lines to the stylus point, tracking errors might be measured directly with a protractor. R. J. Gilson's factors would place *B* on the other side of the datum line.



It follows from the foregoing that $p+q=\sin O2L$. This facilitates the process of calculating the zero tracking radii in a case such as that dealt with in Gilson's final paragraphs page 64, *Wireless World* Oct. 1981. After finding *O* with his formula 4(b), find $p+q$ from this equation. Then *p* and *q* can be found from $pq/p=(p+q)-p$. There seems to be quite a bit of latitude for rounding off the results while ensuring negligible changes in the values of *L*, the intermediate radius and all angles.

P. E. Cryer,
Thornlie,
Western Australia.

THE NEW ELECTRONICS

I have every sympathy with Hugh Jacques article in your January issue – and I certainly do not find low standards in Germany an excuse for our own low standards, as C. Wehner's letter in the April issue seems to imply (in part at least).

I am now a secondary school teacher of physics and have been appalled at the philosophies built into education; standards here are definitely falling – but a whole re-shuffle of aims and objectives and a change in examination syllabuses and in the exams themselves all combine to camouflage the drop in standard. I have often wondered when this fall in standard was going to affect university standards and higher up. Mr Jacques article confirms my fears.

What with a philosophy that views the child in terms of its needs instead of in terms of its responsibility and society's expectations from it – there has developed the sort of approach which has the following characteristics:

1) educationally – the child considered in terms of its needs must be given automatic promotions to prevent any sense of inferiority, frustration or maladjustment;
2) socially – the same child must be guaranteed cradle-to-grave security lest a trauma be produced;
3) the cure for failure to learn is to devaluate learning and the cure for social failure is to devaluate success.

I trust this will give food for thought for concerned parents and then, perhaps, lead them to action.

S. Georgeoura
Ardgay
Ross-shire

WOODPECKER

Mr Martinez' letter, (April), gives an interesting and quite possibly correct explanation of the Russian "Woodpecker" transmissions. There are one or two points arising from his letter.

The suggestion that the code auto-correlation, *i.e. the "compressed" radar signals, would have virtually no sidelobes may be a little optimistic. One might expect, in a practical system, that the peak signal sidelobes would not be more than about 25 dB at best below the main lobe. One would also have to examine the ambiguity functions of these signals to determine their properties in the range-Doppler domain where their sidelobe performance might be rather different if the radar were used to detect high-velocity incoming targets.

Another point arises from the statement that the compressed signal would have "31 times the amplitude . . ." etc. The equalizer, (i.e. the matched filter), would theoretically conserve signal energy and its peak output would have 31 times the peak *power* of the uncompressed signal, not 31 times its amplitude.

Finally the statement about the radar having 31 times the "sensitivity" of a 100μs radar of the same power, should be interpreted with caution. Two radars of differing pulse durations but of the same *mean* power, and having properly matched filters in the receivers, would have the same "sensitivity". Their difference in the present context would, as Mr Martinez states, lie in their resolution capability. Pulse compression, as such, does not introduce some mysterious improvement in system sensitivity; with matched filter receivers, whatever the transmitted pulse duration, the "sensitivity" remains a function of the ratio of the received signal *energy* to noise power spectral density.

* (strictly the *cross*-correlation function of the transmitted signal with that received, taking account also of any "weighting" which might be used to improve signal sidelobe levels, albeit at some expense to resolution.)

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THE FUNCTION OF FUNCTIONS

I was interested to read Thomas Roddam's remarks (*Wireless World*, December, 1981. p. 37) concerning the notion that used to be fairly prevalent, that denies the existence of sidebands in amplitude modulation. After all, with "pure" amplitude modulation the number of cycles per second of the wave remains constant whether it be modulated or not, doesn't it? Be it said that the idea is not entirely dead even yet; there are still people to be found who hanker after it. And it may be said that they are in tolerably good company, too, as anybody may see for themselves by consulting the files of **Nature** for 1930 (pp.92-3, 198-9, 271-3, 306-7, 726-7) in which Sir Ambrose Fleming, no less, categorically denies the existence of sidebands, declaring on the contrary that they are but a mathematical fiction, and stubbornly refusing to accept correction from his colleagues.

The curious thing about it all is that the sideband-deniers have never had any difficulty in accepting that a baseband signal occupies finite spectrum space, not realising, of course, that a baseband signal is but two (superimposed) sidebands, "centred" on zero frequency. A simple thought-experiment: displace the carrier frequency progressively upscale from zero and observe the two sidebands separating out.

And consider, furthermore, that proper reconstruction of a baseband signal to (say) audible form requires re-insertion of the zero-frequency carrier, e.g. in the polarizing firld of a loudspeaker or telephone receiver.

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