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VERSATILE CURRENT MONITOR

TERRY DE VAUX-BALBIRNIE

Keep an eye on the current situation!

THIS neat little monitor module will allow the current flowing through some existing circuit or piece of equipment to be monitored. An audible or visible warning will then be given if it rises above or, alternatively, falls below some preset threshold value. Such a circuit will find numerous uses for power supplies, charging units and certain battery-operated devices.

The circuit draws current from the supply to the existing device so does not require a power supply of its own. The current drawn for its own operation depends on the applied voltage. However, in the prototype unit this never exceeds 100µA on standby which may be regarded as negligible. While actually operating, the current rises by that required by the warning device.

MULTI-USE

If the existing circuit is powered using a *fixed-voltage* supply, it should be possible to provide a warning when the "normal" current varies by as little as five per cent. However, if the voltage varies to some extent (such as when batteries are used) such precision will not be available.

Even so, many readers will wish to use the monitor to react to relatively large changes in current (such as when a filament lamp connected to a circuit "blows"). If the applied voltage varies by, say, 20 per cent it should still be possible to use it for this type of application.

MOTORING ON

One typical example of an application would be to check that a small motor was not being overloaded. When running normally under a light load, the current will be relatively small. As the loading increases, the speed falls and the current will rise. When it exceeds the "normal" value, the current monitor circuit could provide a warning.

The current to be monitored should fall within the range of 40mA to 2A. The operating voltage (that is, the voltage used by the existing equipment) should lie between 3V and 15V *smooth d.c.* This covers a wide range of devices. However, check this point before starting construction work.

VERSATILITY

The operating conditions are determined by a set of small on-board switches. According to their setting, a warning will be given under one of the following conditions:

● When the current rises above a preset threshold value.

● When the current falls below a preset threshold value.

● Continuously if the current rises momentarily above the threshold value since last reset

● Continuously if the current falls below the threshold value momentarily since last reset.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Versatile Current Monitor is shown in Fig.1. The existing connections between the power supply and the equipment to be monitored (the load) is cut and the new ends connected to a section of terminal block TB1 on the new circuit panel.

Instead of flowing directly from the supply to the load, the current must now flow through resistor R1 (the "sensing resistor"). A small voltage (a few tens of millivolts) will then be developed across it. Although this is "lost" as far as the load is concerned, it is normally too small to have any practical effect.

The sensing resistor may be a single resistor or up to three of them connected in parallel to obtain the required value – see Table 1. It may also be made up of a closed loop of printed circuit board (p.c.b.) copper track which has been "built into" the layout specially for the purpose.

The track "resistor" (nominal value 0·05 ohm) may be appropriate for any current between 400mA and 2A. Ordinary resistors will probably be needed for a current smaller than this. Sometimes the user will need to experiment to find the best method for a given application and more will be said about this later.

IN COMPARISON

The first active part of the circuit is a low-power operational amplifier (op.amp) IC1. By minimising the current required for its own use, that drawn by the circuit as a whole is reduced. The specified unit requires only 10µA nominal.
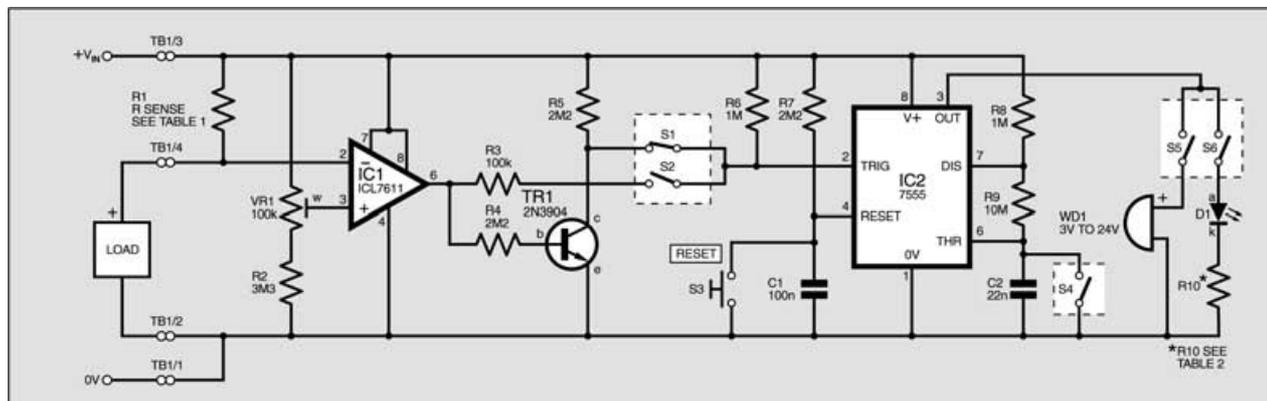

Fig.1. Complete circuit diagram for the Versatile Current Monitor.

Op.amp IC1 is used as a comparator which responds to the voltages applied to its two inputs. These are the inverting (–) input (pin 2) on the one hand and the non-inverting (+) one (pin 3) on the other. If the voltage at pin 3 exceeds that at pin 2, the output (pin 6) goes high. Otherwise, it remains low.

The inverting input (pin 2) receives the voltage developed across the load. This will be slightly less than the supply voltage – the difference being that existing across sensing resistor, R1. The non-inverting input (pin 3) receives the voltage obtained from the potential divider consisting of preset potentiometer VR1 in the upper arm and fixed resistor R2 in the lower one.

MAKING ADJUSTMENTS

With VR1 suitably adjusted, it can be arranged for the same voltage to appear at IC1 pin 3 as at IC1 pin 2 when the threshold current flows through the load. If the current drawn by the load now rises by a small margin, the voltage across sensing resistor R1 will increase slightly and that across the load will fall. The op.amp will switch on and the output (pin 6) will go high. With less than the threshold current flowing, the output will remain low.

In theory, this effect is independent of the supply voltage. This is because, if this rises or falls, the voltages at both op.amp inputs will be affected in the same proportion.

However, this is only partly true and then only with fairly small changes in voltage. The circuit will then not "see" changes in current due to a variation in voltage. The normal current may be regarded as rising or falling with small changes in applied voltage and the circuit arranged to trigger when it rises or falls for some other reason (such as a fault developing).

Imagine switch S1 is *on* and switch S2 *off* for the moment – the purpose of these switches will be described presently. Op.amp IC1's output is applied to the base of transistor TR1 via resistor R4. The low state here keeps the transistor *off* and the collector (c) is *high.* In this way, the original signal has been inverted.

Switch S1 contacts allow this state to be applied to the trigger input (pin 2) of a monostable centred on IC2, a low power timer i.c. The specified device has a very low quiescent current requirement – 60µA approximately. This, again, minimises the current required by the circuit as a whole. However, with the trigger input, pin 2, kept high nothing further happens because it is a characteristic of this type of device that triggering occurs with a *low* state.

MOMENTARY ACTION

If the current flowing through the load increases, IC1 will switch on and the high state of its output will allow current to enter the base of transistor TR1. The transistor turns on and its collector goes *low.* The low state applied to IC2 pin 2 now triggers the monostable and the output, pin 3, goes high for as long as the current remains above the threshold value.

If the current only rose momentarily above the threshold value and immediately fell again so that the high state on pin 2

Table 1

Threshold current (mA)	Value of R1 (ohms)
40	1
80	0·5 (2 off 1 ohm in parallel)
120	0·33 (3 off 1 ohm in parallel)
150	0·27
250	0·15
400	0·1

was restored, the monostable output would remain high for a time determined by the values of resistors R8 and R9 and capacitor C2.

Assuming that switch S4 is off for the moment so that capacitor C2 is operative, with the values specified, this time will be some 0·2 second. This sets the *minimum* operating period and is designed to prevent repeated short-period "chirping" from the buzzer near the threshold value. The timing could be increased by raising the value of resistor R9 or capacitor C2.

The monostable output can be made to operate either the buzzer WD1 or l.e.d. D1 (by closing switch S5 or S6 respectively). Resistor R10 is the l.e.d. current-limiting resistor and will be chosen according to the approximate operating voltage of the circuit. A table of values is shown in Table. 2. These allow 15mA approximately to flow through the l.e.d. at the voltage shown.

Note that when the warning device operates, this in itself causes a rise in current through the sensing resistor. It therefore assists triggering on rising current and to some extent reacts against it on falling current. However, the change is small and, in practice, is of little consequence.

INTO REVERSE

To reverse the operating condition so that triggering occurs when the current falls below the preset level, the inverting effect of transistor TR1 is removed. Switch S1 is now set *off* and S2 *on.* The logic state of IC1 output, pin 6, is now applied (via resistor R3) direct to the monostable trigger input.

If both switches S1 and S2 were to be switched on (by mistake), there would be a set of conflicting logic states and this should be avoided. If both switches were set *off* (again, in error), then IC2 pin 2 would be left unconnected or "floating". This would leave the i.c. vulnerable to damage by the pickup of stray static charge. This is avoided by including resistor R6 which maintains pin 2 in a high state under these circumstances.

The reset input (pin 4) of IC2 must be kept high to enable the i.c., resistor R7 achieves this. However, when first powered-up, this type of timer often self-triggers due to the sudden rise in voltage level. In an effort to avoid this, capacitor C1

Table 2

Supply Voltage	Value of R10 (Ohms)
3	67
6	270
9	470
12	680
15	820

holds pin 4 low for a short time until it has charged sufficiently through R7. With the values specified, this will take 0·2 second.

When switch S4 is on, it short-circuits timing capacitor C2. This prevents it from charging and has the effect of turning IC2 into a latch. Once triggered, the output will then remain on until cancelled by taking the reset pin 4 low. This is done by operating Reset switch S3. This switch could be situated off-board if required.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full-size underside copper foil track master are shown in Fig.2. This board is available from the *EPE PCB Service,* code 335.

Begin construction by drilling the p.c.b. fixing holes and then solder the i.c. sockets, terminal block and switches in position. Note that the three switches S4, S5 and S6 are part of a *four-way* d.i.l. block. This is because groups of three such switches do not appear to be available. The second one from the left is not used.

If you wish to mount switch S3 off-board, the specified type of p.c.b. mounting tactile unit would probably not be convenient to use. In this case, use any other small pushbutton, push-to-make, switch.

Follow with all resistors, except R1, preset potentiometer VR1 and the two capacitors. Preset VR1 is specified as a *multi-turn* type. This is definitely advised rather than using the single-turn variety because it greatly simplifies adjustment at the end.

FILL THAT GAP

If the anticipated operating current exceeds 400mA (and up to the 2A limit), solder the link wire (a short piece of single-strand connecting wire) into the gap in the high-current loop as shown dashed in Fig.2. This puts the copper track "resistor" in the R1 position. The position reserved for fixed sense resistor(s) R1 is left empty.

It was found in the prototype unit that the p.c.b. track could be used for a current as low as 200mA. For values between 200mA and 400mA, it may therefore be worth experimenting to see whether it is necessary to use physical resistors for R1. Whether or not this is possible will depend on the width and thickness of the copper track on any particular specimen of p.c.b.

If the current to be monitored is expected to lie between 40mA and 400mA, leave the high-current link disconnected and, referring to Table 1, solder a resistor or resistors into R1's position(s) to make up the required value.

The table shows how 2 or 3 one-ohm resistors may be used to provide values of 0·5 ohm and 0·33 ohm respectively. Copper pads on the p.c.b. have been left for these. Of course, single units may be used if available.

Unfortunately, resistors of a small physical size (low power rating) in values less than one ohm are not easy to obtain. The alternative is to use units of, say, 3W rating in as small a size as possible. An additional pad has been left on the p.c.b. to allow one large unit to be mounted flat if required (see photograph).

The value of sense resistor R1 is not too critical. If the proposed threshold current is not shown in Table 1, use the nearest value.

PRECAUTIONS

Complete construction of the p.c.b. with the polarity-sensitive components, namely – transistor TR1, audible warning device WD1 and l.e.d. D1. Finally, insert the i.c.s into their sockets.

Since the i.c.s are CMOS devices, they are vulnerable to damage by static charge such as may exist on the body. To avoid possible problems, touch something which is earthed (such as a metal water tap) before unpacking them and handling their pins.

TESTING

Switch S1 on and S2 off if triggering is required on *rising* current and S1 off and S2 on if it is required on *falling* current. Switch S4 off (for momentary triggering). Switch both S5 and S6 on so that the l.e.d. and the buzzer are both in circuit. Connect the supply wires and the load to the terminal block taking care to observe the polarity. *The circuit will be damaged if the polarity is incorrect.*
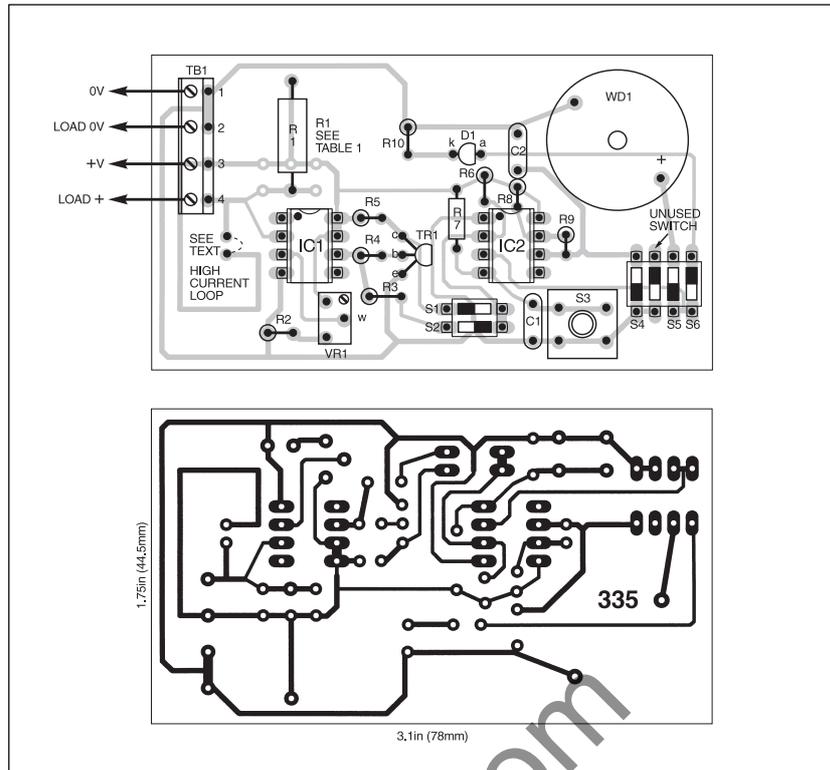
Fig.2 (above). Printed circuit board component layout and full-size copper foil master. The completed board is shown in the photograph.
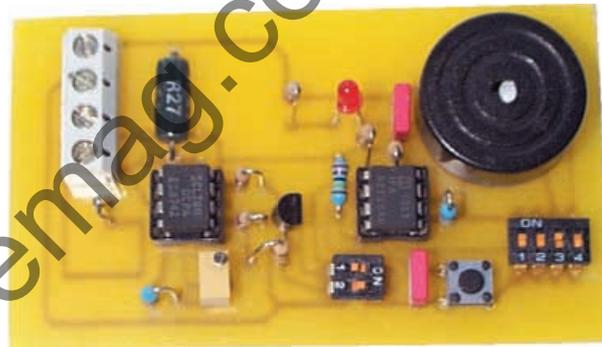
Allow the external circuit (load) to operate normally. The buzzer and l.e.d. may be operating already. Adjust preset VR1 until the critical point is reached. If the switching point is not sharp (the buzzer "chirps" at the threshold value), it may be necessary to improve the degree of smoothing of the supply. In most cases, however, it will not matter.

Allow the current to rise or fall as appropriate to give the signalling condition and check for correct operation. Adjust VR1 so that this happens at a suitable point. If the circuit is operated from a battery you will need to check at the upper and lower voltage limits to arrive at the best setting for VR1.

BUILDING BRIDGES

It is possible that the high-current p.c.b. "resistor" is not physically identical to that in the prototype. Its resistance may therefore need to be modified. If using this method and the voltage drop is insufficient (see below), de-solder the link wire and include an extra short length of 20 s.w.g. bare copper wire. If the voltage drop is excessive, "bridge" sections of the track using single-strand connecting wire to reduce the resistance.

Apply a digital multitester between terminal block points TB1 and TB2 (that is, across the sensing resistor) to check the millivoltage drop at the threshold current. The circuit will work satisfactorily with a drop of only 20mV to 40mV. In the prototype unit, good operation was obtained down to 10mV.

If it is much higher than this, it will involve an unnecessary loss to the external circuit. It may then be lowered by reducing the value of sense-resistor R1. Conversely, if the voltage is too small so that the circuit fails to work, R1 should be increased.

When the circuit is working correctly, switch on S4 to check that *continuous* mode works and that it can be cancelled by pressing switch S3.

Certain loads, such as filament lamps and motors, draw a current much higher than the rated value for a short time on switching on. The current then settles to the nominal value. This should be borne in mind if connecting this type of load especially if "continuous" mode has been selected. You may then need to manually reset the circuit once the current has returned to normal. Any violent changes in the load may cause triggering anyway and you may need to press the reset switch.   □