Multi-micro Four Channel Power Controller

As depicted on the front cover, the uses to which this project can be put are many and varied. In conjunction with a computer, four or eight appliances may be turned on and off in any sequence.

John Baker

The obvious application for this project is as a sequencer for disco lights, but together with a suitable computer it can be used in any application that requires up to four mains loads to be controlled. In fact, by building two printed circuit boards the unit can be converted into an eight channel controller if desired.

The maximum continuous power per channel is 300 watts, but this could be boosted substantially by adding heatsinks to the switching devices. These have a current rating of 8A, which corresponds to 1920 watts with the 240 volt UK mains supply, but when using two or more channels the maximum of 13 amps available from a normal mains outlet has to be taken into consideration.

The circuit incorporates a simple zero crossing detector to help reduce radio frequency interference and other problems that can occur with rapid switching of certain types of load.

Methods Of Control

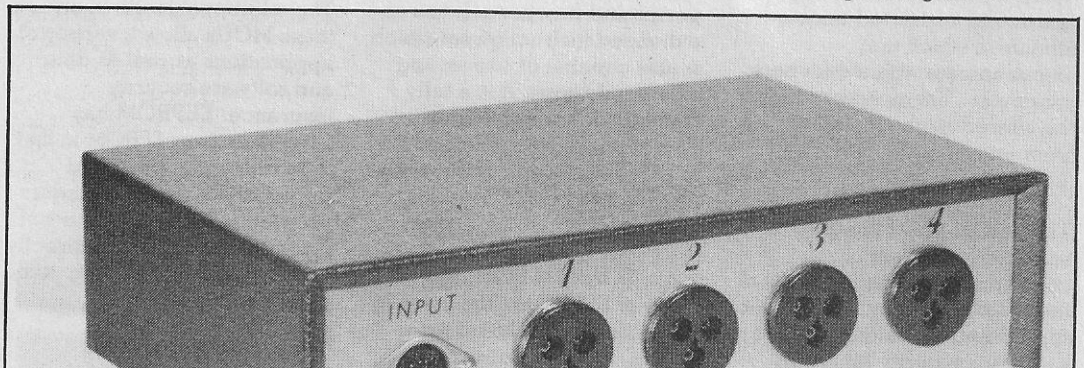
Simple on/off control of mains equipment by a computer can be achieved very easily if a suitable latching output port is available. All that is needed is a relay and a relay driver transistor. Although this method of control is normally very easy to implement, in practice it is not without its drawbacks, and it is not suitable for all applications.

The relatively slow switching speed of a relay is unlikely to be of any importance in practical mains control applications, but radio frequency interference caused by contact bounce and a lack of syncronisation with the mains supply could be severe in a situation where frequent switching occurs. A lack of syncronisation can also result in reduced life when controlling light bulbs.

A relay can be rather noisy audibly as well as electrically; something that is more of a problem if several of them are being repeatedly switched on and off. In general they have a shorter operating life than a semiconductor switching device.

The obvious alternative to a relay is a triac, but this does not provide the isolation between the load and the driving circuit that is an innate characteristic of a relay. This is not an accademic point, and driving a triac from the output port of a computer without using some form of isolation circuit would be extremely dangerous, and could well fail to work anyway.

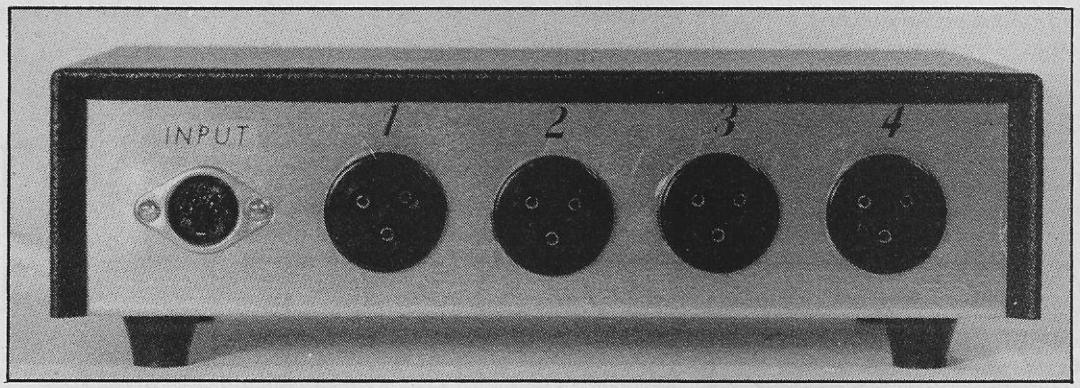
There are actually several types of isolation circuits to choose from, including pulse transformers, Piezo-electric couplers, and opto isolators. The latter are not the most convenient in use, but are versatile, relatively inexpensive, and are also readily available. There are actually several types of opto isolator, but they all have an LED with its light output directed towards a photocell of some kind. The component is contained in an opaque case which shields the photocell from ambient light and ensures that it only responds to the light output of the LED. The most common form of opto isolator, and the type used in this power controller design, has an infra-red LED driving a silicon NPN phototransistor.



Zero Crossing

On the face of it there is no

problem if a mains load is controlled by a simple switch that is not syncronised to the mains supply. After all, ordinary light switches etc provide just such a switching action. In practice, problems can arise where the switching occurs very frequently, which is not normally the case with ordinary mains switches, but is the case in an application such as a light sequencer or sound to light unit.



The waveform diagram of **Figure 1 a** helps to illustrate the problem. This is the output waveform obtained if the switching occurs when the mains supply is at its peak level, and there is an almost instant rise to a potential of about 340 volts. The fast rising edge of the waveform plus the high peak voltage contribute to the generation of strong harmonics on the output that extend well into the radio frequency spectrum, and can cause severe radio interference.

The waveform of **Figure 1 a** has a "clean" rising edge, and is the type that would be obtained when using a semiconductor switching device. The contact bounce of a mechanical switch could result in noise spikes on the waveform which would multiply the problem.

Of course, the switching action will not always occur when the signal is at its peak level, but on average the mains potential will be at around 240 volts when switch-on occurs. Of course, switching off when the mains supply is at a high voltage provides a waveform that has an almost instant drop from a high voltage to zero volts, and as far as the generation of radio frequency interference is concerned, this is just as bad.

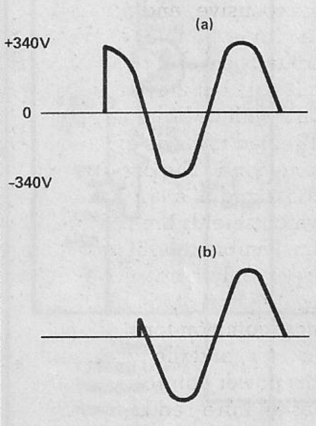


Figure 1. Illustrating the effect of using a zero crossing detector.

In addition to the interference problem, when this type of waveform is repeatedly applied to some types of load, problems can occur. In particular, the thermal shock to the filament of a bulb can result in significantly reduced life.

Filtering can be used to give a slower switching speed and reduced interference, but a better way of doing things is to use a circuit that has a zero crossing detector. The idea of the zero crossing detector is to ensure that switch-on can only occur when the mains supply is at zero volts. Practical circuits of this type are not true zero crossing types, and actually prevent switching unless the mains supply is at a potential of a few volts or less.

The effect of the detector on the waveform of **Figure 1 a** would be to delay the moment of switch-on slightly, giving a waveform of the type shown in **Figure 1 b.** Although the switching still occurs almost instantaneously, the relatively low voltage at the time when switching occurs prevents strong radio frequency signals from being generated.

Radio frequency generation is usually reduced by around 30 to 40dB, which is sufficient to render it insignificent without needing to resort to filtering. An instant rise to a potential of just a few volts will not harm the filament of a lightbulb at all.

The zero crossing does not eliminate the problem of interference being generated when the load is switched off. Provided the switching device is a triac it does not need to though, since the hold-on characteristic of a triac eliminates the problem. For those who are not familiar with triacs it should perhaps be explained that once switched on a triac remains in that state until both the gate current is reduced below the trigger level, and the current flow through the device falls to a low level.

When controlling an AC load the hold-on effect therefore prevents the device from switching off until virtually the end of the half cycle, regardless of what point the half cycle the gate current is removed.

System Operation

The block diagram of **Figure 2** shows how one channel of the unit operates, but note that some stages are common to all four channels.

Starting at the output of the unit, a triac is connected in series with the mains supply and the load. Power will therefore be connected through to the load when the triac is switched on. The digital output of a computer can normally only supply a few milliamps at most, but the C226D triac used in this design can require a trigger current as high as 50 milliamps. Taking into account losses through the opto isolator, a substantial amount of current amplification is obviously needed between the isolator and the triac. This is provided by a simple buffer stage.

The zero crossing detection is provided by the mains transformer, fullwave rectifier, and electronic switch. The fullwave rectifier ensures that the polarity of the signal fed to the input of the electronic switch is always positive regardless of the polarity of the mains supply. The electronic switch is turned on whenever the input voltage is a few hundred millivolts or more, and when switched on, it short circuits the output of the opto isolator to ground, thus preventing the triac from being triggered.

Due to the step-down action of the mains transformer, although the electronic switch prevents triggered at potentials of more than a few hundred millivolts, in terms of main voltage this corresponds to a potential of about 15 volts or more. However, as explained previously, true zero crossing or something closely approaching it is not really necessary, and in practice the circuit performs very well.

A supply of about 9V is needed to power the buffer stage, and this is obtained by smoothing the output of the fullwave rectifier. Separate opto isolators, buffer stages, and triacs are needed for each channel, but the power supply ▶

and zero crossing detector stages are common to all four channels

Circuit Operation

The circuit is more simple than one might expect, and the full circuit diagram appears in **Figure 3.**

If we take one channel of the unit, IC1a is the opto isolator for channel 1. This is in fact one section of an ILQ-74 quad opto isolator, the other three sections being used in the other three channels (one in each). The cathode of the input LED is connected to a common input line, and this would normally be connected to the ground terminal of the computer's output port. The anode terminal is fed from an output line of the port by way of current limiting resistor R3.

Of course, there is no electrical connection from the LED to the phototransistor, giving the required isolation, and the ILQ-74 can withstand input to output voltages of at least 1500 volts. Even allowing for transients on the mains supply this rating should be more than adequate.

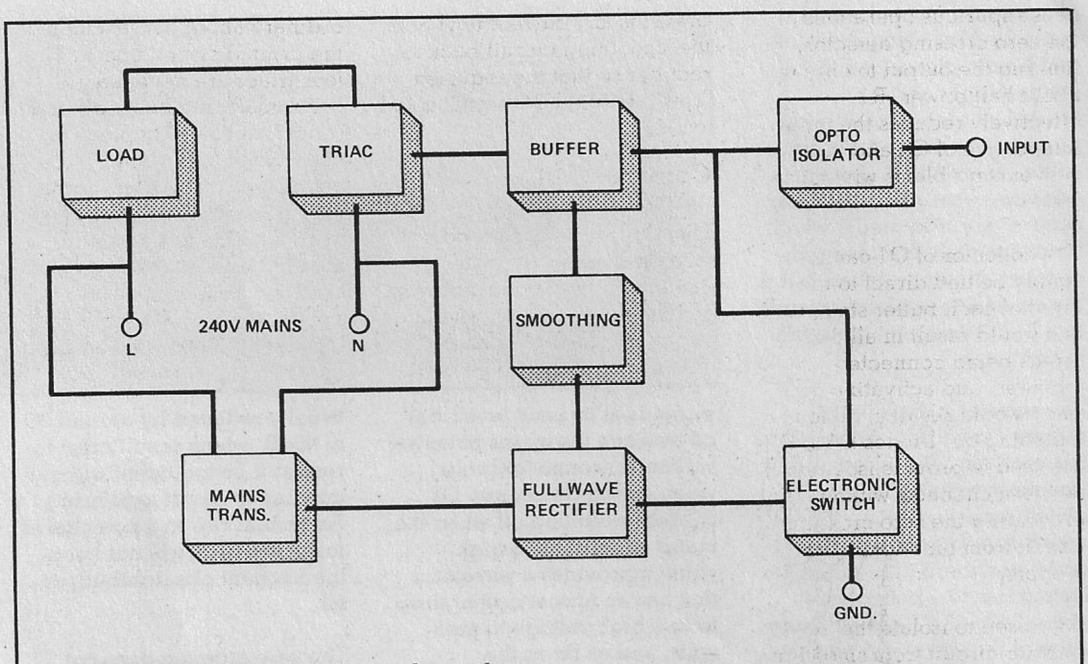


Figure 2. Block diagram of one channel.

On the output side of the isolator the output transistor has its collector terminal connected to the positive supply rail. The emitter terminal drives emitter follower buffer stage Q2 via R4. Q2 in turn drives the gate of the triac via current limiting resistor R5.

T1 is the mains transformer and its output is fullwave rectified by the standard push-pull rectifier formed by D1 and D2. The electronic switch is merely transistor Q1 which operates as a common emitter switch. R2 provides current limiting to protect the base/emitter junction of Q1, and although R1 provides no obvious function, without this component, noise pick-up at Q1's base would otherwise

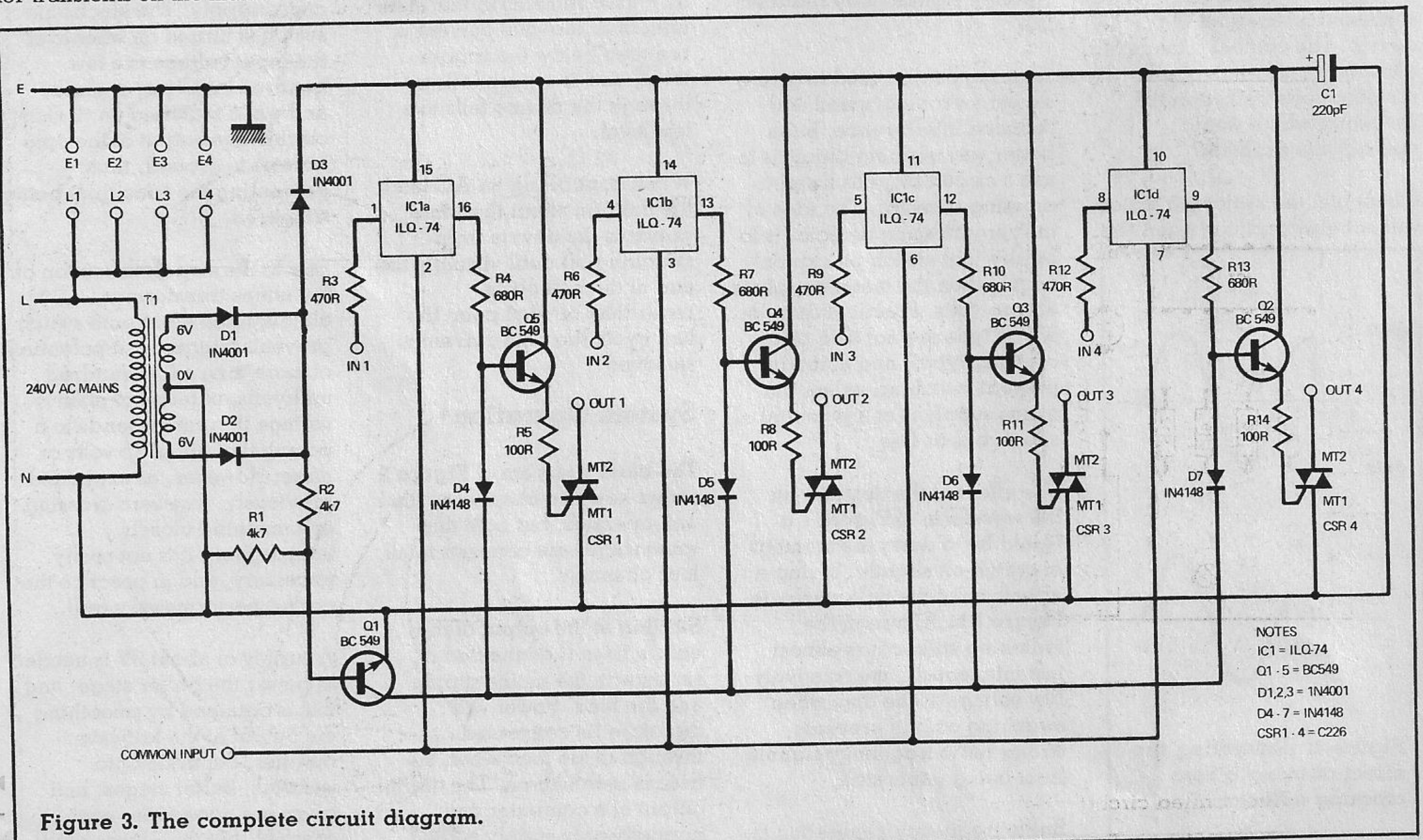


Figure 3. The complete circuit diagram.

cause spurious operations of the zero crossing detector, limiting the output to only about half power. R1 effectively reduces the input impedance of Q1 and thus prevents problems with noise pick-up.

The collector of Q1 cannot simply be tied direct to the input of each buffer stage as this would result in all the inputs being connected together, and activating one stage would result in all four switching on. Diodes D4 to D7 are used to provide isolation between channels without preventing the zero crossing circuit from functioning properly.

D3 is used to isolate the rectifier circuit from smoothing capacitor C1. This is essential as otherwise C1 would smooth the input signal to the zero crossing circuit and hold the triacs in the off state. D3 prevents any current flow from the smoothing circuit back to rectifier so that the required "raw" rectified DC signal is fed to Q1.

Construction

The exact form construction takes mechanically, will depend on the application you have in mind, and on whether or not a 4 channel or an 8 channel version is to be built. The printed circuit design of **Figure 4** should suffice whatever the intended application of the unit, and as explained earlier, two boards are used if an 8 channel controller is required. If this is done, one mains transformer is adequate to drive both boards. In the description that follows it is assumed that the unit is constructed as a 4 channel unit having four mains outlets mounted on the case.

There is little out of the ordinary about construction of the printed circuit board. The four triacs are mounted horizontally on the board and should be bolted in place to ensure that they cannot accidentally come into contact with one another. Loads of up to about 300 watts can be handled without the need for heatsinks, but for loads of around 300 to 600 watts, small U shaped aluminium heatsinks should be constructed and fitted to the triacs.

By mounting the triacs off-board on a large heatsink, loads of over a thousand watts can be handled, but with a normal 13 amp mains outlet as the power source the maximum power per channel is 780 watts for a 4 channel version and 390 watts for an 8 channel unit. Note that the heat-tab of each triac connects internally to its MT2 terminal. If the triacs are mounted on an off-board heatsink they must be effectively insulated from it, and the heat-tabs must not be allowed to come into electrical contact with any other part of the circuit.

As IC1 is not one of the cheapest devices available it is a good idea to fit it in a 16 pin DIL integrated circuit holder, making quite sure that it is fitted the right way round. Pins are fitted at the positions where connections to off-board components will be made.

A metal instrument case which measures 203 by 127 by 51mm will comfortably accommodate all the components. T1 and the printed circuit board are mounted on the base panel of the case. A soldertag on one of T1's mounting bolts provides a chassis connection point for the mains earth lead. The mains earth lead also connects through to the appropriate terminals of the output sockets, but no other parts of the circuit

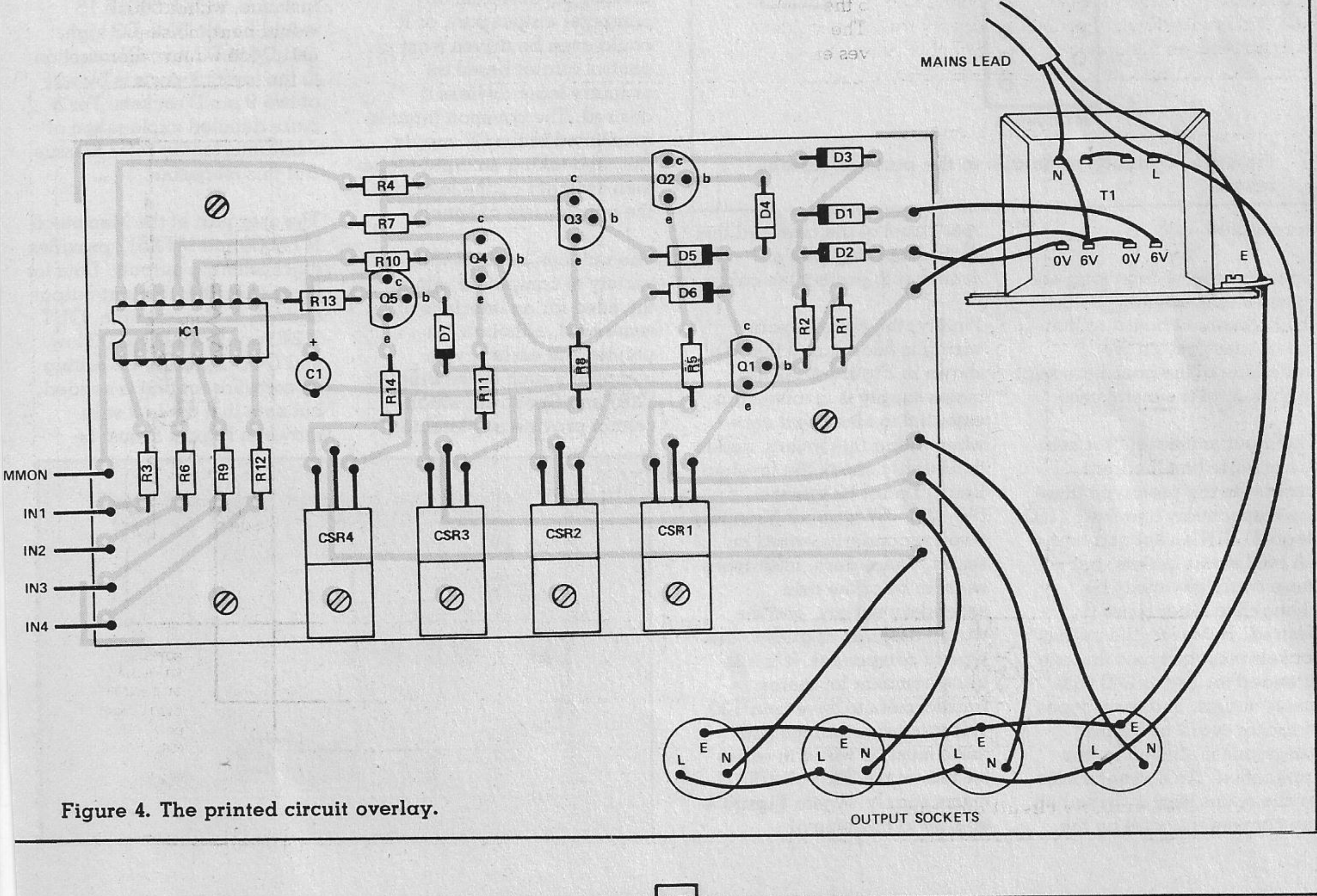


Figure 4. The printed circuit overlay.

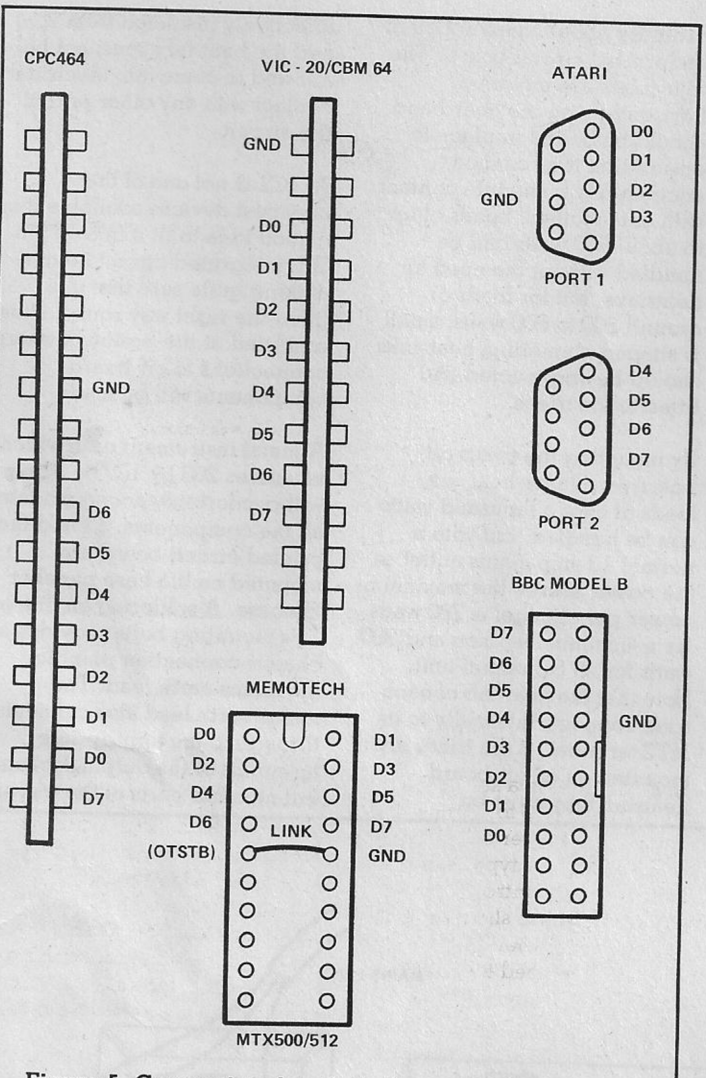


Figure 5. Connection details to the ports of various micros.

are earthed.

Spacers at least 6mm long are used on the mounting bolts for the component board so that the connections on the underside of the board are kept well clear of the metal case.

The input and output sockets are mounted on the front panel. On the prototype these are respectively one 5 pin (180 degree) DIN socket and four SA1404 mains outlets, but these could obviously be changed to other types if desired. However, the output sockets must be types that are intended for use as 240 volts mains outlets, and other types of socket could be highly dangerous if utilized in this application. An entrance hole for the mains lead is drilled at any convenient point on the rear panel of the case and this should be fitted with a grommet to protect the cable.

Finally, the point to point wiring is added, and this is all shown in **Figure 4.** As the mains supply is involved it is essential to take great care when fitting this wiring, and to thoroughly check the finished unit. T1 must be either a 6V—0V—6V type, or have twin 6 volt secondaries wired in series. These days, most types seem to be of the twin secondary variety, and the wiring diagram applies to this type of component. It is also quite common for mains transformers to have twin 120 volt primary windings and these must be wired in series for use on the 240 volt UK mains supply. Again **Figure 4** applies to this type of transformer.

A point that must be stressed is that the circuit connects direct to the mains supply, and it would accordingly be dangerous to touch any of the wiring once the unit is connected to the mains. For reasons of safety it is essential to use a case that has a screw fixing lid so that there is no way of gaining access to the interior of the unit and the dangerous wiring.

Of course, it is perfectly safe to touch the wiring to the input socket which should be totally isolated from the mains supply. It would be advisable to check with a multimeter set to its highest resistance range that there is no electrical contact between any of the input leads and the mains supply prior to connecting the unit to the mains supply and testing it.

In Use

There should be no difficulty in driving the unit from any computer output port, or it could even be driven from a control circuit based on ordinary logic devices if desired. The common input is connected to the 0V supply rail, and taking an input higher then switches on the load for the appropriate channel.

The unit can be used with a variety of computers without the need for an interface of some kind, although, as pointed out earlier, with computers such as the Sinclair ZX81 and Spectrum which cannot provide any latching output lines it is necessary to control the unit via a suitable output board. **Figure 5** gives details of how the unit can be driven directly from a number of popular computers. Of course, with a 4 channel controller only outputs D0 to D3 are required. D4 to D7 drive the second printed circuit board in an 8 channel controller.

Starting with Atari computers, the unit can be driven from joystick ports 1 and 2 of the Atari 400, 600XL, 800 and 800XL. Although these are primarily intended to act as input ports, the simple software routine given below is all that is needed to change the relevant lines to latching outputs:

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POKE 54018,56

POKE 54016,255

POKE 54018,60
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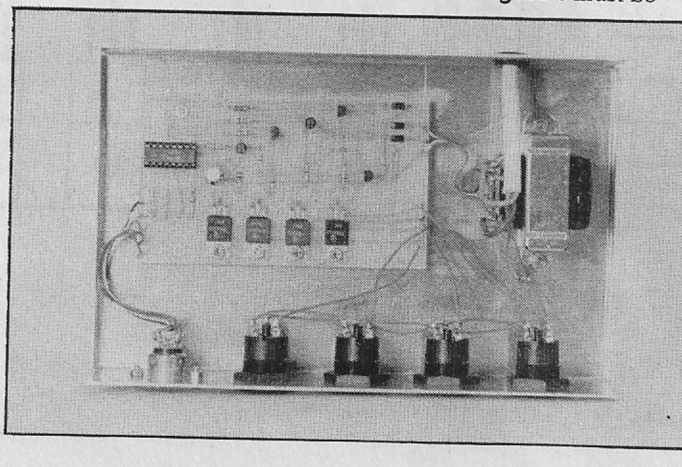
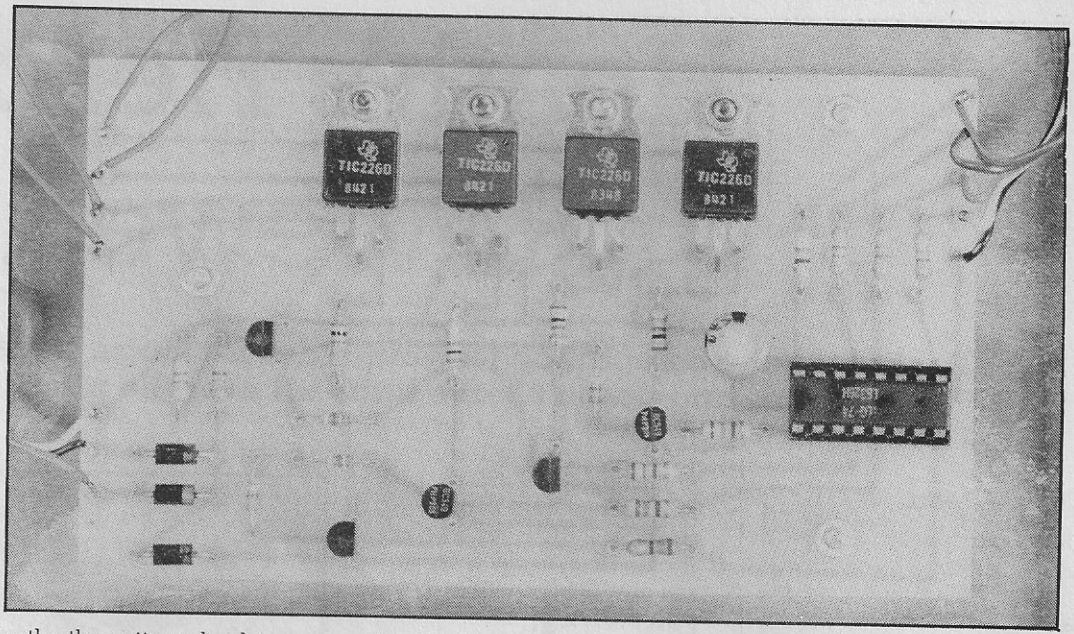
Data for the controller is then written to address 54016. For instance, POKE 54016,15 would be set D0 to D3 high, and D4 to D7 low. Connection to the joystick ports is by way of two 9 pin D sockets. For a more detailed explanation of Atari interfacing refer to issue 3 of this magazine.

The user port of the Memotech MTX500 and MTX512 provides eight latching outputs. Data for these is written to input/output address 7. For example, OUT 7,240 would set D0 to D3 low, and D4 to D7 high. No setting up software routine is needed, but note that the link wire shown in **Figure 5** must be





included in order to take the outputs into the active state. The user port is the 20 pin DIL socket on the printed circuit board, and connection to it is via a DIP plug.

The Commodore 64, VIC-20, and BBC model B computers all have a similar user port that can be used to provide eight output lines. The lines can in fact be set to act as inputs or outputs, and in this case they are set as outputs by writing 255 to the data direction register, as detailed below:

POKE 56579,255(CBM 64)

POKE 37138,255 (VIC-20)

?&FE62=255 (BBC model B)

Data for the controller is then written to addresses 56577, 37136, and &FE60 respectively. For example, to set DO high and all the other lines low these commands would be used:

POKE 56577,1(CBM 64)

POKE 37136,1 (VIC-20)

?&FE60=1 (BBC model B)

Connections to the two Commodore machines are made via a 2 by 12 way 0.156 inch edge connector, but the BBC model B user port requires a 20 way IDC header socket.

Lastly, the unit can be driven from the printer port of the Amstrad CPC464. A 2 by 17 way 0.1 inch pitch edge connector is required. Data for the port is written to input/output address &EF00. There is a slight complication in that D7 is inverted and the other lines are not. Thus the command

OUT &EF00,255

would set all the lines high except D7. This should not really complicate the software too much, and is of no consequence if the controller is a 4 channel type since D7 will then be left unused anyway.

No software is included with this article since even a beginner at writing programs should have no difficulty in writing suitable routines. All that is needed is a series of numbers (from 0 to 15 for a 4 channel controller and 0 to 255 for an 8 channel type) that are written to the controller in sequence, with a short delay between each one. The program is looped to provide continuous sequencing. Another approach would be to produce random numbers at the rate of say, three to four per second, with these numbers being used to give random operation of the lights. Things like moving light displays can also be generated easily.

With a four channel controller a suitable sequence of numbers would be 14, 13, 11, and 7 (this assumes that the lights are arranged in the correct D0 — D1 — D2 — D3 sequence). With the BBC model B computer a sound to light action can be obtained with the aid of the interface and software featured elsewhere in this issue.

DME

Parts List

RESISTORS
All ¼ watt 5% carbon

R1,2	4k7
R3,6,9,12	470R
R4,7,10,13	680R
R5,8,11,14	100R

CAPACITOR

C1	220u 16V radial electro

SEMICONDUCTORS

Q1 to Q5	BC549 NPN silicon
IC1	ILQ-74 opto-isolator
CSR1 to CSR4	C226D trial
D1,2,3	1N4001 rectifier
D4,5,6,7	1N4148 silicon diode

MISCELLANEOUS

T1	Twin 6 volt secondary windings rated at 250mA

Metal case 203 by 127 by 51mm; printed circuit board; four mains outlets (type SA2404 or similar); 5 pin DIN socket; mains lead and plug fitted with 13A fuse; wire; solder; fixings; etc.

Buying Guide

The four mains sockets can be obtained from **Maplin.** Stock number; HL48C.