Our best Musicolour yet . . .

MUSICOLOUR IV

4-channel colour organ plus light chaser

Add excitement to your parties, prawn nights and discos with our new Musicolour IV light show. This is the latest in our famous line of Musicolours and it offers many features such as four-channel "colour organ" plus four-channel light chaser, front panel LED display, internal microphone, single sensitivity control plus opto-coupled switching for increased safety.

by RON DE JONG

Since we published our first Musicolour back in October 1969 most people have probably seen at least one in a disco or at a party – and been impressed. It really adds life to the party with its kaleidoscopic light show beating to the sound of the music. Its continuing popularity is the reason why we have produced updated versions, the last being the Musicolour III in September 1976.

Our latest version is the Musicolour IV and it offers quite a few advantages over previous units. The most obvious change is that the Musicolour IV is a four-channel light unit rather than a three-channel unit; that is it divides the music input into four frequency bands and modulates the lights in each channel according to the amplitude in each band. Typically, four differently coloured flood lights would be connected, one to each channel – red for the lowest band, then yellow, green and blue.

Some basic improvements which have been made in the Musicolour IV are that the separation between frequency bands has been considerably sharpened and the response of the lights is more linear. Also, because of the wide range of the sound-to-light response, individual channel sensitivity controls are not required – just one master sensitivity control. This makes it easy to set up since little adjustment is required to get a good display.

With the flick of a switch the unit also operates as a four-channel light chaser which features forward/reverse plus an automatic forward/reverse which can be adjusted to reverse the direction of the chaser from every ½ second to about 10 seconds. Four chaser patterns can be selected via the PATTERN control and these include single lights chasing, "holes" chasing and two lights chasing – in fact every possible combination. The rate at which the lights chase is set by the SPEED control or the lights can be made to chase in time with the music by switching the MUSIC/OSC switch to MUSIC.

When operating as a light chaser the unit also features zero-voltage switching, ie, the Triacs are switched on only at the beginning of a mains half cycle. This largely eliminates radio interference and reduces the inrush currents to the lights.

Two more features we have included are an internal electret microphone and a LED display on the front panel. The electret can be used in place of the normal input from the speaker output of the amplifier by switching the MICROPHONE/SPEAKER switch. This is a useful in circumstances where it is inconvenient to bring a speaker connection to the Musicolour.

The front panel display consists of four LEDs, one for each channel, and when a particular channel is turned on the corresponding front panel LED will also turn on. This is a useful diagnostic aid and it also clearly shows the operation of the light chaser, eg the pattern selected and forward/reverse. The circuit has also been designed so that the LEDs will be modulated in the Musicolour mode.

Perhaps the most important feature, from a safety point of view, is that we have used opto-coupled Triac drivers. These are relatively new devices similar to opto-couplers, except that instead of having an internal LED optically coupled to a phototransistor, it is coupled to a photosensistive silicon bilateral switch which will directly trigger a normal Triac via a single resistor. This allow us to have all of the Musicolour circuits operate at low potential, except for the Triacs themselves.

CIRCUIT DESCRIPTION

To see how the Musicolour section of the unit works first refer to Fig. 1 which shows a block diagram of the unit. First off there is a switch which selects microphone preamp or the speaker outputs of a stereo amplifier. The signal is amplified and then fed to four bandpass filters which are tuned to the following bandpass frequencies: 0-200Hz, 200Hz-700Hz, 700Hz-2kHz and 2kHz and up. These frequencies were designed to give a reasonable division of the musical spectrum – note that the top filter would seem to have more than its fair share but in fact there are very few musical notes above 4kHz (just harmonics).

Outputs of the filters are rectified and filtered to produce a DC voltage corresponding to the signal amplitude in the four frequency bands. This voltage is then used to control a Triac circuit so that the light output is proportional to the sound amplitude. To understand how this is accomplished we have to examine the operation of a Triac.

The Triac is a bidirectional switching element, ie it is either fully on or off. Since it is bidirectional it has no anode or cathode as such, but has two main terminals called A1 or A2 plus a control terminal called a gate. When a brief trigger pulse is applied between gate and terminal A1 the Triac turns full on and remains on until the load current drops to zero, ie, at the end of each mains half cycle.

PHASE CONTROL

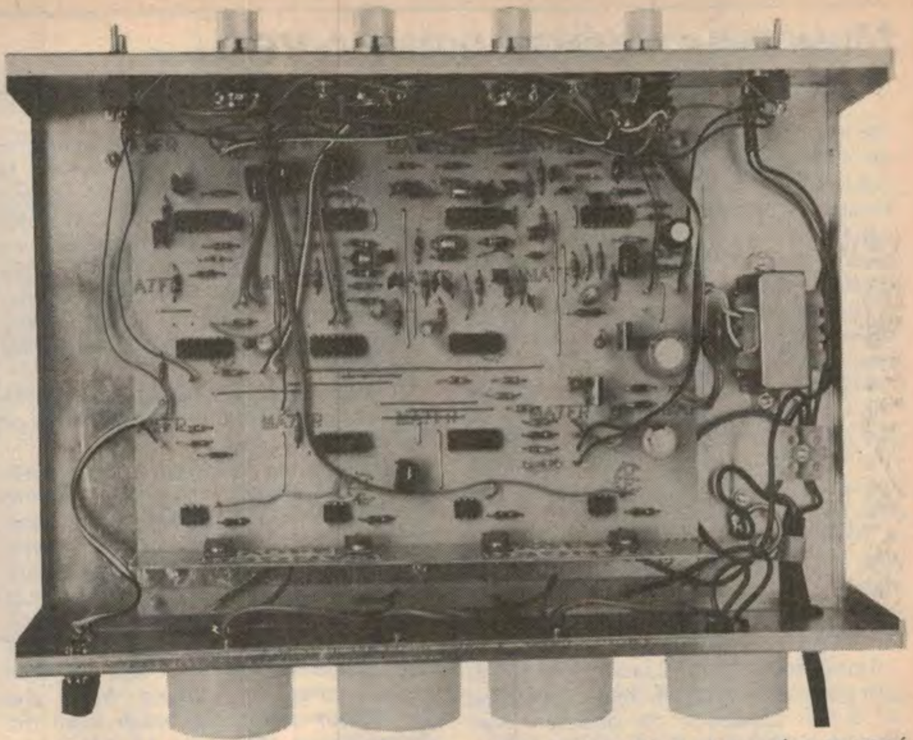
We can thus control the amount of power delivered to a light and hence its brightness by "firing" the Triac at a set time or "firing angle" after the start of each mains half-cycle. This is referred to as phase control. For example, if the Triac is fired at the beginning of each half cycle, full power will be delivered whereas if it is fired at the end of a half cycle, no power is delivered.

To vary the "firing angle" and hence light output in proportion to the signal amplitude we have used a ramp circuit. This circuit consists of four comparators which have their inverting inputs connected to a common "ramp" signal and their non-inverting inputs connected to the outputs of the four filter/rectifiers. The ramp signal is reset high at the beginning of each mains half-cycle and falls to some value toward the end of each half-cycle.

The comparator outputs are used to trigger the Triacs. Now if the input to a comparator is relatively high the comparator output will go high sooner within each mains half cycle, firing the Triac and delivering more power. A low input voltage will cause the comparator output to go high later in each cycle thus firing the Triac later (see Fig. 1). To make the brightness of the lights match the apparent sound level the ramp signal is actually quite complex and takes into account the firing angle versus apparent light output and the logarithmic response of our hearing.

MICROPHONE PREAMP

Referring now to the circuit diagram, the electret microphone is an "insert" type which has an earth connection and output connection which has to be taken to supply via a 4.7kΩ resistor forming the load for the internal FET preamplifier.



View inside the prototype. Use of opto-couplers to drive Triacs means that most of the circuit (but NOT Triacs or heatsink) operate at low potential.

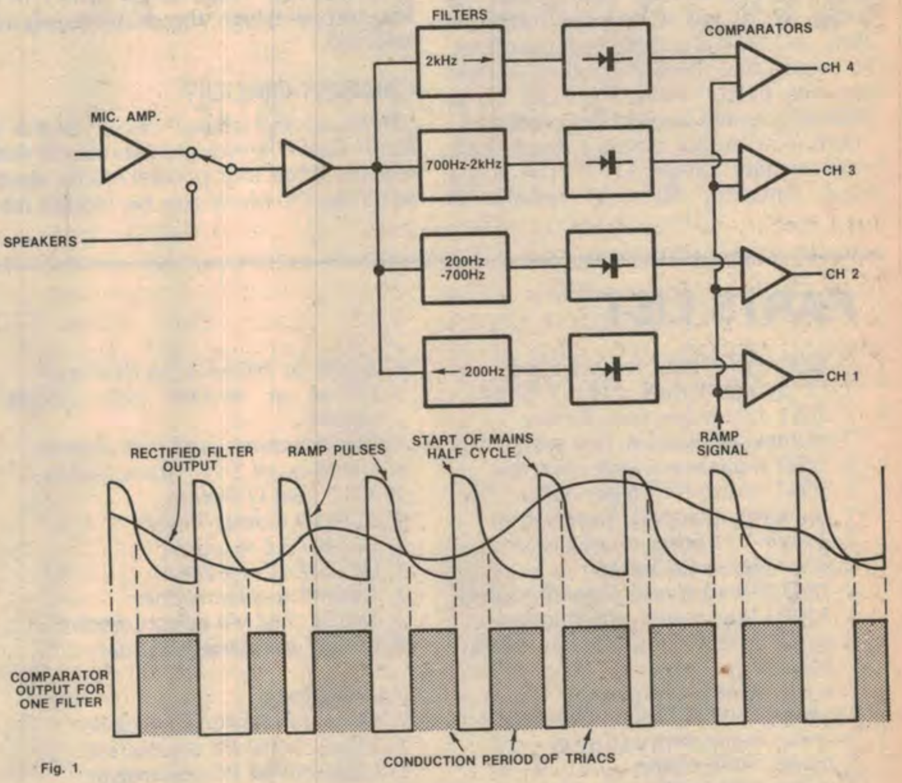


Fig. 1

The supply to the electret is decoupled via a 1kΩ resistor and 100μF capacitor to reduce hum and noise. Output from the electret is coupled to IC1a via a .047μF capacitor. IC1a is connected as a non-inverting amplifier with a 150kΩ resistor on the input to set the DC bias and with a gain of almost 50 set by the voltage divider ratio of the 470kΩ and 10kΩ resistors.

Switch S1 selects either the output of the microphone preamplifier or the speaker outputs of the stereo amplifier. The speaker outputs are mixed and attenuated by the two 10kΩ resistors and the 1kΩ resistor. We have also included a 100Ω resistor in series with the earth line to prevent any earth loops or damage to the amplifier if the speaker active lines are inadvertently connected to the input ground.

The selected input is passed to a 100kΩ pot (sensitivity control), then coupled via a 0.1μF capacitor to another non-inverting amplifier IC1d. This amplifier drives the four filters we mentioned earlier where IC1b is the 200Hz low-pass filter, IC2d and IC2c pass 200Hz to 700Hz, IC2a and IC2b pass 700Hz to 2kHz and IC3d is a 2kHz high pass filter. To ensure that there is good separation between bands, each filter rolls off at 18dB per octave outside the passband.

Each filter output drives a simple half-wave rectifier (diodes D1 to D4) and a 4.7μF capacitor filter. A resistor in parallel with each filter capacitor sets the time constant of the filter which is designed to be long enough to reduce ripple but short enough to make the Musicolour display fairly dynamic. For this reason we have used a slightly longer time constant on the 200Hz low-pass filter by using a 22kΩ resistor whereas the other filters have 10kΩ resistors.

Germanium diodes are specified for D1 to D4 to maximise the dynamic range of the circuit.

The filters are followed by four comparators as shown in Fig. 1. The comparators are LM339 single supply quad comparators, ie there are four comparators in one package. The outputs are open-collector with 10kΩ pull-up resistors and are passed to IC8 which is a 4019B CMOS demultiplexer. The demultiplexer has two sets of four inputs; one set comes from the Musicolour circuit, the other from the chaser circuit. When pin 14 is high and pin 9 low the Musicolour inputs are selected and passed to the four outputs of the device. Alternatively when 14 is low and pin 9 high, the chaser inputs are selected.

CHASER CIRCUIT

Heart of the chaser circuit is IC6 a 40194 CMOS universal bidirectional shift register. It has four parallel inputs labelled P0 to P3 which can be loaded into the register, four outputs labelled Q0 to Q3, a shift-left input labelled DSL and a shift-right input labelled DSR plus a clock input and two control inputs called S0 and S1. The control inputs set the mode of operation: if S0 is high and S1 low then shift right; if S0 low and S1 high shift left; and if both are high, load the register from the parallel inputs.

Two of the parallel inputs P0 and P3 are wired with P0 to Vcc and P3 to ground. The two other inputs, P1 and P2, go to a 2-pole 4-position rotary switch, S5, which selects four possible patterns by switching P1 and P2 through the four possible combinations of high and low. It may not be immediately obvious but this simple arrangement offers every possible pattern for a four channel chaser. For example, a single light chasing would correspond to P1 and P2 low, while a hole chasing would be P1 and P2 high.

To load the selected pattern the two control inputs S0 and S1 must be both high as we mentioned earlier. To accomplish this and also control the left/right shift control we have connected both S0 and S1 to the Q and Q-bar outputs of a 4013 CMOS D flipflop IC9a. Normally the Reset and Set inputs of the flipflop, pins 4 and 6, will be pulled low via the 10kΩ resistor and the Q and Q-bar outputs will be the complement of each other. If a high was last clocked into the flipflop Q will be high and Q-bar low making IC6 shift right; alternatively,

PARTS LIST

1 K&W Instrument case, C1284
1 PC board, 81mc8, 211 x 175mm
1 2851 12V mains transformer
1 aluminium heatsink (see text)
4 SPDT miniature toggle switches
1 SPDT centre-off toggle switch
1 momentary-contact pushbutton
1 2-pole 4-position rotary switch
4 large LEDs with bezels
2 1MΩ (linear) rotary potentiometers
1 100kΩ (log) rotary potentiometer
4 surface-mounting 3-pin mains sockets
1 4-way speaker terminal
1 electret microphone insert
1 2-way mains terminal strip
1 mains cable clamp
1 mains cable and plug
6 large rubber grommets
4 6mm plastic board supports
2 solder lugs

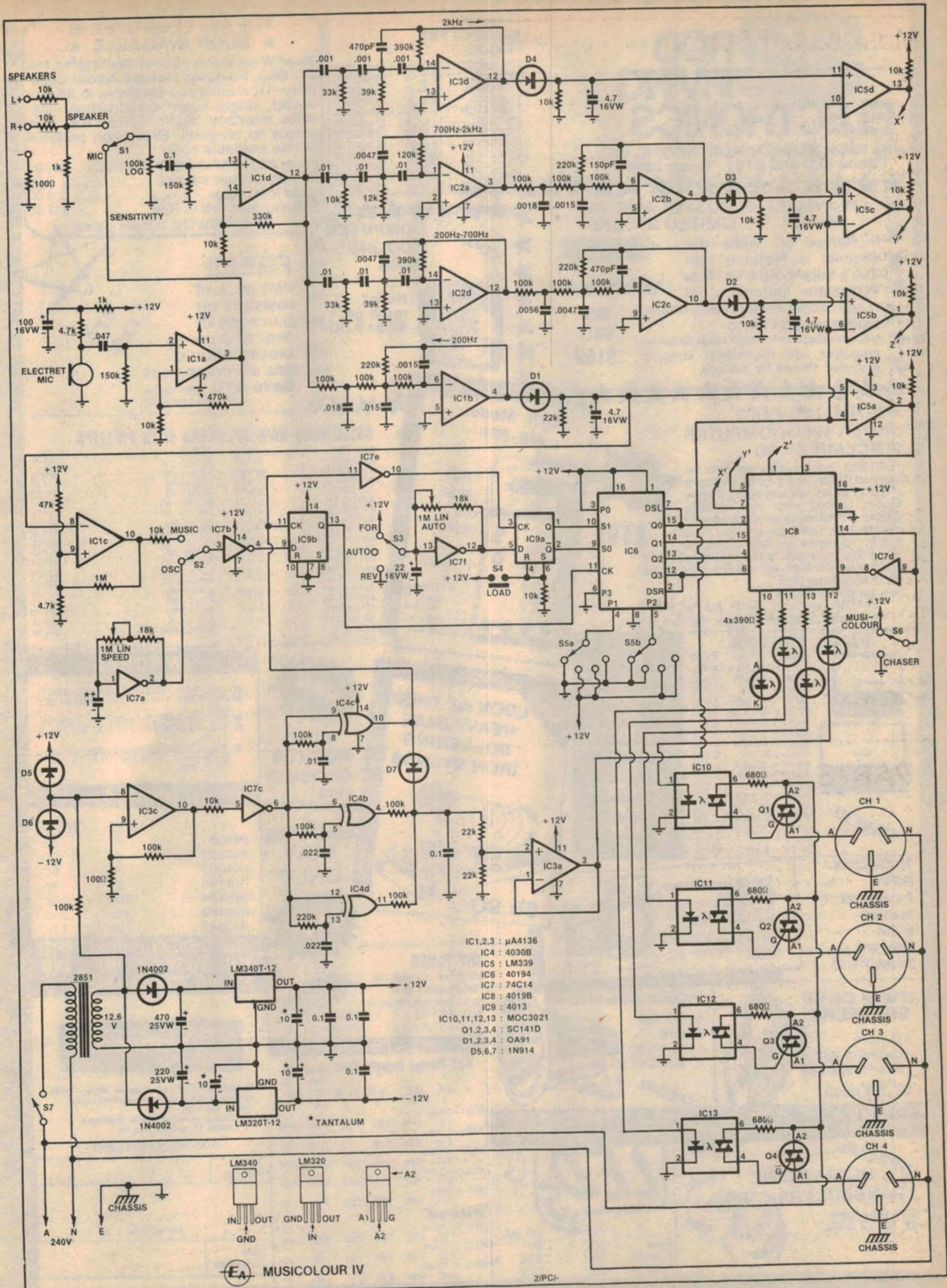
SEMICONDUCTORS
4 MOC3021 optically-coupled Triac drivers
3 μA4136 quad op amps
1 LM339 quad comparator
1 4030B or 4070B quad XOR gate
1 74C14 or 40106B hex Schmitt trigger
1 40194 bidirectional shift register
1 4019B quad 2-to-1 demultiplexer
1 4013 dual D flipflop
4 SC141D 6 amp Triacs
1 LM340T-12 regulator
1 LM320T-12 regulator
2 1N4002 rectifier diodes
3 1N914, 1N4148 silicon diodes
4 OA391 germanium diodes

CAPACITORS
1 470μF/25VW PC electrolytic
1 220μF/25VW PC electrolytic
1 100μF/16VW PC electrolytic
1 22μF/16VW tantalum or low leakage electrolytic
3 10μF/16VW tantalum electrolytic
4 4.7μF/16VW PC electrolytic
1 1μF/16VW tantalum or low leakage electrolytic
5 0.1μF greencap (metallised polyester)
1 .047μF greencap
2 .022μF greencap
1 .018μF greencap
7 .01μF greencap
1 .015μF greencap
1 .0056μF greencap
3 .0047μF greencap
1 .0018μF greencap
2 .0015μF greencap
3 .001μF greencap
2 470pF polystyrene or ceramic
1 150pF polystyrene or ceramic

RESISTORS (all ¼W 5%)
1 x 1MΩ, 1 x 470kΩ, 2 x 390kΩ, 1 x 330kΩ, 4 x 220kΩ, 2 x 150kΩ, 1 x 120kΩ, 15 x 100kΩ, 1 x 47kΩ, 2 x 2 x 33kΩ, 3 x 22kΩ, 2 x 18kΩ, 1 x 12kΩ, 2 x 39kΩ, 15 x 10kΩ, 2 x 4.7kΩ, 2 x 1kΩ, 4 x 680Ω, 4 x 390Ω, 2 x 100Ω.

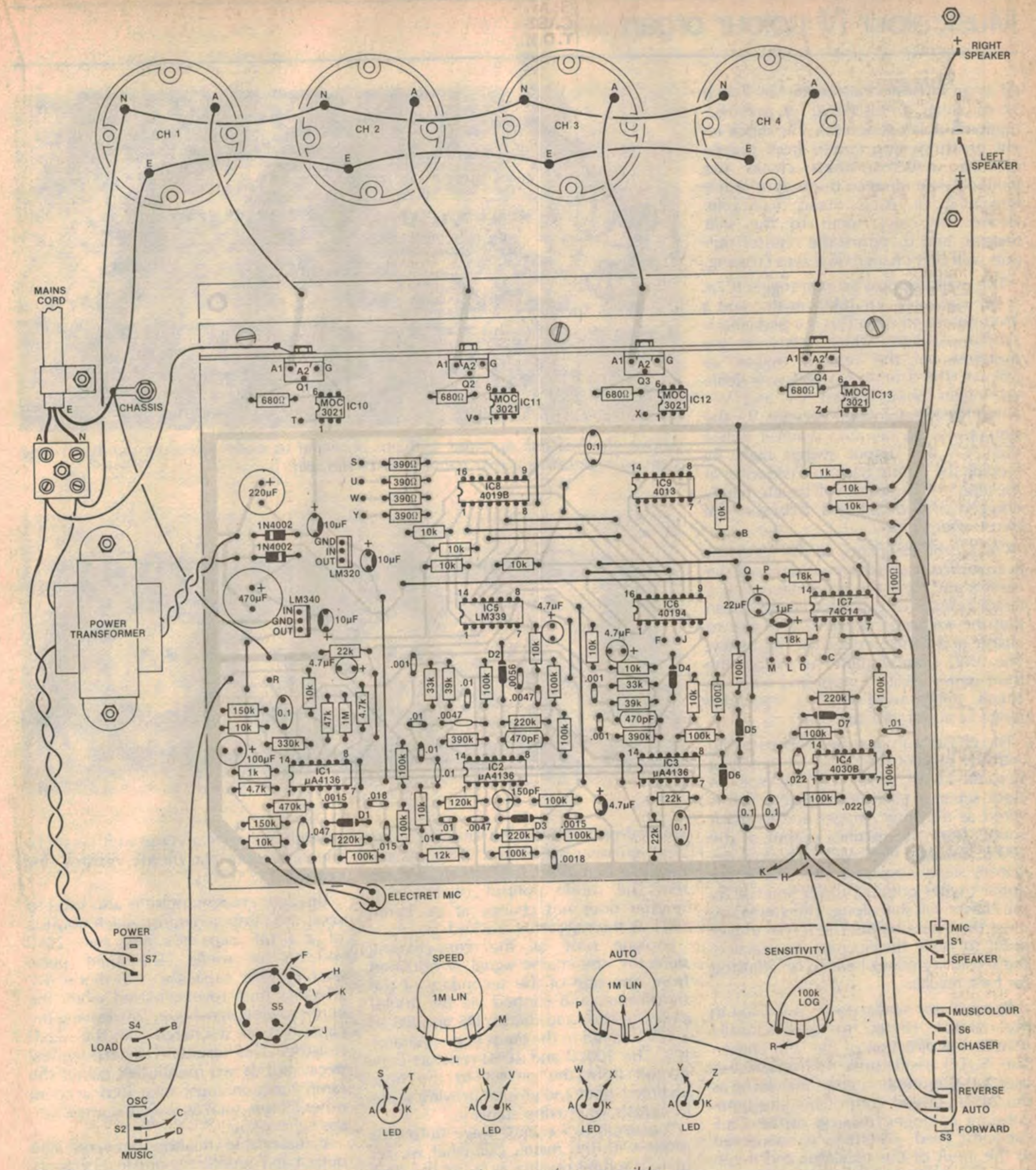
MISCELLANEOUS
Board pins, 10 9mm screws plus nuts, 8 12mm screws plus nuts, ½ metre rainbow cable, 240V AC rated hook-up wire.

NOTE: The "B" suffix on CMOS part numbers indicates that it is a buffered device. Where buffered devices are specified they must be used.



IC1,2,3 : µA4136
IC4 : 4030B
IC5 : LM339
IC6 : 40194
IC7 : 74C14
IC8 : 4019B
IC9 : 4013
IC10,11,12,13 : MOC3021
Q1,2,3,4 : SC141D
D1,2,3,4 : OA91
D5,6,7 : 1N914

MUSICOLOUR IV



Follow this wiring diagram exactly to make your Musicolour as safe as possible.

if a low was clocked in, Q would be low and Q-bar high, resulting in a shift left.

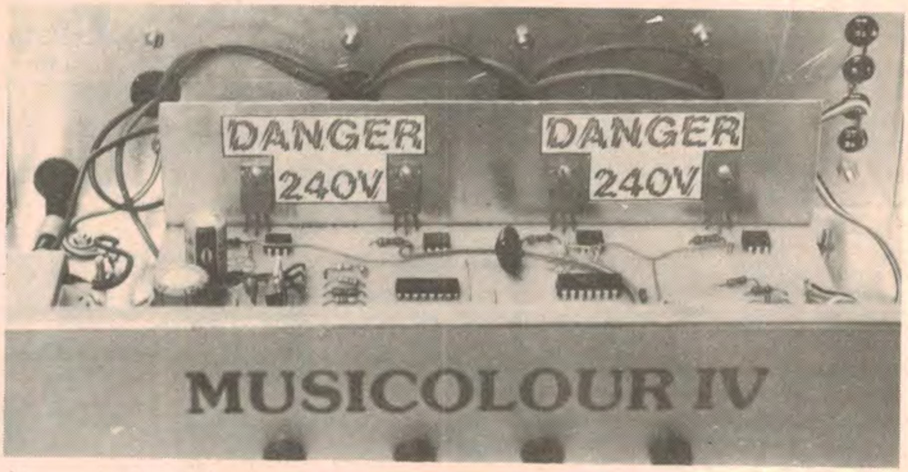
When both the Reset and Set inputs are pulled high via the front panel LOAD button, S4, both outputs of the flipflop will go high so S0 and S1 go high loading the parallel inputs into the shift register on the next clock pulse. If S4 is held down the selected pattern will be held and can be clearly seen on the front panel LED display or the lights themselves and when it is released the lights will chase.

ZERO-VOLTAGE SWITCHING

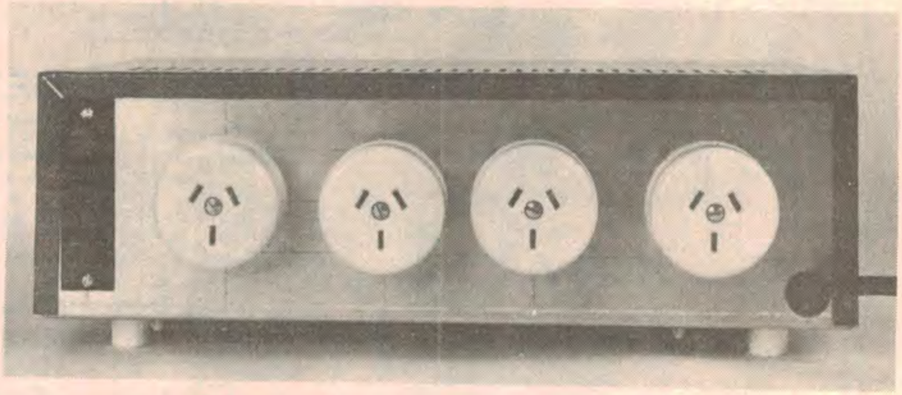
The rate at which the lights chase depends on the clock input to the shift register. This could come from a simple oscillator but since we require zero-voltage switching we must somehow ensure that the outputs of the shift register only change at the zero crossing points, eg, if the shift register was clocked right in the middle of a mains half-cycle at least one output will go high turning a Triac on.

This is avoided by taking the clock input from the output of the other D flipflop IC9b. The data (D) input of the flipflop goes to IC7b, a Schmitt trigger used as an inverter and thence via switch S2 to either an oscillator or a music-triggered pulse generator. The clock input of the flipflop comes from a zero crossing detector which clocks the flipflop's data input to the output at the beginning of each mains half-cycle. Hence the clock input to the shift register, and therefore the register outputs, will only change on a zero crossing.

The oscillator uses Schmitt trigger IC7a, a 1μF capacitor, an 18kΩ resistor and a 1MΩ potentiometer. This is a particularly simple oscillator which relies on the hysteresis of the Schmitt trigger, as follows. The Schmitt has two well defined trigger points called V+ and V–; when the input voltage exceeds V+ the output will go low and when it is less than V– the output swings high. By feeding the output back to a capacitor at the input the capacitor will be alternately charged and discharged between the two trigger points.



Above: the heatsink operates at mains potential so make sure that you fix warning signs to it. Below is a rear panel view of the unit.



Clearly the frequency of the oscillator is governed by the time constant of the resistor and capacitor combination, eg, a larger resistor or capacitor would mean that the capacitor would take longer to charge and hence reduce the frequency. The 1MΩ potentiometer is in fact the front panel SPEED control and with the circuit values used gives a frequency range of about 1Hz to 50Hz.

The chaser can also be clocked along with the beat of the music by switching S2 to the MUSIC position. In this case the clock signal is taken from IC1c which is wired as a Schmitt trigger and its input comes from the rectifier output of the 200Hz low pass filter. When the low frequency signal amplitude rises above the upper trigger point of the Schmitt IC1c, the chaser will shift along. The amplitude must then pass below the lower trigger point to reset the Schmitt. In practice, the sensitivity control has to be adjusted for best results.

An oscillator similar to IC7a is used in the AUTO circuit to automatically reverse the direction of the light chaser. The AUTO oscillator is IC7f which also uses a 1MΩ potentiometer functioning as the AUTO speed control but the time-constant is longer because of the 22μF capacitor used. Switch S3 is connected to the input of the oscillator and it can force the input high or low, while the centre-off position allows the oscillator to function. This corresponds to forward, reverse and auto operation.

Output of the oscillator is fed to the data input of IC9a which as we mentioned above controls the direction of the chaser. The clock input of the flipflop comes from IC7e which inverts the zero crossing signal fed to IC9b. Since both flipflops are clocked on the positive transition of their clock inputs, IC9b will be clocked on the positive transition of the zero crossing signal and IC9a on the negative transition. This merely ensures that the mode control of the shift register does not change at the same time as the register is clocked.

Looking now at the zero-crossing detector, the mains signal is obtained from one side of the secondary of the transformer and clipped via the 100kΩ series resistor and diodes D5 and D6 to ±12V and fed to the input of comparator IC3. The 100kΩ and 100Ω resistors connected from the output to the non-inverting input and ground provide some hysteresis, improving stability.

The result is a square wave output in phase with the mains, but what we require is a brief positive pulse at the start of each half-cycle. This is accomplished by further squaring the signal with another Schmitt inverter, IC7c, which drives IC4c, a 4030B exclusive OR gate. One input receives the square wave signal directly while the other input is connected via a 100kΩ resistor and .01μF capacitor so that it is slightly delayed. Now since the output of the XOR gate will be high only while its two inputs are at different logic levels a brief high pulse will be generated at the start of each half-cycle and the width is set by the time constant of the resistor and capacitor to 0.7ms.

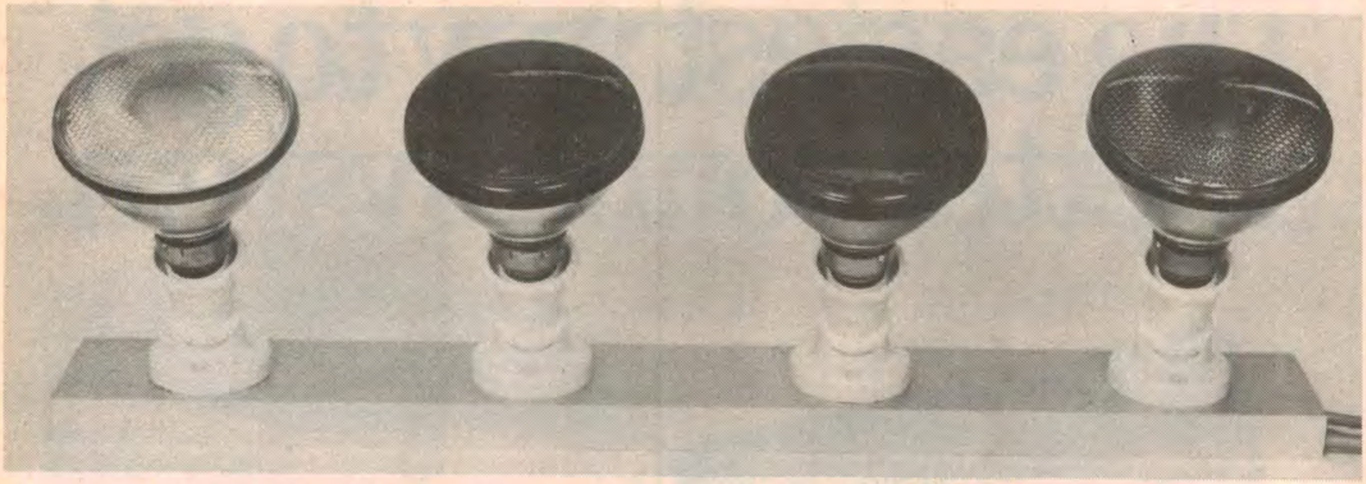
The zero crossing pulse is also used to reset the ramp generator which consists of a 0.1μF capacitor and two 22kΩ resistors in series. The brief pulse charges the capacitor via diode D7 which is then reverse-biased when the zero-crossing signal goes low leaving the capacitor to discharge via the 22kΩ resistors. This results in an exponential decay but as we mentioned earlier the ramp function must take into account other factors such as the firing angle versus light output.

A reasonable relation between light output and apparent sound level was obtained by using IC4b and IC4d. These two XOR gates work in the same way as

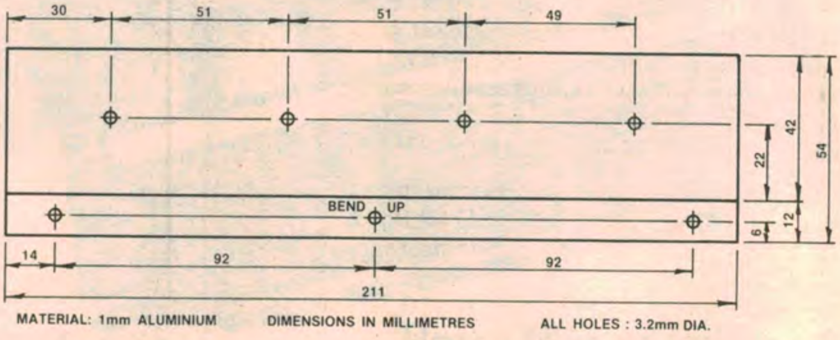
We estimate that the current cost of parts for this project is approximately

$95

including sales tax.



We used red, yellow, green and blue flood lights for a dramatic colour display. Maximum load is 600W per channel.



This metalwork diagram gives the dimensions of the aluminium heatsink.

IC4c except that because of the longer time constants used their pulse widths are 1.6ms and 3ms respectively. The outputs are then resistively mixed with the exponential decay waveform to yield the required ramp signal.

Referring back to IC8, the demultiplexer, regardless of whether the Musicolour or Chaser section is selected, the signal passes to the four outputs of the 4019B where each output drives a 390Ω resistor in series with a front panel LED and then the internal LEDs of the MOC3021 Triac-triggers, IC10 to IC13.

At the time of writing it appears that the MOC3021 is not quite as readily available as the MOC3020 which is similar in all respects except that it requires a higher LED current to ensure that the silicon bilateral switch is latched. Due to the limited current available from the CMOS driver IC8, some low spec MOC3020s may not work. Nevertheless we used MOC3020s in our prototype without any problems so if you cannot obtain MOC3021s then MOC3020s should prove suitable.

The Triac-trigger is connected between terminal A2 and gate on Triacs Q1 to Q4 which are all SC141D 6-amp devices. A 680Ω resistor in series with each Triac-trigger limits the repetitive surge current to a safe value of about 0.5 amps. Finally the switched outputs from the Triacs are taken to mains sockets on the back of the unit along with neutral and earth connections.

Since all four outputs could be full on in at least one operating mode, the recommended maximum light load is limited not by the rating of Triacs but by the 10-amp rating of the power point, ie, 600W per channel or 2400W total.

Power for the unit is obtained from a simple voltage doubler consisting of a 12V transformer, two 1N4002 rectifier diodes and a capacitive filter. This is followed by an LM340T-12 positive 12V regulator and an LM320T-12 negative 12V regulator to generate ±12V. Tantalum capacitors on the outputs provide high frequency decoupling and stability while 0.1μF capacitors distributed around the board provide additional decoupling.

CONSTRUCTION

Looking at the construction now, most of the components are mounted on a single PC board coded 81mc8 and measuring 211 x 175mm. Use the component overlay diagram as a guide to mounting the components and in particular note the orientation of the diodes, electrolytics, regulators and ICs. To avoid damage to the CMOS ICs due to static electricity use an earthed soldering iron and solder the IC supply pins first to enable the internal protection diodes.

The four Triacs are all mounted on one heatsink without insulating washers as the heatsink also acts as the connection from the mains active line to the A2 terminal of the Triacs via their mounting tabs. The heatsink can be fashioned from a sheet of 1mm thick aluminium folded into an L-shape as shown in the accompanying diagram. Mount the heatsink onto the board with three screws then bolt the Triacs to it.

We housed our unit in a K&W case Model C1284 which consists of a U-shaped aluminium base and steel cover. Drill holes in the rear panel for the mains sockets, mains entry hole and speaker terminal. As a guide the sockets should be mounted with centres approximately 60mm apart and 45mm up from the base. When mounting the speaker socket make sure that it does not interfere with the cover.

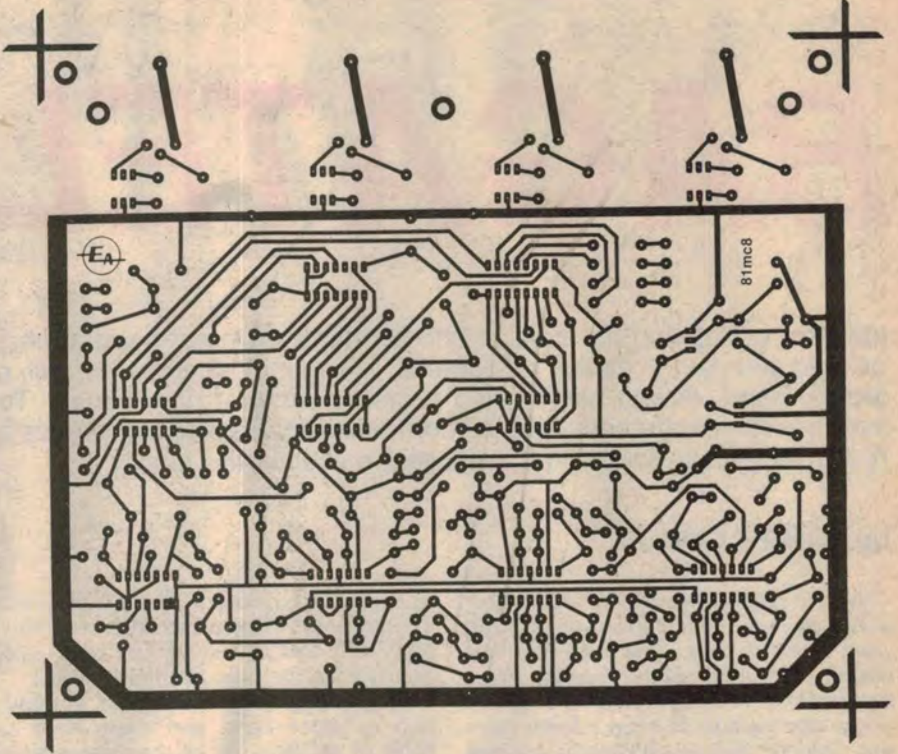
The electret microphone insert that we've used is quite inexpensive and readily available from most retailers such as Dick Smith Electronics and Jaycar. It is mounted on a rubber grommet on the bottom of the chassis and positioned about 15mm back from the front panel (see photograph). The rubber grommet provides a suitable mounting and also some acoustical isolation from the case. We would however recommend that a less rigid mounting such as foam rubber be used in more demanding situations.

Scotchcal front panels should be available from most kit suppliers. Alternatively, the half-size artwork shown elsewhere in this article can be used to produce one. Usually the Scotchcal panel as supplied will not be cut to shape so use a ruler and a sharp knife to scribe along the border of the panel and then bend the Scotchcal back and forth along the border to obtain a clean break – note this is much faster than actually cutting all the way through with a knife. Note that the Scotchcal panel should be sprayed with clear lacquer and allowed to dry before affixing to the chassis.

After affixing the Scotchcal to the front panel drill mounting holes from the Scotchcal side of the panel being careful not to lift the Scotchcal. Mount the LEDs, switches and potentiometers then hold the PC board and transformer in the chassis to obtain drill centres for their mounting holes. The board can be mounted on the chassis using 6mm tapped spacers or plastic board supports and the wiring completed using the wiring diagram. To simplify wiring and for a neat appearance we would recommend that PC board pins be used.

The LED bezels we used were of an attractive one piece plastic construction and relatively cheaper than "chrome" types. Nonetheless these LED bezels are quite expensive and we would suggest that normal red LEDs and separate LED mounting bezels be used.

The mains cable should enter the unit through a grommeted hole and be securely clamped. Terminate the active (brown) and neutral (blue) wires in an insulated terminal block and solder the earth wire directly to a lug bolted to the chassis. Wiring to the back panel mains sockets should also pass through grommeted holes and only mains rated cable should be used. Apart from the connection to the mains socket the only other mains connection to be made is to the heatsink. This is accomplished by connecting a wire from the mains active to a lug placed on the mounting screw of one of the Triacs.



Above is a half-size reproduction of the printed circuit board. Finished boards and front panels are available from the usual retail outlets.

Right: make two copies of this warning sign and attach it to the heatsink with double-sided tape. ►

While most of the Musicolour circuitry is at a safe earth potential, the heatsink and Triacs are at mains potential. So just to emphasise this and avoid any carefree approach to the unit we would strongly suggest that you fix warning signs to the heatsink (see photographs of our unit). The artwork for these signs is shown elsewhere in this article and it can be photocopied and attached to the heatsink with double-sided tape.

With all the wiring completed recheck the wiring and component placement or better still have someone else check it. If you are satisfied that all is well switch the unit on, switch to chaser mode, select the first pattern and press the load button with the MUSIC/OSC switch set to OSC. The front panel LED display will now show the chaser operation with the LEDs turning on and off in sequence. You should be able to readily verify that the other functions work.

If there are any problems, however, then disconnect the mains active lead to the heatsink at the terminal block and also the neutral lead going to the mains sockets. With these disconnected the board should be safe to work on.

Left: half-size reproduction of the front panel artwork.