2-Channel Infrared Remote Control

Use it to switch mains appliances on or off

Need an inexpensive two-channel remote control? Well our new Infrared Remote Control has a range of 20 metres and can independently control two appliances. You can use it to turn off (or mute) the sound output of a TV receiver during commercials or switch lights, alarms, radios etc. The applications are limited only by your imagination.

by RON DE JONG

Remote controls come as standard equipment with many television sets and some of the latest cassette decks but, as far as we know, there are no commercially available remote controls designed to simply switch appliances on or off. Considering the number of possible applications for such a unit, we think that our new Infrared Remote Control will be quite popular.

The most obvious application is to switch the TV sound off during commercials. This is quite easily done with our new unit because each of the two channels controls a relay. It is simply a matter of connecting the relay contacts of one channel in series with one of the speaker leads. Muting can also be provided by connecting a suitable resistor across the relay contacts.

Because the unit has relay outputs it can be used to directly switch mains appliances (lights, alarms, motors, heaters etc). It could be used, for example, to activate a motor-driven curtain rail or to switch the jug on. If you've ever woken up in the morning and felt that you just couldn't get out of bed (at least not for a few minutes), then the Infrared Remote Control is just the thing – press one button and the curtains open to a bright sunny morning; press the other and the "jug's on the boil".

As an additional benefit we have also provided an option for using the remote control as a light beam relay. In this role, it is similar to the unit described last month, except that this unit will switch mains operated alarms.

The unit consists of two parts: a small hand-held battery operated transmitter and a larger receiver unit. The front panel of the receiver features three LED indicators: one is the power indicator while the other two indicate whether channel one or two are on/off.

There are two buttons on the transmitter, one each for the two channels. If the button for one particular channel is pressed that channel will, for example, turn on. When the same button is pressed again that channel will turn off. In other words, the output alternates between on and off each time the button is pressed.

Range of the remote control is over 20 metres which should be sufficient for most situations. Because infrared light reflects off walls and ceilings the transmitter does not have to be pointed directly at the receiver – it will operate the receiver when pointed in almost any direction in the same room.

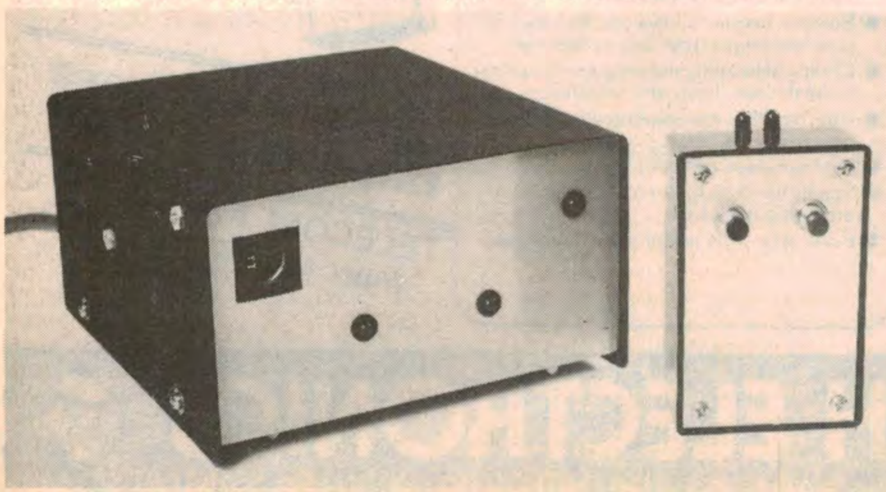
THE CIRCUIT

Circuitry for the receiver and transmitter is relatively simple and low in cost. The hand-held transmitter uses one CMOS IC, a Darlington transistor and a couple of infrared light emitting diodes. The receiver uses just five transistors, four CMOS ICs and two relays.

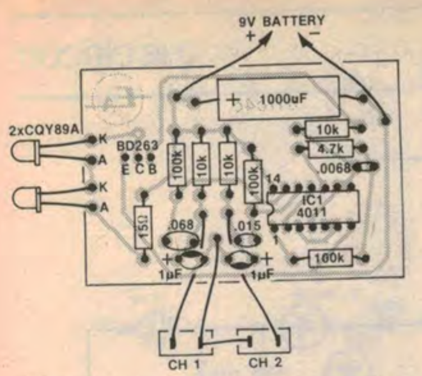
Let's look at the transmitter circuit first: This uses a 4011 quad NAND gate and three of the gates, 1a, 1b and 1c, are arranged as a standard three-gate CMOS oscillator with the exception that one of the inputs of gate 1a is used to "enable" the oscillator. The oscillator runs at 10kHz and is enabled, ie, it runs, whenever pin 2 of the 4011 is high. Pin 2 is controlled by gate 1d which pulls pin 2 high when either one of its inputs, pins 12 and 13, are pulled low.

Normally both inputs of gate 1d will be high by virtue of the 100kΩ pull up resistors at each input. If one of the buttons is pressed, however, the resistor capacitor network associated with that button generates a short pulse as follows. Looking at the "CH 1" button, for example, there is initially no voltage across the .068μF capacitor since both sides have been pulled up via the 10kΩ and 100kΩ resistors.

When the "CH 1" button is pressed, however, the switch side of the capacitor goes low and because the voltage across the capacitor cannot

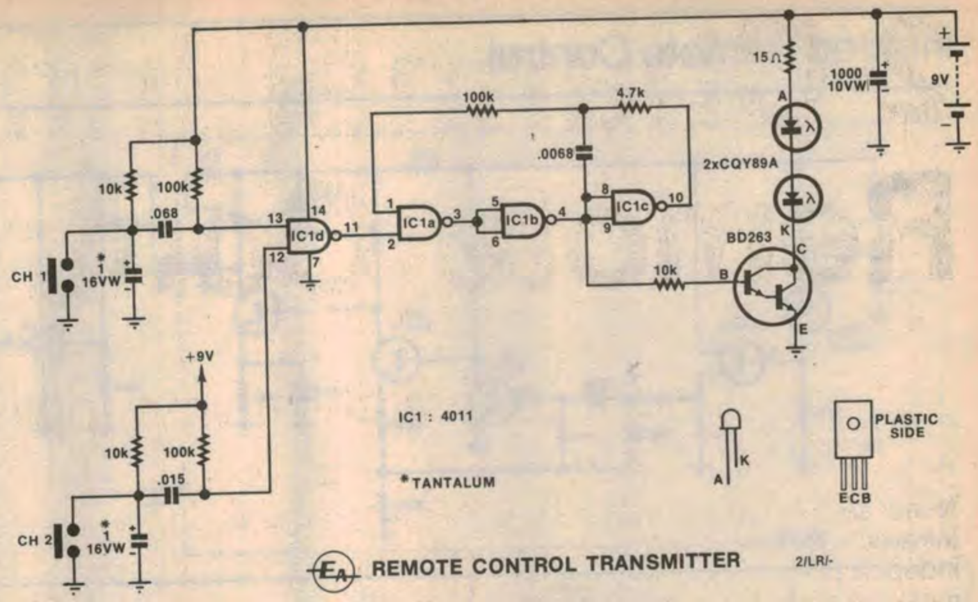


The completed remote control receiver (left) with its companion transmitter unit.



ABOVE: The component overlay diagram for the transmitter circuit.

RIGHT: The transmitter consists of a CMOS oscillator and a Darlington transistor output stage driving two infrared LEDs.



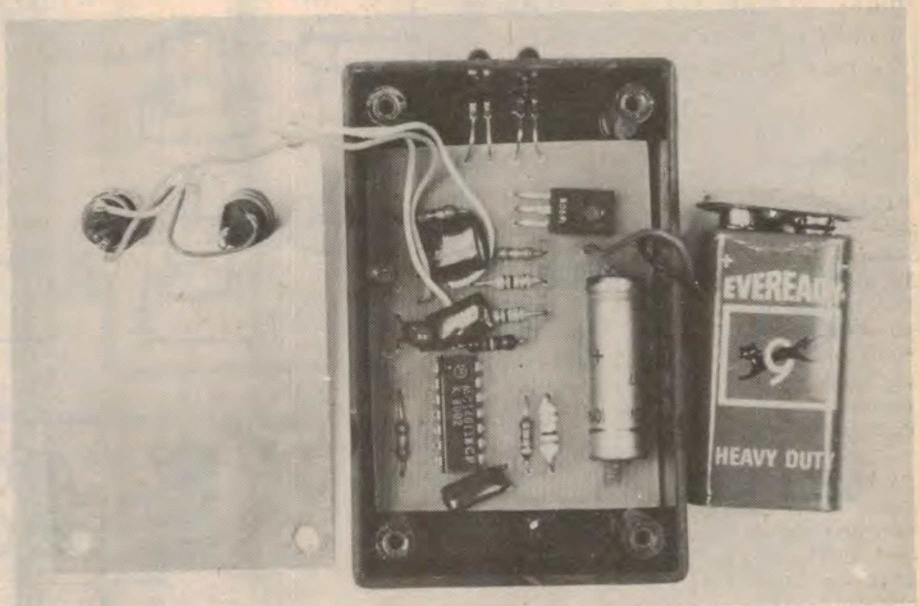
change instantaneously the pin 13 input of gate 1d will also go low, forcing the output of 1d high and enabling the oscillator.

Eventually the voltage at the input of the gate will reach ½Vcc as the .068µF capacitor is charged via the 100kΩ pull up resistor and the output of gate 1d will again return to zero and disable the oscillator. The period for which the oscillator is enabled is dependent on the time constant of the .068µF capacitor and 100kΩ resistor and is roughly 6ms. The pulse length generated by the "CH 2" button circuit is similarly dependent on the 100kΩ resistor and 0.015µF capacitor in its circuit, and is about 1ms.

The 1µF capacitors across the "CH 1" and "CH 2" buttons provide debouncing. If the switch momentarily opens due to contact bounce the voltage across the switch will not immediately change because of the time constant of the 10kΩ pull up resistor and the 1µF capacitor. The time constant selected is long enough to prevent any multiple pulses but is short enough to allow either button to be pressed several times in rapid succession.

The CMOS oscillator drives an output stage consisting of a BD263 Darlington transistor and two infrared light-emitting diodes. A 10kΩ resistor limits the base current of the Darlington and prevents the output of the oscillator from being unduly loaded. The Darlington provides the necessary gain and high current capability to drive the LEDs while the 15Ω series resistor limits the LED current to a safe value and prevents damage to the LEDs.

Even so, the peak current is more than 300 milliamps which is more than the battery could supply on its own. Most of that peak current is supplied by the 1000µF capacitor which means that the battery has an easier job. When the buttons are not being pressed, the current drawn from the battery is very low, typically around 10 microamps, so we have omitted a power switch. Even with very frequent use, we estimate that the battery should last for more than one year.



Inside the assembled transmitter unit. Note how the infrared LEDs are arranged.

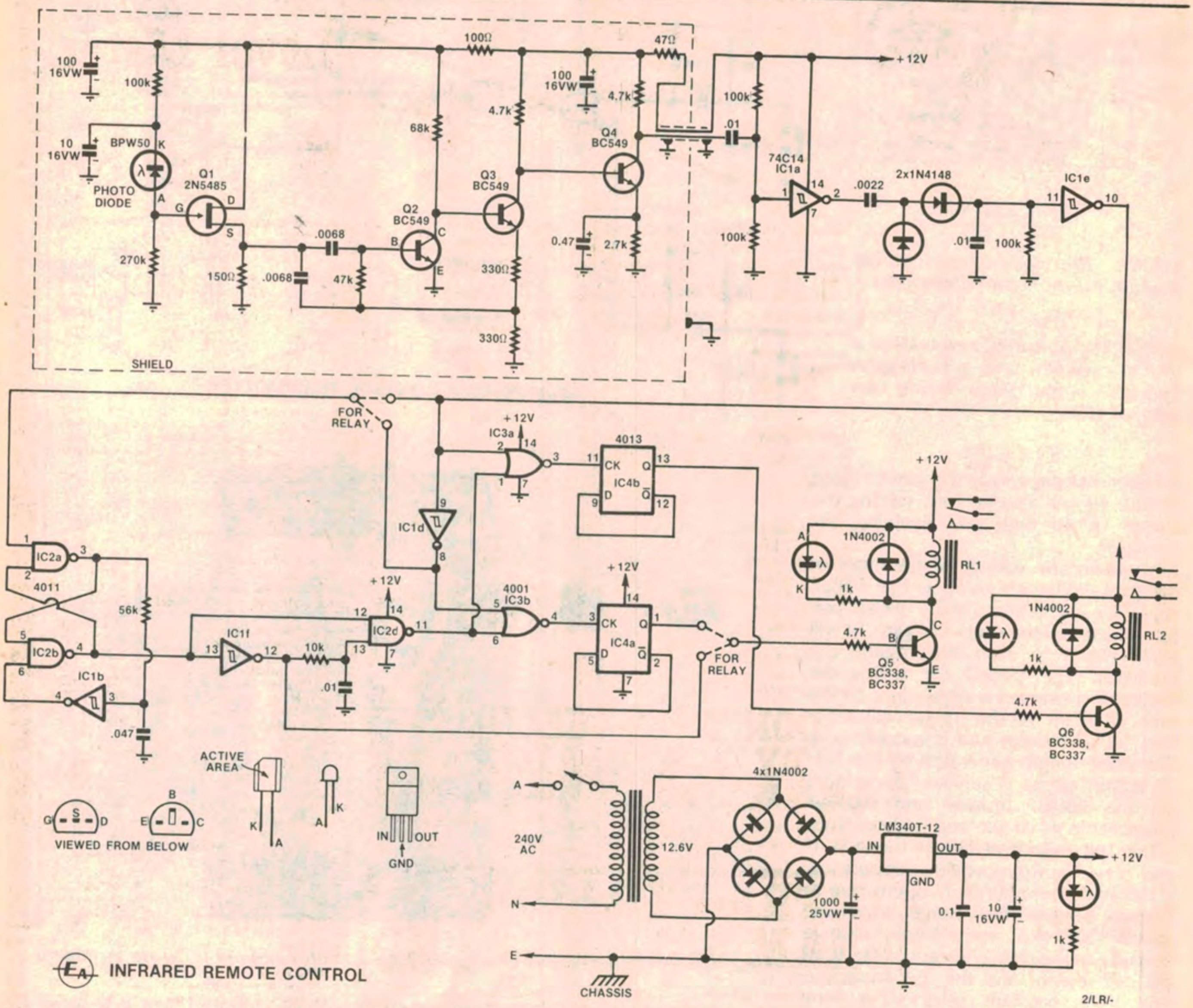
The infrared diodes used are Philips type CQY89A. They are plastic-pack devices and are similar in appearance to the familiar red LED, except that the plastic encapsulation is a deep violet colour.

The receiver circuit consists of two distinct parts: a preamplifier and a decoding circuit. The preamplifier amplifies the infrared signal from the transmitter and generates a high-level signal for the digital decoding circuitry. Due to the sensitivity of the preamplifier, it is enclosed in a separate diecast box mounted inside the receiver. This is standard practice in commercial remote control units.

The preamplifier is similar to the circuit used in the Infrared Relay (see April issue) but with some component changes to account for the different supply voltage. Infrared light generated by the LEDs is picked up at the receiver by a special infrared photodiode, Philips type BPW50. This device is specifically designed to match the CQY89A LED, and includes an integral infrared filter that almost completely rejects visible light.

In operation the BPW50 photodiode acts essentially as a current source, ie, it generates a current proportional to the incident light. To generate a usable voltage signal we have connected the photodiode in series with a 270kΩ resistor. The voltage across the resistor will thus be related to the incident light.

The other (cathode) side of the photodiode is connected to the +12V supply via a simple decoupling network consisting of a 100kΩ resistor and 10µF capacitor. In this configuration the BPW50 is reverse-biased, giving two important benefits: it reduces the sensitivity of the circuit to ambient light; and it reduces the junction capacitance of the



The circuit shows optional links for those who wish to experiment with single channel relay operation (see text).

photodiode and hence increases the frequency response.

The upper limit to the frequency response is in fact determined by the junction capacitance, the 270kΩ resistor and the capacitance of the following stage, and is about 40kHz – well in excess of the 10kHz frequency we want to receive.

The signal from the photodiode is fed to Q1, a 2N5485 JFET. The JFET is connected as a "source follower" and offers a high input impedance, a low output impedance, and a voltage gain of 0.3 to 0.5. This sort of impedance matching would be difficult to achieve using bipolar transistors and the circuit would be more complex than the simple "self biasing" JFET circuit we have used.

Following the JFET buffer stage is a two-transistor bandpass filter comprising transistors Q2 and Q3. Centre frequency of the filter is around 10kHz and the Q is 10; ie the bandwidth of the filter is 1kHz. The response of the filter is wide enough to pass the 10kHz signal from the transmitter, even allowing for some mistuning between the transmitter and filter frequencies, but it is selective enough to almost completely eliminate interference from other sources (eg fluorescent lights).

There are still some harmonics generated by fluorescent lights which extend up to 10kHz and beyond, however, and this plus other factors limit the ultimate sensitivity of the receiver.

The filter circuit used is called a "multiple feedback" filter and is commonly used with op-amps, though we have adapted the circuit for use with a transistor amplifier. Disregarding the two .0068μF capacitors for the moment, Q2 and Q3 form a two-stage inverting amplifier. Both transistors operate as common emitter amplifiers, with the second stage providing two separate outputs: one from Q3's collector and the second from the junction of the two 330Ω emitter resistors.

Biasing of the circuit is achieved by the 47kΩ resistor from Q3's emitter back to the base of Q2. The actual filter com-

> We estimate that the current cost of parts for this project is about
>
> **$65**
>
> including sales tax.

ponents are the two .0068µF capacitors, the 47kΩ resistor and the 100Ω output impedance of the JFET buffer. These determine the centre frequency and Q of the filter.

The collector output of Q3 provides an amplified version of the filter output which is DC-coupled to Q4, another common emitter amplifier. Q4 provides an additional gain of around 150 and, because of the emitter bypass capacitor, also provides further attenuation of unwanted low frequency signals.

Following Q4 the signal is AC-coupled to the digital decoding circuits. IC1a is a CMOS Schmitt trigger whose input (pin 1) is biased at half the supply voltage by the two 100kΩ resistors. When the amplitude of the signal from Q4 exceeds the upper and lower trigger levels of the Schmitt trigger, the device will generate a squared up version of the signal.

The output of IC1a will therefore be a brief 10kHz signal either 1ms long or 6ms long, depending on whether the "CH 1" or "CH 2" transmitter button was pressed. These bursts of 10kHz signal are decoded into digital pulses of the same duration by a diode-pump circuit consisting of two 1N4148 diodes, .0022µF and .01µF capacitors, and a 100kΩ resistor.

The circuit is actually an AC-coupled rectifier, but the .0022µF coupling capacitor is about five times smaller than the .01µF filter capacitor. So any one cycle of the transmitted signal, or even interference, will charge up the .01µF capacitor only fractionally and some five cycles of signal are required to charge up the .01µF capacitor to the trigger voltage of the following Schmitt trigger IC1e. This provides some degree of interference suppression but does not affect the sensitivity of the receiver.

So now we have a digital pulse from IC1e with pulse length dependent on which button was pressed on the transmitter. To control the appropriate relay we have to be able to distinguish between the two pulses and this is accomplished by a decoding circuit consisting of IC2, a 4011 CMOS quad NAND gate, and IC3, a 4001 CMOS quad NOR gate.

Heart of the circuit is a monostable consisting of IC2a and IC2b arranged as an RS flipflop. The R and S inputs are pin 6 of IC2b and pin 1 of IC2a respectively. Normally both inputs are high but when a low pulse is received the Set(S) input goes low, latching the flipflop outputs pin 3 high and pin 4 low.

The flipflop now remains latched regardless of the Set input but is reset after about 4ms by Schmitt trigger IC1b. Normally, the input of IC1b is low. When the output of IC2a (pin 3) goes high, the .047µF capacitor charges up via the 56kΩ resistor until the trigger voltage is reached some 4ms later. IC1b then generates the Reset pulse to pin 6 of IC2b.

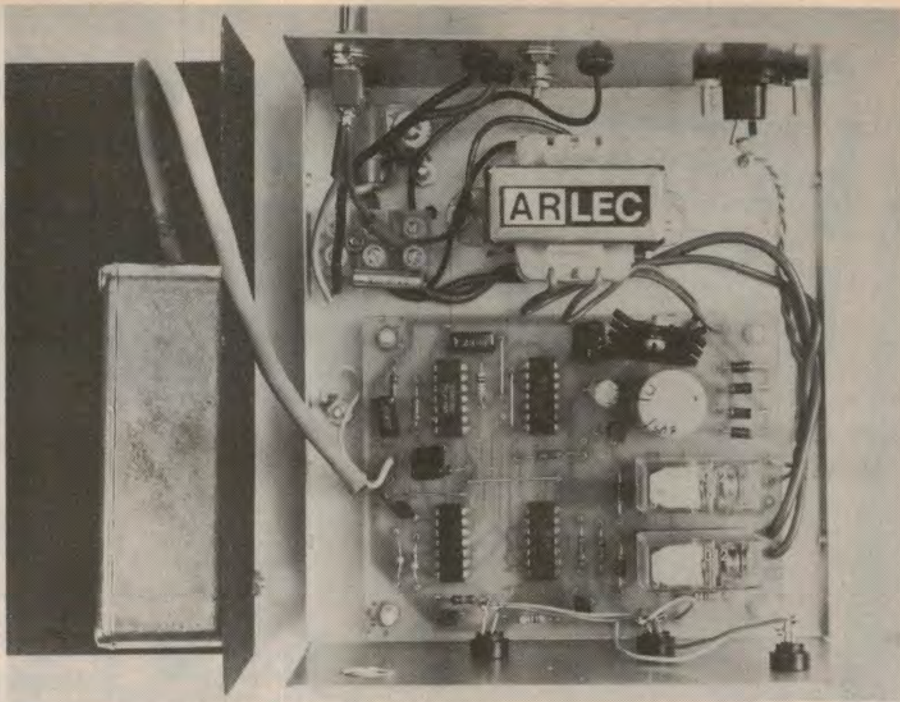
The 4ms monostable pulse from pin 4 of IC2b is then used to produce a narrow trigger pulse 4ms after the beginning of the signal from the transmitter is received. This trigger pulse is generated by inverting the monstable pulse, delaying it via the 10kΩ and .01µF RC circuit and NANDing with the original monostable signal. Since the output of IC2d will only go low when both inputs are high, it will generate a pulse equal to the delay of the RC circuit.

The trigger pulse thus occurs after the end of the 1ms "CH 1" signal but during the 6ms "CH 2" signal, and is fed to the pin 1 and pin 6 inputs of CMOS NOR gates IC3a and IC3b. The other input of IC3a is fed the received pulse direct from IC1e, while the input to pin 6 of IC3b is an inverted version of this signal. Since both inputs of a NOR gate must be low for its output to go high, only one of the two NOR gates will pass the trigger pulse from IC2d, depending on the length of the received signal.

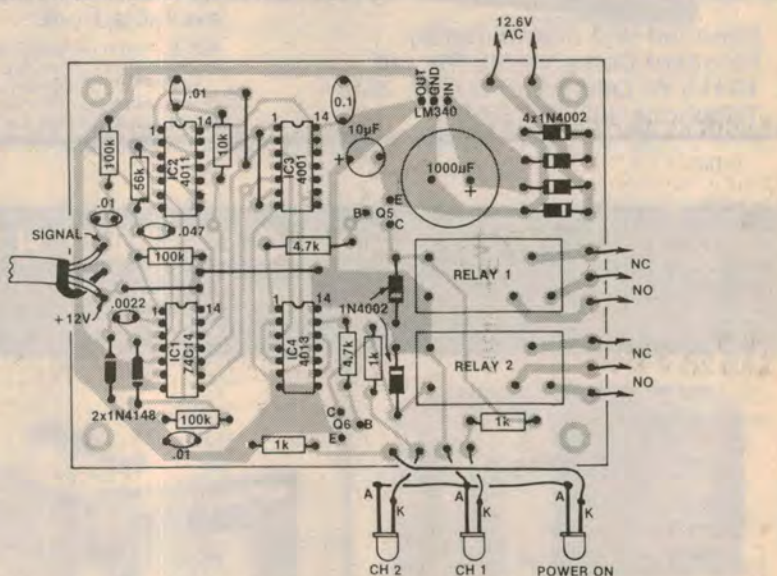
To explain further, when a "CH 1" 1ms pulse is received, the pin 5 input of IC3b will be low by the time the trigger pulse occurs while the pin 2 input of IC3a will be high. Hence only IC3b passes the trigger pulse.

IC3a operates in similar fashion whenever a "CH 2" 6ms pulse is received.

The signal pulses from the NOR gates trigger either IC4a or IC4b, both CMOS D flipflops. These are configured so that each pulse to the clock input of the



Inside the completed remote control receiver. The earth track on the PCB should be connected directly to chassis as shown at left.



Component overlay diagram for the main receiver PCB. The spare holes permit the optional linking arrangement for single channel relay operation.

flipflop toggles its output state. Outputs from the flipflops drive transistors Q5 and Q6 via current-limiting resistors and these in turn drive 12V SPDT relays. A diode across each relay protects its associated driver transistor from inductive kickback when the relay is de-energised.

Also wired across each relay is a series LED/1kΩ resistor combination to provide channel on/off indication.

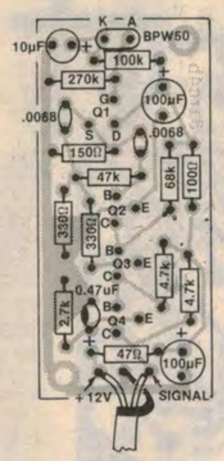
For those who wish to experiment, the circuit shows optional links for relay type operation (eg a burglar alarm). In this mode, the infrared transmitter described last month is used. When the beam is broken, the unit triggers, turning relay one on for a period set by the 56kΩ resistor and .047μF capacitor in the monostable circuit. The .047μF capacitor should be increased to 10μF and the 56kΩ resistor increased to 1MΩ for a 10 second period.

The whole unit is powered from a simple power supply consisting of a 12.6V transformer, a bridge rectifier and 1000μF filter capacitor, and a three terminal 12V regulator. High frequency decoupling is provided by the 10μF and 0.1μF capacitors. The power indicator LED is wired to the +12V supply via a 1kΩ current limiting resistor.

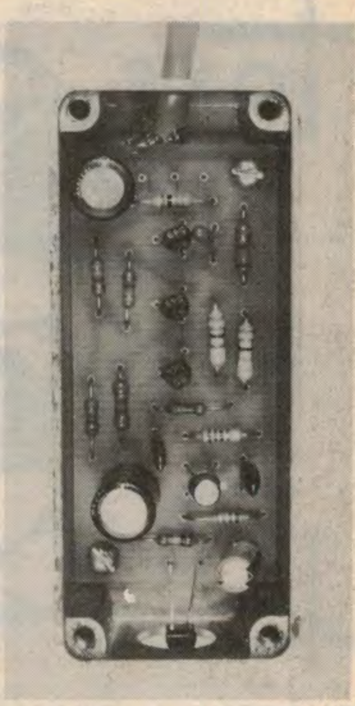
CONSTRUCTION

Construction can begin with the receiver, which is housed in a metal case measuring 150 x 76 x 134mm (D x H x W), although any metal case of sufficient size can be used.

Most components are mounted on two printed circuit boards (PCBs): a main board coded 81rc4a and measuring 79 x 105mm; and a preamplifier board coded 81rc4b and measuring 74 x 33mm. Use the board overlays provided to mount the components and take the usual precautions with component polarity and with the CMOS ICs. Note that the BPW50 photodiode is mounted using almost its full lead length, as shown in one of the photographs.



LEFT: Here is the component overlay diagram for the preamplifier/filter PCB.



RIGHT: The preamplifier PCB is mounted inside a metal diecast case. Note how the BPW50 infrared photodiode is arranged.

A separate aluminium diecast case measuring 92 x 38 x 31mm is used to house the preamplifier PCB. You will have to drill two mounting holes for the board, together with a 12mm diameter hole in the front of the case to allow light access to the BPW50 photodiode. A smaller 5mm hole at the other end of the diecast case carries the output cable to the main PCB.

With the preamplifier assembly and main PCB completed, the various components can be mounted inside the receiver case. Use the layout shown in

PARTS LIST

1 metal case, 150 x 76 x 134mm
1 diecast aluminium case, 92 x 38 x 31mm
1 plastic zippy box, 83 x 54 x 28
1 PC board coded 81rc4a, 79 x 105mm
1 PC board coded 81rc4b, 74 x 33mm
1 PC board coded 81rc4c, 61 x 42mm
1 transformer, type 2851 240V to 12.6V
2 12V SPDT PC-mounting relays
1 240VAC SPDT miniature toggle switch
2 momentary contact pushbutton switches
1 9V transistor battery, Eveready 216 etc
1 battery clip to suit battery
4 9mm Richco plastic board supports
15cm of twin-conductor shielded cable
1 mains cord and plug
1 3-way mains terminal strip
1 mains cord clamp and grommet
1 surface mounting mains socket (optional, see text)
3 small grommets (optional)
1 speaker socket (optional)

SEMICONDUCTORS
2 4011 CMOS quad NAND gates
1 4001 CMOS quad NOR gate
1 74C14 CMOS hex Schmitt inverter
1 4013 dual D flipflop
1 LM340T-12 three terminal regulator
1 BD263 NPN Darlington transistor
2 BC337 NPN transistors
3 BC549 NPN transistors
1 2N5485 N-channel JFET
1 BPW50 infrared photodiode
2 CQY89A infrared LEDs
3 large LEDs (assorted colours)
6 1N4002 power diodes
2 1N4148, 1N914 diodes

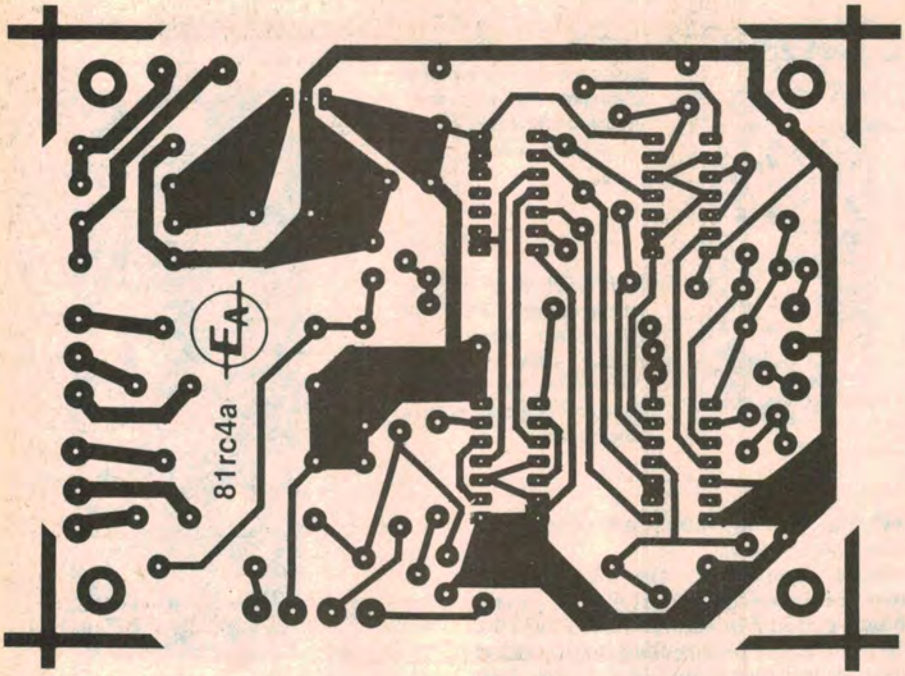
CAPACITORS
1 1000μF 25VW PC electrolytic
1 1000μF 10VW axial electrolytic
2 100μF 16VW PC electrolytics
2 10μF 16 VW PC electrolytics
2 1μF 16VW tantalum
1 0.47μF 25VW tantalum
1 0.1μF metallised polyester (greencap)
1 .068μF greencap
1 .047μF greencap
1 .015μF greencap
3 .01μF greencaps
3 .0068μF greencaps
1 .0022μF greencap
1 0.1μF 250VAC metallised paper (optional, see text)

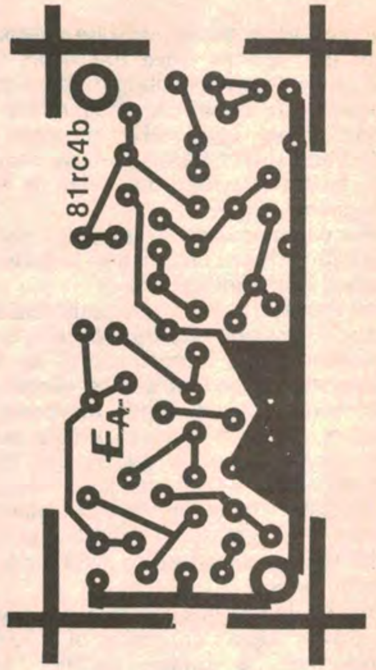
RESISTORS (all ¼W, 5%):
1 x 270kΩ, 7 x 100kΩ, 1 x 68kΩ, 1 x 56kΩ, 1 x 47kΩ, 4 x 10kΩ, 5 x 4.7kΩ, 1 x 2.7kΩ, 3 x 1kΩ, 2 x 330Ω, 1 x 150Ω, 1 x 100Ω, 1 x 47Ω, 1 x 15Ω.

MISCELLANEOUS
Machine screws and nuts, hookup wire, mains rated wire, solder lugs, solder etc.

NOTE: Ratings are those used in the prototype. Components with higher ratings may generally be used provided they are physically compatible.

ACTUAL SIZE PCB ARTWORKS





the photographs to drill the relevant mounting holes and don't forget to drill a 12mm hole in the front panel to line up with the hole in the preamplifier case.

The preamplifier is mounted on one side of the case using the same screws used to secure the preamplifier PCB. It must be arranged so that, when the assembly is completed, the BPW50 photodiode sits just behind the front panel. We used 9mm Richco plastic board supports to mount the main PCB and connected it to the preamplifier via a 120mm length of twin-core shielded cable.

It is a good idea to earth the main PCB directly to the case via a solder lug, and to fit a small aluminium heatsink to the LM340T-12 regulator IC to aid heat dissipation.

The mains cord should be passed through a grommetted hole in the rear of the chassis and anchored with a cord clamp. Terminate the mains active (brown or red) and neutral (blue or black) wires to the insulated terminal block and solder the earth (green or green with yellow stripe) wire to a solder lug near the transformer. The mains on/off switch is mounted on the rear panel, and should be wired to switch the active line to the transformer primary.

This done, the transformer can be bolted into position and its secondary leads terminated directly to the PCB. The primary leads are connected to the neutral terminal on the mains terminal block and to the on/off switch. Keep all mains wiring neat and tidy, and sleeve the terminals of the on/off switch with plastic tubing to avoid the possibility of electric shock.

Note that a 0.1μF 250VAC (ie mains rated) capacitor must be connected across the relay contacts when switching mains appliances. This is to prevent turn-off voltage spikes from triggering the circuitry. This capacitor can be mounted on the mains terminal strip.

We wired our unit so that one relay is used to switch a mains output socket bolted to the rear of the case. If you elect to do the same, make sure that all wiring to the relay contacts and to the socket is mains rated. The wiring is most conveniently run to the mains socket via the mains terminal strip.

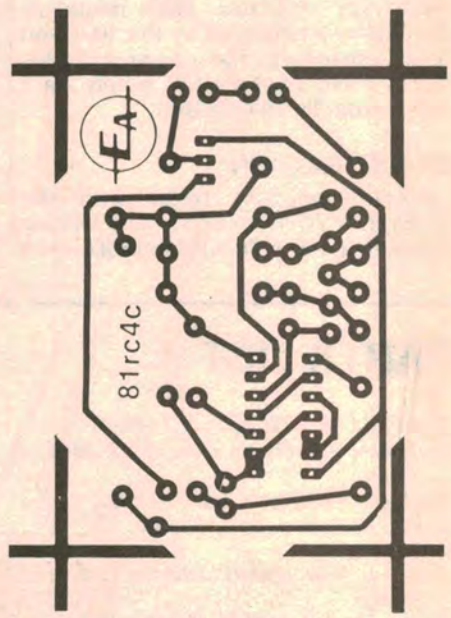
The second relay in the prototype was wired to a 2-pin speaker socket and is intended to switch low voltage circuitry.

The transmitter is built on a PCB measuring 61 x 42mm (code 81rc4c), and is housed in a small plastic zippy box.

The "CH 1" and "CH 2" buttons are mounted on the aluminium front panel of the plastic case, about 18mm from one end of the panel and about 21mm apart from each other. The only other modifications to make to the box are to drill two holes for the infrared LEDs. These should be drilled 8mm from the bottom of the case and about 8mm apart.

The transmitter PCB has no mounting holes and is designed to sit at the bottom of the case, being held in place by the battery and the lid of the box. There should be no problems with this arrangement. In fact there are some distinct advantages; no screws underneath the case to scratch furniture (the prized coffee table) and it also makes assembly easier.

The IR LEDS should protrude from the case by at least 5mm so that the emitting portion of the diodes is completely exposed to improve the range of the transmitter within a room.



The capacitors should be laid flat on the board so that they have a low profile. This is necessary in order to accommodate the battery which sits immediately between the board and the lid of the case, albeit with a thin layer of foam sandwiched between them.

Finally, go over all the wiring in the transmitter and receiver units and check that it is correct. Pay particular attention to the mains wiring, especially if you have wired up the optional mains output socket. To test the unit, simply switch on and check for correct operation.