Stereo infra-red remote control

Build it for your hifi system

If you are a keen hifi enthusiast, you are sure to be interested in our new infra-red remote control system. With it you can adjust your sound level up and down at will, without ever leaving your seat and it has negligible effect on signal quality. Best of all, it is easy to build and surprisingly low in cost.

by RON DE JONG

Remote controls are very popular with colour television receivers and are also available as an optional accessory with some of the latest tape and cassette decks. But there is only one remote control that we know of which can be added to a stereo amplifier or receiver. For this reason alone, we are sure that our new remote control system will find wide acceptance.

There are a lot of situations in which a remote control can be very convenient. Imagine reclining on the sofa and your favourite piece of music suddenly bursts from the FM airways — without a moment's hesitation you advance the volume to let the music really blast out. Then the station announcer returns and you ease the level back — all without even getting up.

It's also great at parties, where it's usually difficult to even reach the stereo let alone control it with any degree of certainty!

You can also use the remote control to mute the amplifier while you answer the telephone or callers at your home —no need to race for the volume control, just quickly stab the "down" button on the remote control module a couple of times and the volume is reduced to an unobtrusive level.

The remote control isn't just for stereo systems either. It can be used for setting the volume level of your TV — even to the point of cutting off the sound completely, particularly during commercials. The applications don't stop there either: the remote control could be adapted to switch appliances on or off, or maybe even used to control a light dimmer. We have no doubt that our readers can dream up many more interesting applications.

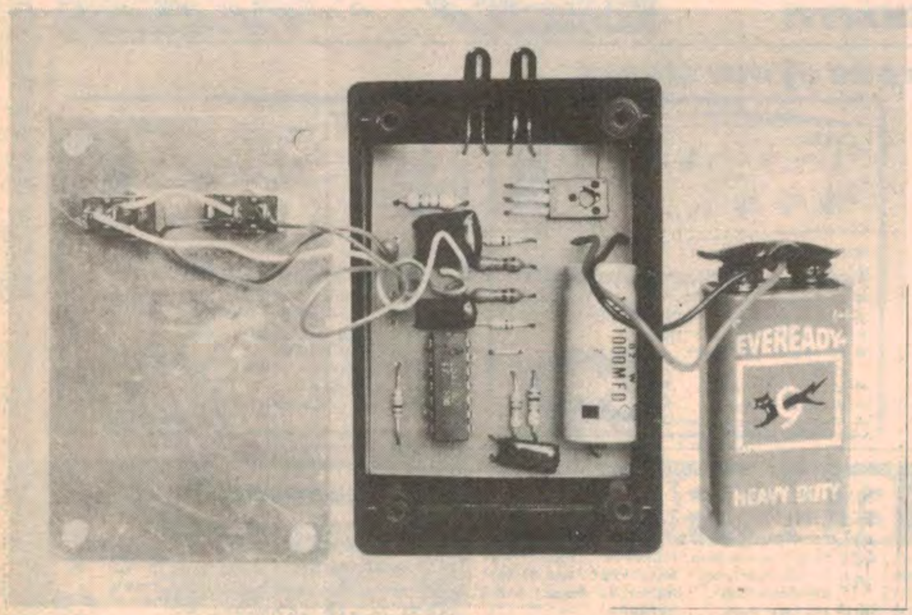
The infra-red remote control system comprises two parts: a small hand-held module with two buttons is the transmitter while a larger cabinet with an inscrutably dark front panel is the receiver. This sits on or next to your amplifier or receiver and is hooked up so that it controls the volume level.

Behind the dark panel of the receiver are eight light-emitting diodes. Spread out behind this red perspex panel, these LEDs show the volume setting which has been selected by pressing the "up" or "down" buttons on the transmitter module.

Only one LED is lit at any time. Each time you press one of the transmitter buttons, the light will move across the panel of the receiver, one step at a time. The lowest volume level is indicated by the LED at the extreme left-hand side of the receiver panel while the highest volume level is set by the extreme right-hand LED.

When you reach the highest volume level, continued pressing of the "up" transmitter button will not change the level — you must press the "down" button to shift the level. Similarly, when you reach the lowest volume level, continued pressing of the "down" button will not change the level. Hence the volume level will not suddenly change from the lowest to the highest in one sudden jump — a big advantage for your ears (and nerves)!

Performance of the infra-red remote control system is summarised in an accompanying panel. The maximum range of the transmitter for reliable



Inside the assembled transmitter unit. It's very simple and uses just one IC, a couple of LEDs, a Darlington transistor and a handful of other components.

The completed prototype, shown here with Playmaster hifi equipment. Eight LEDs behind the red perspex panel of the receiver (top) show the volume level that has been selected.

operation of the receiver is over 20 metres. This means that it will be more than adequate in domestic situations. You will be able to use it not only by pointing the invisible infra-red beam of the transmitter directly at the receiver but you can also operate by pointing the transmitter module at the ceiling or walls. You can even use it around corners or from other rooms.

There are several ways in which the infra-red remote control system can be used with your stereo system. For example, if you have a separate control preamplifier and power amplifier you will be able to connect the remote control receiver between the two. Or if your amplifier or stereo receiver has preamplifier outputs and power amplifier inputs you can remove the normal bridging links between these inputs and outputs and connect the remote control receiver in the same way.

The most common method will be to use the "tape monitor" facility which is provided on most stereo amplifiers and AM/FM receivers. The basic idea is to connect the remote control receiver as though it was a tape deck. The tape record outputs of the amplifier are connected to the inputs of the control receiver while its outputs are connected back to the tape monitor inputs on the amplifier.

Many of the more pretentious amplifiers have facilities for monitoring from two tape decks. This makes it easy to connect the remote control unit to the "tape 1" monitor while still retaining monitor facility at "tape 2".

When using your infra-red remote control, your amplifier's volume control becomes the master control. Use it to set the maximum volume level with the remote control set for the highest level.

If your amplifier does not have provision for two tape decks but you still wish to have a tape monitor facility, then it will be necessary to add this to the remote control. This is easily done with the aid of a circuit shown elsewhere in this article.

The total circuitry for this infra-red remote control system is relatively simple and low cost. The hand-held transmitter uses a mere handful of components, comprising one CMOS IC, a Darlington transistor and a couple of infra-red light-emitting diodes plus a few resistors and capacitors. The receiver includes ten low cost ICs, a photodiode and eight ordinary LEDs. All that will not set you back by more than about $45.

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, pin 12 and 13, are pulled low.

Normally both inputs of gate 1d will be high by virtue of the 100k 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 "up" button for example, there is initially no voltage across the .068uF capacitor since both sides have been pulled up via the 10k and 100k resistors.

When the "up" button is pressed however the switch side of the capacitor goes low and because the voltage across the capacitor cannot 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 .068uF capacitor is charged via the 100k 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 .068uF capacitor and 100k resistor and is roughly 5ms. The pulse length generated by the "down" button circuit is similarly dependent on the 100k resistor and 0.15uF capacitor in its circuit and is about 1ms.

The 1uF capacitors across the "up" and "down" buttons provide debouncing. If the switch momentarily opens due to contact bounce the voltage across the switch will not immediately

Specifications:

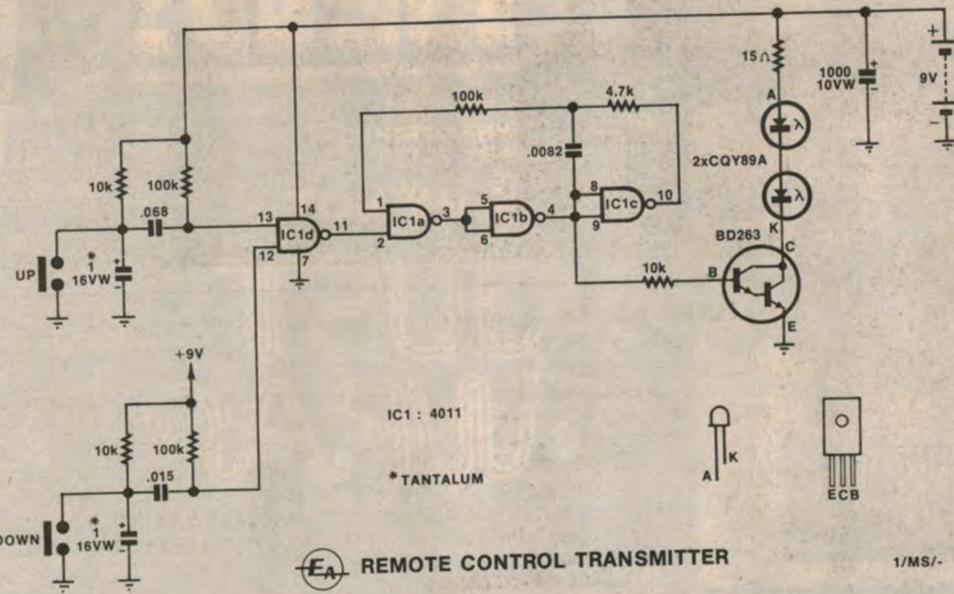
TRANSMITTER

RANGE: greater than 20 metres
SIGNAL: down pulse — 1ms burst at 10kHz; up pulse — 6ms burst at 10kHz
ESTIMATED BATTERY LIFE: greater than one year

RECEIVER

Specifications of the audio section at maximum selectable output level.
FREQUENCY RESPONSE: 10Hz to 20kHz ±1dB
S/N RATIO: 75dB with respect to 100mV input
THD: typically .035% at 1kHz and 10kHz with respect to 100mV
MAXIMUM INPUT VOLTAGE: 5V RMS
ATTENUATION STEPS: 0, -3, -7, -12, -18, -25, -33, -42dB
POWER CONSUMPTION: 5 Watts

Stereo infra-red remote control: for your hifi system



The transmitter circuit consists of a CMOS oscillator and a Darlington transistor output stage driving two infra-red LEDs.

change because of the time constant of the 10k pull up resistor and the 1uF 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 infra-red light-emitting diodes. A 10k 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 15 ohm 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 1000uF 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.

The infra-red diodes used are Philips type CQY89A or Siemens type LD271. These are plastic-pack devices and are similar in appearance to the more usual red LEDs with the difference that the plastic pack of the CQY89A is very deep blue while the LD271 is light blue.

Let us now turn to the receiver circuit which consists of four main sections: preamplifier, demodulator, display and audio attenuator. The transmitted pulse from the handheld unit is detected by a photodiode. The signal from the photodiode is amplified and filtered by op amps.

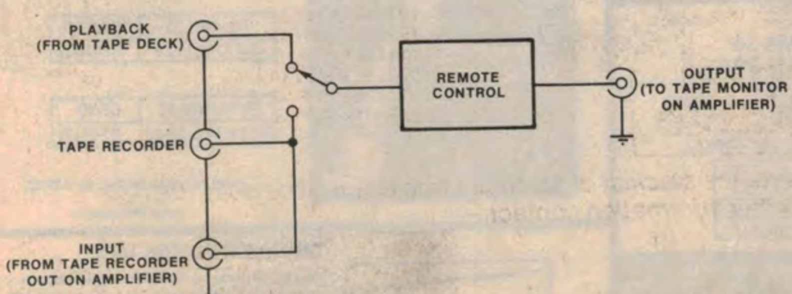
Filtering is necessary to remove the large amount of ambient noise which is picked up by the photodiode from sources such as fluorescent lights. Most of the "noise" due to this source is centred about 100Hz but there are harmonics extending right up the audio range to beyond 1kHz.

The photodiode is reverse biased via a 220k resistor connected to the cathode.

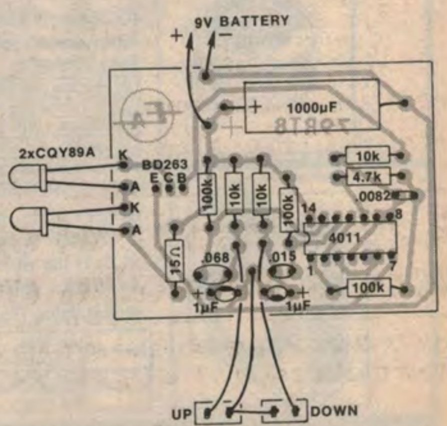
The reason for reverse bias is to improve the switching speed of the diode and, more importantly, to reduce the effects of ambient light on the sensitivity. The biasing network is decoupled by a 10uF tantalum capacitor and 100k resistor, to reduce the effect of supply ripple, and also eliminate any feedback from the following stages.

The output of the photodiode is coupled to op amp 1b which is arranged as an inverting amplifier. The .0022uF capacitor in series with the input provides DC isolation and also rolls

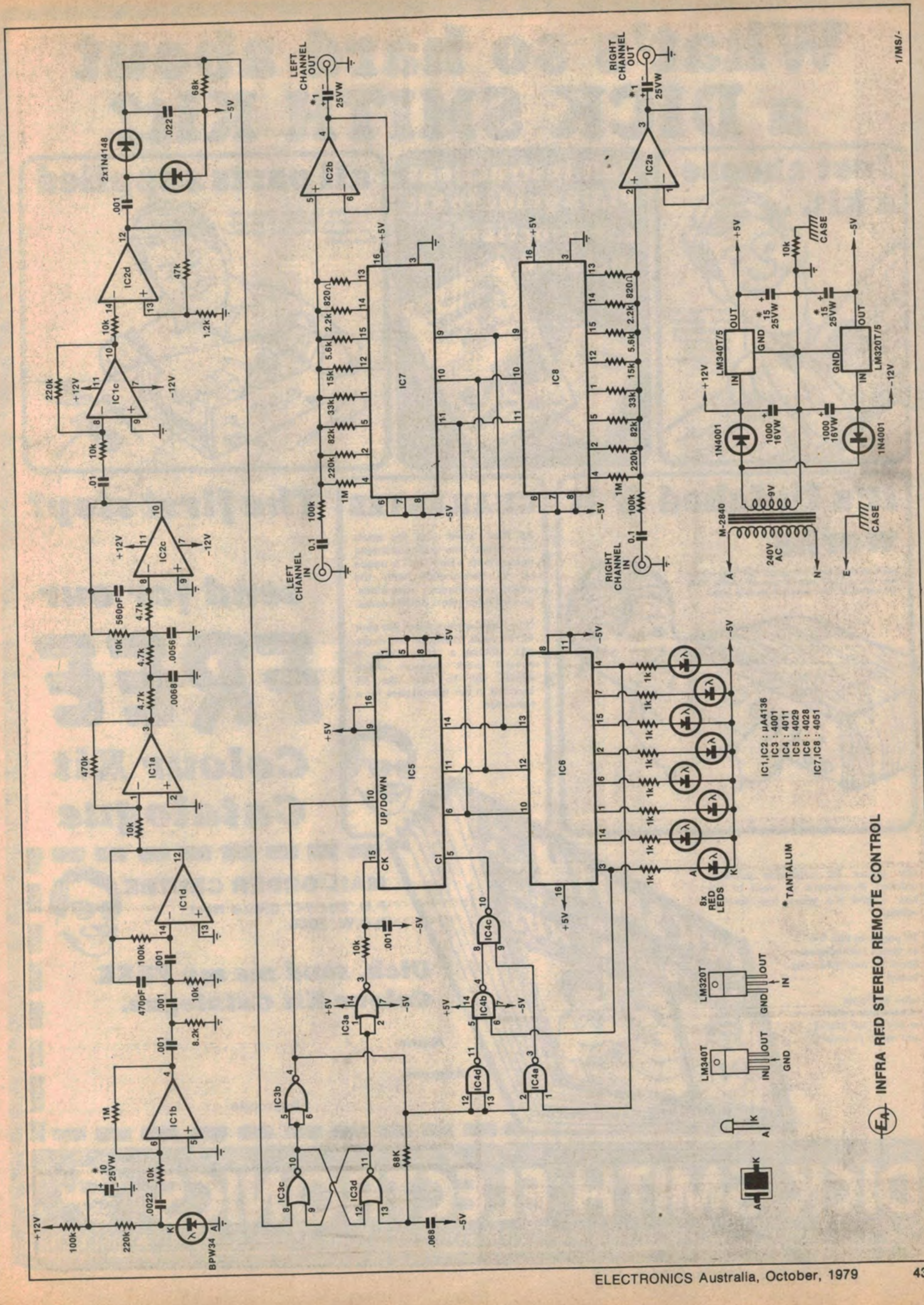
The receiver circuit (following page) consists of four main sections: preamplifier, demodulator, display and audio attenuator.



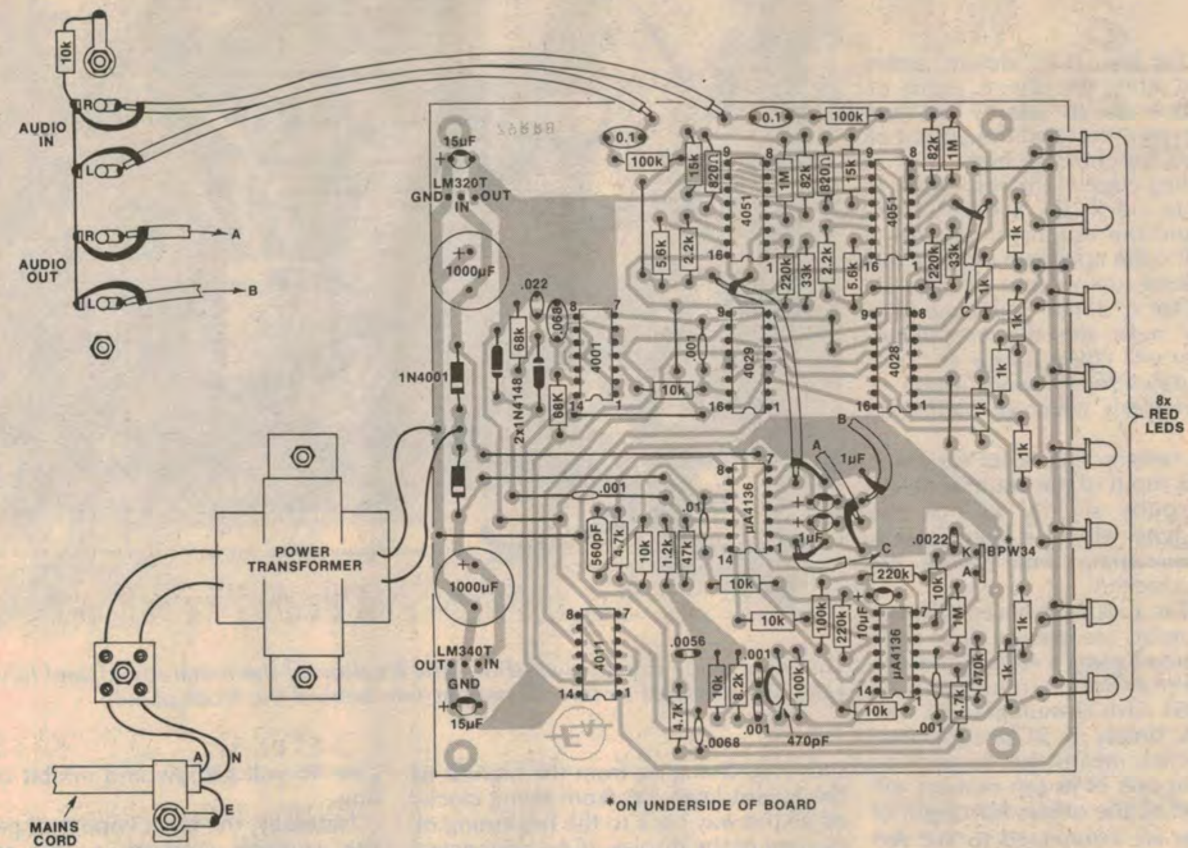
Use this circuit if you wish to retain tape monitoring facilities. The circuit could be built into the remote control receiver or into a separate box.



The component overlay diagram for the transmitter. The CMOS IC should be the last component soldered into circuit.



INFRA RED STEREO REMOTE CONTROL



The wiring diagram for the receiver. Note that a metal shield is required over the audio buffer section (see text).

off the frequency response below about 8kHz. The attenuation provided is sufficient to prevent any 100Hz "noise" from overloading the first stage.

In the following stage, op amp 1d is arranged as a third order high pass filter with rolloff again at about 8kHz. The rate of attenuation is 18dB per octave which almost completely removes any vestiges of low frequency interference. The attenuation at 100Hz for example is about 40dB due to this stage alone.

The low pass filter is in turn followed by another inverting amplifier and then by a third order low pass filter which rolls off the response above 12kHz. The combined effect of the low and high pass filters is to pass only a quite narrow range of frequencies between eight and 12kHz, i.e. 2kHz either side of the nominal transmitter frequency. The narrow bandwidth of the amplifier minimises the effects of interference and it also reduces any noise contributed by the op amps themselves. It is wide enough, though, to allow for a reasonable margin of error in the transmitter frequency so no tuning is necessary.

Low pass filter IC2c is followed by op amp IC1c connected as an inverting amplifier driving, in turn, op amp IC2d connected as a Schmitt trigger. The Schmitt trigger output is normally high or low and switches to the opposite polarity only when the input signal exceeds a certain threshold. Thus the Schmitt trigger helps ensure that the receiver response is the same whether the transmitter is close or distant.

An interesting feature of the rectifier following IC2d is the fact that the .001uF coupling capacitor is 22 times smaller than the filter capacitor at the output of the rectifier. So any one cycle of the transmitted signal, or even interference, will charge up the filter only fractionally and some seven cycles are in fact required before the output voltage of the filter reaches a voltage sufficient to trigger the following CMOS logic. This provides a reasonable measure of interference suppression without effecting the sensitivity of the receiver.

The output of the rectifier filter will appear as a pulse to the CMOS circuit and with the filter time constant used the duration of the pulse will be approximately the same as when the signal was originally transmitted. As noted above the "down" pulse is about 1ms long while the "up" pulse is about 6ms long. This difference in pulse length is decoded by the three CMOS NOR gates which follow the filter.

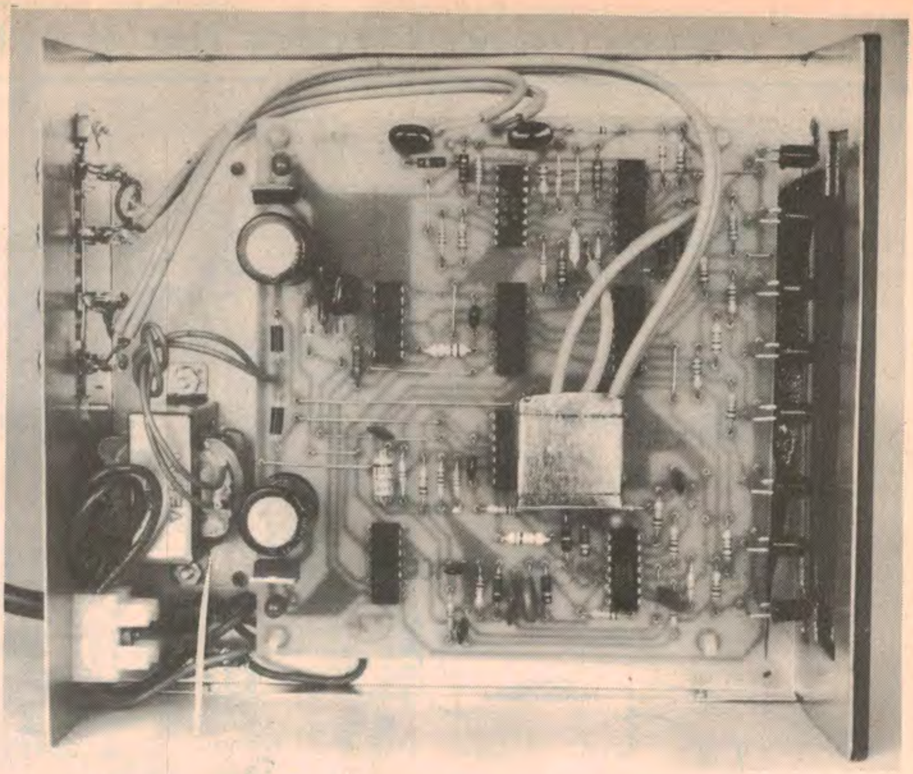
The NOR gates are arranged as an RS flipflop. Pin 8 input of gate 3c and pin 13 input of gate 3d correspond to the R and the S inputs respectively. Normally both inputs are low but when a pulse arrives due to a signal transmission the flipflop is set, with the output of gate 3c low and the output of gate 3d high. The flipflop would remain in this state if not for gate 3b. The output of this gate goes high and resets the flipflop via the 68k resistor and 0.68uF capacitor which comprise a time delay circuit.

The flipflop is reset about 3.5ms after the leading edge of the pulse signal which is after a "down" pulse would finish but before an "up" pulse has ended. So if an "up" pulse was received the R input of the RS flipflop will still be high immediately after the flipflop is reset and the output of gate 3c will

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

$45

including sales tax.



This view inside the receiver shows the location of the metal shield, and how the LEDs are arranged to form a straight line behind the front panel.

therefore be low. If a "down" pulse is received however, the R input of the flipflop would be low by the time the flipflop was reset and the output of gate 3c will therefore be high.

The leading edge of the reset pulse is also used to clock IC5, a 4029 CMOS counter, and the output of gate 3b is connected to the up/down input of the counter. Since the output of gate 3b will be low for a "down" pulse and high for an "up" pulse after the reset signal, the counter will count up for an "up" pulse and down for a "down" pulse — which is precisely what we want it to do.

The 10k resistor and .001uF capacitor at the clock input of the counter delays the reset pulse slightly so that the up/down signal will have been present for an appropriate time before the counter is clocked.

The 4029 is a four bit binary counter and the outputs are used to drive both a display circuit using a 4028 IC and the audio attenuation circuits which employ 4051 CMOS multiplexers. The 4028 IC is simply a BCD-to-decimal decoder which means that for a given binary input one of its ten outputs will be high and all the others low. Eight of the outputs are connected to the red LEDs mounted across the front panel.

The purpose of the LED display is of course to show the current volume level selected. It also confirms visually that you have indeed changed the volume level when using the remote control transmitter.

To prevent the volume level from suddenly changing from the highest to the lowest level, i.e. from being clocked all the way back to the beginning or the end of the display, IC4 is connected so as to inhibit clocking of the counter in the wrong direction. If the counter is being clocked up and it is already at the highest level the output of gate 4a will go low forcing the output of gate 4c high and inhibiting counting. Similarly if the counter is being clocked down when it is already at its lowest level, gate 4b will go low and inhibit counting.

Naturally, the most important part of the remote control is the audio attenuation circuit which consists of two eight-channel analog multiplexers and two op amps, one each for the two stereo channels. The attenuation is passive, performed by a voltage divider consisting of a 100k resistor in series with the input signal and one of eight resistors which is selected by the 4051

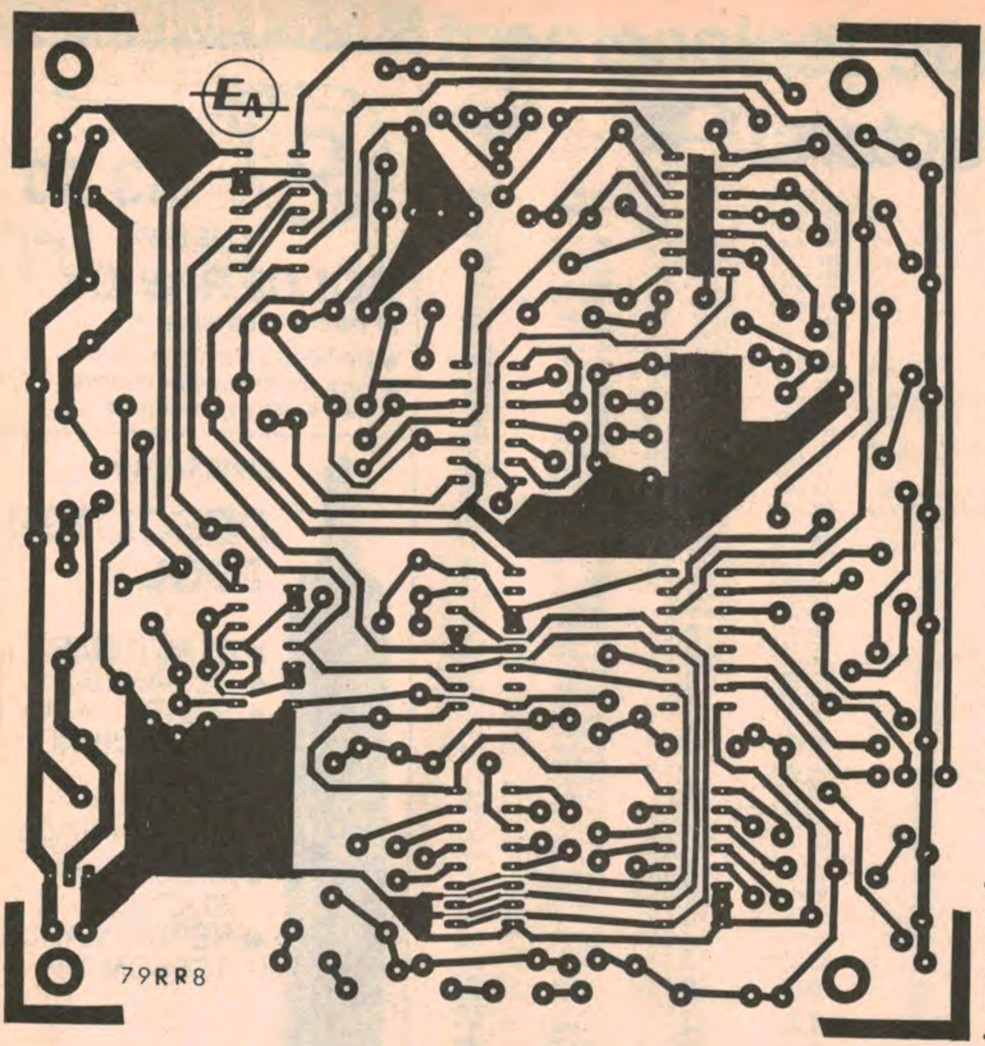
PARTS LIST FOR THE REMOTE CONTROL

1 Metal case, 160 x 70 x 184mm (W x H x D)
1 Power transformer 9V, M-2840 or similar
1 Plastic "zippy" box, 83 x 54 x 28mm
1 PC board, 129 x 123mm, coded 79RR8
1 PC board, 47 x 61mm, coded 79RT8
1 Piece of dark red perspex, 156 x 67mm
1 Piece of Kodak 87 infra-red filter (see text)
1 Mains cord and plug
1 4 way RCA panel socket
2 Momentary-contact push buttons
4 20mm Richco supports
1 9V transistor battery, Eveready 216 or similar
½ Metre of figure-8 shielded audio cable
1 two way mains terminal strip

SEMICONDUCTORS
2 4011 CMOS ICs
1 4001 CMOS IC
1 4029 CMOS IC
1 4028 CMOS IC
2 4051 CMOS ICs
2 uA4136 op amps
1 LM340T-5 regulator
1 LM320T-5 regulator
2 1N4001 diodes
1 BD263 Darlington transistor
2 CQY89A or LD271 infra-red LEDs
1 BPW34 or BP104 photodiode
8 Large red LEDs
2 1N4148 diodes

RESISTORS
(5% tolerance, ¼ or ½W)
3 x 1M, 1 x 470k, 4 x 220k, 7 x 100k, 2 x 82k, 2 x 68k, 1 x 47k, 2 x 33k, 2 x 15k, 11 x 10k, 1 x 8.2k, 2 x 5.6k, 4 x 4.7k, 2 x 2.2k, 1 x 1.2k, 8 x 1k, 2 x 820 ohms, 1 x 15 ohms.

CAPACITORS
2 1000uF/16VW electrolytics
1 1000uF/10VW electrolytic
2 15uF/25VW tantalum
1 10uF/16VW tantalum
4 1uF/25VW tantalum
2 0.1uF metallised polyester (greencap)
2 .068uF metallised polyester
1 .022uF metallised polyester
1 .0082uF metallised polyester
1 .0068uF metallised polyester
1 .0056uF metallised polyester
1 .0022uF metallised polyester
5 .001uF metallised polyester
1 560pF polystyrene or ceramic
1 470pF polystyrene or ceramic
NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may generally be used provided they are physically compatible.



provide a split 10V supply for the CMOS circuitry.

Well, while the circuit might be regarded as relatively complicated, the construction is fairly straightforward. For the receiver we used an inexpensive case which is available from Dick Smith Electronics and other parts suppliers. Approximate dimensions are 160 x 70 x 184mm (W x H x D).

The first step in the construction of the receiver is to make the cutout in the front panel for the display LEDs and the photodiode. The cut out should be wide enough so that all the LEDs are visible and it should also be cut very close to the bottom of the case so that the photodiode has as large a window as possible. Then with the cutout complete, blackout the rest of the front panel with black paint or insulation tape and then attach the red perspex panel using double sided tape or glue. Alternatively, if a more robust arrangement is desired, the perspex can be attached by four small screws at the corners.

At left is an actual size reproduction of the artwork for the receiver PC board. Commercial boards will be available from the usual components suppliers.

multiplexer (in each channel).

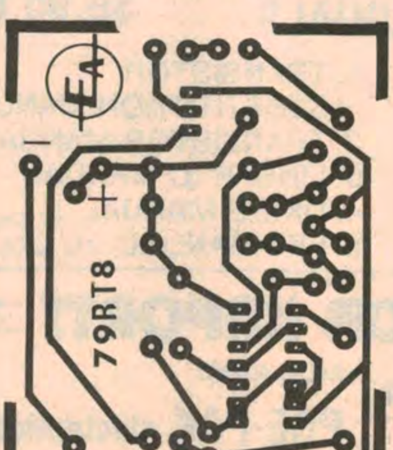
The larger the value of the resistor selected the less the attenuation, and the smaller the resistor the greater the attenuation. The resistors are therefore arranged in such an order that when the counter is clocked up, a higher value resistor is selected and when clocked down a lower value resistor is selected.

The attenuation at the highest volume level can be regarded as 0dB although it is actually about 0.4dB due to the 1M resistor (which is necessary to bias the op amp IC2a or IC2b). From there down, the attenuation increases in approximate steps of 3, 4, 5, 6, 7, 8, and 9dB giving a maximum attenuation of -42dB at the lowest volume level. This should be more than adequate for most situations.

The reason for using this apparently strange series of attenuation steps rather than having say 3dB per step is that greater control is desirable at higher volume levels. Most volume controls actually work in this fashion anyway.

The attenuated signal output from the 4051 multiplexers is buffered by an op amp in each channel. These are connected as "voltage-followers" to provide unity gain. The output of the op amps is coupled via 1uF tantalum capacitors to the output sockets.

The power supply uses two half-wave rectifiers to provide plus and minus 12V rails which are used to power the uA4136 quad op amps. These require a fairly high supply voltage in order to cope with large audio signals. The 12V rails also feed positive and negative 5V regulators, LM340T and LM320T, to



Actual size artwork for the transmitter.

The red perspex for the front panel can be obtained from suppliers of cut to order plastics. We obtain ours from FX plastics 77 Sydenham Rd, Marrickville and they can supply the perspex in a minimum of 900 square cm at a cost of $2.27 plus a $2.00 cutting charge. Its probably a better idea though to obtain the perspex from kit supplies as this is more than required.

Next assemble the components onto the PC board but leave the photodiode and the LEDS to last. When mounting the LEDs for the front panel display, the leads should be bent at right angles close to the body so that when the LEDs are inserted into the board they will point straight toward the front panel. The LEDs should also be mounted about 15mm above the board so that when the board is mounted on the plastic board supports, the LEDs will be slightly over half way up the panel. Solder only one lead of each LED and adjust them individually so that they're all in a straight line and then solder the remaining leads.

The photodiode is a Philips type BPW34, though again there is an equivalent Siemens device with the type number BP104. The BP104 has an integral infra-red filter so it is relatively

(continued on p125)

INFRA-RED . . . from page 48

unaffected by visible light but the BPW34 has no filter and it is necessary to use an external filter placed directly in front of the photodiode to reduce interference.

Kodak Wratten gelatin filter No. 87 is the recommended infra-red filter and it can be obtained from any of the larger photographic suppliers such as Kayell Photographics, 143 York Street, Sydney. The filter is normally supplied as a sheet, 75mm square and costs more than $5 which is fairly steep considering that a piece about 20mm square is all that is required. We hope that kitset suppliers will make suitable arrangements.

The photodiode is mounted underneath the board and soldered to two lengths of wire so that it hangs about 10mm below the board, though the distance is best determined by actually pushing the board down onto the plastic board supports and checking that the photodiode has the best "window".

Two other lengths of stout wire are soldered to the earth track just in front of the photodiode. These are bent upward at the bottom so that they can support the infra-red filter, which should be placed so it completely covers the front surface of the photodiode. The filter is not necessary if you are using the Siemens BP104 photodiode. The only point to note when using the BP104 is that the cathode is marked with a blue dot.

The only other item to be mounted on the board is a metal shield. This is located over the audio buffer section next to one of the uA4136 op amps as can be seen in the photograph of the receiver. The purpose of the shield is to prevent any audio signals from being coupled to the input of the infra-red circuitry. The shield can be fashioned from some tin plate and it is fastened to

(Continued on page 128)

Infra-red remote control. . .ctd from p125

the board via wire links which are soldered both to the shield and to the underlying earth pad.

After completing the board the transformer and RCA sockets should be mounted. A rectangular cutout is required for the RCA sockets and this can be done by drilling a series of holes or by using a nibbling tool and then filing the edges straight. The earth connections on the socket are soldered together and then soldered to an adjoining lug on the chassis via a 10k resistor. The purpose of the resistor is to ensure that the case isn't "floating". We've used a resistor rather than a link to prevent any ground loop problems.

Since the power consumption of the receiver is very low we have omitted a power switch. This simplifies the wiring and also the operation. You need not bother to turn the unit off when you turn the rest of your system off. With an estimated power consumption of about five watts the cost of leaving the unit running for a year is about $1.30, assuming a cost of three cents per kilowatt-hour.

Now the board can be finally mounted on the chassis with the transformer leads and the shielded cable connected. With power applied first check that the ± 12 and $+5$ volt supplies are operational. If there is nothing seriously wrong with the board then at least one of the display LEDs should be on — so far so good. To check the overall operation though you'll have to assemble the transmitter.

We housed the transmitter in a small plastic box that is inexpensive, and readily available from part stockists. The "up" and "down" 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 infra-red LEDs. These should be drilled 8mm from the bottom of the case and about 8mm apart from each other.

The PC board 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. The foam helps to keep the battery and board firmly in position.

With the transmitter completed, you should now be in a position to check the remote control out. If it fails to work at all check the polarity of all the electrolytics and diodes and the orientation of the voltage regulators and the ICs. If it works but not with the range you expected you may have the BPW34 (BP104) receiver diode in the wrong way or it may not have a good view through the front panel — this is very important. The larger the window available to the diode the better it will perform.

The receiver may also suffer from interference. If electrical interference is a severe problem it can be solved by shielding of the first stage of the infra-red circuitry with tin plate. Flourescent lights will also effect performance if the receiver is pointed directly at them.

With all checks complete you are ready to sit back and enjoy the luxury and convenience of infra-red remote control. Set the maximum volume levels as described above, tune in to your favourite station and enjoy your latest addition to hifi appreciation. We hope you like it!