Modern Opto Device Projects

R. A. PENFOLD

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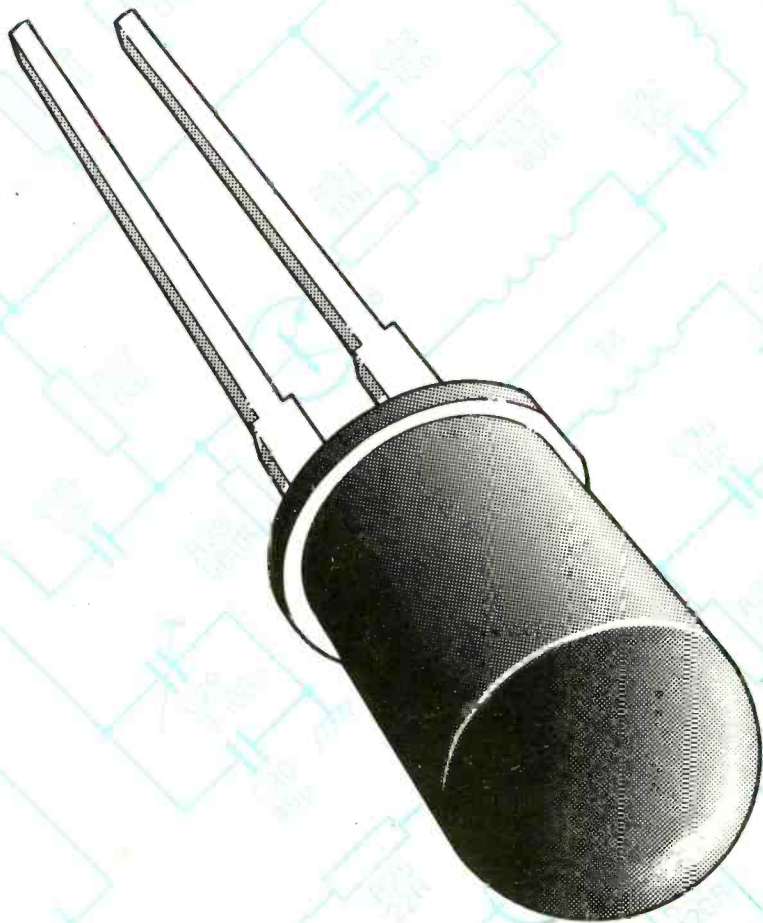
MODERN
OPTO DEVICE
PROJECTS

OTHER BOOKS OF INTEREST

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by

R. A. PENFOLD

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PREFACE

As little as fifteen to twenty years ago the range of opto-electric devices available to the amateur electronics enthusiast was strictly limited. There were cadmium sulphide photoresistors, one or two phototransistors, but apart from a few other devices such as cathode ray tubes and "magic-eye" tuning indicators, that was about it. Things have changed quite radically since those days, and throughout the seventies and eighties there has been a procession of new opto-electric devices, including such things as light emitting diodes, liquid crystal displays of varying degrees of complexity, and sensors of various types.

These devices represent one of the most interesting aspects of modern electronics and many are worth trying out purely for their interest value. On the other hand, they mostly have as much practical application as play value, and are not just examples of the common phemonenon of clever technology in search of practical applications. They are consequently of interest to both the experimenter and those who are looking for solutions to practical problems.

This book provides practical designs which utilize a range of modern opto-electric devices, including such things as fibre optic devices, ultrabright light emitting diodes and passive infra-red detectors. While many of these designs are not in the "dead simple" category, they should be within the capabilities of anyone with a certain amount of experience at electronics construction, and one or two of the more simple designs are suitable for beginners.

R. A. Penfold

CONTENTS

Chapter 1

FIBRE OPTICS

Fibre optics have for many years now been hailed as the way of things to come, but have so far had only limited impact. Some of the problems involved with fibre optic communications have proved to be difficult and time consuming to crack, especially the problems of high attenuation over a given length of cable, and the relatively high cost of effective fibre optic cables. Fibre optics are now beginning to have a greater impact on the electronics world, and it is an area which offers a lot of scope for the electronics experimenter.

Advantages

Electronic signals have for many years been sent quite successfully over ordinary "hard-wire" links, or via radio links of one kind or another, and on the face of it there is no way of justifying all the expense and effort that has so far gone into fibre optic development. In fact fibre optic links, whether for something like high quality audio or video links over long distances, or control links over relatively short distances, can have definite advantages.

One big advantage of fibre optic links is their total immunity to pick up of electrical interference. Ordinary wired links can be designed to minimise this problem, but it is difficult to totally eliminate it, and doing so can be extremely expensive indeed. Obviously the non-electrical nature of a fibre optic cable makes electrical interference irrelevant, except in that pick up of interference in the electronics at the receiver is still possible. However, effective screening of the receiver circuit is unlikely to prove to be particularly difficult.

In a similar vein, high speed signals sent down an ordinary electrical cable tend to radiate electrical interference which can disrupt radio and television reception in the viscinity. Again, a fibre optic cable it is totally free from electrical radiation, and although the transmitter unit might generate a certain amount of radio frequency radiation, it is quite easy to contain it using simple screening techniques.

Stemming from this lack of radiation, in a system having several cables running side-by-side there is no problem with crosstalk.

Obviously light could leak from cable to another, but fibre optic cables are enclosed in an opaque outer sleeving which in practice results in no significant leakage, and certainly nothing like enough to give any crosstalk problems. This lack of radiated signal makes fibre optic links relatively secure and virtually tap-proof.

Other advantages include no fire hazard problems as there are no electrical signals to cause sparking or the possibility of excessive currents flowing and causing overheating of the cable. There is electrical isolation through the link so that problems with earth loops can not occur. With suitable transmitting and receiving circuits it is possible for fibre optic links to have very large bandwidths. Wide bandwith links can be produced using coaxial electrical cables, but modern optic cables generally have lower losses than coaxial types in wide bandwidth applications. Optic cables are usually narrow and light, as well as being resistant to weather and many chemicals. This often enables them to be used easily in hostile environments or awkward situations where electrical cables, particularly coaxial types, might be less well suited.

Despite their advantages fibre optic cables have yet to achieve really widespread use. The obvious drawback is that electrical signals can not be feed direct to an optical cable, and in many cases the expense and difficulty of the necessary encoder and decoder circuits could not be justified. We are nowhere near the stage where electrical and electronic equipment could be economically wired up with fibre optic cables, and they are generally only used where distances of at least several metres are involved, or freedom from electrical interference is of crucial importance.

An important point to bear in mind when using optical fibres is that they normally have a recommended minimum radius, and if they are bent through a tighter curve than this it is quite likely that the cable will sustain serious damage at that point, rendering it useless. The "minimum bend" radius as it is usually termed in the data sheets, is generally between about 50 and 80 millimetres. There is a popular electronics joke about tying a knot in a mains lead to make it more difficult for the electricity to run down the cable, and thus reduce the power fed the device served by the cable. The effect of curves in a mains cable may be insignificant, but with fibre optic cables curves (even ones that are inadequate to damage the cable) can impede the propagation of the light waves and cause significantly increased losses.

Cable Basics

Although many people seem to be under the impression that a fibre optic cable just consists of a glass filament contained in an opaque outer sleeving, things are actually a little more complicated than this. These days the glass filament is more likely to be polymer than glass, and the usual arrangement is as outlined in Figure 1 where there is a central core having a high refractive index and an outer cladding of lower refractive index. Refraction where the inner filament and the outer cladding meet enables light to travel down the cable by effectively bouncing from wall to wall down the cable. It is this bouncing effect that enables the cable to operate as a light guide, taking the light around corners and bends. The angle at which the light is reflected depends on the characteristics of the cable and the entry angle of the light. In Figure 1 the light ray is subjected to "high order mode" propagation, but light entering at a shallower angle would bounce off the wall of the cable at a much shallower angle, and would consequently travel much further per bounce. This is termed "low order mode" propagation. The practical importance of these two modes is that light travelling through the cable in the high order mode has to travel significantly further than light which is propagated in the low order mode. This smears signals sent down the cable, and limits the maximum frequency that can be accommodated. This is only of significance in very wide bandwidth links though, and with the types that we will consider

Fig. 1. Cross section through an optical fibre showing high order propagation

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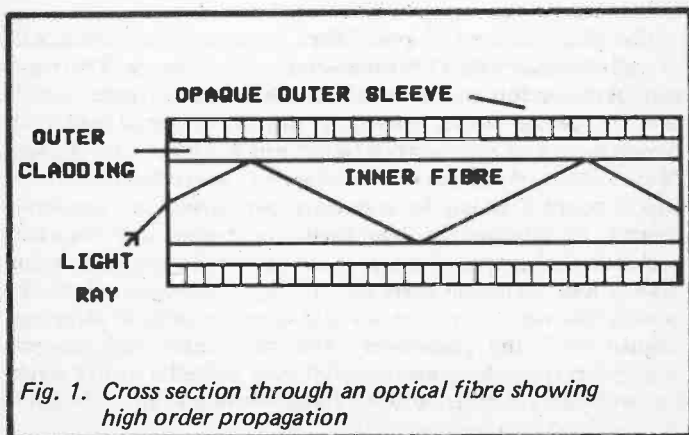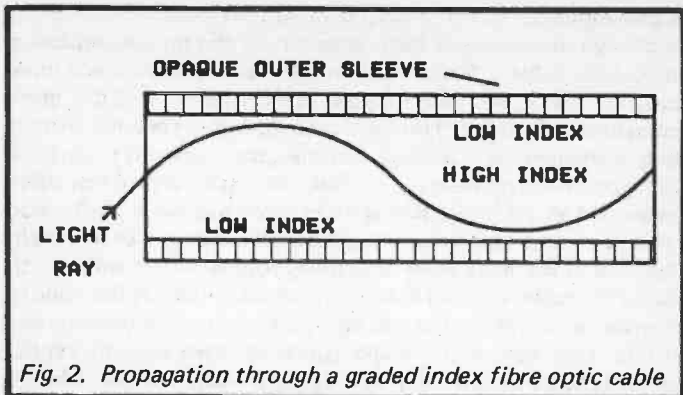
Fig. 2. Propagation through a graded index fibre optic cable

here it is not a practical consideration. So called "Single mode" cables are designed so that only one mode of propagation is supported, but it is not necessary to use a cable of this type with the relatively narrow bandwidth systems described in this book.

There is an alternative type of cable called "graded index" cable (as opposed to the "stepped index" type described previously). This is actually quite similar to the stepped index cable, but there is a gradual change from a high refractive index at the centre of the cable to a lower value close to the sleeving. This results in the light travelling down the cable in much the same way as described previously, but with the light taking a curved route (as in Figure 2) rather than being propagated in straight lines.

The standard size for optical fibre cables is 2.2 millimetres in overall diameter with a fibre diameter of 1 millimetre. There are various connectors available for use with this size of cable, as well as a few devices which connect to suitably prepared cables. A typical connector system has a "plug" which is fitted onto the end of the cable and secures it to the "socket" which mounts on the circuit board and has an apperture into which the photocell (emitter or detector) fits. The analogy with electrical plugs and sockets is perhaps not a very good one in that an optical connector system does not usually carry the light signal and does not usually contain any optics – it is just used to keep the cable in place and aligned with the photocells. The photocells with integral connectors that I have encountered have all had a sort of screw terminal into which the cable is fully pushed home, after which it is secured by tightening the terminal.

An important factor to keep in mind is the light wavelength at which the emitter has its peak output. Ideally the receiving device should have a peak response at a matching frequency, and it must certainly have reasonably high sensitivity at this frequency. Also bear in mind that the cable will only have a limited bandwidth, and it must provide reasonably low losses at the output wavelength of the emitter. Most opto devices intended for fibre optic applications operate at peak efficiency in the infra-red or nearly infra-red part of the spectrum. Most cables are quite efficient in the visible light part of the spectrum, and some are designed to peak at the centre of the visible light range. The majority have optimum efficiency in the infra-red part of the spectrum though.

Fibre optic cables are usually supplied with unprepared ends, and may be extremely inefficient unless the ends are properly cut and polished. In my experience the cable will give good results if it is cut at right angles using a sharp modelling knife, cutting through it cleanly in a single movement. A fine file can be used to polish the ends of a cable, but if it has been cut properly in the first place this is unlikely to significantly increase the level of light transmission. It is important that the cut is made perpendicular to the cable, as an angled cut will give reduced efficiency, and will tend to shift the optimum light entry angle off its normal end-on angle.

What can be very much more difficult than cutting the cable is stripping off the outer sleeving from the end of a cable. This is often necessary in order to fit the cable into a connector, and like stripping sleeving from an ordinary wire lead, it is important not to nick the inner part of the cable. With electrical leads this is mainly to avoid the severe physical weakening effect this has on the cable, but this in not a major factor with an optic cable except in an extreme case. It is more a problem of the efficiency of the cable being greatly reduced unless due care not to damage the fibre is taken.

Ordinary wire strippers can sometimes be quite effective with fibre optic cables, but most cable/stripper combinations do not seem to give good results. A method which often works well is to make a slit along the sleeving over the entire length of the piece that is to be removed. This requires a very sharp knife, with due care being taken not to cut too deep and not to slip and cut yourself or the worktop (the small round shape of fibre optic cables makes them a little awkward to deal with). Once this cut has been made it is quite easy to peel back the piece of sleeving and trim it off with the knife.

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Audio Link

A good starting point for someone wishing to experiment with fibre optic communications is to build an audio link. In its most basic form this would consist of a simple amplitude modulation system with the brightness of the transmitting LED being varied in sympathy with the amplitude of the audio input signal. This would give corresponding variations in the leakage current through the receiving photocell, which would be converted to a varying voltage by adding a load resistor in series with the photocell. This signal would be amplified and would provide the audio output signal.

In practice this simple method has its drawbacks, and the main one is simply a lack of linearity through the photocells. This lack of linearity is directly reflected in the distortion performance of the link which is consequently very poor. Readers with the appropriate technical knowledge might like to experiment with a system of this type, but it is not a topic that will be persued further in this book.

A system which generally gives better results is a frequency modulation type, which is essentially the same as the system used for high quality VHF radio broadcasts. However, in this case we are dealing with a carrier frequency of around 100kHz rather than the 100MHz of a band II radio transmission. A system of this type can be quite simple, and the block diagram of Figure 3 shows the basic arrangement for a simplex (single way) link of this type.

The transmitter is based on a voltage controlled oscillator (VCO), and as its name implies, the output frequency of this circuit can be varied by means of a control voltage. This voltage is the audio input signal in the present application, and as the signal voltage rises and falls, so does the VCO's output frequency. A lowpass filter is used to process the audio input signal before it is fed to the VCO, and this is to prevent heterodyne "whistles" from being generated due to beat notes between the VCO and any high frequency input signals. In most cases the input signal will only span the audio range, but there could be distortion products at higher frequencies, and there is also the possibility of radio signals being picked up in the wiring and reacting with the VCO signal or harmonics on the VCO's output signal.

The output of the VCO drives the emitting device, and with simple links of the type described here this device is a light emitting diode (LED) of some kind. In order to get good results it is generally necessary to drive the LED at a substantial current,
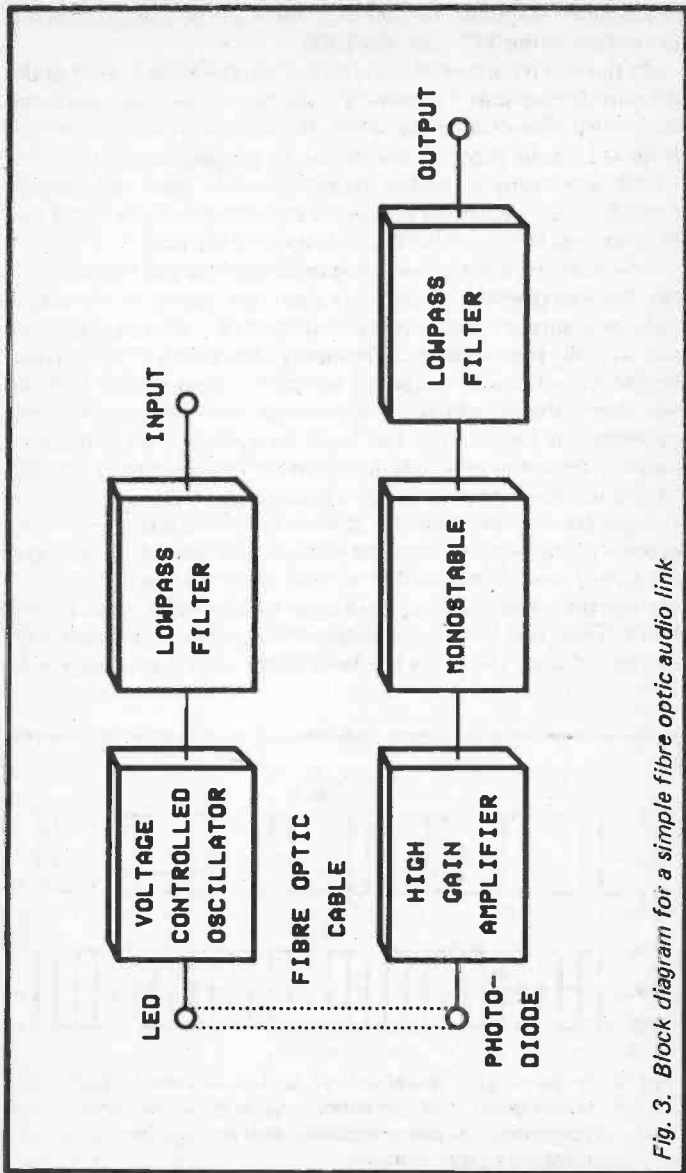
Fig. 3. Block diagram for a simple fibre optic audio link

and a buffer amplifier will therefore normally be needed between the output of the VCO and the LED.

At the receiving end of the system a photo-diode is used as the detector (or possibly a photo-transistor would be used here), and even with efficient coupling of light through the system the output from the photo detector is unlikely to be very large. In fact it would by typically only a few millivolts peak to peak. A high gain amplifier is consequently needed in order to boost the signal to a high enough level to drive the next stage of the unit.

This next stage is a monostable multivibrator and it must be of the non-retriggerable variety. It therefore provides an output pulse of a duration that is controlled by the C – R timing network and is totally independent of the input pulse duration. This gives a simple but effective frequency to voltage conversion, and the waveforms shown in Figure 4 help to explain the way in which this operates. In Figure 4(a) the input frequency is such that the output from the monostable has a 1 to 3 mark-space ratio, and the output is in the high state for 25% of the time. The average output voltage (as indicated by the dotted line) is consequently one quarter of the high state output voltage. In Figure 4(b) the input frequency has been doubled so that there are twice as many output pulses in a given period of time, and the mark space ratio is 1 to 1. This gives an average output voltage of half the high state output voltage, and twice the level of the previous example. In
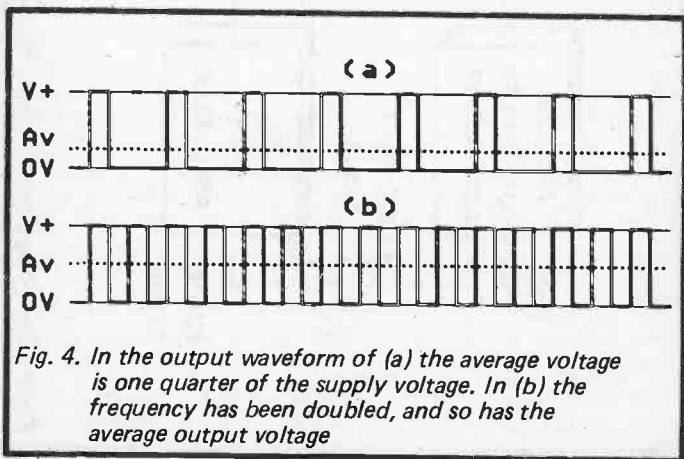
Fig. 4. In the output waveform of (a) the average voltage is one quarter of the supply voltage. In (b) the frequency has been doubled, and so has the average output voltage

other words, the monostable is not just giving a frequency to voltage conversion, but it is also providing a linear characteristic.

The output from the monostable does not itself constitute an audio frequency signal, but a lowpass filter is all that is needed in order to smooth the pulsed output into a normal audio signal. The main drawback of this very simple form of frequency to voltage conversion is that a high degree of attenuation (preferably 80dB or more) is needed at the minimum output frequency of the VCO in order to give a low ripple output. On the other hand, this system is very simple and reliable in other respects, and with modern circuits it is not difficult to produce an output filter having a suitably sharp cut off characteristic. A small amount of residual carrier signal on the output would probably not be a serious problem anyway, since the carrier is always at frequencies well outside the audio range, and any breakthrough at the output will therefore be inaudible.

This may seem to be an unnecessarily complicated way of doing things, but it does have its advantages, particularly with regard to the linearity through the system. The main point to note in this respect is that linearity through the LED and the photo-diode is totally irrelevant as they are used as switches and not in a linear mode. In theory the system has perfect linearity, but in practice a certain amount of distortion will be generated, mainly due to non-linearity in the VCO's control characteristic, but other stages of the system can also contribute significant distortion levels. Even so, a simple system can achieve a total harmonic distortion level of under 1% together with a high signal to noise ratio.

Transmitter Circuit

The full circuit diagram of the transmitter unit appears in Figure 5.

There are various integrated circuits that are suitable as the VCO, as well as numerous discrete component configurations, but for an inexpensive system the popular NE555 is the obvious choice, and although it is a very cheap device, it offers a quite reasonable standard of performance. It can be frequency modulated by coupling the input signal to pin 5, which connects to the potential divider that sets the 1/3 V+ and 2/3 V+ switching thresholds of the device. In effect the upper threshold is raised and lowered so that the time taken for timing capacitor C2 to oscillate between the two levels can be raised and lowered. This does not give the standard VCO effect in that increased input voltage gives reduced output frequency, and reduced input
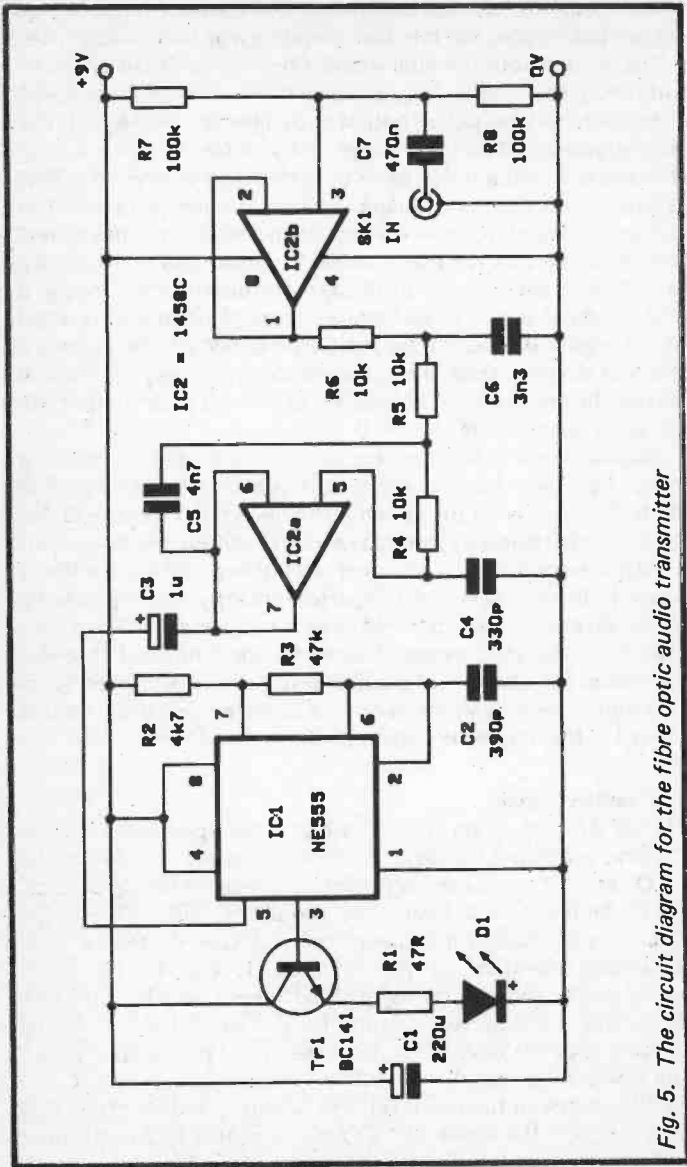
Fig. 5. The circuit diagram for the fibre optic audio transmitter

voltage results in boosted output frequency. This is of no real importance in practice, and the system stills works perfectly, but with a phase inversion of the signal through the overall system.

Tr1 is an emitter follower buffer stage which provides the high drive current needed by the LED (D1). The NE555 can actually provide quite high output currents, but it seems to be possible to set the LED current more accurately and reliably with the buffer amplifier added. R1 sets the LED current at about 40 milliamps, but as the LED is switched off for approximately 50% of the time this results in an average LED current of only about 20 milliamps. The output current can be raised or lowered by altering the value of R1 if desired, and the output current is inversely proportional to the value of this component (e.g. halving its value doubles the output current). Bear in mind that most LEDs can take a maximum average current of only about 50 to 100 milliamps though, and obtaining long range using a high output power is not a practical proposition.

The input filter is a conventional 18dB per octave type based on IC2a. The cut off frequency is at about 10kHz or so, and the system does not achieve the full audio bandwidth of about 20kHz. The centre carrier frequency is about 30kHz, and the minimum carrier frequency is close to the 20kHz upper limit of the audio range. This, on the face of it, does not give much scope for using a higher filter cut off frequency so as to give the full audio bandwidth. By making R4 to R6 (and the equivalent resistors in the filter at the receiver) 5k6 in value, the system can in fact accommodate the full audio spectrum, but it is also necessary to reduce the value of C2 to 180pF in order to raise the carrier frequency to an adequate figure (about 60kHz) to accommodate the extra bandwidth. C4 in the receiver circuit should also be reduced in value to 180pF incidentally.

This increase in bandwidth leaves the system more exposed to problems with heterodynes and general noise, and the photocells may be less effective at the higher frequency range. Good results should be obtained provided a strong signal is present at the receiver, but under marginal conditions results may be degraded to an unacceptable level. It is therefore advisable to use the values specified in the components list unless the full audio bandwidth is really needed.

IC2b operates as an input buffer stage which ensures that the filter is fed from a suitably low source impedance, and it gives the unit a reasonably high input impedance of about 50k.

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Components for Fibre Optic Transmitter (Fig. 5)
Resistors (all ¼ watt 5%)

R1	47R
R2	4k7
R3	47k
R4	10k
R5	10k
R6	10k
R7	100k
R8	100k

Capacitors

C1	220μ 10V elect
C2	390pF ceramic plate
C3	1u 63V elect
C4	330p ceramic plate
C5	4n7 polyester layer
C6	3n3 polyester layer
C7	470n polyester layer

Semiconductors

IC1	NE555
IC2	1458C
Tr1	BC141
D1	see text

Miscellaneous

SK1	3.5mm jack socket

Circuit board, case, battery, etc.

Receiver Circuit

The main receiver circuit diagram appears in Figure 6, but the output filter circuit is shown separately in Figure 7.

D1 is the detector diode, and it operates in the reverse bias mode where its leakage resistance provides a sort of light dependent resistance action. R1 is its load resistor, and C2 couples the output from the detector circuit to the input of the amplifier. This is a two stage capacitively coupled design with both stages operating in the common emitter mode. This gives a high overall voltage gain of more than 80dB. Provided a reasonably strong input signal is present, this gives a sufficiently
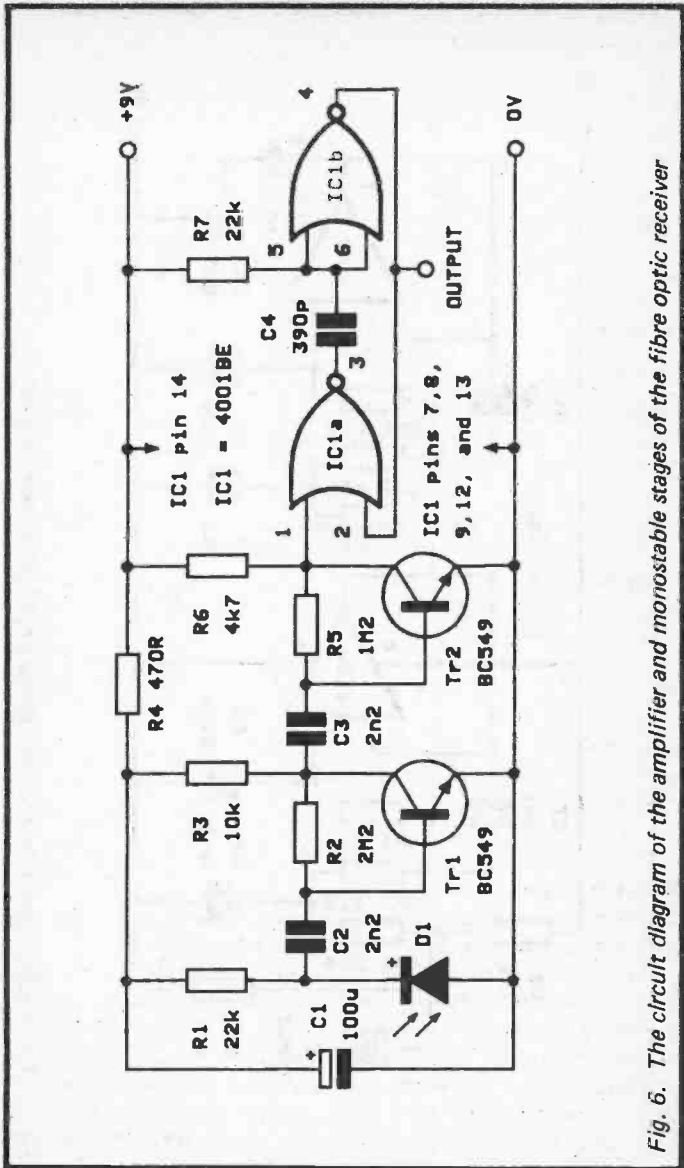
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Fig. 6. The circuit diagram of the amplifier and monostable stages of the fibre optic receiver
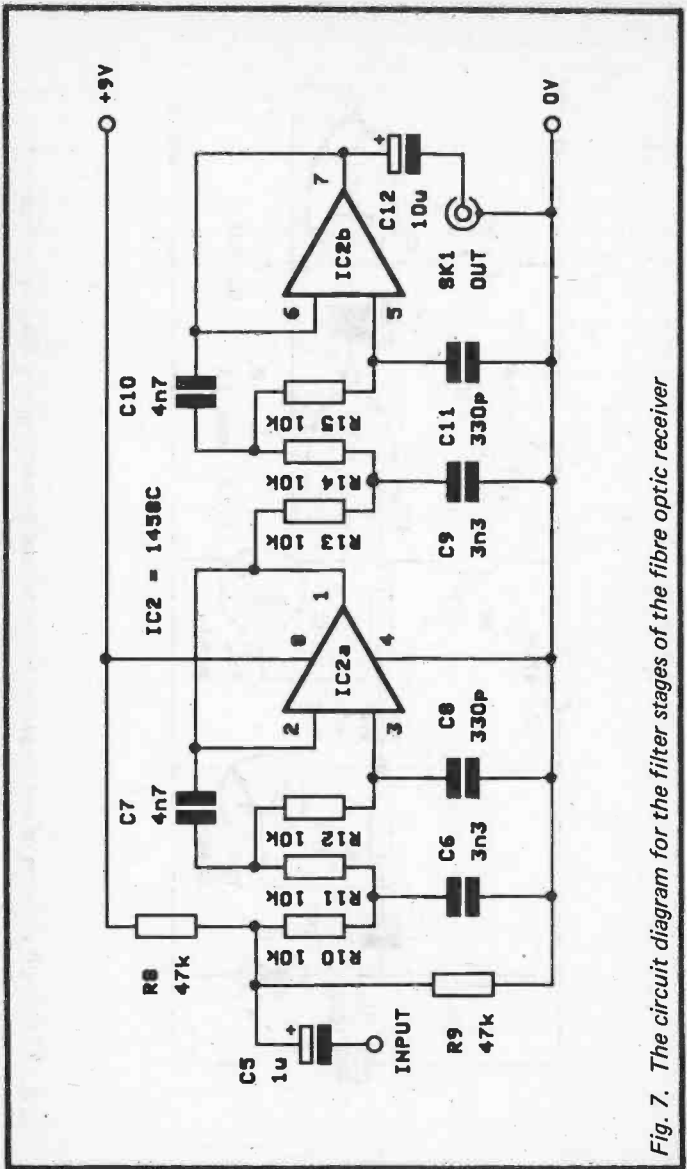
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Fig. 7. The circuit diagram for the filter stages of the fibre optic receiver

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high output voltage swing at the collector of Tr2 to drive the monostable multivibrator.

The latter is a conventional CMOS type formed from two 2 input NOR gates (IC1a and IC1b) with C4 and R7 as the timing components. The other two gates of IC1 are unused, but their inputs are tied to earth in order to prevent spurious operation of these gates.

Turning our attention to Figure 7, this is basically just two third order (18dB per octave) filters of the type used in the transmitter unit. They are connected in series so as to provide a total of six poles and an overall attenuation rate of 36dB per octave. This gives around 100dB of attenuation of the carrier signal at its lowest frequency, and an output signal which has a reasonably low carrier content.

The system will handle input voltages of up to 1 volt RMS or so without producing serious distortion, and there is slightly less than unity voltage gain through the system.

Components for Fibre Optic Receiver (Figs. 6 and 7)
Resistors (all ¼ watt 5%)

R1	22k
R2	2M2
R3	10k
R4	470R
R5	1M2
R6	4k7
R7	22k
R8	47k
R9	47k
R10 to R15	10k (6 off)

Capacitors

C1	100μ 10V elect
C2	2n2 polyester layer
C3	2n2 polyester layer
C4	390p ceramic plate
C5	1μ 63V elect
C6	3n3 polyester layer
C7	4n7 polyester layer
C8	330pF ceramic plate
C9	3n3 polyester layer
C10	4n7 polyester layer

| C11 | 330pF ceramic plate |
| C12 | 10μ 25V elect |

Semiconductors

IC1	4001BE
IC2	1458C
Tr1	BC549
Tr2	BC549
D1	see text

Miscellaneous

SK1   3.5mm jack socket
Circuit board, case, battery, etc.

Components for Data Link Receiver (Figs. 6 and 11)
Resistors (all ¼ watt 5%)

R1	22k
R2	2M2
R3	10k
R4	470R
R5	1M2
R6	4k7
R7	22k
R8 to R13	5k6 (6 off)

Potentiometer

VR1   22k sub-min hor preset

Capacitors

C1	100μ 10V elect
C2	2n2 polyester layer
C3	2n2 polyester layer
C4	390p ceramic plate
C5	3n3 polyester layer
C6	4n7 polyester layer
C7	330p ceramic plate
C8	3n3 polyester layer
C9	4n7 polyester layer
C10	330p ceramic plate

Semiconductors

IC1	4001BE
IC2	1458C
IC3	CA3140E
Tr1, Tr2	BC549 (2 off)
D1	See text

Miscellaneous

SK1	25 way D connector

Case, circuit board, wire, etc.

Construction

Construction of the unit is mainly quite simple and straightforward, and from the electrical point of view the main point to watch is that due care is taken with the layout of the amplifier in the receiver unit. This has high gain, a fairly wide bandwidth, and an input and output that are in-phase. Any stray feedback of significant proportions from the output to the input of the circuit is therefore likely to cause instability. Use a layout that keeps these two points in the circuit as well isolated from one another as possible. IC1 is a CMOS device and it consequently requires the standard antistatic handling precautions to be observed. The main precautions are to use a socket for the device, and not to plug it into circuit until the unit is in all other respects finished. Until it is time for IC1 to be plugged into the holder it should be left in its antistatic packaging (which is usually conductive foam or a plastic tube). Try to avoid touching the pins as far as possible and handle the device as little as possible when fitting it. Also avoid having any obvious sources of static electricity in the viscinity when dealing with this component.

From the mechanical stand-point the only real complication is the fibre optic connections. The prototype was constructed using a Motorola MFOE71 emitter and an MFOD71 diode detector. These are very convenient in use as they both have screw terminal type fixings for standard 2.2/1 millimetre fibre optic cable. With devices of this type about 4 millimetres of sleeving should be removed from each end of the cable so that the ends can be fully pushed home into the devices. The terminals should only be tightened just enough to hold the cable firmly in place. These components are intended for mounting directly on a printed circuit board, and a small nut and bolt (6BA or M3 bolts about 6 millimetres long are suitable) can be used to fix each one more securely to its board. Do not worry if the light output from the

emitter seems rather dim – its peak output is at about 820nm, which is well into the infra-red spectrum. Most of its output is therefore invisible to you (but there will be some output in the visible red part of the spectrum). With these two devices a range of about 20 metres should be easily attained using any reasonable quality fibre optic cable (i.e. a type having an attenuation level of about 1.2dB per metre). Of course, with the emitter having most of its output in the infra-red part of the spectrum, the cable must be a type which provides good efficiency at the relevant wavelengths.

The circuits should work well with any other emitters and photo-diodes intended for use with fibre optic cables. In most cases though, it will be necessary to obtain suitable connectors separately. In fact it is quite possible to use opto devices that are not specifically intended for fibre optic use, and a connector system can be improvised without too much difficulty. In the case of the connectors it is just a matter of using a bit of ingenuity and whatever suitable materials are to hand. I have found that grommets and heat-shrink sleeving are quite useful as the basis of a home-made optic connector system.

Any light emitting diode can be used to direct light down a fibre optic cable, but the best devices are something like a hundred times more effective than the worst. Ordinary 3 millimetre and 5 millimetre diameter LEDs do not seem to give a high enough output for even short range use, and the "high-brightness" types are much better. Best of all are the "ultra-bright" devices which often achieve their high output levels, at least in part, by using a lens which gives a very narrow beam of light. Obviously for the present application there is no disadvantage in this. 5 millimetre diameter LEDs seem to be better than the 3 millimetre types which generally have an output intensity which is only about half that of the larger devices. Some 5 millimetre diameter LEDs currently available have an output intensity of typically 250mcd at a drive current of 20 milliamps, and they are not particularly expensive.

Virtually any photodiode is suitable as the detector, but it must obviously have good efficiency at the wavelength at which the LED has its peak output, and it must be a type which physically enables the light output from the cable to be efficiently coupled into it. Something like a large area infra-red photo-diode offers less than the ideal physical characteristics, with the fibre optic cable providing only a narrow light source.
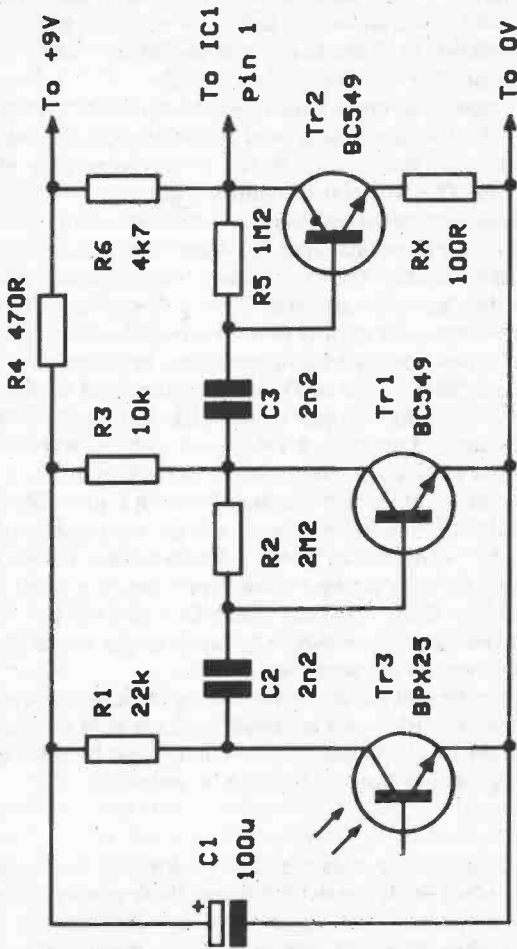
Fig. 8. The modified section of the receiver circuit to permit use of a photo-transistor

Photo-transistors having built-in lenses (such as the BPX25 and TIL81) can provide quite good results, but with these the gain of the amplifier might be excessive. The problem is really one of stray feedback to the base of the photo-transistor causing instability, and the component layout of the unit needs to be carefully designed in order to prevent problems arising, or the gain of the amplifier must be reduced slightly.

Figure 8 shows the way in which a photo-transistor can be used in the receiver. The input circuit and amplifier are much the same as before, but the detector diode has been replaced by photo-transistor Tr3. The collector to emitter leakage current is being used as a light dependent resistance with the base terminal of the transistor being left unconnected. Resistor "RX" has been added in the emitter circuit of Tr2 to introduce local negative feedback and reduce the gain of the amplifier slightly. If necessary the value of RX can be increased slightly so as to introduce more feedback and further reduce the gain of the amplifier, or if the component layout permits, the emitter of Tr2 can be connected direct to the 0 volt supply rail so that full gain is provided. Although a BPX25 is specified for the Tr3 position, a TIL81 and a BPY62 were tried in the circuit and were also found to work perfectly well.

For good results at low cost the best solution is probably to use an ultrabright LED as the emitter and a photo-transistor as the detector, in conjunction with home-made fibre optic terminations. Using a set up of this type I found a range of 20 metres could be easily achieved, and although I did not try the equipment over greater distances, a much larger range than 20 metres would almost certainly be possible.

As it stands the unit provides only monophonic operation and a one way link. By using two complete systems with a twin fibre optic cable (or two separate cables running side by side) either stereo operation or a two way link can be provided.

Data Link

When connecting computers together via RS232C or the similar (and compatible) RS423 serial interfaces there can be problems with earth loops and with radio frequency interference being radiated. A fibre optic data link avoids both problems, and it is not difficult to produce a system that can handle standard serial signals at any baud rate up to the normal maximum of 19200 baud. One way of tackling the problem would be to use the serial input signal to directly gate the transmitting LED on and off. A detector

circuit and DC amplifier would then be used at the receiver to detect the pulses of light and convert them back into a serial signal at the appropriate voltage levels.

There is a severe drawback with this method in that the output from the detector circuit would almost certainly be at a very low level unless quite expensive emitter and detector devices were to be used. This would make it difficult to obtain good reliability and long term stability. An advantage of this direct approach is that it enables quite high baud rates to be handled, and even without resorting to any particularly exotic photocells a baud rate of 200k baud or more could probably be accommodated. With the right devices baud rates of several megabaud or even several tens of megabaud can be handled. However, as normal home and business computers do not support baud rates of more than 19.2k baud, this high speed capability is largely of academic interest for most users.

Better results can be obtained using a frequency modulation system, much like the one in the audio link just described. However, with a computer data link there are only two signal levels to contend with, and the carrier wave is therefore switched between two frequencies rather than being swept up and down in frequency. This is actually the same system that is used in modems in order to provide computer communications via the telephone system, but where modems use frequencies ranging from a few hundred Hertz to a couple of kilohertz, in this case much higher frequencies can be utilized. The practical significance of this is that the maximum baud rate is not limited to 300 or 1200 baud as in the case of modems, and the system described here can comfortably handle 19200 baud.

The block diagram of Figure 9 outlines the arrangement used in a simple tone encoder/decoder optical data link, and this has obvious similarities to the audio link described previously.

A voltage controlled oscillator again forms the basis of the transmitter, with its output driving the transmitting LED (via a buffer stage if high output currents are required). The input signal is in the form of a logic signal, but RS232C links do not use normal 0 volt and 5 volt logic levels. The nominal signal levels are plus and minus 12 volts, but the minimum requirement is only plus and minus 3 volts, and the maximum (unloaded) output level is plus and minus 24 volts. With RS423 serial interfaces the signal voltages are generally somewhat lower at about plus and minus 5 volts, which is within the minimum requirements of the RS232C
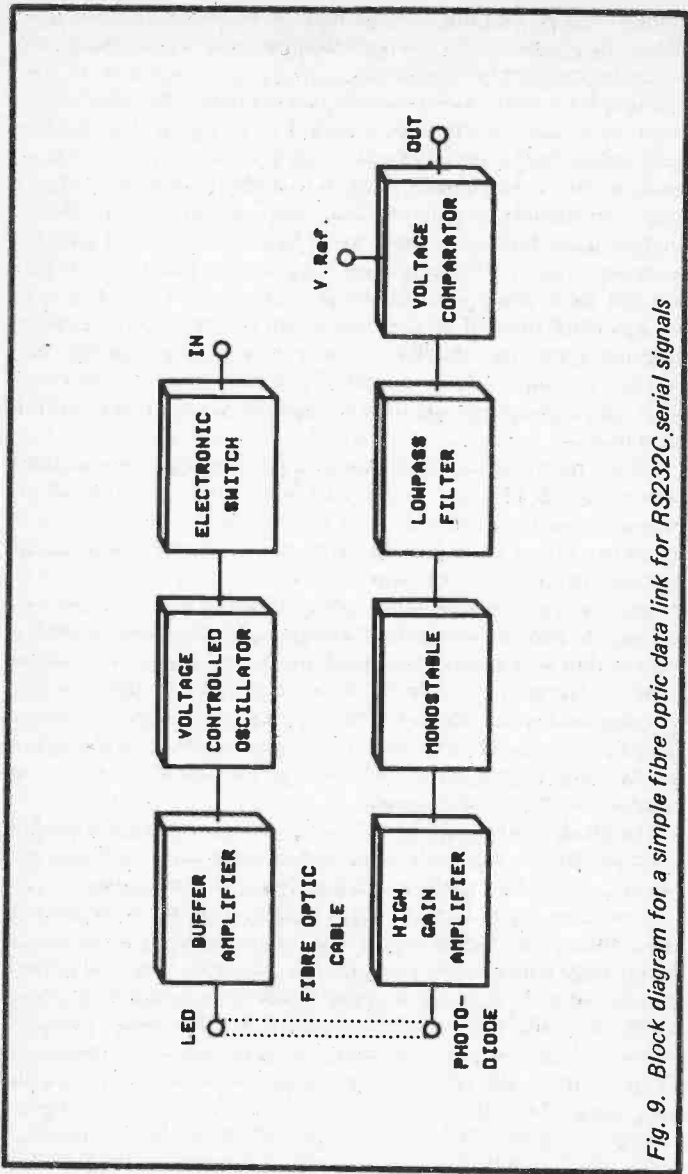
Fig. 9. Block diagram for a simple fibre optic data link for RS232C serial signals

system, and provides compatibility with it. In this case the input signal is used to drive an electronic switch which it closes when the signal goes high. The switch closing reduces the input voltage to the VCO and takes the output frequency higher.

At the receiver there is again a high gain amplifier, a monostable, and a lowpass filter. These provide an output voltage which switches higher and lower in sympathy with the RS232C input signal, but the switching speed is too low and the voltage levels are wrong, and this signal can not directly drive an RS232C or RS423 input. A voltage comparator is all that is needed to provide the speeding up and level conversion so that a fully compatible RS232C and RS423 output signal is produced. With serial signals the mark space ratio of the signal is all important, and any "smearing" of the signal is likely to give corrupted data. The reference voltage fed to the comparator must be accurately set half way between the two peak levels of the input signal so that the mark space ratio of the original signal is accurately preserved.

Transmitter Circuit
The full circuit diagram for the data link transmitter appears in Figure 10.

Like the audio link transmitter, this one is based on an NE555 operating in the standard astable configuration, and the LED is driven by way of an emitter follower buffer stage. R2, R3, and R5 are used to pull the control voltage input of IC1 slightly higher than its normal level, and this gives a quiescent output frequency of about 40kHz. Tr1 operates as the electronic switch, and it is a simple common emitter type having R1 to provide current limiting and D1 to give reverse voltage protection. With the input signal at the −12 volt level Tr1 remains cut off, and the output frequency stays at its 40kHz quiescent level. However, when the input signal goes to the 12 volt level Tr1 becomes biased hard into conduction. It then pulls the voltage at the junction of R2 – R3 – R5 down to little more than 0 volts, and consequently pulls the control voltage fed to IC1 much lower. This sets the output frequency to a somewhat higher figure of around 60kHz. The circuit is designed to operate from a 5 volt supply as most computers are capable of supplying +5 volts at the sort of currents involved here (the circuit draws about 35 milliamps of supply current).
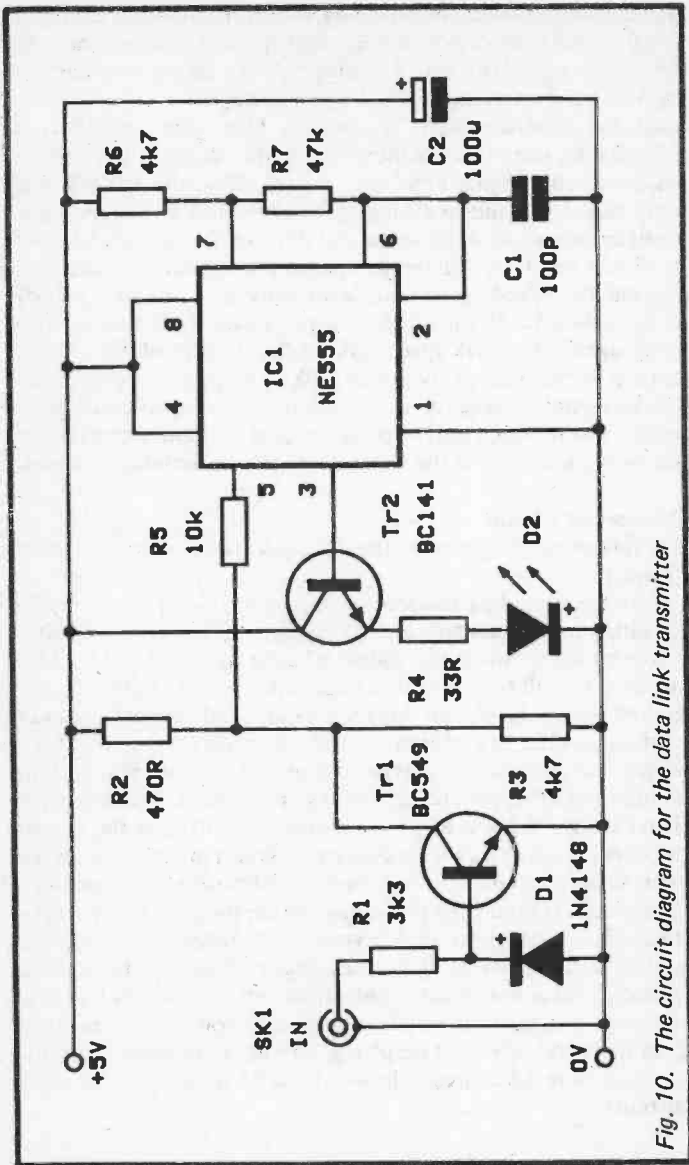
Fig. 10. The circuit diagram for the data link transmitter

Components for Data Link Transmitter (Fig. 10)
Resistors (all ¼ watt 5%)

R1	3k3
R2	470R
R3	4k7
R4	33R
R5	10k
R6	4k7
R7	47k

Capacitors

C1	100pF ceramic plate
C2	100μ 10V elect

Semiconductors

IC1	NE555
Tr1	BC549
Tr2	BC141
D1	1N4148
D2	see text

Miscellaneous

SK1	25 way D connector

Circuit board, case, battery, etc.

Receiver Circuit

The detector, amplifier, and monostable circuits used in the audio link are also used in the data link receiver. No modifications at all are required to the circuit, but note that the output signal must be taken from pin 3 of IC1 and not from pin 4 (as was previously the case). This gives a complement of the normal output of the monostable, so that the output voltage from the lowpass filter is at a low level when the carrier is at its higher frequency, and a high level when the carrier is at the lower frequency. The voltage comparator gives an inversion which gives the correct high frequency to high output voltage and low carrier frequency to low output voltage relationship, so that there is no inversion through the system as a whole.

Figure 11 shows the filter and comparator circuits. The filter is very much the same as the one used in the audio link, but in this case it must use DC coupling, and the cut off frequency must be
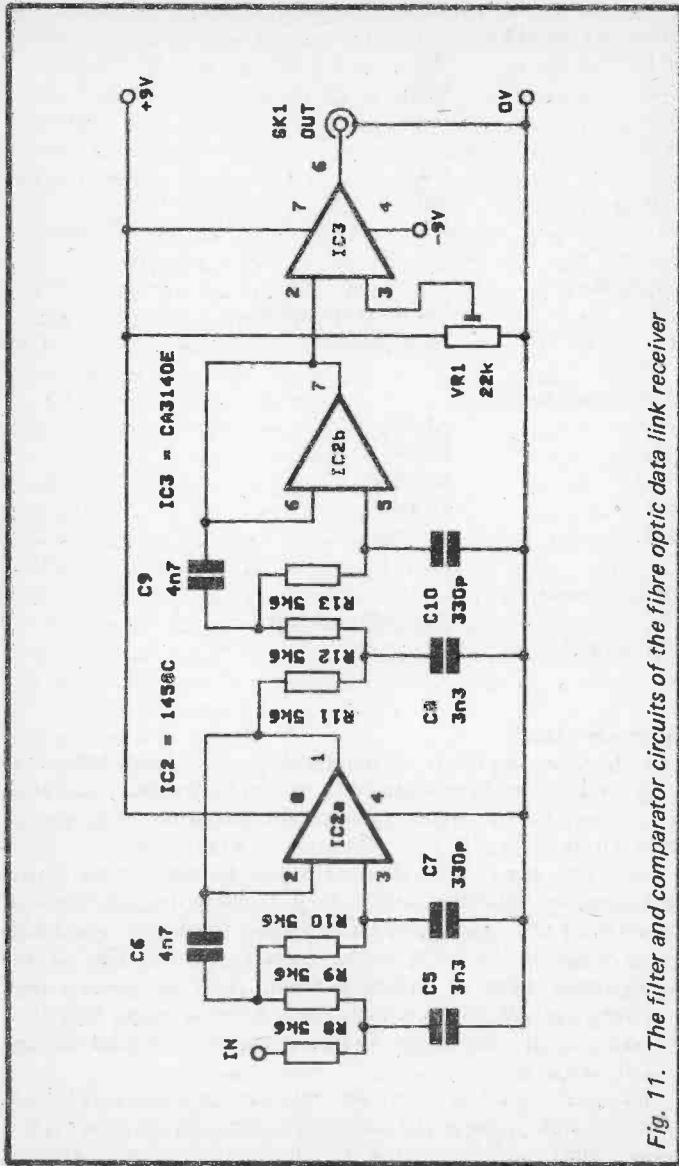
25

Fig. 11. The filter and comparator circuits of the fibre optic data link receiver

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somewhat higher. The maximum switching frequency is produced when the input signal is alternate "marks" and "spaces", and with a 19200 baud signal is 9.6kHz. The filter's cut off frequency is about double this figure, thus enabling the maximum 19200 baud rate to be comfortably handled by the system. The circuit still provides around 40dB of attenuation at the lower carrier frequency so that there is a reasonably low ripple content on the output signal.

IC3 is an operational amplifier which operates here as the voltage comparator. VR1 is connected as a potential divider across the supply rails and it provides the reference voltage for the comparator. Originally a resistor was connected between pins 3 and 6 of IC3 to provide positive feedback and a trigger action rather than a simple comparator action. However, the output of IC3 seems to switch cleanly from one state to the other without the aid of any hysteresis, and so this resistor has been omitted from the final design.

Note that IC3 is powered from a −9 volt supply and not from the 0 volt rail. This is done in order to give output levels of around −9 volts and +7.5 volts, which are sufficient to drive RS232C and RS423 interfaces properly. In practice it may well be found that the circuit will drive serial interfaces properly even if pin 4 of IC3 is simply wired to the 0 volt supply rail and the negative supply is omitted, provided only a short connecting cable is used between SK1 and the computer (or whatever). Correct operation can not be guaranteed unless a negative supply is used.

What is often the most convenient way of obtaining a negative supply rail is to derive it from the positive supply using a DC to DC converter. A circuit of this type is shown in Figure 12, and it is based on an ICL7660 integrated circuit which is specifically designed for this purpose.

The ICL7660 is basically a high frequency audio oscillator driving a DPDT electronic switch. The action of the circuit is to first connect C1 across the positive input supply where it becomes charged up, and then to connect it across the negative output supply where it discharges, but it is connected across the output with the appropriate polarity so that the non-earthy output is negative of the earth rail. This process is repeated several thousand times per second with C1 transferring power from the input supply to the output, and C2 smoothing the pulsed output signal to give a reasonably low ripple final supply output. D1 is a protection diode.
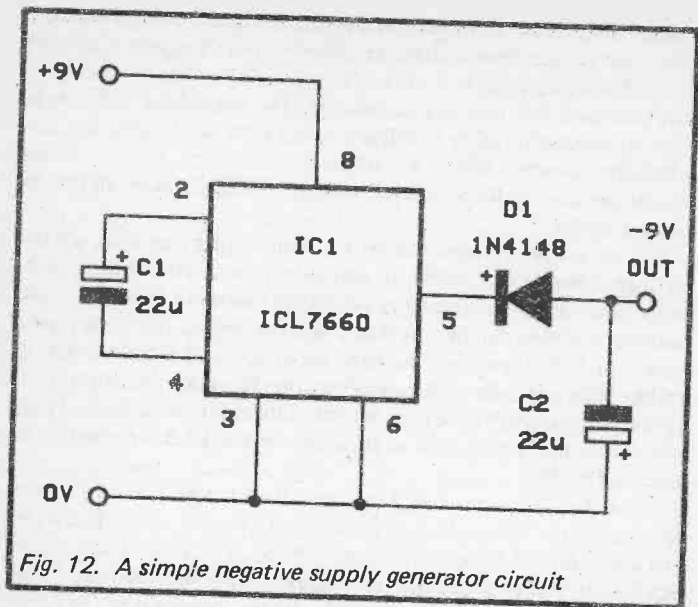
Fig. 12. A simple negative supply generator circuit

There are inevitably losses through the electronic switches, and the output voltage is not equal to the positive input voltage. The ICL7660 is quite efficient though, and the loaded output voltage should only be about 1 volt less than the input voltage, which is quite sufficient for the present application. Note that the maximum input voltage for the ICL7660 is only 10 volts, and that a nominal 9 volt supply therefore represents about the maximum safe supply voltage for the device.

Construction

The constructional notes for the audio fibre optic link apply equally to this system, except that in this case there is a second MOS device in the form of IC3, and the usual antistatic handling precautions also need to be observed when dealing with this component.

In the components lists 25 way D connectors have been specified as the input and output sockets, and these are the standard RS232C connector. Many computers that have a serial interface do not use this type of connector though, and it may well be more convenient to use something like a 5 way DIN socket, or

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whatever type of connector happens to match your computer equipment. The manual or manuals for your equipment should give connection details for the serial ports. The "signal ground" and "data output" terminals are coupled to the transmitter, while the receiver drives the "signal ground" and "data input" terminals.

As described here the system provides only simplex operation without any handshake lines being implemented. For full duplex operation it would be necessary to build up two systems with a separate fibre optic cable for each one, so that there would be a separate system to carry the signals in each direction. Handshaking could be implemented by adding further links, but with serial systems that operate over more than very short distances it is unusual to bother with hardware handshaking. Normally the system is designed in such a way that the receiving equipment can keep up with a continuous data flow so that handshaking is unnecessary, or in some cases a form of software handshaking is adopted.

Adjustment

If suitable test gear is available, couple a squarewave signal of around 10kHz in frequency and a few volts peak to peak in amplitude to the input of the system. Use an oscilloscope to monitor the output waveform of the receiver, and adjust VR1 for a 1 to 1 mark-space ratio.

Without the aid of test equipment it is still possible to set up VR1 properly. The computer connected to the transmitter unit should be set up to repeatedly send a short group of characters at the highest baud rate the system will ever need to handle. The receiving terminal should be set up so that it displays received characters on the television or monitor screen. There should be a narrow range of settings which provide uncorrupted data at the receiving terminal, and VR1 is merely adjusted to roughly the centre of this range of settings.

The system is capable of handling any standard baud rate or word format, but the transmitting and receiving terminals must, of course, be set up to use the same baud rate and word format.

Apart from use as a serial data link the system has other possible uses. It is effectively DC coupled, and it can be used for remote control purposes if used with suitable input and output circuitry. Where a number of control lines are required, one solution would be to use several of these links in parallel.

However, if more than a couple of lines are needed it would probably be better to use a single link with a UART (universal asynchronous transmitter/receiver) at each end of the system. The UART at the transmitter would be used to convert parallel data to serial data suitable for transmission through the link. The UART at the receiver would then convert the serial data back into parallel form. Up to eight lines could be carried by a single link using this system.

Light Pen

Although using a fibre optic cable in a light pen application might seem to be just a gimmick with only disadvantages and nothing definite in its favour, a fibre optic light pen is really a perfectly practical device. It is admittedly likely to be more costly than a conventional equivalent, but the cost of a short piece of fibre optic cable plus a suitable detector and optic connector system is not that large these days.

In its favour this method has simplicity of the "pen" construction and excellent screen resolution. Construction of the so called "pen" (i.e. the part which is held and aimed at the screen) is very simple since it does not need to contain any electronics, not even the photocell. The latter is contained in the case which holds the main electronics, and the light from the screen is guided to it by the fibre optic cable. If desired, an old pen case or something of this nature can be fitted at the end of the fibre optic cable in order to make it easier to hold, but it is not needed for any other reason.

The high degree of precision is obtained due to the narrow filament diameter of the cable which, as explained previously, is normally only some 1 millimetre in diameter. This, coupled with the fact that only light running almost parallel to the end of the cable will be efficiently coupled through it, makes the unit sensitive over only a very small area of the screen. This is obviously important if the light pen is to be used in drawing or other applications which require a high degree of resolution, although for something like menu selection it is of somewhat less significance. It is possible to obtain a high degree of resolution from a conventional light pen, but the built-in lenses of most photocells are not good enough to give really good results. Improved performance consequently requires the use of an extra lens or something like a short but narrow piece of tubing to reduce the pen's angle of view. Using a fibre optic cable is almost

certainly a better and easier way of doing things, as well as giving the project more interest value.

Fundamentals

Although many people seem to imagine that a light pen produces a light beam, it does of course detect light. When used in the most basic way the pen simply indicates whether the pen is aimed at a bright or dark part of the screen, rather than indicating an absolute position on the screen. A basic set up of this type is rather limited in scope and is a bit crude even for simple applications such as menu selection. On the other hand, it can be made to operate in conjunction with virtually any spare digital input on the computer.

Many computers have a special light pen input (usually on the expansion bus or a joystick port rather than at a special light pen port), and with these it is normally possible for the pen to indicate an absolute screen position, although not necessarily with any great precision or reliability. This depends on the design of the light pen hardware within the computer, and some are very much better than others. Also, the degree of precision is affected by the resolution of the computer's screen, and again, some machines are capable of much higher resolution than others.

It is possible for the light pen to indicate a particular screen position due to the way in which the display is produced. It operates in the general manner shown in Figure 13, and the picture is produced by a line scanning process. In Figure 13 the solid lines represent the lines scanned by the electron beam of the cathode ray tube (CRT) while it is activated. The dotted lines show the flyback paths, and during these periods the beam is blanked so that nothing is produced on the screen. The general action then, is for the beam to start in the top left hand corner of the screen, and to scan across and down the screen in a series of lines until it reaches the bottom right hand corner. The beam is then taken back to the top left hand corner, and the process is repeated indefinitely.

The beam is not simply switched full on all the time it is being scanned along a line, but is modulated in intensity so that the brightness of the line is varied. In practice there are hundreds of lines and they are closely packed together. At normal viewing distances the individual lines can not be seen, and they merge together to form the picture. Close inspection of most monitor or
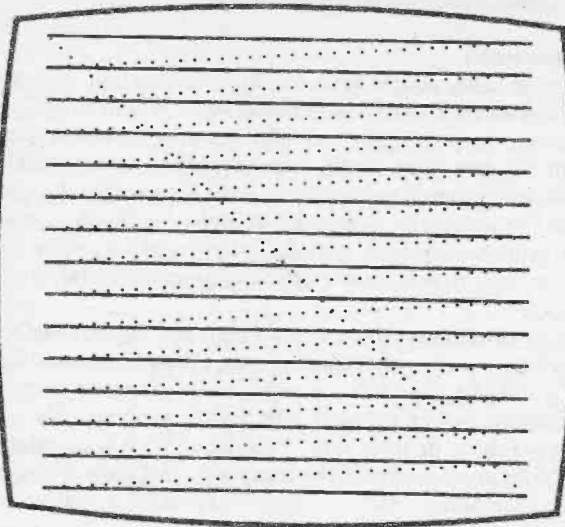
Fig. 13. A computer display is generated using a scanning process (solid lines represent the scans and the dotted lines are the flyback periods)

television screens will reveal the lines though. With a normal television picture a system called "interlacing" is used, and this means having every other line scanned on the first pass over the screen, with the remaining lines being scanned on the next pass. Fifty scans of the screen are completed each second, but as two scans are needed per complete picture, there are only twenty five pictures per second. The point of interlacing is that it gives a more flicker-free picture.

If a light pen is held over a part of the screen that is reasonably bright, this will not result in its output triggering to the appropriate logic state and staying there until the pen is removed from the screen. The scanning process produces what is really a spot of light that is moved across and down the screen, and although the scanning action is too fast for the human eye to perceive, the light pen will detect the spot as it passes through its

field of view. The light pen therefore produces an output signal that consists of fifty brief output pulses per second.

The video circuits of the computer produce the timing signals that control the scanning. Some extra hardware in the video circuits is used to provide a counter of some kind, and a typical arrangement would be to have a counter that is incremented each time a new line scan is started, and another which runs from (say) 0 to 255 as each line scan progresses. The pulses from the light pen are used to halt the count, and the numbers in the counters then give X and Y co-ordinates which indicate the screen position of the light pen. Note that the counters do not always give X and Y co-ordinates directly, and with the popular 6845 video controller chip for example, the numbers in the two light pen registers form one large number and not separate co-ordinates. In this case the number increases as the spot progresses from the top left hand corner of the screen to the bottom right hand corner. Obviously some simple mathematical manipulation is all that is needed to convert the single large number into separate X and Y co-ordinates, but the exact formula needed will vary from one screen mode to another.

Circuit Operation

Light pens can be extremely simple, as can be seen by refering to the the circuit diagram of the fibre optic light pen which appears in Figure 14.

D1 is the photocell and is a photo-diode operated in the reverse bias mode. On the prototype an MFOD71 diode was used in the D1 position, and this is a good choice as it has a built-in fibre optic cable connector (of the screw terminal type) and reasonable sensitivity at visible light wavelengths. However, any photo-diode which offers good sensitivity over the visible light spectrum and can be efficiently coupled to a fibre optic cable should be equally suitable. The current flow through D1 when the spot of light is detected is likely to be quite low at no more than a few microamps, and possibly not even as much as this. Its output is therefore coupled to a high gain DC coupled amplifier which uses both Tr1 and Tr2 as common emitter stages. VR1 enables the sensitivity of the pen to be set at a suitable level. The output pulses at the collector of Tr2 are fed to two inverting Schmitt triggers wired in series, and these provide normal 5 volt logic compatible (antiphase) outputs. Output 1 is normally high and pulses low when the spot of light is detected – Output 2 is normally low and
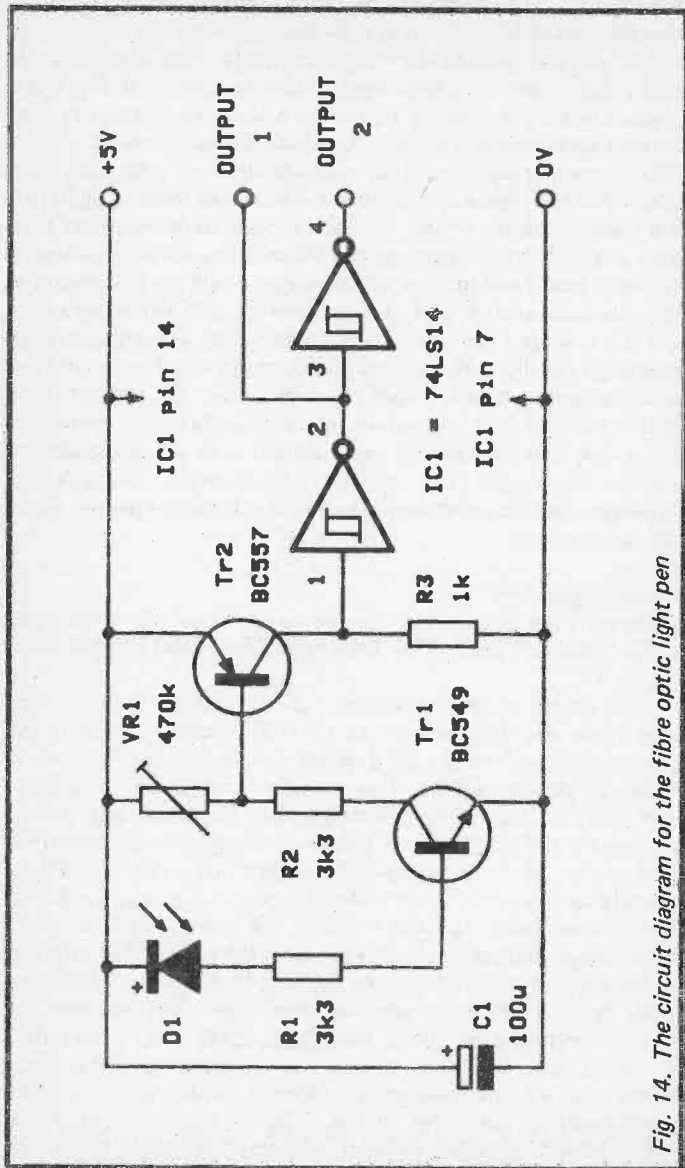
Fig. 14. The circuit diagram for the fibre optic light pen

pulses high when the light spot is detected. The manual for your computer might not actually state which particular type of signal is required, and it is then a matter of using trial and error to determine which one gives correct operation. With all the light pen inputs I have encountered it is only possible to obtain good results if the input signal is a pulse of a particular polarity.

The circuit of Figure 14 is compatible with most computers, but in some cases it is desirable or even essential to have an open collector output stage. This can be the case when the input line that is used for the light pen input is also used for some other purpose, such as monitoring the keyboard. Driving the light pen from an ordinary logic output can result in the keyboard reading process being disrupted, with the wrong characters being returned when certain keys are operated, or some keys being "frozen" out. An open collector output stage can easily be added to the light pen circuit, and the necessary additional circuitry is shown in Fig. 15. This circuit will almost certainly need to be driven from Output 2 of the original circuit, so that the output transistor is normally switched off, and is briefly switched on by each output pulse from the light pen circuit. No pull-up resistor should be needed at the output as this will presumably be already present in the computer.
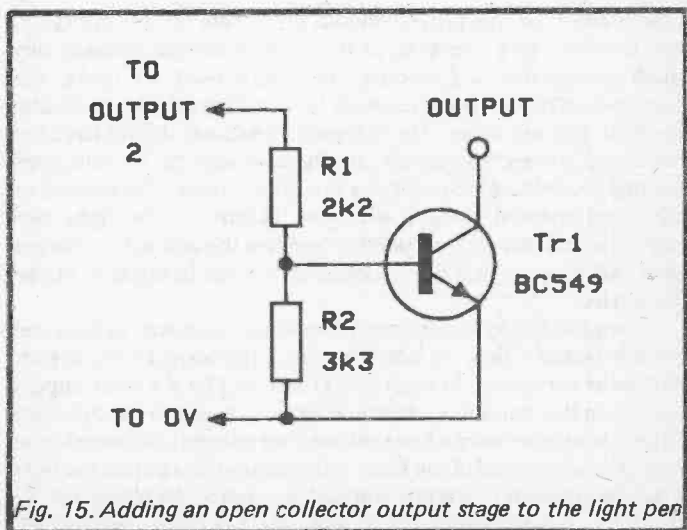

Fig. 15. Adding an open collector output stage to the light pen

Components for Light Pen (Fig. 14)
Resistors (all ¼ watt 5%)

R1	3k3
R2	3k3
R3	1k

Potentiometer

VR1	470k sub-min hor preset

Capacitors

C1	100μ 10V elect

Semiconductors

Tr1	BC549
Tr2	BC557
IC1	74LS14
D1	see text

Miscellaneous
Case, about 1 metre of fibre optic cable, wire, etc.

Construction

Construction of this project should offer little of real difficulty, and it should be possible to fit the electronics into virtually any small plastic case. Obviously the plug used to make the connections to the computer must be varied to suit the particular machine you are using. The computer's manual should have the necessary connection details, or there should be an advanced manual available which contains this information. The manual or advanced manual should also give details of the light pen registers, and there is little point in building the unit unless you are sure that you can find the information needed in order to utilize the device.

As explained earlier, it may be necessary to resort to trial and error in order to find out which output is the correct one for your particular computer. In most cases there will be a +5 volt supply output on the computer which can be used to power the light pen (which consumes only a few milliamps of current). Remember to prepare the free end of the fibre optic cable so that so that the light from the screen is efficiently coupled through to the photo- diode. It is by no means essential to fit some form of hand grip onto the

free end of the cable, but as fibre optic cable is quite narrow it is advisable to do so as it can be awkward to hold for long periods of time. There should be no difficulty in fitting something like the case of an old ball-point onto to end of the cable.

The resolution provided by the pen is extremely good, and compares very favourably with the conventional light pens that I have encountered. Unfortunately, the supporting hardware in some computers is less than 100% reliable, and this can result in the occasional "glitch" with a totally wrong screen position being indicated. This can usually be effectively combatted in the software, with perhaps several readings being taken and averaged, with any that are well away from the average being deleted and a new average then being taken in order to determine the final answer. By this means it is usually possible to obtain accurate and consistent results.

With VR1 set at about half maximum value the light pen will probably work quite well, but it is worth experimenting with various settings to determine which one gives the best overall level of sensitivity and accurate results. One final point to bear in mind is that the the pen detects light, and can therefore only read a screen position if the screen is reasonably bright at that position.

Chapter 2

PASSIVE IR DETECTORS

Although devices for passive infra-red detection have been in existence for a number of years, it is only relatively recently that they have become readily available to amateur electronics enthusiasts. So also have the special lenses for use with these devices, and quite high performance units can now be produced using what are really very simple circuits comprised of just a handful of components. These devices certainly represent an interesting aspect of electronics and have numerous possible uses including such things as burglar alarms, automatic doors, and automatic lighting.

Basics

It would perhaps be as well to start with an explanation of just what is meant by a "passive" infra-red detector. This is a device which merely detects infra-red radiation produced by a source of some kind, but which will normally be a person. In other words it is a circuit which is designed to detect body heat, and then to operate an alarm generator (or whatever). It differs from active infra-red detectors in that they transmit an infra-red signal of some kind, and detect anything that interferes with this signal in the appropriate way. In most cases units of the active type transmit a beam of infra-red pulses, and a receiver unit picks up these pulses and holds-off an alarm generator while they are received. If someone should break the beam so that the pulses no longer reach the receivers the receiver circuit activates the alarm. There is a alternative and much less common type of active sensor, and this is the type which transmits a pulsed infra-red beam and detects the presence of objects by the infra-red signal that they reflect back to a receiver unit mounted alongside the transmitter. However, units of this type generally have very restricted ranges and respond with reasonable sensitivity over only a very restricted area. The broken beam type circuit gives very good range (as much as 100 metres being achievable without having to resort to anything too elaborate), but has a very narrow corridore of coverage. Passive infra-red detectors, with the aid of a suitable lens, can be made to cover quite a wide area, making them suitable for many everyday applications where active detectors are of little practical use.

Normal semiconductor infra-red devices work in the part of the light spectrum which is close to the red end of the visible light spectrum, or in terms of wavelength at around 850 to 950nm. These are virtually useless for passive infra-red detection where much longer wavelengths are involved (around 1 to $20\mu m$), and devices designed specifically for this application are required in order to obtain really good results. These devices have little in common with ordinary photodiodes and the like, and they are made from a material such as lead zirconate titanate and consist of a slice of the material with electrodes on opposite faces. When subjected to heating the device produces small opposite electrical charges on the electrodes, and this effect is similar to the more familiar Piezo electric effect which is utilized in such things as crystal microphones and ceramic pick-ups, and which generates a similar electrical signal when subjected to physical distortion. Like a ceramic pick-up, the signal produced by a passive infra-red sensor, or "pyro" sensor as they are popularly known, is at a high impedance.

Practical pyro sensors are usually more than just the sensing element, and generally include a source follower stage to give the device a relatively low output impedance. Figure 16(a) shows the
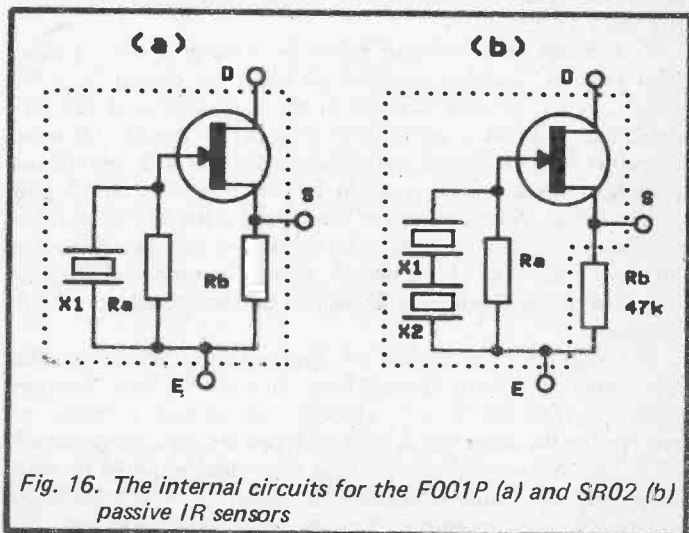

Fig. 16. The internal circuits for the F001P (a) and SR02 (b) passive IR sensors

circuit for the F001P device, which has a single sensor, a junction gate field effect transistor to operate as the source follower, and built-in gate bias and source load resistors (Ra and Rb respectively). Some devices use a different arrangement, and Fig.16(b) shows the internal arrangement for the SR02 (or the almost identical SRA02). This has two sensing elements connected in series, but this is not done, as one might think, in order to simply double up on the output voltage from the device. In fact the two sensing elements are connected in anti-phase, so that rather than adding together to give a stronger output, the two signals actually cancel one another out and give zero output.

This might seem to be completely pointless, and to understand the reason for doing this you must first understand the basic way in which these devices are operated. They are not simply used to detect the presence or absence of body heat, and although operation of this sort would be possible, it would give poor results in practice. There are two problems with this system, and one is simply that the shift in the DC output level produced by the sensor when body heat is detected is likely to be extremely small, even at short ranges. This gives problems in detecting the shift without spurious triggering of the circuit being caused by drift rather than heat being detected. The second problem is that of ambient heat producing signals that can produce spurious triggering and swamp the wanted signals.

Passive infra-red detectors minimise these problems by using high gain AC coupled amplifier to boost the output from the sensor, but it is then changes in the infra-red level that are detected, and not a continuous high level. Passive infra-red detectors are consequently movement detectors, and they will not respond to someone who is within the monitored area but keeping perfectly still. A lens system of some kind is used to convert the movement of someone within the monitored area into a burst of infra-red radiation which sweeps across the sensor. This is an aspect of things which we will consider in more detail later in this chapter.

Returning to the subject of dual opposed sensors; under quiescent conditions the output from the sensors is zero, since any infra-red received by one element will almost certainly be received by the other one as well, and their output voltages cancel each other out to give zero volts (or a very low potential anyway, as perfect cancelling is unlikely in practice). When someone moves across the monitored area they cause a beam of infra-red

radiation to be swept across the sensing elements, with first one and then the other being subjected to the beam. This prevents any significant cancelling of the two output signals occuring, and results in first one sensor providing an output pulse and then the other providing a signal. The two signals follow one after the other with no real delay between them, and they are of opposite polarity, so that they effectively combine to produce a single output pulse of double the amplitude produced by a single sensing element.

Dual opposed sensors therefore have good immunity to background infra-red and a relatively strong output signal when activated. They are comparatively expensive though.

The passive infra-red circuit described here will work with a wide range of pyro sensors, but obviously some will work better than others, and the exact level of performance obtained depends on the quality of the pyro sensor used. It is even more dependent on the quality of the optical system though, and it is primarily this factor which determines how well or otherwise the system will function in its intended application.

An important point to note is that some pyro sensors have an integral source load resistor whereas others require a discrete resistor. The F001P has a built-in source load resistor, but as shown in Fig.16(b), the SR02 requires an external 47k load resistor (as do the SRA02, the SSC10, the RPY97, and most other pyro sensors). Where appropriate this resistor must be included, and the passive infra-red detector circuit will not work at all if it is omitted and no internal load resistor is present.

Pinout diagrams for the F001P and SR02/SRA02 devices are shown in Figure 17. The F001P has an unusual encapsulation which consists of a retangular plastic housing with the three leadouts coming from the base, and the window is situated at at the front of the device. The leadouts are long enough to permit the device to be mounted horizontally if necessary. The SR02 and SR02A are in a standard three lead TO-99 type metal encapsulation, but with a large rectangular window in the top of the casing (Figure 17 shows a top view of this device, as indicated by the position of the tab). Note that the window of dual element types is rectangular rather than round or square, and that in order to obtain good results the device must be orientated correctly. The device must be arranged so that the beam of infra-red radiation is swept from one element to the other, which means that the device will normally be positioned so that the window is
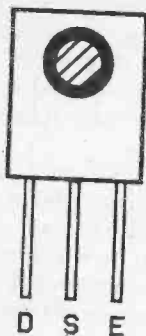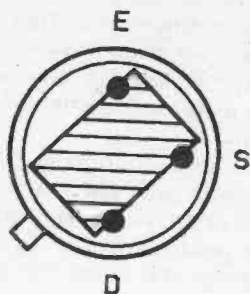
Fig. 17. Pinout details for the F001P and SR02

horizontal and not vertical. Alignment does not seem to be very critical though, and errors as large as 45 degrees still seem to give good results. With a 90 degree error though, the system would probably give only very restricted range, if it worked at all.

Detector Circuit

The circuit diagram for a simple passive infra-red detector is shown in Figure 18.

IC1 is the pyro sensor, and it has been assumed here that an F001P will be used, but the only modification required for an SR02, SRA02, or similar device, is to add a 47k load resistor from the "S" terminal to the 0 volt supply rail.

IC2a provides the first stage of amplification, and this device is operated in the non-inverting mode. It has a slightly unusual feedback circuit, and the point of this arrangement is to give a combination of high gain and good low frequency performance without the capacitors in the circuit taking a very long time after switch-on to reach their normal working charges. This type of feedback network is actually quite common in RIAA pre-amplifiers, but it is perhaps of even more benefit in this application where the circuit must have a good response well into
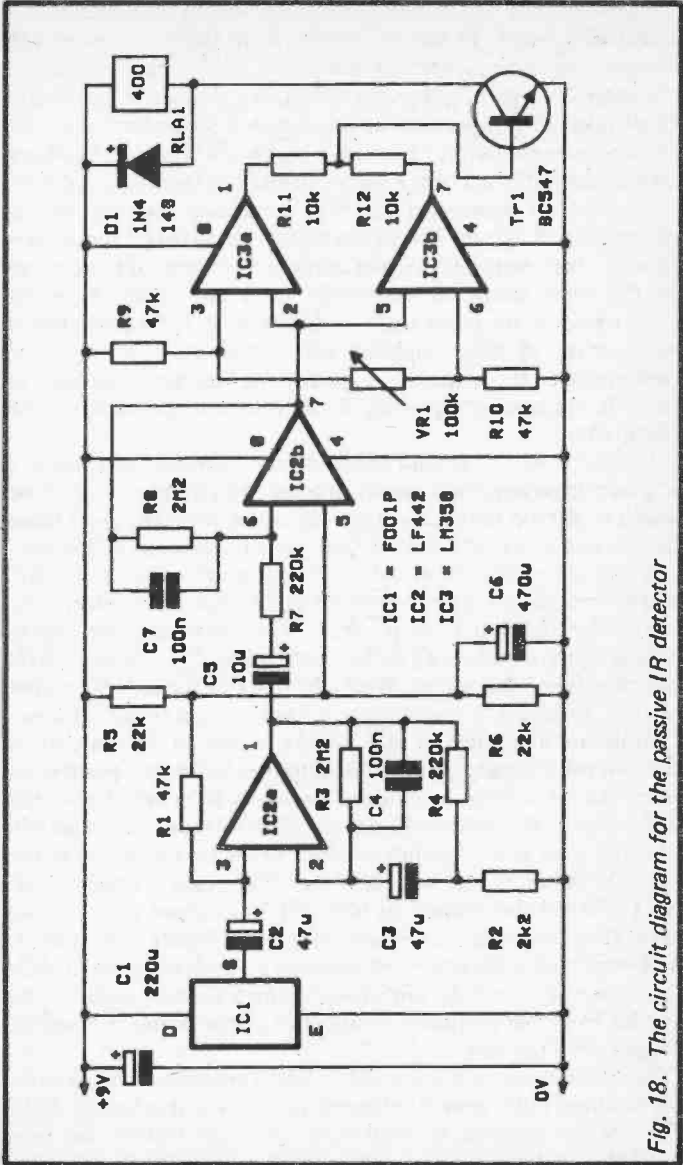
42

Fig. 18. The circuit diagram for the passive IR detector

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the sub-audio or "infra-bass" part of the sound spectrum as it is sometimes called. In fact the signals from the pyro sensor will normally be at frequencies of around 0.5 to 2Hz, making the use of relatively large coupling and decoupling capacitors necessary. It still takes several seconds for the circuit to settle down and start to operate properly, but with a more simple feedback arrangement it could take a matter of minutes instead of seconds.

C4 severely attenuates the high frequency response of the circuit, as well as quite low frequencies come to that. Frequencies of more than about 2Hz are not produced by the pyro sensor, and so this very restricted bandwidth does not adversely affect sensitivity. On the other hand, it does greatly reduce the output noise level of the amplifier and helps to give improved performance. In particular, it greatly reduces the possibility of spurious triggering, especially if the circuit is operated at high sensitivity.

IC2b acts as the second stage of amplification, and this is a standard inverting mode circuit. It again has a frequency response which is given a 6dB per octave roll-off at frequencies of more than a couple of Hertz, with C7 providing the filtering in this case. The circuit operates from a single 9 volt supply rail with R5, R6, and C6 providing a centre tap on the supply rails for bias purposes.

The output from IC2b is normally at about half the supply potential, but it will swing slightly either side of its quiescent level due to noise on the output. When the unit is activated, the output of IC2b produces a much larger output voltage swing. The two operational amplifiers of IC3 are connected to form a sort of window discriminator, and if the output of IC2b goes positive by more than a certain amount the output of IC3a switches to the high state. If the output of IC2b goes low by more than a certain amount, then IC3b's output switches to the high state. In either case Tr1 is biased into conduction and the relay is switched on. VR1 controls the amount by which IC2b's output voltage must shift away from the quiescent bias level before the relay is activated, and it therefore operates as a sensitivity control. It is important not to set the sensitivity too high because noise on the output from the amplifier would then cause frequent spurious triggering of the unit.

D1 is the usual protection diode which suppresses any reverse high voltage pulse generated across the relay as it is switched off. Do not be tempted to omit this – semiconductors are very intolerant of high voltages, and without D1 the unit could easily

sustain a lot of expensive damage. The quiescent current consumption of the circuit is quite low at only about 2.5 milliamps, but it is substantially higher than this when the relay is activated. The exact current consumption depends on the coil resistance of the relay, and is about 25 milliamps with a 400 ohm type. The circuit will operate with any relay that has a coil resistance of about 200 ohms or more and which will operate reliably from a nominal 9 volt supply. Obviously the relay must have contacts of the appropriate type and of adequate voltage/current rating, but the requirements here are totally dependent on your intended application for the unit.

Components for Passive IR Detector (Fig. 18)
Resistors (all ¼ watt 5%)

R1	47k
R2	2k2
R3	2M2
R4	220k
R5	22k
R6	22k
R7	220k
R8	2M2
R9	47k
R10	47k
R11	10k
R12	10k

Potentiometer

VR1	100k lin

Capacitors

C1	220μ 10V elect
C2	47μ 16V elect
C3	47μ 16V elect
C4	100n polyester
C5	10μ 25V elect
C6	470μ 10V elect
C7	100n polyester

Semiconductors

IC1	F001P (see text)
IC2	LF442

IC3	LM358
Tr1	BC547
D1	1N4148

Miscellaneous

RLA1   Relay with coil suitable for 9 volt and coil resistance of about 200R or more (contacts and ratings as required)

Fresnel lens (see text), circuit board, control knob, case, etc.

N.B.

The F001P was available at the time of writing from Maplin Electronic Supplies Ltd., P.O. Box 3, Rayleigh, Essex SS6 8LR.

The SRA02, and SSC10 pyro sensors, the CE24 fresnel lens, and window material were available at the time of writing from Chartland Electronics Ltd, P.O. Box 83, Cobham, Surrey KT11 2QB.

Construction

As far as the electronics are concerned there is little of difficulty in building this unit. Although it has very high gain there is relatively little risk of instability as the amplifier section of the circuit has such a limited bandwidth. Care to avoid earth loops should be taken though, and the supply needs to be reasonably stable if the unit is to give reliable results.

The mechanical side of construction is far less straightforward as there is the optical system to contend with. Where a fairly large area is to be monitored a fresnel lens designed specifically for this application offers the best performance, and a range of up to about 10 metres over a wide angle of coverage is possible. The basic set up used with a fresnel lens is shown in Figure 19.

The lens is a piece of flexible plastic which is positioned in front of the pyro sensor and given the appropriate degree of curvature. The lens is effectively a large number of lenses combined in one unit, or "multi-faceted" as it is usually termed. Its basic effect is to give "blind" areas where the unit is very insensitive, with areas of high sensitivity in-between them. This breaks the monitored area up into a number of zones of high and low sensitivity, and there is typically two dozen or more zones of high sensitivity.

Although I stated earlier in this chapter that passive infra- red

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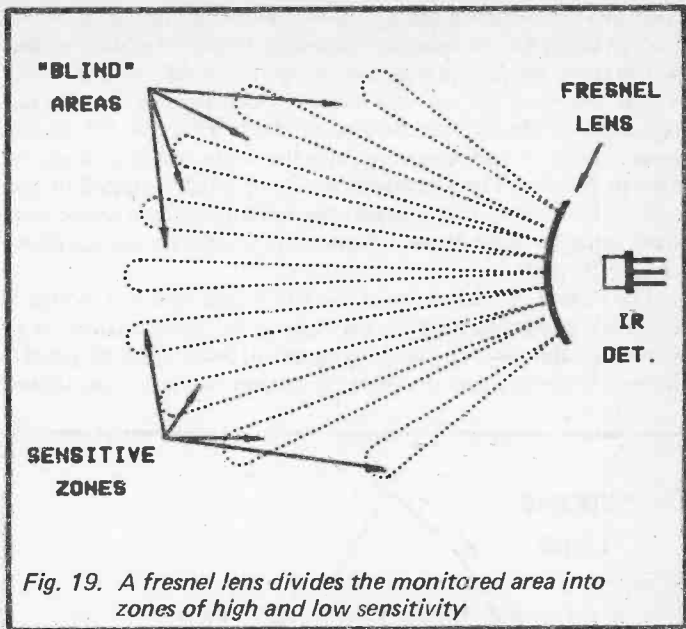
Fig. 19. A fresnel lens divides the monitored area into zones of high and low sensitivity

detectors are a form of movement detector, not just any form of movement will do. In common with most types of movement detector they are very sensitive to movement in one direction, while being almost oblivious to movement at right angles to this. In the case of a passive infra-red detector it is movement across the monitored area that is most readily detected, as the person detected by the unit then moves rapidly from a sensitive zone to an insensitive one, on to another sensitive zone again, and so on, giving a series of strong output pulses from the pyro sensor. In theory, anyone moving straight towards the sensor will not cross from one zone to another and will not activate the unit. In practice this seems to produce sufficient variation in the infra-red level received by the pyro sensor to trigger the unit, although the range is very much less for movement in this direction. Note that the directions which give optimum and minimum sensitivity are the opposite to those of Doppler shift type detectors, such as the popular ultrasonic detectors used in burglar alarm systems. If you are used to dealing with Doppler type detectors you will need to

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bear this fundamental difference in mind when deciding on the best position for an infra-red detector. Correct sighting of the sensor is essential if the unit is to give good results, and with (say) a unit intended for use in a system which provides automatic operation of doors, the obvious method of having the sensor above the door and aimed out into the room would actually be very ineffective. The unit would work much better placed to one side in the room so that anyone approaching the door would pass from zone to zone several times, and would almost certainly trigger the unit.

The fresnel lens I have used is a CE24 type which, although a relatively inexpensive type, provides good performance. It is virtually a flat piece of plastic as supplied, and it must be given a form of mounting that provides the correct curvature. As shown
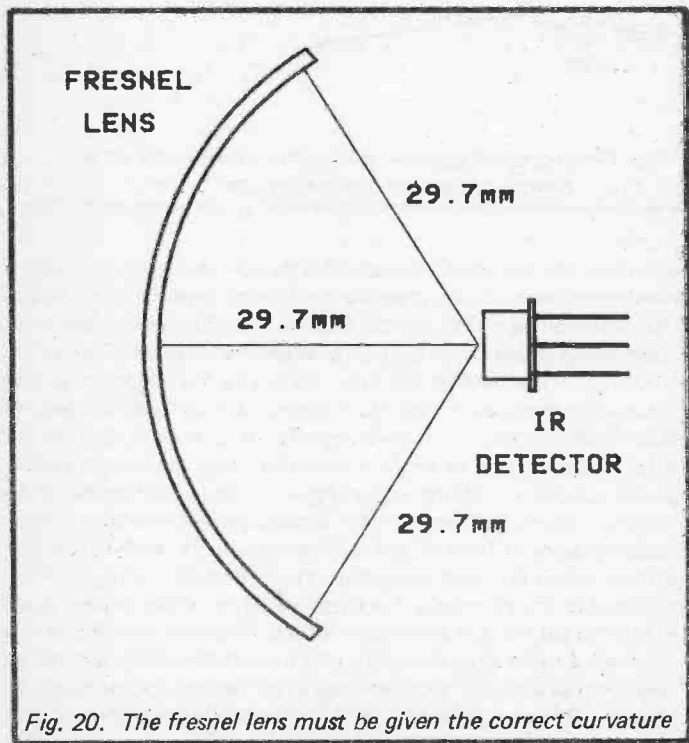
Fig. 20. The fresnel lens must be given the correct curvature

in Figure 20, the ideal curve is one which keeps the distance from the window in the pyro sensor to the fresnel lens at 29.7 millimetres. The sensor should be positioned so that it is about half way up the lens, and remember that with dual element sensors the window and the lens should be aligned properly.

If you are trying to stretch the range of the system to its limits it is important to have the lens and pyro sensor mounted as accurately as possible. In practice there does not seem to be any great loss of performance if small inaccuracies are allowed to creep in, and quite good results often seem to be produced if the mounting of the lens and (or) the pyro sensor are far from totally accurate. The importance of having the lens and sensor accurately placed therefore depends largely on the level of performance required, but probably few constructors have the tools to permit precision mounting of these two components anyway.

I found that good results could be obtained by making a cutout in the front panel of the case about 48 millimetres wide by 45 millimetres high, and then bevelling the side edges of this. The idea here is to glue the lens in place on the bevelled edges, with the lens having been curved to enable it to fit into place. It is easily glued in place using a good quality general purpose adhesive, and as the lens tries to uncurl it tends to force itself tighter into the cutout, so that the glue has to provide little adhesion initially in order to prevent the lens from falling out of place while it sets.

Note that the lens is designed to have its smooth surface facing outwards. It is advisable to use small pieces of thick card or sheet plastic to fill in the semicircular areas at the top and bottom of the lens. Otherwise these gaps could encourage turbulence around the pyro sensor which could result in spurious triggering of the unit. The pyro sensor must be fitted centrally behind the lens and 29.7 millimetres (or thereabouts) behind it, and this is a matter of designing the unit so that the circuit board can be positioned to bring the sensor to the correct place. If you are using the F001P this will probably be easier if it is mounted horizontally. Spacers and washers over the board's mounting screws can be used to set the sensor to lens distance correctly.

An alternative method is to shape two pieces of sheet plastic material (or even just copper laminate board) so that they can be mounted on the printed circuit board, and the lens can then be glued in place over them so as to give the correct curvature. Of course, things must be arranged so that the pyro sensor fits on the

right part of the board so that it is brought centrally beneath the lens, and it should be mounted at the appropriate height above the board to give the correct sensor to lens distance. This method is a somewhat neater way of doing things, but when trying this I found it to be less easy than one would expect. There is no real problem in shaping the end cheeks with the correct 29.7 millimetre curve, but I found it quite difficult to get the whole assembly to fit together strongly and reliably. It requires the use of top quality adhesives plus a fair amount of skill and patience.

With this second method a large cutout is still required in the case in order to provide the sensor and lens with a window for the infra-red radiation to pass through. In order to give the unit a neat finish some window material can be glued in place behind the cutout, and special window material for this application is available. Ordinary window material for use with LED displays etc. is unlikely to be much use in the present application.

Shutter

Where a range of only a few metres is required it is not necessary to resort to a lens at all, and simple shuttering can be used to give zones of high and low sensitivity. Actually, where high sensitivity is not needed it is probably best not to use a lens as apart from unnecessary expense it could also result unwanted triggering of the unit by people who should be out of range, and the shuttering system probably represents a much better choice.

This basic idea is shown in Figure 21, and all that is required is a sheet of material having (say) vertical slits placed in front of the sensor so that it can "look" through the slits to some parts of the monitored area, but is shuttered off from others. Around ten or twelve slits should be sufficient to give good results, and some window material can be fitted over the shuttering in order to discourage turbulence around the pyro sensor. A more simple method which might give good results would be to drill vertical rows of holes rather than to cut slits.

When deciding on the placement of the unit it is as well to bear a few points in mind. First and foremost, as explained previously the unit is most sensitive to people moving across the monitored area and is least sensitive to people moving straight towards the sensor so that they do not move from one zone to another. It is therefore essential to position the unit such that in normal operation people will be moving across the monitored area and optimum reliability will be obtained. Do not forget that it is infra-
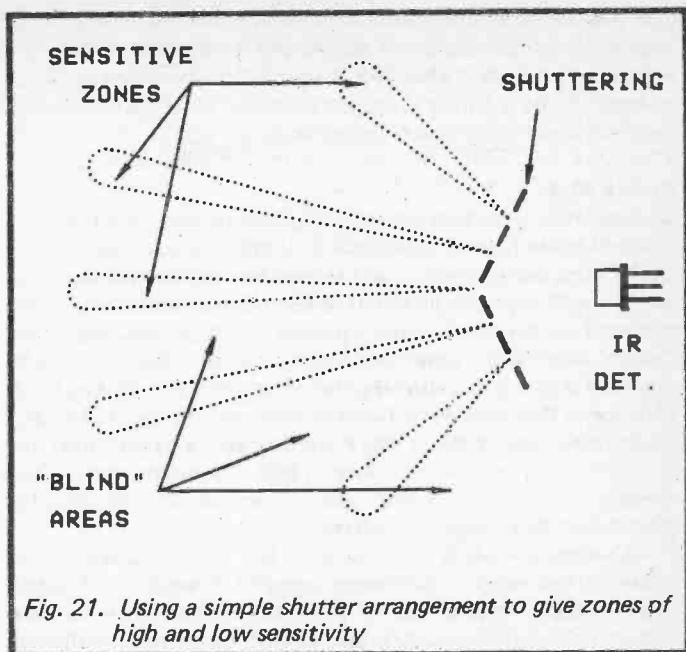
Fig. 21. Using a simple shutter arrangement to give zones of high and low sensitivity

red radiation that the device detects, and it will therefore respond to anything that provides a suitable signal and not just people. Infra-red systems are generally thought to be less prone to spurious triggering than most other forms of movement detector, and the unit should not be triggered by something like a moth flying through the monitored area (which is sufficient to trigger most ultrasonic types). It is possible for units of this type to be triggered by something like the warm turbulent air from a radiator, and the unit should not be aimed at any obvious sources of infra-red energy. Although units of this type are often mounted quite high up in a room, this is not necessarily the ideal place for them. If they can be accommodated at a height of around 1 to 1.5 metres this is where optimum results are likely to be obtained.

Units of this type are less than ideal for use out-of-doors where turblutent air can tend to cause unwanted triggering. They seem to be much better than ultrasonic alarms in this respect though, and when experimentally trying out a system outside it seemed to

give reliable results provided the sensitivity control was set back slightly from the maximum usable indoor setting. Setting the sensitivity control is always a matter of trial and error, in an attempt to find a setting that gives adequate sensitivity but which does not result in spurious operations of the unit.

Broken Beam

Broken beam type detectors usually utilize an active system where a pulsed beam from a transmitter is aimed at a separate receiver circuit some distance away, and anyone moving through the beam momentarily cuts off the signal to the receiver and activates the system. It is possible to have a passive broken beam type circuit though, albeit with a somewhat lower maximum range than can be achieved with a conventional set up. It is not a true broken beam detector in that there is no beam of infra-red energy, and what is really happening is that a lens is used to give a passive infra-red detector a very narrow corridore of high sensitivity, and anyone crossing through this "beam" produces an output pulse from the pyro sensor that triggers the electronics.

Although a system of this type has the disadvantage of relatively low range, a maximum range of as much as 30 metres can be achieved, and this is perfectly adequate for the vast majority of applications. Actually it is possible to obtain sufficient

Fig. 22. Using a lens to make the detector highly directional
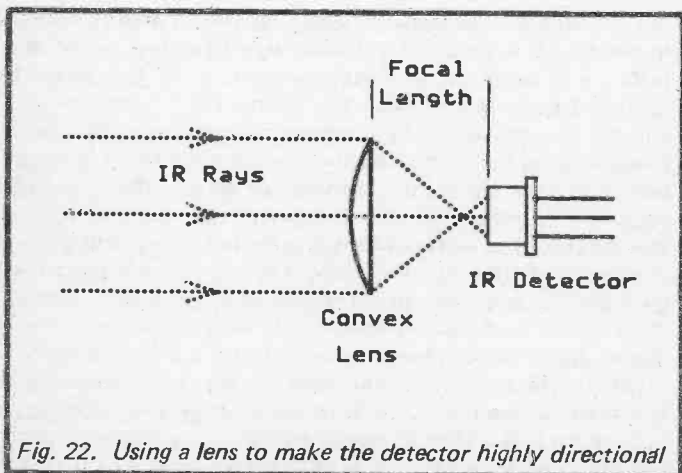
infra-red pick up at greater ranges, but there is a problem with the beam spreading as the range increases. This means someone crossing through the beam at extreme range will take a relatively long time to do so, and this can result in an output pulse from the sensor of such low frequency that the amplifier does not respond to it properly, and the device is not triggered.

The lens system for a broken beam type alarm is relatively simple, and all that is needed is an arrangement of the type shown in Figure 22. The lens is a plano convex or double convex type, and it should have a diameter of around 25 to 40 millimetres and a focal length of about 20 to 50 millimetres. The pyro sensor is positioned centrally behind the lens, and at a distance from it which is equal to the focal length of the lens. The lens has the effect of gathering up infra-red radiation over a relatively large area and concentrating it onto the sensor. In this way it effectively provides gain and boosts the range of the sensor. It only correctly focusses light that comes from almost directly in front of the lens, and this makes the system highly directional so that the narrow corridore of high sensitivity is obtained.

Although a system of this type is very simple in theory, there is a major problem in practice. This is due to the fact that most lenses are intended for operation in the visible light part of the spectrum, and they may not work well at long infra-red wavelengths. This might result in no more than a slight change in the focal length of the lens, making it necessary to shift the pyro sensor backwards or forwards slightly in order to obtain optimum results. In an extreme case the lens could be virtually opaque to the wavelengths involved here, making it totally unusable in the present application.

A lens specially produced for this application is available, and it is advisable to use this rather than to obtain a lens which is fine in theory, but may well be completely useless in practice. In this application a single element pyro sensor such as the F001P or SSC10 seems to be preferable to a dual element type. The circuit of Figure 18 is perfectly suitable for operation as a broken beam type unit, if used with a suitable lens system of course.

Modifications

As described so far, the system merely provides a switching action from the relay when someone is detected in the monitored area. The relay does not latch in the "on" state, and it might not even stay switched on for the whole time that someone is within the

monitored area. What normally happens is that someone moving within the unit's field of view causes the relay to switch on and off as they move from one zone to another. In some applications this is perfectly satisfactory, and in a burglar alarm system for example, the relay contacts would be wired into the loop of switches along with door and window switches, and once activated it would be the alarm that would provide the latching action. Similarly, in many automatic control applications it is merely necessary for the sensor circuit to provide a switching pulse which sets things in motion. The control circuit then provides its own reset pulse (or it is provided via some mechanics in the system) when it has completed the task (opening a door, or whatever).

For some applications it is necessary for the circuit to either provide latching, or to at least provide a hold-on so that once activated the relay remains switched on for some period of time. In the case of built-in latching, this would be required if the unit was to be used as a stand-alone burglar alarm rather than as part of a system. The hold-on is required in an application such as automatic lighting, where it is needed to prevent the lights from being flashed on and off as someone moves around the room. It would also prevent the lights from switching off simply because someone kept fairly still for a while.

Taking the hold-on problem first, this is easily solved by modifying the output stage of the unit, as shown in Figure 23. D2 and C8 form a simple charge storage circuit, and when one of the outputs of IC3 goes high C8 is charged to about half the supply voltage. D2 blocks any flow of current back into R11 or R12 and the output stages of IC3, and the only discharge path for C8 is through R13 and into the base of Tr1. When the unit is activated, C8 is almost instantly charged via the relatively low source impedance of the drive signal, but the input impedance into Tr1 is very high, giving a much longer discharge period. The input impedance to Tr1 is made suitably high by using it as the first device in a Darlington Pair which is comprised by Tr1 and Tr2.

The practical result of this is that once triggered, the relay remains switched on for some time even if no further triggering occurs. The hold-on time is controlled by the value of C8, and with the specified value the relay should hold-on for half a minute or more after triggering (the exact time will vary considerably from one unit to another). If required, the hold-on time can be increased by using a higher value component in the C8 position, or decreased by using a component having a lower value. The delay
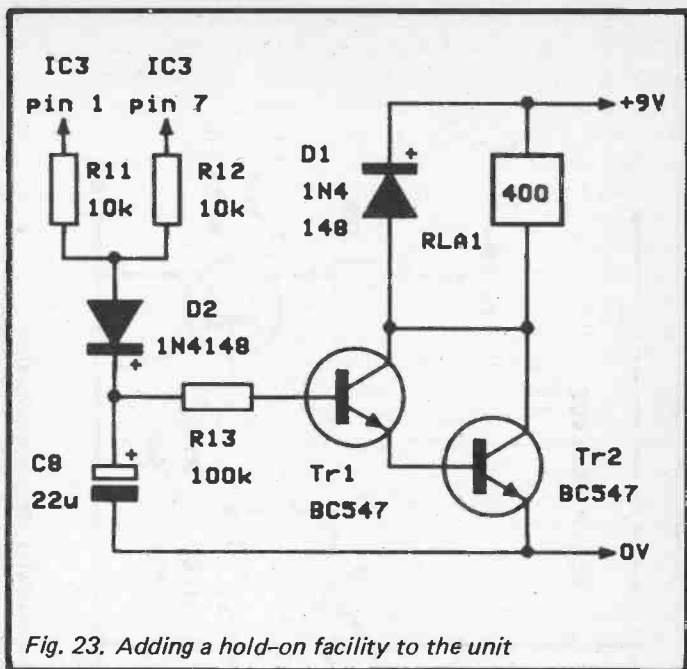
Fig. 23. Adding a hold-on facility to the unit

time is proportional to the value of this component. Note though, that if C8 is made too high in value it will take a long time to charge up to a potential that switches on the relay, giving the unit what might be an unacceptably slow switch-on characteristic. In a lighting application it is probably best to use a fairly long hold-on time, since it is probably better to have the light remain switched on for a minute or so after everyone has left the room, rather than to have the light occasionally switching off while someone is present in the room.

Automatic lighting is one of those things which is not quite as simple and straightforward as it might at first appear. An infra-red detector system will turn on the light when someone enters the room, and keep the light switched on for as long as they stay in the room and move slightly from time to time, but it will do so regardless of whether it is dark or not. The most simple way of preventing this is to use a photocell circuit, such as the one provided in Figure 24, to deactivate the unit in daylight.
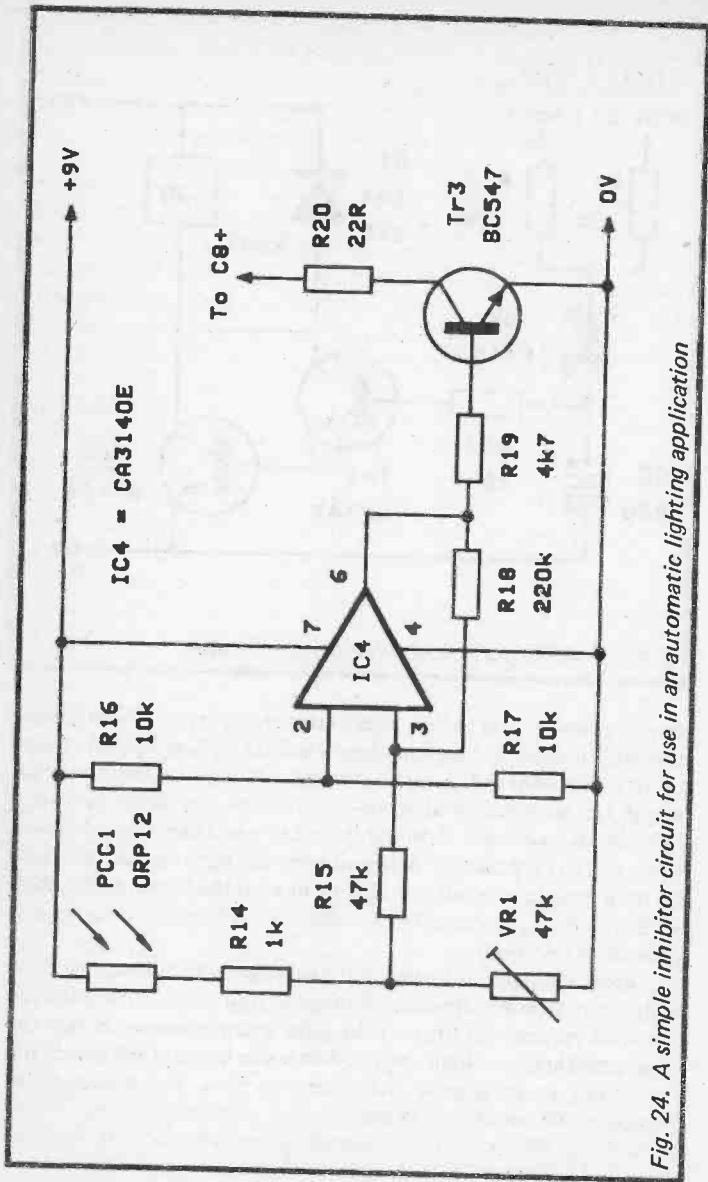
Fig. 24. A simple inhibitor circuit for use in an automatic lighting application

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PCC1 is a cadmium sulphide photoresistor, and its resistance decreases as the light level to which it is subjected is increased. In this circuit it is connected as part of a potential divider network wired across the supply rails, and the output voltage of this circuit rises with increased light level. IC4 is an operational amplifier, but it is operated as a Schmitt Trigger circuit in this case, and its output triggers to the high state if the light level is above a certain level. This trigger threshold can be varied by means of VR1 which consequently operates as a sensitivity control. When the light received by PCC1 is above the threshold level and IC4's output triggers high, Tr3 is switched on and it holds C8 in the discharged state. The required action is thus provided, with the sensor circuit being held in the "off" state when the ambient light is above the threshold level.

Note that even if the unit is already triggered and the ambient light goes above the threshold level, the artificial lighting becomes unnecessary and the unit will automatically switch it off. R18 introduces a certain amount of hysteresis to the trigger circuit, and this gives a higher light level at which the sensor becomes inhibited than the one at which it is enabled again. This, together with the triggering, ensures that the sensor is always fully enabled or totally cut off and does not hover at some intermediate state, and it also prevents the lighting from being repeatedly switched on and off when the ambient light is close to the threshold level.

An essential point to bear in mind with a circuit of this type is that it can only function properly if the photocell is mounted where it will receive the ambient lighting, but will not be subjected to the output from the lamp that is being controlled. Otherwise there is a strong likelihood of the system breaking into oscillation, with the lamp being switched on, the photocell detecting the increased light level and switching it off again, the reduced light level resulting in the sensor being activated again with the light being switched on, and so on.

It will often be necessary for PCC1 to be remotely located from the main unit so that it can be kept away from the controlled lamp, and a connecting cable a few metres in length will then be required. This is perfectly acceptable, but the connecting cable should be a twin screened type. The inner conductors should carry the two connections to PCC1 while the outer screening should be earthed to the 0 volt supply rail.

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Additional Components for Inhibitor Circuit (Fig. 24)
Resistors (all ¼ watt 5%)

R14	1k
R15	47k
R16	10k
R17	10k
R18	220k
R19	4k7
R20	22R

Potentiometer

VR1	47k sub-min hor preset

Semiconductors

IC4	CA3140E
Tr3	BC547

Miscellaneous

PCC1	ORP12

Latching

Latching can easily be added to the infra-red detector circuit, and very few additional components are required, but a basic latch circuit will often be of little practical value. The first problem is that of the unit tending to trigger at switch on due to the voltage changes that occur as the capacitors in the circuit assume their normal working charges. To the output stage these are indistinguishable from the signals produced when the unit is activated, and they would latch the relay in the "on" state. This could be overcome by manually resetting the unit after a few seconds, but this is obviously an unsophisticated and inconvenient way of doing things.

Another problem is that of getting away from the unit without triggering it. The standard burglar alarm answer to this problem is to have a delay which holds the unit in an inactive state for about half a minute so that the person switching on the device has plenty of time to get out of range before the unit becomes fully active. This method also overcomes the problem of the unit triggering itself at switch-on. Figure 25 shows the circuit diagram for a latching output stage which incorporates an "exit" delay facility.

Fig. 25. The circuit diagram for the latch and exit delay

R11, R12, Tr1, RLA1, and D1 are the original output stage, and as before, when one of IC3's outputs goes high Tr1 is biased into conduction and the relay is switched on. The latching is provided by Tr2, and under quiescent conditions this device is switched off and has no effect on the circuit. However, when Tr1 turns on, the voltage developed across R14 and R15 is sufficient to bias Tr2 into conduction. It then provides Tr1 with a base bias current via current limiting resistor R13, and this current holds Tr1 in the "on" state even if both of IC3's outputs now take up the low state again.

S1 is a "reset" switch, and when operated it short circuits the base of Tr1 to the negative supply rail. This switches off Tr1 which in turn cuts off the relay and Tr2. The relay therefore remains switched off when S1 is released, unless the unit is reactivated of course. The unit can also be reset by simply switching off the power for a second or two and then switching it on again. This is not quite the same as operating S1 in that pressing S1 only resets the latch, and it does not start a new exit delay cycle. On the other hand, switching off and then turning the unit on again does start a new exit delay period as well as resetting the unit.

If a basic latch is all that is required, then the rest of the circuit (which provides the exit delay facility) is unnecessary. The device at the centre of the delay circuit is IC4, and this is a 555 timer device operated in the standard monostable mode. It is provided with a trigger pulse at switch-on by the C – R network, R17 – C8. R18 and C9 are the timing components, and the specified values give an exit delay period of approximately half a minute. The output pulse duration is about 1.1 CR seconds, and by using suitable values is it possible to obtain any desired delay time from a fraction of a second to a few minutes. There is no point in using very short pulse durations in this application, but in certain circumstances a longer delay might be helpful. In theory it is possible to obtain very long delay times, but in practice the high values that would be needed for R18 and C9 would probably result in failure. With a high value for the timing resistor and C9 having a high value as well, the result could be that the charge current would be matched by the leakage current. The voltage on C9 would then cease to rise, and the two thirds of the supply voltage threshold level at which the timing periods ends would never be reached.

To avoid this it is advisable to keep the value of R18 at no more than about 2M2, and to use a tantalum bead capacitor for C9.

These components have much lower tolerances and leakage levels than ordinary electrolytic capacitors, and they therefore offer much more predictable results as well as better reliability. The maximum value in which tantalum bead capacitors are readily available seems to be 100μ, which with a 2M2 timing resistor represents a delay time of just over 4 minutes (4 minutes and 2 seconds to be precise), which should be more than sufficient.

The positive output pulse from IC4 is used to switch on Tr3 which operates as a common emitter switch. It is connected in parallel with S1, and holds the latch in the reset state until the end of the timing period when Tr3 is switched off.

Of course, in a stand-alone burglar alarm application an alarm generator of some kind will be needed, and in its most basic form this can just be the usual alarm bell activated via a set of normally open relay contacts. If preferred, a more sophisticated set-up can be used, such as an electronic alarm generator having facilities which could include an entrance delay and automatic switch-off after a preset delay.

Additional Components for Latch and Exit Delays (Fig. 25)
Resistors (all ¼ watt 5%)

R13	4k7
R14	47k
R15	100k
R16	3k3
R17	100k
R18	1M2

Capacitors

C8	220n polyester
C9	22μ 10V tantalum bead

Semiconductors

IC4	NE555
Tr2	BC557
Tr3	BC547

Miscellaneous

S1	push to make – release to break type

Finally

By using the basic sensor circuit with a suitable optical system and, where necessary, one of the modifified output stages, it can operate in a wide variety of applications, including such things as burglar alarms, automatic lighting, and automatic doors. Passive infra-red detection is also something which represents an interesting field for the experimenter, and is something which is well worth investigating just for its interest value and even if you have no obvious use for equipment of this type, you will probably soon discover one or two.

Chapter 3

MISCELLANEOUS PROJECTS

In the previous chapter I mentioned that there was a form of active infra-red sensor which relies on infra-red pulses from the transmitter being reflected back to the receiver by the target object. Systems of this type have a severe drawback in that they provide what is normally only a very limited maximum operating range. With an ideal target object, which would be a highly polished mirror positioned so as to reflect the signal from the transmitter straight back the the receiver, a range of several metres can be achieved. Under practical operating conditions the target object is likely to be far less co-operative than this, and a maximum operating range of around half a metre to one metre would be a more realistic expectation. With a target object that is a very poor reflector of infra-red the range could well be very much less than this.

Despite the range limitations, units of this type do have practical applications, and in particular they are popular in the field of robotics. They can be used to give a robot a very simple "eye" which gives warning if it is about to run into something. This is very much better than the common alternative of using microswitches to act as collision detectors, as the microswitch method is rather a case of "shutting the stable door after the horse has bolted", whereas the infra-red detector system enables possible disaster to be avoided. There are other applications for this type of infra-red detector system, such as detecting that a car is within a certain distance of the rear wall of a garage, and to give warning that it should be taken no closer.

System Operation
A detector of this type can be very simple and inexpensive, and Figure 26 shows the block diagram for a basic system. The transmitter is just an oscillator operating at a fairly high audio frequency and driving an infra-red light emitting diode via a buffer stage. The latter is needed because the diode has to be driven at quite a high current in order to give enough reflected signal for reasonable results. The exact operating frequency of the transmitter is not important, but it needs to be fairly high so that the receiver can easily distinguish between the pulse signal and
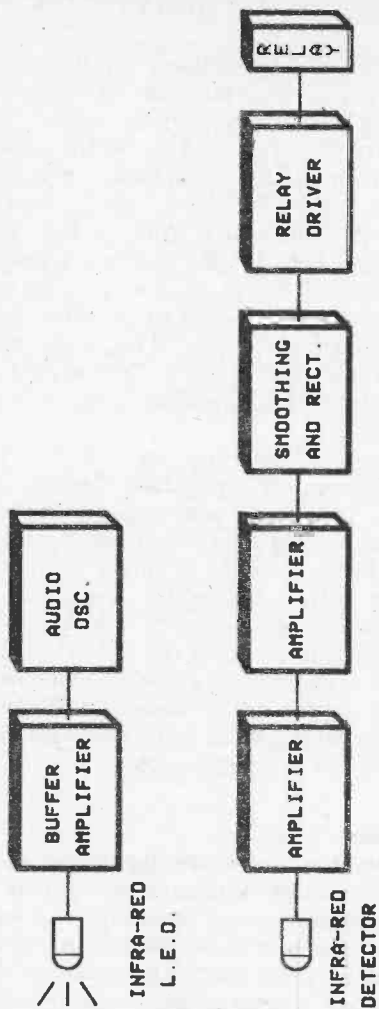
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Fig. 26. Block diagram for the active infra-red sensor

any background noise. In particular, the pulse signal must be easy to separate from 100Hz "hum" from mains powered filament lamps. On the other hand, if the operating frequency is made too high the infra-red transmitter and detector devices will provide less than optimum efficiency, as probably will other parts of the system. A frequency of somewhere around 10kHz offers a good compromise.

The point of using a pulsed signal is that this type of signal can easily be detected and used to operate a relay or some other output device. A straightforward DC signal to the transmitting diode would produce an equally strong reflected signal from the target object, but the minute DC signal from the infra-red sensor device would be very difficult to detect reliably. Apart from problems with drift in the detector circuit causing spurious operation of the unit, changes in the ambient infra-red level could (and probably would) have the same effect. With the pulsed beam system the ambient infra-red level is irrelevant unless it becomes so high the the sensor becomes saturated, which is never likely to happen in practice.

At the receiver the sensor feeds into a two stage high gain amplifier, and the output pulses from this are rectified and smoothed to give a DC signal that is roughly proportional to the strength of the received signal. This DC signal is used to operate a relay via a simple driver circuit, but under quiescent conditions there will be no significant signal picked up by the sensor, the DC bias signal will be negligible, and the relay will not be activated. With a suitable target object within range the DC bias signal becomes quite strong, and the relay is activated.

Transmitter

The circuit diagram of the transmitter appears in Figure 27, and this is basically just a 555 timer used in the astable (oscillator) mode. It provides a roughly squarewave output at a frequency which is set at about 5kHz by timing components R2, R3, and C1. Tr1 is an emitter follower buffer amplifier which drives infra-red light emitting diode D1 by way of current limiting resistor R1. The buffer stage may seem to be unnecessary as the NE555 is capable of directly supplying quite high output currents. However, in practice it seems to be possible to set the drive current more consistently if the buffer stage is included. The drive current to D1 is approximately 100 milliamps, but as the current is switched off for about 50% of the time the average drive current is around 50

Fig. 27. The circuit diagram for the active infra-red sensor transmitter
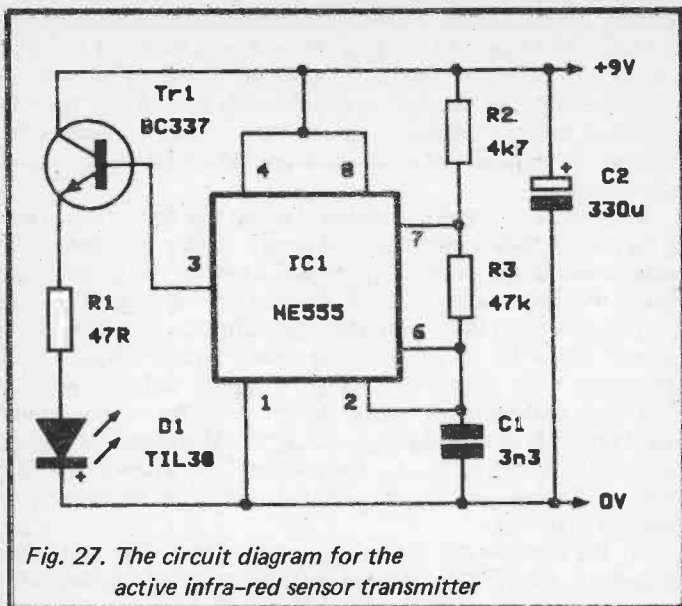
milliamps. The current consumption of the circuit as a whole is slightly higher at around 58 milliamps.

Components for Active IR Sensor – Transmitter (Fig. 27)
Resistors (all ¼ watt 5%)

R1	47R
R2	4k7
R3	47k

Capacitors

C1	3n3 polyester layer
C2	330µ 16V elect

Semiconductors

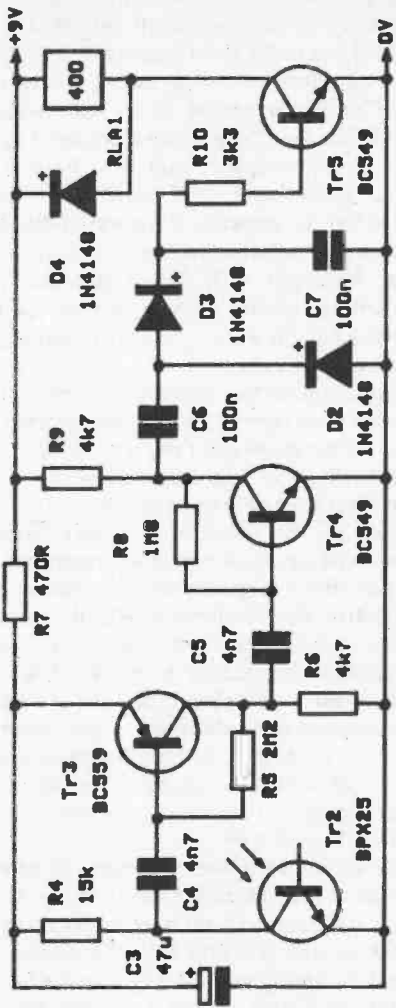|	
IC1	NE555
Tr1	BC337
D1	TIL 38

Fig. 28. The circuit diagram for the active infra-red sensor receiver unit

Receiver

Figure 28 shows the full circuit diagram for the receiver.

The infra-red detector is Tr2, and this is a BPX25 phototransistor. This device is not specifically intended for infra- red applications, and it has quite good sensitivity in the visible light spectrum (as does not incorporate an infra-red filter). Like most opto devices, its peak response is in the infra-red part of the spectrum, and it offers good sensitivity when used in the current application. It is aided in this respect by a built-in lens which increases the light gathering area of the device. This increased pick-up is obtained at the expense of increased directivity, but a sensor having strong directional properties is no real drawback in this application. Although a BPX25 is specified for the Tr2 position of this circuit, similar devices such as the BPY62 and TIL81 seem to work equally well. Note that no connection is made to the base terminal of Tr2.

In infra-red applications that involve the reception of pulsed signals the most common type of sensor is a large area photodiode specifically intended for use in infra-red remote control and active sensing systems. In this case I did not find one of these devices (a TIL100 to be precise) gave such good results as a phototransistor having an integral lens. This is presumably due to the lack of a lens to give the photodiode strong directional properties and effective gain. Readers who like to experiment with their projects might like to try a TIL100 or similar photodiode in the circuit, together with a suitable lens system. The diode simply connects in place of Tr2 with the cathode connected in place of Tr2's collector terminal, and the anode connected in place of Tr2's emitter. The lens needs to be a convex or double convex type, used in the same way as the one in the in the infra-red beam project featured in the previous chapter, but at the wavelengths involved here a lens for use with visible light should function quite well and there is no need for a special infra-red type.

The output pulses from the sensor circuit will often be only a few millivolts peak to peak in amplitude, or when the unit is used at extreme range the output signal here might be slightly under one millivolt peak to peak. Tr3 and Tr4 are both operated as high gain common emitter amplifiers and they give a total voltage gain of over 80dB (10000 times). When a suitable target object is within range this gives an output signal from Tr4 of a few volts peak to peak, and when this is rectified and smoothed by D2, D3 and C7 it produces a sufficiently strong positive DC bias to take

Tr5 into conduction. The latter then activates the relay, which in turn activates the controlled equipment via suitable contacts. In some applications a logic compatible output may be preferable to the relay, and in this case D4 and the relay can be omitted, and Tr5 can be used as an open collector output to pull a TTL logic input low when the unit is activated.

Components for Active IR Sensor – Receiver (Fig. 28)
Resistors (all ¼ watt 5%)

R4	15k
R5	2M2
R6	4k7
R7	470R
R8	1M8
R9	4k7
R10	3k3

Capacitors

C3	47μ 16V elect
C4	4n7 polyester
C5	4n7 polyester
C6	100n polyester
C7	100n polyester

Semiconductors

Tr2	BPX25
Tr3	BC559
Tr4	BC549
Tr5	BC549
D2	1N4148
D3	1N4148
D4	1N4148

Miscellaneous

RLA1	Relay with coil suitable for 9 volt operation and coil resistance of about 200R or more. (contacts and ratings as required).

Construction
Although construction is not difficult in most respects, there is a potential pitfall in that the receiver has a fairly high sensitivity

which leaves it vulnerable to stray pick up and feedback which could cause instability. Taking the stray feedback first, the output of the amplifier at Tr4's collector is in-phase with the input at Tr3's base, and the component layout must be designed to give good isolation between these with no easy feedback paths. Less obviously, feedback to the base of Tr2 can also cause problems, despite the fact that there are no connections to this terminal and it is not forward biased.

The problem of stray pick up other than feedback is mainly one of the signal from the transmitter being received at the receiver via stray electrical pick up rather than by way of reflected infra-red signals. There should be no major problem in avoiding excessive pick up of this type, and it is mainly a matter of leaving a gap of about 10 millimetres of more between the transmitter and receiver circuits, and preferably having an earth plane on the board to provide a degree of screening between the two circuits. It is also advisable to keep leads at the output of the transmitter and the input of the receiver as short as possible, especially the wiring around R4, Tr2, C4, Tr3 and R5.

Another point to keep in mind is that direct optical pick up of the transmitted infra-red signal must be kept to a minimum. The directional properties of the transmitting and receiver photocells help in this respect, but the sensitivity of the circuit is such that if any optical path is left between the transmitting LED and receiving phototransistor then the infra-red pulses will find it. It is not just direct pick up straight between the two that has to be contended with, but due to the short distance between the photocells light reflected via (say) the circuit board can also block the system. The best way around this problem is to use small opaque tubes of some kind to shield both the transmitting and receiving photocells. Any stray optical pick up should then be totally insignificant.

The two photocells should ideally be positioned quite close together (around 40 millimetres or so apart), but the exact distance does not seem to be too critical. The prototype readily detected my hand at a range of half a metre or so, which is about as good as can reasonably be expected from a unit of this type. In some circumstances only a very short operating range may be required, and the sensitivity of the unit can then be reduced by making R1 at the transmitter higher in value. In theory, each time the value of this component is raised by a factor of four, the range of the unit is halved. By making R1 much higher in value there is

the benefit of a significantly reduced current consumption from the transmitter circuit.

Audio Isolator

Opto-isolators tend to be regarded as strictly for use in triac drive circuits where a mains load is being controlled, and the driver circuit must be isolated from the mains for safety reasons. However, these devices can (and often are) used in applications where digital or audio signals must be coupled from one circuit to another with no electrical connection between the two. This is not invariably done to provide isolation from the mains supply, but say in the case of digital signals it may be done in order to prevent problems with earth loops (as in the MIDI musical interface for example). With audio signals earth loops can also be a problem, and an opto-isolator can be used to avoid these. Audio isolator circuits are more commonly used though in applications where an audio output is required on a piece of equipment (such as a television set) which has a "live" chassis.

The audio isolator circuit described here can be used either to avoid earth loops or to give isolation from a "live" chassis. It has to be emphasized that **if it is used for mains isolation purposes it is imperative that the person installing the circuit knows exactly what he or she is doing, as errors would be potentially very dangerous, and could even have fatal consequences.** When used in this way it is therefore a project that should only be undertaken by suitably experienced constructors. Of course, if it is only being used to eliminate an earth loop, then there should be no safety hazard and those of relatively limited experience should have no difficulty in building and installing the unit.

Operating Principle

On the face of it there should be no difficulty in coupling an audio signal through an opto-isolator. All that is needed is a bias circuit at the input of the device so that the audio signal modulates the input current, and then at the output side the device dumps its varying output current into a load resistor. The original audio signal is then produced across the load resistor, or it is in theory at any rate. Unfortunately, in practice the linearity through an opto-isolator is generally quite poor, and the resultant audio quality tends to be far from hi-fi. In fact it would probably not even qualify as acceptable mid-fi, and the distortion level could be very high indeed.

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Better results can be obtained using a system of frequency modulation or pulse width modulation. Both of these methods transmit a pulse signal through the opto-isolator, and linearity through the device (or lack of it) therefore has no significant affect on the audio output quality. Both systems are perfectly practical for this application, but pulse width modulation is perhaps slightly simpler, and can provide excellent results using quite low cost components. The unit described here is of the pulse width modulation variety.

The block diagram of Figure 29 helps to explain the way in which the system functions. The input signal is fed to one input of a voltage comparator via a lowpass filter. The audio signal is modulated onto a carrier wave which is at an ultrasonic frequency, and the purpose of the lowpass filter is to prevent any high frequency signals from reaching the modulator where they could produce heterodyne whistling sounds on the output signal. In most cases there will be no significant high frequency content on the input signal anyway, but it is advisable to include the input filter just in case. Also, stray pick up of radio signals in the input wiring can sometimes lead to problems, and these can be avoided by the inclusion of the lowpass filter.

A clock oscillator feeds into the other input of the voltage comparator, and this provides a triangular output waveform at a frequency of around 80kHz. This arrangement gives the required pulse width modulation, and the waveforms of Figure 30 show the way in which this operates. In (a) the audio input to the voltage comparator is at its normal quiescent level, which is half way between the peak voltages of the clock signal. When the clock signal is at the higher voltage the output of the comparator goes high, and when the clock signal is the lower of the two input voltages the comparator's output goes low. This gives a squarewave output with a perfect one to one mark-space ratio, and an average output voltage that is equal to about half the supply potential. In (b) the bias voltage has been set much higher, and as a result of this the clock signal exceeds the input voltage on only a small part of each half cycle. The output signal is consequently a series of much narrower pulses than before, and the average output voltage is much lower. The bias level has been reduced in (c), and consequently the clock signal is at a higher level than the bias voltage for the majority of the time. This results in an output signal that is a series of relatively long pulses, and the
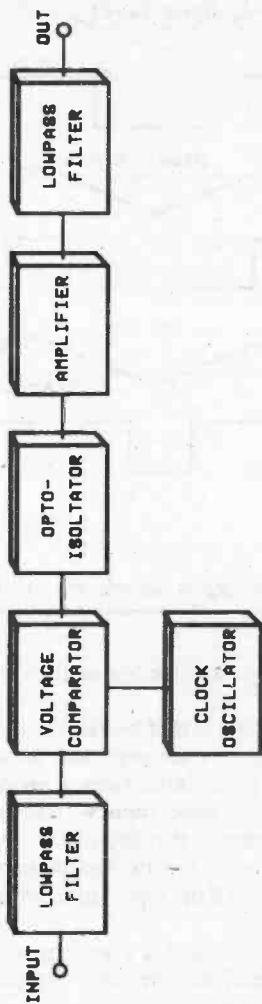
Fig. 29. Block diagram for the audio isolator
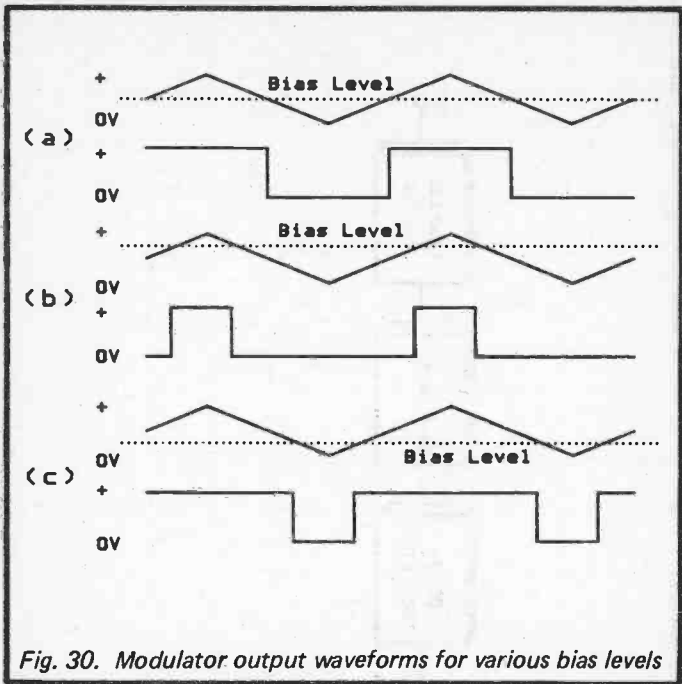
Fig. 30. Modulator output waveforms for various bias levels

average output voltage is much higher than with the bias voltage at its normal level.

The point to note here is that by varying the input voltage, the average output voltage of the comparator is varied as well. In this example an increase in the input voltage produces a reduction in the output voltage, and a lower input voltage gives a higher output voltage. This simply means that there is an inversion through the modulator, which is of no practical consequence. This inversion would in fact be avoided if the inputs to the comparator were to be swopped over.

In practice the input signal is a varying voltage rather than a series of fixed voltages, but provided the clock frequency is at least double the maximum input frequency, the average output voltage will vary in sympathy with the input voltage. Figure 31 shows the way in which the pulsed output waveform changes with a triangular input signal supplied to the modulator.

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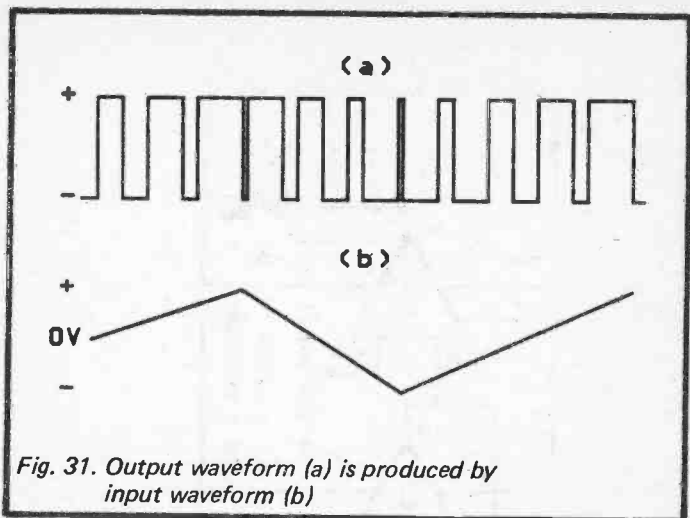
Fig. 31. Output waveform (a) is produced by
input waveform (b)

Although this system does not guarantee good linearity,
provided the clock signal has good linearity and the comparator
has sufficiently fast rise and fall times, good results will be
obtained.

Returning to Figure 29, the output from the comparator is
applied to the input of the opto-isolator, and here it pulses an
infra-red LED. On the output side of the opto-isolator there is a
phototransistor, and this provides an output signal that does not
bear a great deal of resemblance to the input signal. The reason
for this is the relatively slow switching speed of an ordinary
inexpensive opto-isolator. There are relatively expensive high
speed types that could be used, but a more simple and cheaper
alternative is to use an ordinary opto-isolator in conjunction with
an amplifier, and this combination can provide a good quality
output which retains the mark-space ratio of the original signal
and which has suitably fast rise and fall times.

The final stage is a lowpass filter, and this smoothes the pulses
to give an output potential that is equal to the average voltage of
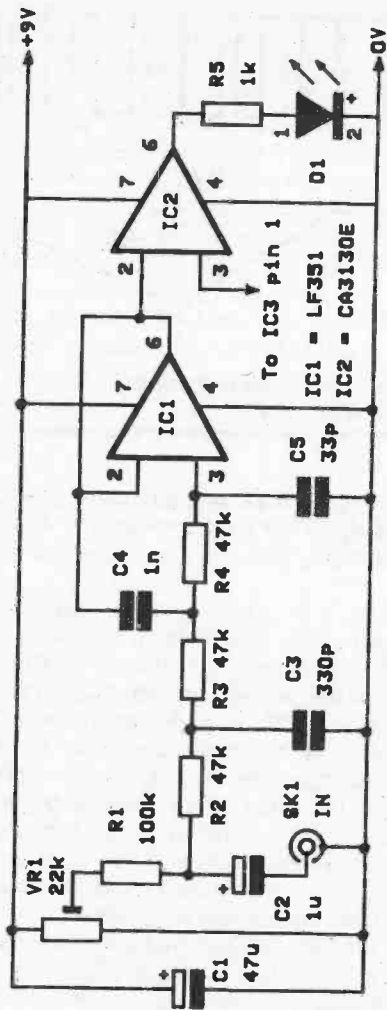the pulse signal, or the wanted audio output signal in other words.

Fig. 32. The circuit diagram for the input filter and comparator

Modulator Circuit

The main circuit diagram for the modulator section of the unit appears in Figure 32, but the clock oscillator circuit diagram is shown separately in Figure 33.

Taking Figure 32 first, the input filter is a conventional third order (18dB) per octave active type based on IC1. VR1 sets the input bias level, and this is adjusted to give optimum large signal handling from the unit. This is more a matter of setting a suitable bias level for the comparator than for the input filter, and the comparator is driven directly from the output of IC1.

The voltage comparator is, of course, IC2, and this is a CA3130E operational amplifier. This device is an externally compensated type, but in this case it is operated open loop and the highest possible slew rate is required, and consequently no compensation capacitor is included. When used open loop the CA3130E is perfectly stable without including this capacitor. D1 is the LED in the opto-isolator which is an inexpensive TIL111 type (or any near equivalent). R5 is the current limiting resistor for D1, and it sets the LED current at only about 5 milliamps or so.

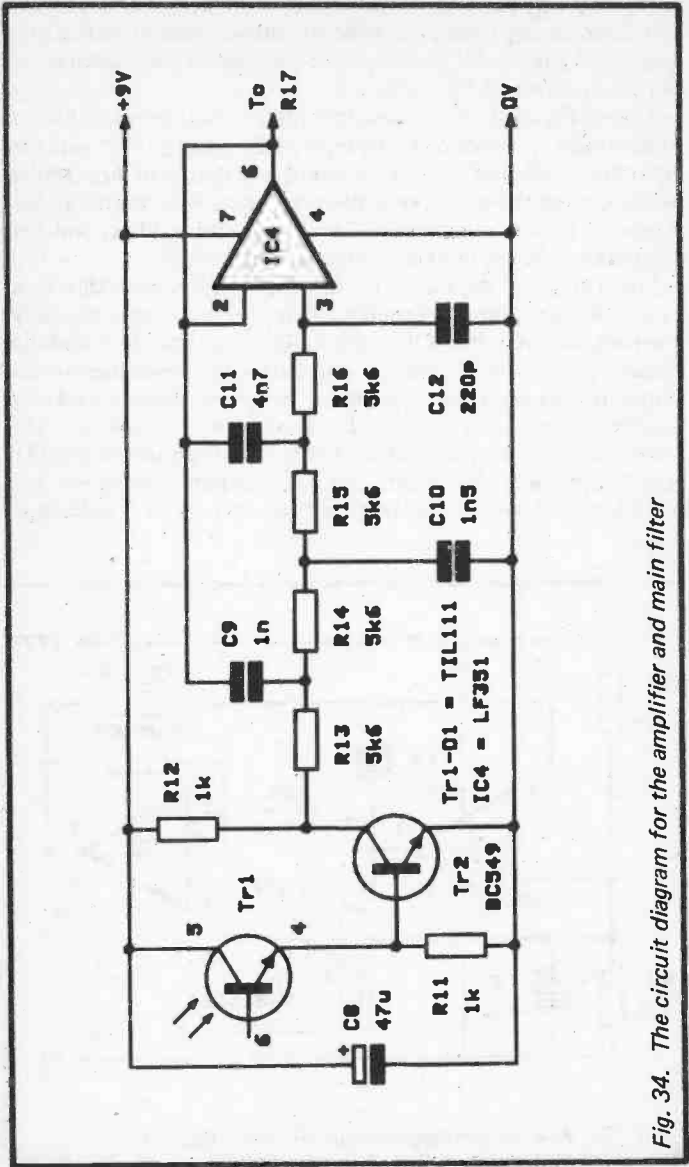Fig. 33. The circuit diagram for the clock oscillator
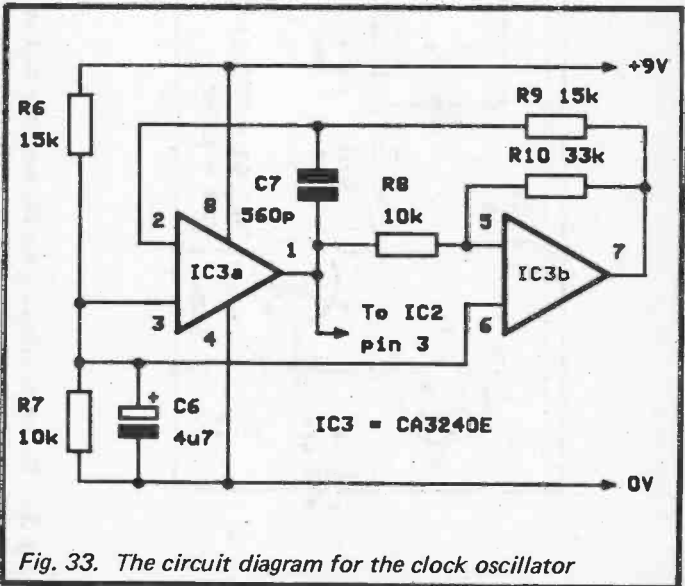
Fig. 34. The circuit diagram for the amplifier and main filter

Turning now to Figure 33, this is a conventional oscillator circuit of the type which uses a Miller Integrator (IC3a) and a Schmitt Trigger (IC3b). This gives a squarewave signal from the output of IC3b, and the triangular signal that we require in this application is available at the output of IC3a. R6 and R7 provide a bias voltage for the circuit, and this voltage is somewhat less than the usual mid-supply level. This is done in order to compensate for a lack of symetry in IC3's output stages, and to consequently improve the output waveforms. Due to the fairly high operating frequency of nearly 80kHz it is essential to use a device in the IC3 position that has both a fairly wide bandwidth and a high slew rate. The bias potential must also suit the output characteristics of the device used in the IC3 position. For these reasons the use of other dual operational amplifiers in the IC3 position is not recommended, and would almost certainly produce inferior results.

Figure 34 shows the main circuit for the output side of the circuit, but an additional filter circuit is shown in Figure 35. Of course, these circuits have no electrical connection with those of Figures 32 and 33. They must be powered from separate 9 volt
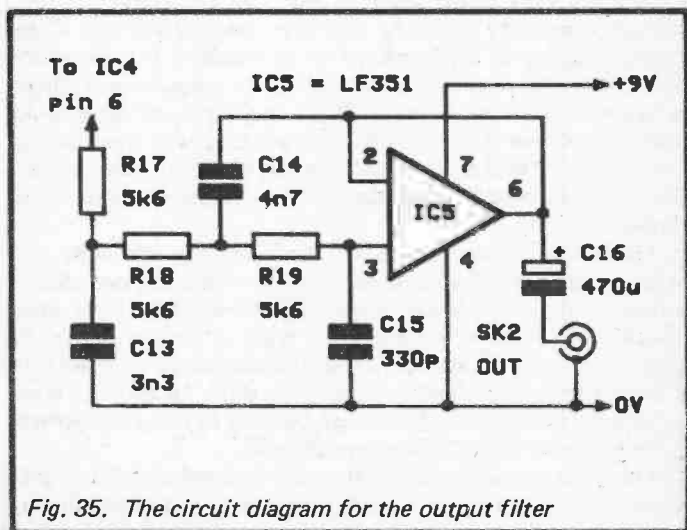

Fig. 35. The circuit diagram for the output filter

supplies and the 0 volt earth rails must not be connected. Otherwise the unit becomes pointless and there is no electrical isolation through the circuit.

Tr1 is the phototransistor in the opto-isolator, and it is used to directly drive the base of common emitter switching transistor Tr2. Load resistor R11 ensures that leakage currents in Tr1 can not hold Tr2 permanently switched on. The lowpass filter is a straightforward fourth order (24dB per octave) type having a cutoff frequency of about 20kHz. This gives a reasonably ripple-free output signal, but for really good results some further filtering is required. This is the purpose of the circuit shown in Figure 35, which is a third order lowpass filter, again having a cutoff frequency of about 20kHz. The two filters have a combined attenuation rate of some 42dB per octave, and with the clock frequency almost two octaves higher than the cutoff frequency, this gives around 80dB of clock attenuation at the output.

The importance of the degree of clock attenuation depends on just what will be connected to the output of the unit. With headphones a very high level of ripple is often unimportant, and most headphones can actually be driven direct from a pulse width modulated signal. This is possible as the frequency response of the headphones is not sufficient to permit them to reproduce the clock signal, and they consequently respond to the average output voltage, effectively providing their own lowpass filtering. If the output is going to be connected to an amplifier it is generally necessary to have a low level of ripple on the output signal. There is otherwise a risk of instability in the amplifier, and there could also be problems if the loudspeakers are multiway types having "tweeters". At best there would be a loss of fidelity, and at worst the tweeters would burn out due to the strong clock signal being directed to them.

The unit can drive most types of headphones satisfactorily, and it is generally best if high impedance types have the two phones wired in parallel and low or medium impedance types have series connection. With low impedance types it will probably be beneficial to wire a resistor of about 47 ohms in value in series with C16 to attenuate the output signal somewhat. Of course, stereo headphones can be accommodated, but only by using two isolator circuits, one to handle each stereo channel.

The input signal should be around 1 to 2 volts peak to peak. Input levels much above 2 volts peak to peak will cause clipping and serious distortion, and with sources of this type an input

attenuator must be used to reduce the input signal to an acceptable level. There is about 6dB of voltage gain through the unit incidentally, so the maximum output level is a little over 4 volts peak to peak.

Provided an appropriate input level is used the unit will provide an excellent signal to noise ratio and quite low distortion levels. The filters in the unit have a 20kHz cutoff frequency, but their cumulative effect provides an overall frequency response which falls slightly short of the full audio bandwidth. However, probably few people have hearing which is sufficiently good to notice the very slight shortfall, and in many cases the source signal will not merit the full bandwidth of the unit anyway. When testing the unit with a high quality FM radio source there was very little discernable difference between the direct signal and the one taken via the isolator.

Components for Audio Isolator (Figs. 32, 33, 34 and 35)
Resistors (all ¼ watt 5%)

R1	100k
R2	47k
R3	47k
R4	47k
R5	1k
R6	15k
R7	10k
R8	10k
R9	15k
R10	33k
R11	1k
R12	1k
R13 to R19	5k6 (7 off)

Potentiometer

VR1	22k sub-min hor preset

Capacitors

C1	47μ 10V elect
C2	1μ 63V elect
C3	330p ceramic plate
C4	1n polyester
C5	33p ceramic plate
C6	4μ7 63V elect

C7	560p ceramic plate
C8	47μ 10V elect
C9	1n polyester
C10	1n5 polyester
C11	4n7 polyester
C12	220p ceramic plate
C13	3n3 polyester
C14	4n7 polyester
C15	330p ceramic plate
C16	470μ 10V elect

Semiconductors

IC1	LF351
IC2	CA3130E
IC3	CA3240E
IC4	LF351
IC5	LF351
Tr1-D1	TIL111 or similar opto-isolator
Tr2	BC549

Miscellaneous

SK1	3.5mm jack socket
SK2	3.5mm jack socket

Circuit board, 8 pin DIL IC holders (2 off), wire, solder, etc.

Stroboscope

A conventional stroboscope uses some form of gas discharge tube to provide bright flashes of light at the required frequency, which can be anything from a few Hertz to (typically) a few hundred Hertz. The general idea of units of this type is to aim the light pulses at a piece of machinery which is in otherwise dark conditions. By synchronising the frequency of the flashes with the movement of the machinery, the movement appears to be "frozen". If synchronisation is not quite perfect the effect is to give the impression that the machinery is running in slow- motion, either forwards or backwards, depending on whether the stroboscope is running slightly too slow or too fast.

These days there is an alternative to the usual gas discharge tubes in the form of so called "superbright" and "ultrabright" light emitting diodes. It has to be admitted straight away that these devices do not provide an output level equal to that produced by

most gas discharge tubes, even if a number of them are used and they are driven with a high pulse current. On the other hand, they are a far cry from the original light emitting diodes which often failed to glow noticeably even under moderately bright conditions. The best of the very high brightness types give an output which is around one hundred times brighter than a standard LED driven at the same current. To be precise, the output is about 250mcd for one of the best ultrabright types, as opposed to around 2mcd for a standard 5 millimetre red LED. 3 millimetre diameter LEDs generally have much lower light output levels than the 5 millimetre variety, and I would not recommend the use of 3 millimetre LEDs in this application. As an indication of just how good these ultrabright LEDs are, under normal indoor lighting conditions one of these devices can shine a beam of light onto a wall one metre away if it is driven at something approaching its maximum current rating.

LEDs are an attractive proposition for a stroboscope as they can operate at quite high frequencies and require nothing elaborate as far as the driver circuit and the power supply are concerned. Although their light output is still relatively limited, it is sufficient to give usable results in most circumstances, and a device of this type certainly represents an interesting and unusual project that can be constructed at quite low cost.

Circuit Operation

Figure 36 shows the circuit diagram of a simple LED stroboscope.

It is basically just a 555 timer device used in the astable mode to generate a series of brief pulses which are fed to the ultrabright LEDs. With a standard 555 astable the high output time is longer than the low output duration as the output goes to the high state during the charge period, and low while the timing capacitor is discharging. The capacitor is charged via both of the timing resistors, but it discharges through just one, and the charge part of the cycle must therefore be longer.

There is more than one way around this problem, but in this case steering diode D3 is used to effectively bypass R5 and VR1 during the charge period, and the charge rate is then controlled by the series resistance of R3 and R4. Both components have been made comparatively low in value so that the charge time is kept suitably short. During the discharge part of each cycle D3 blocks any significant current flow through R4, and the discharge rate is controlled by the relatively high series resistance of VR1 and R5.
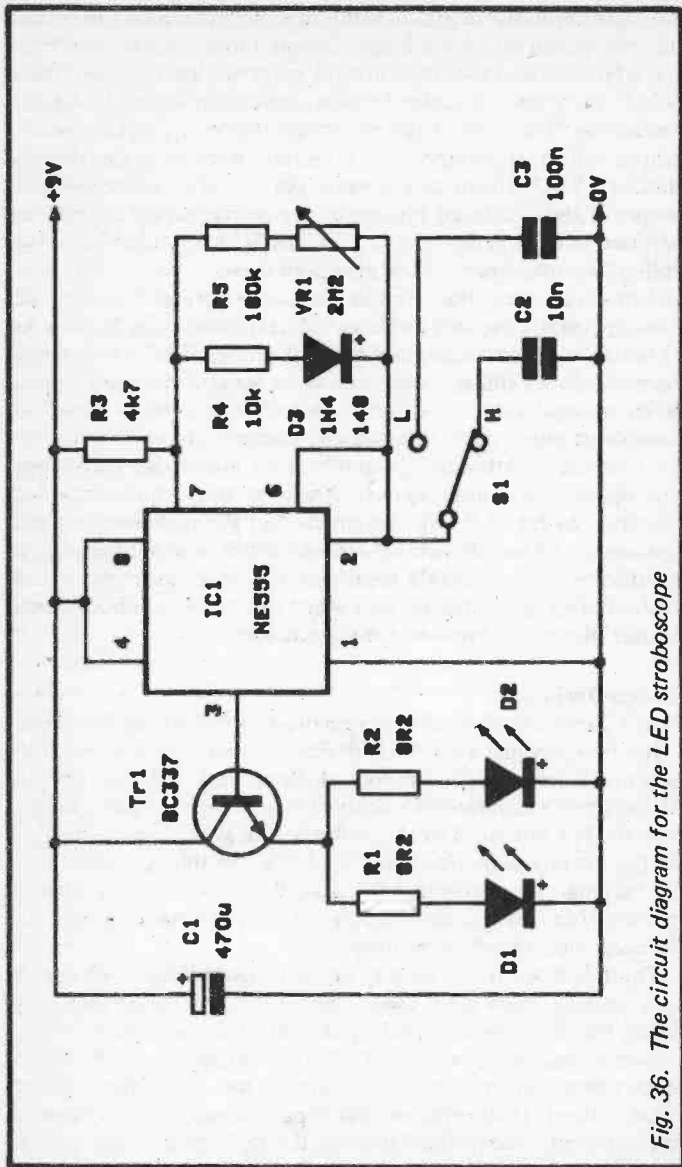
Fig. 36. The circuit diagram for the LED stroboscope

The circuit therefore provides the required brief positive output pulses at a frequency which can be controlled by VR1. S1 enables one of two timing capacitors to be selected (C2 and C3), and these provide the unit with two frequency ranges. The approximate frequency coverage is 5 to 50 Hertz on the low ("L") range, and 50 to 500 Hertz on the high ("H") range. When dealing with machinery it is more normal to talk in terms of revolutions per minute (RPM) than frequency in Hertz, and in RPM terms the two ranges cover from about 300 to 3000 RPM, and 3000 to 30000 RPM, which should cover most requirements.

Tr1 acts as an emitter follower buffer stage at the output of IC1, and it drives two ultrabright LEDs (D1 and D2) by way of separate current limiting resistors (R1 and R2). The current through each LED is quite high at something in excess of 500 milliamps, and on the face of it this is far too high for these two components to survive. In fact it gives an excessive current flow in Tr1 as well. In practice Tr1 and both of the diodes survive the experience as the pulses are very brief with a much longer period from one to the next. This results in a very much lower average output current which is always less than 50 milliamps per diode, and comfortably within the capabilities of these components.

C1 is a supply decoupling capacitor, and it has been given a fairly high value so that it can provide the large pulse of current needed on each strobe if the power supply should tend to sag under the heavy loading. It is important that the supply is capable of delivering these bursts of high current as without them the LEDs will lack the required brightness.

Components for LED Stroboscope (Figs. 36)
Resistors (all ¼ watt 5% unless noted otherwise)

R1	8R2 (1W)
R2	8R2 (1W)
R3	4k7
R4	10k
R5	180k

Potentiometer

VR1	2M2 linear

Capacitors

C1	470μ 10V elect
C2	10n polyester
C3	100n polyester

Semiconductors

IC1	NE555
Tr1	BC337
D1	5mm ultrabright LED
D2	5mm ultrabright LED
D3	1N4148

Miscellaneous

S1   SPDT toggle switch

Case, circuit board, connecting wire, etc.

Construction and Use

The unit is very simple and there is really nothing that should prove at all difficult as far as construction is concerned. In use it has to be borne in mind that the light output of the unit is quite low, and it will therefore only work reasonably well under quite dark conditions. Stroboscopes are mainly used under quite dark conditions anyway, and the unit can obviously not function well when the ambient light level is sufficient, for the moving parts to be "frozen" to be clearly visible. A more severe limitation is that most ultrabright LEDs are quite directional, and consequently a pair of them will not light up a very large area. Moving the unit back from the mechanism under examination enables the beam to spread and cover a wider area, but the light becomes less intense as a result of this.

In most cases it is likely that only a small area will need to be covered by the unit, but if necessary IC1 can be used to drive further pairs of LEDs, although each pair should be driven by way of its own emitter follower buffer stage and not from Tr1. Of course, each LED must also have its own 8R2 series resistor to provide current limiting. The cost of eight or ten of these LEDs is quite reasonable, and would enable a fairly large area to be covered at good intensity.

As the output pulse duration remains constant over VR1's full adjustment range, the overall brightness is greater at the high frequency end of its adjustment range than at the low frequency end. Ideally the pulse width and frequency would be varied together, but this would require a dual gang potentiometer having a different value for each gang, and suitable components do not seem to be available to small scale users. An easy way around the problem is to replace S1 with a standard 12 way rotary switch, and

then to have a range of twelve timing capacitors instead of just two. This would enable most frequencies to be obtained on several ranges, giving several brightnesses to choose from. A point to bear in mind is that the sharpness of the "frozen" image degrades as the brightness is increased, because the LED is switched on for a greater part of each cycle. With a multirange version of the unit you can select the best compromise between sharpness of image and brightness.

In order to "freeze" the device under investigation it is just a matter of carefully adjusting VR1 to give the desired effect. If the strobe frequency is set at half, a third, a quarter (etc.) of the correct frequency the mechanism will still seem to stop, but the brightness of the strobe light will be much less than it could be, and it is therefore better to use the highest frequency that "freezes" the action. Setting the frequency at two, three, four (etc.) times the correct frequency will give a sort of "frozen" action effect, but because the strobe light is firing more than once on each cycle of the mechanism under test, moving parts will appear in more than one position. This could be useful, but in most cases it will simply provide confusing results and is best avoided. The strobe frequency must be adjusted very accurately in order to completely "freeze" the mechanism being viewed, and this is more easily achieved if VR1 is fitted with a large control knob. Alternatively a potentiometer of about 10k in value can be wired in series with VR1, and this will act as a "fine" frequency control.

Remember, do not be tempted to touch a piece of machinery that appears to be "frozen" as accidents may result.

Camera Trigger
An increasingly popular use of opto electronics in the field of photography is to provide an automatic camera trigger of some kind. The most common type of triggering device, and the one which is probably applicable to the widest range of uses, is the broken beam type. This can be used for things such as triggering the camera as an object falls through the beam and into a bowl of water so that water splashes can be photographed, or for the advanced wildlife photographer there is the absorbing subject of photographing birds and insects in flight.

There are two basic methods of taking these types of photograph, and the easiest is to use triggering of the camera. This permits photographs to be taken using flash or, where light levels

permit, available light. It is only possible with cameras which have provision for an electric shutter release (such as some Minolta models), or where electrical triggering is possible via an automatic winder or motor drive (as with some Pentax cameras for instance). Many of the more recent and sophisticated cameras can be fired in this way, but it is a method that is obviously far from applicable to all cameras.

The second method is to take the photographs under very dark conditions, with the camera shutter set to "B" so that it can be held open while the exposure is made. The photograph is taken by triggering an electronic flashgun. These are normally fired by a set of switch contacts in the camera, and thus can be triggered by an automatic trigger circuit. The drawback of this method is that it is relatively awkward to take most types of photograph under very dark conditions, and unless the exposure is made within a fairly short space of time there is a danger of the film becoming fogged.

Actually there is a third alternative, and this is to build up a simple mechanism which can be operated electrically, and which will operate the camera by pressing on the push button of a cable release. This method enables either flash or available light shots to be taken, and it is applicable to any camera which can take a cable release (which practically any camera of reasonable quality can do). In theory a unit of this type is very easy to build as it is little more than a solenoid and a very basic mechanism. In practice it can be a little difficult to get everything to fit together reliably, and some cameras have shutter mechanisms that require much greater triggering pressure than one would expect. However, for someone with the necessary skills to undertake the mechanical side of construction competently there should be little difficulty in implementing a system of this type for most cameras.

Circuit Operation

The necessary electronics for a system of this type can be very simple, and the basic set up is to have a transmitter which provides a beam of infra-red pulses, plus a receiver circuit which detects any interruption of the signal and triggers the camera or flashgun. What is required from the transmitter is therefore exactly the same as in the active infra-red detector system described previously in this chapter, and exactly the same circuit is used in this system. As this circuit (Figure 27) has already been described it will not be considered further here.

The receiver unit of the active infra-red sensor could also be
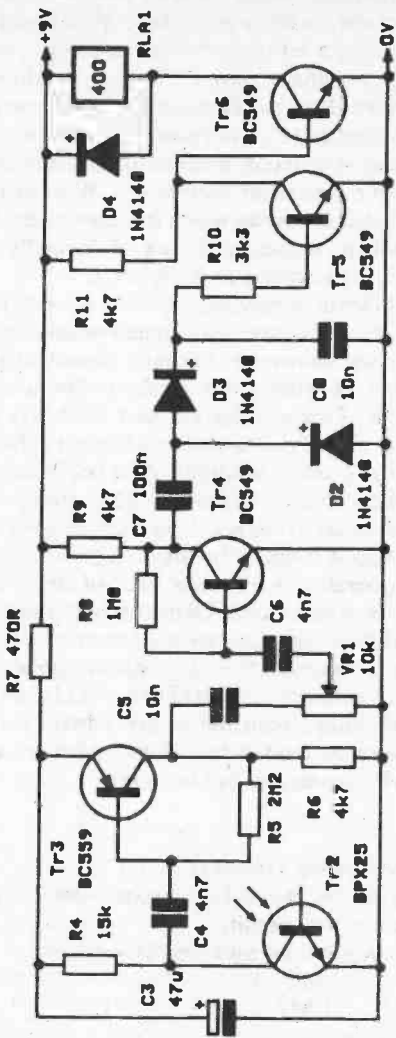
Fig. 37. The circuit diagram for the IR camera trigger

used in the present application, but it is less than ideal. Firstly, the relay would be energised under stand-by conditions and would be turned off when the beam was broken. This is not in itself a problem, as by using a set of normally closed relay contacts the required triggering of the camera or flashgun would be obtained when the beam was broken. However, it would mean that the relay would consume quite a lot of power, and as units of this type are usually battery powered in order to make them portable, this would result in a rather short battery life. It is therefore much better to use a modified circuit which switches on the relay when the beam is broken, and to use a set of normally open relay contacts to control the camera or flashgun.

Another worthwhile refinement is to add a sensitivity control. Ideally the sensitivity of the receiver should be just high enough to reliably prevent the camera or flashgun from being spuriously triggered, so that anything even partially obscuring the beam activates the unit. This enables the unit to detect quite small insects (or whatever) which are not large enough to fully block the beam, or which in practice are unlikely to cut through the beam accurately enough to fully block it. The modified infra-red receiver circuit appears in Figure 37, and this is clearly very similar indeed to the original circuit. The first difference is the inclusion of VR1 which operates as a volume control style variable gain control. In the smoothing circuit C8 has had its value reduced by a factor of ten in order to speed up the response time of the circuit to one which is more appropriate for the current application. At the output of the unit an inverter stage (Tr5 and R11) has been added between the smoothing circuit and the relay driver so that Tr6 and the relay are normally held in the off state, but are switched on when the beam is broken and Tr5 turns off.

Components for Camera Trigger (Fig. 37)
(Transmitter is as for the active infra-red sensor unit, the list below is for the receiver circuit).
Resistors (all ¼ watt 5% unless noted otherwise)

R4	15k
R5	2M2
R6	4k7
R7	470R
R8	1M8
R9	4k7

| R10 | 3k3 |
| R11 | 4k7 |

Potentiometer
| VR1 | 10k log. |

Capacitors
C3	47μ 10V elect
C4	4n7 polyester
C5	10n polyester
C6	4n7 polyester
C7	100n polyester
C8	10n polyester

Semiconductors
Tr2	BPX25
Tr3	BC559
Tr4	BC549
Tr5	BC549
Tr6	BC549
D2	1N4148
D3	1N4148
D4	1N4148

Miscellaneous
| RLA1 | Coil resistance of about 200R or more suitable for nominal 9 volt operation, at least one set of normally open contacts of adequate rating for device to be controlled. |

Case, circuit board, control knob, wire, solder, etc.

Construction

As pointed out before, the circuit has quite high gain and the component layout needs to be carefully designed in order to avoid problems with instability due to stray feedback. Apart from this construction of the system is quite straightforward, but unlike the active infra-red sensor project, in this case the transmitter and receiver are built as entirely separate projects with each one having its own power source. This can be a 9 volt battery, but as the transmitter has a fairly high current consumption of something over 50 milliamps it is advisable to use a fairly high capacity

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battery for this unit. A PP9 size battery or six HP7 size cells in a plastic holder should suffice.

The transmitter and receiver are both quite directional, and they must therefore be quite accurately aimed at one another in order to obtain sufficient pick up at the receiver to hold the relay in the "off" state. A maximum range of over 1 metre should be obtained, and the range might be as much as 2 metres. This should be more than adequate for a camera trigger application. Remember that for optimum sensitivity VR1 should be backed off to the point where the relay is only just kept in the "off" state.

For connection to a flashgun a flash extension lead will be needed, with the plug at the non-flashgun end being cut off so that the cable can be connected to the relay contacts. For connection to a camera or winder the appropriate electric release cable must be obtained, with the push button switch being removed to permit connection to the relay contacts. As the unit uses a relay to control the flashgun or camera, it provides a good simulation of a manually operated switch, and should work well with any camera, flashgun or winder. The only exception to this is with some
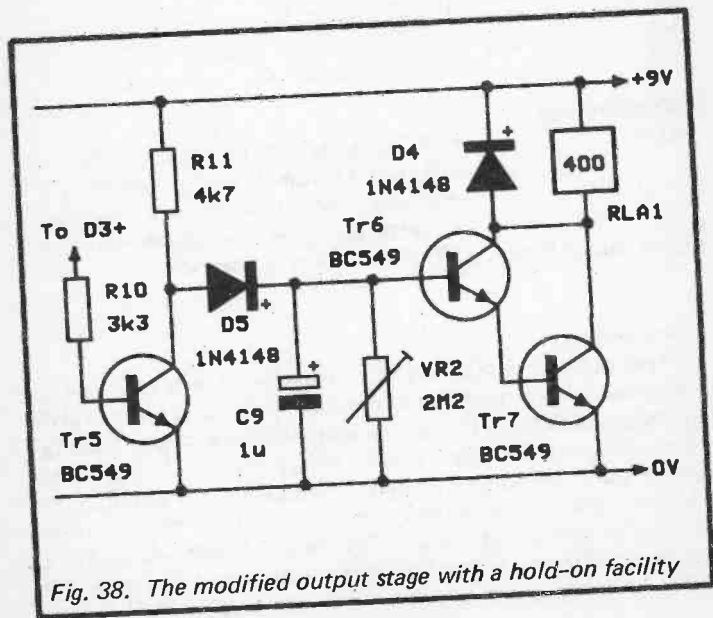

Fig. 38. The modified output stage with a hold-on facility

cameras and winders that are rather slow to operate, and which might not be operated reliably by the very brief pulse from the unit when a small object passes rapidly through the beam.

The solution to the problem is to use the modified output stage of Figure 38 which uses a simple charge storage circuit that holds the relay on for about one second once the unit has been activated. VR2 would normally be set at maximum resistance, but in the unlikely event of there being any problems with multiple triggering of the camera VR2 can be backed-off somewhat to give a shorter trigger period.

If the unit is used with a flashgun the alternative output stage of Figure 39 might be preferred. This uses a thyristor or SCR (silicon controlled rectifier) to fire the flashgun, and the advantage of this method is that it is fully electronic and is consequently very fast. Note that the thryristor must be a C106D or a similar type that will operate from a low gate current if it is to operate properly in this circuit. Also, the flash lead must be connected to the unit with the polarity indicated in Figure 39, and the correct polarity can be determined by checking the voltage across the flashlead using a
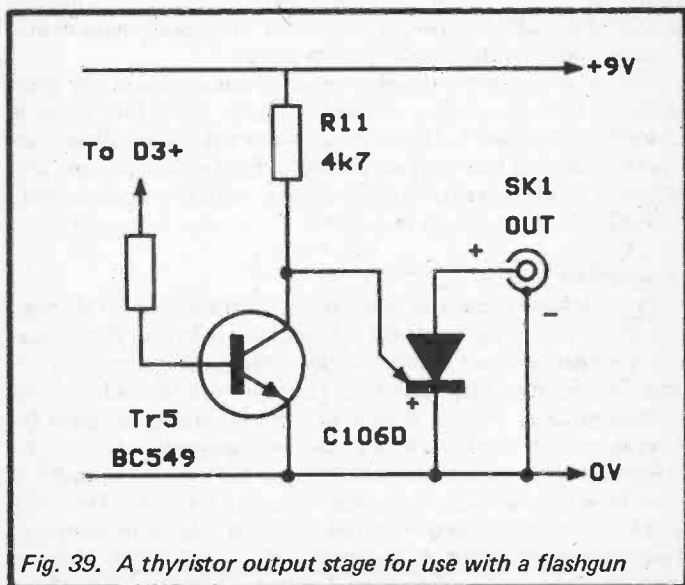

Fig. 39. A thyristor output stage for use with a flashgun

mulitmeter set to a high DC voltage range. No damage will result to the thyristor if the polarity of the flashlead is wrong, and trial and error can be used if a suitable multimeter is not available.

Infra-red Communicator

The idea of using infra-red for communications purposes is by no means a new idea, and systems for military use have been in existence for more than twenty years. In principle the idea is similar to the light beam telephone systems that are described in the electronics press from time to time, but with an infra-red system the light beam is invisible, and there is no obvious sign of a communications link. Unlike radio communications systems, an infra-red type is virtually tap-proof, and it is presumably these two security factors that made infra-red communications systems attractive for military applications.

Whether or not infra-red communications systems have any real advantage over other methods in non-military applications is debatable, but they certainly represent an interesting type of project for the electronics experimenter. Systems of this type could use a simple amplitude modulated beam system, like conventional light beam telephone designs, but infra-red devices provide the wider bandwidth needed for a frequency modulation system, and this offers better quality results.

We will not consider the electronics of this system in any great detail as it is very similar to the fibre optic audio link which is described in chapter 1. However, in this case the transmitter must operate with the low level output signal from a microphone, and an audio bandwidth of only about 3kHz is sufficient as we are only dealing with voice signals in this case.

Transmitter

Figure 40 shows the circuit diagram for the transmitter. This has a 555 timer device acting as the voltage controlled oscillator, and the modulation input at pin 5 is driven from the output of a two stage common emitter amplifier. The latter provides a high level of voltage gain, but this is necessary as the unit is designed for operation with a low impedance dynamic microphone (the type sold as replacements for use with inexpensive cassette recorders), and these generally give an output of under 1 millivolt RMS. C4 and C6 provide high frequency roll off which helps to prevent high frequency signals from entering the VCO, and it also gives an improved signal to noise ratio. The carrier frequency is about
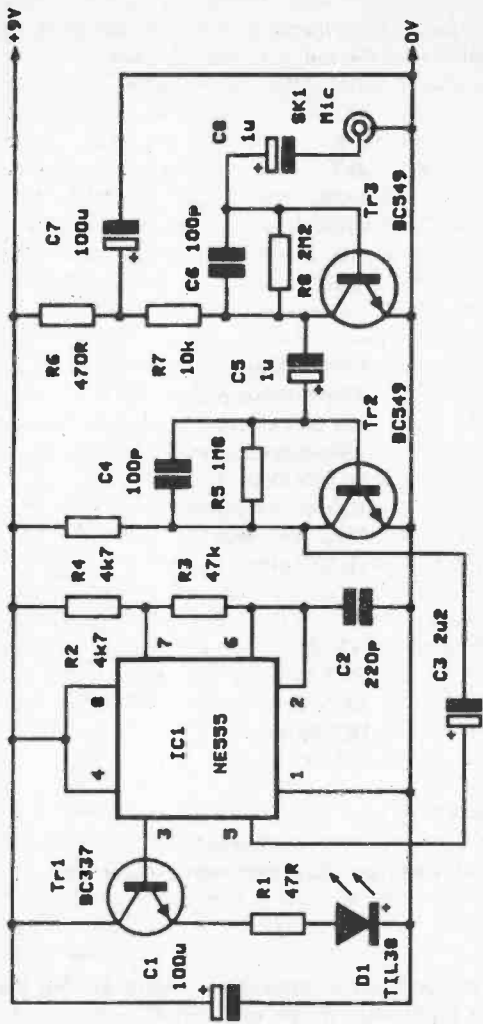
Fig. 40. The circuit diagram for the infra-red communicator (transmitter section)

40kHz, which is more than adequate for a system which has considerably less than the full audio bandwidth.

Components for IR Communicator – Transmitter (Fig. 40)
Resistors (all ¼ watt 5% unless noted otherwise)

R1	47R (1W)
R2	4k7
R3	47k
R4	4k7
R5	1M8
R6	470R
R7	10k
R8	2M2

Capacitors

C1	100μ 10V elect
C2	220p ceramic plate
C3	2μ2 63V elect
C4	100p ceramic plate
C5	1μ 63V elect
C6	100p ceramic plate
C7	100μ 10V elect
C8	1μ 63V elect

Semiconductors

IC1	NE555
Tr1	BC337
Tr2	BC549
Tr3	BC549
D1	TIL38

Miscellaneous

SK1	3.5mm jack socket

Circuit board, case, lens (see text), wire, solder, etc.

Receiver

The main receiver circuit appears in Figure 41, but the output filter circuit appears separately in Figure 42.

The receiver has Tr4 as the infra-red sensor followed by two high gain common emitter amplifiers. The two 2 input NOR gates of IC2 are wired to operate as a monostable multivibrator which
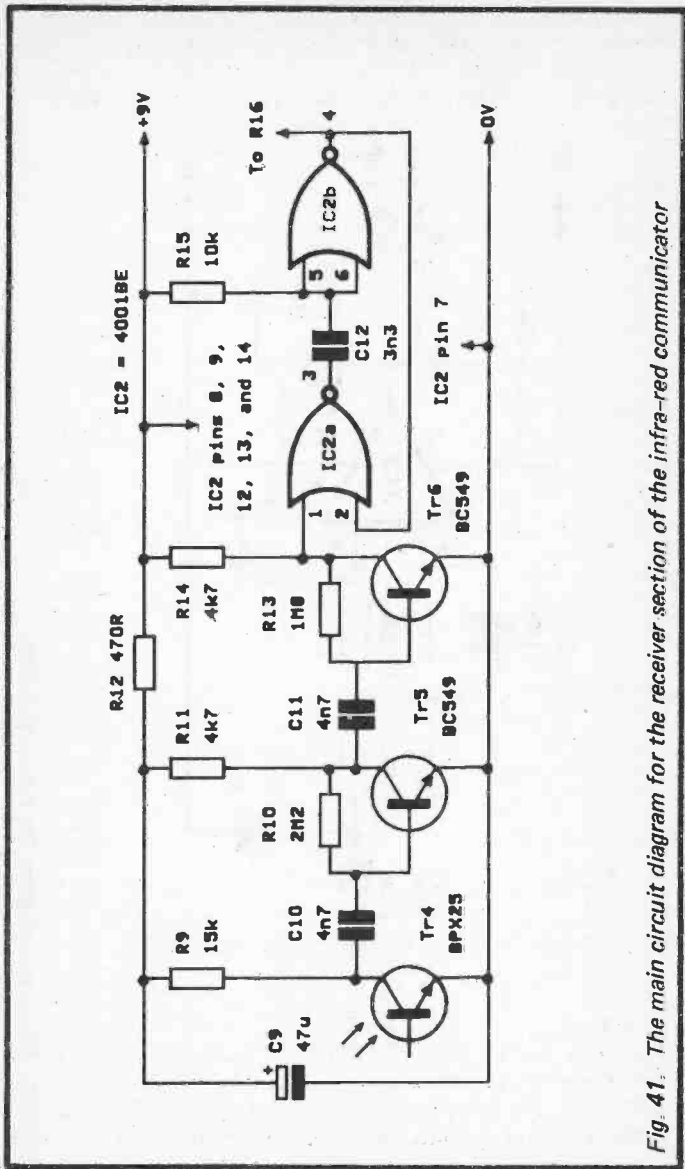
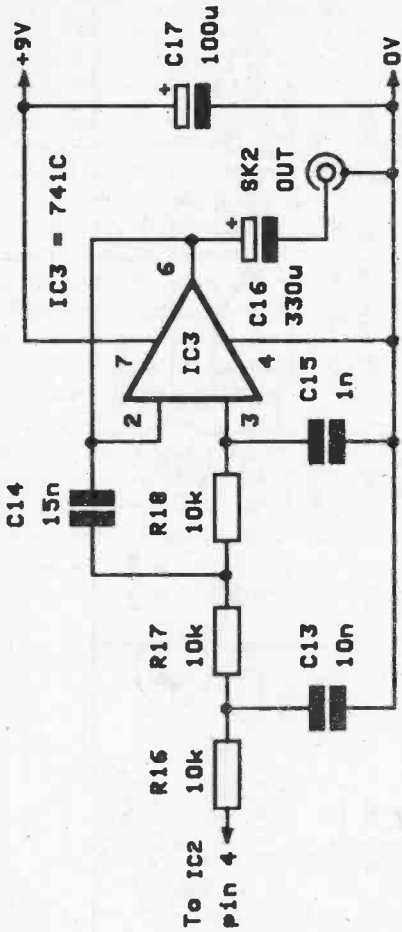Fig. 41. The main circuit diagram for the receiver section of the infra-red communicator

Fig. 42. The circuit diagram for the output filter

acts as the demodulator. The other two gates of IC2 are left unused, but their inputs are connected to the positive supply rail to prevent spurious operation of them.

With some types of headphone and earphone it is possible to obtain quite good results if they are driven direct from the output of the monostable. However, results are generally better with an improved signal to noise ratio if some lowpass filtering is used at the output of the unit, and IC3 acts as the buffer amplifier in a third order lowpass filter having a cutoff frequency of approximately 3kHz. Although this filter provides an attenuation rate of only 18dB per octave, with the carrier frequency nearly four octaves above the cutoff frequency this still gives a high degree of carrier suppression (nearly 70dB in fact).

The receiver can drive most types of earphone and headphone, but it is not suitable for operation with low impedance earphones (crystal types are perfectly suitable though). With low and medium impedance headphones it is advisable to use series rather than parallel connection of the phones, and results will probably be much better with a resistor of about 47R connected in series with C16 if the unit is used with 8 or 16 ohm impedance types. The circuit could be used to drive a simple single IC audio power amplifier if loudspeaker operation is required, but bear in mind that if the unit is built as a two way system with loudspeaker output that transmit/receive switching will be needed. Simultaneous communications both ways is not feasable with loudspeaker output as it would result in acoustic "howl- around"

Components for IR Communicator – Receiver (Figs. 41 and 42)
Resistors (all ¼ watt 5%)

R9	15k
R10	2M2
R11	4k7
R12	470R
R13	1M8
R14	4k7
R15 to R18	10k (4 off)

Capacitors

C9	47µ 10V elect
C10	4n7 polyester
C11	4n7 polyester
C12	3n3 polyester

C13	10n polyester
C14	15n polyester
C15	1n polyester
C16	330µ 10V elect
C17	100µ 10V elect

Semiconductors

| IC2 | 4001BE |
IC3	741C
Tr4	BPX25 or similar
Tr5	BC549
Tr6	BC549

Miscellaneous

| SK2 | 3.5mm jack socket |

Case, circuit board, lens (see text), wire, solder, etc.

Construction and Use

This is another circuit which has a high level of voltage gain, and which consequently requires a carefully designed component layout. In this instance both the transmitter and the receiver contain high gain amplifiers, but the amplifier in the transmitter unit has a much more limited bandwidth which makes it very much less critical as far as the component layout is concerned.

Without the aid of an optical system the range of the unit is, to say the least, likely to be quite limited. In fact the maximum range is likely to be no more than two or three metres. However, with a simple system of lenses added this can easily be boosted by a factor of more than ten, giving a usable range of 30 metres or more. It is only fair to point out that a system of this type will not provide very long ranges, as it is obviously a means of communications that is very much in the "line of sight" category. With highly efficient lens systems it is supposedly possible to obtain ranges in excess of a kilometre, but a range as large as this is a little impractical in that aiming the transmitter and receiver units correctly becomes virtually impossible. Maintaining them in correct alignment would also be extremely difficult as the slightest knock to either unit could well be sufficient to cut communications.

The optical system does not need to be anything very complex, and probably the best system to adopt is the one shown in Figure

Fig. 43. The simple optical system for the infra-red communicator
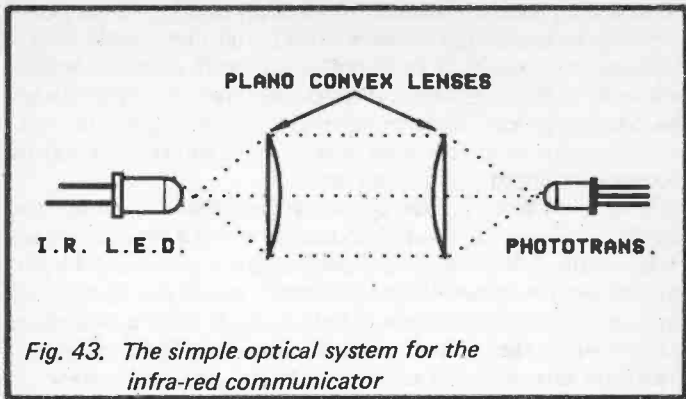
43. This is similar to the optical system for the passive infra-red beam project described previously, with a convex lens added in front of the receiving photocell so as to give it a larger pick up area and a very narrow angle of view. A lens of the same type is added in front of the transmitting photocell, and this has the effect of concentrating the infra-red signal into a narrow beam. Figure 43 is slightly idealised in that it tends to suggest that there is no spreading of the beam from the transmitter, and that the receiver has a field of view which is equal to the diameter of the lens. This would give a range that was only limited by the attenuation of the infra-red signal as it passed through the air, which would normally be many miles. On the other hand it would make alignment of the system practically impossible, and the fact that the beam spreads out as the range from the transmitter increases, and the viewing area of the receiver similarly increases, makes the system usable. It does limit the range though, and if the range is boosted by using a more efficient optical system, setting up the equipment becomes more critical. The optical system therefore has to be chosen to give a good compromise between range and ease of setting up.

The lenses I used were a type having a diameter of 30 millimetres, and a focal length of 80 millimetres. The quality of the lenses is not important for an application of this type where we are only interested in roughly focussing a beam of light, and image quality is not a consideration. Inexpensive plastic types costing a few pence each are just as suitable as highly expensive colour correct glass types costing many pounds. The lenses do not need

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to have the precise characteristics given previously, but they must be positive lenses (not concave types), and they should have a diameter of around 25 to 50 millimetres with a focal length of about 30 to 100 millimetres. The distance from the front of each photocell to its lens should be equal to the focal length of the lens, and in order to obtain good results the photocells should be accurately centred behind their lenses.

With even a very basic optical system the transmitter and receiver units need to be quite accurately aimed if good results are to be obtained. What seems to be the easiest way of doing things is to first aim the transmitter as accurately as you can by eye, and then use the receiver as a sort of field strength meter to determine exactly where the transmitter is actually aimed. With a little trial and error any necessary corrections to the aim can be made, so that the transmitter is known to be accurately aimed at the site where the receiver will be positioned. It is then just a matter of putting the receiver in place and adjusting its orientation for optimum results. The importance of getting the optical alignment correct can not be over-emphasized. With everything set up correctly it should be possible to obtain a good clear output signal with minimal background noise even at a range of 30 metres or so, but with the aim of one of the units even a couple of degrees out there may be no reception whatever. Remember that the units must be correctly aligned in two planes (horizontally and vertically) and not just laterally.

A two-way system is, of course, perfectly possible, but a transmitter and a receiver are needed at each end of the system, and there can be difficulties in aligning the system if they are built as a single unit. The problem is simply that as a receiver is turned to aim it correctly, the transmitter in the same box will be taken out of alignment. This can be overcome by first aiming the transmitter in the normal way, and then aligning the receiver by altering the position of the phototransistor behind the lens. This is much more difficult and awkward than it sounds, and it is actually much easier to construct each station of the system as separate transmitter and receiver units, or perhaps to have them as separate units but fitted on a single base which enables them to be individually aimed. In other words, to mount each unit on the base using some form of pan and tilt head, such as a type intended for photographic use.

Conclusion

Like the other projects described in this book, the infra-red communicator represents an interesting and potentially useful project which is well worth trying. Modern opto-electronic devices offer good performance at low cost, and possibly represent the most interesting field of electronics for the experimenter.
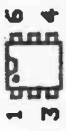
Fig. 44. Semiconductor pinout details (IC top views, transistor base views)

C106D

G A K

BPX25

BC337
BC547
BC549
BC557
BC559

1N4148

+   +

TIL111

TIL38

K   A

LM358
CA3240E LF442
LF351   CA3130E
CA3140E ICL7660
1458C   NE555

74LS14
4001BE

BERNARD BABANI BP194

Modern Opto Device Projects

■ In recent years, the range of opto devices available to the home constructor has expanded and changed radically. These devices now represent one of the more interesting areas of modern electronics for the hobbyist to experiment in, and many of these devices have useful practical applications as well.

■ This book provides a number of practical designs which utilize a range of modern opto-electric devices, including such things as fibre optics, ultra bright LEDs and passive IR detectors etc.

■ While many of these designs are not in the "dead simple" category, they should be within the capabilities of anyone with a reasonable amount of experience at electronics construction and some of the more simple designs are suitable for beginners.