Infrared 'trip' relay

Cut the beam of invisible light and 'trip' a relay or alarm — this simple project can be used as an automatic 'door minder', door opener, a burglar alarm or whatever.

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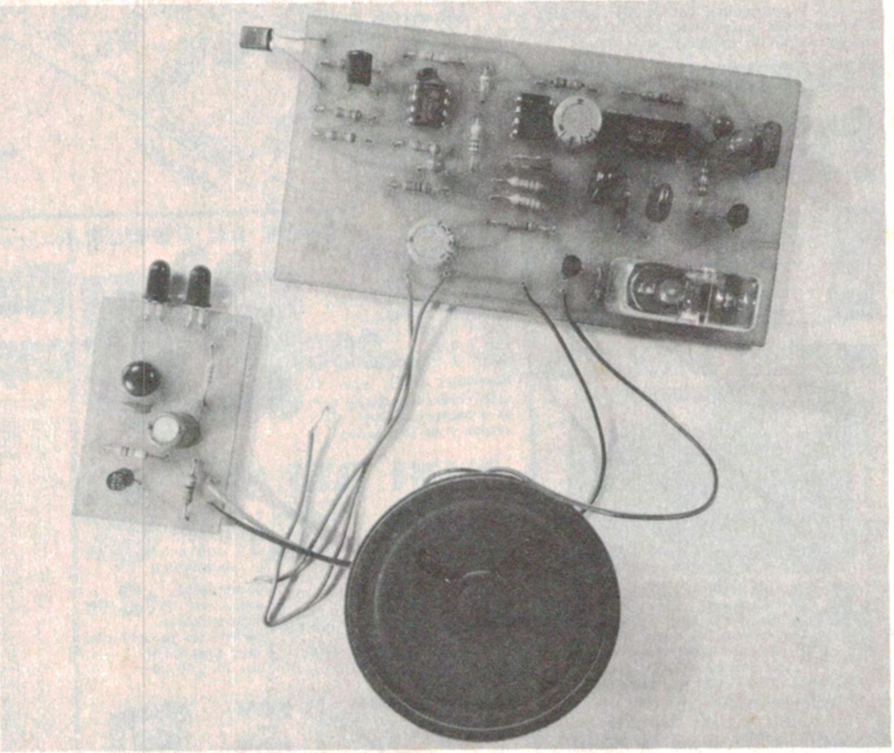


EVERYONE is familiar with the kind of door that's operated by an invisible beam. As you approach the door your body interrupts the beam, which triggers a switch to open the door. The same principle can be used for other things as well, like a 'door minder' alarm. The beam is set up across the doorway and when a person walks through it an alarm is set off.

This project is the basis of such a system. It comprises a transmitter which emits a beam of infrared radiation and a receiver which detects that radiation. As long as the receiver continues to receive the radiation nothing happens, but if the beam is interrupted a relay is energised (or 'tripped') and latched on for a fixed period of time. The contacts of this relay could carry the current for any 12 volt device, like a lamp, a piezoelectric siren, a small motor or whatever the application calls for. At the same time as the relay is energised, a low-level oscillator is switched on so that a buzzing noise can be heard through a loudspeaker if this is wanted.

The infrared beam is produced by two infrared light emitting diodes. These are just like any other LED, except that the light they emit has a longer wavelength. They use quite a lot of current, so to prevent batteries going flat too quickly they are supplied with very brief pulses of current at intervals of a few milliseconds, so that they emit short, intense bursts of radiation. This also makes it easier to detect the radiation. The range of the system is about two metres, which we thought was adequate for many applications. You could increase the range to about three metres by using two transmitters instead of one, but to increase it further requires a disproportionate amount of power. The range is inversely proportional to the square of the radiated power, so that doubling the range means quadrupling the amount of radiation transmitted, tripling the range means increasing the transmitted radiation by nine times, and so forth.

Construction

We recommend that you use our designs of printed circuit boards to construct the transmitter and receiver, but they are not essential.

Start by mounting the resistors on both boards, referring to our layout diagrams for their positions. Like all the components, these go on the plain side of the board, with their leads pushed through the holes and soldered to the tracks on the other side. Next, solder in all the capacitors on both boards, making sure that all the electrolytic or tantalum capacitors are correctly oriented with their positive leads at the ends we have shown.

Now mount the two infrared LEDs (LED1 and LED2) on the transmitter board. They must go in the right way round, with their cathodes (marked k on our diagrams) at the correct end. After that, mount the two transistors on the transmitter board (Q1 and Q2), making sure that their base, emitter and collector leads (marked b, e and c on our diagrams) are in the correct positions.

Turning to the receiver board, mount the two potentiometers (RV1 and RV2), then insert the diode (D1) and the infrared detecting diode (IRD1), making sure their cathodes are at the correct ends. In the case of IRD1 you also have to make sure that the sensitive side of the diode faces away from the board so that it can be pointed at the transmitter. The diode has two faces, one flat and one bevelled near the top, the flat side being the sensitive side. Mount IRD1 high enough above the board for it to be bent over to face the proper way.

Then mount the two transistors (Q1 and Q2), making sure you get all their leads in the right places. After that you can tackle the integrated circuits (IC1, IC2 and IC3). Make sure you put them in with the notch or spot at the same end

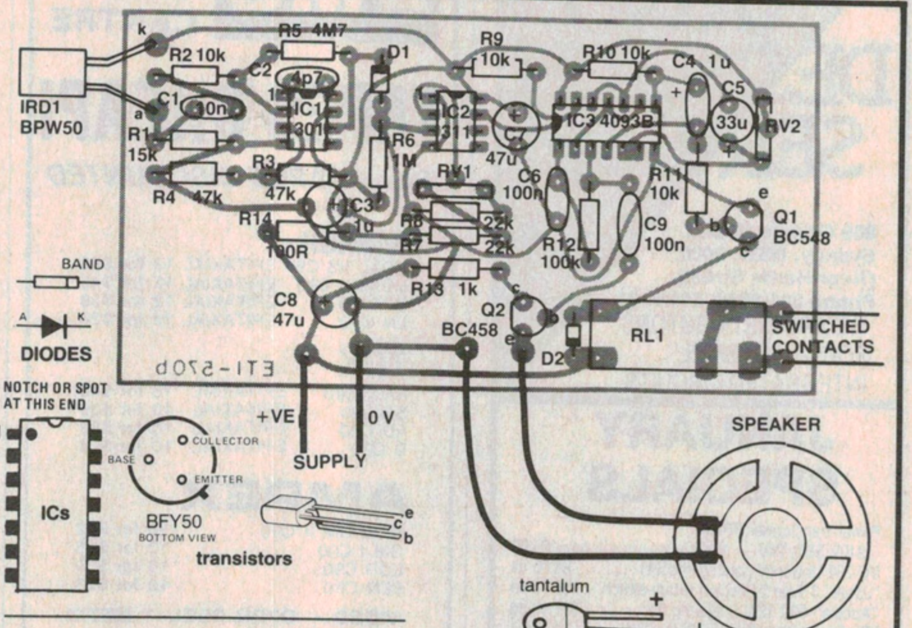
PARTS LIST — ETI 570

ETI-570a Transmitter

Resistors	**all ½W, 5%**
R1	47R
R2	10M
R3	3R3
Capacitors	
C1	1n greencap
C2	100u/16 V electro.
Semiconductors	
LED1,2	CQY89A or similar
Q1	BC558, BC178 or similar
Q2	BFY50 or similar
Miscellaneous	
ETI-570a pc board; case to suit, etc.	

ETI-570b Receiver

Resistors	**all ½W, 5%**
R1	15k
R2,R9-R11	10k
R3, R4	47k
R5	4M7
R6	1M
R7, R8	22k
R12	100k
R13	1k
R14	100R
RV1	100k min. vertical mount trimpot.
RV2	1M min. vertical mount trimpot.
Capacitors	
C1	10n greencap
C2	4p7 ceramic
C3, C4	1u/16 V tantalum
C6, C9	100n greencap
C5	33u/16 V tant, or RBLL
C7, C8	47u/16 V electro
Semiconductors	
D1	1N914,1N4148 or sim
D2	1N4002, etc.
IRD1	BPW50 or similar
Q1,Q2	BC548,BC108 or similar
IC1	301
IC2	311
IC3	4093B



Miscellaneous

RL1	SPDT pc mount relay with 12 V coil

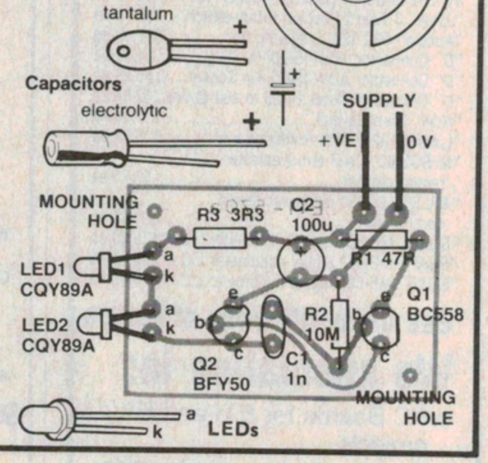
ETI-570b pc board, miniature 8 ohm speaker, case to suit, etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$21—$25

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



as our layout diagrams show, and take care when soldering them in that you don't overheat them. Use a reasonably small bit, don't spend too long over each pin and allow the whole IC to cool down for a few seconds between soldering each of the pins.

Finally mount the relay, connect the loudspeaker to the board (using insulated hookup wire), attach two insulated leads for the power supply, and attach the battery clip to the transmitter board. The transmitter and receiver are now both completed.

Setting up

Connect a 12 volt battery or power supply. Adjust RV1 for minimum resistance. With the transmitter turned off, increase the value of RV1 until the relay just operates. You will notice that the relay will switch off as the latch resets at the end of the timing period, then switch on again as the latch is set again.

Turn on the transmitter and move it away from the receiver, keeping the two LEDs pointing towards the receiver all the time. You should be able to move two metres away without anything happening. If you find that the receiver is not sensitive enough, you can add another infrared receiving diode in parallel with IRD1 to increase the amount of radiation it picks up. If the range is OK, check that the relay operates when the beam is broken.

The volume of sound from the speaker can be altered by altering the value of R13. Reducing the value of R13 increases the volume, increasing R13 reduces it. You can also vary the time that the relay contacts are closed by varying the setting of RV2.

Housing

As individual applications of this project will vary widely, we have not described how to house it in any specific way. However, a few hints may help. The transmitter could be housed in any convenient small container, such as a jiffy box or even a cheap plastic soapholder from a chain store. The two infrared LEDs can be mounted in any convenient position, secured with common LED 'collar' mounts. When mounting the LEDs, keep in mind how you will mount the transmitter box so that the LEDs face in the desired direction.

The receiver can also be mounted in any suitable housing. The infrared receiver diode may be mounted off the pc board or the board positioned so that the diode is held against a hole cut in one side of the case. Alternatively, the receiver diode may be mounted on a tagstrip bolted in an appropriate position. You can secure a small piece of infrared filter plastic over the hole in the case. This will provide some physical protection for the diode. Kodak 'Wratten 89c' or a similar type of filter plastic will do. Make sure you correctly identify the sensitive face of the diode.

For outdoor applications, where the units may be exposed to the weather, we recommend you use aluminium diecast boxes. They're more expensive than other housings, but they're very robust and can be sealed against the weather. ▶

HOW IT WORKS

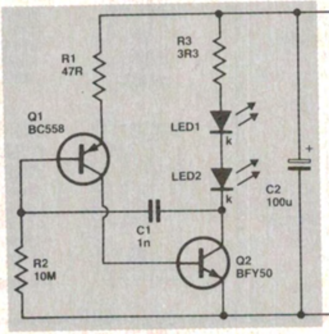
TRANSMITTER

A serial multivibrator allows frequent short pulses of current through two infrared LEDs, so that they emit pulses of radiation towards the receiver. To ensure a reasonable battery life, the duration of each pulse is kept short compared to the interval between pulses. Because the pulse length is short, the LEDs can pass a current of more than one ampere without burning out, thereby producing a high level of radiation that can be detected at a distance of about two metres. The radiation output is further increased by using two LEDs in series.

When the circuit is turned on, the base of Q2 is at a low voltage and Q2 is therefore turned off. This means that Q2's collector is at a voltage close to the battery supply voltage. A small current therefore flows through R3, LED1, LED2, C1 and R2 to ground. The voltage drop across R3 caused by this current keeps the base of Q1 at a 'high' voltage, so that Q1 is turned off. As C1 charges, it develops a voltage across its plates that opposes the flow of current through R3. The voltage on the base of Q1 therefore starts to drop, and when it has dropped about 0.7 volts below the supply voltage, Q1 turns on. This allows current to flow through the base-emitter junction of Q2 and turn that transistor on also, so that a large current can flow through R3 and the two LEDs.

The current through Q2 is large because of the low value of R3, and the high internal resistance of the battery means that it cannot supply this current without a considerable drop in the voltage across its terminals. The current therefore comes mainly from the discharging of capacitor C2. Once C2 has discharged, the low voltage across the battery terminals cannot drive enough current through R1 and Q1 to keep Q2 turned on, so this transistor turns off again, cutting off nearly all the current through the LEDs and allowing the battery voltage to rise again.

While Q2 is turned on, its collector voltage is low, which allows C1 to discharge, so that when Q2 turns off again the circuit is in the same state as it began in and the whole cycle repeats itself over and over again until power is turned off. The frequency of the pulses depends on the time taken for C1 to charge (which depends mainly on the battery voltage and the values of C1 and R2). The duration of each pulse depends on the time taken for C2 to discharge (which depends mainly on the battery voltage and the values of C2 and R3). The values we have specified for components give pulses a few microseconds long at intervals of a few milliseconds. The peak current through the LEDs is about one amp, but the average current is only about one milliamp.



INFRARED TRANSMITTER

RECEIVER

The pulses of infrared radiation emitted by the transmitter are detected by an infrared receiving diode and amplified by an op-amp. The output pulses from the op-amp are used to keep a capacitor discharged, and a comparator IC compares the voltage across this capacitor to a reference voltage. As long as the reference voltage is higher, the comparator puts out a 'high' voltage and nothing happens. When the infrared beam is interrupted, there are no current pulses to keep the capacitor discharged, so its voltage rises and the comparator output swings low. This low voltage operates a latch, one of whose outputs switches on a transistor to allow current through a relay to close its contacts. The other latch output switches on an oscillator to produce a tone in a loudspeaker. When a set period of time has expired, the latch is automatically reset, cutting off current to the relay and loudspeaker.

When a pulse of infrared radiation strikes the receiving surface of the reverse-biased infrared receiving diode (IRD1), it conducts a pulse of current. The voltage drop across R1 caused by this current pulse is applied to the inverting input of op-amp IC1 via coupling capacitor C1. The non-inverting input of IC1 is held at a steady voltage by the potential divider R3 and R4. Negative feedback through R5 sets the gain of IC1 at around 500. Since the input pulses are applied to the inverting input of IC1, the amplified output pulses are negative-going.

The diode D1 passes only the negative pulses, which discharge capacitor C3. Because R6 has a high value, C3 cannot charge much between pulses, so that a continuous series of pulses from the transmitter keeps C3 discharged, with a low voltage across its plates. If the beam from the transmitter is interrupted, C3 charges up and the voltage across it rises.

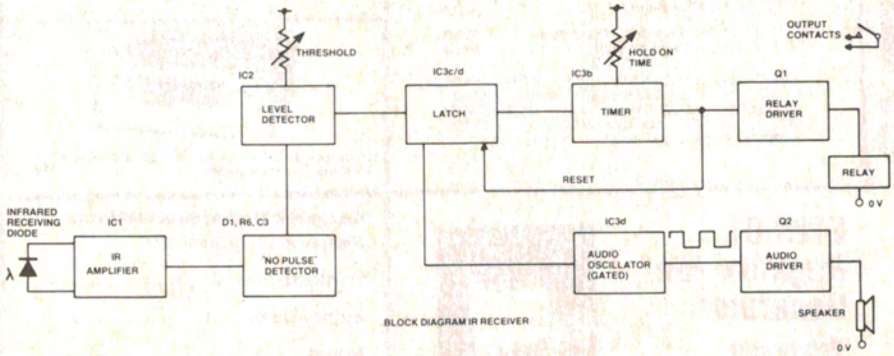
IC2 is a comparator. Its output (at pin 7) is high when the voltage on pin 2 is higher than the voltage on pin 3. If the voltage on pin 3 is higher than the voltage on pin 2, the output of IC2 is low. Pin 2 is held at a constant preset voltage by the potential divider chain of R7, RV1 and R8. When pulses are being received, C3 is discharged and the voltage on pin 3 is therefore low; when the beam is interrupted, C3 charges up and the voltage on pin 3 rises, switching the output of IC2 from high to low.

IC3b, IC3c and IC3d are Schmitt-triggered NAND gates connected as a latch circuit. If either of the inputs of a Schmitt-triggered NAND gate is low, then its output is high. If both inputs rise above a 'threshold' voltage, the output goes low. If either input then falls below a second threshold voltage, the output goes high again.

When power is first turned on to the circuit, pins 5 and 6 of IC3b are held high via RV2, so that its output (pin 4) is low. This means that current can flow through R10 and C4 to pin 4 of IC3b and the voltage drop across R10 caused by this current makes pin 8 of IC3c go low. Output pin 10 of IC3c therefore goes high and so does input pin 12 of IC3d. If pulses are being received from the transmitter, pin 13 of IC3d is also high, so that output pin 11 is low. Input pin 9 of IC3d is therefore held low also, and this low on pin 9 keeps the output of IC3c high, even after pin 8 goes high again, because capacitor C4 has charged up and stopped current flowing through R10.

When the pulses are interrupted, pin 13 of IC3d goes low, sending output pin 11 high. Pin 9 therefore goes high too and since pin 8 is also high, output pin 10 goes low. Current then begins to flow through RV2 and C5 to pin 10, causing a voltage drop across RV2 which sends pins 5 and 6 of IC3b low. Output pin 4 of IC3b therefore goes high and current flows from this pin through R11 to turn on transistor Q1, allowing current through the relay to close its contacts. At the same time, the high on pin 11 of IC3d is applied to input pin 2 of IC3a, which is another Schmitt-triggered NAND gate configured as a square wave oscillator. Capacitor C5 slowly charges up from current through RV2, developing an increasing voltage across its plates. After a while, the voltage on C5 forces the inputs of IC3b above the threshold voltage and its output (pin 4) goes low, cutting off the bias current to Q1, which therefore turns off and stops current to the relay so that its contacts open again. The low on pin 4 of IC3b allows a pulse of current to flow through R10 and C4, which resets the latch.

When pin 2 of IC3a goes high, the other input (pin 1) is initially low, so that output pin 3 is high. This allows current to flow from pin 3 through R12 and C6 to ground. At first the voltage drop across R12 caused by this current keeps pin 1 low, but after a short time C6 has charged up and developed a voltage across its plates which forces pin 1 above the threshold level. Pin 3 therefore goes low and C6 discharges into it through R12. As C6 discharges, its voltage drops and after a little while pin 1 drops below the threshold, so that pin 3 goes high again. The oscillator is then in the same state it began in and the process repeats itself over and over again, producing



BLOCK DIAGRAM IR RECEIVER

SILICON PHOTO P-I-N DIODE

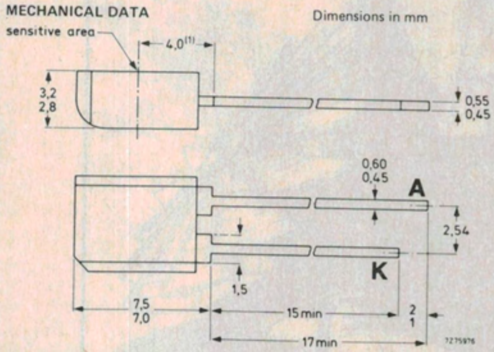
Silicon photo p-i-n diode in a plastic envelope with an infrared filter.

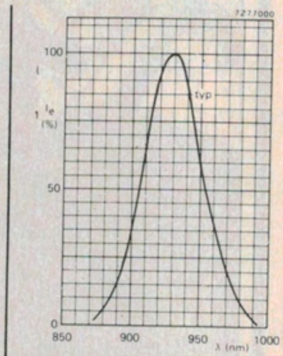
QUICK REFERENCE DATA

Continuous reverse voltage	V_R	max.	32	V
Total power dissipation up to T_{amb} = 47,5 °C	P_{tot}	max.	150	mW
Junction temperature	T_j	max.	100	°C
Dark reverse current V_R = 10 V; E_e = 0	$I_{R(D)}$	<	30	nA
Light reverse current V_R = 5 V; E_e = 1 mW/cm²; λ = 930 nm	$I_{R(L)}$	>	30	μA
Wavelength at peak response V_R = 5 V	λ_{pk}	typ.	930	nm
Sensitive area	A	typ.	5	mm²

MECHANICAL DATA

Dimensions in mm



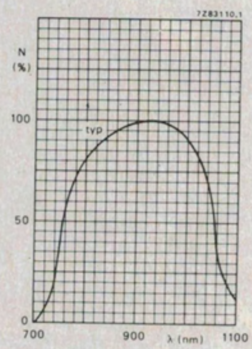


GaAs LIGHT EMITTING DIODE

Epitaxial gallium arsenide light emitting diode intended for remote-control applications. It emits radiation in the near infrared when forward biased. Infrared translucent epoxy encapsulation (dark blue).

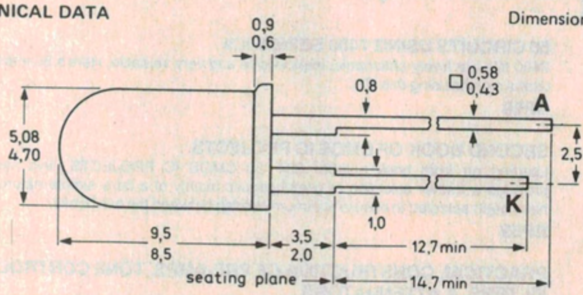
QUICK REFERENCE DATA

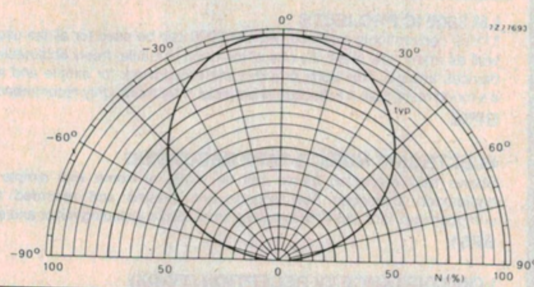
Continuous reverse voltage		V_R	max.	5	V
Forward current (d.c.)		I_F	max.	130	mA
Total power dissipation up to T_{amb} = 25 °C		P_{tot}	max.	215	mW
Junction temperature		T_j	max.	100	°C
Radiant intensity (on-axis) at I_F = 100 mA	CQY89A	I_e	>	9	mW/sr
	CQY89A-1	I_e		9 to 20	mW/sr
	CQY89A-2	I_e	>	15	mW/sr
Wavelength at peak emission		λ_{pk}	typ.	930	nm



MECHANICAL DATA

Dimensions in mm





an oscillating voltage at pin 3 which is coupled to the base of Q1 via C9. Q1 therefore turns on and off in time with the oscillations, providing an oscillating current through the loudspeaker. When pin 2 of IC3a goes low again, after the latch has reset at the end of the timing period, the output of IC3a is held high all the time, preventing oscillations. ●