Proximity Detector

This project will endow a robot with infra-red vision, and it's not much bigger than a human eye-ball. Alternatively you use it in applications such as batch counting. Design and development by Rory Homes.

THIS PROJECT provides a very useful means of detecting the presence of anything by the reflection of infra-red light, and provides a direct digital output of object detection.

The transmitter and receiver of the infra-red beam are both mounted on the same miniaturised PCB, which is housed in a short length of aluminum tube for shielding and protection. By the use of modulation and high power bursts of infra-red at a very low duty cycle, a detection range of over 30 cm is achieved. The receiving photo-amplifier is tuned to the same modulating frequency of 1 kHz, and thus provides good rejection of stray infra-red interference. Bright lights will not affect the operation of the module.

The module features a wide supply voltage range with a LED to indicate correct operation. A preset adjustment pot at the rear of the sensor allows the detection range to be preset at any distance between 1 and 35 cm.

Construction

Although the PCB layout (Fig. 2) is quite dense, with several vertical mounting resistors, the assembly should be straightforward. The only component of note is PR1, a ¾" 20 turn rectangular cermet preset. These are readily available, though, and should fit the board exactly. The power transistor Q3 is mounted flat, with the metal side face down; likewise, observe the orientation of the other transistors. Photodiode D1 has a chamfered edge on one side; this is mounted to face the infra-red emitter LED2, so allowing the sensitive surface to face outwards. The infra-red LED should be mounted with the flat side facing away from the photodiode (the flat identifies the cathode). After assembly of the board it is important to mount a small guard between the infra-red emitter and detector, to prevent infra-red light passing directly to the detector before it has been reflected. The guard should be a 7 mm square, cut from un-etched PCB or a piece of aluminum. It can be stuck between the two diodes and directly in front of C4 with a blob of epoxy.

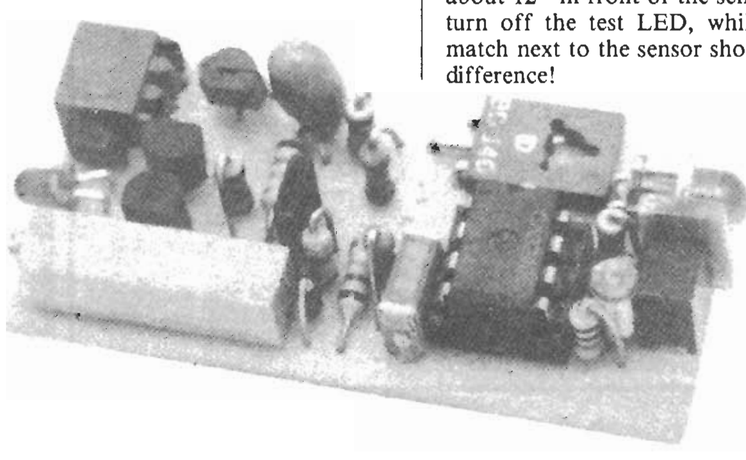
The board is mounted in a 55 mm length of aluminum tube, of internal diameter 27 mm or greater.

The diagram of Fig. 3 illustrates how a nut is soldered sideways onto the PCB track directly beneath the 3-way connecter socket. Holes are drilled in one end of the tube to mate up with the indicator and preset adjustment screw. A rectangular hole also needs to be cut, allowing access to the connector socket. A bolt can now be used to tighten the board against the tube end. The sensing end of the tube may be covered with anything that is transparent to infra-red (red filter plastic polarising sheet, or just clear plastic). If openings are cut for the emitter and detector then an aluminum disc could also be used. The disc should be cut to fit the tube and mounted flush against the small guard plate with epoxy. The sensor tube may be mounted with a circular clamp that tightens round the tube; this can be seen on the photographs of our prototype.

C2, the smoothing capacitor, is shown on the circuit diagram as a 100uF 10V tantalum electrolytic. This value was chosen to fit on the PCB and consequently limits the supply to 9 V maximum, although the circuitry is capable of operating up to 35V. To allow higher supply voltages, change C2 to 22uF 35 V tantalum. An additional electrolytic of 100uF 40 V should be mounted underneath the board and soldered to the same pads as C2.

The sensor is now ready for testing, and the three way connector plug should be wired to a suitable power source capable of providing 100 mA (this is for the benefit of the bulb, if used; the circuit itself only takes 20 mA). A 9 V battery is adequate. One of the test circuits illustrated in Fig. 4 should be adopted; if the LED arrangement is used, for example, the LED will be on when the sensor points into free space. Start with the preset fully anticlockwise; this gives minimum sensitivity and the sensors should not trigger at all.

Keeping the sensor pointed at free-space, the preset should be turned clockwise to increase the sensitivity until the LED just goes out. The preset should now be backed off until the LED just goes out. The preset should now be backed off until the LED just comes on again, thus setting the maximum range. Placing a hand about 12" in front of the sensor will now turn off the test LED, while striking a match next to the sensor should make no difference!



HOW IT WORKS

The proximity sensor works on the principle of transmitting a beam of modulated infra-red light from the emitter diode LED2, and receiving reflections from objects passing in front of the beam with a photodiode detector D1. The circuit can be split into three distinct stages; the infra-red transmitter, the photodiode amplifier, and a variable threshold comparator.

The transmitter provides 1 A peak current pulses for 10 uS through the infra-red emitter diode, at a repetition rate of 1 kHz. Q1 is arranged as a constant current source to supply the base of Q2, and to charge up C1. As C1 charges up, the base voltage of Q2 rises until it reaches about 0V6 relative to ground. Q2 then turns on, so turning on another constant current source formed by Q3 and LED1. This current source sets a temperature compensated voltage of about 1V5 across R3, thus defining a current of 1 A through the infra-red emitter LED2. After Q3 turns on, a negative pulse through C1 and R2 is set at 10 uS. A 10 uS pulse every 1 mS is equivalent to a duty factor of 1:100, so that although 1 A peak pulses are generated, the average current required is only 10 mA. Capacitors C3 and C2 are there to provide power supply smoothing to decouple the fast current pulses.

The detector is built around IC1, a CA3240 dual op-amp. IC1a is configured as an inverting amplifier with a gain of — 2. It amplifies the infra-red signal picked up by photo-diode D1. C4, which couples the diode signal to IC1a, acts as a high-pass filter in combination with the input impedance of the amplifier. Positive-going pulses of 10 uS duration are fed from the output, via rectifier D2, to a smoothing filter C5 and R9. This provides the signal voltage reference for the inverting input of comparator IC1b. A 2V7 reference, formed by R8 and ZD1, provides the biasing voltage for the photodiode through R7. It also provides the reference voltage for the non-inverting comparator input, set by potential divider PR1.R10 creates positive feedback round the comparator, to improve the switching, and introduce a small amount of hysteresis. Thus, if a reflected light signal received due to the presence of an object rises above the threshold set by PR1, the comparator output will go into negative saturation. The comparator output is used to turn Q4 on or off, thus providing an open collector output for digital interfacing to logic circuits.

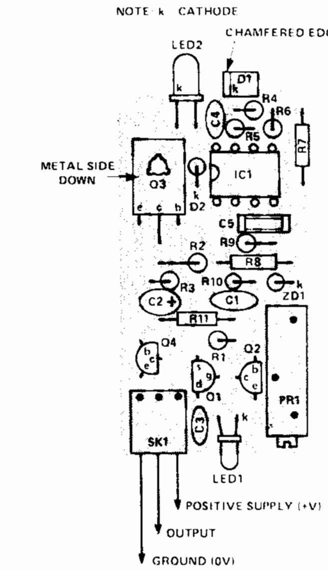


Fig. 1 Component overlay for the optical sensor. The photos overleaf show how small the unit is.

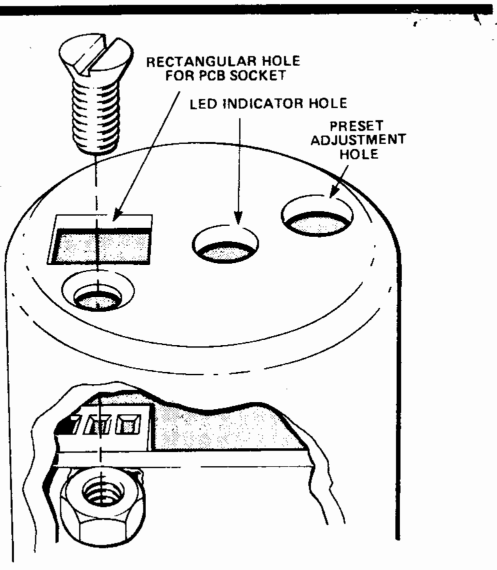


Fig. 3 This is how we mounted the PCB in the aluminum tube. The nut is soldered to the ground track under SK1.

NOTE:
IC1 IS CA3240
Q1 IS 2N3819
Q2,4 ARE MPS6515
Q3 IS BD140 OR TIP30C
D1 IS PHOTODIODE
D2 IS 1N4148
ZD1 IS 2V7 400mW ZENER
LED1 IS 3mm RED LED
LED2 IS INFRA-RED LED

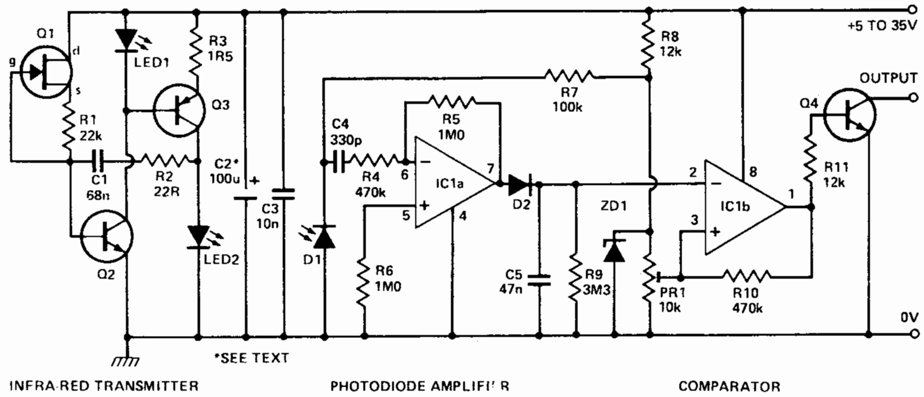


Fig. 2 Circuit diagram for the sensor.

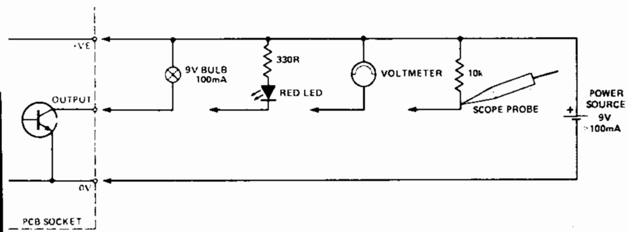


Fig. 4 Any of these test circuits may be used to check out the sensor.

PARTS LIST

Resistors (all ¼W,5%)

R1 22k
R2 22R
R3 1R5
R4,10 470k
R5,6 1M0
R7 100k
R8,11 12k
R9 3M3

Potentiometers

PR1 10k ¾" 20 turn cermet trimmer

Capacitors

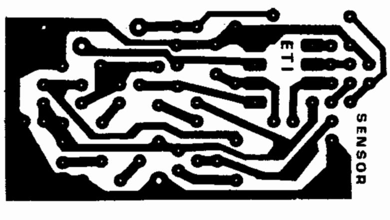
C1 68n ceramic
C2 100u 10V tantalum (see text)
C3 10 n ceramic
C4 330p ceramic
C5 47n polycarbonate

Semiconductors

IC1 CA3240
Q1 2N3819
Q2,4 MPS6515
Q3 BD140 or TIP30C
D1 Photo-diode (TIL100 or similar)
D2 1N4148
LED1 3 mm red LED
LED2 infra-red LED (TIL38 or similar)
ZD1 2V7 400 mW zener diode

Miscellaneous

PCB; any three-way PCB plug and socket; aluminum tube (27 mm diameter, 55 mm long).



ETI