Infrared Object Counter

Count objects with up to 255 pulses per count.

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Most object counters around today implement a mechanical method of counting and those that don't use some very sophisticated and expensive methods of determining the presence of an object. These may take the form of magnetic induction or single ended optical detection, both of which have some major drawbacks. I required an object counter that could count objects of different size, shape, composition and orientation as they pass the sensor.

I decided that an optical method was best suited to the task. For this reason I used an infrared transmitter and receiver; this was superior to the mechanical method because there is no physical contact made between the object and the sensor. I also had the problem that the object might break the beam more than once during the pass, *eg*, a car has two sets of wheels as seen from the side, giving two counts for one object, so a programmable divider was included to count once when the beam was broken a desired number of times. The number of objects that have passed the sensor is displayed on a seven segment display.

How It Works

As can be seen in the block diagram (Fig. 1) an oscillator generates pulses of infrared light at a predetermined frequency, in this case 5kHz. This light is then detected by the receiver and amplified. The amplified signal is then fed through a filter that only allows a signal of 5kHz to pass, followed by a pulse shaping circuit which outputs one pulse every time the beam is broken. This is sent to the programmable divider or directly to the counters, whichever is required.

The counters are decade counters and directly drive the displays from their decoded outputs, thus eliminating the need for counters, decoders and drivers.

Circuit

The transmitter is based on the NE555 timer IC configured in the astable multivibrator mode (Fig. 2). The advantage of

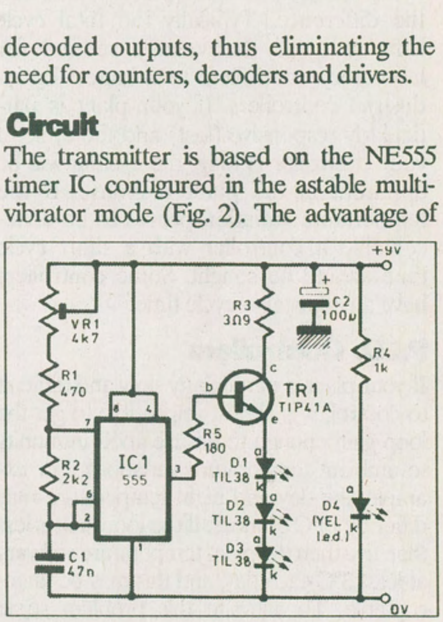

Fig. 2. Transmitter circuit diagram.

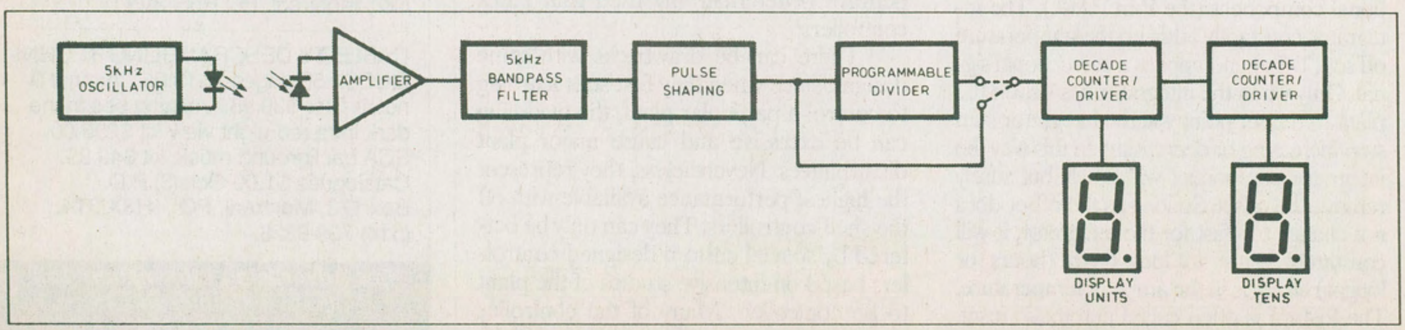

Fig. 1. Block diagram of the IR Object Counter.

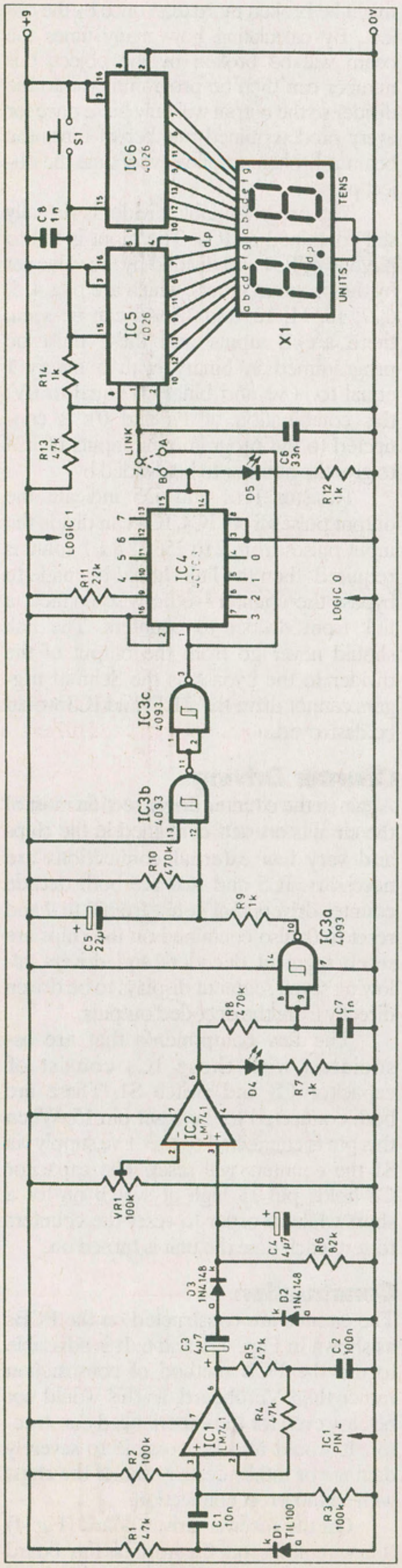

Fig. 3. Receiver and counter circuit.

using a pulsed beam in preference to a continuous beam is that the beam can be encoded in a way that the receiver can differentiate from any other light source. This allows the system to be used in optically noisy environments, such as those that are prone to lights being turned on and off or even the transition from day to night. These environmental changes can cause the receiver to trigger a false count.

There is also a power saving when using the encoded system because the output diodes are flashed on and off many times a second; the output is only on for half the time, so only half the power is used.

The timing components VR1, R1, R2 and C1 are selected to produce 5kHz at the output. VR1 is incorporated so that the transmitter can be fine tuned to the optimum for the environment. The output of the NE555 can only sink loads up to 200mA, so transistor TR1 is used to drive the output diodes as these take 100mA each.

Resistor R3 should not be replaced by a lower value than 3.9 ohms or this might damage the transistor TR1. R4 and D4 are only incorporated to indicate the connection of power to the transmitter as the output diodes do not emit any visible light.

Receiver And Filter

The device used to receive the infrared signal is the TIL100 photo diode (Fig. 3.). This diode works best when light in the infrared spectrum falls upon it. When the light falls upon the sensor the current flowing through it increases. If this diode is connected in reverse bias across the supply through a pullup resistor, we can get a change in potential at the point where they meet; this is proportional to the light falling on the sensor. This potential is also oscillating at the same frequency as the transmitter, so we can AC couple the signal to the amplifier via C1.

The amplifier is designed so that only a signal of 5kHz can pass easily due to the feedback arrangement of R4, R5 and C2. At low frequencies, the gain of the amplifier is approximately 1:1, but at 5kHz the impedance of C2 decreases so that the gain of the amplifier increases to several thousand. The 5kHz frequency at the output of the amplifier is then sent through a voltage doubler circuit D2, D3, and smoothed by R6 and C4. It then reaches the pulse shaping stage.

Pulse Shaping

Pulse shaping is required to shape the smoothed signal into a pulse with fast attack and fast decay, eliminating the risk of

PARTS LIST

TRANSMITTER

Resistors

All 1/4W, 5%

R1	470
R2	2k2
R3	3R9
R4	1k
R5	180

Potentiometer

VR1	4k7 hor. trim

Capacitors

C1	47n
C2	100u 16V

Semiconductors

IC1	555 timer
TR1	TIP41A NPN
D1-3	TIL38 infrared diode
D4	LED

RECEIVER

Resistors

All 1/4W, 5%

R1,4,5,13	47k
R2,3	100k
R6	82k
R7,9,12,14	1k
R11	22k

Potentiometer

VR1	100k hor. trim

Capacitors

C1	10n
C2	100n
C3,4	4u7 16V
C5 22u	16V
C6	33n
C7,8 1n	

Semiconductors

IC1,2	741 op amp
IC3	4093 quad NAND Schmitt
IC4	40103 divider
IC5,6	4026 counter driver
D1	TIL100 photo diode
D2,3	1N4148
D4,5	LED

X1 double 7-seg. common cathode display

Miscellaneous

Short length of 16-way ribbon cable, wire, solder, etc.

a false reading by unwanted noise spikes. Noise spikes can occur by the switching on and off of light switches, etc., in the close proximity of the receiver.

The first stage of the pulse shaping is to compare the input pulses with a known potential; this is done by a comparator circuit. A 741 operational amplifier (IC2) is used to compare the potential set at pin two by the potentiometer VR1 — this is know as the reference potential. The input signal is connected to pin three and is then compared with the reference potential. If the signal is greater than the reference, then the output goes high. If the signal potential does not reach the reference potential, then the output will remain low. By using a comparator all the noise spikes less than the reference potential are eliminated. The output of the comparator then feeds R7 and D4. This diode emits light when the beam remains unbroken and stops emitting when the beam is broken.

The next stage is formed by IC3 which consists of four 2-input NAND gates, which can be used as Schmitt triggers, simplifying the task of pulse shaping. (As the Schmitt trigger is a dedicated pulse shaping device, it is an obvious choice.) The input pulse is fed into the first two gates for shaping and the third is incorporated as an inverter to invert the output of IC3b ready to be fed through the dividing circuit.

Pulse Dividing

As described previously, the pulse divider was incorporated to enable the use of the system in applications where the beam might be broken more than once by the object. By calculating how many times the beam will be broken by the object, this number can then be programmed into the divider so the output will only pulse once for every predetermined number of times the beam is broken, or once every time the object passes.

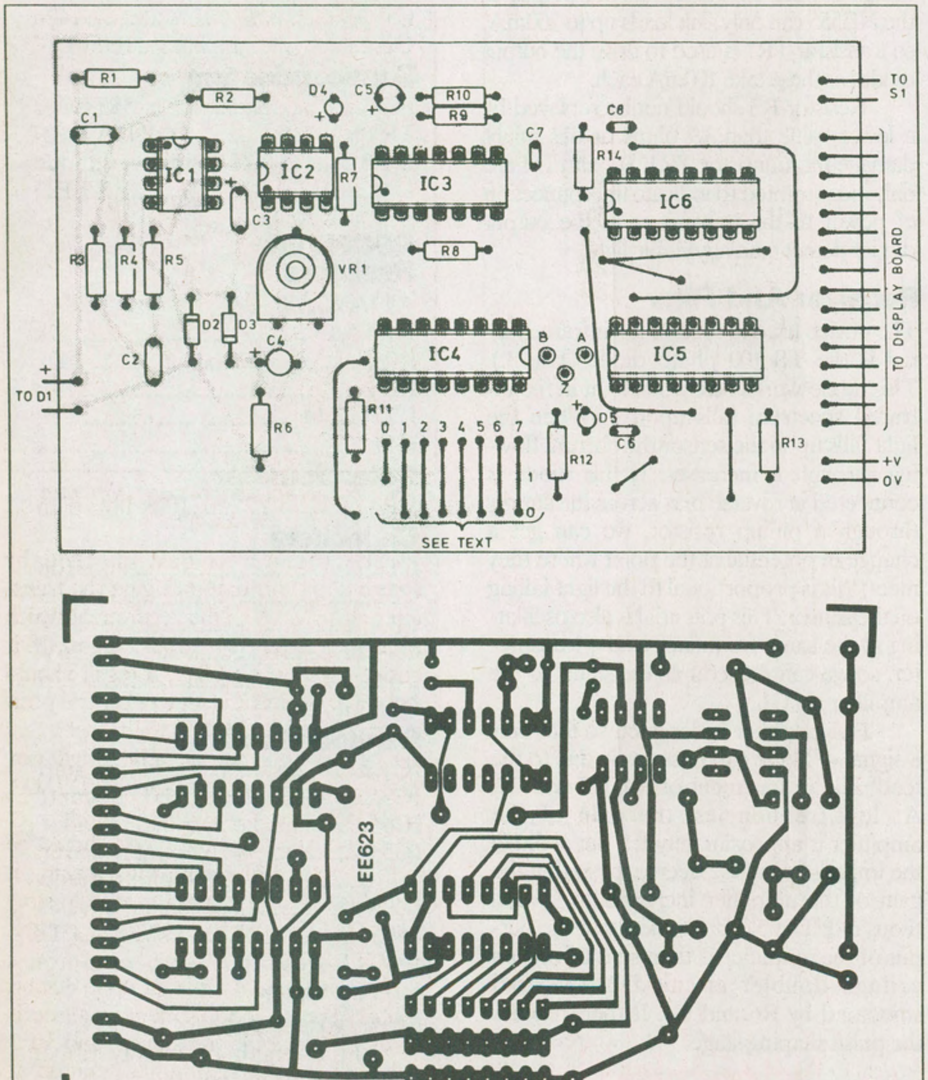

Fig. 4. The component overlay (top) and the PCB for the Object Counter.

The programmable divider is virtually self-contained as IC4. The input is fed to pin one of IC4 and divided by the value set by the program inputs, which are pins 4, 5, 6, 7, 10, 11, 12, and 13. As can be seen, there are 8 inputs and these must be programmed in binary, with a binary 1 equal to +ve and binary 0 equal to 0V; this combination of 1's and 0's is connected to the programming inputs of IC4 to give the number to be divided by.

Resistor R12 and D5 indicate the output pulses from IC4. IC4 can divide the input pulses from 2 to 256; if a 1:1 count is required then the link should be made to bypass the counter—otherwise connect a link from divider to counters. The link should never go from the output of the divider to the bypass as the Schmitt triggers cannot drive the LED and IC3 would be destroyed.

Counter Driving

Again in the counter driver section most of the circuits are self-contained in the chips and very few external connections are necessary. IC5 and IC6 are both decade counter drivers that count from 0 to 9 and reset to 0; also contained on the chips are seven segment decoders and drivers, allowing seven segment displays to be driven directly from the decoded outputs.

The few components that are associated with these ICs consist of capacitor C8 and switch S1. These are both connected to the reset pin 15. When this pin is connected to the +ve supply via S1 the counters will reset. The capacitor C8 holds pin 15 high at switch on for a short while in order to reset the counters to zero each time the unit is turned on.

Construction

The circuits are constructed on the PCBs as shown in Figs. 4, 5 and 6. It is advisable to use the PCB method of construction rather than Veroboard, as this would not be easy even for the experienced constructor. It would also be possible to severely damage or totally destroy one of the chips with an incorrect connection.

On the receiver driver board (Fig. 4) the wire links on the top of the board should be connected first using insulated

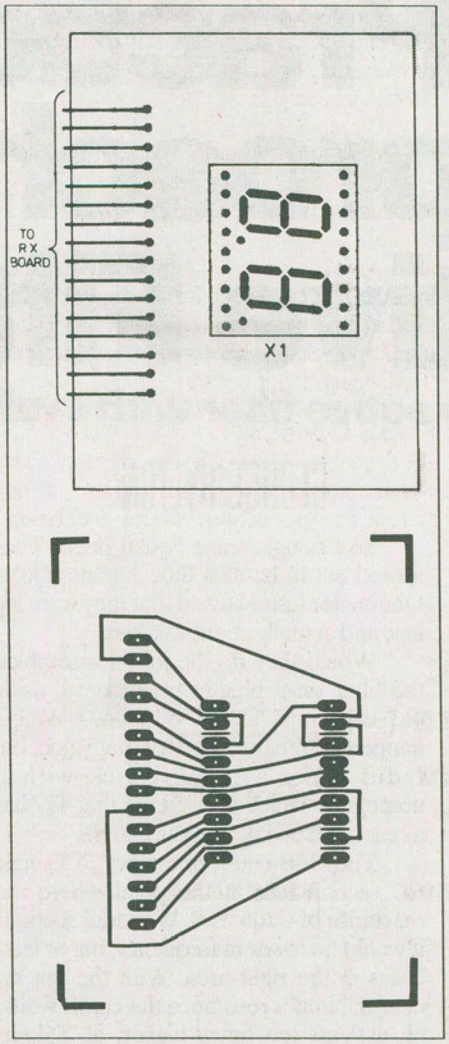

Fig. 5. The component overlay (top) and the PCB for the display.

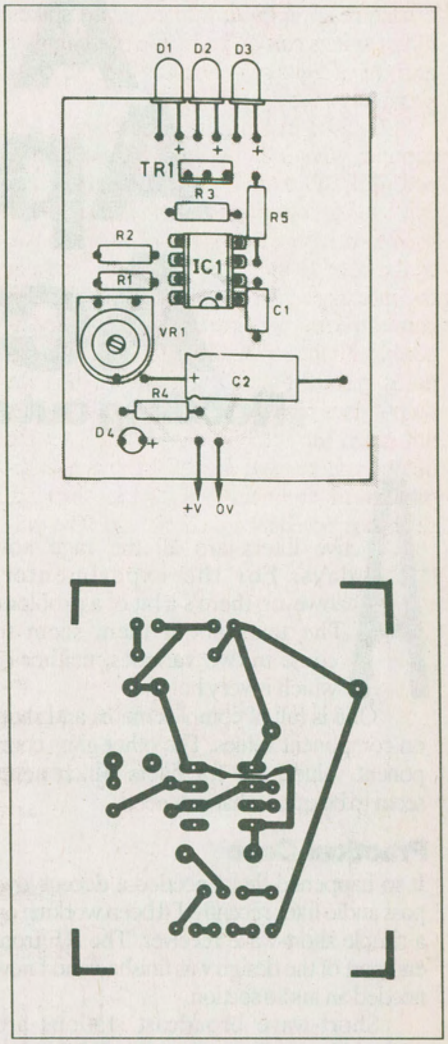

Fig. 6. The component overlay (top) and the PCB for the transmitter.

connecting wire (these replace the double-sided PCB used in the prototype). Then all resistors should be connected. The resistors should then be followed by inserting the signal diodes D2 and D3, ensuring the correct orientation. Then connect the remaining capacitors and LEDs, also ensuring the correct orientation.

The ICs should be connected using IC sockets since it's very difficult to remove them once they have been soldered in place. Components IC3, IC4, IC5 and IC6 are all CMOS devices and should be handled with all static handling precautions. D1 could be connected to the PCB or connected remotely via two connecting wires, but pay particular attention to the orientation of this device. The long lead should be connected to the positive and the short lead connected to the 0V line.

The transmitter board (Fig. 6) is assembled in much the same way, with the resistors and capacitors connected in place first. This should then be followed by D1, D2, D3 and D4 connected in forward bias with the long lead to the positive. Finally IC1 and TR1 should be connected in. The display board should cause no problem in construction but make sure that the display is the correct way around.

Setting Up

Before testing the board the programmable divider should be set up using solder links. All eight programming presets or IC4 must be connected to either positive for logic 1 or the 0V rail for logic 0. Any count can be made between 1 and 255 and this is set in binary using solder links to the supply rails as shown in the connection diagram. Having worked out the number of times the object will break the beam, the number can be set up as an eight-bit binary code.

Each preset input of IC4 corresponds to a single bit of an eight- bit binary number as follows:

0	1	2	3	4	5	6	7
1	2	4	8	16	32	64	128

Thus any number can be programmed up to 255 by connecting the appropriate input to either positive input or ground. For example, if you require one count for every 122 times the beam was broken:

$$122 = 0\times128 + (1\times64) + (1\times32) + (1\times16) + (1\times8) + (1\times2) + (0\times1)$$

This is 01111010 in binary, set by connecting the programming inputs in the following way:

Preset 7 goes to 0V
Preset 6 goes to +ve
Preset 5 goes to +ve
Preset 4 goes to +ve
Preset 3 goes to +ve
Preset 2 goes to 0V
Preset 1 goes to +ve
Preset 0 goes to 0V

A word of caution: the preset inputs 0-7 do not correspond to the IC pin numbers (see Fig. 3), so check before you start.

Testing

The transmitter may be powered by any voltage source of eight or nine volts. When powered up you will not be able to see anything being emitted, as infrared is invisible to the human eye. However, checking pin three of the NE555 with either a high impedance earphone or an oscilloscope should confirm the presence of high frequency oscillation.

The receiver is best checked by powering up and then bringing the transmitter close to D1 of the receiver, at which point the LED D4 should light. If it doesn't, try rotating VR1, a result should be obtained when it is set to a central position. If the diode still stays unlit, check that photo diode D1 is connected the right way around, and also check that C3, D2, D3, are the right way around.

In use, the receiving diode should be covered by a light guide, thus making it more directional and less sensitive to stray pickup. A small piece of rubber sleeving is ideal for this.

An operational range of up to 3.5m is possible. The only adjustment required is to alter VR1 on the transmitter and VR1 on the receiver for optimum operation. It is also necessary to set the programming of the divider and the link to count pulses or count the output of the divider, as described earlier. ■