Experimenter's Corner

By Forrest M. Mims

MISSING-PULSE DETECTORS

Missing-pulse detectors can be found in applications ranging from moderately sophisticated, break-beam intrusion detectors to adjustable-duration event timers. Figure 1 is the circuit for a simple but reliable missing-pulse detector made from a 555 timer.

The circuit, which was adapted from one given in the Signetics 555 applications note, is a modified monostable multivibrator. In operation, an input pulse applied to pin 2 triggers the one-shot. The output then goes high for a period determined by the values of timing components *R1* and *C1*.

A 555 monostable ordinarily ignores trigger pulses that arrive *during* the timing period. In this circuit, however, *Q1* fools the one-shot into accepting a trigger pulse during the timing cycle. Refer to the schematic and you'll see why. Normally, *Q1* is off, but a trigger pulse biases it into conduction. This discharges *C1*. Simultaneously, the trigger pulse initiates a new timing cycle.

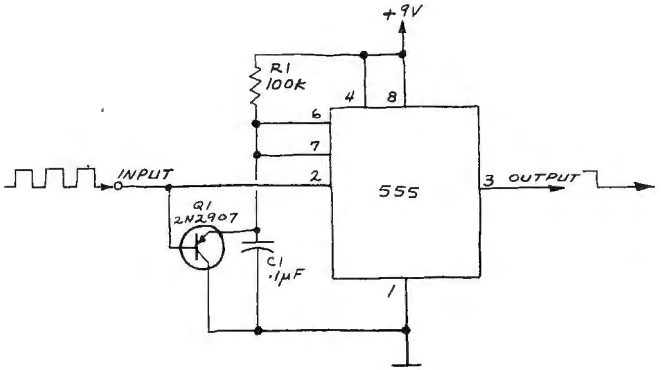

Fig. 1. Basic missing-pulse detector circuit.

If the interval between incoming pulses is *less* than the timing period, the output of the 555 will remain high. Should an incoming pulse not arrive until *after* the previous timing cycle has ended, the output will go low until the pulse arrives. By adjusting the time constant so the timing cycle is slightly longer than the interval between incoming pulses, the circuit will respond to missing pulses by switching low until a new pulse arrives. The circuit can also be adjusted to respond to a *decrease* in the frequency of incoming pulses.

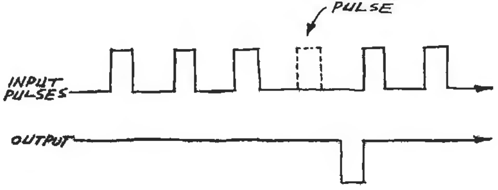

Fig. 2. Missing-pulse detector timing diagram.

If this explanation of how a missing pulse detector works seems complicated, the timing diagram in Figure 2 will help you understand what happens. Although the diagram illustrates a single missing pulse, a series of two or more missing pulses might also occur. Should this happen, the output will remain low until the pulse train is again received.

Simplified Missing-Pulse Detector. The circuit shown in Fig. 1 is commonly used in missing-pulse applications, but that shown in Fig. 3 is simpler. In this circuit, the reset pin is connected to the trigger input. A pull-up resistor connected to $+V_{CC}$ must be added, but the transistor across *C1* (*Q1* in Fig. 1) is no longer needed.

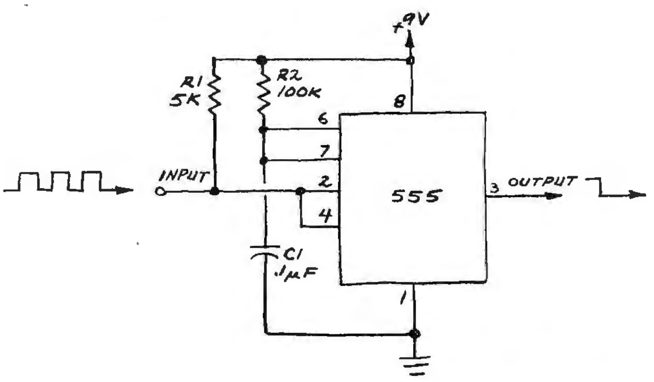

Fig. 3. Simplified circuit for a missing-pulse detector.

Break-Beam Object Detector. Figure 4 shows a simple but effective infrared, break-beam object-detection system comprising a pulsed LED transmitter optically coupled to a missing pulse detector. In operation, pulses from the transmitter are detected by phototransistor *Q3*, which is used to reset *and* trigger the one-shot before the timing cycle can be completed. Blocking the path between the transmitter LED *(LED1)* and *Q3* will cause the receiver LED *(LED2)*. to glow. The receiver LED will go off when the optical channel is reopened.

The sensitivity of the circuit is determined by *R2* and the phototransistor. The resistance of *R2* can be less than 33,000 ohms, but the receiver's sensitivity will be reduced. Sensor *Q3* can be a standard silicon phototransistor, but a Darlington phototransistor will provide higher sensitivity.

Timing components *R3* and *C2* determine the time constant of the one-shot. A fixed resistor can be used for *R3* if its value is such that the timing cycle is longer than the period between transmitter pulses. The time required for the circuit to respond

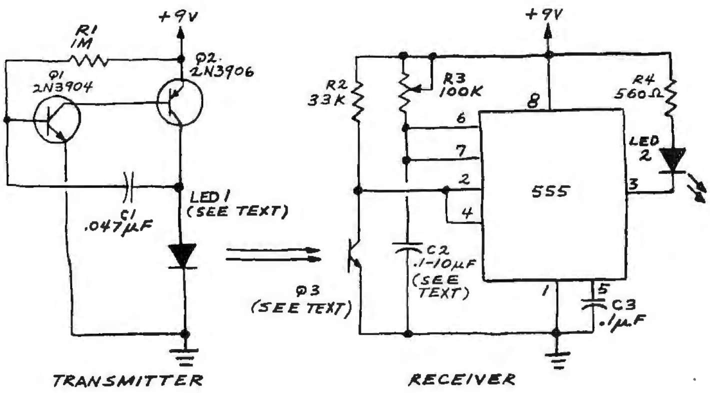

Fig. 4. Schematic for a break-beam object detector.

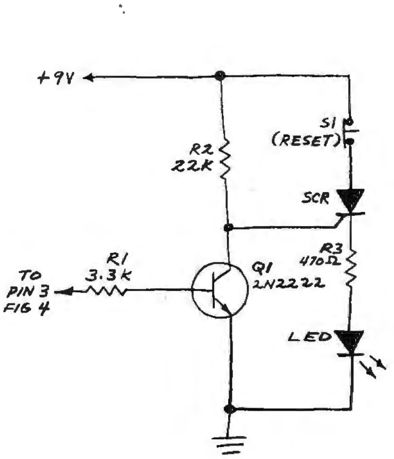

Fig. 5. SCR output circuit.

to a missing pulse is the difference between the transmitter-pulse interval and the receiver's time constant. Therefore, the circuit will appear to respond almost immediately to an obstruction placed in the optical path when the time constant is slightly longer than the pulse interval. On the other hand, the circuit will require as much as a few seconds to respond if the time constant is much longer than the pulse interval. Increasing *R3*, *C2* or both will increase the time constant.

Long time constants make possible such specialized applications as detecting slow-moving objects or long objects moving through the optical channel at the same velocity as short objects. A long time constant also provides a degree of false-alarm immunity when the system is used as an intrusion alarm because the detector can thus be adjusted to ignore falling leaves and other transient interruptions.

The range of the system is determined by the sensitivity of the receiver and the optical power radiated by the transmitter LED. For best results, use a photodarlington for *Q3* and stick to the relatively powerful transmitter circuit shown in Fig. 4. Be sure to use a GaAs:Si device for *LED1*. Suitable types include the Optron OP-190 or OP-195 and the G.E. 1N6264. Also, don't allow too much ambient light to strike *Q3* (although some dc illumination will provide base bias and increase *Q3*'s sensitivity).

With these components, the maximum detection range will be a few handbreadths. Adding lenses to both the transmitter and receiver will increase the operating range. Best results will be obtained with lenses having a focal length approximately equal to the diameter of the lens (which corresponds to an *f* number of 1). With 5-cm diameter, *f1* lenses, a range of a few meters or more can be achieved.

Adding an Output Latch. The output pin of the receiver (pin 3 of the 555) switches from a low to a high state when a missing pulse occurs and, after a timing interval, returns to its low state. In some applications, such as intrusion alarm systems, it's necessary to latch the output to a high state once a single missing pulse has been detected. Figure 5 shows one way the latching function can be achieved with the help of an SCR. This simple circuit is designed to be connected directly to pin 3 of the 555 in Figure 4.

An SCR is triggered by a positive gate voltage. Because the 555 output is normally high, *Q1* is required to invert the output. Resistor *R3* limits current flowing through the indicator LED. If the resistance of *R3* is too low, excessive current will flow through the LED and SCR. On the other hand, if the value of *R3* is too high, the current through the SCR will be less than its minimum *holding current*. This means the SCR will turn off and on, rather than latching on, when the 555 output changes states.

Reset switch *S1* is a normally closed pushbutton. If the 555 output is high (for example, when the transmitted signal is being received) and the SCR has been gated on by a previous missing pulse, pressing *S1* will turn off the SCR and prepare it to latch onto the next missing pulse.

Optically-Coupled Slot Switches. Slot switches are made by mounting a LED and phototransistor so they face one another across a narrow space in a plastic fixture. Applying a forward current to the LED switches the phototransistor. An opaque object (magnetic tape, paper card, etc.) inserted in the slot blocks the beam from the LED and turns the phototransistor off.

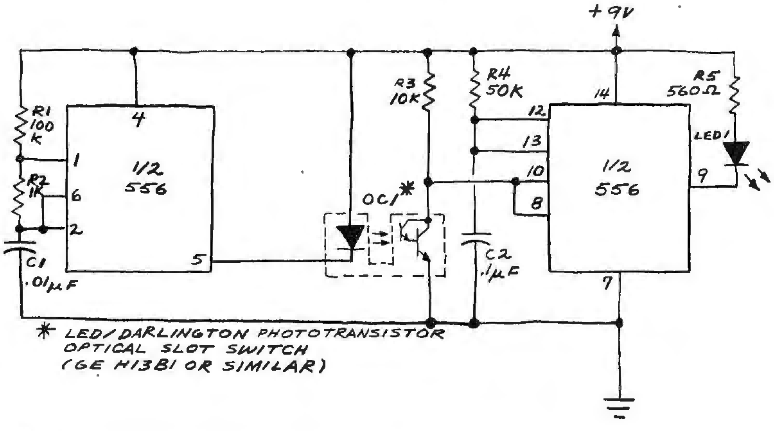

Fig. 6. In slot switch circuit, one half of 556 is a pulse generator and the other a missing-pulse detector. Blocking the slot between the LED and the photo transistor causes the detector to change states and energizes the light emitting diode.

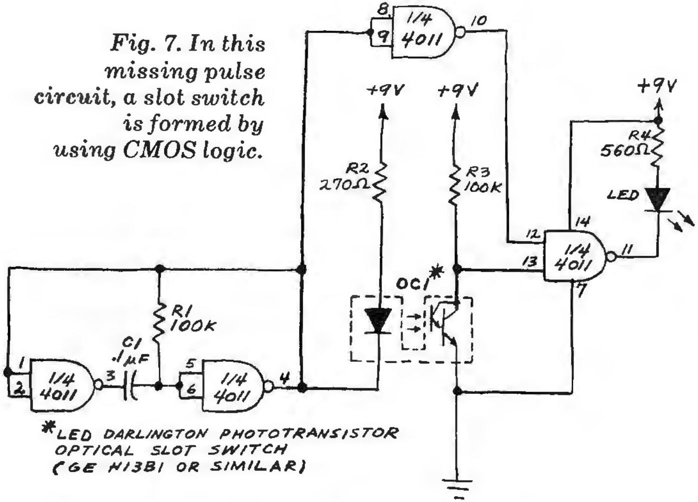

Fig. 7. In this missing pulse circuit, a slot switch is formed by using CMOS logic.

Many optoelectronics companies make various types of optical slot switches. If you can't find one, or if you don't like the prices of those you find, it's easy to improvise by mounting an infrared LED and photodarlington on a suitable jig. The gap between the two components should be a few millimeters.

Usually, a dc bias is applied to the LED in a slot switch. It's possible to achieve the same results—and at the same time save current—by pulsing the LED and connecting the phototransistor to a missing pulse detector. Here are two examples.

556 Slot Switch. In the circuit shown in Fig. 6, one half of a 556 dual timer serves as the pulse generator for a LED. The remaining half is connected as a missing pulse detector. Pulses from the transmitter continually reset and trigger the one-shot. Blocking the slot between the LED and phototransistor causes the missing pulse detector to change states and light the indicator LED.

The SCR latch in Fig. 5 can easily be added to this circuit. Also, you can experiment with *R4* and *C2* in the receiver portion of the circuit to alter its response time. For example, if the timing cycle of the receiver is 100 milliseconds longer than the period between pulses from the LED, the slot switch will ignore an interruption lasting less than 100 milliseconds.

CMOS Slot Switch. A single 4011 quad NAND gate can provide the bulk of the transmitter and receiver electronics for a pulsed break-beam slot switch based on the missing-pulse principle. Figure 7 is the schematic diagram of the slot switch.

In operation, the LED in the slot switch is pulse-modulated by the astable multivibrator formed by two of the gates in the 4011. Timing components *R1* and *C1* determine the pulse rate and *R2* limits the peak current through the LED. Pulses from the LED are detected by the Darlington phototransistor in the slot switch and presented to one input of a NAND gate. The inverted output from the multivibrator is presented to the second input of the NAND gate. When optical pulses are received by the phototransistor, its collector goes low, causing the output of the NAND gate to go high. When the slot is obstructed, both inputs to the NAND gate go high each time the slot switch LED is pulsed. This turns the indicator LED on.

Although the indicator LED appears to be glowing continuously when the slot is obstructed, it is actually flashing at the same rate at which the slot switch LED is pulsed. ◇