

Application Note AN-3010

Using the QVE00033 Surface Mount Phototransistor Optical Interrupter Switch

Description

The QVE00033 phototransistor optical interrupter switch, consists of an infrared LED emitter that is optically coupled to a phototransistor detector through a 0.4mm aperture on both sides. The emitter and detector are separated by a slot, 2mm wide and 3.7mm deep. The QVE00033 is configured in an SMD style and packaged in a temperature resistant black plastic housing for reflow soldering mounting.

Operation

This optical switch is designed to indicate the presence or absence of a vane or shield that has been placed in the emitter to detector path. Under normal or non-blocked operation, the LED shines IR light on the phototransistor. This received light develops a photocurrent in the phototransistor. This photocurrent can be converted to a logic control indicating the aperture is not blocked. When a shield or other IR opaque material is used to interrupt the light path between the LED and the phototransistor, the phototransistor photocurrent is reduced to zero. This extremely small value of photocurrent can also be converted to a logic compatible signal indicating the optical path in the slot has been interrupted. This switch provides high mechanical sensitivity. Once the vane has moved to the center of the optical aperture, a movement of only 0.4mm will cause the detector path to be interrupted.

Interfacing

The QVE00033 is compatible with all families of CMOS logic (3.3V, 5V, and 15V). Compatibility with TTL logic families is possible when a buffer or amplifier is connected between the phototransistor and the logic gate.

The IR LED emitter is commonly continuously powered, forcing a constant DC current through the LED. The LED is connected to the DC supply via current limiting resistor. The value of this resistor is determined by the following equation:

$$R_{IN} = (V_{CC} - V_F) / I_F \quad (\text{Eq 1})$$

V_{CC} = supply voltage

V_F = LED forward voltage = 1.2V

I_F = LED forward current = 5mA

$$R_{IN} = (5V - 1.2V) / 0.005A = 760 \text{ ohms, select } 680 \text{ ohms}$$

This minimizes any aliasing or timing issues when the output of the switch is interrogated by a microprocessor or microcontroller.

The next part of the design is to determine what logic sense is desired when the optical path is interrupted. The QVE00033 has the flexibility of providing a logic high or low when the optical path is obstructed.

Common Emitter Configuration

Figure 1 shows a connection called common or grounded emitter phototransistor amplifier. As the graph below the schematic shows, the logic output is high or "1" when the path is blocked. This is because the blocked phototransistor is conducting very little current, and the 68K load resistor pulls the input of Fairchild TinyLogic™ buffer high. As the shield is pulled out of the interrupter's throat, the 0.4 mm aperture becomes exposed and IR light falls upon the phototransistor. This light generates a photocurrent that flows from the collector to emitter of the phototransistor. This increase in current develops a voltage across the collector load resistor. The collector to emitter voltage can be calculated from equation 2.

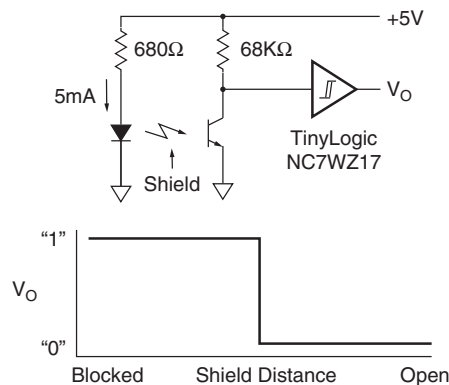


Figure 1.

$$V_{CE} = V_{CC} - I_{CE} \cdot R_L \quad (\text{Eq 2})$$

This equation shows that as the collector current increases the voltage across the collector to emitter (V_{CE}) decreases. This equation can be used to select the value of the collector load resistor. The QVE00033 shows that the collector to emitter current will be approximately 100 μ A when the LED current is 5 mA. The collector current was guardbanded to 80 μ A, to compensate for transistor gain when in saturation. The load resistor can be solved by rearranging equation 2.

$$R_L = (V_{CC} - V_{CE}) / I_{CE} \quad (\text{Eq 3})$$

$$R_L = (5V - .4V) / 80\mu A$$

$$R_L = 57.5K, \text{ select } 68K \text{ for temperature guardbanding}$$

The schematic found in Figure 1 shows the collector of the phototransistor connected to the input of the Fairchild TinyLogic™, NC7WZ17, Schmitt trigger buffer gate. The Schmitt trigger sharpens the output edges of the interrupter, minimizes timing jitter, and improves noise margin of the interface.

Common Collector Configuration

Figure 2 shows a connection called common or AC grounded collector phototransistor amplifier. As the graph below the schematic shows, the logic output is low or “0” when the path is blocked. This is because the blocked phototransistor is conducting very little current, and the 68K load resistor pulls the input of Fairchild TinyLogic™ buffer low. As the shield is pulled out of the interrupter’s throat, the 0.4 mm aperture is exposed and IR light falls upon the phototransistor. This light generates a photocurrent that flows from the collector to emitter of the phototransistor. This increase in current develops a voltage across the emitter load resistor.

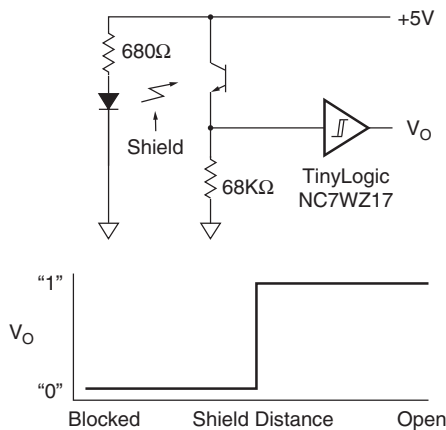


Figure 2.

The load (68K) or output voltage can be calculated from equation 4.

$$V_L = I_{CE} \cdot R_L \quad (\text{Eq 4})$$

This equation shows that as the collector current increases, the voltage across the load resistor increases. Equation 2 can be used to select the value of the emitter load resistor. The QVE00033 shows that the collector to emitter current will be approximately 100 μA when the LED current is 5 mA. The collector current was guardbanded to 80 μA , to compensate for transistor gain when in saturation. The load resistor can be determined by rearranging equation 4.

$$R_L = V_{CC} / I_{CE} \quad (\text{Eq 5})$$

$$R_L = 5\text{V} / 80\mu\text{A}$$

$$R_L = 62.5\text{K}, \text{ select } 68\text{K for temperature guardbanding}$$

The schematic found in Figure 2 shows the emitter of the phototransistor connected to the input of the Fairchild TinyLogic™, NC7WZ17, Schmitt trigger buffer gate.

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