Application Circuits for the Phototransistor Switch

Application Bulletin 213

General Description
Phototransistors circuits may be adjusted for a selected sensitivity range and often do not require additional amplification. They can be applied in two modes, Active or Switch mode.

"***Switch mode***": means the phototransistor will either be "off" or "on" for a digital logic response to the object sensed.
"***Active mode***": means the phototransistor generates an output response based on the light or irradiance level. $I_{C(on)}$ will be proportional to the coupled light intensity.

The examples in this bulletin apply to reflective and slotted OPB switches as well as Optek discrete IRLED and Phototransistor pairs, when also applied in object sensing applications. Circuits are designed for the "S*witch Mode"* and based on typical product performance and application conditions. Each application design should be evaluated for adjustments to these circuit values in order to optimize the performance of the optical sensor. Application variables will include: aperture size, reflective surfaces and blocking material, sensing distance, etc…

For "*Active Mode*" operation adjust the load resistance by decreasing the value of R2 based on application experiments. This value will typically be less than 5KΩ.

Basic Interface Circuits for CMOS

The common-emitter circuit will generate an output signal which transitions from high to low high when the phototransistor detects light or infrared radiation. This is commonly referred to as an "inverting logic condition".

The common-collector circuit will generate an output signal which transitions from low to high when the phototransistor detects light or infrared radiation. This is commonly referred to as a "non-inverting logic condition".

These two circuit examples are compatible with all CMOS logic in the 3.3V to 15V versions. Collector circuit current (I_C) is limited to approximately 0.5mA. If optical signal levels are very low, increase the load resistance R2.

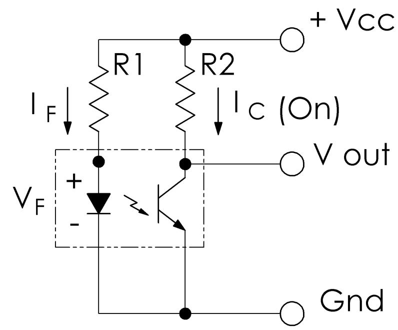

Figure 1: The common-emitter circuit
LED Off/Blocked = Output High

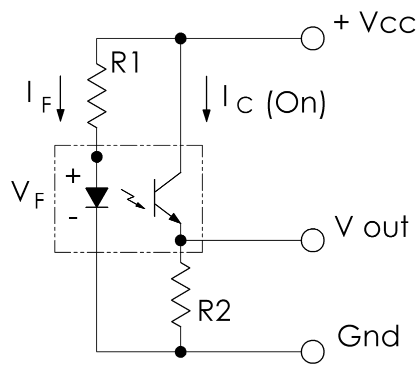

Figure 2: The common-collector circuit
LED On/Unblocked = Output High

Conditions

I_F = 20mA, V_F = 1.5V & V_{CE} = 0.3V (typical)

$$R1 = \frac{(VCC - VF)}{IF}$$

$$R2 = \frac{VCC - VCEsat}{IC(on)}$$

Example for V_{CC} = 5 volts

$$R1 = \frac{(5V - 1.5V)}{20mA} \sim 180\Omega$$

$$R2 = \frac{(5V - 0.3V)}{0.5mA} \sim 10K\Omega$$

For V_{CC} = 15 volts
R_1 ~ 675Ω and R_2 ~ 29KΩ

For best compatibility with CMOS, a condition of phototransistor saturation is best. When fast switch response times are needed or direct TTL compatibility is required, consider the addition of a buffer as shown in figures 3 through 6.

Interface Circuits for TTL or Hardware Drivers

The transistor buffer is a cost effective choice in single-sensor applications where logic buffers and gates may not be available packaged singly. More versatile, this circuit can provide optimum noise immunity, faster switching speeds, or directly drive low current mechanical relays if using a 2N2219 or equivalent for Q1. R_3 can be 1KΩ to support 1.6mA TTL sink current. R4 will typically be about 50KΩ.

Complete saturation of the phototransistor is not necessary, however, adjustments to R_2 may be required if sensor is too sensitive or affected by ambient light interference. Connect Vout direct to TTL, or R_3 may be a substituted for a relay input.

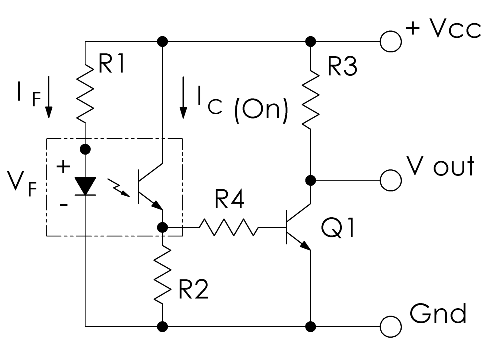

Figure 3: Adding a transistor buffer stage

Conditions

I_F = 20mA, and V_F = 1.5V (typical)
V_{CEsat} = 0.3V (typical)

Example for V_{CC} = 5 volts

$$R1 = \frac{(5V-1.5V)}{20mA} \sim 180\Omega$$

R_2 ~ 5K to 10KΩ
R_3 = 1KΩ
R_4 ~ 50KΩ
Q_1 is a PN2222A or 2N2219 type.

The logic buffer (SN74S00 or equivalent) is a popular interface option and provides fast switching and good signal conditioning. Refer to Figure 4.

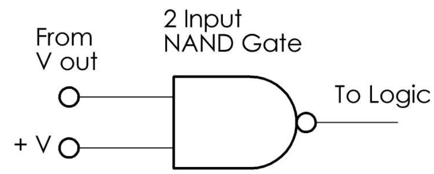

Figure 4: Adding a Buffer IC to Figure 1 or 2

The schmitt trigger inverter (SN7414 or equal) provides hysteresis and helps to stabilize the logic signal when sensing marginal photocurrent levels or slow mechanical transitions.

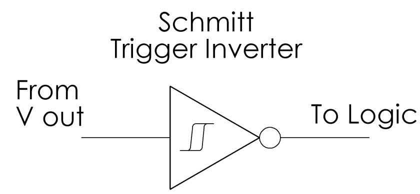

Figure 5: Adding a Schmitt Trigger Inverter IC to Figure 1 or 2

The voltage comparator interface (LM339, or equal) features a voltage reference that may be used to set a threshold level:
R_2 should be equal to Vref / $I_{C(on)}$.

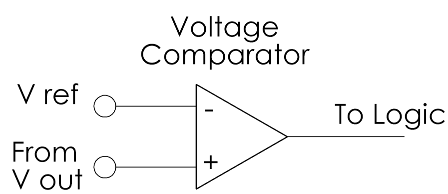

Figure 6: Adding a Voltage Comparator to Figure 2. Select R_2 = **Vref** / $I_{C(on)}$

Conclusion

Environmental effects, such as temperature and contamination, for example, must be taken into consideration when evaluating the circuit design. Also aging effects may account for up to 25% reduction in LED efficiency when operated at these suggested levels. Please consult the Optek product specification for the applied product before choosing or finalizing a circuit design.