Application Note 59

Vishay Semiconductors

Solid State Relay Input Resistor Selection

DESCRIPTION

Solid state relays (SSRs) are commonly driven by TTL or buffered CMOS logic gates. These gates, when used to sink current, provide adequate drive for SSRs. An open-collector output is not required to drive the SSRs, but it can be useful to perform a logic OR function.

When using logic drive, an input resistor is usually required to limit current through the control LED to a recommended value. The recommended operating current for most SSRs is between 1 mA and 20 mA depending upon the application. LED currents below the recommended value can inhibit relay operation should temperature increase, while higher currents can manifest reliability problems. The following discussion helps in the selection of the proper resistor for specific applications.

A quick recommendation for 5 V power supply operation of most SSRs is to use a 560 Ω resistor. This combination provides an LED current range of 5 mA to 9 mA, thereby optimizing LED current, surge capability, and turn-on/off times. This calculation has taken into consideration power supply variations, temperature variations from - 40 °C to + 85 °C, and manufacturing variations. It uses a 10 % tolerance, 300 ppm/°C input resistor. Likewise, for operation to only 70 °C, a 680 Ω resistor would suffice.
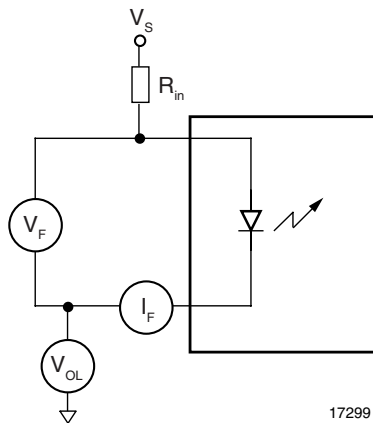

Fig. 1 - Input Resistor Diagram

The formula for resistor selection is:

$R_{in} = [V_S - (V_F + V_{OL})]/I_F$ (1)

Where:

R_{in} is the input resistor.

V_S is the power source used.

V_F is the forward voltage outdrop of the LED.

V_{OL} is the low-level output of the driving logic gate or the collector-emitter voltage of the driving logic transistor.

I_F is the forward current through the LED.

In choosing appropriate input resistors for a design, parameter variations must be considered. For the power source, consider power supply variations and tolerance. For LED voltage drop, manufacturing variations affecting V and V_F temperature variations must be considered. V_F ranges from 1.15 V to 1.45 V at I_F = 10 mA and 25 °C, because of manufacturing variations. V_F decreases an additional 1.4 mV/°C with higher temperature and increases proportionally with a lower temperature. For the input resistor itself, consider the resistor tolerance and resistor temperature coefficient.

To determine the maximum value for the input resistor in a specific application, obtain the following values:

$I_{F (min.)}$ - the lowest desired LED current

$V_{S (min.)}$ - minimum voltage of power source

$V_{F (max.)}$ - obtain from figure 2

Select the value at the coldest anticipated operating temperature and the lowest desired I_F operating current. Extrapolate desired temperatures in between given temperatures.

$V_{OL(max.)}$, maximum low-level output voltage at desired I_F value.

Use the following formula to calculate the maximum value for the input resistor.

$$R_{in(max)} = \frac{V_{S(min)} - (V_{F(max)} + V_{OL(max)})}{I_{F(min)}}$$

To determine the minimum value for the input resistor in a specific application, obtain the following values:

$I_{F (max.)}$ highest desired LED current.

$V_{S (max.)}$ maximum voltage of power source.

$V_{F (min.)}$ obtain from figure 2. Select the value at the hottest anticipated operating temperature and the highest desired I_F operating current. Extrapolate desired temperatures in between given temperatures.

$V_{OL(min)}$ minimum low-level output voltage at desired I_F value.

Use the following formula to calculate the minimum value for the input resistor.

$$R_{in(min)} = \frac{V_{S(max)} - (V_{F(min)} + V_{OL(min)})}{I_{F(max)}}$$

Select a value of resistance between the minimum and maximum values. If the minimum calculated value for the input resistor exceeds the maximum calculated value, the maximum calculated value should be used. Remember to consider resistor tolerance and temperature coefficients when choosing the resistor.

It is often desirable to operate at the lowest possible LED current.

Example:

For operation between - 40 °C and + 85 °C, using a power source of 5 V, what input resistor would provide an LED current of 4 mA?

To solve this problem, simply determine the maximum input resistor value. This will set up the lowest LED forward current.

Determine the maximum input resistor value.

$I_{F\ (min.)}$ = 0.004
$V_{S\ (min.)}$ = 4.5
$V_{F\ (max.)}$ = 1.5
$V_{OL\ (max.)}$ = 0.25
$R_{in\ (max.)}$ = 4.5 - [1.5 + 0.25])/0.004 = 688 Ω

Select a resistor with a value below 688 Ω so that with resistor tolerance and temperature variations, the maximum input resistor value is not exceeded.
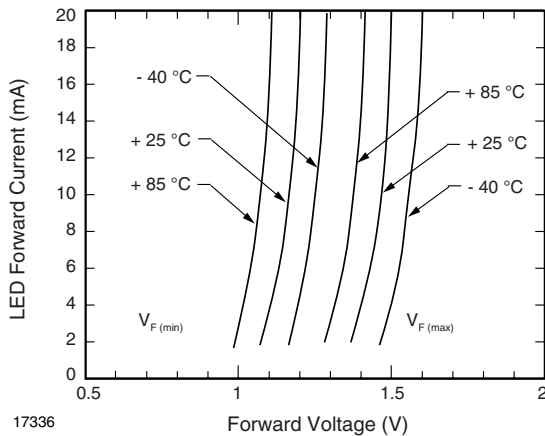

Fig. 2 - LED Current and Voltage vs. Temperature

FASTER TURN-ON/OFF TIMES

Improved turn-on times for form A SSRs and improved turn-off times for form B SSRs can be realized by using a current peaking circuit on the input of the SSR. A simple RC network placed in parallel with the LED current-limiting resistor will provide a current spike to the LED. This current spike, if of proper amplitude and duration, will speed-up the turn-on or turn-off times equivalent to those shown in the parameter curves for higher LED drive current values. All SSRs will improve their turn-on or turn-off characteristics by using the peaking circuit, but certain SSRs that have a V_{BE} multiplier circuit built in will benefit especially. For instance, turn-on time for the LH1500 can be reduced to < 100 µs. The SSRs with V_{BE} multipliers are the LH1525, LH1533, and LH1550 form A and all form B SSRs.

Figure 3 shows a simple RC peaking circuit. Turn-on and turn-off times are dependent upon the SSR type, V_S, the control driver, the RC network values, and the value of R_{in}.

Within the RC network, R_p limits the peak amplitude current through the LED and C_p sets the pulse time constant. For adequate pulse duration, try C_p values between 0.3 µF and 3.0 µF. For adequate peak pulse current, try Rp values from 10 Ω to 200 Ω.
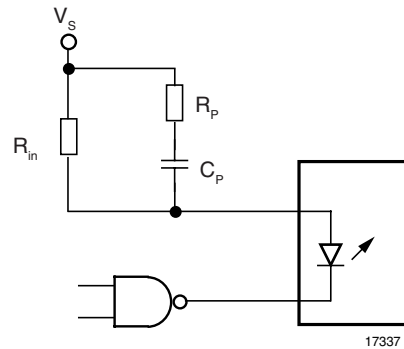
$$R_p = (V_S - V_F)/I_{peak}$$

Limit the pulsed current through the LED to 300 mA.

Fig. 3 - RC Peaking Circuit