The latest electronic equipment is characterized by smaller size, greater functionality and better performance than ever before. If size is to be reduced and performance increased, power management of the electronic device is a serious issue. For these reasons semiconductor relays have become very popular when galvanically isolated switching of load circuits is required. Besides other advantages, semiconductor relays are smaller than electromechanical relays and have a lower power consumption. Nevertheless there are some basic points one should pay attention to when using a PhotoMOS relay in an electrical circuit.

The input side of a PhotoMOS relay consists of a light emitting diode. If a current flows through the LED it starts emitting light. The light passes through a silicon resin, providing galvanic isolation of input and output circuits, and is detected by an array of solar cells. This results in a voltage drop across the solar cells, which is used to drive MOSFETs switching the load circuit. High-function Economy types of PhotoMOS relays (e.g. AQV254) have a maximum LED operate current I_{Fon} of 3 mA (typical 0.9 mA) at an ambient temperature of 25°C. The LED's forward voltage V_F for 5 mA forward current is 1.14 V, hence R_F can be calculated:

$$R_F = \frac{Vcc - V_F}{I_{Fon}} = \frac{5V - 1.14V}{3mA} = 1.287k\Omega$$

This calculation is valid for a simple driving circuit like shown in Figure 1 below.

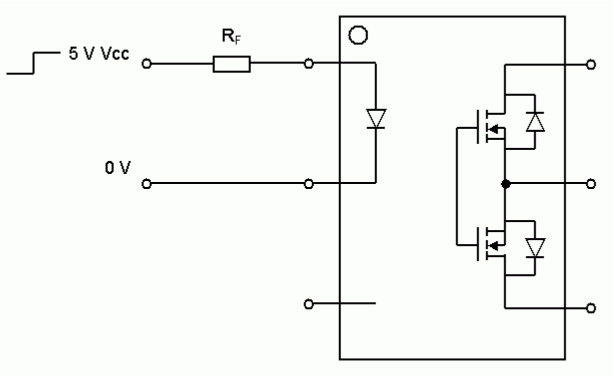

Figure 1: Simple PhotoMOS driving circuit

As already implied, temperature is a central issue when designing modern electronic circuits. Since the LED operate current increases as the temperature rises, a value I_F of 5 mA at a maximum temperature 85°C should be supplied for safe operation.

The LED's forward voltage depends on the forward current and the temperature. For the above values, it will decrease to approximately 1.03 V, as seen in Figure 2.

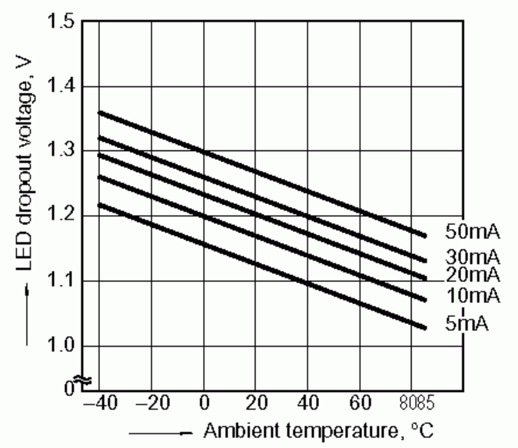

Figure 2: LED forward voltage vs. ambient temperature

Hence the maximum value for R_F can be calculated:

$$R_{F\,\max} = \frac{Vcc - V_F}{I_{Fon}} = \frac{5V - 1.03V}{5mA} = 794\Omega$$

Assuming a resistor with a 5% tolerance and a temperature coefficient of 250 ppm/K, we will choose the next lower value from standard resistors: R_F = 680 Ω.

$$\begin{aligned} R_{F'} &= 1.05 \cdot R_F\,(1 + (\Delta T \cdot 250 ppm / K)) = \\ &= 1.05 \cdot 680\Omega(1 + (60K \cdot 250 ppm / K)) = \\ &= 1.05 \cdot 680\Omega \cdot 1.015 = 724{,}71\Omega \end{aligned}$$

Since $R_{F'}$ is smaller than R_F, the standard resistor of 680 Ω will ensure safe operation over the whole temperature range. If supply voltage contains ripple the lowest possible value of Vcc has to be used for calculation. Pay attention to the PhotoMOS relay's highest possible value of the driving signal and maximum forward current.

Power consumption of PhotoMOS relays is much lower compared to electromechanical relays, nevertheless some logic circuits cannot sink or source much current. Driving a PhotoMOS relay with such logic circuits requires additional parts, e.g. bipolar transistors or CMOS gates. Newer CMOS gates can sink significantly more current than parts using older technologies.

An example for controlling a PhotoMOS relay with a transistor or a CMOS inverter is given in Figure 3.

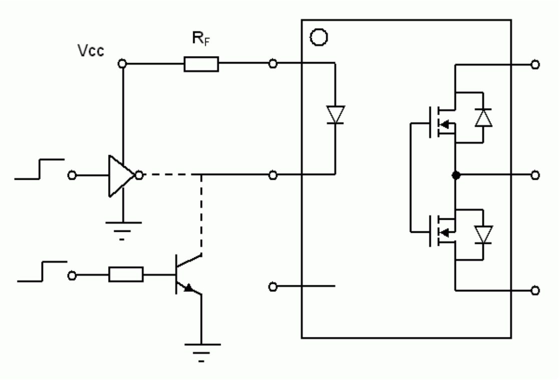

Figure 3: PhotoMOS driving circuit

This circuit requires more parts and an additional voltage supply. Care has to be taken when calculating the value of R_F, since there is a voltage drop V_{on} across the bipolar transistor (saturation voltage V_{CESat}) or across the output of the CMOS inverter (LOW level output voltage V_{OL}). Because of this voltage drop the voltage across the input resistor is lower and R_F can be calculated:

$$R_{F\,\max} = \frac{Vcc - V_F - V_{on}}{I_{Fon}} = \frac{5V - 1.03V - 0.4V}{5mA} = 714\Omega$$

Based on this result we can compare the maximum allowable resistor value R_{Fmax} with the worst case value $R_{F'}$ of a 680 Ω resistor (5% tolerance, 250 ppm/K and 85°C ambient temperature). Since $R_{F'}$ = 724.71 Ω is greater than R_{Fmax} a resistor value of 680 Ω is not sufficient to guarantee switching operation under all conditions. For this example one could choose a resistor value of 470 Ω, 560 Ω or a 680 Ω resistor with a higher tolerance class.

Reducing the value of R_F causes higher currents to flow through the LED. Providing a higher LED current will lead to higher currents in the array of solar cells. Hence loading and unloading of the output MOSFET's intrinsic capacitors will be done faster with a higher solar cell current, and faster switching times of the PhotoMOS relay can be realized (Figure 4, valid for AQV25_).

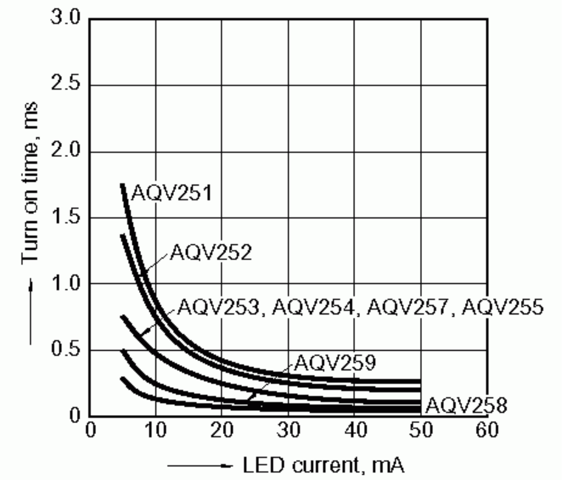

*Figure 4: Turn on time vs. LED current for AQV25_*

As stated above, higher LED currents lead to faster switching times. On the other hand, increasing the LED current of the PhotoMOS relay results in increased power dissipation. To compensate for this effect, provide a higher LED current for switching operation and reduce it afterwards to lower power dissipation. This can be done with a simple circuit as shown in Figure 5.

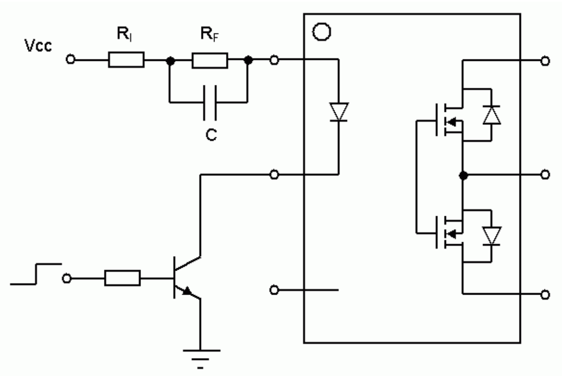

Figure 5: PhotoMOS speed-up circuit

The capacitor has no voltage drop across it when the circuit is in an off-state. As soon as a control signal is applied, this results in a high inrush current, limited by the resistor R_I, through the capacitor and the LED. After the capacitor C is charged, current no longer flows through it, so that the two resistors R_I and R_F determine the LED current. Based on the previous calculations the maximum value for $R_I + R_F$ = 714 Ω.

The resistor R_I determines the peak inrush current value, which shall be 20 mA for this example. The value V_F for the LED forward voltage at 20 mA current and ambient temperature of 85°C can be taken from Figure 2.

$$R_I = \frac{Vcc - V_F - V_{on}}{I_F} = \frac{5V - 1.11V - 0.4V}{20mA} = 174.5\Omega$$

We will choose a standard resistor value of 150 Ω for R_I.

$$R_F = R_{F\max} - R_I = 714\Omega - 150\Omega = 564\Omega$$

This yields a standard value of 560 Ω. Checking $R_{F\max'}$ will result

$$R_{F\max'} = 1.05 \cdot (R_I + R_F) \cdot (1 + \Delta T \cdot 250 ppm / K) =$$
$$= 1.05 \cdot (150\Omega + 560\Omega) \cdot 1.015 = 756\Omega$$

which is higher than $R_{F\max}$. Therefore R_F will be reduced to 470 Ω to ensure safe operation over the whole temperature range. The inrush current will decrease according to an e-function. To have any effect on the switching time of the relay, the following assumption can be made: time constant $\tau = R_I \cdot C$ shall be equal to two times the maximum turn on time $\tau = 2 \cdot T_{on}$.

$$C = \frac{\tau}{R_I} = \frac{2 \cdot T_{on}}{R_I} = \frac{2 \cdot 2ms}{150\Omega} = 26.6\mu F$$

We can choose a standard value C = 22 µF. Pay attention when using a bipolar transistor: its collector current must reach the desired current values for both peak and continuous state. To realize this, a sufficient base current must be supplied. Please note the DC current gain of your transistor and its tolerances when designing the base resistor for safe switching conditions.

Circuit simulation programs like PSpice are very useful for designing electrical circuits. By using computer aided design programs, influences of single parts and parameters can be easily determined. Please visit our internet online catalogue to download the latest PSpice models for our PhotoMOS relays. After considering design rules, your circuit design can be verified with a simulation program and by an experimental set-up.

As previously seen, it is quite easy to control PhotoMOS relays if one pays attention to a few key points. This makes it easy for the user to make use of the advantages PhotoMOS relays offer over electromechanical relays:

- Low input power consumption
- Small size
- High switching frequency
- Higher lifetime
- Stable contact resistance over lifetime
- No switching noise
- No contact bounce
- No contact arcs

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