Semiconductor and Electromechanical Relays

Many people believe that in the age of the microchip and its bits and bytes of modern electronic circuits, relays no longer have a role to play. However this is not the case, electrically controlled switches are still used in many applications because of their relative simplicity, long life and reliability. Relays are the optimal switching solution for a wide variety of applications: industry or home appliance, telecommunications, precision measurement, the automotive sector and many other areas in a growing global economy.

A relay is an electrical component whose output circuit(s) is closed and / or opened depending on application or removal of a suitable voltage to the electrically insulated input circuit. For many years the electromechanical relay was the only choice for realizing such a switching function for an electrical output circuit, which results from the relative movement of mechanical parts. During the last two decades and with the emergence of semiconductor technologies, switching output circuits with an electrical control signal has also been realized by electronic, magnetic, optical or other means that require no mechanical movement. This application note discusses the features of different switching solutions and explains two different semiconductor technology based relay types in more depth.

The basic function of a non-polarized power relay can be described quite easily: voltage applied to the coil produces coil current which leads to a magnetic flux. Since the armature is mounted near the coil, there is no significant stray flux and the excitation flux encloses the system. Since the yoke (4) is moving, the corresponding contact system is actuated and the contact 7-8-9-10 is opened and 7-8’-9’-10’ is closed.

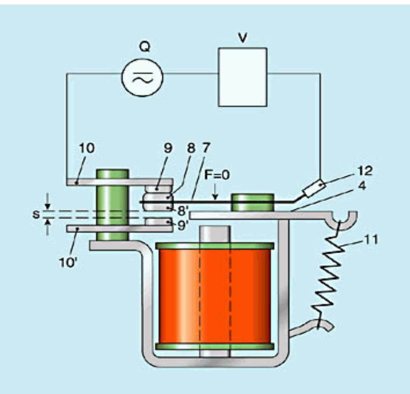

Figure 1: Construction of a non polarized electromechanical relay

While the relay is excited, the tension of the reset spring (11) increases, leading to stored energy. When the coil applied voltage decreases, this stored energy causes the armature and the contact spring to return to the rest state.

This is a simple example of a non-polarized relay. Today’s non-polarized relays employ an increased number of design details in order to offer advanced features. By employing permanent magnets in the magnetic circuit of the relay, efficient polarized relays offer increased advantages, such as reduced coil power consumption, higher contact force and bistable behaviour.

Due to arcs created during switching and mechanical effects, the electromechanical relay suffers wear during its lifetime. In order to prevent this, a contactless system was born: semiconductor technology. Panasonic Electric Works pursued two paths during the evolution of semiconductor relays: MOSFET-based (PhotoMOS) and Triac-based (SSR) relays. Table 1 provides an overview of the technical differences between electromechanical relays (EMR) and semiconductor based relays (PMOS & SSR).

	PMOS & SSR	EMR
Advantages	Contact reliability Long lifetime Low control current Switching frequency Noiseless operation No contact arcs Shock resistant	High breakdown voltage Surge and noise resistant Form A / B / C contacts Load current: µA to A Galvanic isolation of open output No leakage current
Disadvantages	Leakage current Weak against voltage surge Higher contact resistance	High volume Coil energy consumption Unstable contact resistance Contact wears out Operation creates noise Contact bouncing Creates contact arcs

Table 1: Differences between electromechanical relays and semiconductor relays

Simplifying this table, one could state: one system’s strength is the others weakness. Now we will take a closer look at semiconductor based relays that offer increased lifetime with stable behaviour realized by small control currents.

Both semiconductor relays have galvanically isolated input and output circuits, whereby the control signal from the input side is optically detected by the output side, triggering the switching operation.

The major difference between the two different technologies can be found in the semiconductor device switching the output: PhotoMOS relays employ two MOSFETs – SSRs utilize Triacs.

The construction of a PhotoMOS relay is illustrated by Figure 2. The input pins are connected to a light emitting diode. This LED is located on the upper part of the relay and if a current flows through it, it starts emitting infrared light. Below the LED there is an array of solar cells integrated into an optoelectronic device, located at least 0.4 mm from the LED. The optoelectronic device serves as a control circuit for switching the power MOSFETs and therefore the load circuit. These DMOS transistors are source coupled because of their intrinsic bulk-drain-diode in connection with drain and source. Thus a single transistor is only capable of switching a DC voltage since the diode will become forward biased if load polarity reverses. Hence using a PhotoMOS relay for switching AC voltages requires two source coupled DMOSFETs like illustrated in Figure 2.

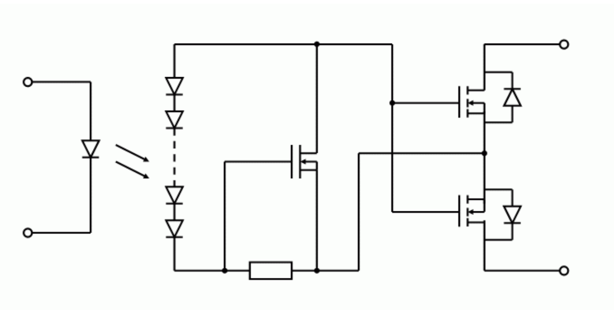

Figure 2: Electrical circuit of a PhotoMOS relay

The output MOSFETs' on-resistance and maximum load voltage are a trade-off. For this reason, load current (limited by on-resistance and the resulting power dissipation) and load voltage are related to each other. Corresponding PhotoMOS relays either have a relatively high load voltage with a smaller load current or vice versa. This fact is illustrated by Panasonic Electric Works' PhotoMOS Selector Guide (Figure 3) which can also be found in the internet: http://www.panasonic-electric-works.com. Utilizing this Selector Guide helps you find the perfect PhotoMOS relay more quickly.

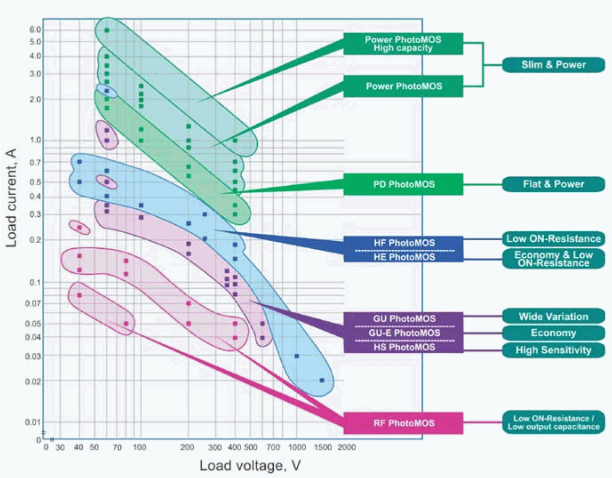

Figure 3: PhotoMOS Selector Guide

When it comes to switching main network voltages and high currents, Solid State Relays (SSR) surpass PhotoMOS relays. The SSR is composed of a low current control input side (typical 5 mA to 20 mA, depending on type of SSR) and a high current load side, whereby the relay provides an electrical I/O isolation of several thousand volts. When current flows through the LED on the input side, it emits light which is detected by a trigger circuit after passing through a silicon resin. The trigger circuit acts like a small triac device and is used to trigger the gate of a larger triac that switches the load in the presence of a load voltage across the triac's output. Once triggered to an on-state, the triac maintains this state until the load current crosses zero and the trigger pulse on the input is absent.

Upon activation of the input signal, the output is activated in one of two ways: zero-crossing and non zero-crossing.
Zero-crossing: When the input signal is activated, the internal zero-crossing detector circuit triggers the triac to turn on as the AC load voltage crosses zero.
Non zero-crossing: When the input signal is activated, the output immediately turns on, since there is no zero-crossing detector circuit.

Care has to be taken when inductive loads are involved: Voltage spikes may appear across the output when switching to the off-state, as the SSR turns off when the load current is zero, which is not necessarily the case for the load voltage due to the phase difference of inductive loads. The generated voltage spike must not exceed the maximum load voltage rating nor the dV/dt rating, which is the ascending slope of the voltage spike.

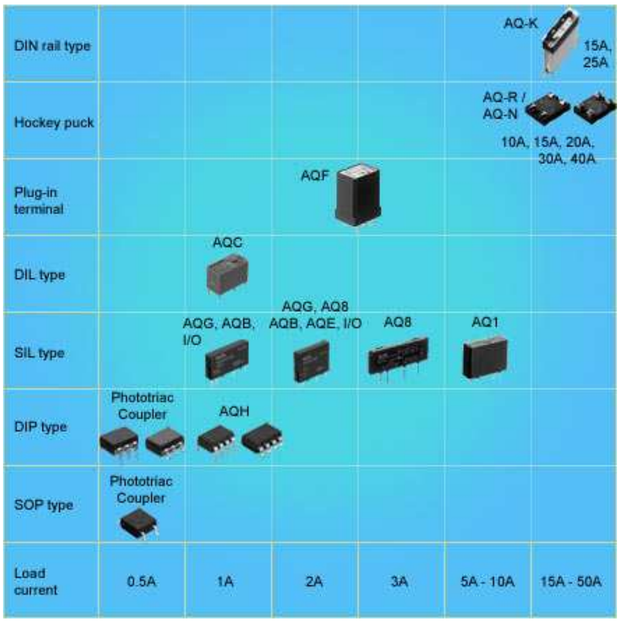

Figure 4: Overview of SSR relays

Solid State Components are available in a broad product range for switching main network voltages of 100 / 200 V AC and currents from 50 mA to 40 A. Package options range from DIL packages to SIL to hockey puck and DIN rail mounting types.

The constructional distinction of the output element of PhotoMOS and SSR causes different preferred applications for the twosemiconductor relay types (Table 2).

	PMOS	SSR
Advantages	Controls small analog signals Low leakage current AC and DC loads Form A / B contacts Small size	Best at control of 100/200 VAC and 50/60 Hz High capacity control possible (up to 40 A) High switching speed
Disadvantages	Output capacity	High leakage current Protection circuit necessary 1 Form A only Heat sink

Table 2: Differences between PhotoMOS and Solid State Relays

Nevertheless, there are also common characteristics between the two types of semiconductor relays (see Table1): Both are sensitive to overvoltages and excessive currents, which leads to power dissipation and causes internal destruction by thermal stress. Therefore care has to be taken when implementing semiconductor relays. However, if requirements like long lifetime, stable behaviour, small size and switching speed are critical, semiconductor relays are the best choice for you. If you are unsure about the suitability of a relay for your application, regardless if it's a electromechanical or semiconductor type, please contact us.