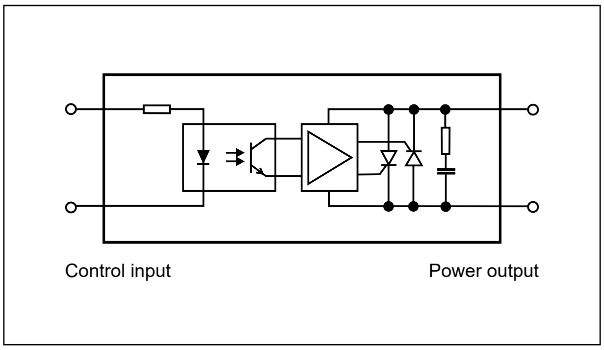
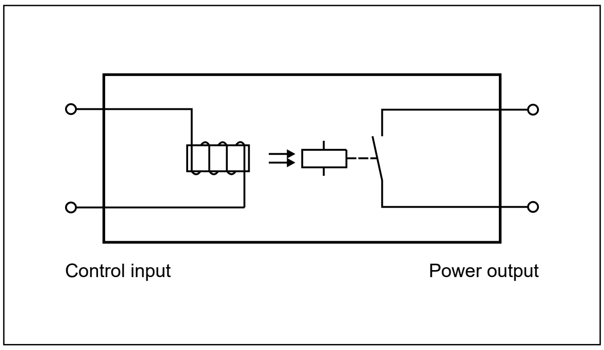
Solid state relays (SSR) and electromagnetic relays (EMR)

At the end of the 1980s, the first solid-state relays appeared on sale. Already at that time the question was asked: will solid state relays (**SSRs**) replace electromechanical relays (**EMRs**)? However, after all these years, both groups are developing side by side and even complement each other.

Solid State Relay - is a static semiconductor relay, which does not have mechanical elements. Connecting element in this case is a semiconductor structure and input circuit (control circuit) is isolated from the output circuit.



Connection diagram of SSR



Connection diagram of EMR

Characteristics of solid state relays (SSR) and electromagnetic relays (EMR)

Systems controlled by solid state or electromagnetic relays have their advantages and disadvantages. Solutions with the use of solid state relays allow to increase the frequency of switching operations and give the possibility to choose the switching method.

Both groups of relays should be treated as separate types of devices.
In order to better understand and use both types of relays, it is good to know the advantages and limitations that result from the design of these relays.

Pros of SSR

- high durability,
- no electrical arc at the contacts,
- no electromechanical interference,
- high resistance to shocks and vibrations,
- high resistance to aggressive environment, dust and chemicals,
- fast switching speeds,
- silent operation,
- low power of the control signal required.

Cons of SSR

- voltage drop across the SSR output terminals,
- necessity to use a heat sink,
- leakage current,
- limited resistance to overvoltages (limitation of current increase -dI/dt, limitation of voltage increase dV/dt),
- can not be used for low signals,
- influence of the electromagnetic environment on their operation.

Pros of EMR

- the same ability to switch AC and DC loads,
- negligible voltage drop across contacts,
- high resistance to overvoltages,
- no leakage current.

Cons of EMR

- contacts wear (shorter service life),
- bounces when connecting and contacts sparking,
- electromagnetic interference,
- long response time,
- insufficient quality when switching on surge currents.

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Advantages of solid state relays

Durability
Lack of moving parts ensures high reliability and increases the number of operations repeatedly. The correct usage of the solid state relay increases the number of performed switching operations several times.

No arc on contacts
In case of solid state relays there is no concept of arc because switching occurs inside the semiconductor material. Burnout and contact wear does not occur, which reduces radio frequency emissions and does not cause contact vibration.

No electromechanical interference
Electronic control eliminates interference in the control signal.

High resistance to shocks and vibrations
SSRs do not have moving parts, they are electronic devices. As a consequence, they are very resistant to high vibrations, which applies to both amplitude and frequency.

High resistance to aggressive environment, dust and chemicals
Compared to electromechanical relays, they are minimally exposed to aggressive environments or dust that can damage the contacts.

Fast switching speeds
SSRs can switch up to several dozen times per second, which is not possible when using electromagnetic relays.

Silent operation
There are no moving parts, so the solid state relay does not make noises like electromagnetic relays or contactors when switching the circuit on and off.

Low power of control signal
The solid state relay has no coil. Comparing to EMR, the larger the electromagnetic relay, then the coil is larger, and thus the coil has need for higher current.

SSR or EMR - which relay should I choose?

What should you do to choose the right relay? Should you choose a solid state relay or electromagnetic relay? Differences between electromagnetic and solid state relays described earlier will help us partly to answer those questions.

How many times does the relay have to operate?
Solid state relays are characterized by long, failure-free operation. For example: if an electromagnetic relay has a lifetime of 100,000 connections, then its semiconductor equivalent will operate 1,000,000 connections. A solid state relay should be used in applications requiring long lifetime.

Where do we use the relay?
Referring to the first point, to ensure a reliable and long lifetime of semiconductor device, it should be remembered that solid state relay is much more exposed to overvoltage, electrostatic and switching discharges. On the other hand, the construction of an electromagnetic relay ensures that they are insensitive to those events.

Do you need quiet operation?
The advantage of using a solid state relay is its noiseless operation.

How fast should the relay react?
The solid state relay is ideal for applications requiring fast response times. Electromagnetic relays due to their construction (moving parts), have response times between 7 and 20 ms, while solid state relays are much faster and additionally handle better at high switching frequencies.

How much space do we have available?
When using a solid state relay, we must remember about proper heat dissipation. A heat sink should almost always be used, so more space is needed for the relay and heat sink.

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Operation sequence

Due to the way of switching, solid state relays can be divided into two basic groups:
• relays switching at zero-crossing,
• random-on relays.

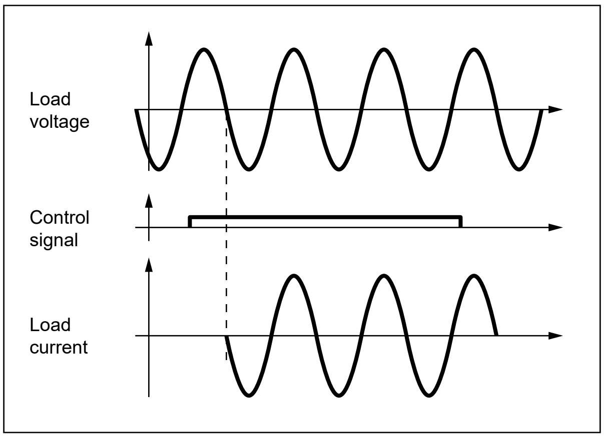
Zero-crossing relays

The relay is switched on when the voltage goes through zero, and it switches off when the current reaches zero. This method of switching allows limiting surge currents generated during switching operations. The relays are recommended for applications controlling resistive, capacitive or slightly inductive loads.

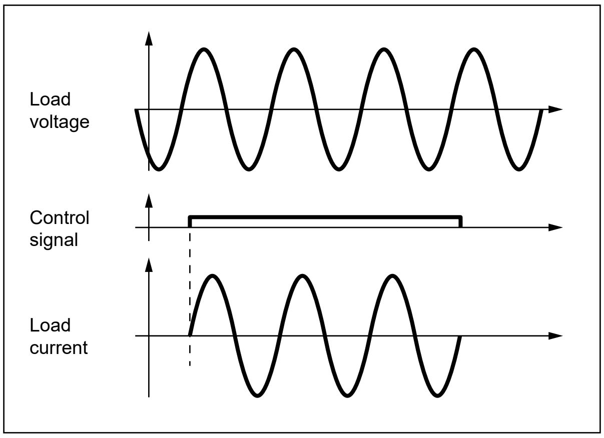
Random-on (instant-on) relays

The relay is activated immediately after the control signal appears (control voltage is applied).
In this case, we have a faster turn on time than when using zero-crossing switching. This type of switching is used for inductive loads in applications where a fast response time is required.

Solid state relays are a good solution as an intermediate element between the control circuit and circuit directly connected to load. Zero-crossing relays and random-on relays are subject to division due to AC or DC control voltage. Relays with AC output are most commonly used.



Zero-crossing switching



Random-on switching

Control signal

Typical control signal voltages for single- and three-phase relays:
• AC control signal: **90...280 V AC**,
• DC control signal: **4...32 V DC**.

Load current

Rated load current of relay for resistive load:
• single-phase: **I=P/220** or **I=P/380**,
• three-phase: **I=P/√3/380**.

Considering the ambient temperature, heat emission and other conditions, include **40...80%** safety margin for load current.

Additional relay protection

For proper protection of the solid state relay, it is recommended to connect in series to the load circuit:
• thermal relay – overcurrent protection,
• ultra-fast fuse with a value less than the I^2t value of the relay – protection against short circuit or overload.

Leakage current

During the SSR is turned-off, we can observe an extremely small current when apply a voltage to SSR output, due to the power component has an impedance. Besides this, the leakage current is caused also by the snubber network which is a resistor and capacitor in series placed in parallel across the output of the SSR. This snubber protects the relay from static and commutating dV/dt.

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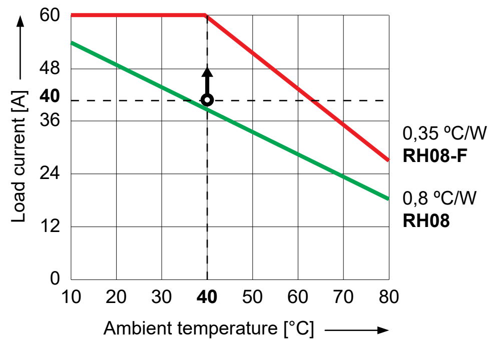
Selection of heat sink

When a SSR is on, the relay will generate heat. The amount of heat generated is a function of the load current. **The maximum chip temperature for a SCR is 125 °C**, if the SCR exceeds this temperature the relay is damaged. Therefore, the use of heat sinks is required. The heat sink takes the heat generated by the SSR and dissipate it keeping the SSR cooler.

To select the proper sized heat sink:
- determine the load current and the maximum ambient temperature the relay will be exposed to,
- use the ”Thermal derating curves” included in the data sheet of selected SSR.

Example: for a single-phase RSR52 60 A, at 40 A load current and ambient temperature at 40 °C:
- on the Y axis we find the current value for which we draw a line perpendicular to Y,
- on the X axis we find the ambient temperature for which we draw a line perpendicular to X,
- we determine the intersection of both lines,



Thermal derating curve

- read the heat sink rating – **always choose the rating above your point**: we need a 0,35 °C/W sized heat sink, since the 0,8 °C/W heat sink will not ensure sufficient cooling of the solid state relay.

Selection of varistor (MOV)

SSR is used for various applications, overvoltage may occur during its operation. Usage of MOV to suppress the transient voltage on power components and reduce the possibility to damage SSR.

To choose an appropriate MOV, determine:
- circuit conditions such as peak voltage and current during the event,
- number of surges the MOV must survive,
- acceptable let-through voltage for the application.

Example: SSR can work without MOV if transient overvoltage endurance is:
- 800 V – SSR can operate a 220 V AC load, or lower,
- 1 200V – SSR can operate a 380 V AC load, or lower.

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