

Solid-state relays (SSR): a relay with isolated input & output, whose functions are achieved by means of electronic components without the use of moving parts. — NARM (USA).

Solid state relays in comparison with conventional relays:

Solid state relays unlike EMR'S make use of solid state electronics for the purpose of switching a given load. The switching devices are typically triacs/scr for AC switching and power Darlington transistor/ mosfet for dc switching.

Functionally ssr works like a conventional relay offering several advantages to the user.

No moving parts, hence longer life.

Better switching reliability

Low power consumption, compatible to IC logic or PLC.

No contact bounce

Resistant to vibration, shock and humidity, salt spray & dirt

No RFI, EMI generation

No arcing of contacts

Loads can be switched at zero crossing or at random depending on the application

ERI DCB thyristor chip relays are highly resistive to temperature cycles compared to conventional relays.

Faster switching possible

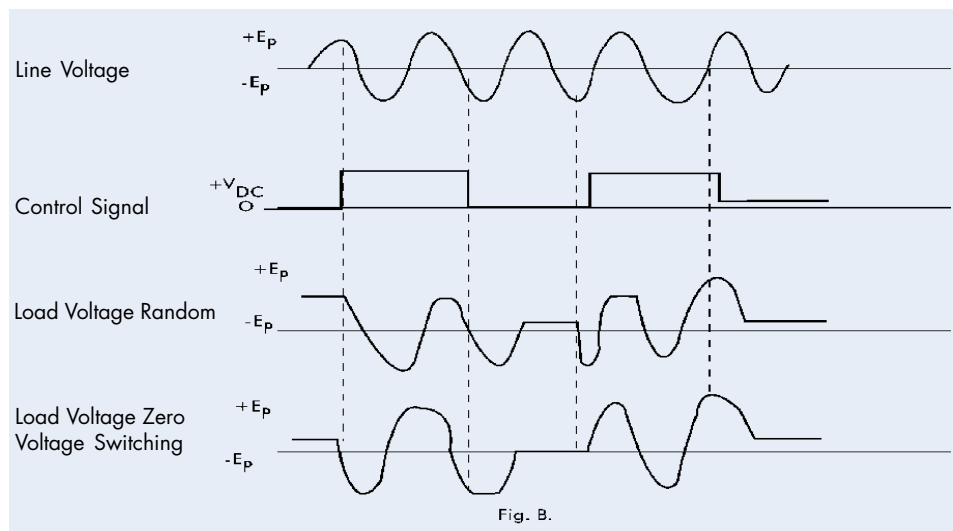
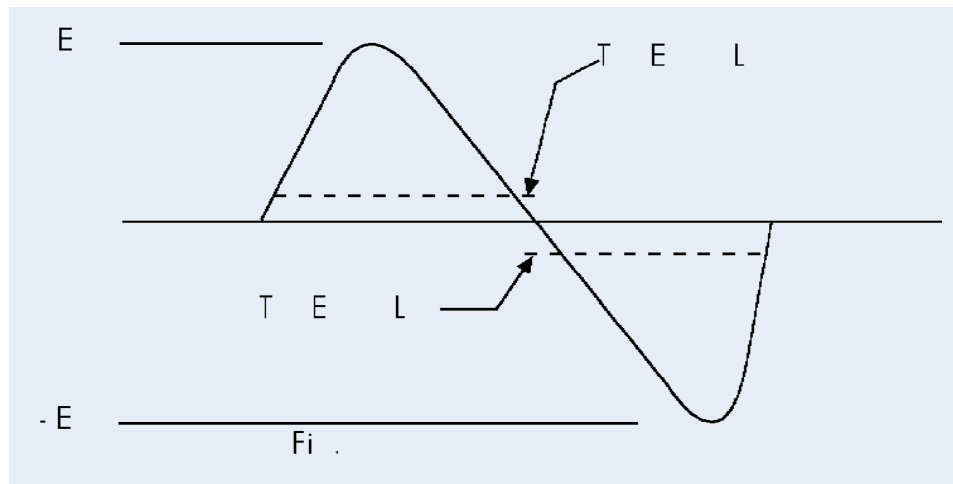
Switching types

There are two types of switching .

Zero crossing(j-type SSR'S):the relay switches on only at zero-crossing point of the AC mains irrespective of where the control signal is actuated.

The relays with this feature are normally recommended for resistive, capacitive loads with low inductance.

Random switching:(asynchronous) the relay switches on instantly where ever the control signal is applied. The typical delay is @ 1.0 ms.



Selecting a proper SSR

Always select a relay whose current rating exceeds the nominal load current.

Verify load current w.r.t ambient temperature for proper heat sink details. (refer derating curves)

An external heat sink is essential to maintain the relay base well within the required limits.

Application of heatsink compound to the relay base before mounting onto the heatsink avoids air gaps and thereby improve heat dissipation.

Ratings are based on single unit in free airflow. For closely packed

units, careful consideration of the ambient temperature will be necessary. If the load current is lower than the holding current ($< 12 \cdot I_{DM}$) of the relay, it is required to take special protection to ensure proper operations. Free wheeling diode to be used across the load in case of dc switching to avoid back e.m.f.

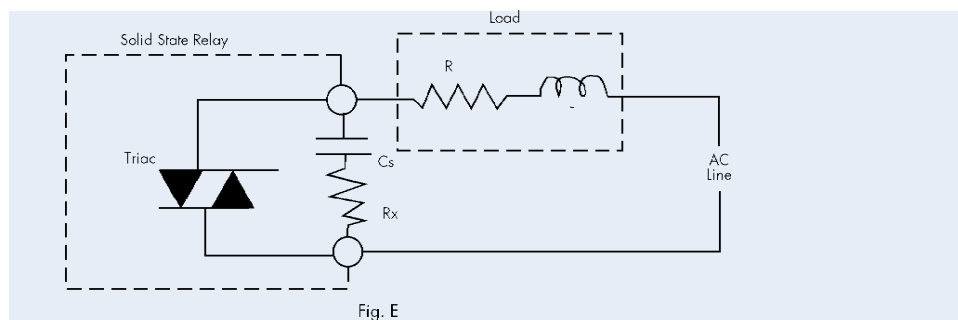
Always protect the output of the relay against voltage transients and load shorts by using appropriate devices.

Make use of MOV'S for voltage transients and semiconductor fuses for short circuits.

Protection devices

RC-Snubber: it is mainly used to suppress the fast load voltage changes arising from inductive loads. Except for the miniature models most of the packages are with built-in snubber circuit.

It also helps to improve the dv/dt rating of the the relay.



Diodes: free wheeling diodes are recommended for dc loads. Though there is a built-in diode across the o/p device, the best way of protecting the relay against back e.m.f is by incorporating the diode across the load.

Fuses: semiconductor fuses are recommended to protect relay against short circuits.

The fuse rating should be smaller than the relay load integral i^2t . this data is available in the relay data sheet.

Varistor: it is recommended to suppress the transient voltages appearing on the Ac mains line which may destroy the o/p device.

In case of motor reversing relays a varistor is a must because at the time of reversing the blocking voltage of the thyristor is easily exceeded.

Load considerations

Most difficulties arising from the application of AC solid state relays are due to an incomplete analysis of the operating conditions that specific loads impose upon the relays.

Resistive Loads

Loads of constant value resistance are probably the simplest application of AC solid state relays. Observing the steady – state current and blocking voltage specifications will normally result in a trouble free application.

The rate-of-rise of current (di / dt) in a purely resistive load is limited only by the line impedances and the turn-on characteristics of the output thyristor. It is possible, particularly in high current applications, to exceed the di / dt to within the relays rating. *The addition of some series inductance especially in high duty cycle applications*, may some times be necessary to limit the di / dt to within the relay rating. The use of relay with zero-voltage switching is an effective way of keeping the di / dt within the rating of the output thyristor. With zero-voltage switching is an effective way of keeping the di / dt within the rating of the output thyristor with zero-voltage switching relay turn-on occurs at a point near the zero crossing of the voltage and, therefore, it is very difficult to have a high di / dt through the relay.

Lamp Loads

Incandescent lamp loads, though basically resistive, present some special problems. Because the cold resistance of a tungsten filament is only 10% or less of the hot resistance, a large inrush current can occur. The duration of the inrush current can range from one half cycle to several cycles, depending on the thermal time constant of the filament. It is essential to verify that this inrush current is within the surge rating of relay.

Because of the unusually low filament resistance at the time of turn-on potential problems with di / dt may be more severe with lamp loads. A zero-voltage switching relay is particularly desirable with tungsten filaments because of the ability to reduce the di / dt stress imposed on the relay and to increase lamp life.

Certain types of lamps can momentarily apply near short circuit conditions on the relay at the moment of burnout. This occurs if a mechanically failed filament falls back across itself or the input lines, in such a manner as to result in a greatly reduced impedance, or if a low impedance gaseous discharge path exists, as it does in some lamps at burnout.

The lamp characteristics at the moment of burnout should be carefully investigated and adequate precautionary measures

taken to assure reliable operation, fast acting semiconductor fuses, of some series impedance line can be used to limit fault current to within capability of the relay.

Capacitive Loads

Capacitive loads are not extremely common but they are encountered in applications such as switching capacitor discharge banks or capacitor input power supplies. Caution must be used with low impedance capacitive loads to verify that the di / dt capabilities of the relay are not exceeded. The di / dt of a discharged capacitive load without external limited impedance can approach infinity. The valuable means of limiting di / dt with capacitive loads.

Particular attention should be given to the safety margin on the relay blocking voltage rating, and voltage transients must be limited when switching capacitive loads. False operation at near peak line voltage into a discharged capacitive load can result in very large and potentially damaging di / dt values. The addition of series line impedance or absolute voltage clamping may be necessary to limit di / dt and protect the relay against the inevitable, occasional large voltage transient on the line.

Inductive Loads, General

Inductive loads are commonly encountered and they present some special operating conditions for an AC Solid state relay. As a result, most application problems with Solid state relays probably occur when inductive loads are being switched.

The most basic inductive load problem is associated with AC Solid state relays that have a triac as the output thyristor, and it is the failure of the relay to commute (turn-off) properly.

This occurs because at the instant of turn-off (zero current through the thyristor) of a lagging power factor load (inductive), the instantaneous value of line voltage can be very high (peak voltage if load is purely inductive). This instantaneous value of line voltage is immediately applied across the triac in the relay when the current goes to zero and can appear as a very high rate of rise of voltage (dv / dt). The high dv/dt can causes the triac to immediately return to the On-state and a "lock-on" conditions occurs. The input circuit no longer has control of the relay and power must be removed from the load circuit in order to turn-off the load. This potential problem is worsened by the fact that the

high dv / dt is applied immediately after current conduction and it is the lower value commutating dv / dt capability (typically 4V/ μ sec) of the triac, not the higher value off-state dv / dt capability (100 V/ μ sec) which determines if successful commutation will take place. This problem is overcome by the use of R-C snubber network (discussed in another section of this manual) which limits the dv / dt applied to the relay at turn-off to a level within the commutating dv / dt capability of the triac. Alternatively, two SCR's connected in inverse parallel may be used to form the output switch in the relay. This technique allows the much higher off-state dv / dt value to be the limiting factor in assuring turn-off. Snubber networks are also used with dual SCR outputs in extremely high dv / dt applications.

An inductive load inherently tends to limit the rate-of-rise of current (di / dt) and, therefore, di / dt problems are relatively uncommon with inductive loads.

Motors

Motors frequently present some problems in addition to those of passive inductive loads. Specifically, motors often have severe inrush currents during starting and produce unusual voltage during turn-off.

The Inrush currents of motors connected to mechanical loads having high starting torque or high inertia should be carefully determined to verify that they are within the surge capabilities of the relay. Both the envelope and the duration of the Inrush current should be examined using an oscilloscope. Frequently, applications require motor starting at short intervals (pulsing) and the effect of the repetitive inrush current, on the thermal operation point of the relay must then be carefully weighed.

The possibility of stalled rotor conditions where current may be six times higher than normal, should be taken into account. An extended stalled rotor condition may require an over sized relay or fuse protection.

The EMF generated by certain motor circuits can require a relay to have a blocking voltage rating greater than would normally be expected based upon the steady-state line voltage applied. This matter can become quite complex, and the voltage applied. This matter can become quite complex, and the voltage applied to a relay by a motor circuit during turn-off an oscilloscope to verify that it is safely below the rated blocking voltage of the relay. Otherwise, "lock-on" or erratic turn-off of the motor may occur. Some motor circuits may require relays with higher than normal blocking voltages, transient limiting devices, or other techniques to withstand the voltage which is produced by a motor during deceleration or reversal.

Transformers

In switching the primary of a transformer, the characteristics of the secondary load should be examined because they are reflected as the effective load on the relay. Voltage transients from secondary load circuits, likewise, are frequently transformed and can be imposed on the relay.

Transformers, present a special problem in that, depending on the state of the transformer flux at the time of turn-off, the transformer may saturate during the first half-cycle of operation at the next turn-on. This saturation can result in a very large current (commonly 10 to 100 times rated primary current) through the relay that could exceed the half cycle surge capability.

Relays having random switching may have a better chance of survival than those with zero voltage switching because they commonly conduct for only a portion of the first half-cycle of the voltage. On the other hand, a random switching relay will frequently turn-on at essentially the zero voltage crossing and then the relay must sustain the worst-case saturation current. Zero-voltage switching relay has the advantage that it turns on in a known, predictable mode and will normally immediately demonstrate (depending on turn-off flux polarity) the worst-case condition. The use of an oscilloscope to study the first half-cycle worst-case condition is advised to verify that the half-cycle surge capability of the relay is not being exceeded. The severity of the transformer saturation problem varies greatly, dependent on such things as the magnetic material in the transformer core, the saturated primary impedance and the line impedance.

A safe rule of thumb in applying an AC solid state relay to transformer primary is to select a relay having a half-cycle surge current rating greater than the maximum applied line voltage divided by the transformer primary resistance, or

$$I \text{ Inrush (Peak)} = \frac{V \text{ Line (Peak)}}{R \text{ Primary}}$$

Where

$$I \text{ Inrush (Peak)} = \text{Worst-case transformer peak half-cycle Surge current.}$$

$$V \text{ Line (Peak)} = \text{Peak value of applied line voltage.}$$

$$R \text{ Primary} = \text{Primary resistance of transformer.}$$

The transformer primary resistance is usually easily measured and can



be relied on as a minimum impedance limiting the current during the first half-cycle of conduction. The presence of some residual flux plus the saturated reactance of the primary will further limit, in the worst-case, the half-cycle surge to safely within the capability of the relay.

Solenoids

In switching AC solenoids, an inrush current occurs until the plunger is seated. The longer the stroke (travel distance of the plunger from rest to seated position) the higher the inrush current. The relay selected, in addition to handling the steady state current (plunger seated), must also have a surge rating capable of handling the inrush current. The operating characteristics of the solenoid should be studied to determine the amplitude and duration of the inrush current.

A safe approach to selecting a relay to switch a solenoid load is to select one with a load current rating equal to, or greater than, the inrush current of the solenoid. If the inrush current is not known, a worst-case current can be calculated from the following.

$$I_{Coil} = \frac{V_{Line (RMS)}}{R_{DC}}$$

I Coil - R D C

Where

I Coil - Worst-case solenoid coil current

V Line (RMS) - RMS value of applied line voltage

R D C - DC resistance of solenoid coil

If a relay is selected based upon the worst-case condition, it will withstand the high current that will result if a mechanical malfunction occurs preventing the solenoid plunger from pulling in.

Low Load Current

If the load current is low it may be necessary to take special precautions to insure proper operation. Solid State Relays have a finite off-state leakage current.

In the example above, the off-state voltage across the load is very high and could cause problems with solenoid drop out and motor overheating. In applications such as this a low wattage incandescent lamp in parallel with load offers a simple remedy. The non-linear characteristic of the lamp allows it to be of lower resistance in the off-state while conserving power in the on-state.

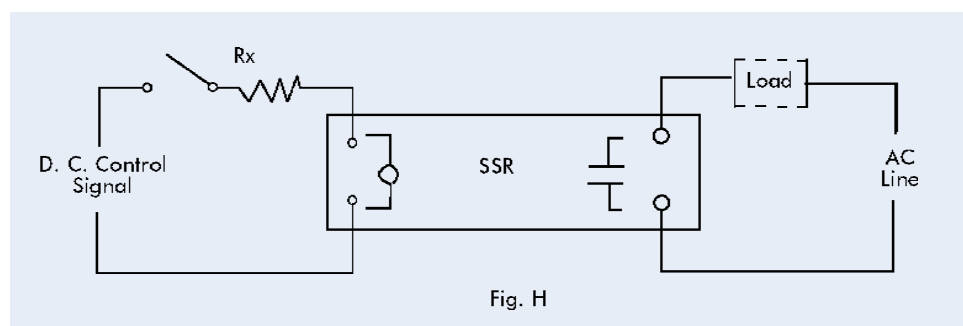


APPLICATIONS

AC solid state relays are used to switch lamps, motors, heaters, computers, solenoid valves, and transformer as encountered in application such as:

- Industrial Process Control Systems
- Machine Tool Controls
- Computers and Computer Peripheral Equipment
- Microprocessor Based Control Systems
- Office and Business Machines
- Vending Machines
- Appliances
- Dispensing Equipment
- Medical Electrical Equipment
- Traffic Control Systems
- Communication Systems
- Environmental Control Systems
- Furnace and Oven Controls
- Temperature Control systems

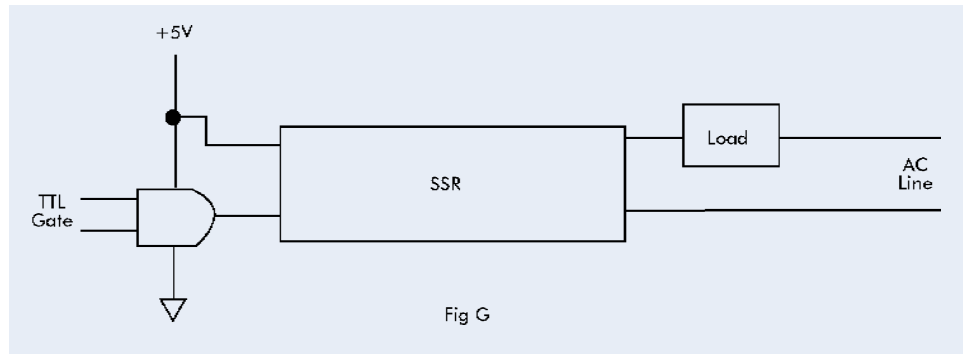
In most applications they are used to interface between a low voltage control source and load operating on the AC line. Figure F shows how the relay is connected into the circuit.



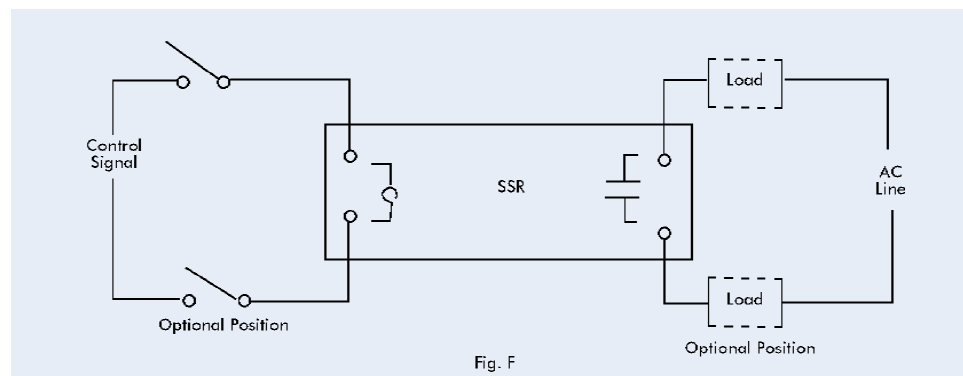
The LOAD can be any one of the numerous types previously discussed. The relay could be an HSSR as well as an SSR.

The control signal may be applied to the relay with switch contacts (as depicted in the drawing), with logic circuits, or by some other

means, when using the common 5V logic (TTL) to drive the relay, it will be necessary to use the logic gate in the sink mode, in most cases, as show in Figure G.



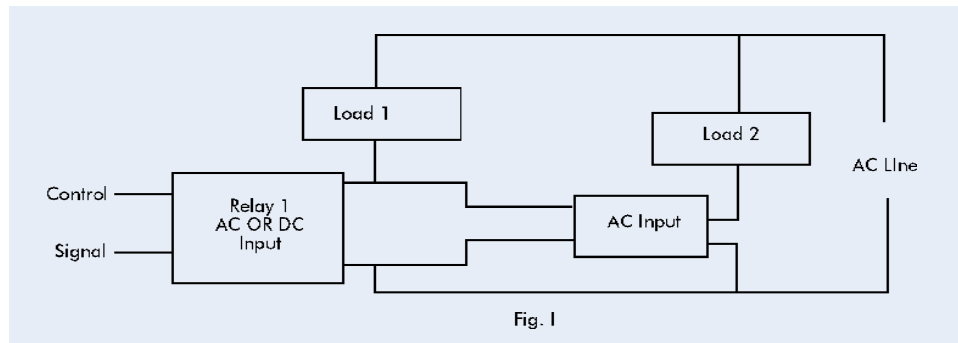
In some applications, the relay may be required to interface with a control signal that exceeds the input voltage rating of the relay. This problem can be solved simply by placing an external dropping resistor, R_x in series with the input of the relay as shown in Fig H. The information necessary to calculate values of R_x for ERI Modules and various control voltage levels is shown in the table in figure.



In addition to the previously discussed straight forward method of using a solid state relay to switch a load, there are numerous circuit arrangement where more than one relay is required to perform a control function. A few of these are described and discussed below;

Single-Pole Double-Throw (SPDT) Circuit

Figure 1 shows how to connect two solid state relays to achieve SPDT switching. RELAY 1 can be either a DC or AC input type, but RELAY 2 must be AC input type.

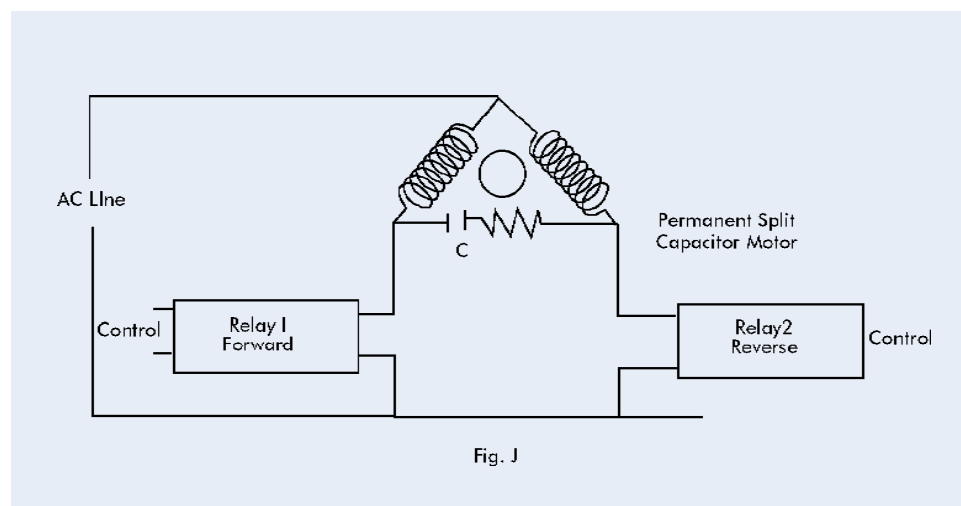


With AC line voltage applied but no control signal, RELAY 1 will be in the off-state (blocking) and line voltage will appear across the output of RELAY 1. This will serve as a control signal for RELAY 2, causing that relay to be in the on-state and current to flow through LOAD 2. Applying a control signal to RELAY 1 will turn-on that relay allowing current to flow through LOAD 1 and dropping the out level of RELAY 1 will be insufficient input to keep RELAY 2 turned on so it will turn off LOAD 2. Thus, by the presence or absence of a control signal at RELAY 1, either LOAD 1 or LOAD 2 can have power applied.

Motor Reversing Control

A method using two solid state relays as a reversing control for a permanent-split capacitor motor is shown in Figure J.

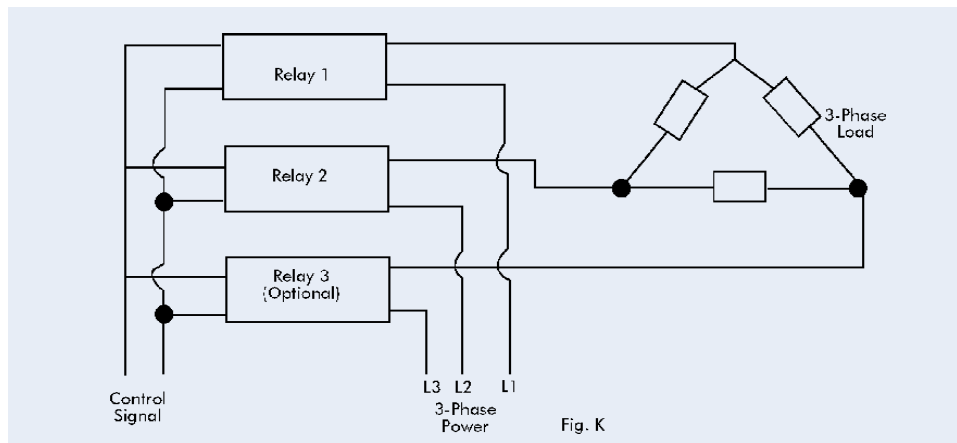
In this circuit, it is important to use relays with adequate blocking voltage rating. Due to the ringing in the L-C-Circuit consisting of the capacitor C and the motor winding, the relay that is in the off-state will have to block greater than peak line voltage. To be safe, it is advisable to use relays that block at least 1.5 times the voltage rating of the capacitor (Resistor R is in the circuit to project the relays should both be turned on at the same time). The resistor value is chosen to limit the capacitor discharge current to a value within the capability of the relay.



The circuit functions by turning on RELAY 1 or RELAY 2 to drive the motor in the forward or reverse direction. The reversing action is accomplished by changing the electrical location of capacitor C relative to the two motor windings.

Three-phase switching

Three-phase loads can be switched using two or three solid state relays. Figure K shows a typical connection. The load be either delta (as shown) or wye connected.



The relay inputs can be supplied in parallel (as shown).

Trouble Shooting Guide

In order to function properly and reliably, a solid state relay must be provided with the correct input and output voltages, and switch a load current within the limitations dictated by rating, heat sinking and temperature. If not properly applied, and on occasion for other reasons, solid state relays can fail to perform properly and the problems will generally show up as:

1. Failure of the relay to turn-off on command.
2. Failure of the relay to turn-on command.
3. Erratic relay operation.

If the problems do occur, the following discussion and outline will aid in locating the problem and determining the cause.

Relay Fails to Turn-off on command

When this occurs, disconnect the input (control signal) to the relay and note the effect. The relay remains on with the input disconnected, the problem could be one of the following.

1. Thermal runaway caused by exceeding the load current capability to the relay
Solution: Select a relay with a current rating to match the requirements of the Load.
2. Thermal runaway caused by inadequate head sinking.

Solution: Remove more heat from the relay by using a larger more efficient Heat sink, or possibly employing forced air cooling, or reduce the ambient temperature.

3. Break over of the output thyristor due to exceeding the voltage rating of the Relay.

Solution: Select a relay with a higher blocking voltage rating. The conditions described can cause the relay output to become permanently shorted, requiring replacement of the relay.

4. Failure to commute properly due to inductive load.

Solution: Add R-C snubber network across output terminals of relay.

5. Partial load activation due to half-cycling relay caused by faulty output Thyristor.

Solution: Consult ERI.

If the relay turns-off with the input disconnected, measure the input (control signal) voltage. An input voltage that exceeds the specified must-release voltage for the relay when the relay is supposed to be turned-off indicates a control circuit problem ahead of the relay that must be corrected. If measured voltage is lower than the specified must release voltage for the relay, the relay has a low release voltage and must be replaced.

Relay Fails to Turn-on on Command

When this happens, a good way to start is by checking all circuit connections and the polarity of the input voltage applied to the relay. If this fails to locate the problem, it will be necessary to make some measurements in the circuit to isolate the trouble area.

Begin by measuring the voltage across the relay input when the relay is supposed to be turned-on. If the voltage is found to be less than the specified must-operate voltage for the relay there is a control circuit problem that must be corrected. If the voltage is found to be greater than the specified must operate voltage, it will be necessary to measure the current being drawn by the input circuit of the relay. No current, indicates an open input circuit, within the relay requiring replacement of the relay. A low current, in all likelihood, would be caused by a control circuit problem ahead of the relay. If the current is normal, the problem could be within the relay or associated with the relay output circuit.

Measure the voltage across the relay output. If there is no voltage across the relay, there is an open load circuit external to the relay. If normal line voltage is across the relay, check the load. If no fault can be found with the load, the relay is defective and should be replaced.



If the load is shorted, it will have to be corrected and it may also be necessary to replace the relay due to possible damage caused by excessive current.

Relay Operates erratically

Whenever a relay does anything other than turn on and off on command, it can be said to be operating erratically. A good initial step towards locating the problem is to substitute a known good relay and observe the performance. If this solves the problem, the original relay is highly suspect. If the problem persists, things to consider and check are as follows:

1. Examine the entire circuit for proper wiring and good connection.
2. Consider the possibility of transients on the input (control signal) or output lines.

This can cause false operation of the relay. Suppression networks or rerouting of wiring may be necessary to solve the problem.



Recommended Heat Sink

qSA		Heat sink type No.	Length
A	32° C/W	60 NI 145 AG	110 MM 145 MM
B	1° C/W	202 MW 204 MWC	50 MM 50 MM
C&D	0.5° C/W	202 MW 204 MWC	135 MM 100 MM
E	0.2° C/W	350 HT DOUBLE SIDED COOLING	225 MM
F & G	0.14° C/W	350 HT 400 MM DSC	

Application Notes

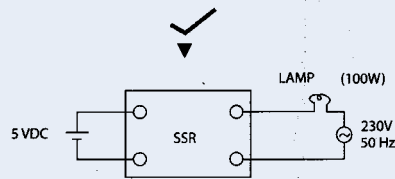
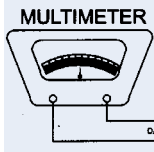
Definition of Solid State Relays (SSR)

A relay with isolated Input & Output, whose functions are achieved by means of Electronic Components without the use of moving parts - NARM (USA)

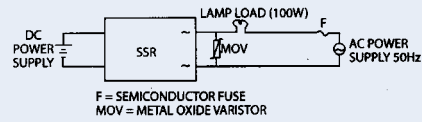
Selecting The Proper SSR

- Select a relay whose current exceeds the normal load current. Verify load current w.r.t ambient temperature (refer to derating curves). SSR should be provided with an external heatsink for $I_L > 3A$. Apply heatsink compound between SSR base & external heatsink. Ratings are based on single unit in free airflow. Ratings for closely packed units, careful consideration of the ambient temperature will be necessary. If I_L is lower than I_H ($< 12 \times I_{DRM}$) it is required to take special protection to ensure proper operations.
- Protect the output device from high voltage transients by using MOVs. Use RC network to improve dv/dt . To protect SSR against short circuits, make use of semiconductor fuses. (I^2t rating of semiconductor fuse must be lower than that of SSR I^2t)

HOW TO INSPECT SSR



TYPICAL CONNECTION DIAGRAM



Recommended Ratings For Motor Loads (ON/OFF)

1. Relays for motor loads are selected on the basis of starting current of the motor. The thumb rule is $I_{start} = 5 \times I_{run}$.
To get the appropriate rating of the SSR, derate the SSR rating by 5 and use it as per derating curve.
2. Make use of 3 single phase SSRs if 001 series is selected. Otherwise, use a single 3 phase SSR if 012 series is selected.
3. For 240 vac 1f SSR (001 series), use MOV type RDN 275/14 one each across terminals 1 & 2.
4. For 440 vac 3 f SSR, use MOV type RDN 510/20 one each across terminals 1 & 2 (1 f SSR) or one each across terminals R&U, S&V, T&W (012 Series).

Selection of protection resistors & fuses for 3 phase motor reversing ssrs

Sl. No.	Current rating for SSR	Wire Wound Resistor Value	Wattage	(English Electric Fuse Rating & Type)
01	10A	6 OHMS	25W	GSB 10
02	16A	4 OHMS	50W	GSB 15
03	25A	2.5 OHMS	75W	GSB 25
04	40A	1.75 OHMS	125W	GSB 45

Capacitor Loads

SSR Part Number	KVAR Rating	Series Inductor value of rated Current
ERI 020 D 165015	3 to 9 KVAR	18-20 μ H
ERI 020 D 169015	12.5 KVAR	10 μ H
ERI 020 D 1612515	18.5 KVAR	6 μ H
ERI 020 D 1617515	25.0 KVAR	3-5 μ H

Heater Loads

Thumb rule : Select SSR current rating at 1.5 times the heater rating. Use suitable external heatsink with heat sink compound to dissipate heat generated by the SSR. For voltage transients make use of metal oxide varistors(MOV) as above. Make use of semiconductor fuses type GSA xx series for single phase and GSB xx series for 3 phase application. xx-respective-current.

Solenoids / Contactors / Coils

SSR O/P voltage rating should exceed the back emf rating of the load. Current rating should exceed the surge rating of the load. Make use of RC network for SSRs which do not have In-Built snubbers.

Note: All electrical parameters measured at TA = 25°C