SPST to DPDT Switching Conversion Module for Solid State Relays (SSR)

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Abstract: All Solid State Relays (SSR) manufactured till today are only capable of Single Pole Single Throw (SPST) switching. The main motive of Solid State Relay(s) was to replace the use of conventional Mechanical Relay(s) for various switching applications. As SSRs offer only SPST switching unlike Mechanical Relay(s) which offers all kinds of switching options like Single Pole Single Throw (SPST), Single Pole Double Throw (SPDT), Double Pole Single Throw (DPST) and Double Pole Double Throw (DPDT) packed inside a single enclosure, the usage of SSRs for switching applications are getting restricted. However in order to solve this problem, using various switching techniques and electronic circuits, we can make a combination of Solid State Relay(s) connected to an electronic module, so that we can make them switch under any configuration such as SPST, SPDT, DPST or DPDT by giving a desired D.C input signal(s). Moreover this module can also be used as anormal Relay Module to control individual Relay(s) separately by switching it to different D.C input signal(s).

Keywords: Relay, Solid State Relays, SPST, SPDT, DPST, DPDT, D.C.

I. INTRODUCTION

After the discovery of Solid State Relay(s), the frequency of applications of Mechanical Relay(s) are slowly getting reduced as they are getting replaced by Solid State Relay(s) which offers multiple advantages like faster switching, less wear and tear etc. over the normal conventional mechanical switching methods used in Mechanical Relays.

Since then lot of research is being carried out to improve the design and switching methods used in SSRs. A favourable SSR must have the following characteristics:

- Must have least resistance when closed and maximum resistance when open.
- Voltage-current characteristics should be nearly linear and should distort switched waveforms to the least.
- Must be non-sensitive to polarity of the switching waveform.
- Any load withstanding capability.
- Reverse leakage current should be as minimum as possible.
- There must be proper isolation or insulation between input signal and switching signal.
- Frequency of switching should not affect the lifetime of the SSR.
- In case of a short circuit it must tend to fail 'open' rather than tend to fail 'shorted' at their outputs.
- Must possess all kinds of switching options such as SPST, SPDT, DPST and DPDT.
- Low power dissipation and heat generation.
- Faster switching with low reaction time.

- Should be able to accept a wide range of input signal for switching the external load.

However the above mentioned favourable characteristics are very difficult to achieve when it comes to practical applications. So this paper provides us with a practical solution for the restricted switching configuration (SPST) of the SSR by the help of an electronic module.

II. THEORY

A. Switches
A switch is an electrical component which makes or breaks an electric connection. This means it can be used to control the logic state of a circuit. They allow control over current flow in a circuit by turning them to on or off. Switches are critical components in any circuit and it requires user interaction or an external control. [1]

B. Types of Switching Methods
Mostly we use 3 types of switching methods in circuits, they are:

- Mechanical Switching
In this type of switching all mechanical parts are used to make or break an electric circuit. The best example is the switches which are used in our homes which **requires an external physical force from the user** to change it state.

- Electromechanical Switching
This type of switching is similar to mechanical switching method and has all mechanical moving parts. But instead

of requiring a physical force from the user to change the state of the switch, this method uses external forces like magnetic force, thrust from a electric motor etc. to change its state. The best example is the **electromechanical relay which exerts magnetic force on the contacts of the switch when the coil placed near to it becomes electrically energized.**

• Electronic Switching
This type of switching method incorporates the use of various semiconductors for switching an electric circuit by **applying a small external voltage**. The best examples are transistors, thyristors, solid state relay etc.
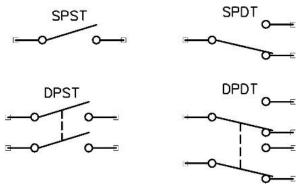
C. Types of Poles and Throws

Fig. 1. Different types of switching configurations.

To break a circuit, a switch must possess at least two terminals. One terminal to let the current in and another to let the current out. But there are many switches that have more than two terminals. To know their working, we need to have idea about poles and throws of a switch. [1]

• Poles: The number of **poles** on a switch defines how many separate circuits the switch can control. So for example, a switch with two poles, can influence two circuits. [1]

• Throws: The **throws** in a switch defines how many positions each of the switch's poles can be connected to. For example, if a switch has two throws, each circuit connected to the pole can be connected to one of two terminals. [1]

Now in accordance to the number of poles and throws a switch can have, the most widely used switching configurations are categorized as:

• Single Pole – Single Throw (SPST)
• Single Pole – Double Throw (SPDT)
• Double Pole – Single Throw (DPST)
• Double Pole – Double Throw (DPDT)

D. Momentary and Maintained switches (Latching or Non-Latching Switches)

•   Momentary or Non-Latching Switches:
This type of switches are monostable in nature, this means that once the external physical or electric input is removed from the switch, it will come back to its original position. For example: Door Bell Switch, Bi-Polar Transistor.

•   Maintained or Latching Switches:
This type of switches are bistable in nature. Once the input is given to change the state of the switch, it will retain the same state even if the external force or electric input is removed. For example: Normal household switch, Latching Relay, Bistable Transistor Circuit

E. Solid State Relays:
A Solid State Relay (abbreviated as SSR) is an electronic switching device which can turn on or off an externally connected load with the help of a small external input voltage when applied across its control terminals. SSRs consist of a control circuit and a switching circuit which are electrically isolated from each other. This isolated region basically consists of an optocoupler connected between the two circuits.[9] When the control circuit input is high, it excites the external circuit optically and thereby switches the connected load to on state. Hence, on removal of external input it will turn the external circuit back to off state.[6] This electronic process of switching can be used as a substitute for the electromechanical switching relays as it shows similar switching characteristics and can switch any load waveforms (a.c or d.c). Similar to electromechanical relays, the SSRs also come inside a packed enclosure for better electrical insulation and optical isolation. Instead of moving contacts in electromechanical relays, power semiconductors such as thyristors, TRIACs or MOSFETs are used to switch the external load.[7]

TABLE I BASIC COMPARISON BETWEEN SSR AND MECHANICAL RELAY

SL. NO.	Solid State Relay	Electromechanical Relay
1.	No moving parts.	Switch contacts have moving parts.
2.	No electromagnetic field is generated so doesn't cause any external interference.	The switch contacts are moved by the magnetic force generated by the coil.

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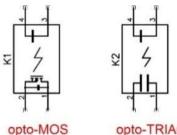
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3.	Switching elements are made up of power semiconductors.	Switching elements are purely made up of metal conductors.
4.	Provides faster switching.	The switching time is long.
5.	Tends to fail 'shorted' during a short circuit.	Tends to fail 'open' during short circuit.
6.	No acoustic noise is generated while switching.	Acoustic noise is generated while switching.
7.	High resistance when closed.	Low resistance when closed.
8.	No sparks or electric arcs are formed while switching high loads.	Sparks and electric arcs may be generated while switching.
9.	Distorts the current-voltage characteristics.	It shows a linear current-voltage characteristics.
10.	Reverse leakage current is high.	There is no reverse leakage current.[4]
11.	Only supports SPST type switching configuration.	Supports all kinds of switching configurations like SPST, SPDT, DPST and DPDT.
12.	Requires lesser area for operation.	Requires comparatively larger area for operation as compared to SSR.
13.	Latching operation cannot be done.	Latching operation can be made.
14.	Heat generation is more during operation.	Heat generation is less during operation.
15.	Almost no wear and tear occurs after repeated operations.	A lot of wear and tear occurs after repeated operations.

F. Classification of Solid State Relays

The following are the classifications of SSR:
- Photo-coupled Solid State Relay.
i) Opto-TRIAC
ii) Opto-MOS
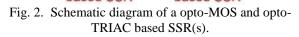- Transformer Coupled SSR
- Hybrid Solid State Relay.

i) Reed Relay SSR

The traditional methods of using hybrid SSRs has nearly declined considering the past few decades as it nearly works the same as the electromechanical relay. In the near future all SSRs used for various applications will be photocoupled ones with either a opto-TRIAC or opto-MOS.[3]

Fig. 2. Schematic diagram of a opto-MOS and opto-TRIAC based SSR(s).

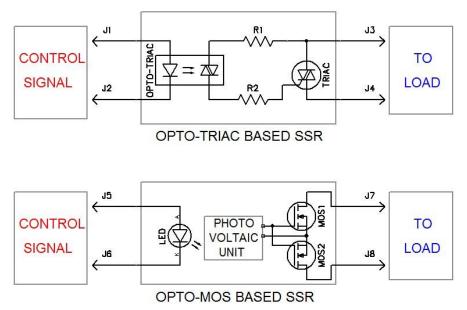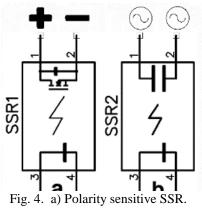Opto-TRIAC SSRs are basically used for switching A.C loads whereas Opto-MOS SSRs are used for D.C load switching.[2]

Fig. 3. Realisation of internal circuit of a opto-TRIAC and opto-MOS based SSRs.

TRIACs are bidirectional devices hence they can easily conduct A.C waveforms whereas the MOSFETs are basically unidirectional devices and this is the reason they are mostly used for switching D.C loads.[5] Hence the SSRs manufactured also comes with two kinds of switching outputs, they are:

• Non-Polarised Switching
This type of SSRs uses TRIAC to switch the external load. As mentioned before, TRIACs aren't polarity sensitive hence this type of SSRs are mostly used for switching A.C loads and they have high resistance.
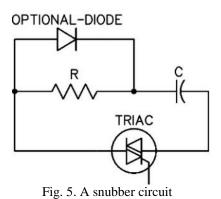
• Polarised Switching
Coming to polarised switching SSRs, they use MOSFETs to switch the external load. MOSFETs have comparatively lower resistance in comparison to the TRIACs and SCRs, but they are polarity sensitive. So the external load must be connected carefully by matching the polarity of the SSR and the input waveform should only be D.C.

Fig. 4. a) Polarity sensitive SSR.
b) Non-Polarity sensitive SSR.

G. Snubber Circuit

Fig. 5. A snubber circuit

A snubber circuit is a type of circuit usually consisting of a resistor and a capacitor connected together to the SCR or the TRIAC as shown in Fig. 5. It acts as one type of enormous voltage protection circuit for the TRIAC or SCR. With the help of snubber circuit, the accidental turn-on of a thyristor or TRIAC due to large voltage (dV/dt) can be prevented. This is done by restricting the rate of rise in voltage (dV/dt) across the thyristor to a value which will not trigger it. [8]

Some snubber circuits have a diode used to connect in parallel with the resistor R.

It is used for the purpose of bypass and thus gives improved voltage (dV/dt) protection. [8] Some SSRs may have inbuilt snubber circuit connected to the TRIAC or SCR.

H. Advantages of a Solid State Relay
In comparison to an electromechanical relay, following are the advantages of a solid state relay:
• It doesn't have any moving mechanical parts.
• It has longer period of operating life.
• It has a bounce-free operation.
• It doesn't get affected to any external electromagnetic interference.
• It has faster or higher frequency switching speeds.
• The control circuit can be controlled by a very low input voltage nearly starting from 3v.
• It can be integrated into many functions at the same time.
• Sparks and electric arcs won't be formed as there is no moving parts and air gap.
• Provides a complete silent switching operation.
• High reliability.
• It is robust and is resistant to external shock and vibration.
• It can accept a wide range of voltage and current as its input.
• Provides high isolation between input and output terminals.[10]

III. DESIGN CONSIDERATIONS

This paper's main motive is basically to solve the restricted switching capabilities of the Solid State Relay by using an external electronic module. Any electronic module will only be useful if it is portable and comes feature packed. So in order to maximise its usefulness, **this module can also be used as a normal relay module by giving inputs at specific terminals as well as a desired switching converter for SPST, SPDT, DPST and DPDT type switching configurations. Moreover there is an option to use the module as a monostable or bistable switch.** That means the user can set the switch according to their wish whether they want to use the module as a latching or non-latching device.

The module consists of 5 Volts Logic. So the module can be powered up by using a USB source. Although all SSRs may not work under 5V range, so the module provides a pathway for an external source which can be helpful for powering the relays.
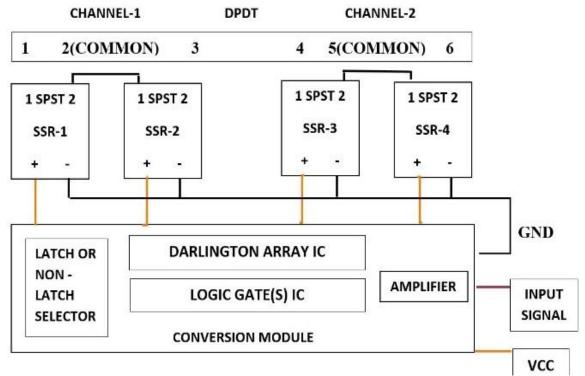
Fig. 6. Block diagram representation of the electronic conversion module

The step by step working of each block (as shown in Fig. 6.) is explained below:

• VCC:
This is the terminal of the module where the voltage has to be provided for the working of logic ICs. As mentioned earlier, VCC for this module is 5V.

• GND:
This terminal is the ground terminal of the module and all the ground terminals of all other input signals must be connected here.

• Input Signal:
If the amplifier circuit is not installed in the module, then input signal voltage must be provided same as VCC (this case its 5V).

If amplifying circuit is attached, then even if the input signal falls below 5V the switching action can be done.

• Logic Gates IC:
This block consists of various logic gates for performing the alternating switching action. Basically it consists only a NOT gate which acts an inverter.

• Darlington Array IC:
Different SSRs may require different voltage for operation. As our module only works with 5V logic input, so the connected SSR may or may not work under this specific voltage.

In order to deal with this problem, this darlington array IC will take up any external power source as its input and it will switch the internal transistors inside it in accordance to the logic outputs from the module and will turn the externally connected SSRs on or off.

• Latch or Non-Latch Selector Switch:
This selection switch provides the user with an option to set the module as a monostable or bistable switch.

By turning this switch on, the input signal is diverted to an SR latch IC which retains the state of the output even after the input signal is removed. In order to reset the state of the module, an external input of 5V must be provided at reset pin terminal of the SR latch.

• SSR connecting terminals:
The SSRs connected to the terminals of the module must match the polarity signs.

A maximum of four SSRs can be connected to the module at the same time.

Considering the kind of application and investment required to manufacture the module, we can classify them into two categories:

• Low cost - **basic functionality conversion module**.
• Medium cost - **multiple functionality conversion module.**

IV. CIRCUIT DIAGRAMS

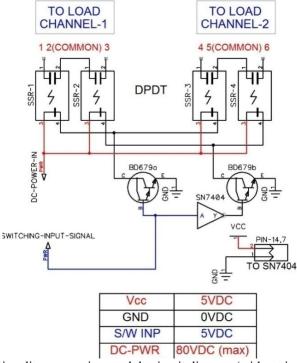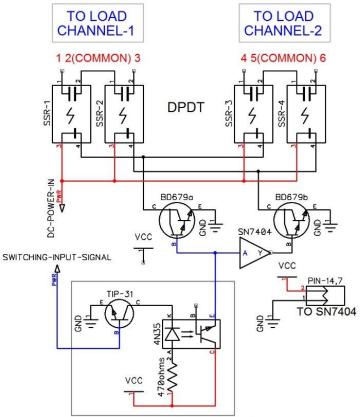| Vcc	5VDC
GND	0VDC
S/W INP	5VDC
DC-PWR	80VDC (max)

Fig. 7. Low cost basic functionality conversion module circuit diagram (without input amplification transistor)

Fig. 8.Low cost basic functionality conversion module circuit diagram (with input amplification circuit).Can accept voltages below 5V for switching.

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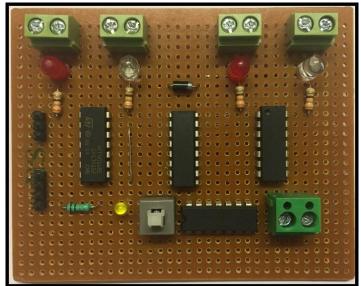Fig. 9. Medium cost multiple functionality conversion module circuit diagram.

IV. IMPLEMENTATION

Fig. 10. A self made multiple functionality conversion module for SSRs.

The speciality SPST to DPDT switching conversion module is that, it can not only be used with SSRs but it can also be used with normal electromagnetic relays. Now depending upon the type of relay attached, the power consumption from the source will vary accordingly. Coming to the power consumption of the module, more power will be consumed by the medium cost multiple functionality type module because it has more number of ICs and components as compared to the low cost basic functionality module.

While connecting the common output terminals of the SSRs one must remember that for SSR with polarized outputs, the common terminals should only be connected between terminals two SSRs having same polarity as shown in fig. 11.
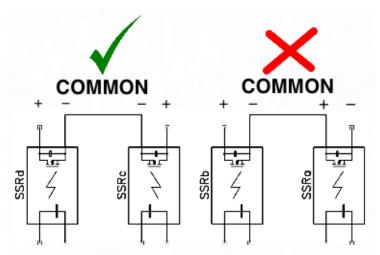

Fig. 21. Correct and incorrect method of connecting the common terminals for polarity sensitive SSRs.

The latching and non-latching functionality of the module cannot be used at the same time. The selection switch can only change the module's switching state to either monostable or bistable. Input signal for switching the circuit should only be D.C. A D.C clock pulse with less frequency can be given at the input terminal to switch the attached relays in a sequence. More frequency of the input D.C signal for switching may lead to failure of the circuit.

V. APPLICATIONS

Some applications of the SPST to DPDT Switching Conversion Module are as follows:
- Can be used where SSRs have to switch between more than one loads.
- It can be applied to circuits having two channels which have to be simultaneously switched on or off.

- Household mains grid switches can be replaced with relays and can be controlled using this module.
- Can be used as a normal 4-channel relay module.
- Can be implemented in small projects requiring the use of relays for switching under any desired configurations.

VI. ADVANTAGES

Coming to the advantages, here the SPST to DPDT Switching Conversion Module offers a many of them, some are as follows:

- Can be used with any type of relays.
- The power consumed by the module is very less.
- The operating voltage is easy to obtain as it uses only 5V which we can even get from USBs.
- The selection switch provides functionality whether to latch or non-latch the switching configuration of the module.
- Can be used with polarized as well as non-polarized output SSRs.
- There is no need of any coding to obtain a particular switching operation.
- This can be directly attached to microcontroller boards for switching as most of them work with 5V logic.
- It can be made portable and handy.
- Simple circuit diagram can be easily be manufactured.
- Use of darlington array IC helps to take in desired voltage to switch the relays with any threshold voltage.
- The input signal can be given as clocked DC pulses for sequenced switched outputs.
- Longer lifetime is achievable as there are no moving mechanical parts.

VII. CONCLUSION

This module should not only be considered as a module which provides various switching configurations for SSRs rather, it should also be considered as an **upgrade over the existing relay modules manufactured for commercial use.** Keeping the switching mechanism simple, easy to use and manufacture is the ultimate goal of this conversion module. SSRs over years of research may gain multiple switching configurations, but this module can never get obsolete in near future as it provides multiple uses.

ACKNOWLEDGMENT

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