Design tips for using the PVX6012PBF high-voltage solid-state relays

About this document

Scope and purpose

All modern day consumer, commercial, medical, and industrial applications have electrical systems operating at their core. The ability to control the high-voltage, high-current section with an isolated, low-input voltage and current switch simplifies the overall system design. Traditionally, electro-mechanical relays (EMRs) have dominated this space but solid-state relays (SSRs) are gaining in significance due to their small size, high switching speed, silent operation, and better reliability among other benefits.

To design with SSRs correctly, engineers need to understand the nuances of their operation and their electrical characteristics. For a successful design, the right SSR matching the application's input, output, load, and thermal conditions needs to be selected.

This application note will discuss the nuances of Infineon's high-voltage PVX6012 solid-state relay which can switch a 400 VDC or 280 VAC_{RMS} 1A load with a typical control input of 3.3 V / 5 mA. Key datasheet parameters are explained, and examples are provided on how to apply them correctly to solve the problem of switching higher voltages and currents. This application note also covers the advantages of the PVX6012 over electro-mechanical relays, typical applications and application block diagrams.

Intended audience

System designers of industrial controls and automation equipment, programmable logic controllers, EV charging stations, automatic test equipment (e.g. multiplexers and data acquisition systems) and robotic systems.

Product disclaimer

Infineon Technologies does not recommend the use of this product in aerospace, avionics, military or life support applications. Users of the PVX6012 in such applications assume all risks of such use and indemnify Infineon Technologies against all damages resulting from such use.

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1 Introduction

The PVX6012 Photovoltaic Relay is a single-pole, normally-open solid-state relay that can replace electro-mechanical relays in a wide variety of applications from industrial automation and controls to automatic test equipment. Many of these applications can benefit from the improved performance of solid-state relays over electro-mechanical relays that perform the same function.

With a load voltage rating of 280 VAC_{RMS} or 400 VDC and a load current rating of 1 A, the PVX6012 is ideally suited for switching medium-power loads. In addition to the intrinsic advantages of SSRs such as high reliability, long life, insensitivity to normal levels of shock and vibration, it offers high operating speed, low and stable on-state voltage drop as well as low off-state leakage current.

The PVX6012 is packaged in a modified 14-pin, molded DIP through-hole package.

2 Functional description

The internal functionality of the PVX6012 can be explained in two stages; the optically coupled input stage and the output switch stage, which consists of two IGBTs along with blocking diodes. Figure 1 shows the internal view of the PVX6012.

The PVX6012 input circuit consists of a GaAlAs light-emitting diode (LED) that converts the input drive current to light. This light is optically coupled to a conversion circuit that is comprised of an integrated array of photovoltaic (PV) cells and associated drive circuitry. The PV cells generate the voltage needed to control the high-voltage output IGBTs that switch the output load. The LED and PV chips are coupled by a translucent dome material that transfers light from one to the other without transferring heat or sacrificing isolation resistance. This optical dielectric material provides the electrical isolation.

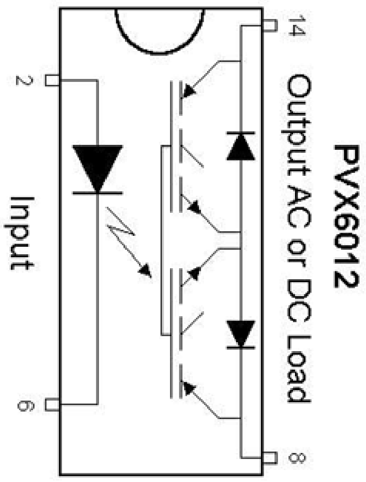


Figure 1 Internal view of PVX6012

When the input signal is HIGH (i.e. control current >= 5 mA), the output PV generates enough voltage to turn on the IGBTs and switch on the AC or DC load. When the input signal is LOW (<= 0.4 mA), the diodes block the AC or DC load resulting in the switch turning off.

3 Key parameters

Input characteristics

Control current

The PVX6012 is a current-controlled relay with a specified current which must be supplied for turn-on. The minimum control current is 5 mA and the maximum allowed control current is 25 mA.

A current limit resistor is necessary when operating from a voltage source. The selected resistor must be of sufficiently low value that the specified turn-on current flows at the minimum signal voltage and lowest operating temperature. The simplified circuit below shows the input circuit consisting of the internal light-emitting diode (LED) plus the external resistor (Rc).

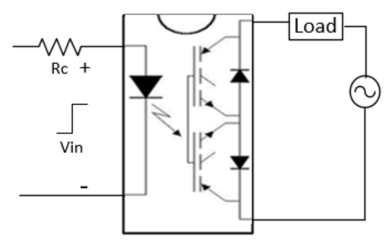


Figure 2 PVX6012 with integrated IGBTs / Diodes switching an AC load

To determine the maximum allowable value of Rc the maximum LED forward-voltage drop (VLED) at the coldest operating temperature (Ta) should be determined from the input characteristics curve shown below in Figure 3.

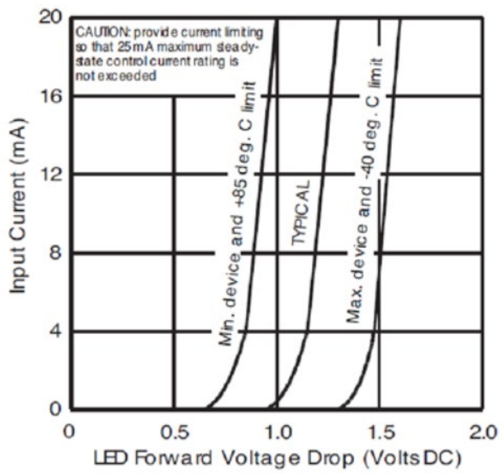


Figure 3 PVX6012 input LED forward-voltage drop (VLED) vs. input current (Ic)

The value used for -40°C operation is 1.6 V DC.

The following equation expresses the maximum allowable value for Rc.

$$Rc_{max} = \frac{(VIN - VLED)}{Ic\_min\ (turn\ on\ current)}$$

Example:

VIN (min) = 4.5 VDC; Ic (min) = 5 mA; Ta = -40 °C

$$Rc_{max} = \frac{(4.5\,V - 1.6\,V)}{0.005\,A} = 580\,\Omega$$

A minimum allowable value of Rc is set by the necessity of not allowing the input current to exceed 25 mA at the highest signal voltage and operating temperature. A high temperature LED drop of 0.9 V is most commonly used for 85 °C ambient temperature.

$$Rc_{min} = \frac{(VIN - VLED)}{Ic\_max\ (turn\ on\ current)}$$

Example:

VIN (max) = 6.0 VDC; Ic_max = 25 mA; Ta = 85 °C

$$Rc_{min} = \frac{(6.0\,V - 0.9\,V)}{0.025\,A} = 204\,\Omega$$

In the above example, a resistor in the calculated range, and near the maximum allowable value, would be selected, for example 500 ohms.

To maximize the lifetime of the LED and overall reliable operation of PVX6012, make sure to limit the input LED current to < 25 mA. This is the absolute maximum current that the internal LED can handle. If the drive current exceeds 25 mA, it will cause overheating of the LED and eventual failure of PVX6012. This is important when the device is operating at higher ambient temperatures, as the LED current increases with temperature.

Reverse voltage

The maximum reverse voltage of the input is 6.0 V. This rating should not be exceeded. If necessary, a protection device may be added to the input, e.g. a diode in parallel across input terminals to keep reverse voltages below the reverse breakdown voltage as shown in the Figure 4 below.

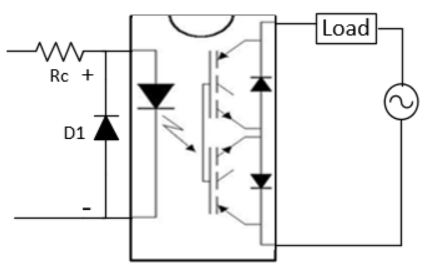


Figure 4 **Reverse-voltage protection of PVX6012 by adding diode D1**

Output characteristics

Operating voltage

With a 600 V peak blocking voltage (Vp), the PVX6012 is rated to be operated up to 280 VAC_{RMS} or 400 VDC. The maximum allowed operating voltages should not be exceeded, otherwise damage to the internal IGBTs and/or diodes may occur. If necessary, a voltage or surge-absorbing element (e.g. varistor, snubber, diode, TVS, etc.) can be added across the output to clamp any voltage transients (for example those generated with inductive loads) to within this rating.

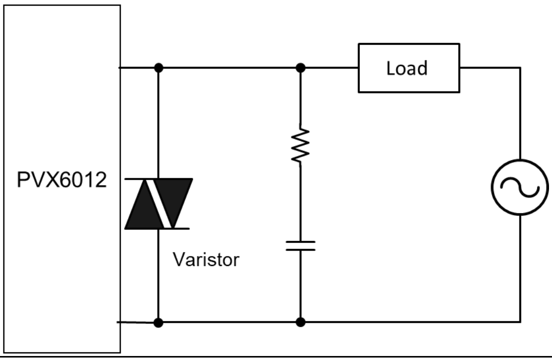


Figure 5 **Use an external varistor with limiting voltage no more than 600 V (peak voltage of the PVX6012) to protect the PVX6012 from overvoltage conditions**

Load current

The PVX6012 can switch 1 A loads up to an ambient temperature of 40°C. Figure 6 shows the maximum load current capacity over temperature. The PVX6012 load current needs to be derated depending on the temperature conditions based on the derating curve shown below.

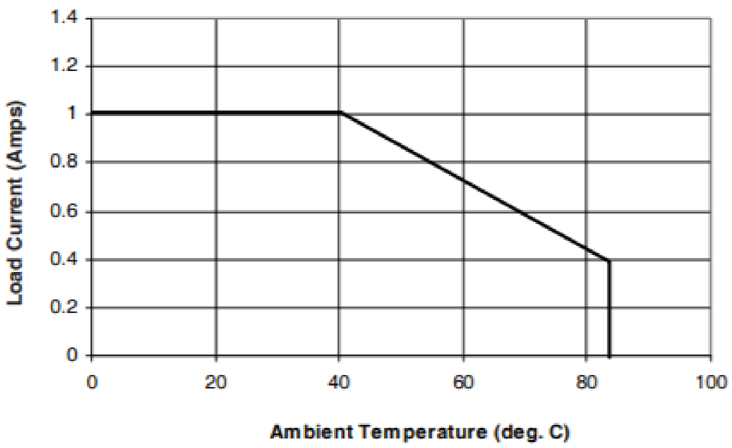


Figure 6 **Current derating vs. temperature capability of PVX6012**

The PVX6012 can switch 400 mA load current at 85°C ambient temperature. A key benefit of SSRs is that they can operate under harsh conditions. The high ambient temperature specification of PVX6012 helps customers to use this part under high temperature conditions such as those in industrial and outdoor display applications.

Surge current

Different loads have different inrush current requirements. For example, the inrush current of a motor can be 5 to 10 times the steady state current, while for an incandescent lamp, inrush current can be 10 to 15 times the steady state current. Hence, when the SSR switches these loads, the surge-current rating of the SSR becomes a critical parameter in choosing the right SSR. Infineon is one of the few companies that specifies the surge-current ratings for 1 second. The PVX6012 can withstand surge currents up to 20 times its nominal load current rating of 1 A for a short duration. The complete surge current rating curve up to 10 seconds is shown below in Figure 7.

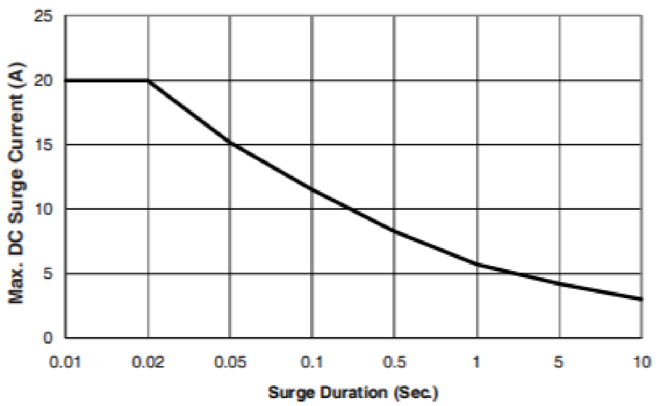


Figure 7 Surge current capability of PVX6012

For protection from inrush currents in the application, check that the load surge-current rating is less than the surge-current rating of PVX6012 given in the Figure 7. If larger surge currents are expected, the device should be protected by a current limiting device, such as a fuse or NTC.

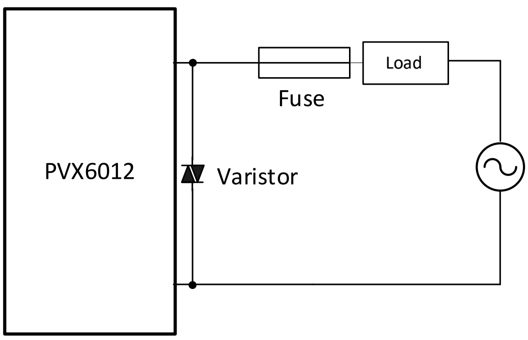


Figure 8 Protection of PVX6012 with fuse for large current limiting

Turn-on (T_{on}) and turn-off (T_{off}) times

Turn-on and turn-of times are defined per Figure 9.

The turn-on and turn-off times are controlled by the input current. Higher input currents imply a higher LED emission intensity which brings about faster switching times. At higher ambient temperatures, LED emission intensity drops resulting in longer switching times.

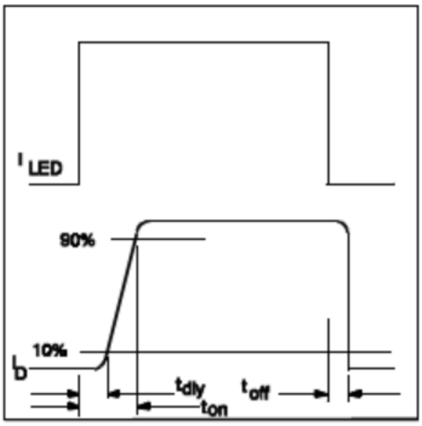


Figure 9 T_{on} and T_{off} timing definition of PVX6012

The PVX6012 typical turn-on and turn-off times for a 1 A, 400 V_{DC} load, with varying input control current are shown in Figure 10 below. As can be seen, the higher the LED current, the faster the turn-on and turn-on times.

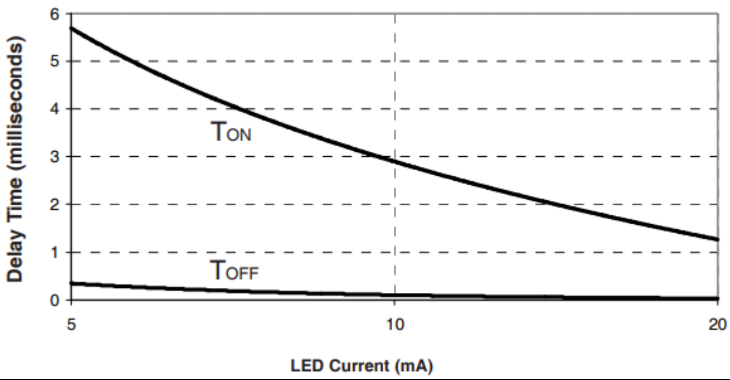


Figure 10 T_{on} and T_{off} time of PVX6012

Output capacitance

Output capacitance is the electrostatic capacitance between the output pins when there is no current input to the LED, i.e. IGBT is OFF. In a non-conductive state, the AC signal leaks through this capacitance. The impedance of electrostatic capacitance becomes smaller with higher frequencies and larger electrostatic capacitance, which means that current flows more easily. When the LED is OFF, it is desirable to have a smaller leakage current on the output side. A lower output capacitance helps in limiting the leakage current (especially at high frequencies). High output capacitance may cause waveform distortion of the output signal. The PVX6012 typical output capacitance graph is as shown below.

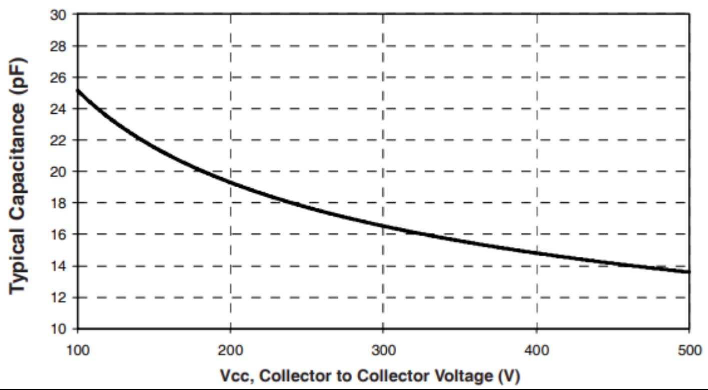


Figure 11 Output capacitance graph of PVX6012

General characteristics

Creepage and clearance

PVX6012 relays are packaged in a modified 14-pin, molded through-hole DIP package. In typical applications, the PVX6012 consumes about 25% of the board volume of a comparable EMR solution. This package helps in easily meeting the creepage distance requirements on the PCB thereby simplifying PCB design.

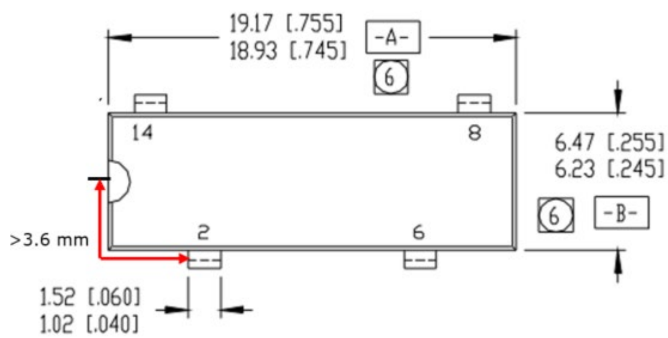


Figure 12 Creepage distance of ~3.5 mm between high voltage and low voltage pins of PVX6012

Minimum dielectric strength, input to output

PVX6012 provides 3750 V_{rms} input-to-output isolation and is recognized by the UL508 component standards (file E88583).

4 Advantages of PVX6012

PVX6012 solid-state relays have the following features and advantages over electromechanical relays of equivalent ratings:

- High-voltage operation – up to 280 V_{rms} AC or 400 V_{DC}
- High load-current switching capability – 1 A at 25 °C or 400 mA at 85°C
- Input-to-output isolation rating of 3750 V_{rms}
- High reliability with extended operational life due to solid-state technology and no moving parts
- Silent operation
- Compact solution
- Faster response time
- Direct logic operation from output of microcontroller without need for external NPN transistor stage
- Lower power consumption due to lower input control current and low on-state conduction losses
- No contact bounce
- Insensitive to normal levels of shock and vibration due to no moving parts
- Insensitive to stray electromagnetic fields (EMFs) and do not generate any electromagnetic interference (EMI) as input-to-output coupling is optical and not magnetic like EMRs
- Positional insensitive and suitable for mounting in vertical or horizontal positions, “dead bug” positions or adjacent mounting
- Do not generate sparks or arcs
- Stable contact resistance over life
- Lower cost-of-use over lifetime of the application due to higher operational lifetime and reliability

5 Application examples

The PVX6012 SSRs can be used in a wide variety of applications. A few typical applications are listed here:

- Industrial controls and automation
- Programmable logic controllers
- Test equipment
- Instrumentation
- Motor control
- Robotics
- Railway signaling
- Security equipment
- Electromechanical relay replacement
- Mercury-wetted reed relay replacement

The figures below show some of the typical application circuits where the PVX6012 can be used:

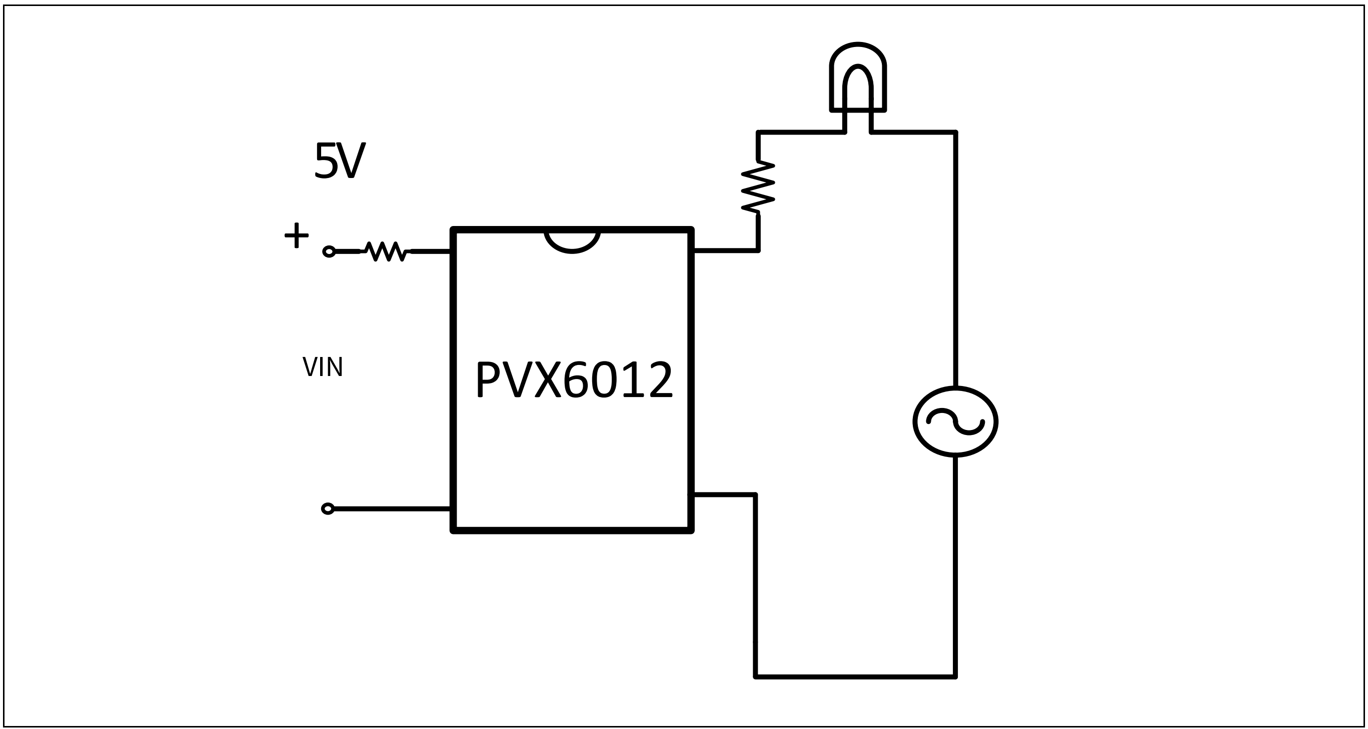


Figure 13 PVX6012 as an AC switch for lamp, light and indicator control in applications such as industrial automation and control and programmable controllers

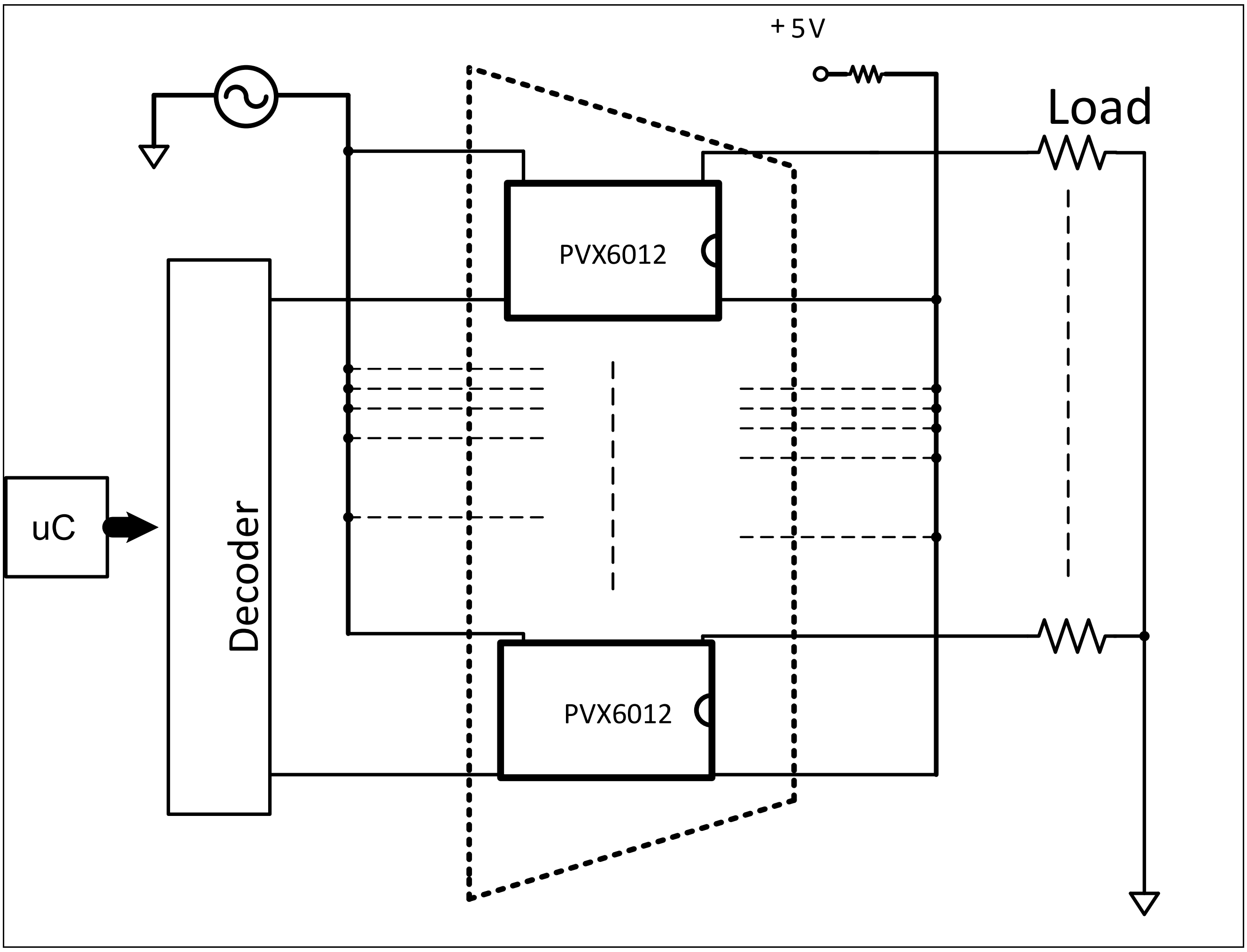


Figure 14 Analog signal multiplexer in applications such as automatic test equipment, instrumentation, data acquisition systems, scanners, etc.

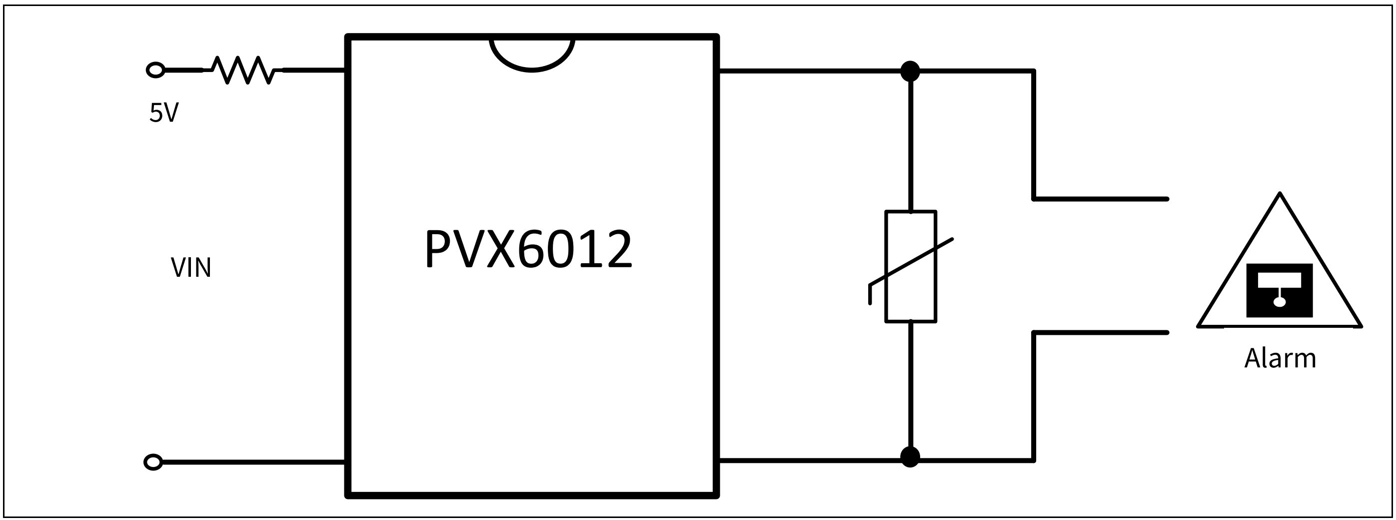


Figure 15 **Alarm switch in security systems and fire or gas alarms**

6 Demo boards

Plug-in demo board options are available to help to quickly evaluate the PVX6012 in different applications. These plug-in boards come with single-ended or double-ended daughter cards, which aid in the drop-in replacement of existing mechanical relays of similar load voltages (280 VAC_{RMS} / 400 VDC max) and load current ratings (1 A max).

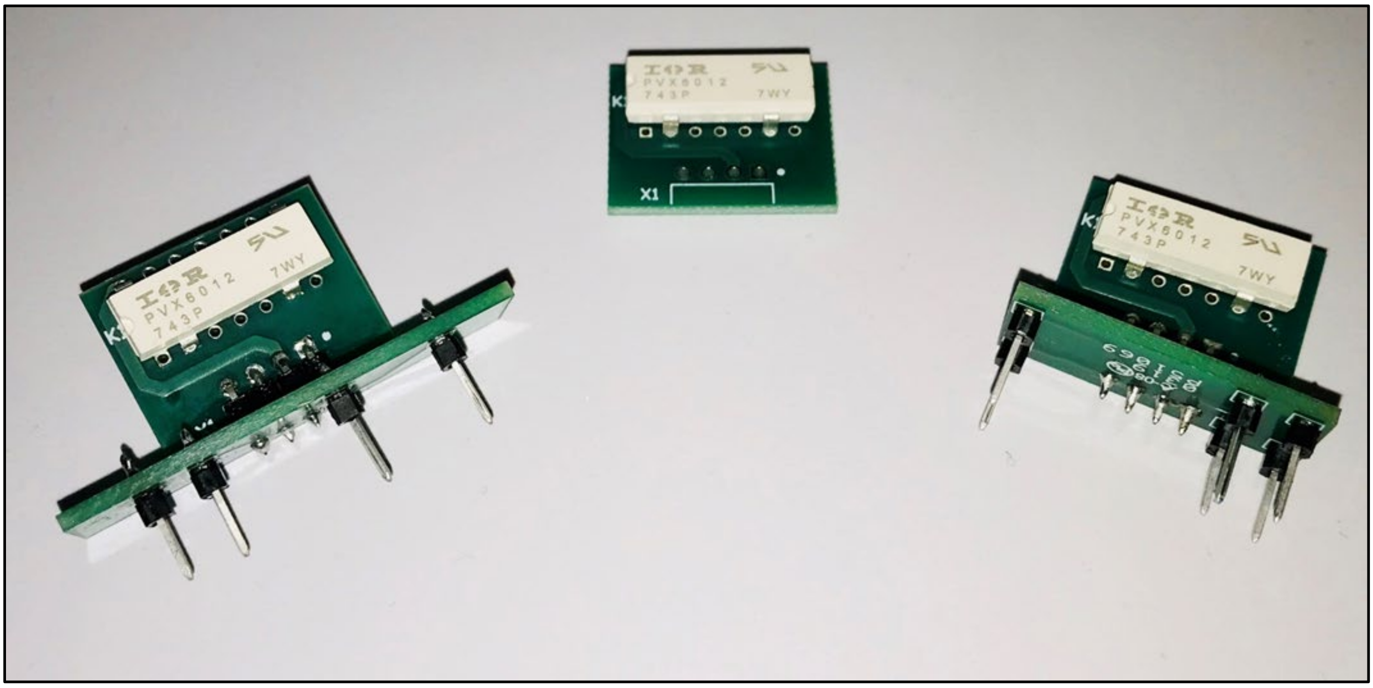


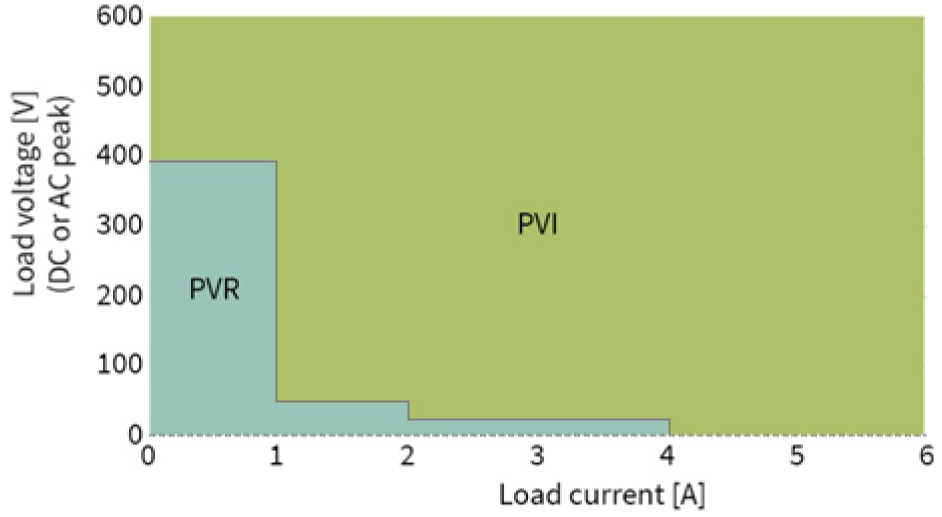
Figure 16 Different plug-in board options available with the PVX6012: single-ended and double-ended relay replacement test boards

7 Summary

This application note describes the internal functionality and key design parameters of the PVX6012. Additionally, it goes over the typical applications and main advantages of PVX6012 over electro-mechanical relays.

8 Additional information

In addition to the PVX6012, Infineon offers other SSRs (also referred to as photovoltaic relays or PVRs) in a wide variety of blocking voltages, and current handling capabilities as shown in the plot below. Infineon also offers photovoltaic isolators (PVIs) that allow designers to use discrete MOSFETs or IGBTs to create custom-made SSRs allowing for an unlimited choice of load current and load voltage depending on the choice of output switch. For further information, please visit our website at: www.infineon.com/ssr.



PVI – Photovoltaic isolators

PVR – Photovoltaic relays

Figure 17 Complete solid-state relay portfolio from Infineon

9 References

[1] The PVI - a New Versatile Circuit Element

[2] The Photo-Voltaic Relay – A new solid state control device

[3] Choosing an Input Resistor for a microelectronic relay

[4] Engineer's Relay Handbook, Fifth Edition, National Association of Relay Manufacturers, Milwaukee, Wisconsin, USA, 1996.

10 Revision history

Document version	Date of release	Description of changes
1.0		Initial release

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