CotoMOS®

Technical & Applications Information

RECOMMENDED PC BOARD PATTERN & PACKAGING (all dimensions in mm)

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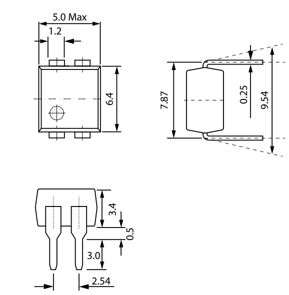
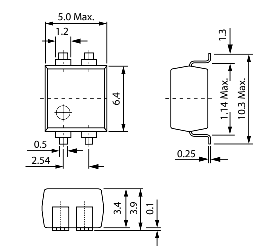
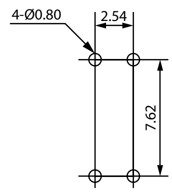
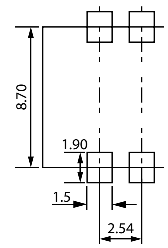
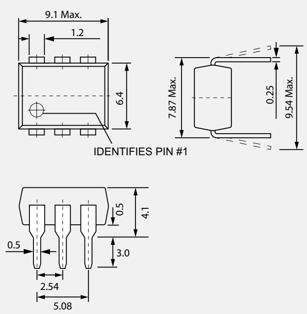
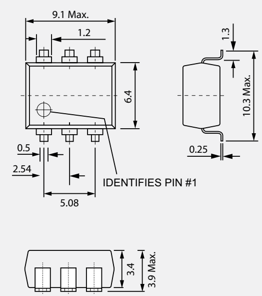
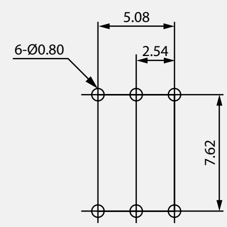
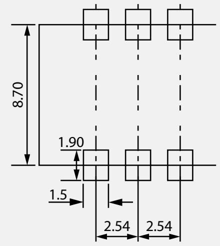
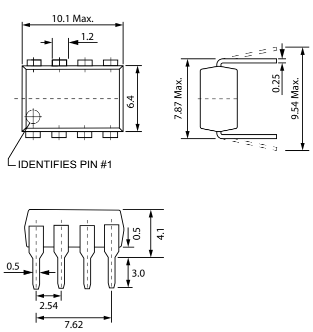
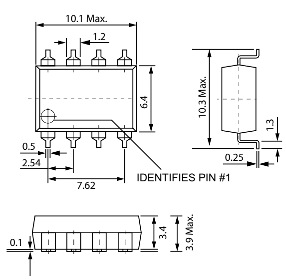
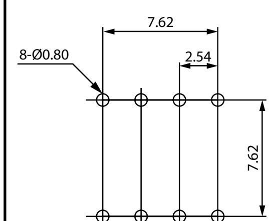
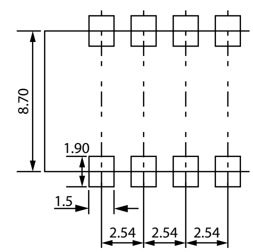
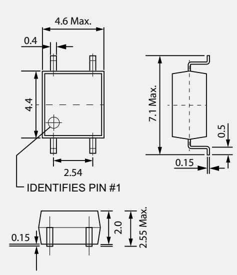
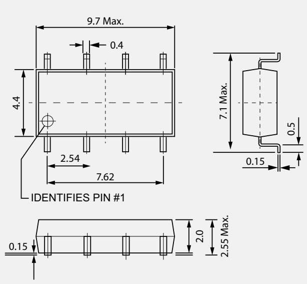
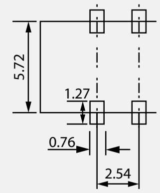
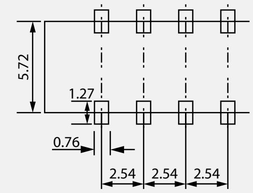
A	DIP 4 	SMD 	DIP 	SMD 
B	DIP 6 	SMD 	DIP 	SMD 
C	DIP 8 	SMD 	DIP 	SMD 
D	SOP 4 	SOP 8 	SOP 4 	SOP 8 

RECOMMENDED PC BOARD PATTERN & PACKAGING (all dimensions in mm)

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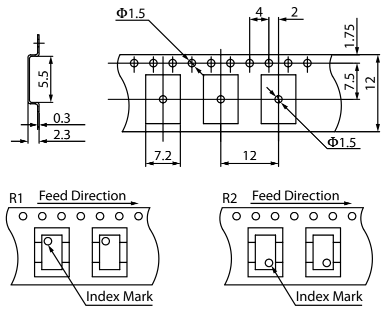
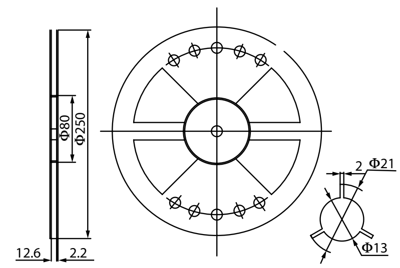
<tr><td>4 Pin SOP</td><td>
</td><td>
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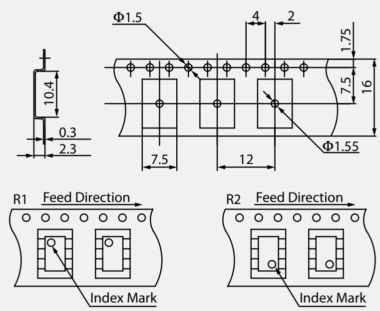
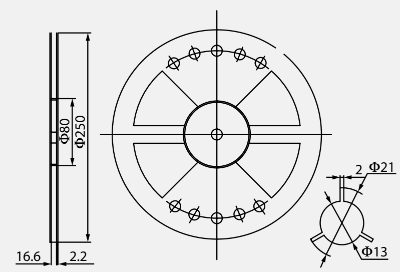
<tr><td>8 Pin SOP</td><td>
</td><td>
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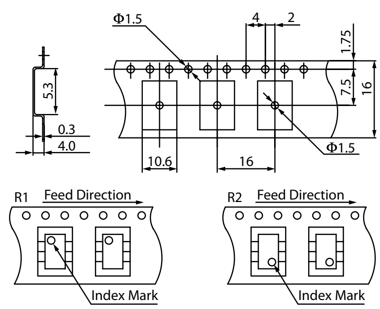
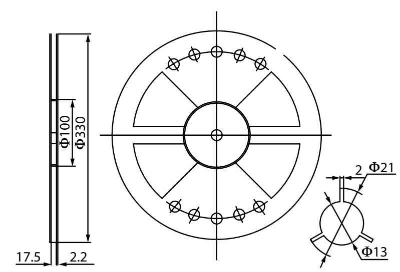
<tr><td>4 Pin SMD</td><td>
</td><td>
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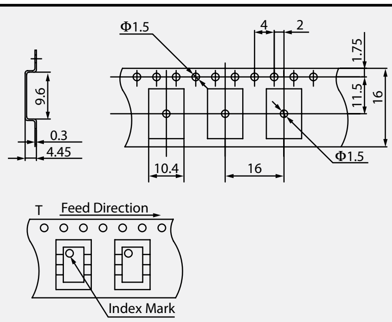
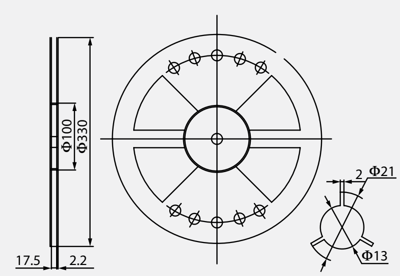
<tr><td>6 Pin SMD</td><td>
</td><td>
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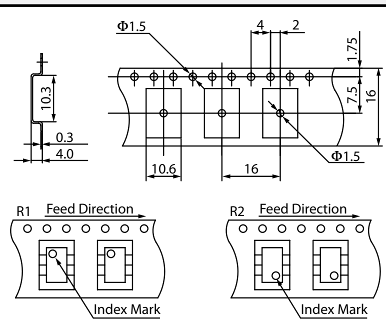
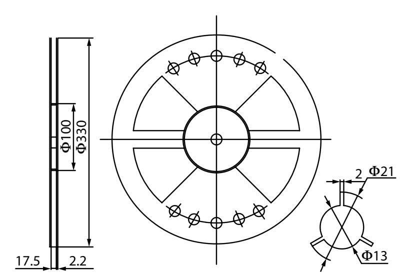
<tr><td>8 Pin SMD</td><td>
</td><td>
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TESTING AND RELIABILITY

The CotoMOS® Series of Solid State Relays are designed with the highest level of quality and reliability in mind. Each model is comprehensively tested and meets the strictest of standards as dictated by many international safety organizations. The CotoMOS® Series Solid State Relays are recognized by the following agencies:

- Underwriters Laboratories (UL) FPQU2.E351594
- Canadian Standards Association (CSA) FPQU8.E351594

ESD INFORMATION

Coto Solid State Relays are tested for ESD susceptibility using two different methods: The Human Body Model (HBM), and the Charged Device Model (CDM).

The HBM is associated with a person who acquires a charge from walking on a carpet, working with plastic, or sitting on an upholstered chair. The charge that is stored on the person's body is discharged through the relay to ground.

The CDM is associated with a charge that is stored on the device itself. The stored energy is then discharged through one pin to ground.

All relays are tested using both methods. The testing is performed in 500V increments up to 2000V. All devices reliably pass both methods of testing. This however, does not mean that the devices are ESD immune. As with all solid state devices, care should still be taken during the handling and use of the devices.

MEAN TIME BETWEEN FAILURES (MTBF) INFORMATION

Mean Time Between Failures (MTBF) is defined as the number of hours of operation a typical device will see before it is expected to become inoperative. The MTBF is typically calculated by testing a representative sample of devices and calculating the average time to failure. Because the CotoMOS® Series is made with solid state components, performing an extended life test is not feasible due to the expected length of time before failure; therefore, MTBF is theoretically calculated. A theoretical MTBF can be calculated by summing the expected MTBF of each individual wire bond and solid state component.

For example: The CT126 has 6 wire bonds, 1 LED, 1 PDA, and 2 MOSFETs. The typical failure rate for wire bonds is 0.000005 per 1000 hours of operation. Each of the four discrete components has a typical failure rate of 0.0001 per 1000 hours. This is a total expected failure rate of 0.00043 per 1000 hours of operation. The MBTF is calculated by dividing the time (1000 hours) by the failure rate (0.00043). This equates to approximately 2.3 million hours between failures.

An additional expression of a device's reliability is the FIT rate (Failure in Time: equal to the number of expected failures in 10^9 hours). This is easily found by using the equation:

$$\text{FIT rate} = 10^9 \div \text{MTBF}$$

The MTBF for all single channel devices is approximately 2.3 million hours @ 25°C (435 FIT's).

The MTBF for all 2-channel, dual channel, and telecom devices is approximately 1.2 million hours @ 25°C (833 FIT's).

(The theoretical information was compiled from *Hybrid Circuit Design and Manufacture*; Roydn Jones)

QUALIFICATION TESTING

Coto Solid State Relays are designed to and meet the highest industry standards as specified by agencies such as Underwriters Laboratories (UL) and Canadian Standards Association (CSA). Before a relay is approved as a standard product, it must first successfully complete a battery of mechanical and electrical qualification tests. These tests audit the relays under various conditions to verify functionality. The following is a list of qualification tests performed on the CotoMOS® Series solid state relays:

- Steady State Life
- Moisture Resistance
- Temperature Cycle
- Temperature Shock
- Solderability
- Solvent Resistance
- Capacitance
- ESD
- Physical Dimensions
- Lead Integrity Bond Strength
- Die Shear Strength
- Flammability and Oxygen Index

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TESTING AND RELIABILITY

PRODUCTION TESTING

In addition to comprehensive qualification testing performed on each model number, each individual relay undergoes 100% parametric testing. As each relay is tested, the results are logged and test reports are generated for each production lot. In addition, Coto compiles test information from several lots over a period of time to track relay quality and reliability, reporting data in several forms including Pareto graphs, histograms, and individual performance details. The following is a list of tests performed on each part:

- LED Forward Voltage V_F
- LED Reverse Current I_R
- On-Resistance Drain to Drain R_{On}
- Off-State Leakage Current I_{Leak}
- Turn On Time T_{On}
- Turn Off Time T_{Off}
- I/O Breakdown Voltage $V_{I/O}$
- Operate Current I_{Fon}
- Release Current I_{OFF}
- Release Voltage V_{OFF}

GLOSSARY OF TERMS

INPUT CHARACTERISTICS	SYM.	
Operation LED Current - Turn on	I_{Fon}	Amount of current required to flow across the input of the relay to guarantee turn-on.
LED Forward Voltage	V_F	Amount of voltage drop as a result of the input LED.
Continuous LED Current	I_F	Current applied to the input of the relay.
LED Reverse Voltage	V_R	Maximum amount of voltage that the input LED can withstand in the reverse biased direction.

OUTPUT CHARACTERISTICS	SYM.	
Switching Voltage	V_L	Maximum steady state load voltage; DC or AC-peak
Switching Current	I_L	Maximum steady state load current; DC or AC-peak
On Resistance Drain to Drain	R_{On}	Contact resistance when the switch is in the closed state
Off State Leakage Current	I_{Off}	Amount of current flow through the switch when the switch is in the open state.
Turn On Time	T_{On}	Amount of time from the application of the input signal to the closure of the switch.
Turn Off Time	T_{Off}	Amount of time from the removal of the input signal to the opening of the switch.
Output Capacitance	C_{Out}	Amount of capacitance across the output of the relay when in the open state.

GENERAL CHARACTERISTICS	SYM.	
I/O Breakdown Voltage	$V_{I/O}$	Breakdown voltage rating between the input and output of the relay
I/O Capacitance		Amount of capacitance between the input and the output of the relay
Total Power Dissipation	P_T	Maximum steady state load power
Operating Temperature	T_{Opt}	Ambient temperature range in which the relay will operate. (See derating curves or call factory to determine performance at specific temperatures.)
Storage Temperature	T_{Stg}	Ambient temperature range to store the relays without permanent damage occurring.
Pin Soldering Temperature	T_S	Maximum allowable temperature for soldering relays into position

MISCELLANEOUS TERMS	
LED:	Light Emitting Diode.
PDA:	Photo Diode Array.
MOSFET:	Metal Oxide Semiconductor Field Effect Transistor.
DIP:	Dual-in-line Package.
SMD:	Surface Mount Device.
SOP:	Small Outline Package

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INPUT CURRENT AND RESISTOR SELECTION

Proper selection of the input current for the solid state relays is vital for ensuring the relay's proper operation over the entire expected operating temperature range. The value of the input resistor, which determines the input current, can be calculated by using the following formula:

$$\frac{V_{cc} - V_F}{R_{IN}} = I_{Fon}$$

Where: V_{CC} = DC supply voltage
V_F = LED Forward Voltage
(See data pages for this value)
R_{IN} = The input resistor value, and
I_{Fon} = Operate LED Current

Several factors go into selecting an input current that best suits a specific application. Three main criteria are the temperature at which the circuit will operate, the required operate time of the relay, and the amount of current available from the power supply.

HIGH TEMPERATURE CONSIDERATIONS

The efficiency of the relay decreases as the temperature increases. Therefore, the ambient temperature plus the expected junction temperature need to be evaluated to make a proper selection. As a general rule, the amount of temperature increase expected at the junction is:

$$T = 100°C \times Watts$$

where T = the temperature rise (in °C) and Watt = the amount of power across the output of the relay. For applications that will see excessive temperatures (>70°C), the recommended input current is 20mA.

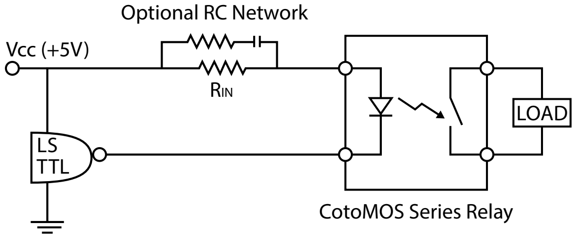
EFFECTS ON SWITCHING TIME

The amount of current applied to the input LED is directly related to the switching time of the MOS FET switch. A higher current at the input can be translated into faster switching at the output. This relationship is more evident in models that do not have current limiting.

MINIMIZING INPUT CURRENT

When current from the power supply is limited, an RC network can be added to the input circuit (See Figure #1) to minimize the current needed to drive the relay. This RC network provides a pulse of current at the time of operate. This current pulse quickly turns the relay on. After the inrush current through the RC network subsides, the quiescent current flow through the input resistor (R_{IN}) sustains the relay in the on position. This RC network can also be used to improve the turn-on time of the relay (as described in previous section). This circuit will not have an effect on the turn-off time of a relay.

Fig. 1: R_{IN} : LED Current Selection Resistor (required) to obtain 5 to 20 mA. Optional RC Network: 1µf capacitor and 180 Ω Resistor



SUMMARY

When selecting the input current, all design variables must be considered. This includes the operating temperature range, the application's required turn-on time, the power supply limitations, the tolerance of the resistors, and the worst case voltage drop of the LED.

AC MODE AND DC MODE

All CotoMOS® Series Single Channel devices have the convenience of being wired for AC operation (AC Mode) or one of three different DC operating configurations (DC Mode). The following is an explanation of the four different modes of operation:

FIG. 1: AC MODE

Connecting the load to be switched between pins 4 and 6 of the SSR will allow for switching of an AC signal or a DC signal in either polarity. The operting parameters for this configuration are noted in the data pages of the specific model numbers under the "AC Mode" headings.

Fig. 1: AC Mode

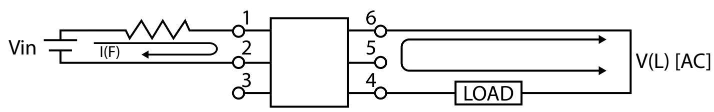


FIG. 2: DC MODE

If the load to be switch is DC and the (+) polarity is always applied to the same pin, the relay can be wire in the DC Mode. In this configuration, the (-) side of the load is connected to pin #5 and the (+) side of the load is connected to pins 4 and 6. The operting parameters for this configuration are noted in the data pages of the specific model numbers under the "DC Mode" headings. Using this configuration, the designer can take advantage of the improved performance: the DC Mode on-resistance is 25% of the AC Mode and the switching current capability is doubled.

Fig. 2: DC Mode

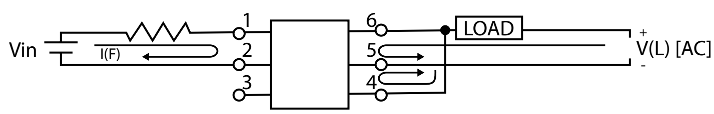
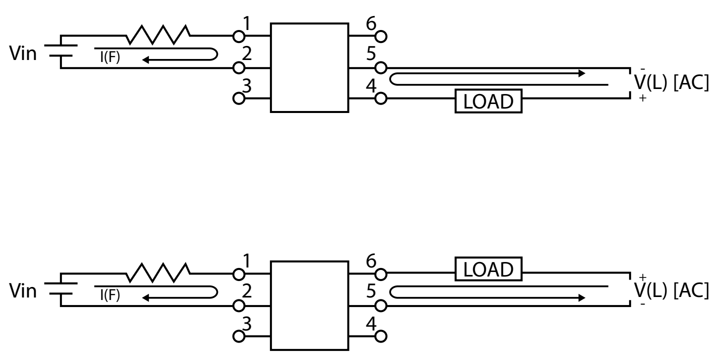


FIG. 3 AND 4: DC MODE MODIFIED

The inherent features of the relay allow the designer to configure the relay as noted in figures 3 and 4. In each case, the (-) side of the load is connected to pin #5 and the (+) side of the load is connected to either pin #4 or pin #6. In either of these cases, the on resistance is 50% of the AC Mode and the allowable switching current increases by about 40%. The relay can also be configured as a two pole device by combining figures #3 and #4. This assumes that the low side of both loads are common to each other.

Fig. 3 and 4: DC Mode Modified



PROTECTING SSR'S FROM OVERVOLTAGE TRANSIENTS

OVERVOLTAGE SUPPRESSION DEVICES

Solid state relays (SSR's) rely on overvoltage suppression devices such as metal oxide varistors (MOVs, Zenor Diodes, Suppresser Diodes) to protect their outputs from voltage extremes such as overvoltage transients. Any voltage that exceeds the SSR's DC or Peak-AC maximum load voltage rating could potentially damage the SSR. A number of overvoltage suppressers, used to protect the SSR against transients, are available. Each type of suppresser has unique inherent characteristics. When choosing an appropriate suppression device, tradeoffs between voltage overshoot, current handling capability, capacitance, leakage current, physical size, surface-mount capability, failure mode, and price need to be considered. Most suppressers can be categorized into one of four groups. The following is a list of the four common suppresser groups and their characteristics.

Zener Diodes: These devices clamp voltages at their reverse avalanche breakdown value. They can be used back-to-back for bi-directional clamping. *Characteristics:* low-voltage overshoot, small size, surface-mount versions available, short-circuit failure mode, inexpensive.

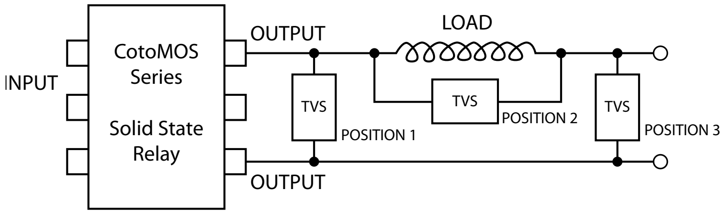
Metal Oxide Varistors (MOVs): The MOV is a voltage dependent variable resistor. The MOVs behave in a similar manner to the back-to-back zener diodes. *Characteristics:* inexpensive, capable of handling large surge currents, surface-mount versions available, short-circuit failure mode, high capacitance, high leakage.

Gas Discharge Tubes: The miniature microgap gas tube clips voltage and then crowbars energy after its sparkover threshold is exceeded. *Characteristics:* capable of handling large surge currents, low capacitance, low leakage current, open failure mode.

Semiconductor Suppressers: These devices are transient suppressers integrating SCR type thyristor and zener functions. These solid-state suppressers clip voltage and then crowbar energy after their zener threshold voltage is achieved. *Characteristics:* low-voltage overshoot, capable of handling large surge currents, low capacitance, low leakage current, short-circuit failure mode, expensive.

SUPPRESSION TECHNIQUES

There are various techniques available to protect an SSR and load from an overvoltage condition. Figure 1 shows an SSR controlling an inductive load. To protect the relay from inductive flyback energy, a transient voltage suppresser (TVS) is placed across the load (Position #2). When the relay turns the load off, flyback energy is shunted across the coil by the TVS, thus eliminating extreme voltage potentials. This TVS will not protect the relay from transients generated from other sources however. To fully protect the relay, a TVS placed across the contacts of the relay (Position #1) is highly recommended. The TVS will protect the relay from any voltage transients when the relay is off.



A third TVS could be added, shunting both the load and the relay (Position #3). This TVS would keep excessive AC source surge currents away from the load and SSR. This technique is commonly used in industrial and telecom applications.

If the load is not inductive, the circuit can be simplified by eliminating the TVS in positions #1 and #2. Also, if extraneous voltage spikes are never expected to exceed the SSR breakdown voltage, a single TVS in position #1 would be sufficient to protect the relay.

SUPPRESSION DEVICE SELECTION

The first selection criteria is whether to use a suppression device that clips the overvoltage and then crowbars the energy, or one that clamps (zeners) an overvoltage. A crowbar device is necessary when the application's typical operating voltage approaches the SSR's maximum load voltage rating. The crowbar protectors pull any transient voltage low keeping the voltage overshoot to a minimum. In contrast, an MOV device typically has overshoot; therefore, the MOV rated breakover voltage should be significantly less than the relays maximum load voltage rating.

Another important difference between a crowbar and a clamp suppresser is impressed voltage. A crowbar protector minimizes power dissipated in the SSR when a fault occurs by becoming a low impedance. If a crowbar protector is placed directly across the SSR's outputs, only a few volts will be across the SSR, thus keeping current flow through the SSR to a minimum. A clamp suppresser, such as an MOV, allows the full clamp voltage across the SSR output. COTO SSRs with current limiting minimize current flow through the SSR when high clamp voltage is present. Care must be taken to ensure that the breakover voltage or clamping voltage of a voltage suppression device never exceeds the SSR breakdown voltage

Other electrical considerations are suppresser capacitance, leakage, and failure mode. The capacitance and leakage of a suppression device may effect the performance of the circuit. The failure mode is important when a TVS becomes damaged during operation. An open failure mode gives the false impression of having protection on the SSR. A short circuit failure mode, however, is easily detected and the SSR never goes unprotected.

GENERAL APPLICATION INFORMATION

TELECOMMUNICATIONS

Solid state relays can be used in several different telecommunications applications including Fax Machines, Modems, PBX, and Central Office switching. In all cases, the requirements are similar: high voltage standoff, high input/output isolation, safety agency certification (UL, CSA, etc.), long life expectancy, and low power consumption. SSRs meet all of these requirements including 5000Vrms I/O isolation on H models.

DATA ACQUISITION / PROCESS CONTROL / INSTRUMENTATION

Solid state relays are ideally suited for many instrumentation and control applications. Their high reliability and long life expectancy make them suitable for many applications where frequent, repeatable switching is required. Coto's solid state relays also have inherently low thermal electromotive force (EMF) voltages generated across their output. This makes them useful for low level data collection applications such as thermocouple scanners.

PCMCIA APPLICATIONS

As electronics devices become increasingly smaller, the demand for relays to meet this requirement increases. Coto's SSRs are available in a low profile package for surface mount applications which must meet strict size constraints. The low profile SOP package has a max height of 2.55mm, which is suitable for PCMCIA applications. See the detailed package drawings on pages 76-77.

SECURITY / GENERAL PURPOSE

Coto solid state relays are completely immune to magnetic and electro-static interference which may impede the proper operation of mechanical relays. This characteristic makes them ideal for applications where false triggering and noise on the signal path are undesirable. In addition, there robust construction and solid state circuitry make them highly resistant to shock and vibration. This ensures a continuous signal in turbulent environments. All of these features make the CotoMOS® series solid state relays ideal for many different security and general purpose applications.

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CURRENT VS. VOLTAGE (IV) CHARACTERISTIC CURVES

Figure 1: Typical IV curve for SSR operating in the AC Mode. (See information regarding AC Mode of Operation on page 82.

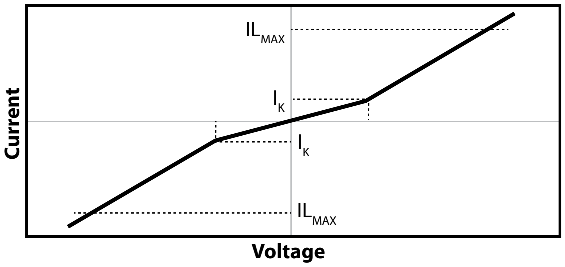
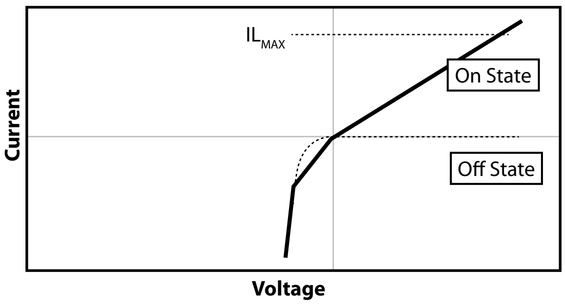


Figure 2: Typical IV curve for SSR operating in the DC Mode. (See information regarding DC Mode of Operation on page 82.



STACKING COTO TECHNOLOGY SOLID STATE RELAYS TO OBTAIN HIGHER SWITCHING VOLTAGES

INTRODUCTION

Standard CotoMOS® solid state relays (SSR) provide switching capability up to 600 VDC/peak AC in 4-pin, 6-pin and 8-pin DIP and SOP packages. Higher switching voltages can be achieved when relays are wired in series (stacked). By adhering to the following recommendations, the SSRs can easily be stacked to achieve switching capabilities into the kilovolt range.

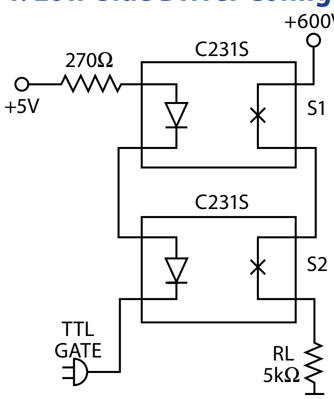
Stacking Relays

Electrical parameters that must be considered when stacking relays are ON-resistance, load voltage, and load current. ON-resistance of the stacked relay becomes the sum of the individual ON-resistances of each relay. Likewise, total load voltage or standoff voltage becomes the sum of the individual load voltages. It is advantageous to choose relays with equivalent load voltages because the relays will equally block the applied voltage. Maximum allowable load current is equivalent to the lowest rated load current of the stacked relays. All of these electrical parameters are important during the dynamic switching and while in the quiescent state. The primary design concern when stacking relays is maintaining a balanced distribution of the load voltage during switching.

Voltage Sharing

Figure 1 shows two C231S relays in a low-side driver configuration.

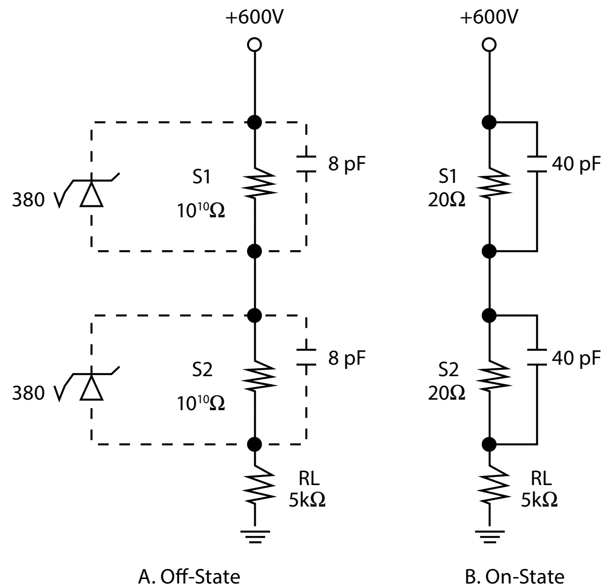
Fig. 1: Low-Side Driver Configuration



The input LEDs are wired in series to obtain simultaneous control from the logic gate. The C231S relay has a rated voltage of 350 V, and when two are stacked they have potential of switching 700V.

Figure 2 (A) depicts a simple electrical model of the relays in the off-state. The 380 V zener diodes represent the avalanche breakdown value of the switches. Compared to the high impedances of the off MOSFET switches, the voltage drop across RL is insignificant and each switch will equally standoff 300 V. Figure 2 (B) shows a simple electrical model with both relays on. Each relay drops 2.4 V, and the remaining 595.2 V is passed on to the load.

Fig. 2: Simple Output Model of Low-Side Driver



Switching: The stacked relay models in Figure 3 will function properly is switches S1 and S2 turn on and off simultaneously; in actuality, this would be an ideal case. Even though Coto SSRs exhibit a tight ton and toff distribution, individual SSRs will still exhibit distinct ton/toff times that need to be considered. Differences in the timing can be minimized (but not entirely eliminated) by increasing LED drive current to approximately 15mA or 20 mA. An extreme case of timing mismatch would be where S1 is fully on while S2 is still off (Figure 3). If this occurs, the full 600 V of power source would be applied directly across S2 and drive it into avalanche breakdown. In this instance, an avalanche current of 120 mA could flow, possibly damaging or destroying the switch. The actually differences in ton and toff will fall somewhere between the ideal and extreme cases. This difference is enough to warrant the use of some form of external conditioning.

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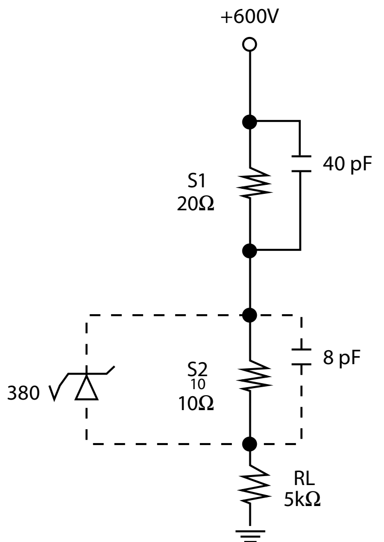
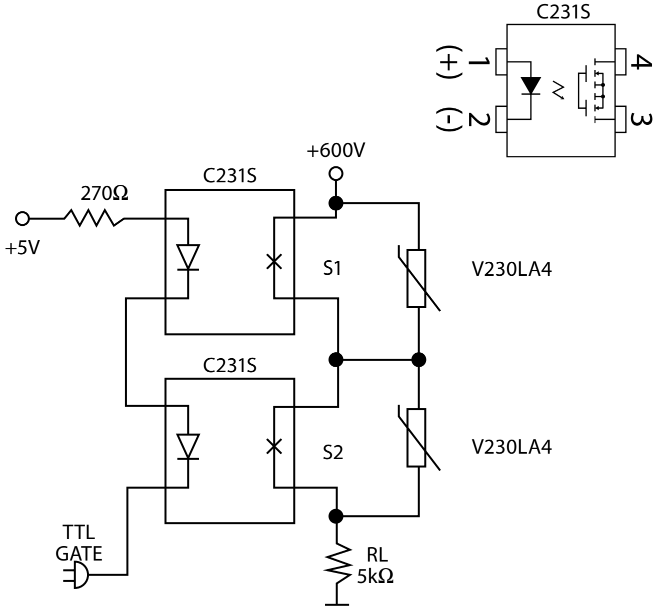
Fig. 3: Simple Output Model of High-Side Driver with Mismatched ton



Voltage Suppression

A method in preventing the SSRs from avalanching is to place a metal oxide varistor (MOV) across the outputs of the relay. A properly selected MOV suppression device will keep the relay from ever exceeding avalanche breakdown. MOV selection is very critical. The maximum standoff voltage of the stacked relay now becomes the sum of the MOV's maximum continuous voltage rating. If the MOV's continuous rating is exceeded, it could conduct substantial current when the stacked relay is supposed to be off. This would create an undesirable leaky operation and eventually destroy the MOV. Also, the SSR's load voltage rating must not be compromised under worst case conditions.

Fig. 4: Low-Side Driver with MOV Protection

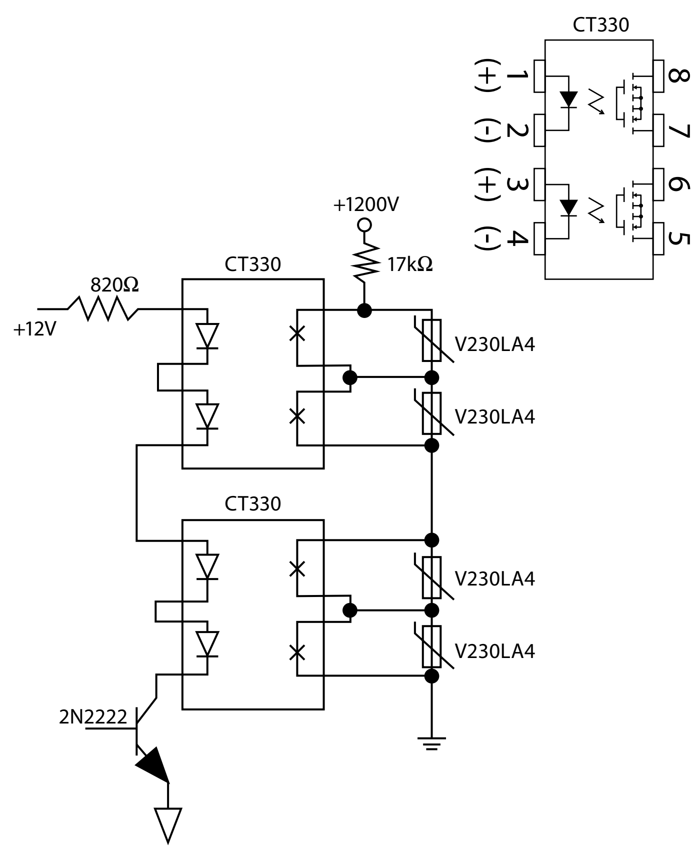


To achieve the 600V switching each MOV must be rated for 300V DC continuous voltage or greater. A Harris Corporation MOV model V230LA4 meets this requirement. Its varistor voltage a 1 mA ranges from 324V to 396 V. To uses this MOV, the load voltage of the individual relays needs to increase to 400 V. To protect against high-current transients that could drive the MOV to even higher varistor clamp voltages, a third SSR may be required. In this case, perhaps a more attractive alternative would be to use a solid-state suppression device. Solid state suppression devices exhibit lower clamp voltage ration values that MOVs. The P3300AA61 Sidactor from Teccor Corp. has a breakover voltage of 330V. This part allows 300 V continuous voltage without exceeding the 350 V load voltage rating of model C231S, even under high-surge current conditions.

A 1200 V Relay

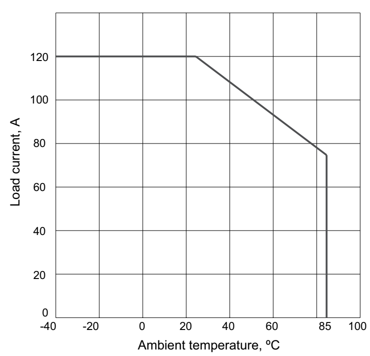
Applying this information, it is very easy to see how a 1200 V relay can be constructed using two CT330 400 V relays. By stacking the outputs of these two relays and using four V230LA4 MOVs (capable of DC operation up to 300 V) for dynamic voltage sharing and protection, we achieve a relay capable of switching 1200 V and 70 mA (see Figure 6). Similarly, even higher voltage and current relays can be created by stacking the desired type and appropriate number of relays.

Fig. 5: A 1200 Low-Side Driver

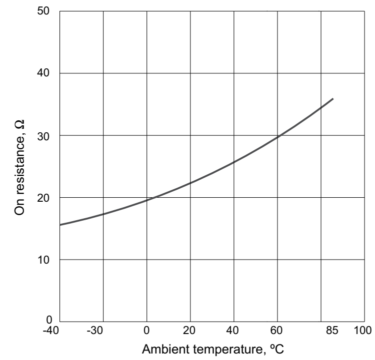


CT130/CS130 GRAPHS

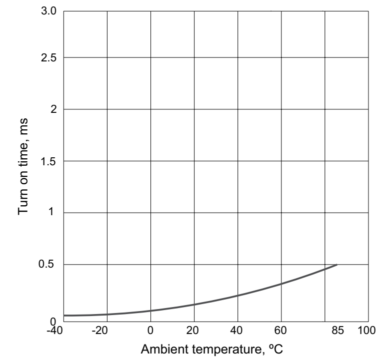
Load current Vs.
Ambient temperature



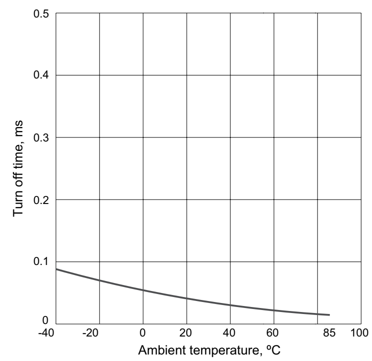
On resistance Vs.
Ambient temperature



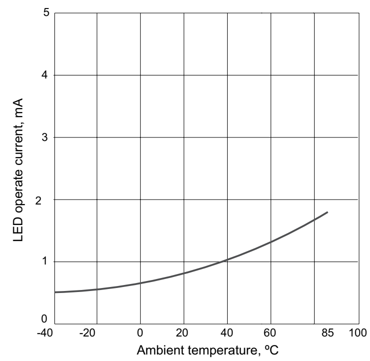
Turn on time Vs.
Ambient temperature



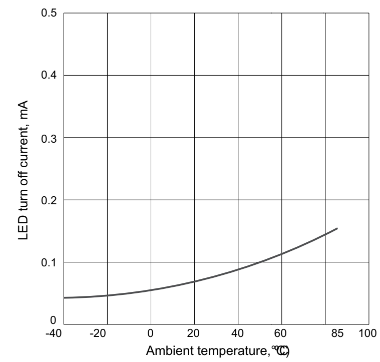
Turn off time Vs.
Ambient temperature



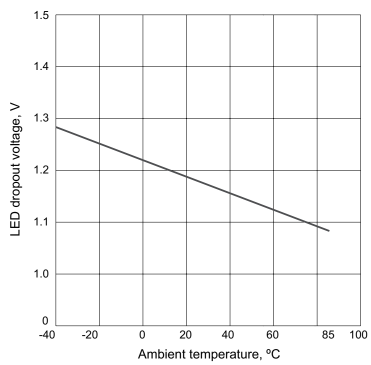
LED operate current Vs.
Ambient temperature



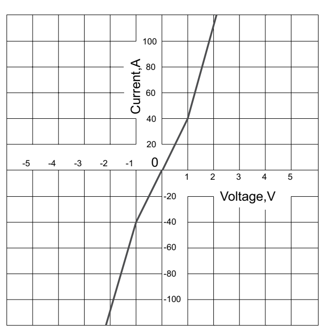
LED Turn off current Vs.
Ambient temperature



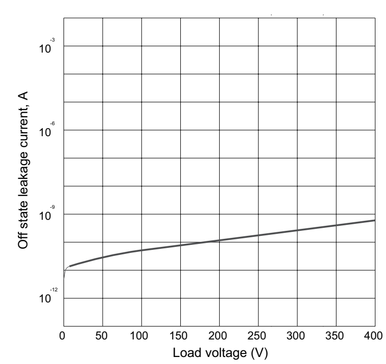
LED forward voltage Vs.
Ambient temperature



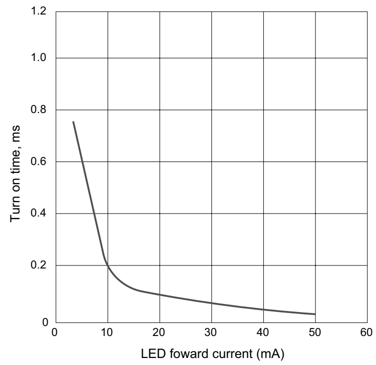
Voltage Vs. current characteristics
of output at MOS portion



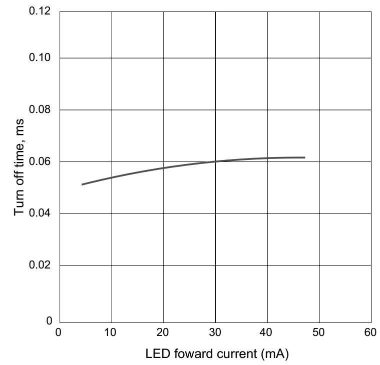
Off state leakage current



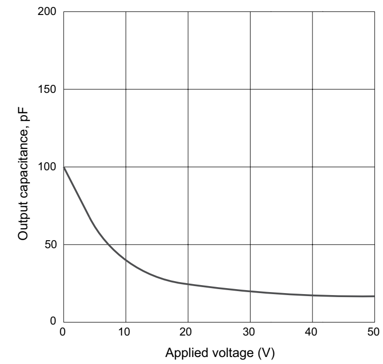
LED foward current Vs.
turn on time characteristics



LED foward current Vs.
turn off time characteristics



Applied voltage Vs.
output capacitance characteristics



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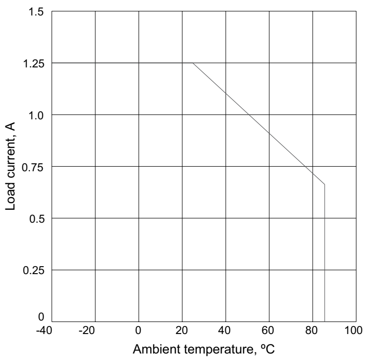
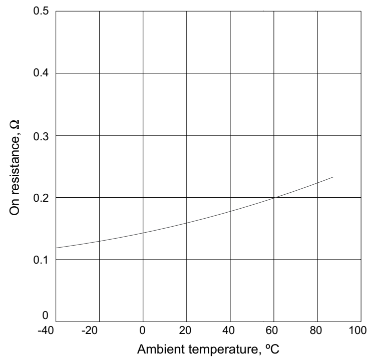
C247S/C347S GRAPHS

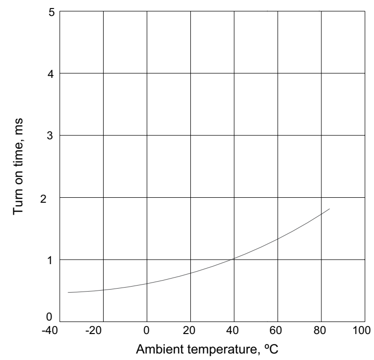
Load current Vs.
Ambient temperature



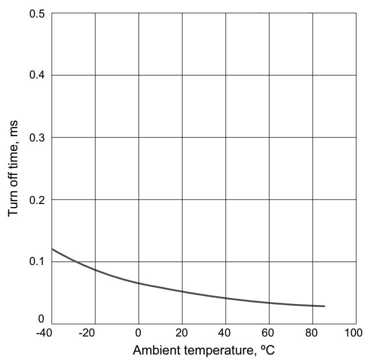
On resistance Vs.
Ambient temperature



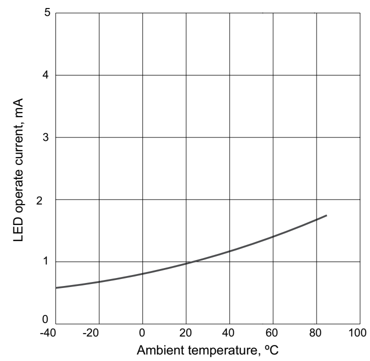
Turn on time Vs.
Ambient temperature



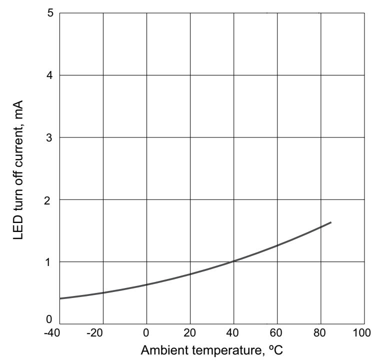
Turn off time Vs.
Ambient temperature



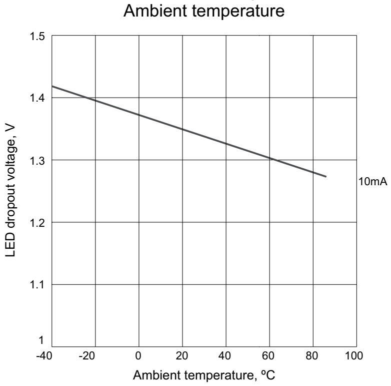
LED operate current Vs.
Ambient temperature



LED Turn off current Vs.
Ambient temperature



LED forward voltage Vs.
Ambient temperature



Voltage Vs. current characteristics
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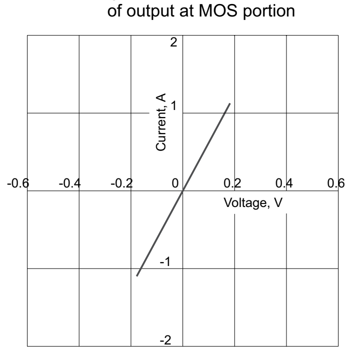
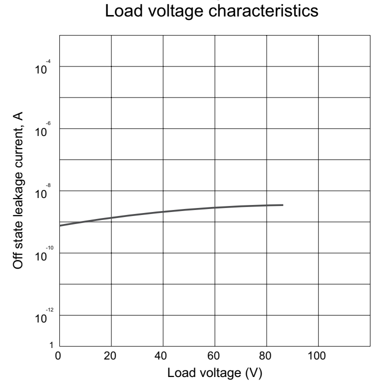
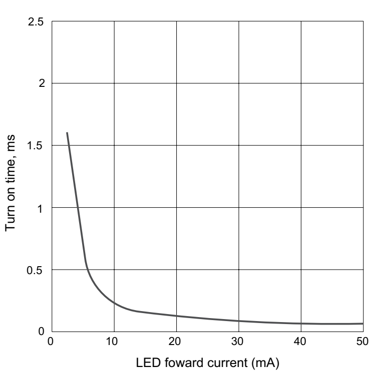


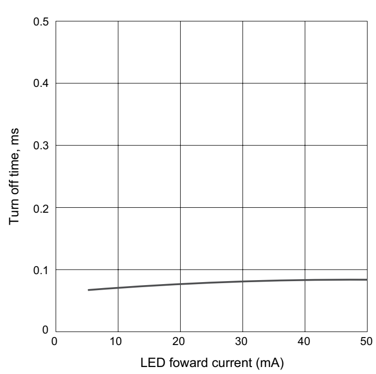
Off state leakage current Vs.
Load voltage characteristics



LED foward current Vs.
turn on time characteristics



LED foward current Vs.
turn off time characteristics



Applied voltage Vs.
output capacitance characteristics