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AND9098/D

Protecting a CCR from ISO 7637-2 Pulse 2A and Reverse Pulses

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APPLICATION NOTE

Introduction

Undesirable voltage spikes can occur in vehicle electrical systems. These transients can cause unprotected devices to exceed their maximum ratings. ON Semiconductor Constant Current Regulators (CCRs) are LED drivers with many automotive applications. This document describes how to keep a CCR from exceeding its maximum reverse and forward voltage ratings. A protection diode can be used to guard against reverse spikes. A resistor-capacitor (RC) network or transient voltage suppression (TVS) diode with an additional resistor can protect against Pulse 2a of the ISO 7637−2 standard.

Typical Transients in Vehicles

Forward and reverse pulses can occur in vehicles due to switching processes and distributed capacitance and inductance of the wiring (Figure 1).

Pulse 2a from ISO 7637−2 is a positive voltage spike (Figure 2). It could occur if a load is disconnected. The resulting change in current leads to a voltage spike due to the inductance of the wiring. Pulse 2a in the worst cases can be a spike of 50 V in addition to a DC source of 14 V or 28 V.

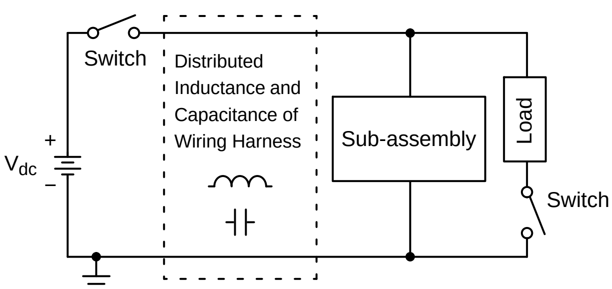

Figure 1. Voltage Spikes can Occur Due to Switching Processes and Distributed Inductance and Capacitance in the Wiring

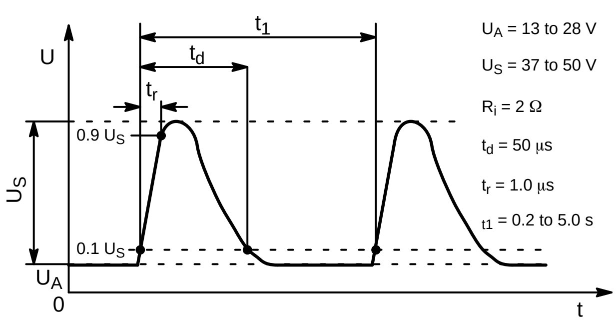

Figure 2. ISO 7637−2 Standard Pulse 2a

About the CCRs

ON Semiconductor CCRs limit the current of any device with which they are in series. The portfolio of CCRs covers a wide range of regulation current levels. Two-terminal CCRs are available as 10 mA, 15 mA, 20 mA, 25 mA, 30 mA, 50 mA, or 350 mA regulation current devices.

Three-terminal CCRs can have their regulation current adjusted via an external resistor. They are made in regulation current ranges of 20 to 40 mA, 35 to 70 mA, 60 to 100 mA, 90 to 160 mA, and 150 to 350 mA. Any of the CCRs may be connected in parallel to provide higher levels of current.

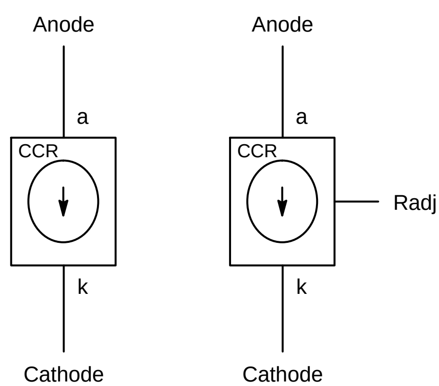

Figure 3. Two and Three-Terminal CCRs

The current through a CCR depends on its anode-cathode voltage (V_{ak}). It will conduct starting from 0 V_{ak} and be near full regulation current at 1.8 V_{ak}. The rated maximum V_{ak} of a CCR is 45 V_{ak}, 50 V_{ak}, or 120 V_{ak}, depending on the particular CCR. All CCRs have a reverse maximum rating of −0.5 V_{ak}. Supplementary circuitry can be used to keep a CCR from exceeding these reverse and forward maximums. CCRs with 120 V_{ak} maximum ratings do not require protection against Pulse 2a.

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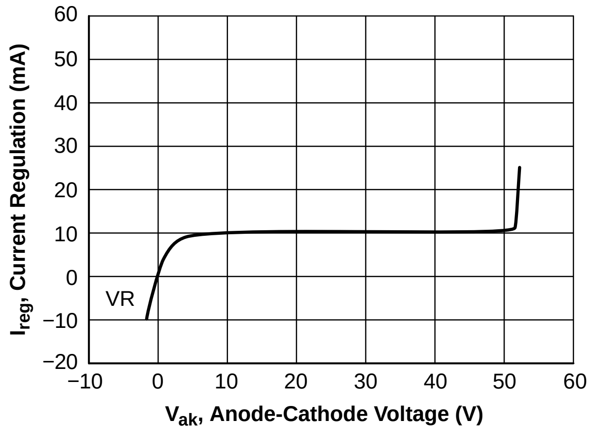

Figure 4. Typical I−V Characteristic of a CCR

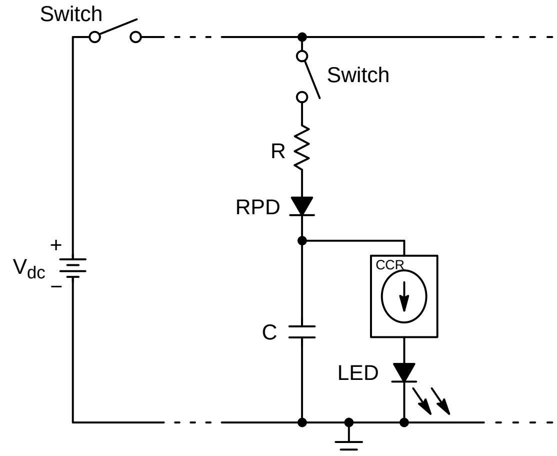

Figure 5. CCR + LED Circuit in Protective Network. Note Placement of R, RPD, and C

Supplementary Protective Circuitry

See Figures 5 and 8 for proper placement of a reverse protection diode (RPD) in a CCR circuit. The ON Semiconductor SURA8160T3G is a good choice for this application. It drops less than 1.0 V in normal operation and has a maximum reverse voltage rating of 600 V.

One way to protect against Pulse 2a is to place the CCR + LED string in an RC network as shown in Figure 5. During normal DC operation, no current will flow through the capacitor. Pulse 2a is a fast-rising voltage spike. Since capacitor current is proportional to change in voltage, the capacitor will have very low impedance during the spike. The voltage will be divided between the resistor and the capacitor.

Capacitors in this application should have ratings of 50 V or higher. The product of the values of the resistor and capacitor needs to be large enough to keep the CCR from exceeding its maximum forward V_{ak} during Pulse 2a. Multiplying ohms and farads gives the time constant in seconds: R x C = τ. Table 1 provides these minimum R × C values for 12 V and 24 V systems. Figures 6 and 7 are oscilloscope screenshots of circuits using these minimum resistor and capacitor values.

Table 1. MINIMUM R X C VALUES TO PROTECT AGAINST PULSE 2a

Electrical System	Minimum R × C = τ Value
12 V	3 μs
24 V	30 μs

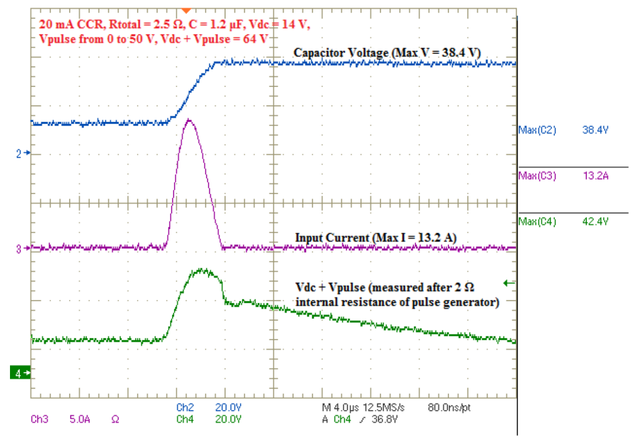

Figure 6. An RC Combination of 3 μs is Sufficient to Protect Against Pulse 2a with 14 V_{dc} + 50 V_{pulse}. The CCR + LED String has 38.4 V Across it at the Peak of Pulse 2a

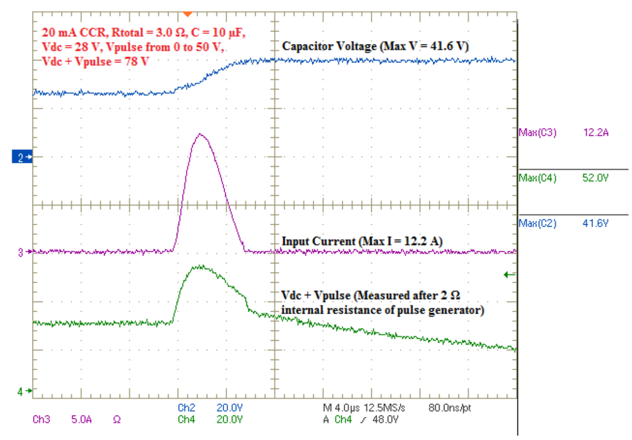

Figure 7. For Pulse 2a with 28 V_{dc} + 50 V_{pulse}, an RC Combination of at Least 30 μs is Recommended

A TVS diode such as the ON Semiconductor 1SMB36AT3G can be used in lieu of a capacitor (Figure 8). The TVS diode acts like a short when the voltage across it is high enough. A resistor of at least 3 Ω must be placed in the circuit as shown in Figure 8. The resistor is necessary so that the total input voltage can be divided between the resistor and the TVS diode. Figure 9 is an oscilloscope screenshot of the TVS circuit subjected to Pulse 2a.

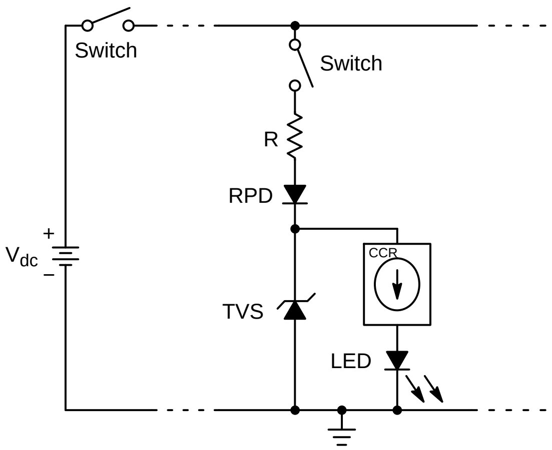

Figure 8. CCR + LED String in Protective Network. Note Placement of R, RPD, and TVS Diode

The resistor in either the RC or the TVS circuit should be chosen carefully. Its value should be small enough not to drop excessive voltage. The relevant equation is $V_{dc} = V_R + V_{RPD} + V_{ak} + V_{LEDs}$. If too much voltage is dropped across the resistor, then there will not be enough voltage available for the CCR + LED string. The resistor must be capable of withstanding the steady state power it will see in normal use as well as the energy of Pulse 2a. Since $P = V^2 / R$, higher resistance values will correspond to lower power on the resistor during transients.

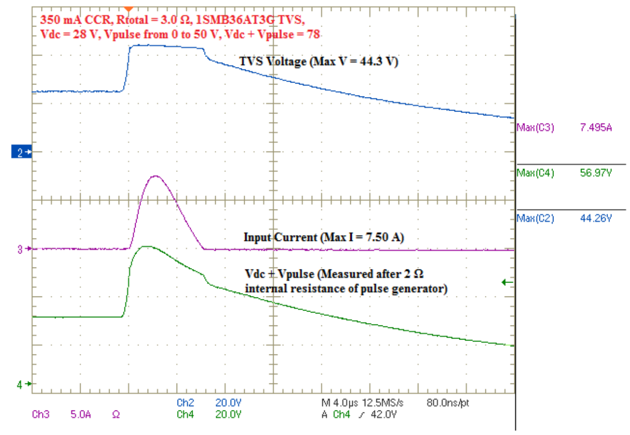

Figure 9. The ON Semiconductor 1SMB36AT3G TVS Diode is Ideal for Protecting Against Pulse 2a

Conclusion

Simple circuitry can be implemented to keep an ON Semiconductor CCR from exceeding its maximum anode-cathode voltage ratings. A protection diode can be used to protect against negative transients. Pulse 2a of the ISO 7637−2 standard can be guarded against by using an RC filter or a TVS diode with an additional resistor.

References

[1] AND8828/D, “Identification of Transient Voltage Noise Sources,” Jim Lepkowski. ON Semiconductor. http://www.onsemi.com/pub_link/Collateral/AND8228−D.PDF

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