

Designing for Isolated DC/DC Converter Shunt Safety



Ron Michallick

Did you know that your shunt regulator is in danger? No? Don't worry – the fix is free. Free is good.

A very common feedback circuit used in isolated DC-to-DC converter applications uses a [shunt regulator](#) such as the [ATL431](#) and an optical isolator to feed back the output voltage to the [Pulse-Width-Modulator \(PWM\)](#) controller. This circuit is effective and easy to use. However, few are aware of the hidden electrostatic discharge (ESD)/electrical overstress (EOS) danger.

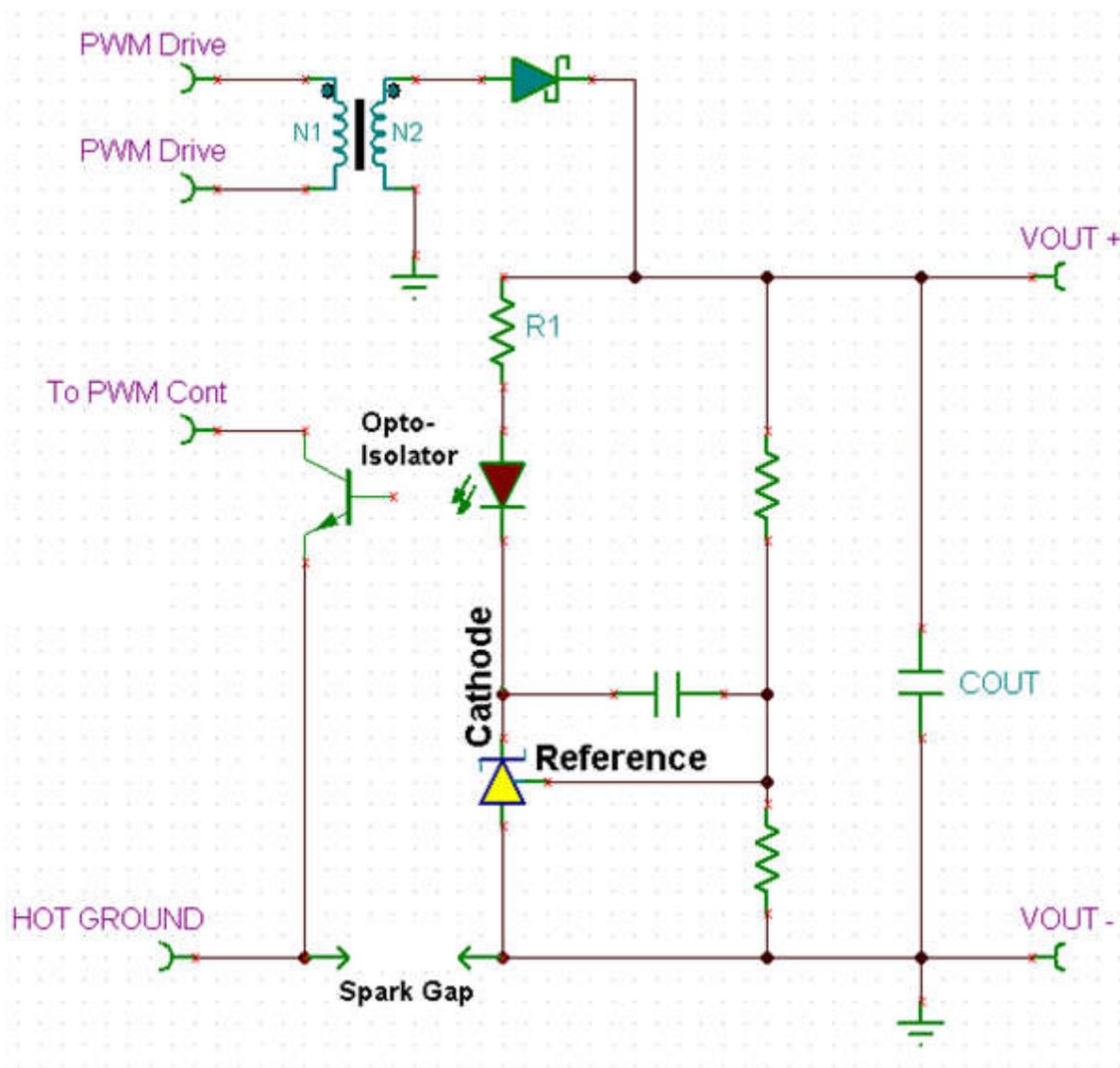


Figure 1-1. Simplified Circuit

At first glance, the shunt regulator in Figure 1-1 seems immune to EOS. An overvoltage on V_{OUT} will cause the cathode voltage to drop and the reference pin will not rise due to the internal diode from the reference pin to the cathode pin. The series resistors will protect the shunt by limiting the current on both the reference and cathode pins. A negative voltage V_{OUT} will not hurt the shunt due to the rectifier clamping the voltage and the series resistors limiting current to the shunt.

However, the shunt regulator can be damaged if the voltage across the isolation becomes too high during an ESD event. The weakest point in the isolation is usually the optical-isolator leads.

Once the optical-isolator gap is breached, the easiest path for ESD discharge will be through the shunt regulator as shown by red line in Figure 1-2.

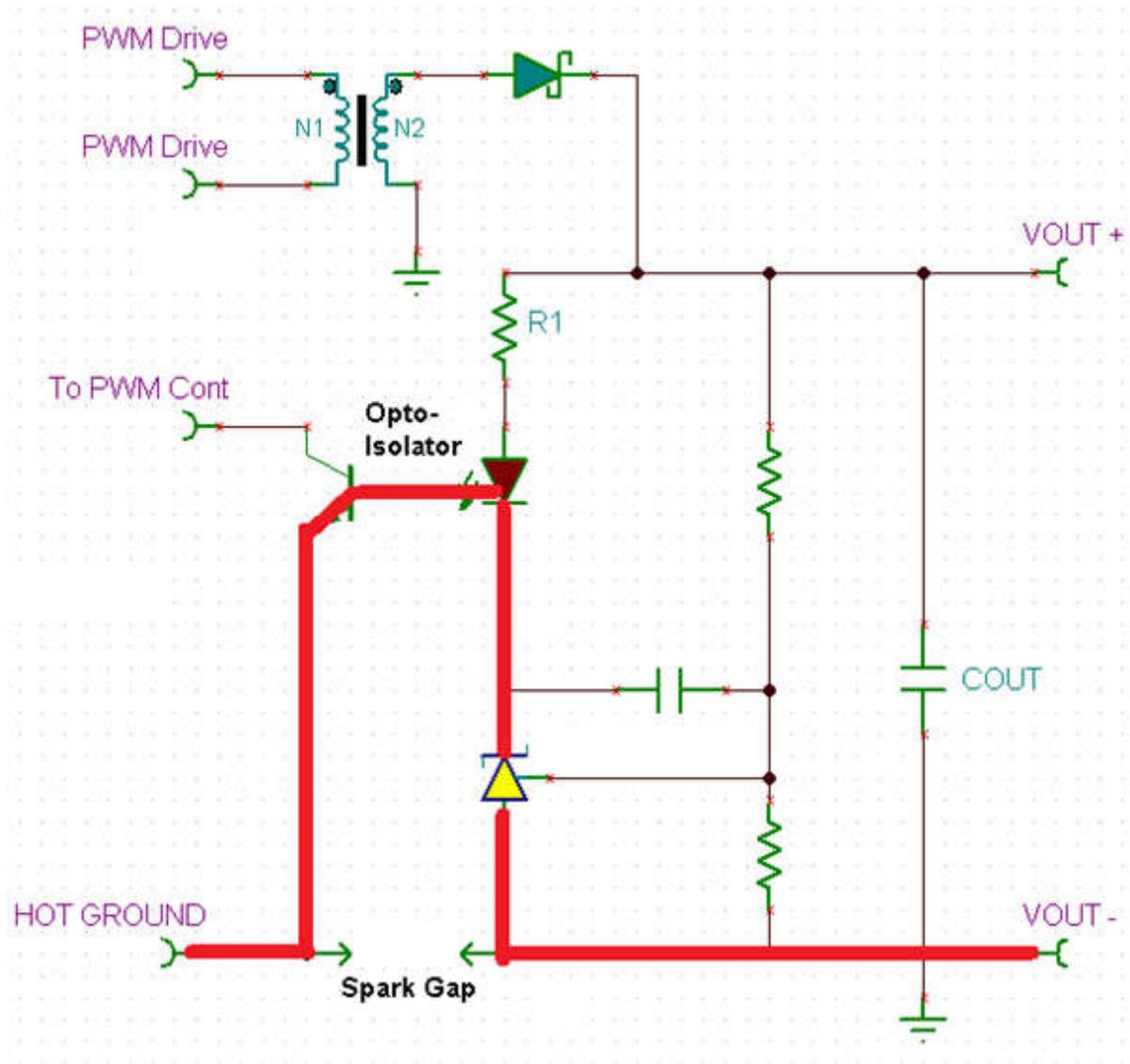


Figure 1-2. The Red Line Is the ESD Path, with an Electric Arc across Optical-isolator Leads

Moving the resistor, R1, from the anode of the optical isolator to the cathode side will protect the shunt during an isolation breach. Moving the resistor has no impact on performance or stability. It works because the optical-isolator breach will now prefer the output capacitor as a path to ground. The red line in Figure 1-3 shows the new ESD path.

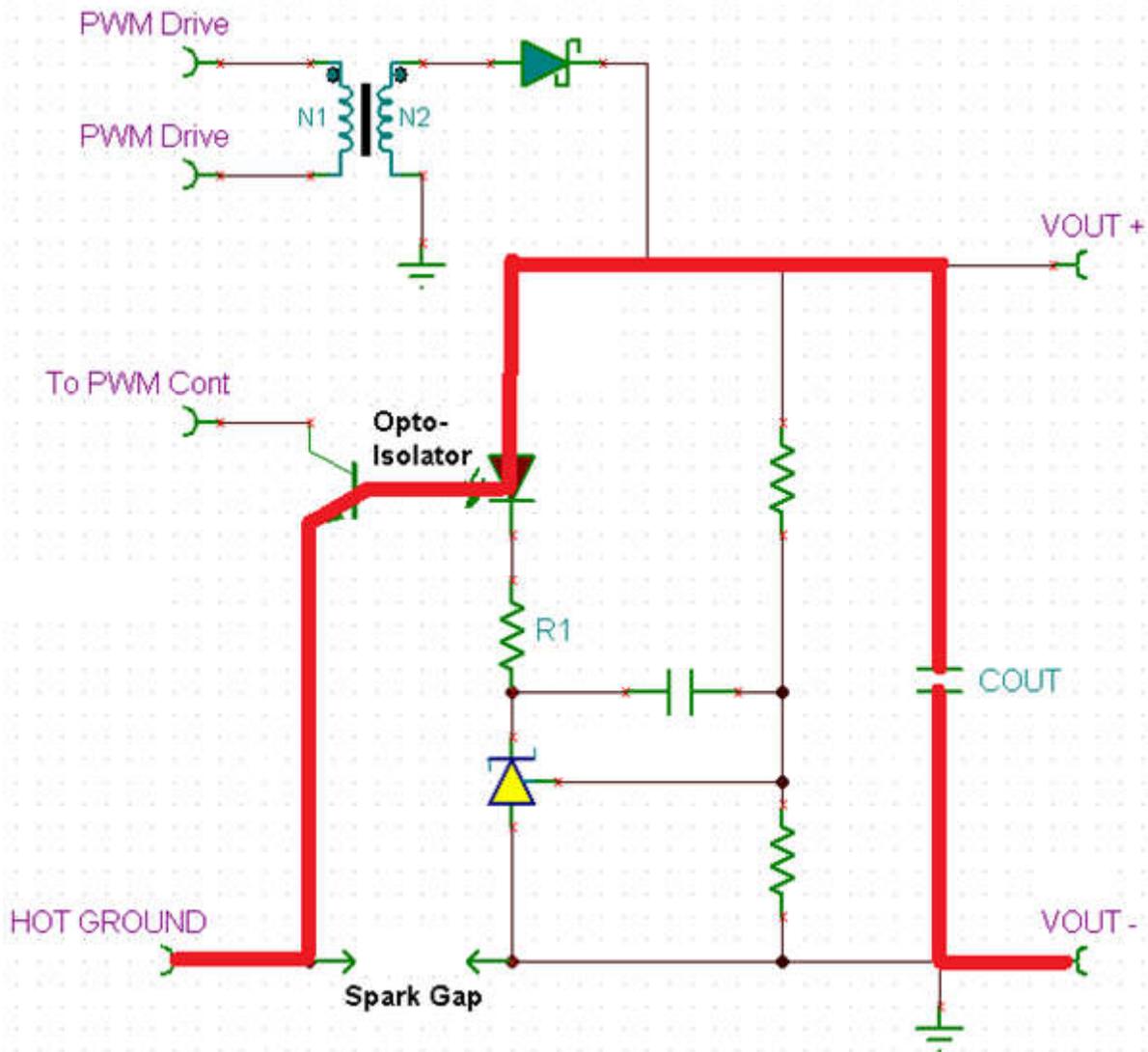


Figure 1-3. The Red Line Is the New ESD Path, with an Electric Arc across Optical-isolator Leads

Now that the shunt regulator is no longer in the primary ESD path, it will survive. The capacitor now takes the current, but it will tolerate much higher ESD energies than the shunt regulator can survive. Depending on which pins on the optical isolator pass the electric arc, there will still be significant danger to the PWM controller and some danger to the optical isolator itself.

Another danger can occur in space-constrained designs. If the shunt or its node traces are placed too close to the isolated (hot ground) traces, there's a chance that an electric arc can occur directly to the shunt or its circuit traces as seen in [Figure 1-4](#). In this case, moving resistor R1 will not protect the shunt. The solution here is to rotate the shunt so that the anode (ground) is the closest node to the traces on the other side of the isolation gap.

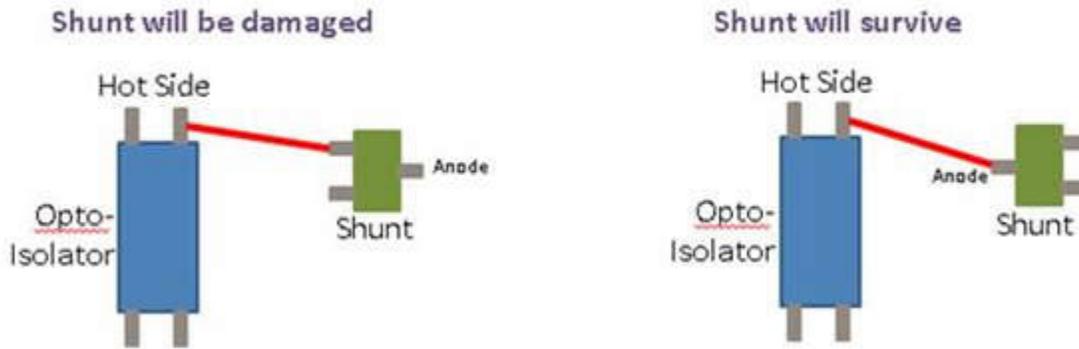


Figure 1-4. Layout Matters. the Red Line Represents an Electric Arc.

For additional protection, you can add an intentional spark gap to cause an ESD event to arc from the ground of one side to the ground of the other side. The spark gap will need a substantially lower breakdown to ensure that the arc doesn't choose an alternate place to cross. It is clear from [Figure 1-5](#) that an arc across a spark gap will not stress the components.

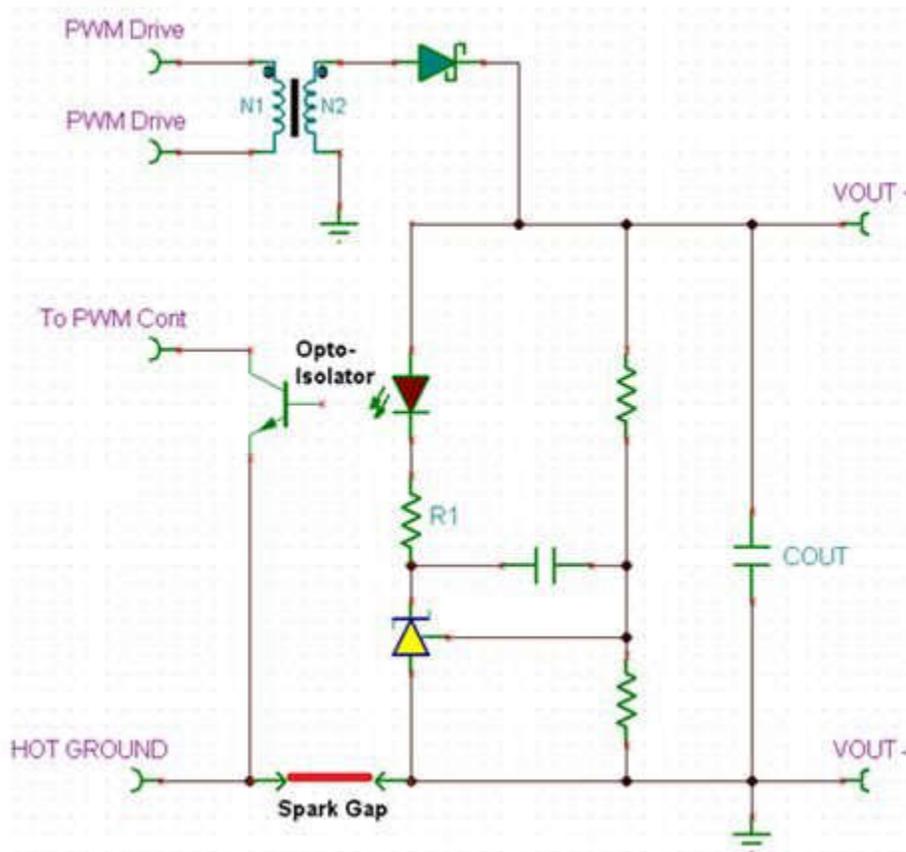


Figure 1-5. Spark Gap Protection Components; the Red Line Represents an Electric Arc

So as you can see, simple changes can greatly improve ESD performance – and as promised, these changes are free. You can apply the feedback safety circuit discussed in this blog to all common-anode adjustable-shunt regulators, including TI's [ATL431/2](#), [TL431/2](#) and [TLVH431](#).

In the next [blog on voltage references](#), Zachary Richards will explain how to create a low component count current sink.

Additional Resources

- Get more information about TI's [voltage reference products](#).
- See other blogs about [power voltage references](#).
- Download the “[Voltage Reference Selection Basics](#)” white paper for a detailed explanation of voltage-reference selection with respect to analog-to-digital converter (ADC) resolution.
- Read Tler Chris Dean's article, “Shunt vs. series: [How to select a voltage reference topology](#).”
- Read TI's Precision Hub blog series, “[Understanding Voltage References](#),” which discusses the applications of both shunt and series references and when to use them.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated