APPLICATION BRIEF

Protecting Against Unintentional AC Power Cross on 12 Vdc Controllers

Introduction

Various types of 12 Vdc controllers are used in multiple applications that compare a sensor signal with a set point and perform calculations according to the deviation between those values. For this application brief, Bourns tested a temperature controller as an example for issues that can arise during setup or from other operational parameters.

Potential Problems

1. A controller is meant to be powered by 12 Vdc, but a field technician may accidentally connect between a 12 Vdc and 120 Vac power line. If the controller (Figure 1) is connected directly to 120 Vac, then the unit will be damaged, absent proper protection.
2. Protection is required for incorrect polarity connections.
3. Protection is required if incorrect rated power supplies are used.

The Bourns Solution

To prevent damage to a 12 Vdc temperature controller from unintentional AC power cross situations, it is highly recommended to include a protection solution in the design. Bourns has tested the combined solution shown in Figure 2 that includes an MOV, a TBU® HSP device and a TVS diode to provide maximum protection against damage. Compared to typical protection methods that only protect against transient overvoltage threats, the Bourns solution also provides protection against unintentional 120 V AC power cross.

Figure 1: 12 Vdc temperature controller

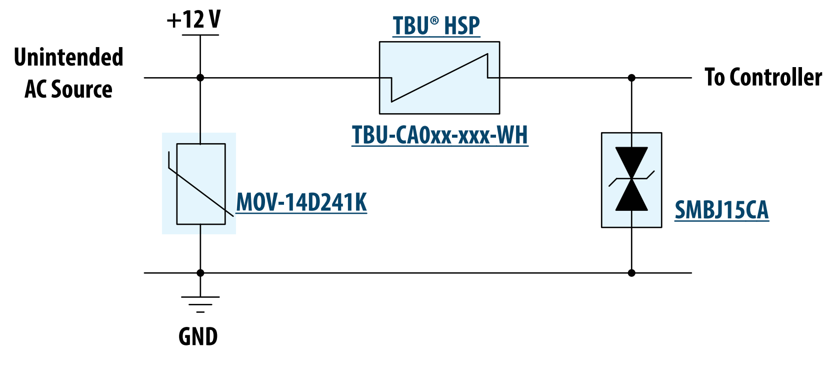

Figure 2: Unintentional 120 Vac power cross schematic

Qty.	Component Description	Part Number & Data Sheet Link	Distributor Inventory
1	Metal Oxide Varistor (MOV)	MOV-14D241K	Check Inventory
1	TBU® High-Speed Protector	TBU-CA Series	Check Inventory
1	TVS Diode	SMBJ15CA	Check Inventory

- Always make sure that the traces have enough clearance.
- TVS diode minimum reverse working voltage must be higher than the controller maximum operating voltage.

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Solution for Unintentional AC Voltage Input

When AC voltage is applied to the input of the circuit as shown in Figure 2, the voltage will rise from 0 V to 120 Vac. Once it exceeds the 15 Vdc rating of the TVS diode, the diode will start to clamp. Current will then start to flow. As soon as the current exceeds 500 mA, the TBU® HSP device will go into its high impedance blocking mode in less than 1 µs. At this point, no current will be flowing into the controller, and it will not power up, which indicates to the user that the controller has no power.

When installed correctly at 12 Vdc, the controller will power-up as usual. During the initial power-up there will be an inrush current that is typically around 1 amp peak (see Figure 3), causing the TBU® HSP to enter its blocking state again. Once the inrush current has settled, the operating current of this controller will be around 10 mA. At this point, since this TBU® HSP has a V_{reset} of 14 Vdc while the system supply is only 12 Vdc, the TBU® HSP will quickly reset after the inrush current. The blocking and reset functions are very quick. Therefore, the inrush current limiting only occurs at the beginning of the start-up.

An important consideration with this circuit is that while the controller is drawing about 10 mA of current during operation, the TBU® HSP with V_{imp} of 850 V has approximately a 10.7 ohm impedance (Rdevice), which adds about 1.07 mW of power loss. For a controller running 100 mA or more, a TBU® HSP with a lower V_{imp} can be used which has lower R_{device} and, in turn, lower power loss. A TBU® HSP with a V_{imp} of 650 V_{pk} has an impedance of about 7 ohms while one with a Vimp of 500 Vpk has an impedance of 5 ohms, making the power loss only 70 mW or 50 mW, respectively.

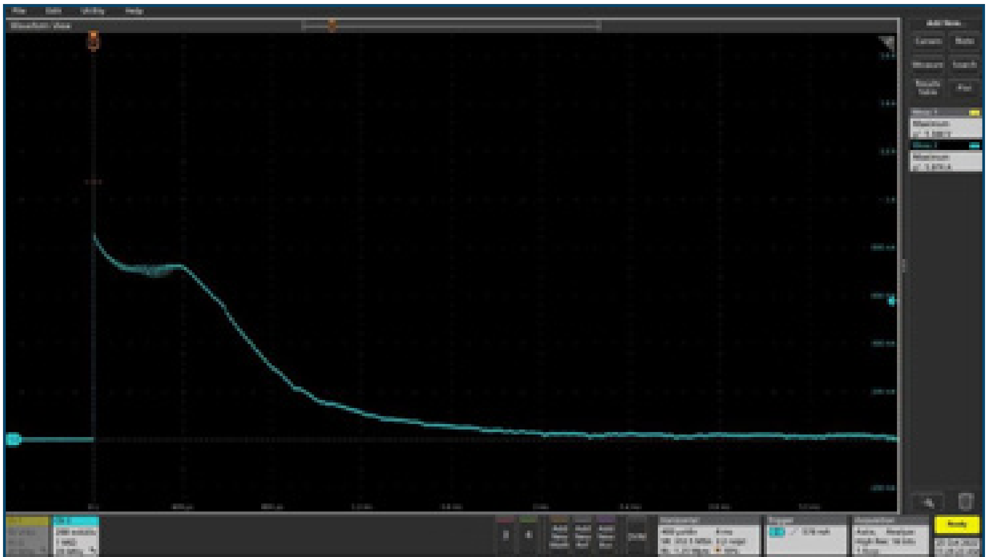

Figure 3: Inrush startup current

The peak impulse withstand voltage is shown as V_{imp}. If this circuit is connected to a protected power supply within a short distance, it is possible that the V_{imp} may not be an issue and a TBU® HSP with a lower V_{imp} could potentially be used. The protected power supply acts as the primary surge protector and most power supplies have a large capacitor value which dampens any overvoltage before it arrives at the TBU® HSP.

The MOV component placed in series before the TBU® HSP will clamp the impulse to prevent it from going above the V_{imp}. Since an MOV's clamping voltage rises with surge current, selecting the right MOV is critical. If the circuit is already behind a protected power supply, then an MOV may not be required.

The TBU® HSP's V_{imp} value determines the voltage level it can withstand during an overvoltage event. A 14 mm MOV has a typical maximum peak current at 4.5 kA. A larger MOV series can be used if a higher transient current rating is required.

Part Number	V_{imp}	R_{device} Typical (Ohms)	Power Loss @ 10 mA (Milliwatts)	Power Loss @ 100 mA (Milliwatts)
TBU-CA050-xxx-WH	500	5.0	5	50
TBU-CA065-xxx-WH	650	7.0	7	70
TBU-CA085-xxx-WH	850	10.7	10.7	107

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Solution for Incorrect Polarity Connection

If the circuit needs to be protected from incorrect polarity, a diode bridge may be installed as shown in Figure 4.

In Figure 5, it is assumed that the +12 Vdc was incorrectly connected. The positive polarity flows are shown with the dotted line, and the solution provides protection for both polarities.

Solution for Incorrectly Rated Power Supply

Both circuits in Figure 1 and Figure 4 will protect from connecting to an incorrect power supply that is above 15 Vdc. Whenever the input voltage exceeds 15 Vdc, the same operations function as described above.

Conclusion

The combination of a TBU® HSP and a TVS diode and/or diode bridge component can protect against all three problems listed above by clamping the transient voltage, blocking the overcurrent, and resetting once the fault subsides. These components work together as a simple yet effective solution offered by Bourns.

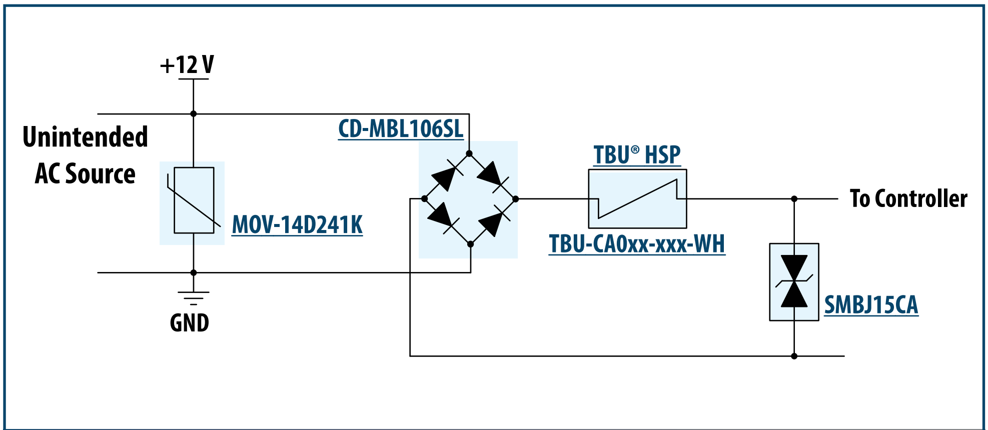

Figure 4: . Incorrect polarity connection protection solution with diode bridge

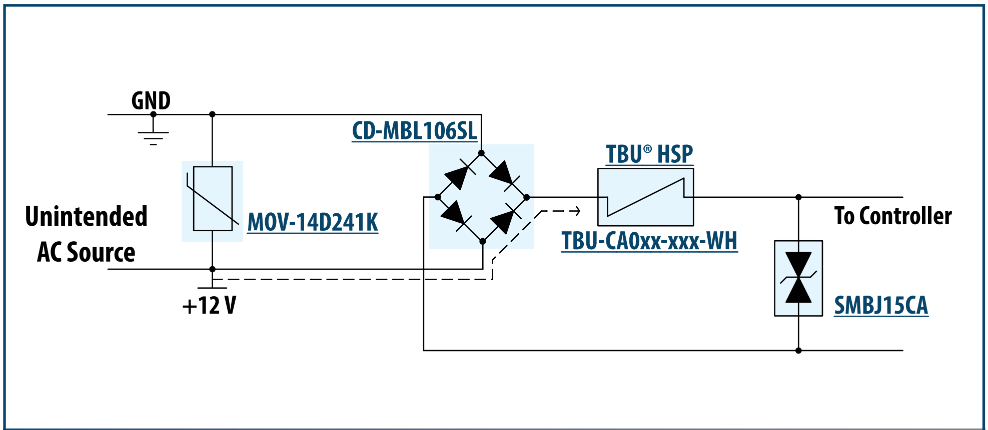

Figure 5: Illustrates reverse polarity in the circuit

Qty.	Component Description	Part Number & Data Sheet Link	Distributor Inventory
1	Metal Oxide Varistor (MOV)	MOV-14D241K	Check Inventory
1	Diode Bridge	CD-MBL106SL	Check Inventory
1	TBU® High-Speed Protector	TBU-CA Series	Check Inventory
1	TVS Diode	SMBJ15CA	Check Inventory

Additional Resources

- PowerPlay Solution™: Universal AC Power (UACP) Protection
- White Paper: A New Universal AC Power Protection Approach
- White Paper: Tips on Selecting the Right MOV Surge Suppressor
- Bourns® Design Tools
- Bourns® Authorized Distributor Inventory Search

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