

Debugging power-supply startup issues

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Introduction

You just received your assembled power supply printed circuit board (PCB) from the manufacturer. You plug it in and guess what? It doesn't work. Whether you are a novice engineer or an industry veteran, you know that sinking feeling. Regardless of how many days and hours you spend running the calculations, perfecting your design, and meticulously placing and routing your PCB, your 3.3-V output shows nothing but zeros on your multimeter or, worse yet, it goes up in a puff of smoke.

Gone are the days where power supplies use simple pulse-width modulators (PWMs) with limited bells and whistles. Integrated circuits (ICs) have dozens of pins and features like soft start, current limiting, pre-bias startup, and boot capacitors. But what do some of these features mean, and which ones are preventing your power supply from working?

This article provides a logical debug process for a malfunctioning design. The troubleshooting process starts with the simple "gotchas" and then tackles more difficult areas that even the experienced designer may find helpful.

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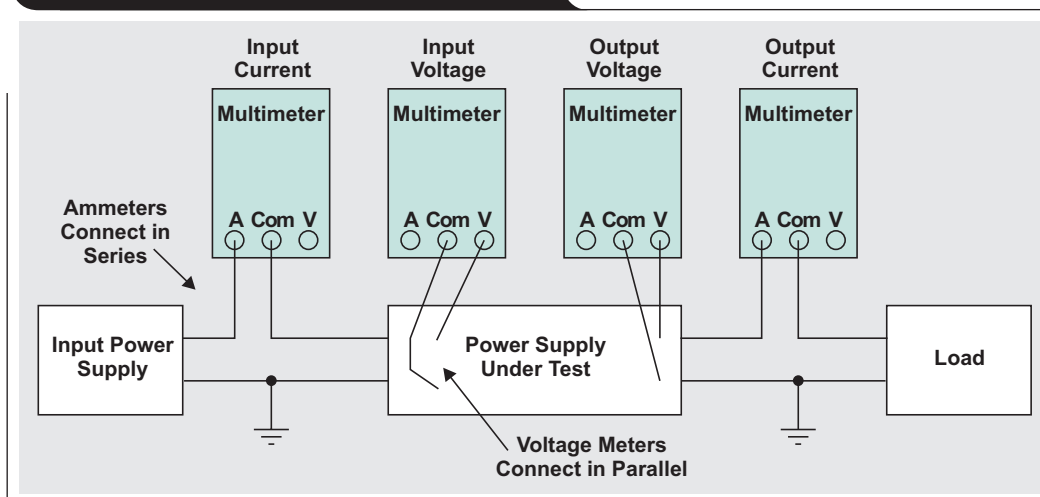
The most obvious mistakes can be very time consuming when debugging a power-supply issue. Before powering up a supply for the first time, it is a good idea to do a visual inspection of the board. The designer needs to check that the correct parts are installed, check for missing parts, inspect all solder joints and verify that parts are soldered

in the proper orientation. Double check to ensure that surface-mount resistors and capacitors were not swapped in assembly and that square ICs are not rotated 90 or 180 degrees. If you did not do a visual inspection and the board failed at turn on, this is good time to find and replace damaged parts, and to check the rest of the board.

Once the visual inspection and part replacement is complete, the next thing to check is that input cables are properly connected. Figure 1 shows a typical single-input, single-output, power-supply test setup.

After input connections are verified, the easiest way to get started on the debugging process is with a multimeter or oscilloscope. A multimeter can be used to ensure the input voltage is being passed to the PCB and arriving at the proper places on the board. If an ammeter is used to measure the input current, the meter could be connected incorrectly or have a blown fuse that would prevent the input voltage from getting to the board. When the power to the board is verified, measure the voltage across the capacitors located next to the IC. Some converters have AVIN and PVIN pins for the analog circuitry and power stage, respectively. Confirm that each of these nodes is receiving its designated voltage. Once you verify that the IC is receiving voltage, the next items to check are the on-board linear regulators or reference voltages. Check the datasheet to ensure the voltages on these pins are correct. Before spending too much time on the debugging process, this would be a good time to check another board. If other boards are working properly, that helps to

Figure 1. Typical power supply test setup



narrow the problem from a design issue to an assembly or PCB issue.

Power supply ICs usually have input-enable or under-voltage lockout (UVLO) circuits. An oscilloscope is useful for checking these voltage levels. Probe the input-voltage and enable pins to observe if each crosses the startup thresholds specified by the IC datasheet. Some converters need a 5-V or 3.3-V bias before the input is applied and enable is toggled. Verify that the bias is present in the correct timing sequence.

Detailed debug procedures

After verifying that the IC is receiving the right voltages on the input and enable pins, the next step is to detect if the IC tries to start. Although your multimeter reads 0.0 V on the output, the device may have started switching before shutting down. Place scope probes on the switch node, input voltage, output voltage, and enable pin. Set the oscilloscope to a normal trigger on the switch node and zoom the x-axis to ~1-ms/div. Apply power to the board and observe if the oscilloscope triggers. If the trigger catches and waveforms appear, the IC has made an attempt to charge the output. The supply could be shutting down from a short circuit. Remove power from the input and measure the impedance from the output to ground (GND). If it is a short or abnormally low impedance, the cause needs to be determined.

Lifting the inductor can help isolate the output node from the IC. If the short is on the output, it could be shorted output capacitors. If the short is on the IC side of the inductor, it could be a number of issues. The first step to isolate the short is to begin removing parts on the shorted node. If this is not successful, a power supply and thermal camera can be used to find the location of the short. Current limit the power supply to a few amperes and apply power across the shorted terminals. Be careful not to exceed the voltage ratings of any components on this node. Then use the thermal camera to observe where the board is heating up. Inspect with a microscope to pinpoint the problem.

If the power supply makes no attempt to switch, verify that the semiconductors are installed properly and are not

damaged. Check the MOSFET impedances. The gate-to-source and drain-to-source impedances should both be high. Then use the diode measuring tool on a multimeter to measure the body diode of all MOSFETs. The source-to-drain body-diode voltages of the MOSFETs should be in the 0.3- to 1-V range. If these terminals are shorted, the device is blown and must be replaced. Check the forward voltage of any other diodes in the circuit for proper orientation.

Soft-start circuits can be used to control the ramp of the power-supply output. This is typically a current source feeding a capacitor. If the capacitor is shorted or intentionally held low, this will prevent the device from switching.

In some cases the power supply boots up and attempts to regulate. It is important to know the protection features inside the power controller. These can include overvoltage protection (OVP), undervoltage protection (UVP), over-current protection (OCP), undervoltage lockout (UVLO), and overtemperature protection (OTP).

If the power supply switches and the output voltage ramps and overshoots, the controller could latch off due to OVP. Check the top feedback resistor to verify that it is installed properly. UVP can occur if the output voltage does not ramp in time. This can happen in an overcurrent situation during startup, or if the supply voltage is lower than the output voltage set point during startup. If the power supply is reaching an overcurrent condition, it may not trip UVP. However, it could have another method of protection. These protections include voltage foldback, hiccup mode, or latching the device off.

Another issue could be that the output capacitance is too large and the converter cannot charge the output before the soft-start time runs out. In this case, a larger soft-start capacitor could help to solve the problem. Most ICs have overtemperature protection to prevent the device from thermal runaway. Use a thermal camera to diagnose this failure as the temperatures can rise well above 100°C. ICs may attempt to restart once cooled, providing a failure signature.

Table 1. Troubleshooting list for power-supply startup issues

Step	Issue	Symptom	Solution
Prior to hooking up any cables, visual inspection			<ul style="list-style-type: none"> • Check BOM and SCH vs. board • Ensure jumpers and 0-Ohm resistors are installed • Ensure that DNP parts are not present • Inspect all solder joints
Hooking up the cables			<ul style="list-style-type: none"> • Ensure all cables are wired correctly • Ensure ammeters are wired in series! • Ensure cables are big enough to handle the current
Applying power	Smoke		<ul style="list-style-type: none"> • Not good, fix bad parts, use current limit when starting. Check multiple boards
	No startup	No voltage to the IC	<ul style="list-style-type: none"> • Check input cables • Check multimeter fuses • Check on board fuses • Check the path from the source to the IC
		Check EN, VREG, VREF	<ul style="list-style-type: none"> • Check the enable voltage, UVLO, soft-start voltage, internal regulators, and internal references. Change ICs that are not correct
		No switching	<ul style="list-style-type: none"> • Check the MOSFETs for shorts • Check the body diodes of the MOSFETs • Check other diodes for proper orientation
		Brief switching	<ul style="list-style-type: none"> • Check the output for shorts • Lift the inductor to help isolate • Use thermal camera to help identify issues
	Startup immediate Shut down		<ul style="list-style-type: none"> • Check for OCP, OVP, UVP • Lift the inductor and add a current loop • Check feedback paths to ensure connectivity • Isolate any external loads on the board • Check to ensure soft start is completing, a larger cap may be required

Table 1 shows a top-level check list for troubleshooting common startup problems. This list applies to the typical switching supply, however, some supply topologies may require more extensive troubleshooting.

Conclusion

Power supplies are complex circuits, so care must be taken with design, layout, fabrication and assembly. The debug process when things are not perfect is an art in itself. Following the tips and process described here could help the designer find a remedy in an efficient and timely manner. Texas Instruments has an archive of over 1,000 built and tested power supply designs.^[1] All of these designs have schematics, test reports and Gerbers available.

References

1. TI reference-design library for power management devices.

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