–48-V/+48-V hot-swap applications

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Introduction

The rapid growth of telecommunications and Internet access systems that run continuously has increased the need for hot-swap solutions that are more reliable and easier to upgrade and repair. Redundant systems or modules are required to prevent the systems from crashing. While redundant systems have been proven to be feasible, they may be costly. Furthermore, the use of a simple redundancy scheme as a backup may not be enough, as overall system integrity may be compromised even though the system is designed to handle such faults. In the end, we have to find a way to update the system regularly by removing redundant parts and/or inserting new modules while the system is still running. That is why hot-plug or hot-swap capability is required in today's high-availability electronic systems.

Realizing the needs of hot-swap applications, Texas Instruments has put a great deal of effort into providing solutions for a variety of end equipment requiring hot-swap capability. TI's hot-swap controllers provide inrush current control during hot insertion and fault protection during operation. They also prevent backplane power disruption during hot removal or insertion.

In particular, the TPS2300/01, TPS2310/11, TPS2320/21, and TPS2330/31 from TI (see References 1–4) cover a variety of hot-swap applications and were primarily designed for 3-V to 13-V applications. TI has already released and is planning several hot-swap devices targeting PCIx, CompactPCI®, and other mass-market applications. Devices like the UCC3913, UC3914, UCC3917, and UCC3921 operate across very wide voltage ranges, from large negative voltages to large positive voltages.

Most telecommunications applications use –48-V or +48-V power supplies, which are then distributed to the cards via the system's backplane. As there are many ways to implement hot-swap in a 48-V system, it is very important to understand the exact requirements of the system before selecting a power management solution. Certain features on some devices may no longer function at higher (or lower) voltage levels, although controlled ramp of power to the card during hot insertion/removal is still possible. By fully understanding the implementation requirements, you may find that there is a larger number of devices available, at a wide variety of price points, depending on the feature set required. The following discussion addresses different topologies in the TPS23xx series of TI's hot-swap controllers.

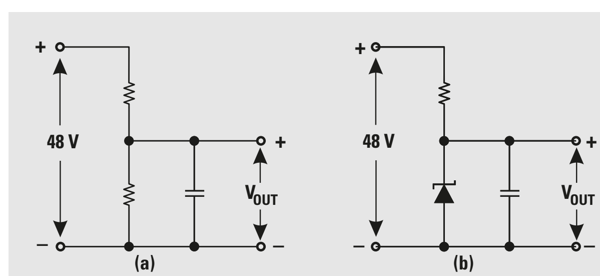
–48-V hot-swap application with low-side NMOSFET

Due to process limitations, the input voltage of the TPS23xx devices must be limited to 13 V (15 V maximum, dynamic). To manage higher voltages, some type of divider or converter is required to reduce the input voltage (48 V) to somewhere below 13 V.

There are several implementations that will keep the TPS23xx input voltage below the maximum limit. Figure 1a demonstrates the simplest topology. Two resistors are used to divide the higher input voltage into a lower voltage. However, in this implementation, the voltage at the output of the divider will track all changes in the 48-V input supply. Because the fluctuations and tolerances of the 48-V supply may vary not only from system to system but also based on the operating mode of the system, use of this scheme may affect the functionality of the controller, or possibly damage the device if large variations, or spikes, occur.

A much better, very simple solution consists of a Zener diode in series with a resistor to get a very steady output voltage from the 48-V source (see Figure 1b). This implementation will allow the voltage to be controlled at the divider to match the input voltage requirements of almost any hot-swap power manager. To eliminate noise or control the ramp-up rate of the output voltage, a capacitor should be added as shown in the figure.

Figure 1. Simple voltage dividers

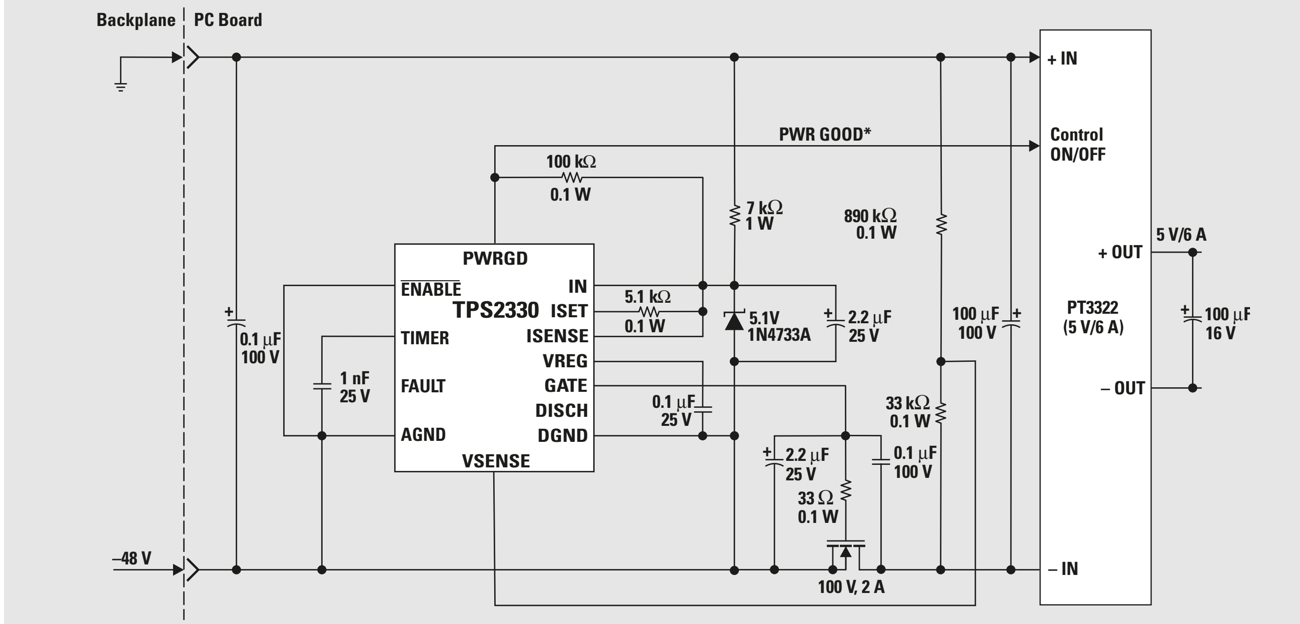


Of course, the performance of many other methods can equal or even surpass that of the Zener diode divider, but such methods tend to be more complicated and more expensive, and may be unnecessary for the –48-V applications. This is why the Zener diode divider is typically used in many 48-V hot-swap applications.

For –48-V hot-swap applications, the plug-in board can be configured as in Figure 2.

In this topology, the Zener diode is a 5.1-V 1N4733A, but higher-voltage (up to 10-V) Zener diodes can be used if desired. Since the TPS2330 consumes very little power for operation, the resistor (in series with the Zener diode) can be as large as 10 kΩ, depending on the threshold voltage desired. The load of the hot-swap control stage is a DC/DC converter—in this case, a Power Trends™ module

Figure 2. TPS2330 for –48-V hot-swap



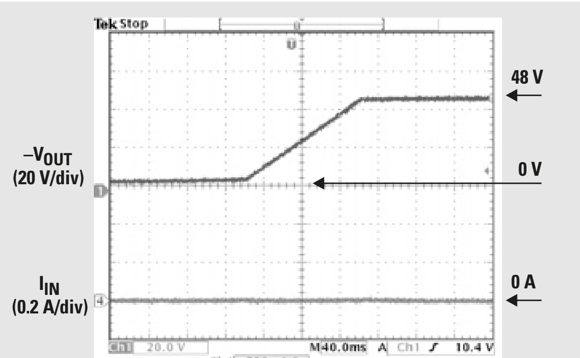
*An extra driving circuit may be needed from PWRGD to Control ON/OFF due to the load driving requirement.

from TI. The main switch is a 100-V N-channel MOSFET, such as IRF530N.

With the component values shown in Figure 2, this circuit can work for –36-V to –72-V applications, which happens to cover the broad range of voltages in telecommunications applications. To make the voltage range wider, the 33-kΩ sensing feedback resistor can be increased.

The curves in Figure 3 show the performance of the TPS2330 during a hot-insertion event. Even though there is a 100-µF capacitor in the output circuit as a load, the inrush current during hot insertion is kept to less than 0.1 A. In a 48-V telecommunications system, a 0.1-A inrush current is negligible and will not cause any problems. If the output capacitance is much bigger than 100 µF, then the

Figure 3. Hot-insertion of –48-V system: output voltage (–V_{OUT} and input inrush current (I_{IN})



value of the 4.7-µF capacitor between the TPS2330 GATE output and the –48-V rail should be increased accordingly. The output voltage curve seems to ramp up from low to high voltage because the output voltage was measured at ground opposed to –48 V to keep measurement simple and safe. Therefore, what we see on the curve is actually –V_{OUT}.

One shortcoming of this implementation is that the hot-swap controller loses the circuit breaker capability because the TPS23xx cannot sense current at voltages above 13 V. Since most implementations use some type of current-limited regulation scheme to bring the 48 V down to more useful voltages like 3.3 V and 5 V, the circuit breaker capability is merely redundant.

Other high-voltage hot-swap applications

If a hot-swap board has two inputs—for example, one at +3.3 V (potentially a V_{AUX} rail) and the other at –48 V—the TPS23xx family can still be used as shown in Figure 4. The trick here is to use a high-voltage PNP to drive the gate of the main power MOSFET. This minimizes the voltage levels applied to the TPS2300, thereby keeping them well within its operating range. In this example the TPS2300 can control the switching and the inrush current during hot insertion of both the low-voltage (+3.3-V) rail and the higher-voltage (–48-V) rail. The TPS2300 will not sustain any high voltage from the –48-V input, and the +3.3-V rail will still have circuit breaker capability.

However, the first input (+3.3 V) of this hot-swap board can operate only between 3.0 to 5.5 V because the IN2 maximum voltage rating is 5.5 V. To get the IN1's operation range up to 13 V, the connection between IN1 and IN2

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must be broken. With a method similar to that previously described, the IN2 input voltage can be limited to well under +5.5 V by a Zener diode so that channel 1 can run up to +13 V.

If a high-side switch is desired, such as in +48-V applications, an NPN bipolar can be used to drive the high-side MOSFET switch, similar to that shown in Figure 4.

Conclusion

A fuller understanding of the overall power management requirements and limitations of the system reveals a greater number of solutions available for managing hot insertion/removal. It is important to understand exactly what the hot-swap power manager needs to provide to the system. The needs include: inrush current limiting, fault current limiting, an electronic circuit breaker, controlled rise/fall time for insertion/removal events, Power Good reporting and supervisor functions, and sequencing control.

Knowing exactly what you need the hot-swap power manager to do allows you to tailor many devices into an effective solution. For example, with the simple addition of a few external components, the TPS23xx hot-swap controllers can be used in very high-voltage hot-swap applications, negative or positive. Likewise, solutions using the UCC3921 or UCC3917 can be simplified greatly by removal of external components that are not required.

References

For more information related to this article, you can download an Acrobat Reader file at www-s.ti.com/sc/techlit/*litnumber* and replace *"litnumber"* with the **TI Lit. #** for the materials listed below.

Document Title **TI Lit. #**

1. "TPS2300, TPS2301: Dual Hot Swap Power Controllers with Independent Circuit Breaker and Power-Good Reporting," Data Sheet slvs265
2. "TPS2310, TPS2311: Dual Hot Swap Power Controllers with Interdependent Circuit Breaker and Power-Good Reporting," Data Sheet slvs275
3. "TPS2320, TPS2321: Dual Hot Swap Power Controllers with Independent Circuit Breaker," Data Sheet slvs276
4. "TPS2330, TPS2331: Single Hot Swap Power Controllers with Power-Good Reporting," Data Sheet slvs277

Related Web sites

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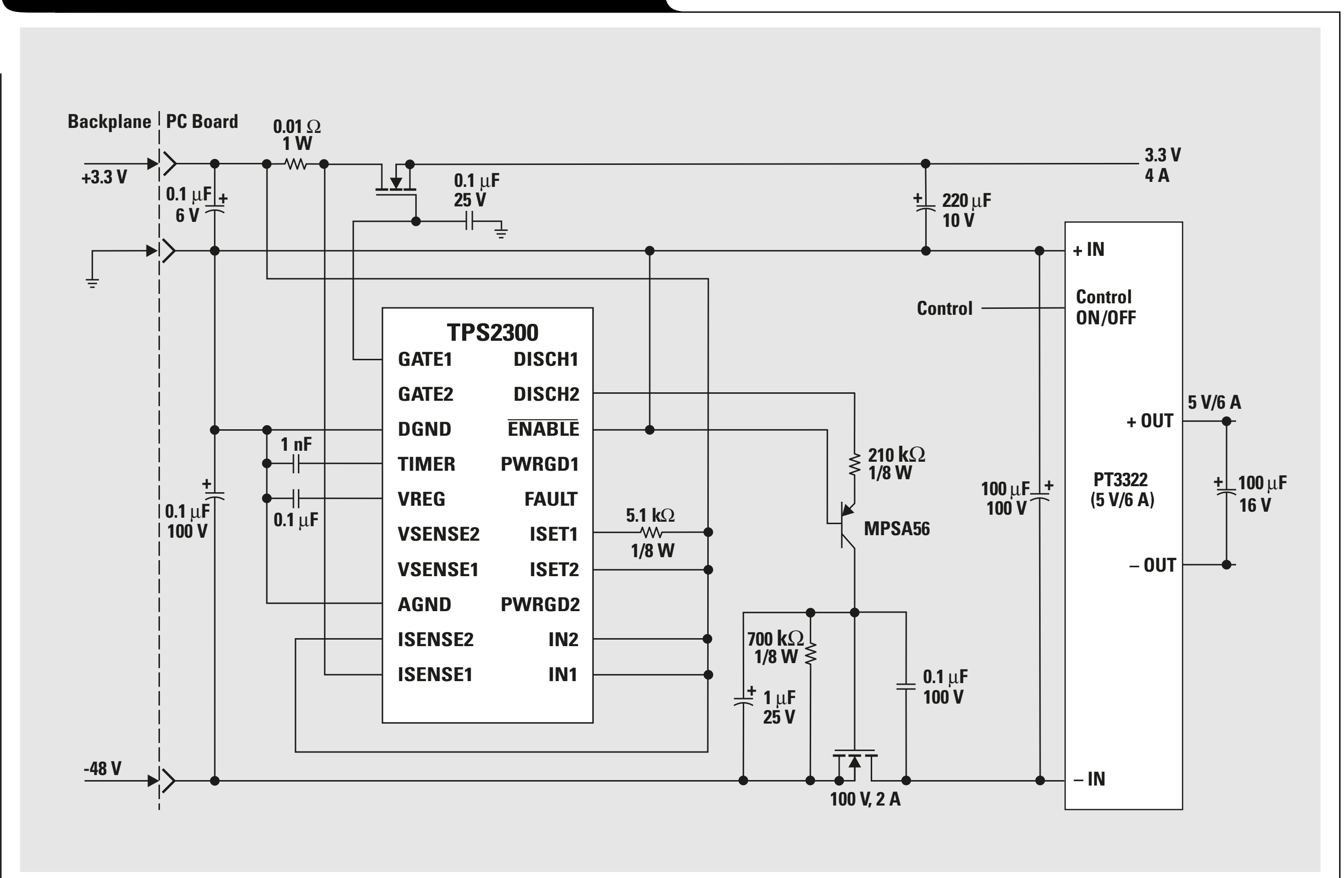
Replace *device* with tps2300, tps2301, tps2310, tps2311, tps2320, tps2321, tps2330, tps2331, uc3914, ucc3913, ucc3917, or ucc3921

Figure 4. +3.3-V and –48-V hot-swappable supplies



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