

±48-V Hot-Swap Applications With TPS23xx Hot-Swap Controllers

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ABSTRACT

The rapid development of telecommunication and networked systems has accelerated the growth of products requiring the hot-plug capability demanded by systems with a continuous uninterrupted power-on requirement. There are many hot-swap or hot-plug power management solutions available in the market today; however, the trick is picking the one that best suits the application's needs. Many applications involve low voltages, but 48 V is the standard backplane voltage in most telecommunications systems. The TPS23xx series of hot-swap controllers, originally designed for low voltage applications, can also be applied to very high voltage systems if used appropriately. This report discusses how to use these devices to control hot-swap events in high voltage environments such as ±48-V systems.

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1 Introduction

With the rapid growth in internet access systems as well as telecommunications, the need for high reliability, easier upgrading, and simpler repair, is more evident. In addition, hot-swap capability is needed in electronic systems that must run all the time. As a result, redundant systems or modules are being used to prevent the systems from crashing. While redundant systems have been proven feasible, they may be costly. Furthermore, any system employing a simple redundancy scheme as a backup may often find that it is not enough. Overall system integrity may be compromised even though the system is designed to handle such faults. In the end, a way must be found to update the system regularly by removing errant parts and inserting new modules while the system is still running. That is why hot-plug or hot-swap capability is required in today's electronic systems.

Texas Instruments Inc (TI) has developed solutions for a variety of end equipment requiring hot-swap capability (e.g., computing, internet access, and telecommunication). TI's hot-swap controllers provide inrush current control during hot insertion, provide fault protection during operation, and they prevent backplane power disruption during hot removal or insertion.

In particular the TI TPS2300/01 [1], TPS2310/11 [2], TPS2320/21 [3], and TPS2330/31 [4] devices cover a variety of hot-swap applications. These devices were primarily designed for 3-V to 13-V applications. TI has already released other hot-swap devices targeting PCIx compact PCs, and other mass-market applications. Devices like the UCC3913, UC3914, UCC3917, and UCC3921 operate across very wide voltage ranges from large negative to large positive voltages.

Most telecommunication applications use -48 or $+48$ V power supplies, which are then distributed to the cards via the system's back-plane. 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, even though a controlled ramp of power to the card during hot-insertion or removal is still possible. By fully understanding the implementation requirements, it may be found that there are a large number of devices available and at a wide variety of prices, depending on the feature set required. The next two sections address different topologies using the TPS23xx series of TI's hot-swap controllers.

2 -48 V Hot-Swap Application With Low-Side NMOSFET

Due to process limitations, the input voltage range that the TPS23xx devices are physically allowed to see is only 13 V (up to 15 V maximum, dynamic). In order to manage higher voltages, some type of divider or converter is required to reduce the input voltage (48 V) to somewhere below 13 V as seen by the TPS23xx.

There are several implementations that can keep the voltage below the maximum limit of the TPS23xx. Figure 1(a) 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 and seen by the TPS23xx tracks all changes in the 48-V input supply. As 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, are seen.

In this topology, the Zener diode is a 5.1-V 1N4733A. But higher voltage Zener diodes (up to 10 V) can be used if desired. Since the TPS2330 consumes very little power during operation, the resistor in series with the Zener diode can be as large as 10 k Ω depending on the threshold voltage desired. In this case, the load on the hot-swap control stage is a TI Power Trends Module dc/dc converter. The main switch is a 100-V N-channel MOSFET, such as the IRF530N.

With the component values shown in the schematic, the circuit works in applications from -36 V to -72 V, which covers the broad range of telecommunications applications. To make the voltage range wider, the value of the 33-k Ω 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- μ F capacitor in the output circuit as a load, the inrush current during hot insertion is kept almost to zero. If the output capacitance is much bigger than 100 μ F, the value of the 2.2- μ F capacitor from the GATE to the -48 V rail should be increased accordingly. Note that the output voltage curve ramps up from low voltage to high voltage, because the output voltage was measured relative to ground rather than relative to -48 V to keep the measurement simple and safe. Therefore, what is seen on the curve is actually $-V_{out}$.

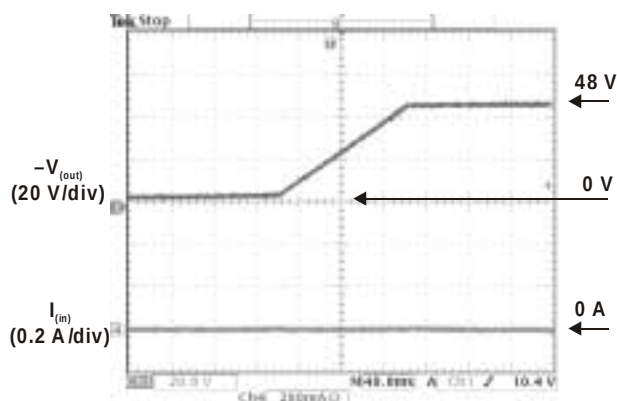


Figure 3. Hot Insertion of -48 V: Output Voltage, $-V_{out}$ and Input Inrush Current I_{in}

One shortcoming of this implementation is that the hot-swap controller loses its circuit breaker capability because the TPS23xx cannot sense current at voltages above 13 V. However, because 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 additional circuit breaker is irrelevant.

3 Other High-Voltage Hot-Swap Applications

Figure 4 shows that if a hot-swap board has two inputs, one at +3.3 V (potentially a V_{AUX} rail) and the other at -48 V, it can still be implemented using the TPS23xx family. The trick here is to use a high voltage PNP to drive the gate of the main power MOSFET. This minimizes the voltage levels seen by 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 high voltage -48 -V rail. The TPS2300 does not sustain any high voltage from the -48 -V rail, and the +3.3-V rail still has circuit breaker capability. However, the first input (+3.3V) of this hot-swap board can only operate between 3.0 V and 5.5 V because the IN2 maximum voltage rating is 5.5 V. Since IN1 can only be operated up to 13 V,

the connection between IN1 and IN2 must be broken to maintain the operating range of IN1. Using a method similar to that shown in the previous section, the IN2 input voltage can be limited to well under +5.5 V by a Zener diode so that channel 1 can run at up to +13 V.

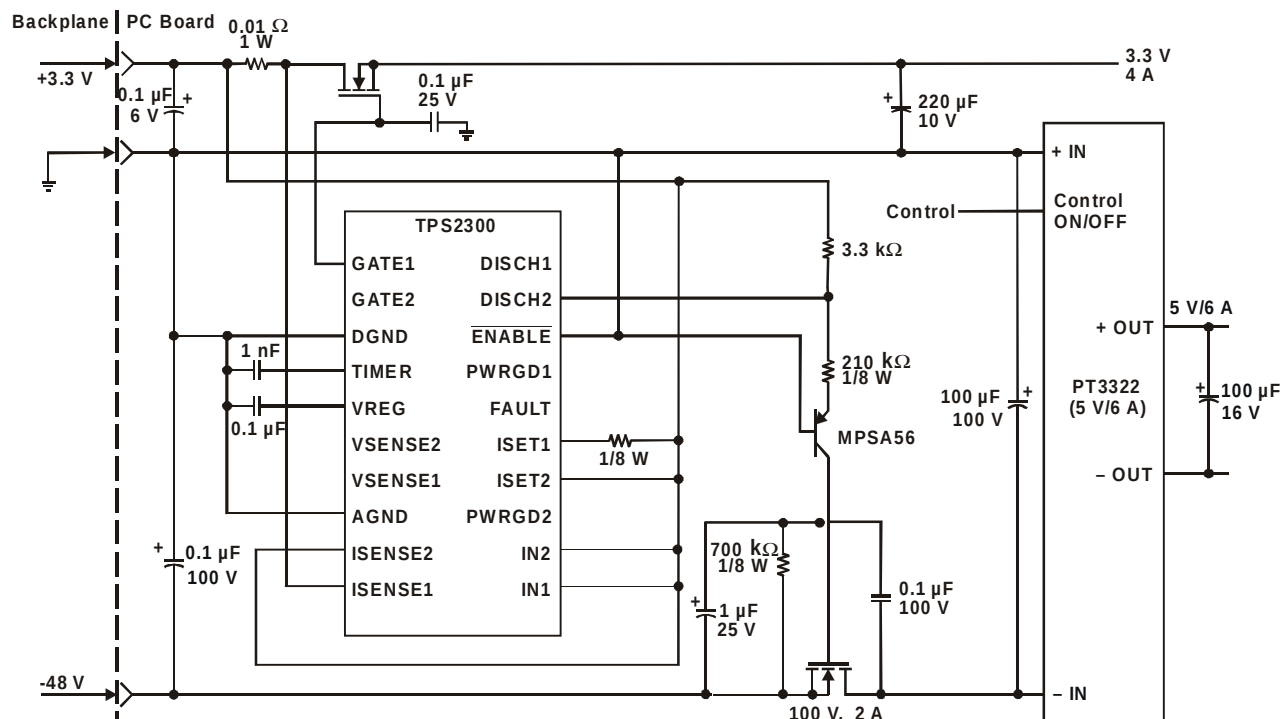


Figure 4. +3.3-V and -48-V Hot-Swappable Supplies

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

4 Conclusion

By more fully understanding the overall power management requirements and limitations of the system, the number of available solutions for managing hot insertion and removal increases. It is imperative to understand exactly what the hot-swap power manager has to provide to the system. Requirements that a hot swap power manager can fulfill are:

- Inrush current limiting
- Fault current limiting
- Electronic circuit breaker
- Controlled rise/fall time for insertion/removal events
- Power-good reporting and supervisor functions
- Sequencing control

By understanding exactly what the hot-swap power manager is required to do, many devices can be tailored to make an effective solution. For example, simply by adding a few external components, the TPS23xx hot-swap controllers can be used in very high negative or positive voltage hot-swap applications. Likewise, solutions using the UCC3921 or UCC3917 can be simplified greatly by removing external components that are not really adding value to the hot-insertion solution requirements.

5 Bibliography

1. *TPS2300, TPS2301 Dual Hot Swap Power Controller With Independent Circuit Breaker and Power-Good Reporting*, Datasheet, Texas Instruments Literature Number SLVS265
2. *TPS2310, TPS2311 Dual Hot Swap Power Controller With Interdependent Circuit Breaker and Power-Good Reporting*, Datasheet, Texas Instruments Literature Number SLVS275
3. *TPS2320, TPS2321 Dual Hot Swap Power Controller With Independent Circuit Breaker*, Datasheet, Texas Instruments Literature Number SLVS276
4. *TPS2330, TPS2331 Single Hot Swap Power Controller With Power-Good Reporting*, Datasheet, Texas Instruments Literature Number SLVS277

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