Using Voltage Supervisors in High Voltage Applications

TEXAS INSTRUMENTS

Introduction

Voltage supervisors come in many form factors with a variety of functions to help designers increase the robustness of their system. This is because voltage supervisors are typically used to monitor power rails for processors to help prevent brownouts and other undesired voltage rail conditions. Another popular purpose of a voltage supervisor is its ability to act as a comparator for battery or system power rail monitoring. One of the challenges that exist is that most of the feature friendly voltage supervisors cannot operate and monitor the same high voltage rails that are beyond the Recommended Operating Conditions. This is a challenge in applications that need early detection such as EV/HEV power train or factory automation where 12V rails need to be continuously monitored. This application note covers several design solutions that can help make every supervisor “Wide Input Voltage.”

Supervisors

Voltage supervisors are typically used to monitor voltage rails for non-ideal voltage rail variations such as undervoltage or overvoltage and notify MCU’s/FPGA’s/ASIC’s/SoC’s of system health. Since voltage supervisors are normally paired with these kinds of processors, supervisors typically have fixed voltage thresholds that are used to monitor common processor voltage rails such up to 5V. Due to this, the VDD recommended operating condition is also limited to similar voltages such as 5.5V on the TPS3890. The challenge arises when there are design requirements that call for a supervisor with the TPS3700 or TPS3890 functionality and flexibility but need it to monitor 12V voltage rails for early detection.

One solution to this is to add additional circuitry to help the supervisor stay within its recommended operating conditions. To do this there are three common approaches which can be either adding in a voltage divider, adding in a Zener diode, or adding in a shunt voltage reference.

Voltage Divider Method

One way of doing this is to use a voltage divider connected to the VDD pin of the supervisor to scale the power voltage rail down to a recommended level. For example, if you have a nominal 12V battery voltage rail that has 40V transients but need to power a TPS3700 of the same rail, the supervisor needs to still function when the rail is 40V. A solution to this is to connect the voltage divider to the VDD pin to scale the power to the recommended level on the TPS3700, as shown in Figure 1. One issue is that the voltage divider is always on and therefore will always have a leakage current. One advantage of the TPS3700 is that it has low Iq which means the resistor values can be increased which lowers the leakage current. The voltage divider method can increase the VDD capabilities of a supervisor as a low solution cost but come at the expense of power.

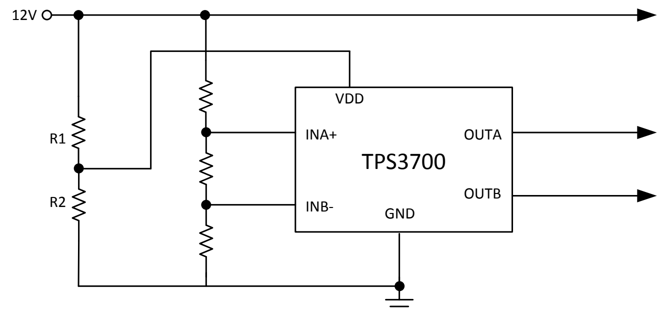

Figure 1. Voltage Divider at VDD

Zener Diode

An alternative option is to use a zener diode to clamp the input voltage, as shown in Figure 2. In this example a 5.5V zener diode, Z1, is used to clamp VDD to 5.5V. Zener diodes conduct very little current in reverse voltage configuration below the 'knee' in Figure 3 and then shunt the rest of the current above its zener voltage (Vz). In the situation that the voltage rail is below 5.5V, the current consumption will be low and it does not limit the voltage at the VDD pin of the TPS3890. This means that the TPS3890 can regulate once the power rail is above the minimum input voltage. The main advantage of the zener diode is to create a low cost buck regulator that is only enabled when the voltage is above Vz.

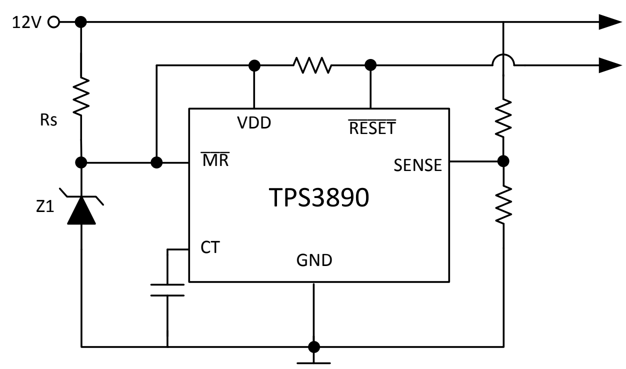

Figure 2. Zener Diode at VDD

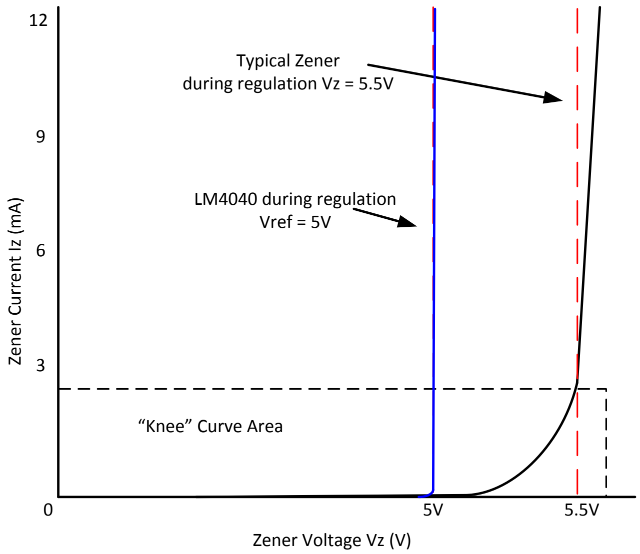

Figure 3. Zener Diode I-V Reserve Voltage characteristics

Once the zener diode cathode is near the 'knee' region close to 5.5V it will start to regulate and protect the VDD pin from violating its recommended operating conditions. This allows the power rail to increase to higher voltages greater than 5.5V. The main drawback of this design is trying to limit the leakage current across the zener diode, or Z1. The value of R1 needs to be scaled to decrease the leakage current across Z1 but it needs to not be too large that it limits the performance of the zener. This is because zener diodes require current to regulate properly or else the voltage at the cathode of Z1 will be clamped too low and the supervisor will not turn on. Due to this design, the leakage current is extremely high as zener diodes require several mA for proper regulation. The leakage current will increase proportionally wider input voltages which can make this solution very power hungry. This solution is more practical in applications that operate with a nominal voltage rail within the recommended operating conditions but need a clamping diode to ensure that the device will still regulate at higher transients.

Shunt Voltage Reference

An option to lower the Zener diode leakage current but still keep its low cost buck capabilities is to instead use a LM4040. The LM4040 has the functionality of a zener diode but with an Iq requirement of only 65µA for proper regulation. This low Iq of 65µA is much less than the typical regulation Iz of a zener that can be upwards of 3-5mA. Another advantage is that the LM4040, compared to a zener, has a very sharp transition region and does not have such a large 'knee' curve as typical zener diodes as shown in Figure 3. This means that the LM4040 has less leakage current prior to its 5V regulation. This also allows a LM4040 to be used as an active clamping diode because the power loses are much lower compared to a zener diode. Figure 4 shows a typical example of how a LM4040 can be implemented with a TPS3890.

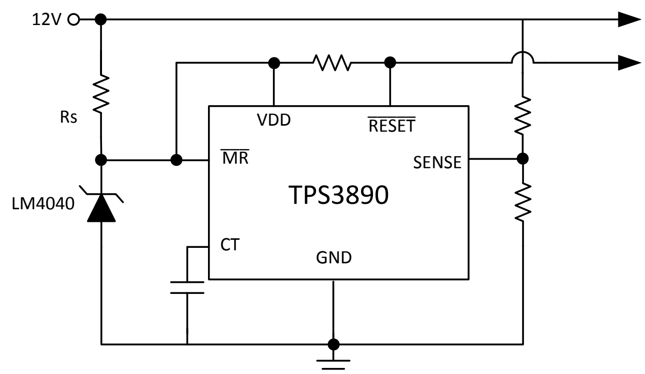

Figure 4. LM4040 at VDD

Table 1. Alternative Device Recommendations

Device	Description
TPS3700	Wide VIN Window Supervisor With Internal Reference for Overvoltage and Undervoltage Detection
ATL431LI	Low Iq, High Accuracy, High Bandwidth Shunt Regulator

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265