1 Abstract

This application note gives an overview of the operation of the TPS2410/12 and TPS2411/13. It describes how each device controls an external N-channel MOSFET to emulate an ideal diode. It does not address the other pin functions of the TPS2410/11, UV and OV inputs, filtering, or the status outputs.

2 Introduction

The TPS2410/12 is designed for applications where dc reverse current is not allowed. While desirable for heavy loads, this type of system can be a problem for low-voltage applications that have abrupt no-load to high-load transitions. In these systems, the bus voltage may droop momentarily and turn off the MOSFET. The TPS2410/12 solves the light load turnoff by maintaining a small voltage across the MOSFET whenever there is at least 10 mV to turn it on. The MOSFET will be turned off slowly if voltage across it is forced below 10 mV, and turns off abruptly if the voltage falls to the programmed fast turn off threshold. The programmed threshold is positive several milli-volts by default, but may be programmed to negative voltages.

The TPS2411/13 is designed for applications that require no-load to high-load transition and can tolerate reverse current. The TPS2311/13 control acts like a comparator with the MOSFET turned on if the voltage across it exceeds 10 mV, and is only turned off abruptly if the voltage falls abruptly to the programmed fast turn off threshold. With this type of operation, the turn-off threshold must be programmed to a negative voltage in order to avoid oscillation at light loads.
3 Operation Description

3.1 TPS2410/12

The circuit shown in Figure 1 is used to demonstrate the operating principles of the TPS2410/12. The A and C pins of the TPS2410/12 refer to the emulated anode and cathode of the equivalent diode, and $V_{AC}$ refers to the forward voltage across it. The diode in the figure is the body diode of the MOSFET.

![Figure 1. External Power MOSFET](image)

Initially, consider the power supply off. When the power supply turns on, the load voltage follows the input voltage through the body diode of the MOSFET. When VDD, the bias voltage to the controller, is between the UVLO (2.375 V) and 3 V, the gate drive becomes active and starts pulling the gate voltage up from ground. When VGATE-A equals the MOSFET threshold voltage, the TPS2410/12 attempts to regulate $V_{AC}$ to 10 mV. If $V_{AC}$ exceeds 10 mV due to the load current through the MOSFET $R_{DS(on)}$, the gate voltage will be driven to about 10 V above VA.

If $V_{AC}$ falls below 10 mV minimum, and is above the default 3 mV fast turn-off threshold, a weak pull down is applied to the gate. This situation could occur when a momentary input droop occurs, or if there is a second power source hot plugged to the power bus. If $V_{AC}$ falls below the programmed turnoff threshold, a fast turn-off comparator drives a very strong gate pull-down to ground.

Although the fast turn-off threshold voltage is resistor programmable at the RSET pin, it is not recommended for use in the TPS2410/12. A no-connect at the RSET pin defaults the fast turn-off threshold of $V_{AC}$ to 3 mV. This small positive value assures no reverse current into a failed power supply. The slightly positive $V_{AC}$ is preferable while the MOSFET gate is in the weak pull-down region and the MOSFET is still conductive.
3.2 **TPS2411/13**

For TPS2411/13, the fast turn-off threshold, $V_{AC}$, must be programmed to a slightly negative value by the $R_{SET}$ resistor at pin 2. The $R_{SET}$ equation from the datasheet is:

$$R_{SET} = \left( \frac{-470.02}{V_{OFF} - 0.00314} \right)$$

The turn on sequence for TPS2411/13 is a little different than the TPS2410/12. When the power supply is turned on, there is conduction through the body diode but when VDD is greater than UVLO and $V_{AC}$ is greater than 10 mV, the controller turns the gate voltage full on. The gate stays on as long as $V_{AC}$ is greater than the turn-off threshold voltage.

If $V_{AC}$ falls below the programmed turn off threshold voltage, the TPS2411/13 rapidly turns off the MOSFET with a strong pull down on the gate.

The MOSFET remains off until $V_{AC}$ is once again greater than 10 mV and the controller turns the MOSFET full on.

There is hysteresis in the controller because the MOSFET gate drive remains off until $V_{AC}$ is 10 mV minimum. The gate is then turned on and remains on until $V_{AC}$ is at the turn-off threshold voltage. This on/off type of control is often better suited to light-load and no-load to heavy-load transients. Reverse current is allowed for a short duration but this avoids instability. The maximum reverse current is:

$$I_R = \frac{V_{TH}}{R_{DS(on)}}$$

Example, for a fast turn-off threshold voltage, $V_{TH} = -.002$ V, and a MOSFET $R_{DS(on)}$ of 0.010 Ω, the reverse current is 200 mA for the fast turn-off time of approximately 130 ns.
4.1 **MOSFET is OFF**

A voltage at $V_{AC}$ greater than 400 mV is a fault condition and FLTB is active.

4.2 **Separate $V_{DD}$ supply**

If the TPS241X and MOSFET manage a bus less than 3 V, a separate supply is used for $V_{DD}$ instead of the bus voltage. The separate supply may be applied at a different time than the bus being controlled resulting in an advanced or delayed gate control. $V_{DD}$ may be above or below the controlled bus voltage providing it is within specification range.

4.3 **Back-to-Back MOSFET**

If a back-to-back MOSFET configuration, Figure 2, is used to eliminate the path through the body diode, no voltage is applied to the load until $V_{DD}$ is greater than the UVLO minimum.

![Figure 2. Back-to-Back MOSFET Configuration](image)

5 **Conclusion**

Two types of controllers are offered to wire-or or connect N+1 power supplies based on the system loading. The TPS2410/12 operates in a linear mode and does not allow reverse current. The TPS2411/13 operates as an on/off controller with hysteresis that allows reverse current for a short duration.

Examples of high availability systems for TPS2410/12:

- Server
- Raid (N+1)
- Telecom

Examples TPS2411/13 usage:

- Battery and Wall Charger
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Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265

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