X80070, The Flexible -48V Hot Swap Solution

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Author: Carlos Martinez

Overview

Systems that use -48V power supplies generally have a requirement that boards may be inserted and removed from the backplane without powering down the system. This “Hot Swap” or “Hot Plug” application requires that minimum current flows into the board when the board and the backplane contacts meet. To meet this specification requires an FET switch that provides power to the high power components on the board only after the board has been connected to the backplane; and turns off the power to the board before it is removed from the backplane.

The X80070 family of devices (X80070, X80071, X80072, X80073) provide multiple control mechanisms to facilitate the managed application and removal of power to a board. These mechanisms include:

- Delayed turn on of the FET after application of power.
- Manual or remote control of the FET to allow the device to be turned on only under system control or turned off prior to removal of the board.
- Control of the gate FET base current for more manageable FET turn on characteristics.
- Dual undervoltage thresholds for operation in a line or battery operated system.
- Various retry options to handle different requirements for FET turn-on operation.

This application note reviews these features and provides some design guidelines for the operation of, and selection of components for the X80070 device.

X80070 Power Supply Circuit

The X80070 requires a 12V power supply, provided on the V_{DD} pin. The circuit in Figure 3 shows a resistor and a 12V zener diode controlling the base of a pass transistor to provide a regulated 12V. With the transistor, a minimum current through the zener provides regulation, while the transistor supplies any current loads required by the X80070. This circuit dissipates less power on average than a zener diode/resistor only combination that must always provide the maximum current needed by the X80070 plus zener regulation current.

This power supply circuit can handle input voltages from -30V to -170V. At -170V, the resistor dissipates a maximum of 2W and the transistor dissipates a maximum of 800mW. The board uses an MJD340 transistor that is rated at 300V and 1.5W.

Overvoltage/Undervoltage Circuits

Inside the X80070 are comparators and programmable voltage references to monitor for one overvoltage and two undervoltage trip points. Intersil programs the overvoltage and undervoltage trip points during manufacturing. There are two optional overvoltage values: 74.3V for the X80070 and X80072 devices and 67.4V for the X80071 and X80073 devices. The overvoltage and undervoltage options are shown in Table 1 below.

The active undervoltage detector is selected by the BATT-ON pin. BATT-ON LOW (or unconnected) sets a higher undervoltage level (42.4V). BATT-ON pulled HIGH sets a lower undervoltage level (33.2V).

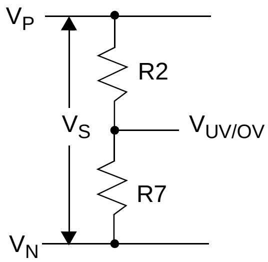
A resistor divider connected between the plus and minus input voltages and the $V_{UV/OV}$ pin (See Figure 1) determines the overvoltage and undervoltage shutdown thresholds and the operating voltage range. Using the thresholds in Table 1 and the equations of Figure the desired operating voltage can be determined. Figure shows the resistance values needed for various operating voltages.

TABLE 1. OVERVOLTAGE/UNDERVOLTAGE DEFAULT THRESHOLDS

SYMBOL	DESCRIPTION	THRESHOLD		MAX/MIN VOLTAGE[1]	LOCKOUT VOLTAGE[2]
		FALLING	RISING		
V_{OV}	Overvoltage (X80070, 72)	3.87V	3.9V	74.3	74.9
V_{OV}	Overvoltage (X80071, 73)	3.51V	3.54V	67.4	68
V_{UV1}	Undervoltage 1	2.24V	2.21V	43.0	42.4
V_{UV2}	Undervoltage 2	1.76V	1.73V	33.8	33.2

NOTES:

1. Max/Min Voltage is the maximum and mimimum operating voltage assuming the recommended VUV/OV resistor divider.
2. Lockout voltage is the voltage where the X8007x turns off the FET.



Voltage divider:

$$V_{UV/OV} = V_S\left(\frac{R7}{R2 + R7}\right)$$

or:

$$V_S = V_{UV/OV}\left(\frac{R2 + R7}{R7}\right)$$

FIGURE 1. OVERVOLTAGE UNDERVOLTAGE DIVIDER

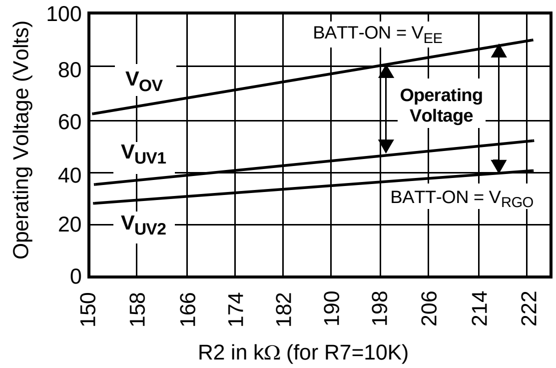
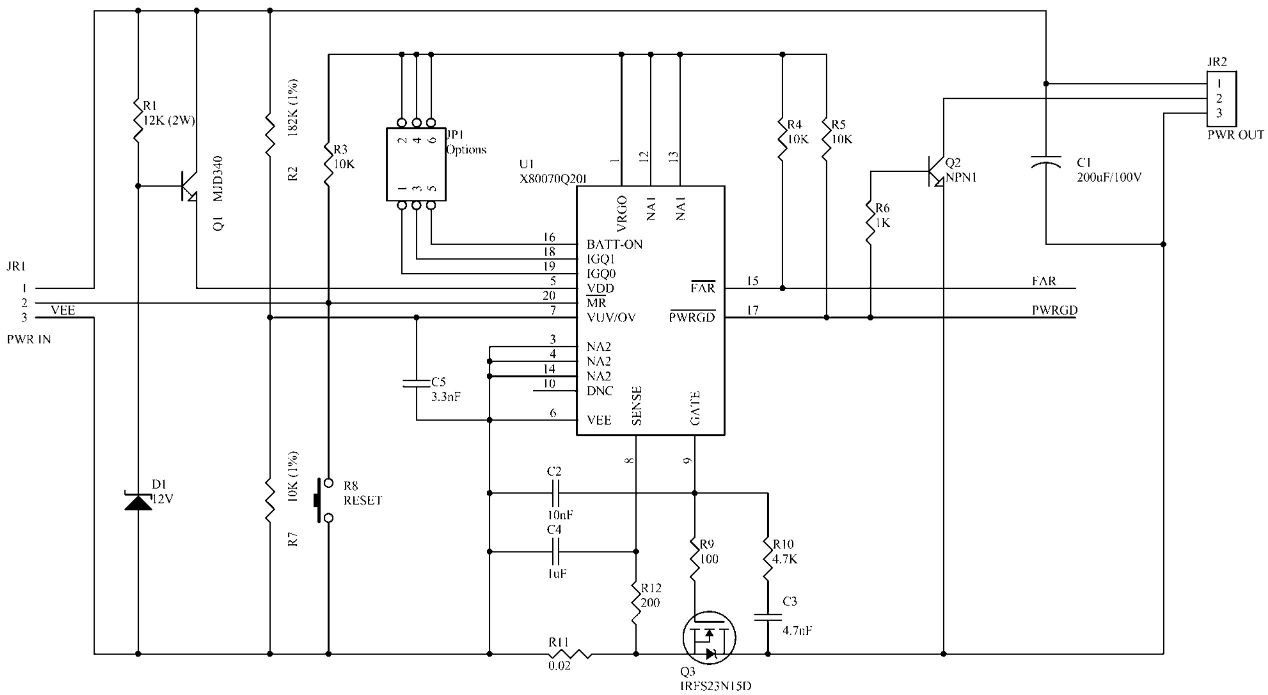


FIGURE 2. OPERATING VOLTAGE VS. RESISTOR RATIO



R12 and C4 are optional for additional over current filtering (200us)
C4 is optional for noise filtering on the over voltage and undervoltage detection

FIGURE 3. APPLICATION CIRCUIT

X80070 hotswap and support circuits

The primary components in the hotswap circuit are the FET and the sense resistor. The FET can be any N-Channel type. This application uses the IRF23N15 MOSFET from International Rectifier, but any FET device operates similarly.

The X80070 overcurrent threshold is 50mV. With a sense resistor value of 25mohm, the overcurrent condition during normal operation is 2 Amps. On an initial turn-on of the FET (insertion,) the X80070 has an overcurrent threshold of 150mV. So, for a system that limits the current to 2A in normal operation, the X80070 allows up to 6A of surge current during insertion. When the $\overline{\text{PWRGD}}$ signal goes active, the current limit drops back down to the normal level.

FET feedback components (C3 and R10) provide compensation for the FET during turn on. The value of the resistance is not critical, but should be greater than 1KOhms. The capacitor value depends on the load and the desired maximum surge current.

A rough calculation for the value of C3 is:

$$C3 = \frac{I_{GATE} \times C_{LOAD}}{I_{INRUSHmax}}$$

Typical values for the feedback capacitor typically range from 2.2 to 10nF.

The X80070 has a programmable gate current, ranging from 10µA to 150µA. The capacitor chosen for this application is

4.7nF. This results in surge currents below the maximim 6A limit into a 200µF load for all but the highest gate current setting (150µA.)

With larger loads, the gate current can be set to lower values using the jumpers on the IGQ pins. Or, C3 can be increased to maintain the desired surge current. The capacitor size is limited by the turn on time of the FET. If the capacitor is too large, the FET remains partially turned on for a longer period, possibly heating the FET. If the capacitor is too small, the internal capacitance in the FET act to turn the FET on too fast and very large surge currents result.

When power is applied to the system, the FET tries to turn on due to its internal gate to drain capacitance (Cgd) and the feedback capacitor C3. The X80070 device, when powered, pulls the gate output low to prevent the gate voltage from rising and keep the FET from turning on. However, unless V_{DD} powers up very quickly, there will be a brief period of time during initial power application when the X80070 circuits cannot hold the gate low. The use of an external capacitor (C2) prevents this. Capacitors C2 and C3 form a voltage divider to prevent the gate voltage from rising above the FET turn on threshold before the X80070 can hold the gate low. Use the following formula for choosing C2.

$$C2 = \frac{V1 - V2}{V2} C3$$

Where:

V1 = Maximum input voltage,
V2 = FET threshold Voltage,
C2 = Gate capacitor,
C3 = Feedback capacitor.

In a system where V_{DD} rises very fast, a smaller value of C2 may suffice, because the X80070 will control the voltage at the gate before the voltage can rise to the FET turn on threshold. This application board assumes that the input voltage rises only to 12.5V before the X80070 reaches its operational voltage on V_{DD}. So C2 is chosen to be 10nF. For a system that turns on very slowly, or one with a capacitor on the VDD line, a larger C2 capacitor is recommended.

X80070 Current Control and Shutdown

In addition to an overcurrent level, there is an overcurrent time delay. For the X80070, this delay is 5µs. That is, in an overcurrent condition the X80070 waits for 5µs before turning the FET off (See Figure 4). For additional filtering, contact Intersil for X80070 devices that are factory programmed with overcurrent filter values of 0µs, 10µs, or 20µs. If 20µs of filtering is not enough (or for a longer time constant with the standard X80070,) an external filter provides any required delay. See Figure 5 for the response to an overcurrent condition during insertion with an external 200ohm resistor and 1µF capacitor. This is an RC time constant of about 200µs.

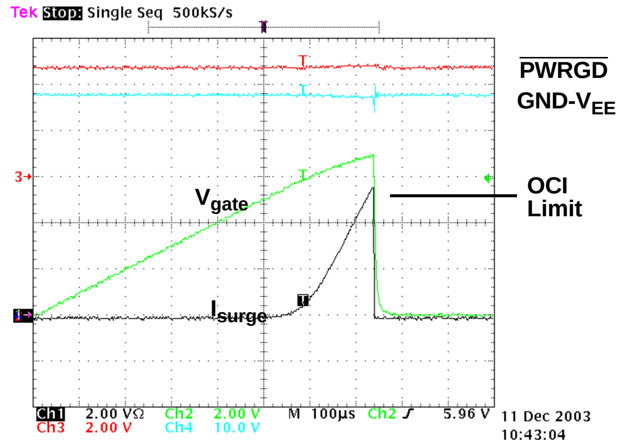


FIGURE 4. FET SHUTDOWN (INTERNAL FILTER)

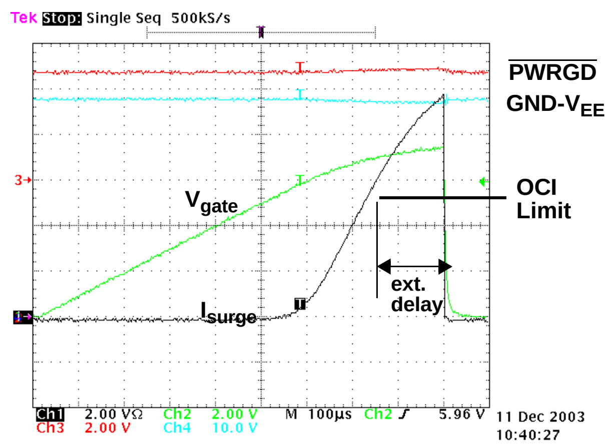


FIGURE 5. FET SHUTDOWN (EXTERNAL FILTER)

Programmable Gate Current

One of the benefits of the X80070 is its ability to program the turn-on surge current with simple jumpers on the IGQ0 and IGQ1 pins. This can reduce the surge current without changing the hardware. For example, if it is necessary to increase the bulk capacitance on the board, a simple jumper can bring the surge current back under control.

The table below shows various measured surge currents with C3=4.7nF; I_{Gate}=10µA, 50µA, 70µA or 150µA; and C_{LOAD}=100µF, 200µF or 300µF. The flexibility of the X80070 is shown by the wide range of surge current settings possible with a only a jumper change on the IGQ0 and IGQ1 pins. Actual waveforms for performance of the circuit using a 200µF load are shown in Figure 6 through Figure 10.

CLOAD		100µF	200µF	300µF
Igate (µA)	10	1A	2.3A	3.2A
	50	1.2A	2.9A	4A
	70	1.6A	3.9A	>6A
	150	3.4A	>6A	>6A

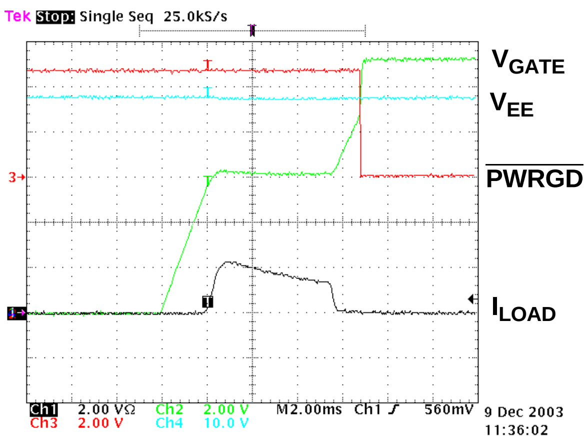


FIGURE 6. FET TURN-ON I_{GATE} = 10µA

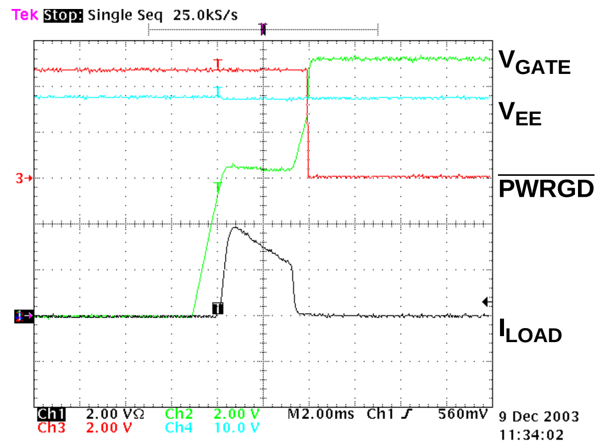


FIGURE 8. FET TURN-ON I_{GATE} = 70µA

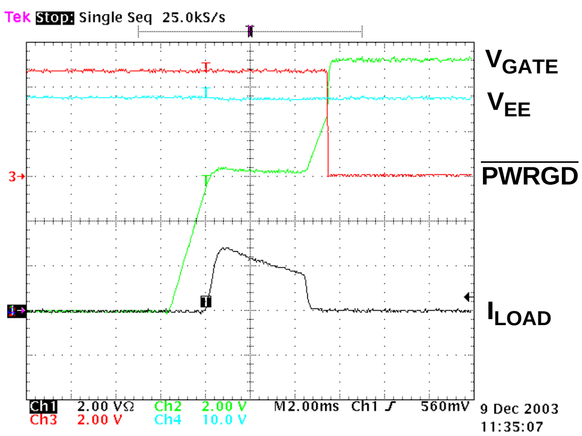


FIGURE 7. FET TURN-ON I_{GATE} = 50µA

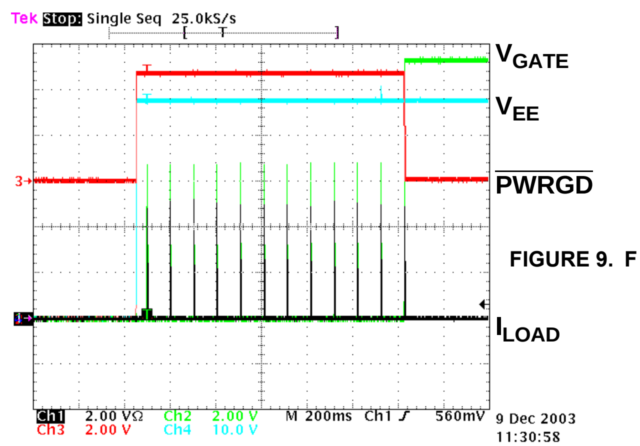


FIGURE 9. FET TURN-ON I_{GATE} = 150µA (RETRIES)

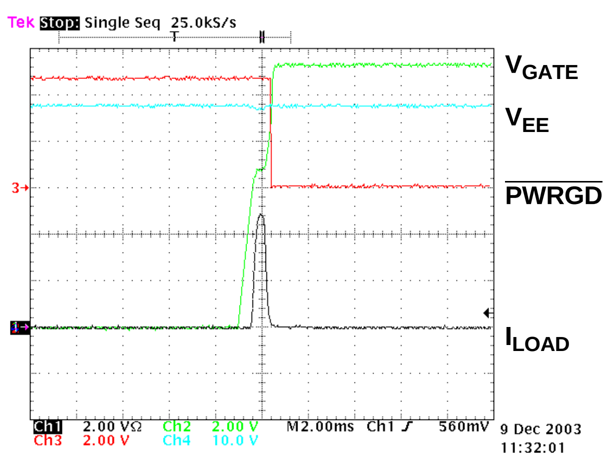


FIGURE 10. FET TURN-ON I_{GATE} = 150µA (FINAL TURN-ON)

X80070 Reset (FET control)

The X80070 device has a $\overline{MR}$ input that signals a "Hot side" reset. Pulling this input LOW results in the FET gate going LOW. This turns off the FET. There are three mechanisms for controlling this input pin.

First, if the internal 50ms delay on power on is not sufficient, the $\overline{MR}$ pin can connect through a resistor to V_{DD} and through a capacitor to V_{EE}. This provides a delay to the FET turn-on until the contact bounce on insertion has decayed.

Second, a manual reset switch can be provided. Pressing the button and holding it turns off the FET. Releasing the button restarts the FET turn-on process (assuming that the input voltage is still within limits.) This switch can be part of a mechanical board insertion/removal mechanism.

Third, a host PC or workstation control of this pin remotely through the backplane and an isolated interface. The user can specify a "Soft-extract" to bring the $\overline{MR}$ pin LOW and turn off the FET or the user can specify a "Soft-Insert" to set the $\overline{MR}$ pin HIGH and turn on the FET.

X80070 Options

The schematic in Figure 3 shows three jumper settings. The first two of these are the control of gate current. The third controls the undervoltage setting. The X80070 has two under voltage thresholds. The first is set for 42.3V. The second is for 33.2V. Typically, undervoltage 2 (UV2) is for operation when there is a battery backup. This allows the system more voltage margin when operating on batteries where the voltage may not be as high.

There are four standard versions of the X80070. The main differences are in the overvoltage and undervoltage settings and the retry response. If the undervoltage or overvoltage settings are not correct for a particular application, they can be factory set to custom levels, on request.

Besides the voltage thresholds, there are a number of parameters in the X80070 family that are factory programmed. If needed, different versions of the X80070 can be provided. See Table 2 for these options, with the standard X80070 settings.

Summary

The X80070 provides a flexible solution for -48V hotswap applications. The ability to set the gate current, change the response to overcurrent conditions, provide dual undervoltage shutsdown thresholds and delay the turnon of the power FET gives the designer many options for configuring and changing the operation of the power supply. This allows the power supply to handle evolving demands in a system or meet the needs of many systems without major design changes.

TABLE 2. X80070 FACTORY PROGRAMMABLE PARAMETERS (BOLD INDICATES DIFFERENCES IN STANDARD DEVICES)

OPTION	FACTORY PROGRAMMABLE OPTIONS	X80070	X80071	X80072	X80073
Over current Filter	0µs, 5µs, 10µs, 20µs	5µs	5µs	5µs	5µs
Retry Options	Always retry (don't set FAR) Always retry (set $\overline{FAR}$ after 1st fail) Never Retry (set $\overline{FAR}$ after fail) Retry 1 time (set $\overline{FAR}$ after fail) Retry 2 times (set $\overline{FAR}$ after fail) Retry 3 times (set $\overline{FAR}$ after fail) Retry 4 times (set $\overline{FAR}$ after fail) Retry 5 times (set $\overline{FAR}$ after fail)	Always retry (don't set FAR)	Always retry (don't set FAR)	Retry 5 times (set FAR after fail)	Retry 5 times (set FAR after fail)
Insertion Over current	1X, 2X, 3X, 4X	3X	3X	3X	3X
Retry Delay	100ms, 500ms, 1s, 5s	100ms	100ms	100ms	100ms
Gate Current IGQ1:0=0,0	10µA, 20µA, 30µA, 40µA, 50µA, 60µA, 70µA, 80µA, 90µA, 100µA, 110µA, 120µA, 130µA, 140µA, 150µA, 160µA	50µA	50µA	50µA	50µA
RESET delay	100ms, 500ms, 1s, 5s	100ms	100ms	100ms	100ms
Over voltage threshold	Any voltage between 1.5V and 4.25V (+/-50mV)	3.9V	3.54V	3.9V	3.54V
Under voltage threshold 1	Any voltage between 1.5V and 4.25V (+/-50mV)	2.24V	2.24V	2.24V	2.24V
Under voltage threshold 2	Any voltage between 1.5V and 4.25V (+/-50mV)	1.76V	1.76V	1.76V	1.76V