Using the X80070 in an Advanced TCA Application

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Introduction

This application note describes one possible implementation of an Advanced TCA (PICMG 3.x) power supply control. This particular implementation shows the power on control of one -48 to 12V, 144W DC-DC power supply, with a number of circuits included to meet the requirements of the PICMG3.x specification.

Some of the key elements in the application are:

- Use of an X80070 hotswap controller

  This device provides a controlled delay on the main FET turn on, changeable FET gate currents to control the FET slew rate, and a PWRGD output that turns on the DC-DC converter only after the main FET is on.

- Input protection

  To conform to the ATCA specification, this section includes the required fusing and filtering at the main power connector.

- DC-DC converter

  The chosen DC-DC converter supplies 12A of output current at 12V. The circuit includes filtering at the input of the supply and enough capacitance to power the board for 5ms during an input short circuit, a PICMG3.x requirement.

- Precharge circuits

  This block is optional, but uses the Early -48V connections of the ATCA backplane to precharge the bulk capacitance of the DC-DC converter. This will minimize the surge current through the main power FET.

- Discharge circuits

  This block will likely be requires in all systems for safety reasons. It discharges the bulk capacitors when the board is removed from the system.

This application example includes a number of external circuits that provide additional circuit protection and additional features. In an actual implementation, some changes may be required, especially in choice of filters, in order to optimize the power supply performance.

X80070 Hotswap Control

The X80070 device is a hot swap controller that allows a board to be safely inserted and removed from a live backplane without turning off the main power supply.

During insertion, the gate of an external power MOSFET is clamped low to suppress contact bounce. The under-voltage/over-voltage circuits and the power on reset circuitry suppress the gate turn on until the mechanical bounce has ended. The X80070 turns on the gate with a user set slew rate to limit the inrush current. The X80070 incorporates an electronic circuit breaker set by a 20mΩ sense resistor. After the load is successfully charged, the $\overline{\text{PWRGD}}$ signal is asserted; indicating that the device is ready to power sequence the DC-DC power brick.

At all times, the X80070 monitors for undervoltage, overvoltage, and overcurrent conditions. If any fault occurs, the gate will be immediately shut off and the $\overline{\text{PWRGD}}$ will be returned to the inactive state. The X80070 contains factory programmable overvoltage, undervoltage and overcurrent detection levels and programmable hardshort retry and gate control slew rates.

Board Schematic and Layout

For the full schematic, see the separate file: ATCA X80070 Schematic.PDF.

X80070 Hot Swap Circuit Power Supply

The X80070 receives power on the V_{DD} pin. The design shows the required 12V supply being generated by a resistor and a 12V zener diode controlling the base of a pass transistor. The transistor must be able to handle more than 80V and more than 0.7W of power dissipation (at 80V). The circuit uses an MJD340 transistor that is rated at 300V and 15W. In the circuit, the voltage is dropped from 48V to 12 V through the 0.25W, 27kΩ resistor R3 to provide 1.3mA for the base drive and for zener regulation. The chosen zener regulates well with 1mA of current.

The 12V regulator needs to provide an estimated 6.5mA typical continuous current (10mA peak). The X80070 requires 2.5mA during normal operation and the isolation circuits (described below) require 4.5mA. This results in maximum continuous power dissipation of 0.36W across the transistor at -48V.

Part of the 12V current goes to powering an ADuM1401 isolation circuit from Analog Devices. This device requires a 5V supply at a maximum 2.4mA. The 5V is supplied by a 5V regulator on the X80070, with an emitter follower providing the needed current.

X80070 Overvoltage/Undervoltage Circuits

The undervoltage/overvoltage is provided by a resistor divider between the -48V and -48V return leads. The resistors in this divider are selected so the Overvoltage (OV) setting is 74.9V, the primary Undervoltage (UV1) setting is 42.4V and the secondary Undervoltage (UV2) setting is 33.2V. The resistors can be changed to change these thresholds, but the ratio of the OV and UV remain fixed by the internal levels. These internal thresholds can be set by Intersil during manufacture, if other OV and UV levels are needed. Contact Intersil for more information about this procedure.

In the X80070 the active undervoltage detector is selected by the BATT-ON pin. If BATT-ON is LOW (or unconnected) then the higher undervoltage level is set (42.4V). If BATT-ON is pulled HIGH, then the lower undervoltage level is set (33.2V). Since the chosen DC-DC converter provides full power down to 35V, it is not desired to turn off the FET above this threshold. As such, the BATT-ON pin is tied HIGH in this application.

This circuit also contains a 6.2V zener diode to protect the device from high voltage transients through the mains and a capacitor to limit any false overvoltage and undervoltage conditions due to input voltage transients.

According to the ATCA specifications, the system must not respond to OV transients shorter than 10ms at 75V. This assumes an input voltage rise time of 10V/ms. The size of a capacitor was determined by simulation. The simulation and results are in the appendices.

Another consequence of the overvoltage test is the generation of a very large current through the bulk capacitor when the input voltage goes from 48 to 72V. Without correction, the X80070 will turn off the FET due to this large current. To deal with this, a current limiter is placed on the main FET. This requires a 100mΩ resistor in line with the main power FET. An NPN transistor monitors the voltage across this resistor. When the current reaches 7.7A, the transistor begins to turn on. This pulls down on the FET gate to partially turn it off. If the current remains at a level greater than 5.5A for more than 10ms, the X80070 turns off the FET, which shuts down the board.

X80070 Hotswap and Support Circuits

The primary components in the hotswap circuit are the FET and the sense resistor. The FET in this application is an IRFS23N15D from International Rectifier. The data sheet for this device is available on the CDROM or from the web site www.irf.com. This FET was chosen to provide the 8A peak, and maximum 5.1A continuous current. The sense resistor value is 10mΩ. This resistor sets the overcurrent condition at 5Am, since the X80070 overcurrent threshold is 50mV. An optional resistor divider in this circuit allows the over current level to be trimmed, to set the over current level to 5.5A, for example.

FET feedback components (C3 and R6) provide compensation for the FET during turn on. The value of the resistance is not critical. The board default is 4.7kΩ. The capacitor value depends on the load capacitance and the desired maximum surge current.

A rough calculation for the value of C3 is:

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

Assuming a gate current of 70µA a maximum surge current of 8A, and a 2200µF load capacitance, C3 is calculated to be 19nF and chosen as 22nF. If the surge current is too high, the gate current can be set to 10µA or 50µA by controlling the IGQ0 and IGQ1 pins of the X80070.

When power is first 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 application of power when the X80070 circuits cannot hold the gate low. The use of an external capacitor (C5) prevents this. Capacitors C3 and C5 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 C5.

$$C5 = \frac{V1 - V2}{V2} C3$$

Where:

V1 = Maximum input voltage,
V2 = FET threshold Voltage,
C5 = Gate capacitor,
C3 = Feedback capacitor.

In a system where V_{DD} rises very fast, a smaller value of C5 may suffice as the X80070 will control voltage at the gate before the voltage can rise to the FET turn on threshold. The application assumes that the input voltage rises only to 20V before the X80000 sees operational voltage on V_{DD}. So C5 is chosen to be 100nF. If C3 is used then the series resistor, R6, is required to prevent high frequency oscillations.

The values of C3 and C5 can be reduced by using the optional pre-charge circuit described below. This circuit gradually charges the bulk capacitor, partially or completely, before the X80070 turns on the FET. This reduces or eliminates the surge current and gives more flexibility in the choice of these components.

X80070 Reset Input

The X80070 device has an MR input pin that signals a “Hot side” reset. Pulling this input LOW tells the device to terminate a hotswap operation that results in the Main FET gate going LOW. This turns off the FET. This application has three board power management mechanisms for controlling this input pin.

First, the IPMI circuit has control of this pin through an isolated interface. The system can hold off the application of power to the board until authorized by the shelf manager. Then it can specify a “Soft-Insert” to set the MR pin HIGH and turn on the FET. Before board extraction, the IPMI controller can specify a “Soft-extract” to bring the MR pin LOW and turn off the FET. If this function is not needed, then the two shutdown control FETs (Q5 and Q6), the resistor (R23) and the isolation circuit (part of U3) can be removed.

Second, assuming that there is no IPMI control and there is a precharge circuit, the MR pin on the X80070 is pulled up with a 100K resistor and has a 10µF capacitor to V_{EE}. This one second (1s) time constant gives the precharge circuit time to work.

Third, without using the precharge circuit (and with or without the remote IPMI control, the capacitor can be removed and the X80070 internal 50ms delay holds off the hotswap operation until the contact bounce on insertion has decayed.

X80070 DC-DC Converter Interface Circuits.

The X80070 powers up one DC/DC converter. Typically this has a 12V or 5V output that is distributed to other DC-DC converters providing a variety of voltage sources. The DC-DC converter specified in this application is a SynQor 144W, 12V module.

The DC-DC converter is controlled by the $\overline{\text{PWRGD}}$ signal. Prior to the main power control FET turning on the $\overline{\text{PWRGD}}$ signal is HIGH. When it is HIGH, the optical isolator is turned on with about 1.5mA of current. This turns on the optoisolator transistor. This pulls the ON/$\overline{\text{OFF}}$ pin LOW and the DC-DC converter output is off.

As the main power control FET turns on, the voltage on gate pin gradually increases, until it is equal to V_{DD}, when the FET is fully turned on. When the voltage on the Gate pin exceeds V_{DD}-1V, the $\overline{\text{PWRGD}}$ signal goes LOW. When it goes LOW, the FET turns off the optical isolator, which allows the ON/$\overline{\text{OFF}}$ input to be pulled HIGH, turning on the DC-DC output. $\overline{\text{PWRGD}}$ is also optionally available to the IPMI controller through the ADuM1401 isolation device.

To meet noise requirements of the ATCA specification, a filter is placed between the FET switch and the DC-DC converter. Also, in order to meet the requirements that the board maintain operation in the event of a 5ms loss of input power, a 2200µF capacitor is placed at the DC-DC converter input. The size of this capacitor can be reduced to 47µF if the secondary of the DC-DC converter can maintain power for the 5ms period. A combination of capacitors on the input and output can be used. This application assumes that additional capacitance on the output of the DC-DC converter cannot be added. The calculation for the input capacitor is:

$$i = C\frac{dV}{dt}$$

Where:

i = maximum DC-DC input current (5A)

dV = change in voltage from 43V (minimum board voltage) to 31V (minimum DC-DC converter turn off voltage)

dT = time required to hold output (5ms)

Therefore: C = 2083µF (Use 2200µF)

IPMI Interface

This interface to the IPMI controller is optional, but if used, it needs to be isolated. This can be done with optoisolator components, but in this application, an Analog Devices ADuM1401 was used. This device takes less current than optical isolators, so it simplifies the power requirements on the -48V side, while providing 2500VRMS isolation. It is also much faster in responding to signals than optically coupled components at the same current.

In this application, the circuit provides three optically isolated control signals. These are Manual Reset ($\overline{\text{MR}}$), $\overline{\text{PWRGD}}$ and $\overline{\text{FAR}}$. The $\overline{\text{MR}}$ signal controls Soft Insert and Soft Extract operations. The $\overline{\text{PWRGD}}$ signal provides an output monitor of the FET status, and the $\overline{\text{FAR}}$ output indicates to the IPMI controller if there was a retry during turn-on of the main FET.

X80070 Options

There are a number of hardware options on the X80070. These are controlled by the connections on the device. If none of the options are needed, the pins are tied to V_{EE} or left floating. Table 1 describes each connection.

TABLE 1. X80000 CONFIGURATION

NAME	DESCRIPTION
BATTON	No connect or connect to V_{EE}: Undervoltage threshold = UV1. Connect to V_{RGO}: Undervoltage threshold = UV2.
IGQ1 IGQ0	Quick select of gate current. IGQ1 IGQ0 0 0 50µA gate current 0 1 10µA gate current 1 0 70µA gate current 1 1 150µA gate current

Input Components

To meet ATCA requirements, each power supply connection must have a fuse and a filter. The fuses on the return lines and the main -48V lines are Littlefuse devices rated at 250V and 7A. Fuses for the Early voltage and enable pins are rated at 250V and 200mA.

The filters chosen for the main power handling pins were surface mount Pi filters from Spectrum. These are rated at 200V and 10A. The capacitance value was 4000pF, but others are available. Also, Spectrum has smaller 100V/10A Pi filters that were selected for the early and enable pins. Depending on the filtering needs, feed through filters can be used instead of the Pi filters.

Also each input requires a blocking diode. The main power lines use high voltage shottkey devices capable of handling 100V and 5A of current. For the early and enable lines, smaller blocking diodes are used.

Precharge Circuit

The ATCA circuit schematic and simulations include the optional precharge control. It is not necessary for the operation of the power supply, but it does have some advantages. With this circuit, the initial insertion surge current is very low. This reduces stress on the high voltage circuits and minimizes the disruption to the -48V backplane. The X80070 is a good choice when using this circuit, because the gate output can turn off the precharge circuit when it turns on the main FET. This reduces the precharge load during normal operation.

Without the precharge circuit, the system powers up as normal, but with a higher surge current. The X80070 helps here as well, because the main FET turn on time can be controlled by the X80070 selectable gate current. This allows a wide range of turn on surge currents, though typically this would be in the 1-7A range. If the surge current is higher than desired even after selecting a smaller gate current, then the feedback capacitor can be increased to reduce the surge.

The precharge circuit works by turning on an FET as power turns on. This FET charges the capacitor through a 50Ω/2W resistor. The resistor wattage can be reduced using derating curves, based on the precharge duration. A zener diode limits the voltage for protection. When the X80070 main FET gate control output turns on, the precharge FET turns off, effectively taking this circuit out of operation.

Discharge Circuit

As part of the ATCA specification, the bulk capacitor needs to be discharged, for safety reasons, when the board is removed from the system. This is accomplished by using a third small FET. This FET is turned off while the board is plugged in and both the -48V Return and -48V pins are connected. When the board is removed, the discharge circuit is powered by the bulk capacitor and the FET is allowed to turn on. The FET remains on until the voltage on the capacitor has dropped too low to keep it on. This is about 10V across the capacitor. The discharge current is limited by a 50Ω resistance.

Summary

This application shows a relatively complete hotswap implementation. Much of the circuitry has been built and tested, and the remainder has been simulated to verify proper operation. Individual hotswap applications will no doubt require some changes to achieve desired functionality. Once a final design is settled on, the areas that will likely deserve special attention are board layout and noise suppression and testing.

Appendix 1 Simulation

This simulation uses a spice simulator. V1 is the main supply source. It is turned on or off, or raised to OV conditions as required by the test. V2 simulates the X80070 gate output. In the initial turn on test, it is delayed (as would the X80070 gate output be delayed) by about 1s. In the OV transient test, this voltage is left on. V3 simulates the board being removed from the system. After the circuit has been operating for about 1s, this supply turns off to mimic the removal of the board.

The load resistor (R3) is 10K in the power up/power down tests, because in these cases, there should be little load. During the OV transient test, the normal operating current is assumed to be 3.3A. As such, R3 is 14Ω.

In the simulation, specific part numbers chosen for components such as FETs, diodes and transistors do not exactly match those chosen for the schematic, but do have similar characteristics.

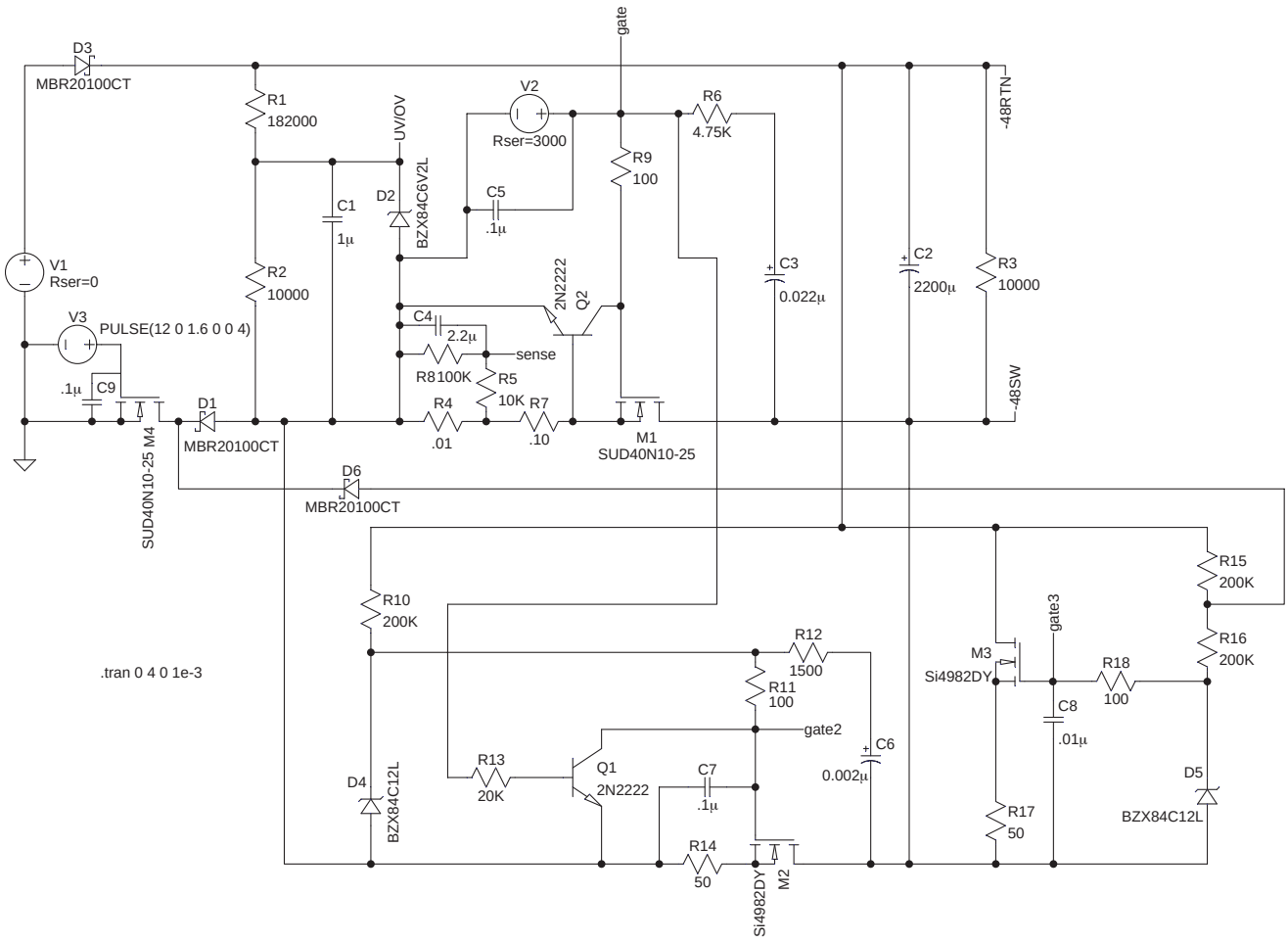

FIGURE 1. OV/UV SURGE PLUS POWERUP PRECHARGE AND DISCHARGE SIMULATION CIRCUIT

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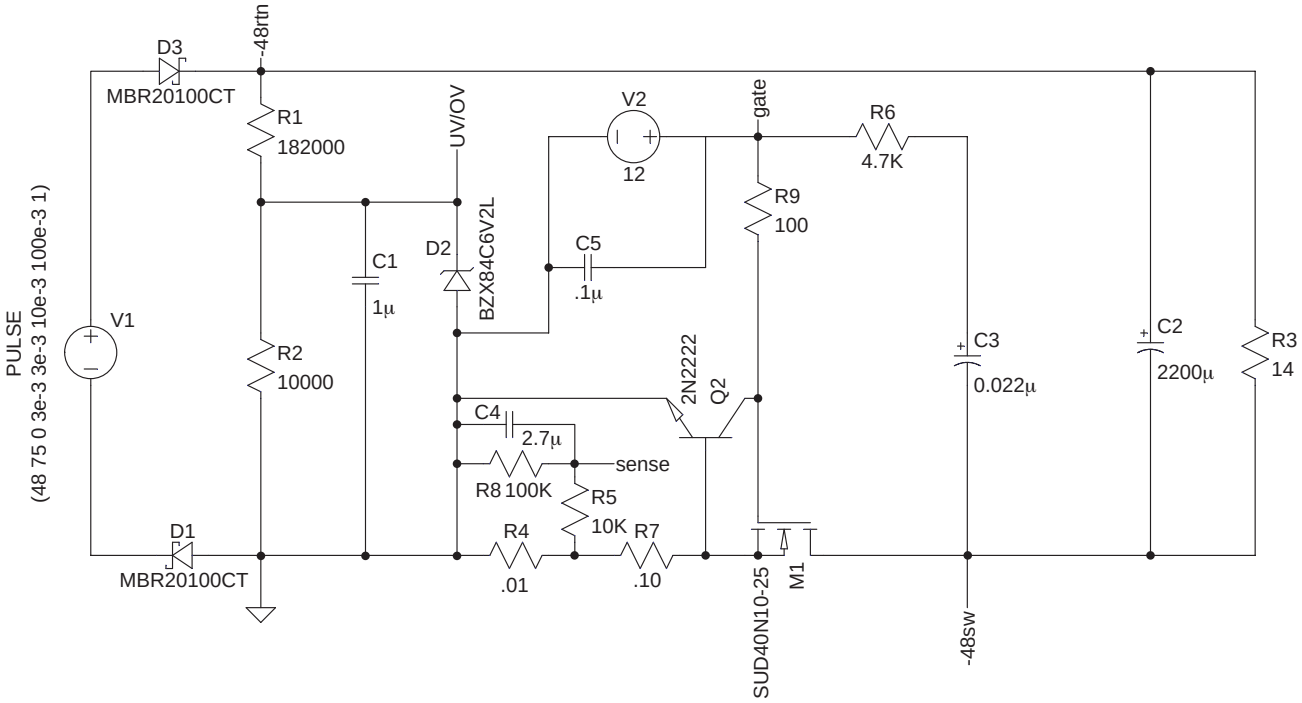

FIGURE 2. 48V to -74V VOLTAGE TRANSIENT SIMULATION CIRCUIT

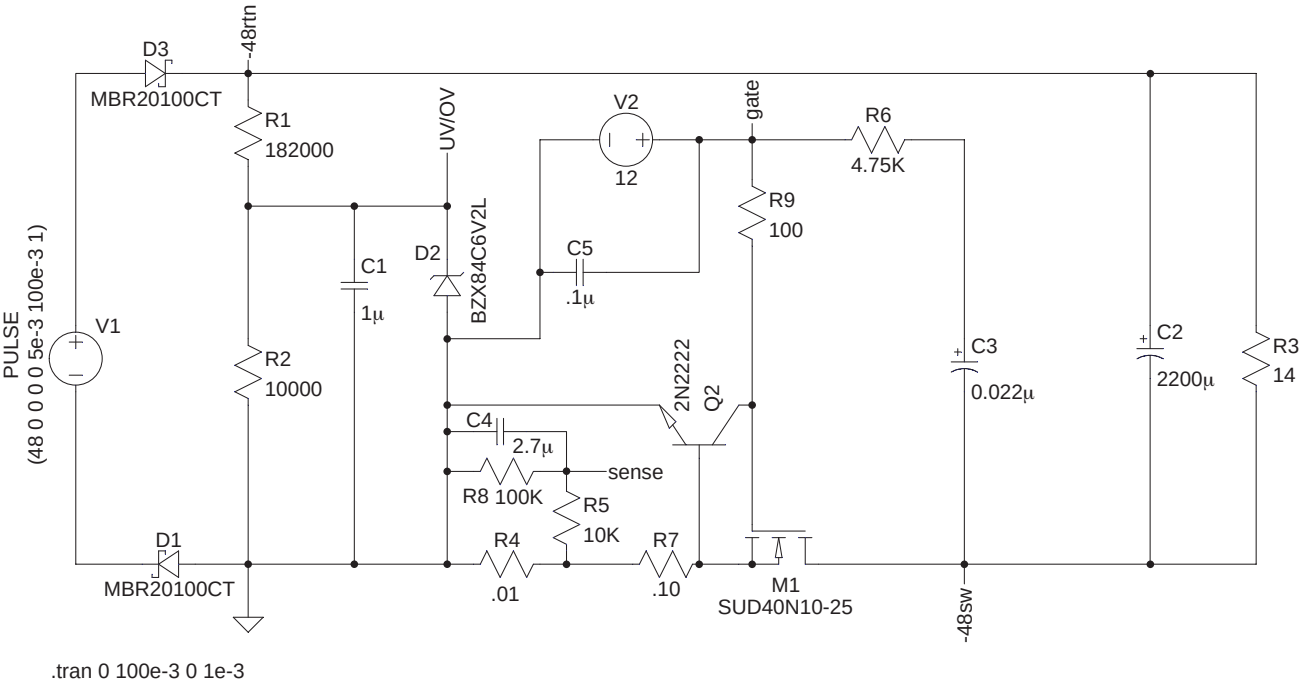

FIGURE 3. -48V to 0V VOLTAGE DROP-OUT SIMULATION CIRCUIT

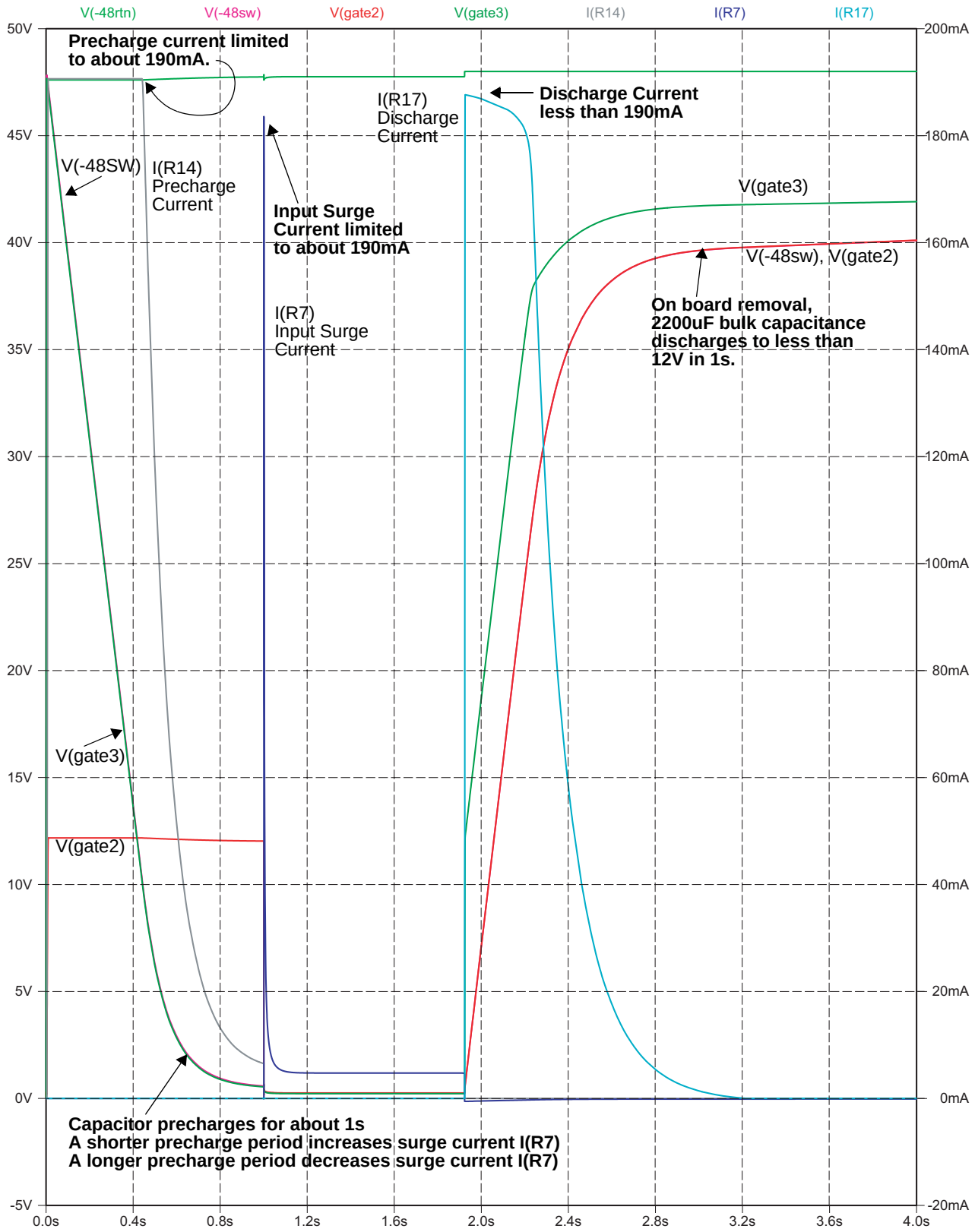

FIGURE 4. POWER UP AND DE-INSERTION PLOT

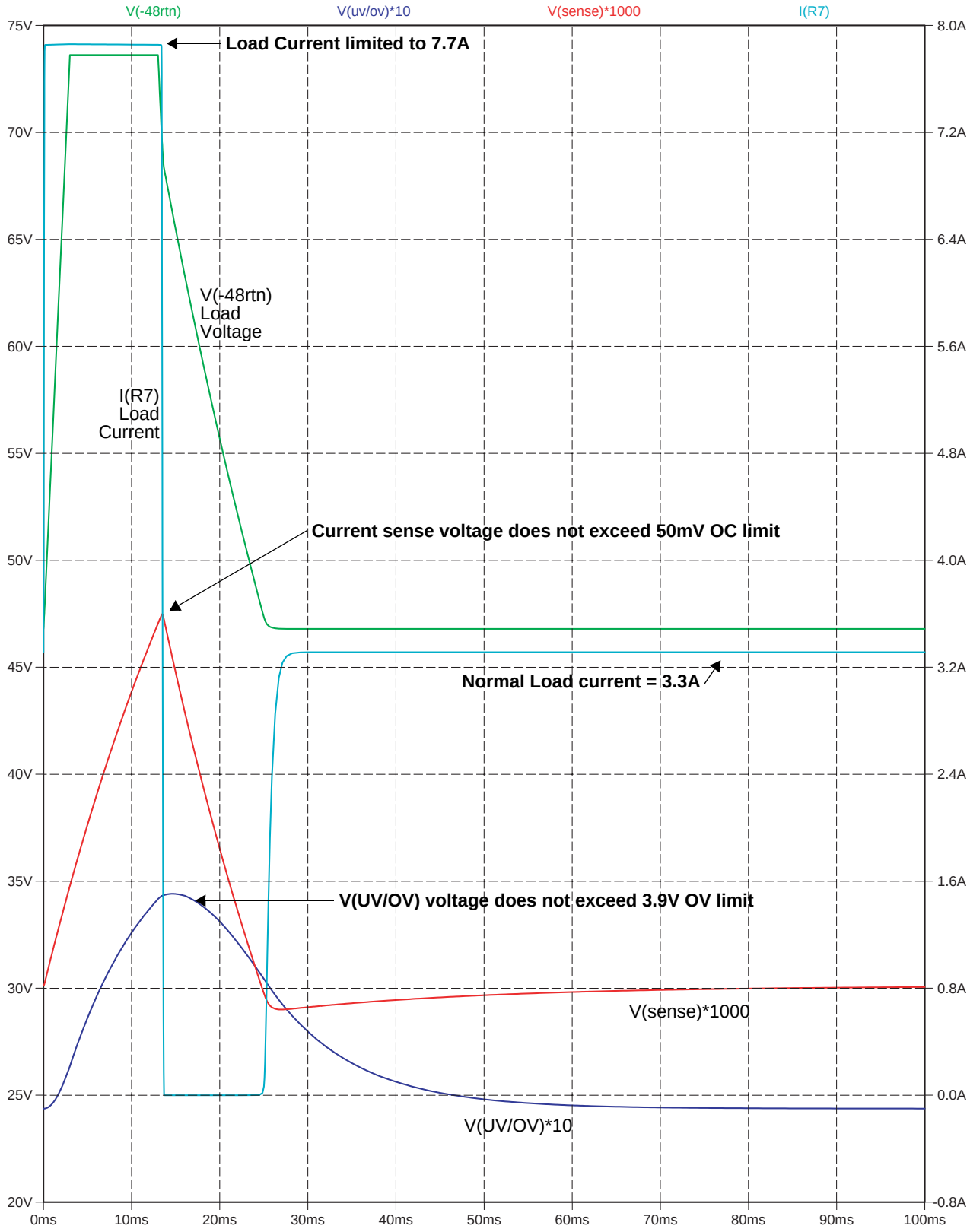

FIGURE 5. OV TRANSIENT TEST PLOT

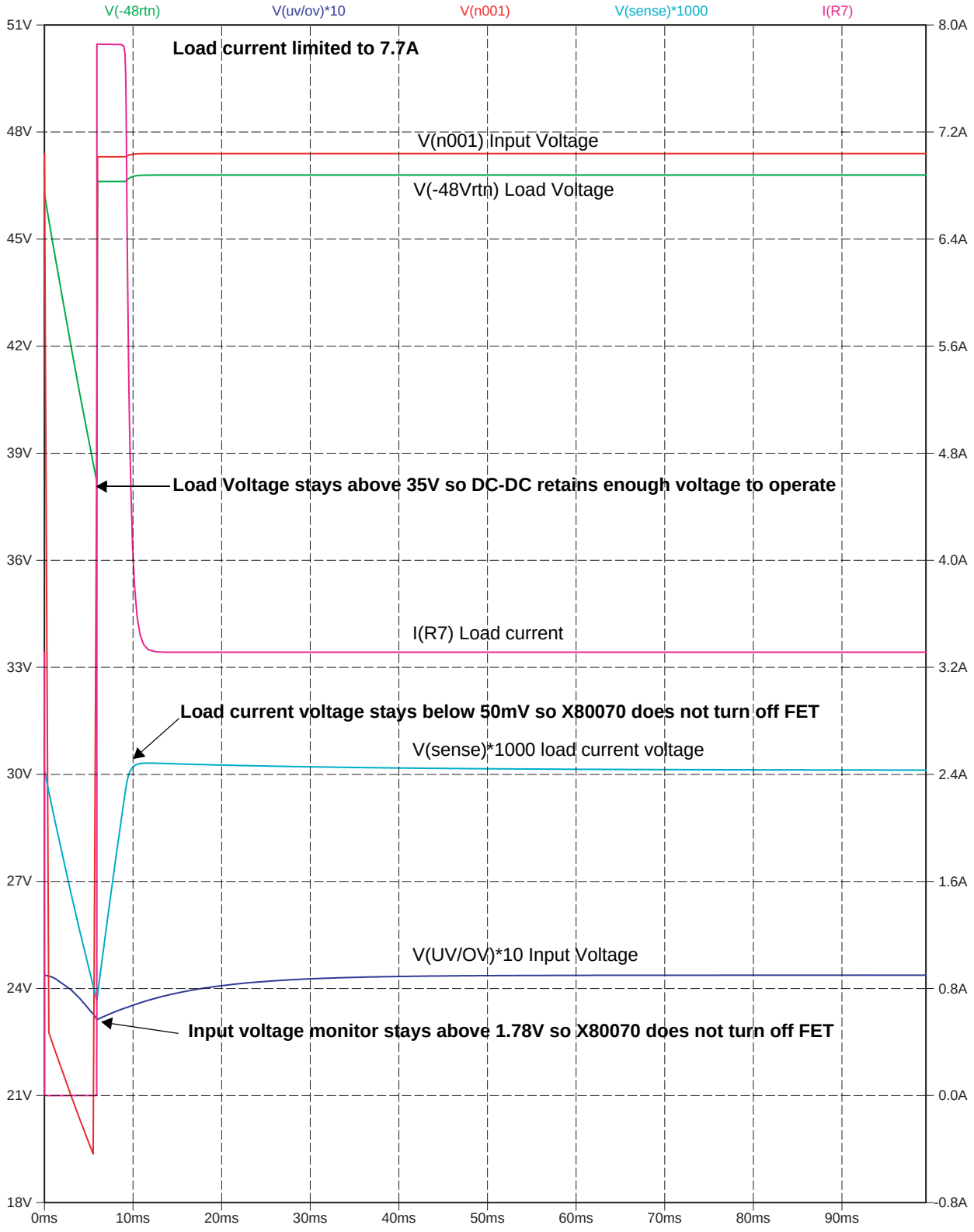

FIGURE 6. UV VOLTAGE DROP OUT TEST PLOT

Appendix 2 Bill of Materials

PART TYPE	DESIGNATOR	DESCRIPTION	PART NUMBER
1µF	C1	Capacitor	*
2200µF 100V	C2	Capacitor	Panasonic: ECO-S2AP222BA
0.022µF	C3	Capacitor	*
2.7µF	C4	Capacitor	*
0.1µF	C5	Capacitor	*
0.002µF	C6	Capacitor	*
0.1µF	C7	Capacitor	*
0.01µF	C8	Capacitor	*
0.1µF	C9	Capacitor	*
0.01µF	C10	Capacitor	*
0.01µF	C11	Capacitor	*
0.01µF	C12	Capacitor	*
0.01µF	C13	Capacitor	*
0.01µF	C14	Capacitor	*
MBRM5100	D1	Schottky Diode	Diodes: MBRM5100
6.2V	D2	Zener Diode	Fairchild: BZX84C6V2
MBRM5100	D3	Schottky Diode	Diodes: MBRM5100
12V	D4	Zener Diode	Fairchild: BZX84C12
12V	D5	Zener Diode	Fairchild: BZX84C12
MBRM5100	D6	Schottky Diode	Diodes: MBRM5100
MBRM5100	D7	Schottky Diode	Diodes: MBRM5100
BAS21	D8	Diode	Fairchild: BAS21
BAS21	D9	Diode	Fairchild: BAS21
BAS21	D10	Diode	Fairchild: BAS21
BAS21	D11	Diode	Fairchild: BAS21
4.7V	D12	Zener Diode	Fairchild: BZX84C4V7
12V	D13	Zener Diode	Fairchild: BZX84C12
7A	F1	Fuse	Littlefuse: 326007
7A	F2	Fuse	Littlefuse: 326007
7A	F3	Fuse	Littlefuse: 326007
7A	F4	Fuse	Littlefuse: 326007
FILTER	F5		Spectrum Control: PSM1-402P-10T
FILTER	F6		Spectrum Control: PSM4-402P-10T
FILTER	F7		Spectrum Control: SSM1-402E-10T
FILTER	F8		Spectrum Control: SSM1-402E-10T
FILTER	F9		Spectrum Control: PSM4-402P-10T
FILTER	F10		Spectrum Control: PSM4-402P-10T
FILTER	F11		Spectrum Control: SSM1-402E-10T
FILTER	F12		Spectrum Control: SSM1-402E-10T
200mA	F13	Fuse	Littlefuse: 326200
200mA	F14	Fuse	Littlefuse: 326200
200mA	F15	Fuse	Littlefuse: 326200

Appendix 2 Bill of Materials (Continued)

PART TYPE	DESIGNATOR	DESCRIPTION	PART NUMBER
FLTR100V10	F16		*
200mA	F17	Fuse	Littlefuse: 326200
IRFS23N15D	M1		*
IRFR120N/SM_2	M2		*
IRFR120N/SM_2	M3		*
DC-DC CONVERTER	M4		SynQor: PQ120QTA12
2N2222	Q1	NPN Transistor	*
2N2222	Q2	NPN Transistor	*
MJD340	Q3	NPN Transistor	*
2N3904	Q4	NPN Transistor	*
2N7002	Q5		*
2N7002	Q6		*
2N7002	Q7		*
182K 1%	R1		*
10K 1%	R2		*
27K	R3		*
10m 1W	R4		*
10K	R5		*
4.7K	R6		*
0.1 4W	R7		*
100K	R8		*
100	R9		*
200K	R10		*
100	R11		*
1.5K	R12		*
20K	R13		*
50 2W	R14		*
200K	R15		*
100K	R16		*
50 2W	R17		*
27K	R18		*
100K	R19		*
100K	R20		*
100K	R21		*
5.1K	R22		*
10K	R23		*
100	R24		*
X80070Q20	U1		*
TLP124B	U2		*
ADUM1401	U3		*

Application Schematic