SUMMIT MICROELECTRONICS, Inc.

Application Note 25

SMH4804, SMP9210 and SMT4004 Telecom Reference Design

INTRODUCTION

This Application Note presents the design of a power system required to convert the -48V bus to multiple voltages typically required by communication equipment such as network processors, DSPs, and miscellaneous ASICs. Included is a review of the entire design with both power management and power conversion blocks, focusing on areas where difficulties often arise. The power management is implemented using a hot swap controller SMH4804, a quad power supply manager SMT4004 and two dual 10-bit nonvolatile DACPOT™s SMP9210 for trimming. The power conversion block is built using Power-One's QHS series of 50A quarter-bricks. Guidelines and optional solutions are provided to increase the likelihood of a trouble-free system power design.

BLOCK DIAGRAM

Figure 1 below displays the block diagram of a –48V primary-side to secondary-side conversion circuit. The individual blocks are highlighted in broken-line boxes. All featured products contain non-volatile, I²C accessible configuration registers which allow design 'tweaks' and board level changes using a software-level interface instead of redesigns, recalls or component changes.

A brief description of each block and its primary functions follows.

Hot-Swap Controller (SMH4804)

Any board or circuit connected to the –48V supply must not cause any disturbance to the bus. A 'Hot-Swap' controller (SMH4804) is used to:

1. Permit live card insertion by soft-starting the in-rush current.
2. Shutdown –48V power to the native board when an overcurrent or other fault jeopardizes the bus.
3. Permit orderly power-on/off sequencing of the DC-DC converters. This includes primary to secondary isolation using opto-isolators with the necessary primary to secondary breakdown voltage rating.

Quad Power Supply Manager (SMT4004)

Once power is available on the secondary-side (the DC-DC converter outputs are active), the SMT4004 provides multiple-voltage tracking and monitors for voltage and current faults. Power supply voltage tracking has become an industry requirement due to the nature of network processors, ASIC's and other such devices using multiple voltages for I/O and core circuitry. The SMT4004 is highly programmable, allowing the management of a wide range of power supply voltages.

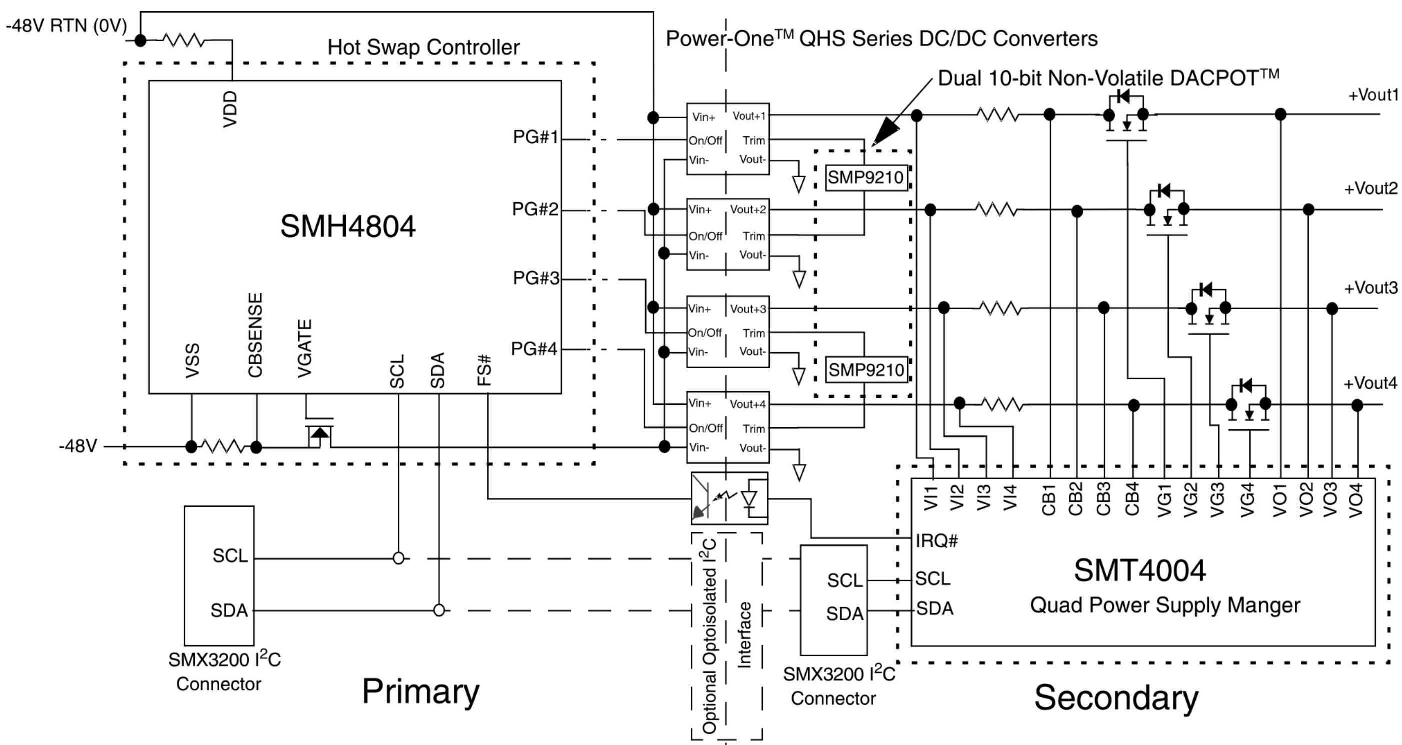


Figure 1: -48V Primary to Secondary-Side Conversion Circuit Block Diagram

Dual 10- Bit Non-Volatile DAC (SMP9210)
Precision control of the DC-DC converters' output voltages is used for voltage margin testing and minor adjustment as dictated by the layout of the printed circuit card and other factors relating to volume production of Telecom system cards. The SMP9210 Dual DACPOT provides a stable means of adjusting the converter output voltages while ridding the system of unreliable mechanical potentiometers.

Optional Opto-isolated I^2C Interface
All programmable devices are easily accessed 'live' with the use of an optically isolated I^2C interface. Low cost, low voltage opto-isolators maintain primary to secondary-side voltage and galvanic isolation permitting 'on the fly' communications with Summit's programmable integrated circuits. Communications may be established using a Summit supplied Dongle or the resident I^2C serial bus. Alternatively, the devices can be programmed separately with a primary and secondary I^2C Interface bus.

HOT-SWAP CONTROLLER SMH4804: (FIGURE 2)
Note: See the SMH4804 Data Sheet, AN21 and the SMH4804EV User's Guide for basic design information.

Nuisance Tripping Avoidance Tips
Although the SMH4804's programmable filter delay times are generally adequate to handle most overcurrent transients, a simple R-C filter placed across the current sense resistor prevents nuisance tripping in very harsh –48V environments. Using a telecom-like printed circuit board, the values of R_{22} and C_{12} were determined empirically by switching in a separate –48V feed (-48V_B) 10% higher in voltage than that already powering the board. The time constant of R_{22} and C_{12} is:

$$\tau = \left(1\times 10^{4}\right)\left(1\times 10^{-7}\right) = 1\text{ms}$$

This time constant adds to that pre-programmed into the SMH4804 circuit breaker configuration register.
Another concern raised by board insertion or the addition or removal of a –48V feed is the change in voltage experienced at the DRAIN SENSE pin of the SMH4804. This pin senses the drain voltage of the MOSFET during both the live-insertion and steady state intervals. An abrupt voltage increase on this pin causes the SMH4804 to immediately de-assert the PG# outputs and shutoff the MOSFET gate drive. Adding a small valued capacitor of 0.01uF-0.1uF from this pin directly to the V_{SS} pins prevents nuisance tripping and unwarranted downtime without otherwise jeopardizing normal operation.

External Slew-Rate Limiting Component Selection
The parasitic capacitances, both static and dynamic, of the N-Channel MOSFET require the addition of a few external components particularly since it is driven by a current source (100μA for the SMH48xx Family). When a card is live-inserted the SMH4804 VGATE output is high impedance until adequate voltage (>9V) is present on the VDD pin. This condition can allow the MOSFET to turn on if the bus produces enough gate voltage to exceed the threshold voltage of the MOSFET. This is prevented by adding 2 capacitors: one across the drain to gate terminal (C2), another across the gate to source terminal (C3). The resistor (R27) in series with C2 forms a negative feedback network with C2 to control the slew-rate current and total soft-start interval. Choose C2 to limit the inrush current during the soft-start interval:

$$C2 \geq \frac{C_{Bulk} \times I_{VGATE}}{I_{Inrush}}$$

Where:
C_{Bulk} is the total capacitance on the drain side the MOSFET (include that present in the DC-DC converters).

I_{VGATE} is the nominal gate drive current from the VGATE pin (100μA).

I_{Inrush} is the maximum desired current passing through the MOSFET during the soft-start interval.

Note: The time required to charge the bulk capacitance is inversely proportional to the inrush current.

Choose C3 to prevent the MOSFET from turning on before the SMH4804 VGATE output becomes active:

$$C3 \geq \left(\frac{V_{IN(MAX)}}{V_{GS(th)}} - 1\right) \times \left(C2\right)$$

Where:
$V_{IN(MAX)}$ is the maximum bus input voltage.

$V_{GS(th)}$ is obtained from the MOSFET data sheet.

Choose the maximum value of R27 that does not interfere with the soft-start action resulting from I_{VGATE} and C2:

$$R27 \leq \frac{I_{VGATE}}{10 \times C2}$$

Reducing R27 below 1kΩ diminishes its usefulness for snubbing and damping abrupt voltage changes so prevalent in –48V Telecom environments.

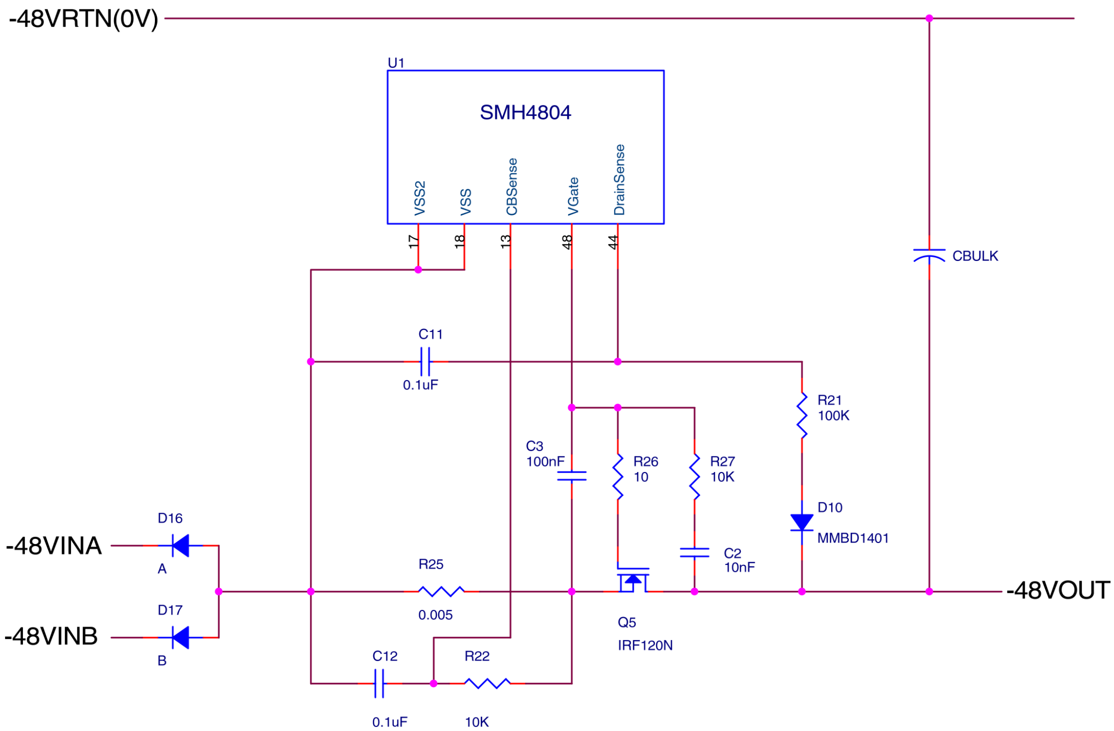


Figure 2: -48V Hot-Swap Circuit Additional Filtering Eliminates Nuisance Tripping

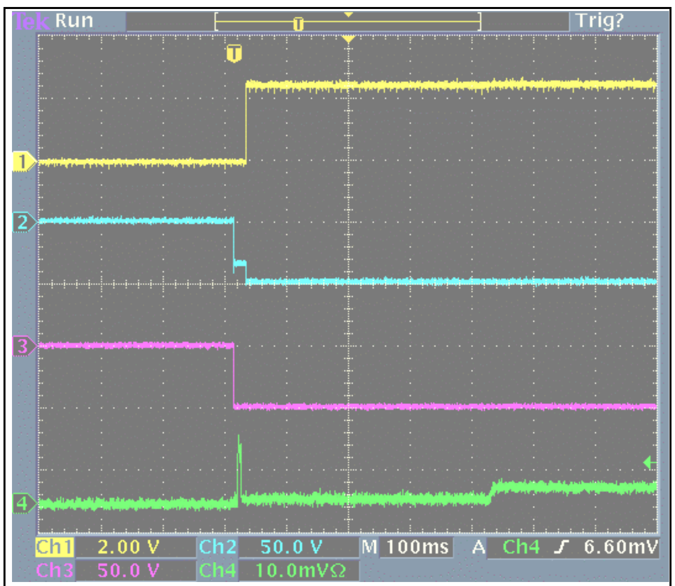


Figure 2A: SMH4804 Hot-Swap (Live-insertion) Event

Tektronix TDS3054 Time/Horizontal division = 100mS
Ch 1: (2V/Div) = 2.5V DC-DC converter output (Yellow trace)
Ch 2: (50V/Div) = SMH4804 PG2# (Blue trace) – Note 1
Ch 3: (50V/Div) = Switched –48V supply (Purple trace)
Ch 4: (2A/Div) = -48V Input inrush current (Green Trace)

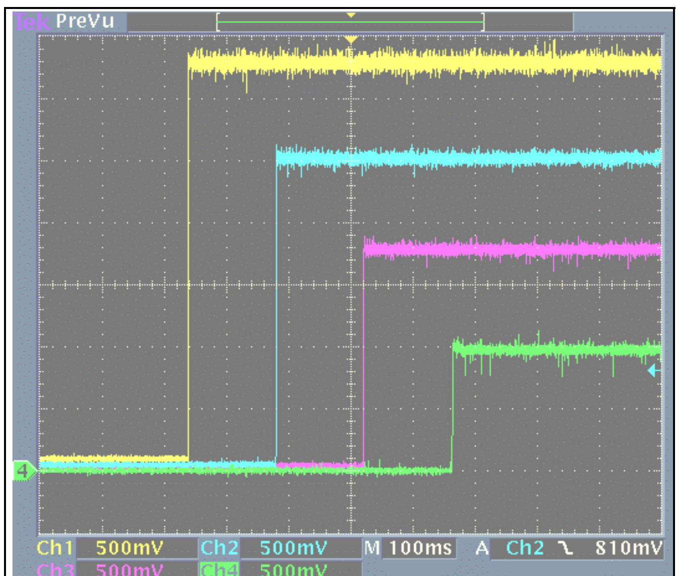


Figure 2B: SMH4804 DC-DC Converter Power On Sequencing Event

Tektronix TDS3054 Time/Horizontal division = 100mS
Ch 1: (1V/Div) = 3.3V DC-DC converter output (Yellow trace)
Ch 2: (1V/Div) = 2.5V DC-DC converter output (Blue trace)
Ch 3: (1V/Div) = 1.8V DC-DC converter output (Purple trace)
Ch 4: (1V/Div) = 1.0V DC-DC converter output (Green Trace)

Note 1 – The PG# outputs first drop to –43V after initial hot swap conditions are met until ready to sequence the DC-DC converter. When ready to sequence, the outputs then drop an additional 5V to enable the DC-DC converter.

QUAD SUPPLY MANAGER (SMT4004): FIGURE 3

Note: See the SMT4004 Data Sheet, AN20, AN22 and the SMT4004EV User's Guide for basic design information.

Nuisance Tripping Avoidance Tips

Some applications using the SMT4004 benefit from the addition of minor external filtering. Additional immunity to transient overcurrent events is obtained by adding an R-C filter between the current sense resistor and the CBx input pin. A 1mS time constant delay results from the addition of R18 and C51.

DC-DC converters exhibiting poor transient output voltage response or excessive output ripple voltage may disturb the tracking waveforms. The addition of a small-value capacitor to each VGATE output (C50) of 1-10nF lowers the effective output impedance of these pins making them less vulnerable to step voltage changes occurring on the drain and source terminals of the MOSFET (Q1).

The capacitor values shown on the VGG_CAP, VDD_CAP and 1.25VREF pins are proven to be ideal for most applications. Be certain to locate these components physically close to the SMT4004 and connect them directly to the device's ground pins.

Systems exhibiting a pre-existing 'early voltage' on the card-side may not track properly if this voltage is excessive (>0.5V). Use a suitable MOSFET (Q6) to discharge this voltage prior to the tracking interval. This function is covered in more detail in the SMT4004 data sheet and other related material found on Summit Microelectronics' web site:

http://www.summitmicro.com/.

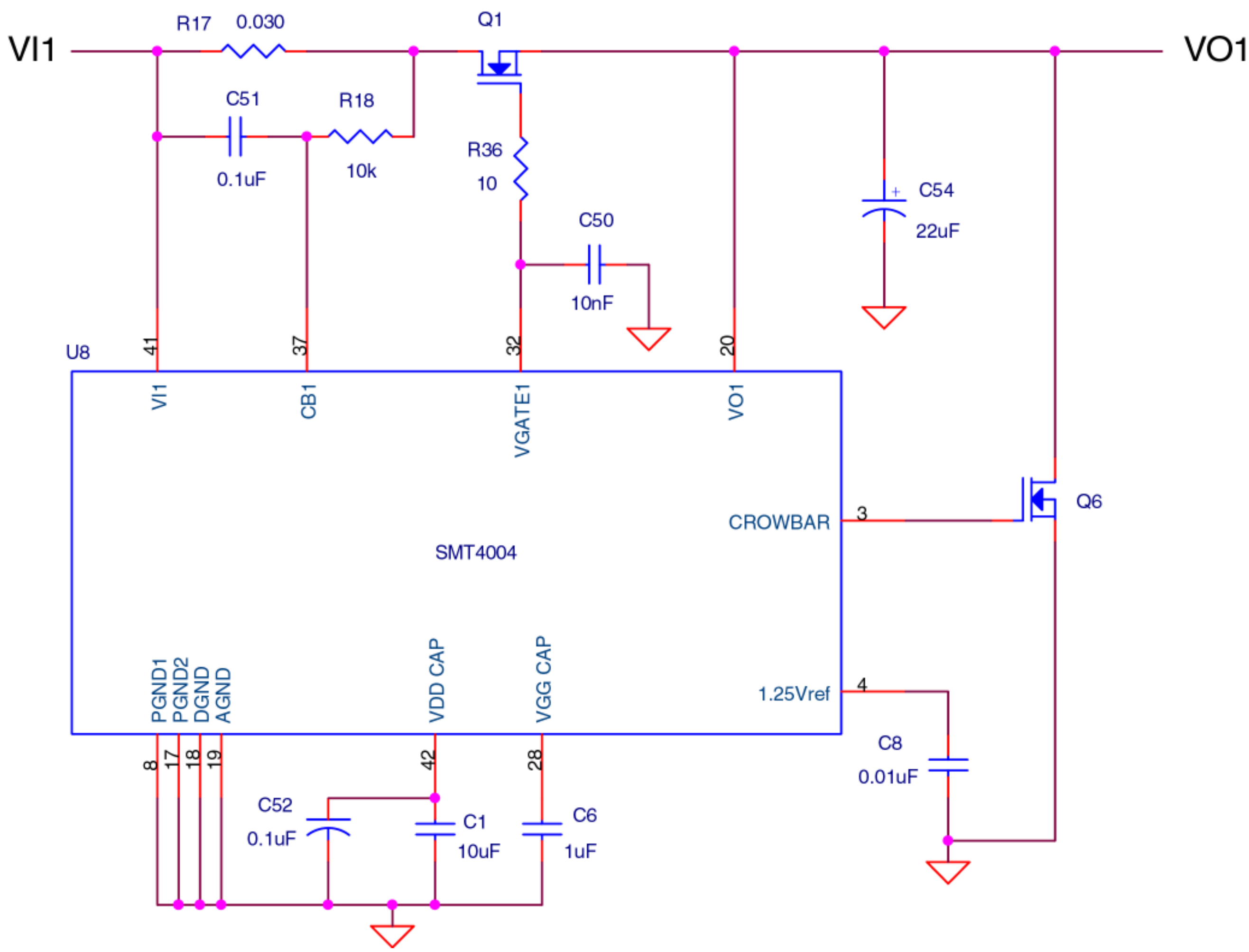


Figure 3: Quad Tracker/Manager Filtering and 'Early Voltage' Circuits

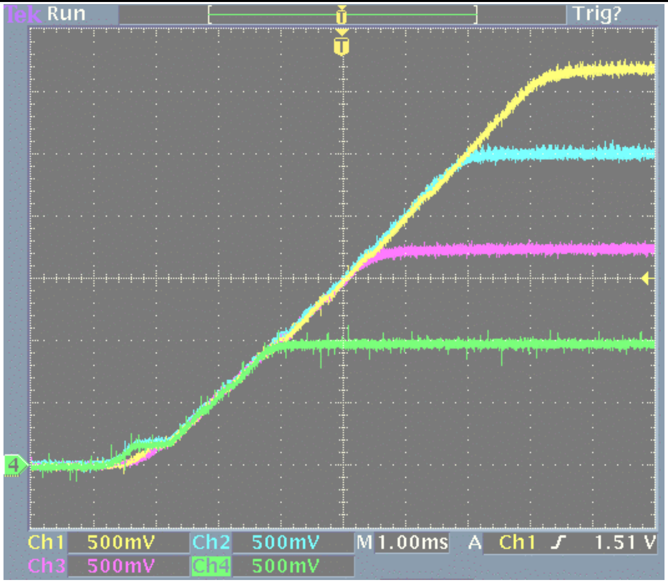


Figure 3A: SMT4004 Tracking Up Event
Tektronix TDS3054
Time/Horizontal division = 1mS

Ch 1: (500mV/Div) = 3.3V Card-Side voltage (Yellow trace)
Ch 2: (500mV/Div) = 2.5V Card-Side voltage (Blue trace)
Ch 3: (500mV/Div) = 1.8V Card-Side voltage (Purple trace)
Ch 4: (500mV/Div) = 1.0V Card-Side voltage (Green trace)

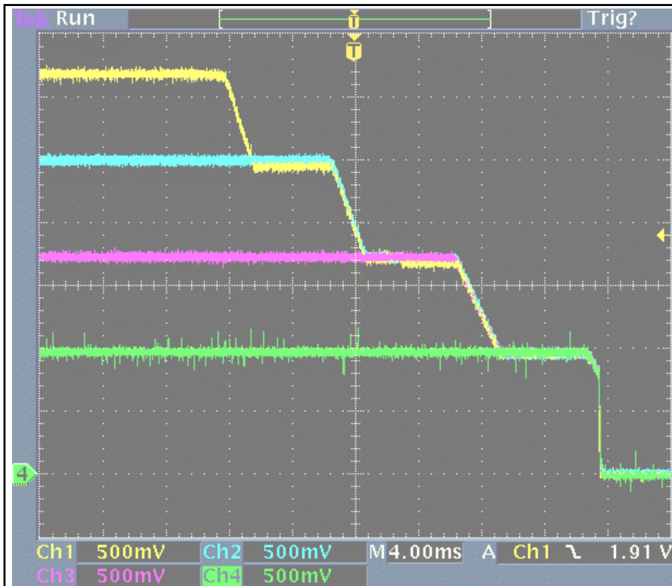


Figure 3B: SMT4004 Tracking Down Event
Tektronix TDS3054
Time/Horizontal division = 4mS

Ch 1: (500mV/Div) = 3.3V Card-Side voltage (Yellow trace)
Ch 2: (500mV/Div) = 2.5V Card-Side voltage (Blue trace)
Ch 3: (500mV/Div) = 1.8V Card-Side voltage (Purple trace)
Ch 4: (500mV/Div) = 1.0V Card-Side voltage (Green trace)

Line Filtering

The EMI filters shown in Figure 15 (U13 and U17), are used to suppress any noise riding on the –48 Volts supply and/or any noise coming from the card supplies that may disturb the card itself or another card in the system. Often times these filters are required to meet conducted (and radiated) emissions standards.

The advantages of split EMI filtering (U13 and U17) may be undermined by the introduction of excessive inrush currents into the filter (U13) residing on the –48V bus (see scope photo, Figure 5B and 5C).

The cause of the inrush current is the C_X (line to line) capacitor, Figure 4. To minimize the inrush current choose a filter with the lowest possible C_X capacitor value. To ensure the inrush current does not disturb the –48V bus, either add a capacitor with a value 5 times that of the filter's C_X capacitor nearby the system card on the motherboard or backplane. Another option is to remove U13 and only use U17. Figure 5A shows the Inrush current without the input EMI filter (U13 removed). Figure 5B shows the inrush current for a filter with a lower C_X capacitor value.

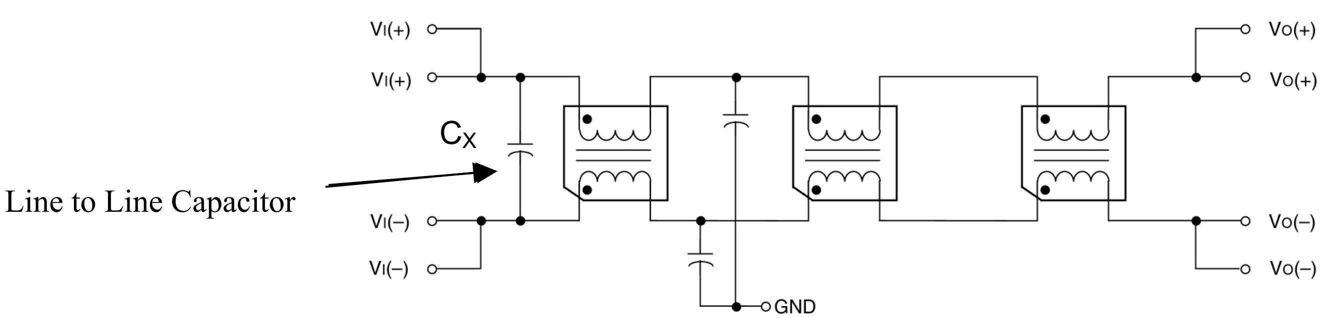


Figure 4 – Internal schematic of the EMI Filters

Figure 5A No EMI Filter before the SMH4804, 5A/div

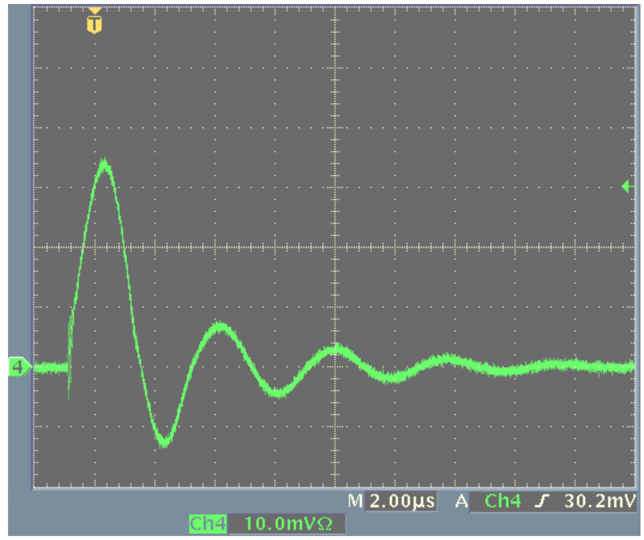


Figure 5B –Power One 10A EMI Filter, 5A/div

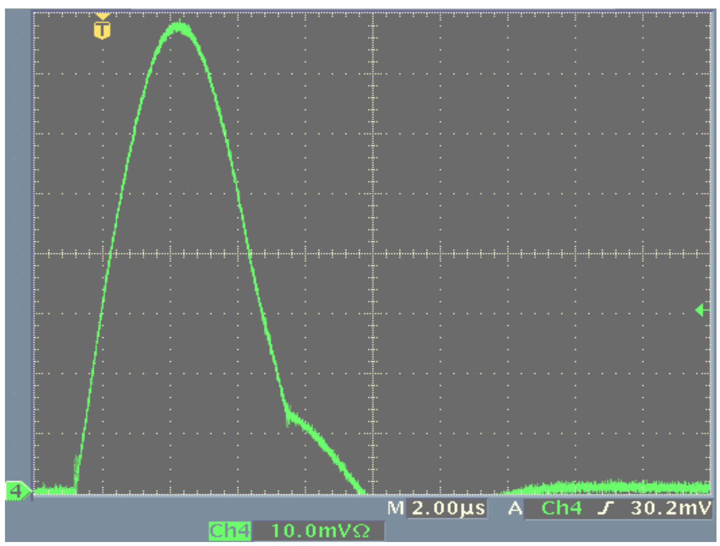


Figure 5C –Tyco 20A EMI Filter, 5A/div

DUAL NON-VOLATILE DAC (SMP9210): FIGURE 6

Nearly all DC-DC converters contain a Trim input pin for minor adjustment to the output voltage. The Trim pin is connected to an internal voltage reference of 1.2V through a series resistor allowing an external impedance, current or voltage source to adjust the output voltage by as much as ±10%. Using the I^2C interface, the SMP9210 DACPOT's output voltage is programmed to finely position the converter output voltage to within specification at the load.

Voltage margining is also possible as is often required during production testing or field-testing to ensure system stability over the permitted operating voltage range.

Local bypassing of the VDD, VREFH and VOUT pins reduces inaccuracies caused by the output ripple voltage from the converters.

Ultra-high resolution of the output voltage setting is achieved using the circuits displayed in Figures 7A and 7B.

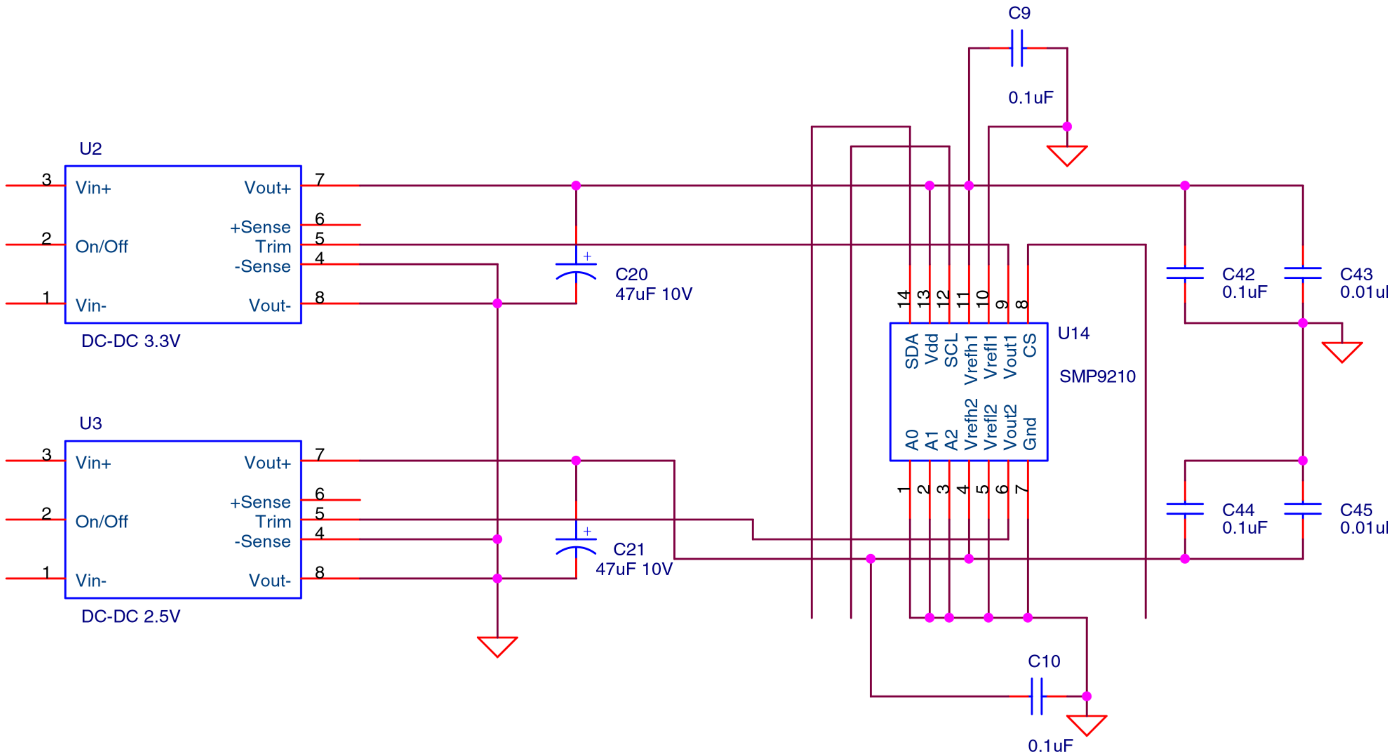
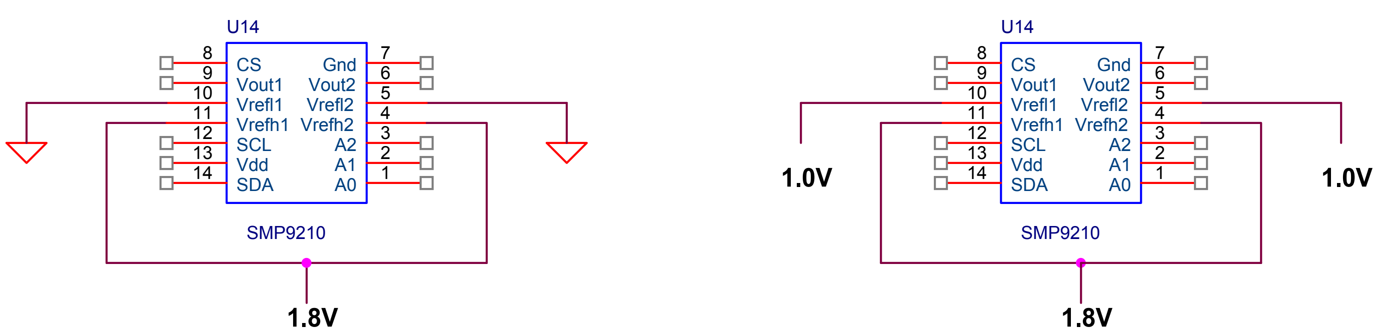


Figure 6: Dual DACPOT to DC-DC Converter Trim/Margin Interface



7A – Minimum trim step = 1.8V/1024 = 1.75mV

7B – Minimum trim step = 1.8V-1.0V/1024 = 781µV

Figure 7A and 7B: Increasing the Trim Resolution

OPTIONAL OPTOISOLATED I²C INTERFACE

The SMH4804 and SMT4004 are usually connected to separate I²C busses, one on the Primary and the other on the Secondary-side of the line card (connected separately to J1 and J5 SMX3200 I²C Headers). However, an optional optically-isolated I²C serial programming bus extends the usefulness of the programmable circuits mentioned herein beyond simple tweaking to field applications where system maintenance, cycling or repairs must be made with minimal down-time. A readily available, low-voltage CMOS logic-level opto-isolator with open drain outputs allows programming of the primary and secondary-side components using the same I²C serial bus (Figure 8). The addition of a low-power, isolated DC-DC converter (U12) allows the system card to be removed for closer inspection. Shown here on the primary-side, the converter is as easily used on the secondary-side if required (Figure 13).

Vendor Part Numbers & Contact Info:

3.3V Digital Opto-Coupler, HCPL-063L:

<u>Agilent</u>: http://www.agilent.com/

DC-DC Converter, B1-0505SSH:

<u>BOTHHAND</u>: http://www.bothhand.com/

Caution: If the system card is live when a programming interface cable is connected, be certain the GND connection of the interface cable is not connected to earth. Otherwise damage and or injury may result.

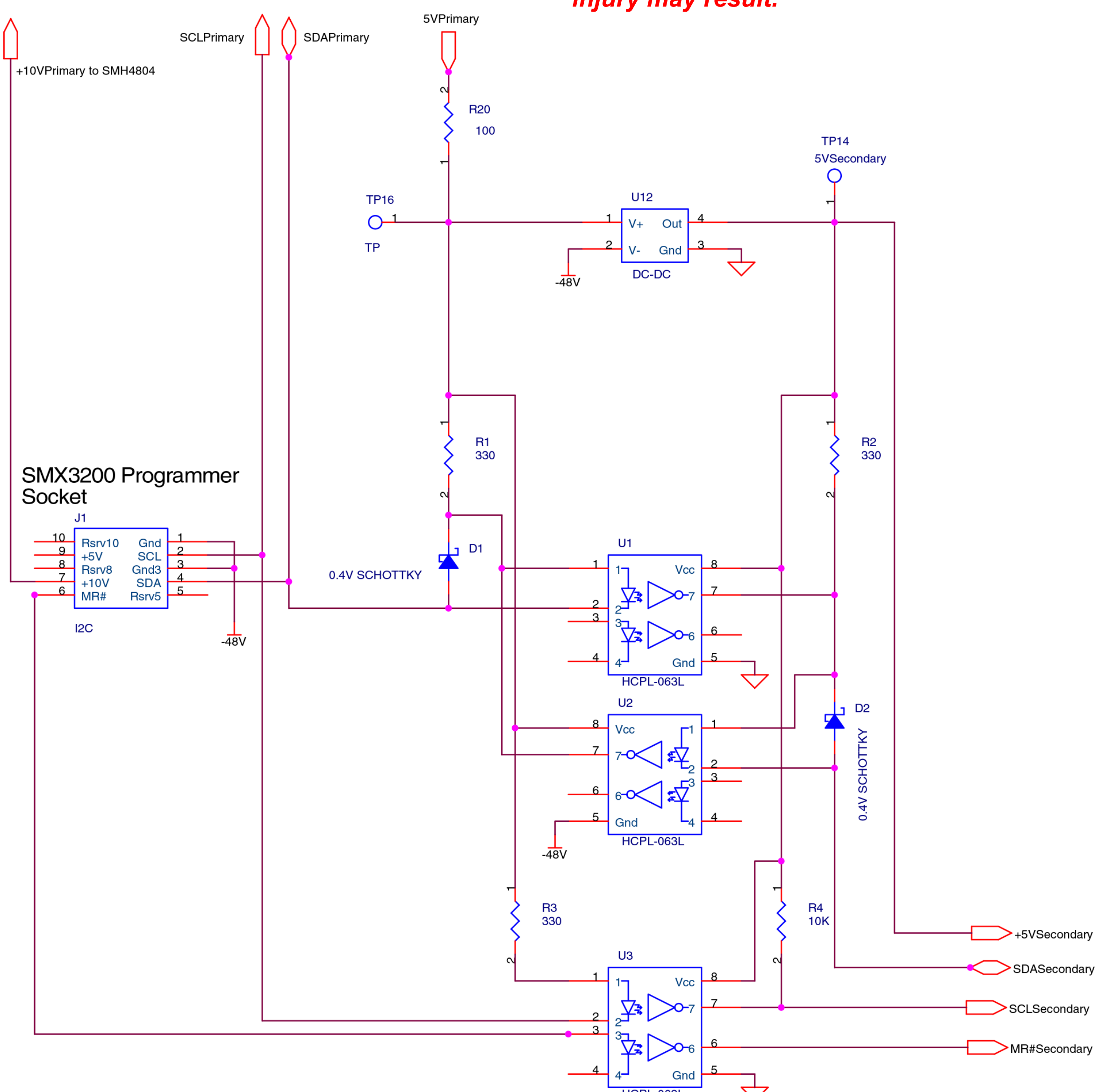
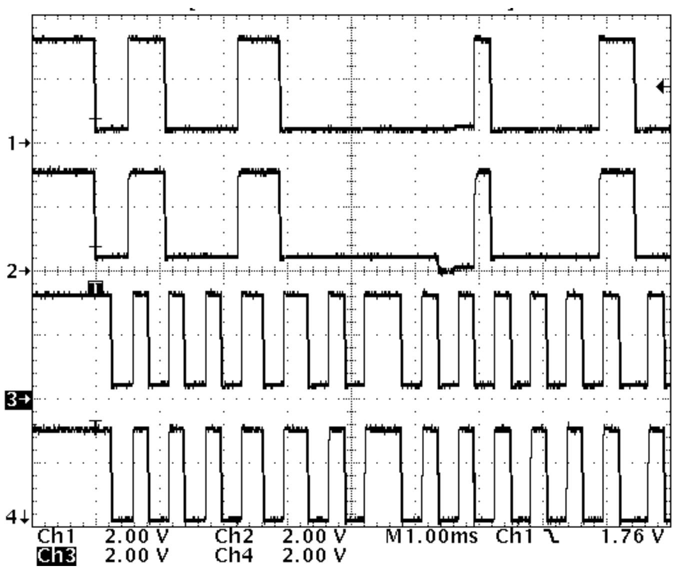


Figure 8: Optional Isolated I²C Interface: Powered and Driven from the Primary-Side



Channel 1 is the SDA-primary signal
Channel 2 is the SDA-secondary signal
Channel 3 is the SCL-primary signal
Channel 4 is the SCL-secondary signal

Figure 9: Isolated I²C Interface: Powered from the Primary-Side, SDA/SCL-primary (Channel 1 and 3) and SDA/SCL-secondary (Channel 2 and 4).

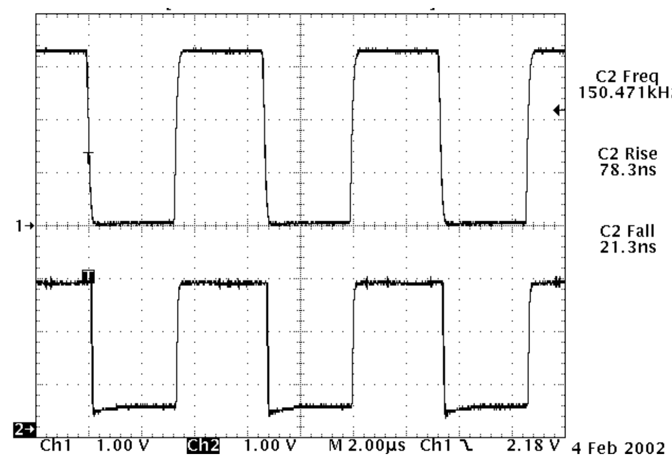


Figure 10: Isolated I²C Interface: Powered from the Primary-Side. This graph indicates the frequency, rise and fall time for the SDA-secondary.
Channel 1 is the SDA-primary signal
Channel 2 is the SDA-secondary signal

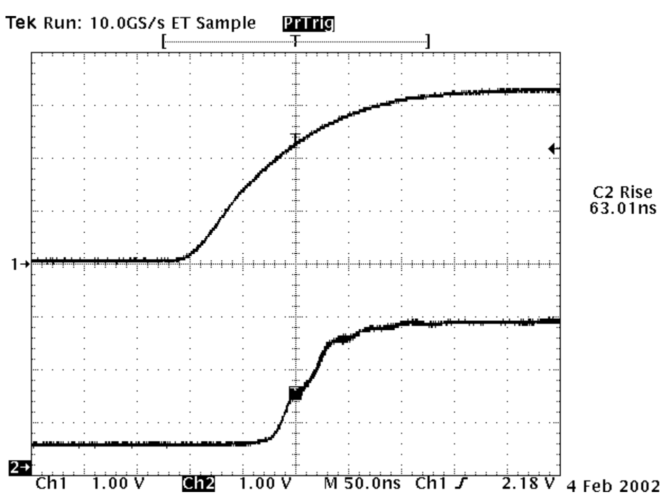


Figure 11: Isolated I²C Interface: Powered from the Primary-Side, the rise time of the SDA Secondary-Side Waveform.
Channel 1 is the SDA-primary signal
Channel 2 is the SDA-secondary signal

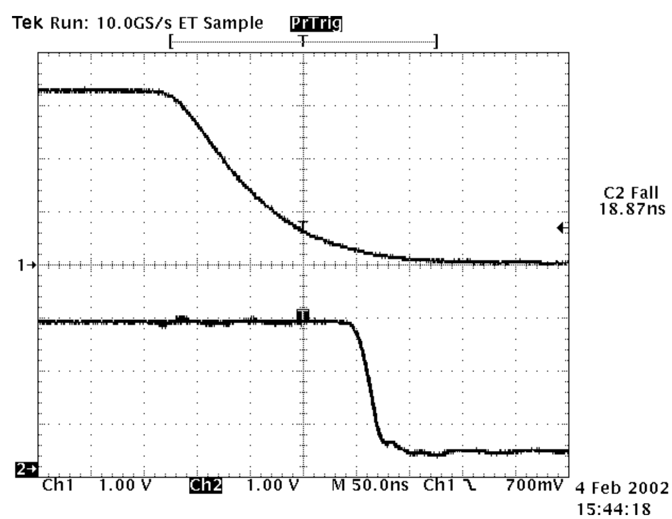


Figure 12: Isolated I²C Interface: Powered from the Primary-Side, the fall time of the SDA Secondary-Side Waveform.
Channel 1 is the SDA-primary signal
Channel 2 is the SDA-secondary signal

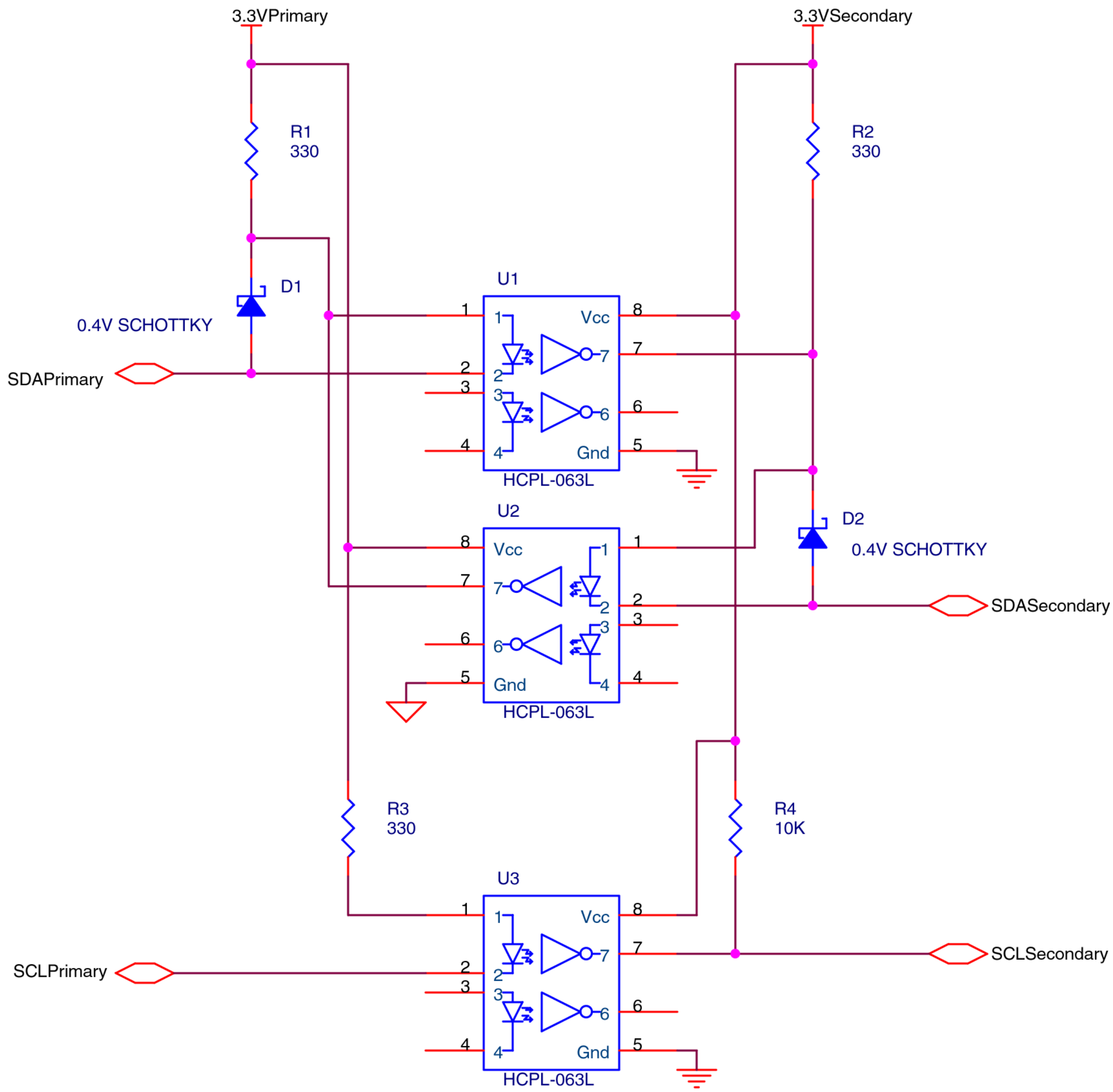


Figure 13: Optional Isolated I²C Interface: Powered Separately and Driven from the Secondary-Side

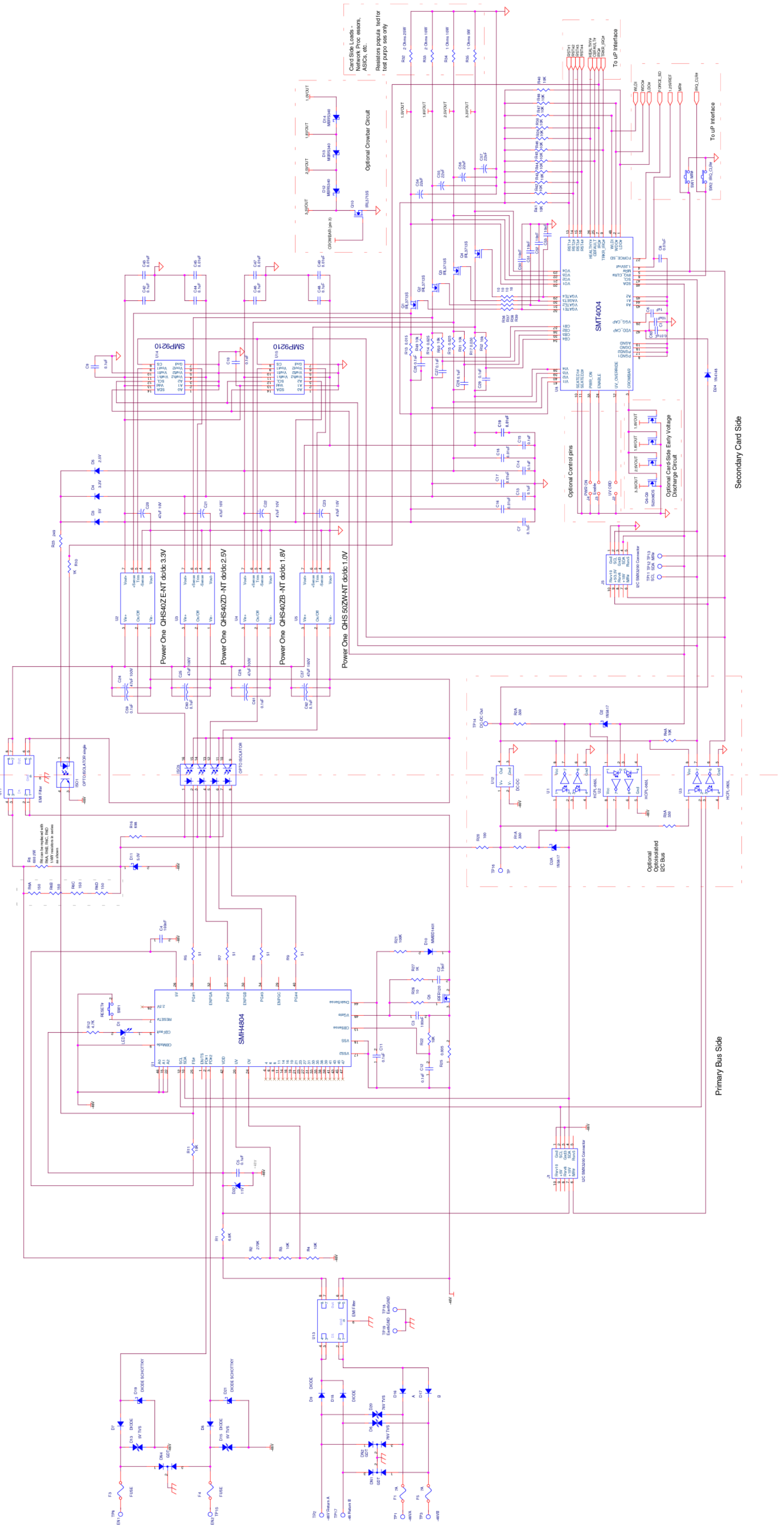


Figure 14 - Entire SMH4804/SMP9210/SMT4004 Schematic.

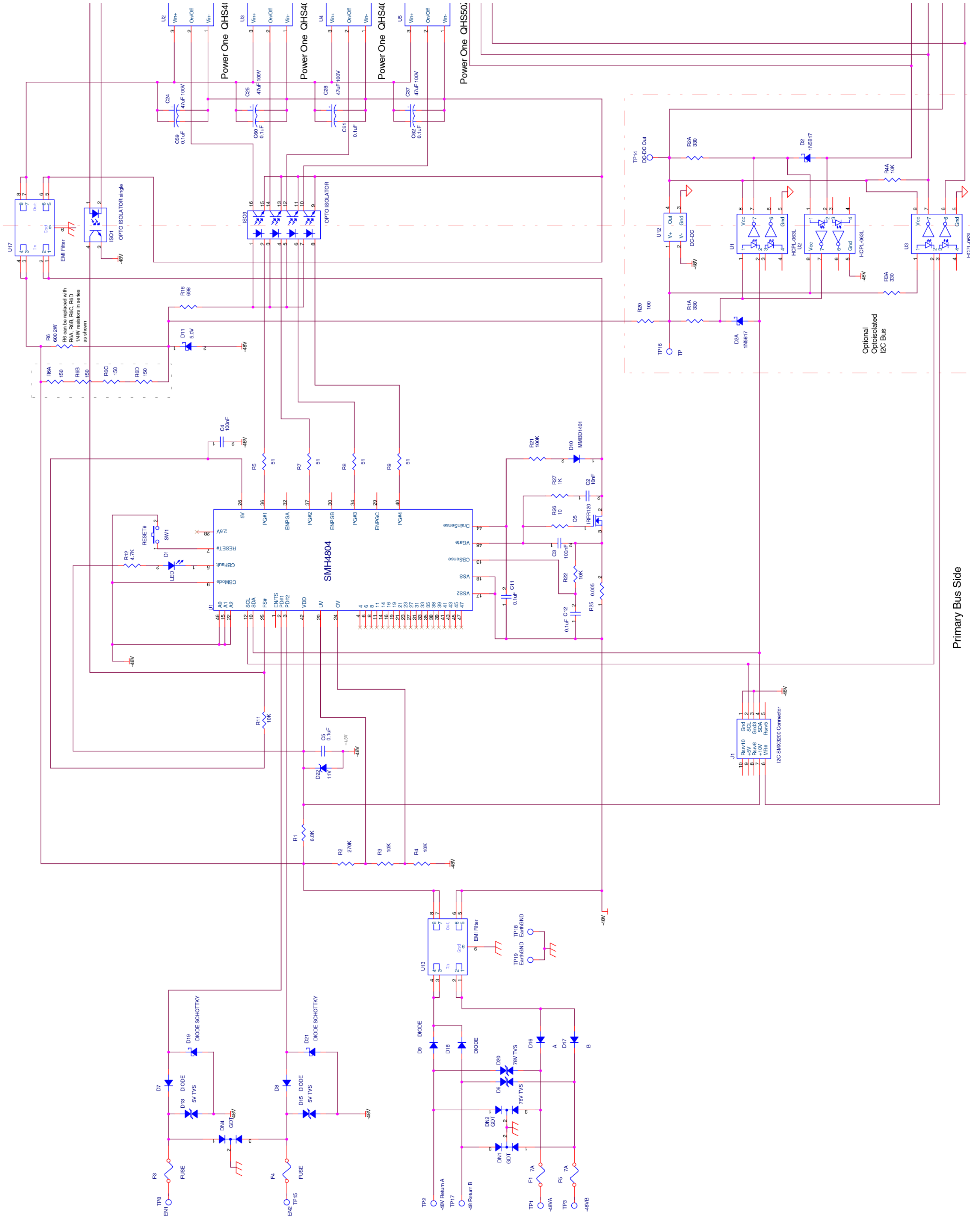


Figure 15 - Entire SMH4804 Primary Bus Side Schematic.

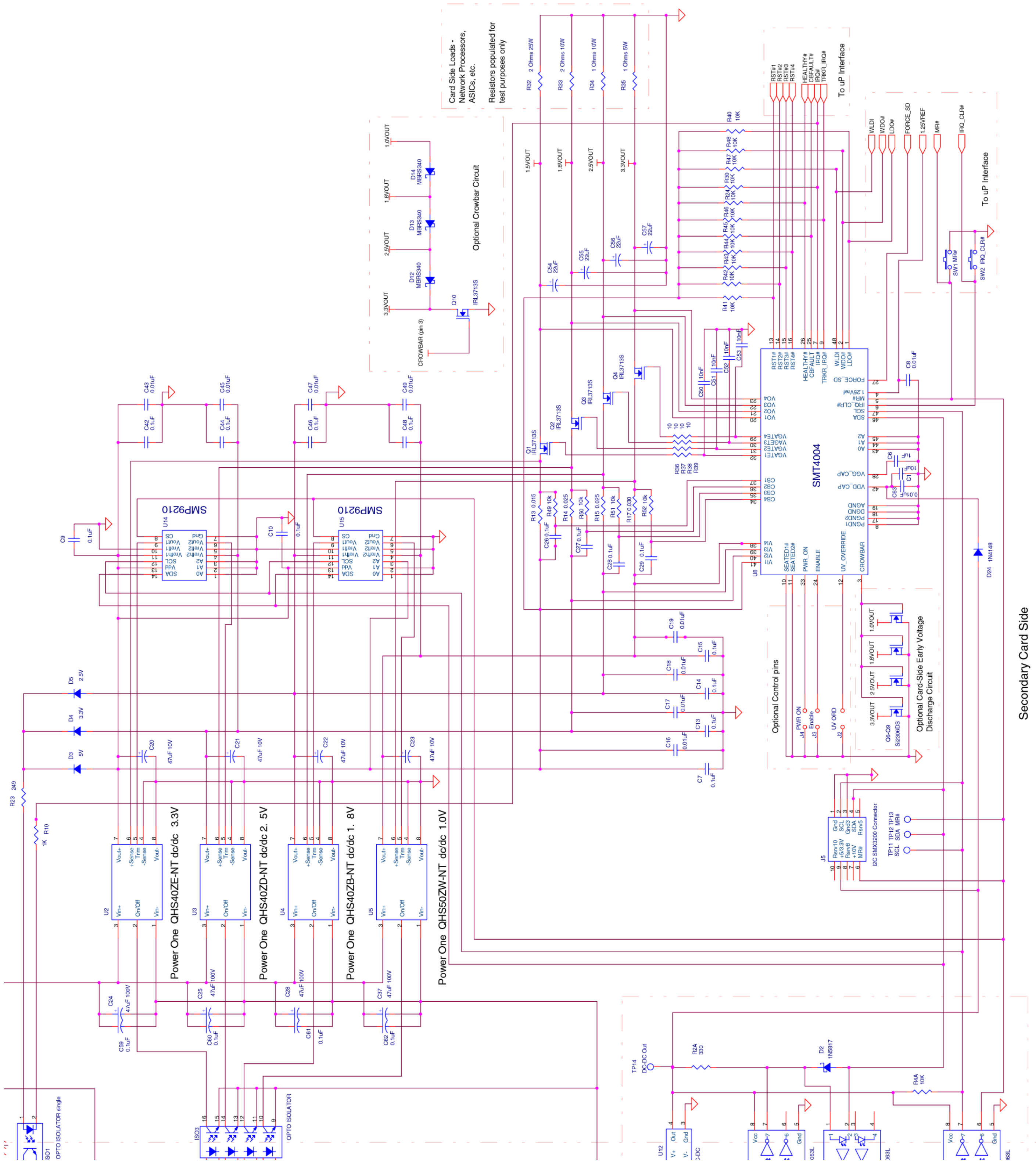


Figure 16 - Entire SMT4004 Secondary Card Side Schematic.

Table 1 - Parts List

Item	Description	Vendor / Part Number	Qty	Ref. Des.
		Resistors		
1	6.8KΩ, 1W, 5%, 2512, SMD	Any	1	R1
2	270KΩ, 1/10W, 5%, 0805, SMD	Any	1	R2
3	330Ω, 1/10W, 5%, 0805, SMD	Any	3	R1A-R3A
4	10KΩ, 1/10W, 5%, 0805, SMD	Any	20	R3, R4, R4A, R11, R22, R24, R30, R40-48, R49-R52
5	51Ω, 1/10W, 5%, 0805, SMD	Any	4	R5, R7-R9
6	150Ω, 1/10W, 5%, 0805, SMD	Any	4	R6A-R6D
7	600Ω, 1/2W, 5%, leaded	Any	1	R6
8	1KΩ, 1/10W, 5%, 0805, SMD	Any	4	R10, R27
9	4.7KΩ, 1/10W, 5%, 0805, SMD	Any	1	R12
10	698Ω, 1/10W, 1%, 0805, SMD	Any	1	R16
11	100Ω, 1/10W, 5%, 0805, SMD	Any	1	R20
12	100KΩ, 1/10W, 5%, 0805, SMD	Any	1	R21
13	249Ω, 1/10W, 1%, 0805, SMD	Any	1	R23
14	10Ω, 1/10W, 5%, 0805, SMD	Any	5	R26, R36-R39
15	0.015Ω, Current-Sense, SMD	IRC OARS series, #OARS-1	1	R13
16	0.025Ω, Current-Sense, SMD	IRC OARS series, #OARS-1	2	R14, R15
17	0.030Ω, Current-Sense, SMD	IRC OARS series, #OARS-1	1	R17
18	0.005Ω, Current-Sense, SMD	IRC OARS series, #OARS-1	1	R25
19	2Ω, 25W, 5%	Load Resistors used for test	1	R32
20	2Ω, 10W, 5%	Load Resistors used for test	1	R33
21	1Ω, 10W, 5%	Load Resistors used for test	1	R34
22	1Ω, 5W, 5%	Load Resistors used for test	1	R35
		Capacitors		
23	10uF, 10V, Tantalum, Size ‘B’	AVX, TAJB106M010	1	C1
24	0.01uF, 100V, ceramic, X7R, 1206, SMD	Any	1	C2
25	0.1uF, 50V, ceramic, X7R, 1206, SMD	Any	23	C3-C5, C7, C9, C10-15, C26-C29, C42, C44, C46, C48, C59, C60-C62
26	1uF, 25V, Tantalum, Size ‘A’ or ‘B’	AVX, TAJA105M025	1	C6
27	0.01uF, 50V, ceramic, X7R, 1206, SMD	Any	9	C8, C16-C19, C43, C45, C47, C49, C63
28	47uF, 10V, electrolytic	Digi-Key P/N P11180-ND	4	C20-C23
29	47uF, 100V, electrolytic	Digi-Key P/N P5596-ND	4	C24, C25, C28, C37
30	NP – 10nF, 50V, ceramic, X7R, 1206, SMD	Any	4	C50-C53
31	22uF, 10V, Tantalum, Size ‘B’	AVX, TAJB226M010	4	C54-C57

Item	Description	Vendor / Part Number	Qty	Ref. Des.
DC-DC Converters				
32	-48V to 3.3V DC-DC Converter	Power One QHS40ZE-NT	1	U2
33	-48V to 2.5V DC-DC Converter	Power One QHS40ZD-NT	1	U3
34	-48V to 1.8V DC-DC Converter	Power One QHS40ZB-NT	1	U4
35	-48V to 1.0V DC-DC Converter	Power One QHS50ZW-NT	1	U5
Semiconductors				
36	LED, Red, 0805, SMD	Digi-Key, P/N 67-1552-1-ND	2	D1
37	Diode, Schottky, 20V, 1.0A, SMD	Digi-Key P/N 1N5817DICT-ND	4	D2, D2A, D19, D21
38	Diode, Small Signal, 1N4148, SMD	Any	8	D3-D5, D7-D9, D18, D24
39	Transzorb, 70V, 15,000W	Crydom P/N 15KP70A	2	D6, D20
40	Diode, 200V, 1.0A, SMD	Fairchild MMBD1401	1	D10
41	Diode, Zener, 5.1V, 500mW, SMD	Digi-Key P/N ZMM5231BCT-ND	1	D11
42	Transzorb, 5V, 600W	Digi-Key P/N SMBJ5.0CADICT-ND	2	D13, D15
43	Diode, Schottky, 40V, 3.0A, SMD	On Semiconductor, MBRS340	3	D12, D13A, D14
44	Diode, 100V, 3A		2	D16, D17
45	Diode, Zener, 11V, 500mW, SMD	Digi-Key P/N ZMM5241BCT-ND	1	D22
46	OPTO ISOLATOR, single	Infineon, SFH690ABT	1	ISO1
47	OPTO ISOLATOR, quad	Infineon, SFH6916	1	ISO3
48	MOSFET, N-Channel, 100V	International Rectifier, IRFR120N	1	Q5
49	MOSFET, N-Channel, 30V	International Rectifier, IRL3713S	4	Q1-Q4, Q10
50	MOSFET, N-Channel, 30V	Vishay-Siliconix Si2306DS	4	Q6-Q7
51				
52	3.3V, Optically-Isolated Gate	Agilent Technologies, HCPL-063L	3	U1A-U1C
53	SMT4004 Quad Tracking Manager	Summit Microelectronics	1	U8
54	SMP9210 Dual DACPOT	Summit Microelectronics	2	U14, U15
55	SMH4804 Hot Swap Controller	Summit Microelectronics	1	U1
Miscellaneous				
56	Gas-Discharge Tube, Dual, 75V	Crydom P/N SL1122090RCIT	3	DN1, DN2, DN4
57	Fuse with Fuse Holder, 5A, SMD	Digi-key, P/N F1228CT-ND	4	F1, F3, F4, F5
58	I^{2}C SMX3200 Connector	Digi-key, P/N A26267-ND	1	J1
59	Connector, 2-pin, dual-row, 0.1" spacing	Digi-key, P/N 929834-2-36-ND	3	J2-J4 (Various)
60	Jumper, 2-pin, 0.1" spacing	Digi-Key, 929955-06-ND	10	(Various)
61	Switch, Pushbutton, Normally Open	Digi-Key, PTS635SL43	3	SW1-SW3 (MR#, IRQ_CLR#, RESET#)
62	Connector, Test Point	Mill-max, 0300-1-15-01-47-27-10-0	18	TP1-TP9, TP11-TP19 (Various)
63	DC-DC Converter	BOTHAND, B1-0505SSH:	1	U12
64	Filter Module, EMI, Conducted	Power One, FC100V10A	2	U13, U17
65	PCB, SMH4804/SMT4004 Reference	Any	1	
66	PCB, SMH4804/SMT4004 Reference	Any	1	

VENDOR CONTACT INFO

Supplier	Web Site
Crydom	http://www.crydom.com/
Power One	http://www.power-one.com/
International Resistive Company	http://www.irctt.com/
AVX Corporation	http://www.avxcorp.com/
Digi-Key Corporation	http://www.digikey.com/
International Rectifier	http://www.irf.com/
Agilent Technologies	http://www.agilent.com/
Bothhand	http://www.bothhand.com/
Infineon Technologies AG	http://www.infineon.com/
Fairchild Semiconductor International	http://www.fairchildsemi.com/
Vishay Intertechnology, Inc.	http://www.vishay.com/brands/siliconix/
Mill-Max Mfg. Corp.	http://www.mill-max.com/
ON Semiconductor:	http://www.onsemi.com/home/