The SA50-120 and the International Space Station

ISS Overview

The International Space Station has been occupied since November of 2000. Bigger than a football field, with a pressurized volumn as large as a Boeing 747, it is capable of supporting an electrical load of 84 kilowatts. The main power bus on the ISS is 120 VDCNOMINAL. Before a vendor is allowed to connect to the power bus, equipment intended for the ISS must go through a rigorous testing and certification process[1]. While it is beyond the scope of this application note to address all the issues involved in this certification, the most common electrical interface concerns will be addressed.

SA50-120 Overview

The SA50-120 is a family of 50 watt, fully isolated DC to DC converters with single or triple outputs. The input volt-age is typically 120V which is ideally suited to the Interna-tional Space station. The SA50-120 has a built in MIL-STD 461 compliant EMI filter. It is fabricated using radiation hardened, hermetically sealed, fully tested and burned-in semiconductor devices[2] and space-grade passive devices assembled onto a PWB[3].

The block diagram in Figure 2 shows the SA50-120 in a triple output configuration. The input is isolated from the outputs and from the case. The outputs are isolated from each other and isolated from the case. Output voltage feedback and external sync are transformer coupled to maintain full isolation.

Figure 3 shows a single output configuration which in-cludes three additional functions: Remote Sense, Remote Adjust and Parallel. Up to five modules can be connected in parallel supporting up to 250 Watts.

Remote Sense Function

For single or parallel operation, the Remote Sense pin can provide accurate regulation at the point of loading.

The remote sense terminals may remain unconnected. For best output voltage regulation however, the remote sense terminal of the SA50 should be connected to a single point, as close as possible to the positive load terminal or point where the voltage regulation is desired to be maintained. For parallel operation, all remote sense pins should be connected together and tied to the remote point. In the same way, the remote sense return terminal of each SA50 module should be connected to a single point, as close as possible to the negative load terminal.

Parallel Operation

Up to five modules may be connected in parallel.

To insure current sharing, the Parallel terminal of every Power Supply module must be connected together to form a common bus. These connections should be made relatively short, but can be made in any configuration.

The expected current sharing accuracy is 10% at maximum load.

External Sync

The Power Supply's internal clock may be synchronized to an external signal. For enhanced system configuration flexibility and noise immunity, the sync input circuit is magnetically isolated from all other circuits and chassis. The interface is shown in Figure 1. The circuit operates from the rising (leading) edge of the sync waveform, that generates a short synchronization pulse to the PWM controller. Note that the sync circuit DC input resistance is 500 Ohms. Specifically, the circuit driving the sync input needs to deliver a minimum of 5 mA of current into the input for a minimum of 50 ns, resulting in a minimum reflected voltage of 4 volts. Higher voltage drives are acceptable up to 10 volts, delivering approximately proportional higher current levels. Maintenance of high level voltage drive beyond 50 ns is not essential for correct synchronization function.

The sync functionality remains the same for a system of paralleled modules. The sync input signal may be applied to any one of the paralleled modules, causing that module only to be syncronized. For best performance, phase shift the sync signal between modules.

The use of the sync function is optional for single and or paralleled operation.

If the Sync Input is not used, one sync pin should be tied to chassis ground, the other pin left floating.

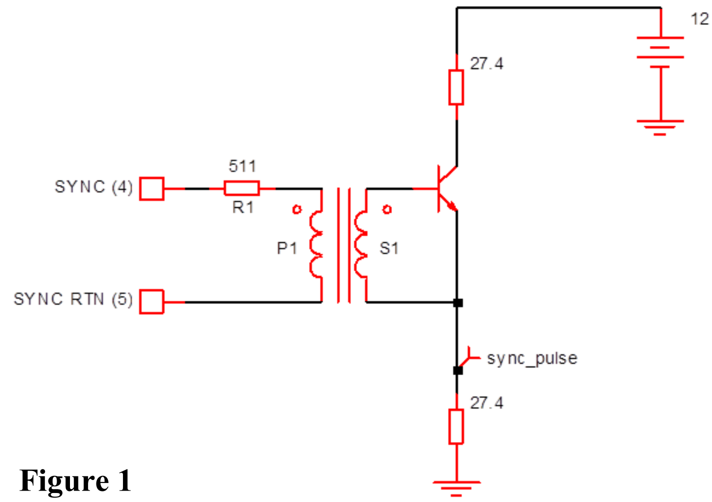


Figure 1

Remote Adjust

The Remote Adjust pin allows the output voltage to be adjusted plus or minus 10% from the nominal voltage.

The set point for the internal TL1431 voltage reference can be set by connecting an external resistor to the R-ADJUST pin of the module. To trim the output voltage down, connect the resistor to $+V_{OUT}$. To trim the output voltage up, connect the resistor to V_{OUT} RTN.

The resistor may be as small as 1 KΩ.

The R-ADJUST function may be used in a system of paralleled modules. All R-ADJUST pins should be tied together with the connections as short as possible.

If the R-ADJUST function is not used, the pin should be left floating.

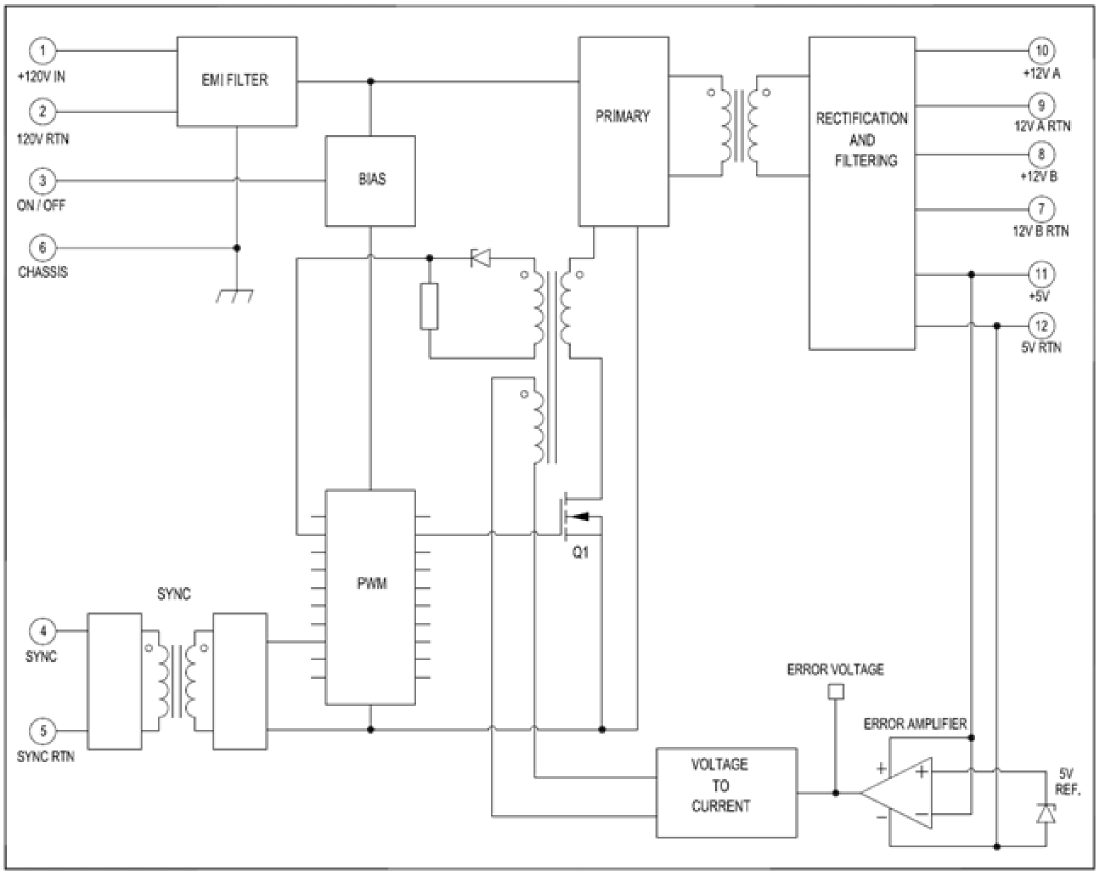


Figure 2

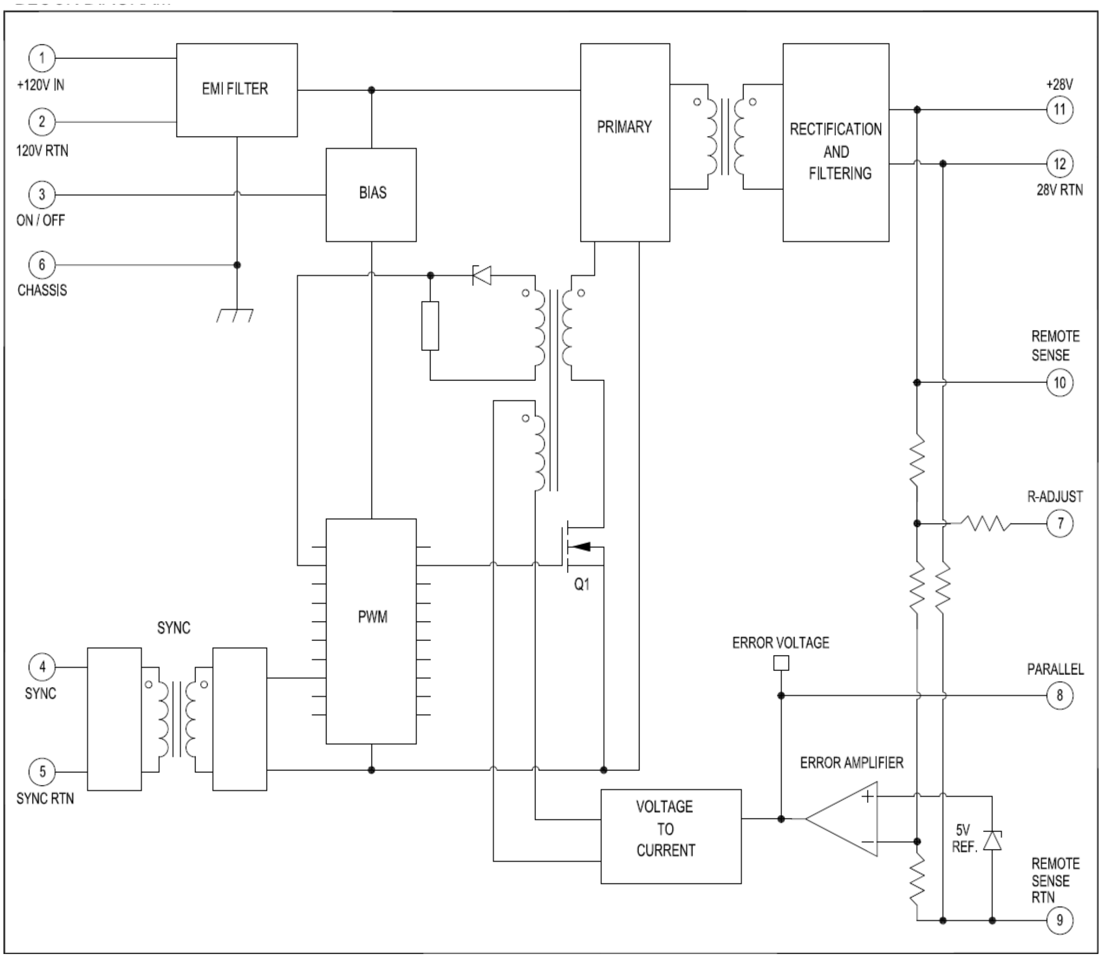


Figure 3

Impedance Matching

Because of the sheer size of the International Space Station, the SA50 will probably be connected to the primary 120V source through a long cable. As can be seen in figure 5, the load impedance increases with frequency due to the inductive nature of the power distribution cabling. Consequently, an Impedance Matching network is required.

The schematic of a typical input filter, including the components external to the SA50 Power Supply, is shown in figure 4. External components are added to increase the input impedance per the SSL requirement is shown in figure 5. Those components and their parasitic elements are modeled to show the impact of the inrush current behavior.

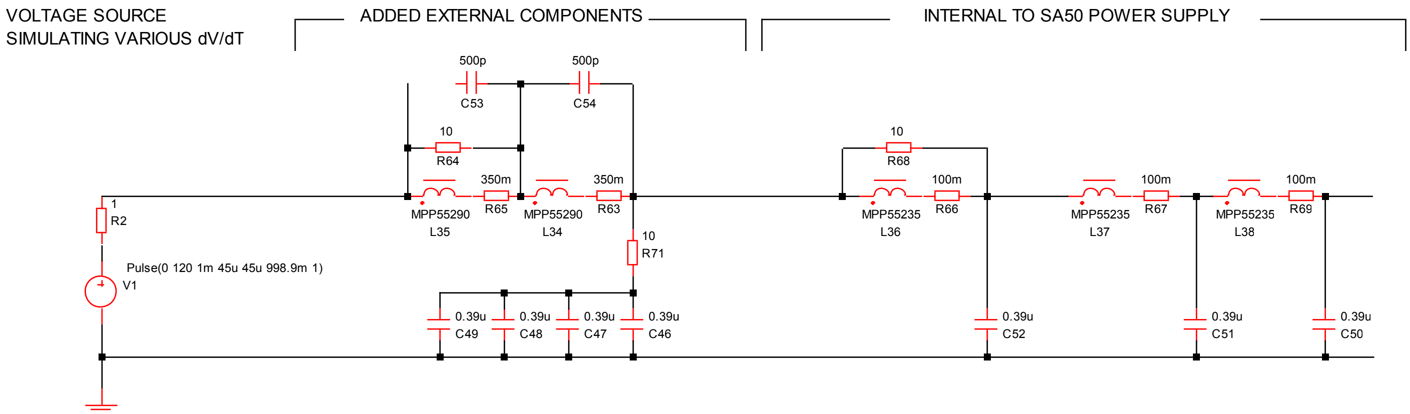


Figure 4

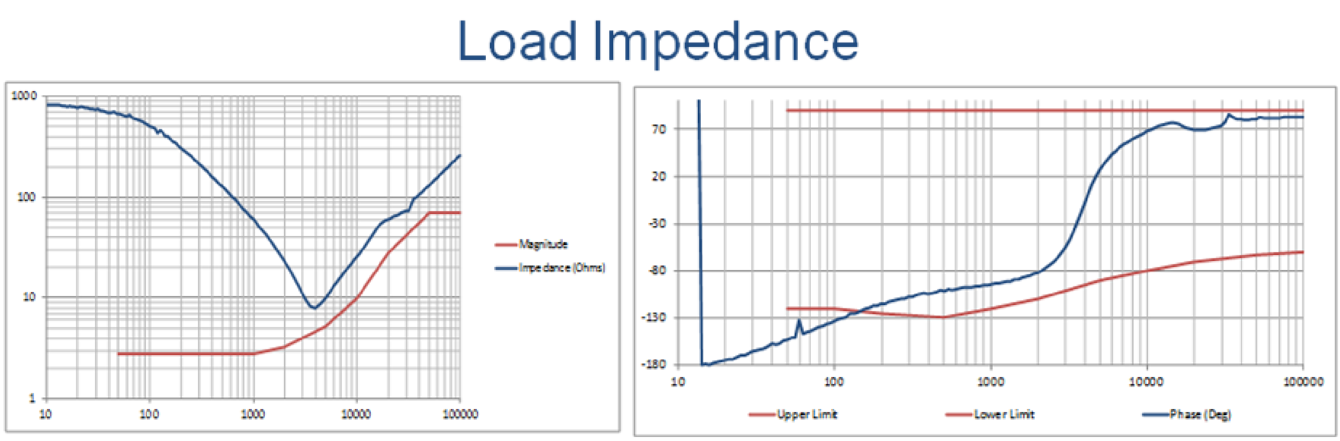
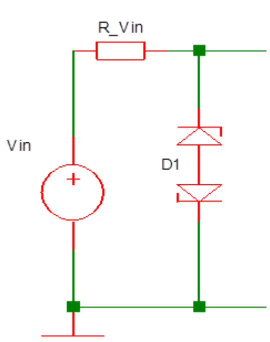


Figure 5



Input Protection

SSP 52051 Section 5.5 injects a 10 µS pulse in excess of 320V. A protection device is required to protect the circuitry in the SA50-120. An appropriate voltage suppression diode should be used as shown in Figure 6.

Figure 6

Inrush Current Limiting

The inrush current drawn by the SA50 Power Supply is a function of the rate at which the input voltage to it is raised. To independently limit the inrush current, a dedicated inrush current limiting circuit must be added externally.

As the rate of rise is increased, the increasing inrush current begins to saturate the inductors in the circuit and cause a disproportional increase in the magnitude of the inrush current.

Schematic of the input filter, including the components external to the SA50 Power Supply, added to increase the input impedance per the SSL requirement is shown in Fig 4. Those components and their parasitic elements are modeled that impact the inrush behavior.

The simulated Inrush current profiles at various input voltage rates of rise are plotted in Fig 7.

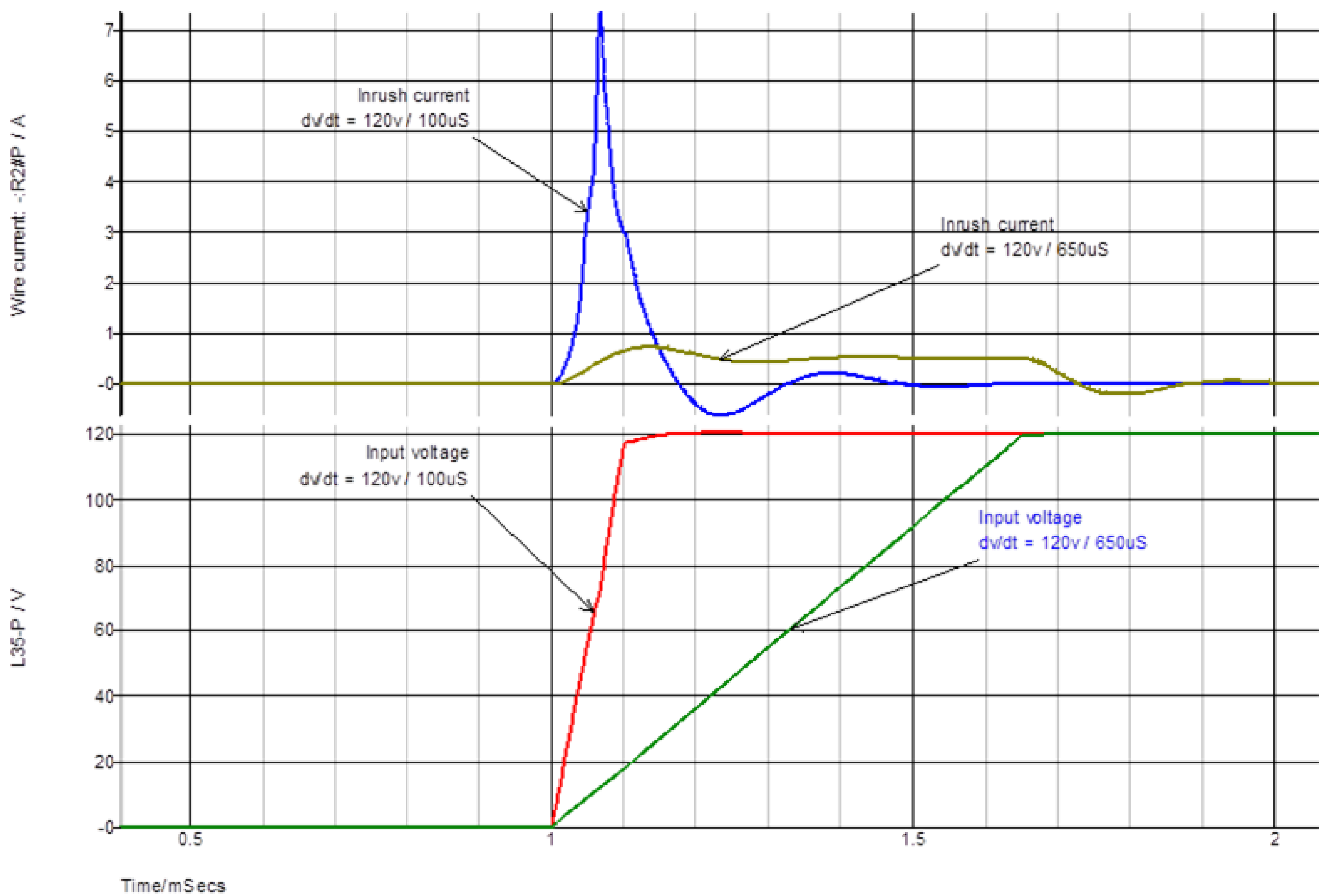


Figure 7

Current Limiting

Continuous over-current protection is inherent due to the use of peak current mode control.

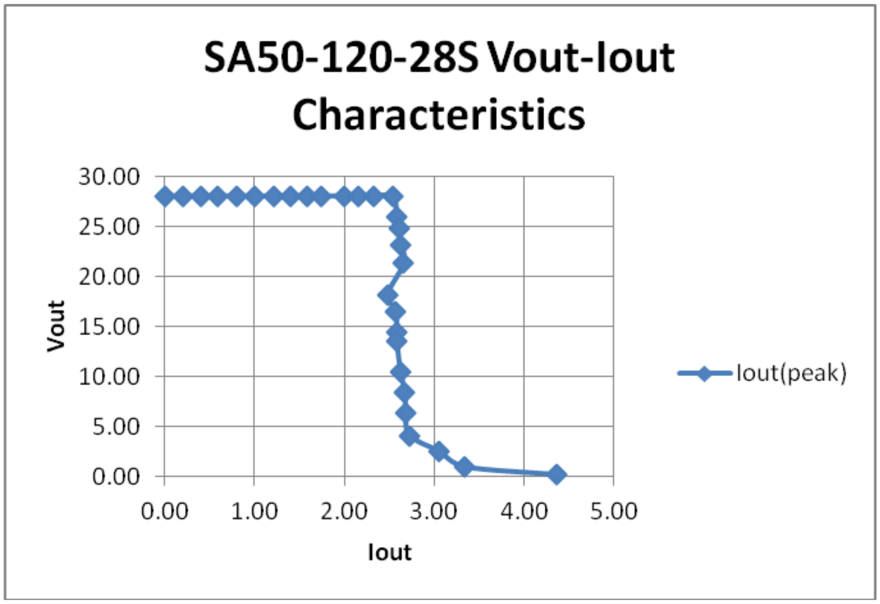


Figure 8

The instantaneous output transient current is limited by the ESR of the output capacitors, and the delivered energy is limited by the capacitance.

The magnitude of the continuous fault current is limited as described in the specification. The converter response time is in the microsecond scale.

The magnitude of the current generally folds out as the output voltage decreases toward approximately to 50% of its nominal value, below which the internal bias under-voltage protection disables the converter. The converter recycles autonomously. The off time is approximately 140 msec.

Bench testing the SA50-120-28S from open circuit to short circuit in 28 steps (resistive loads) shows the characteristics in Figure 8.

Figure 9 shows typical behavior with an acceptable load (9.5 Ω). In Figure 10, the load is set to 1.6 Ω. The converter turns on and starts sourcing current. The output voltage does not rise to an acceptable level, the converter shuts down and after a delay "hiccups" and tries to start again. The converter can run indefinitely in this mode. These "hiccups" can be highly beneficial in cases where a bypass capacitor has shorted somewhere in the customer's system.

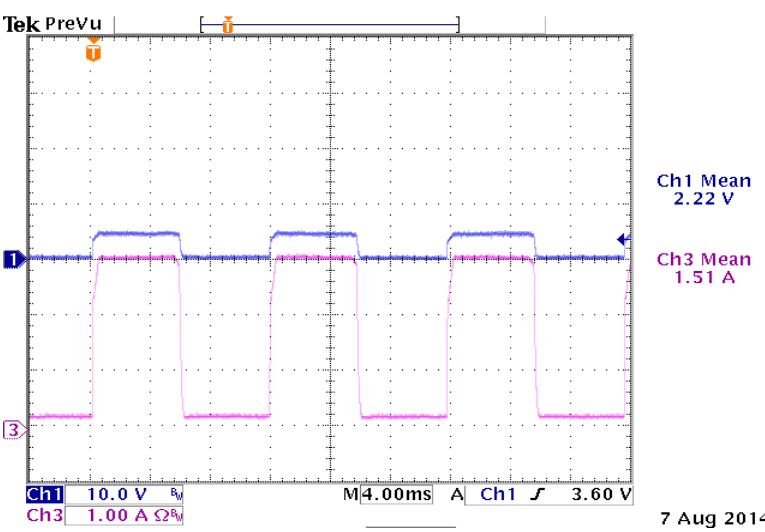


Figure 9

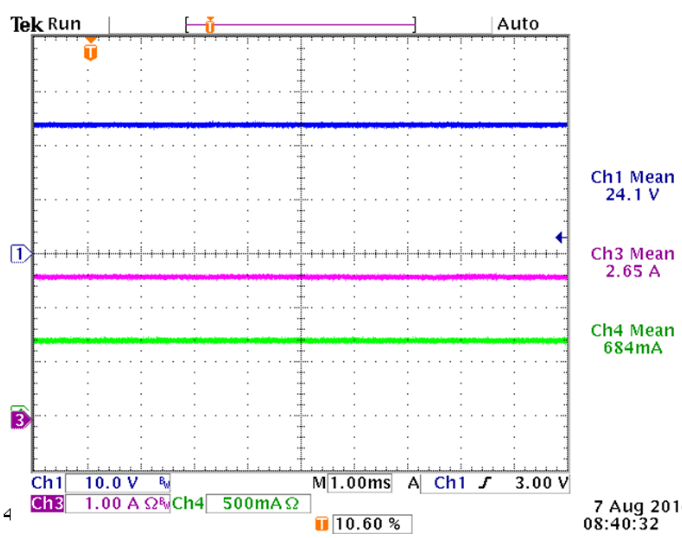


Figure 10

PWB Construction

Manufacturing printed wiring board construction conforms to specifications set forth by IPC:

http://www.ipc.org/default.aspx

Printed wiring boards are designed and accepted per IPC-6012, Class 3, IPC-2221, and IPC-2222.

To verify adequate isolation, during the fabrication process every pair of adjacent traces on the PWB are checked for leakage by imposing a potential differential of 250 volts to verify no leakage.

Conformal Coating

After electrical verification of the unit is complete a conformal coating is applied. Huntsman Arathane 5750 meets the NASA outgassing limits of 1.0% TML max and 0.1% CVCM when tested per ASTM E595.

The SA50-120 family of DC to DC converters use hermetically sealed parts and the PWB is conformal coated, eliminating the need for a hermetically sealed enclosure. The vented housing allows launch of the SA50 family in compartments which vent to vacuum.

Part Level Selection

The standard version of the SA50-120 (Figure 11) uses parts selected to meet the published specifications for radiation and reliability. The SA50-120 family is constructed with tested burned in hermetically sealed semiconductors. Level 1 and Level 2 are NASA reliability terms with Level 1 having higher reliability than Level 2. A Level 1 part has the highest level of manufacturing control and testing per military or DLA specifications and is generally considered a Space Level part. A Level 2 part has less stringent controls and may be used in a Space application if it meets the reliability requirements of the mission. Customers may optionally select higher level parts, perform additional testing, DPA, etc. Please contact the sales department to determine additional costs and lead times.

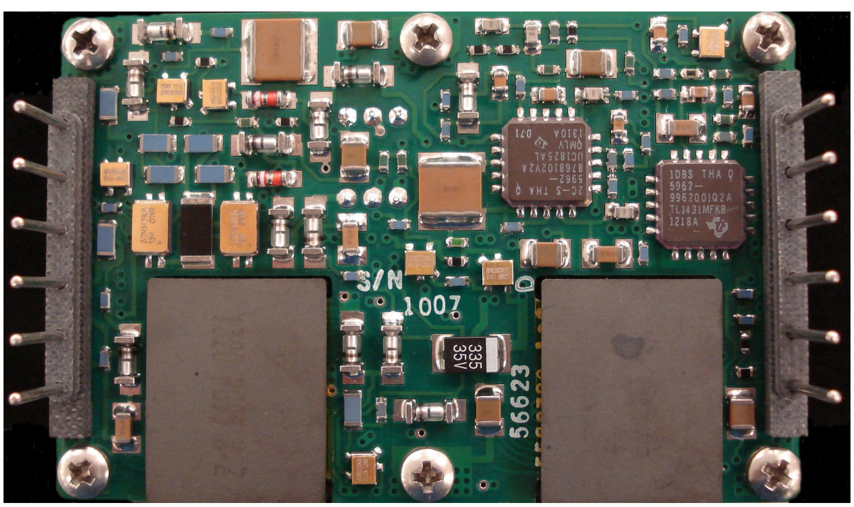


Figure 11

Power Quality Tests

The primary testing specification is SSP 52051 Vol 1. When a unit is submitted to the Johnson Space Center for Power Quality testing and certification it undergoes the following tests:

- Inrush Current
- Inrush Current with RPCM compatibility
- Surge Current
- Impedance
- Large Signal Stability
- Over and Under Voltage Transient Envelope
- Fault Clearing & Protection
- CE01 and CE03
- CE07
- Common Mode Transient Spike Voltage
- Common Mode Current
- Common Mode Isolation
- CS-01 and CS-02
- CS-06
- Non-normal Voltage
- Reverse Current

Figure 12 shows a typical test waveform which is injected into the DUT.

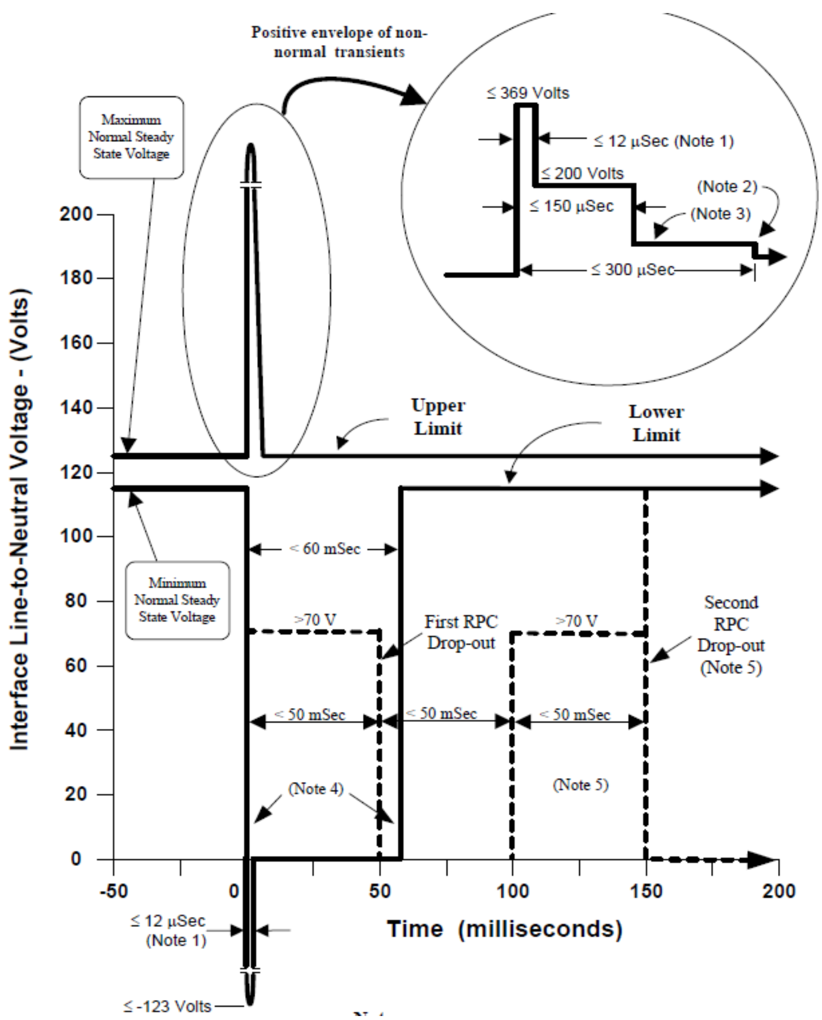


Figure 12

Applicable Documents[4]

SSP 30237 Revision F: Space Station Electromagnetic Emission and Susceptibility Requirements

SSP 30238 Revision D: Space Station Electromagnetic Techniques

SSP 30240 Revision D: Space Station Grounding Requirements

SSP 30243 Revision G: Space Station Requirements for Electromagnetic Compatibility

SSP 30312, Revision H: Electrical, Electronic, and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program

SSP 30425 Revision B: Space Station Program Natural Environment Definition for Design

SSP 30482 Volume 1, Revision C: Electric Power Specifications and Standards Volume 1 - EPS Electrical Performance Specifications

SSP 30482 Volume 2, Revision A: ELECTRIC POWER SPECIFICATIONS AND STANDARDS: VOLUME 2 - CONSUMER CONSTRAINTS

SSP 30512 Revision C: Space Station Ionizing Radiation Design Environment

SSP 41172 Revision U: Qualification and Acceptance / Environmental Test Requirements

SSP 41173 Revision C: Space Station Quality Assurance Requirements

SSP 42004, Part 2, Revision A: Mobile Servicing System to User (Generic) Interface Control Document

SSP 52051 Vol. 1: User Electric Power Specifications and Standards - 120Volt DC Loads

Note 1: See Power Quality Tests, page 8

Note 2: Customers may select various grade parts. See Parts Level Selection, page 7

Note 3: See PWB Construction, page 7

Note 4: This list is supplied as a resource for the ISS designer. There is no warranty to the revision level or if all applicable documents are included.

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