

Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

ISIS Power

David Do

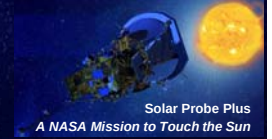
LVPS Engineer (JHU/APL)



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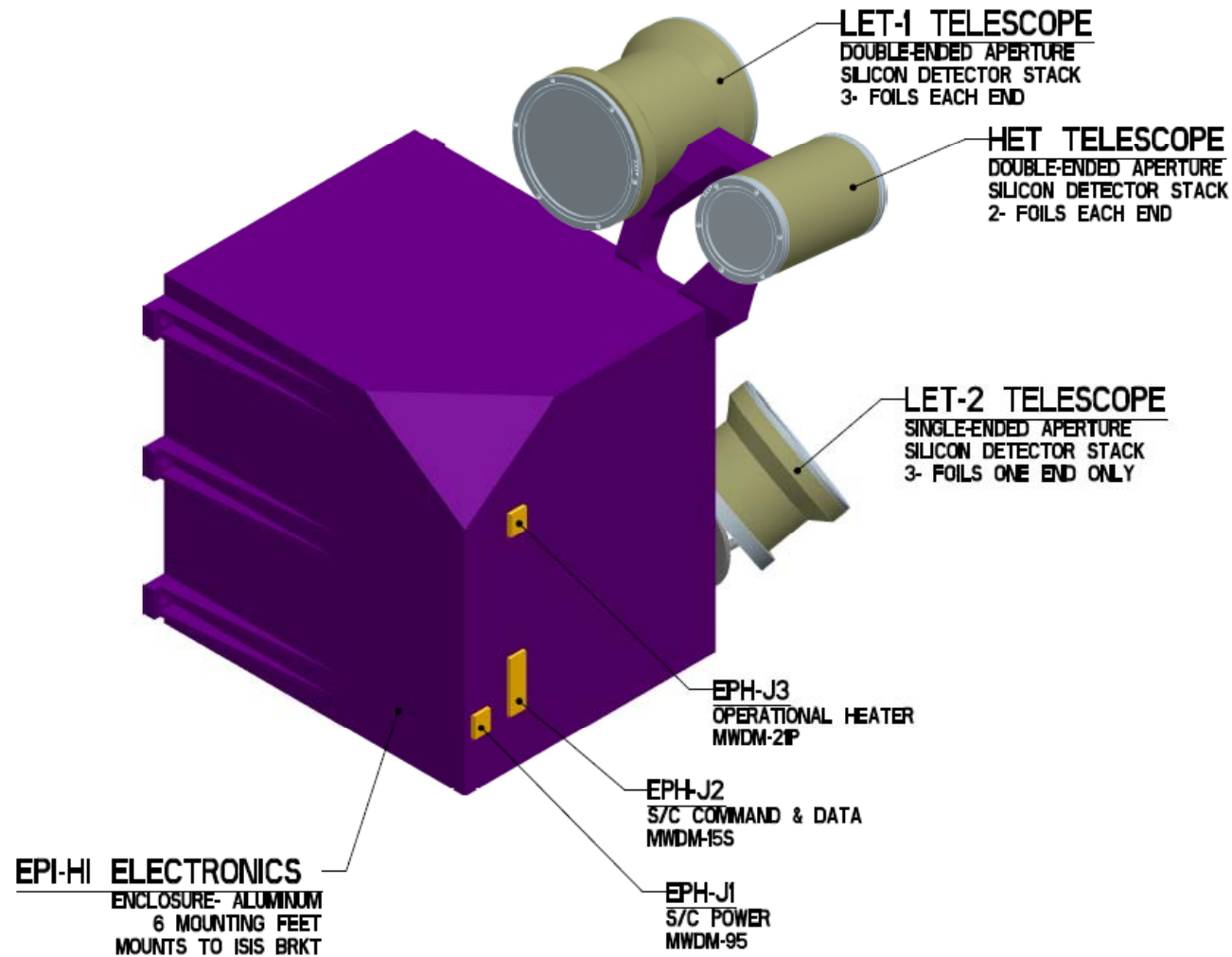
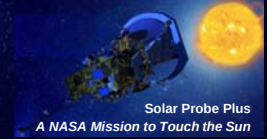
Outline



- Overview
- Requirements
- Packaging
- Analysis
- Parts
- Testing
- Status Summary
- Plan Forward
- Peer Reviews

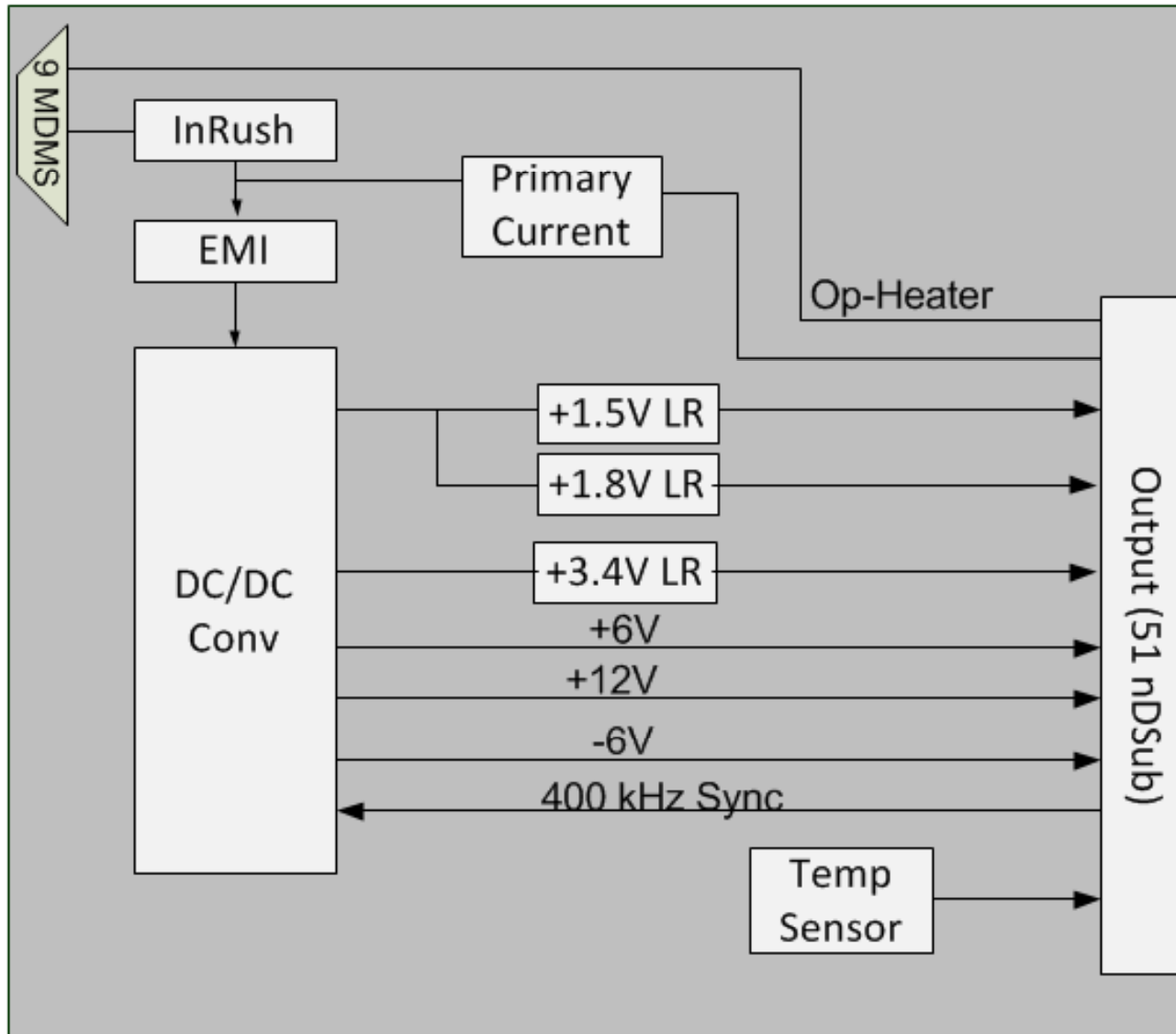
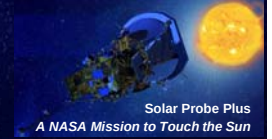


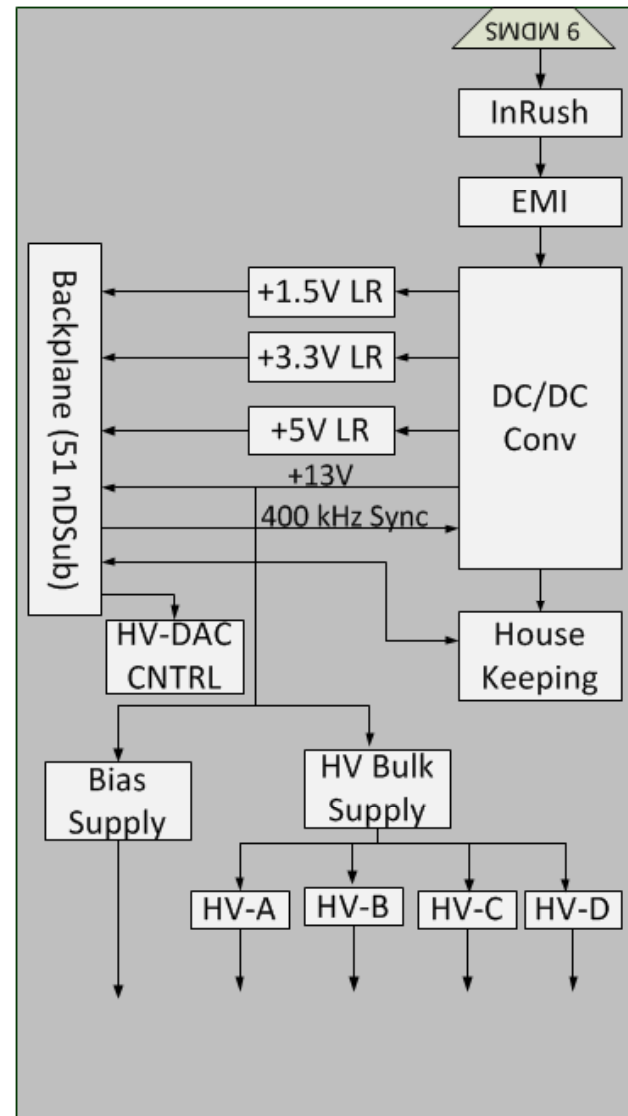
EPI-Hi Electronics Overview





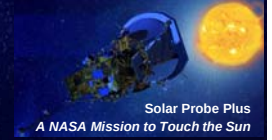
EPI-Hi Block Diagram







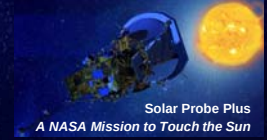
Environment Requirements



- Thermal
 - Survival is -55°C to $+85^{\circ}\text{C}$
 - Operational is -35°C to $+65^{\circ}\text{C}$
- Radiation
 - 25 krad (includes RDM=2 from FASTrad analysis)
 - $\text{LET} > 80 \text{ MeV} \cdot \text{cm}^2/\text{mg}$



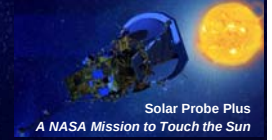
LVPS Major Input Requirements



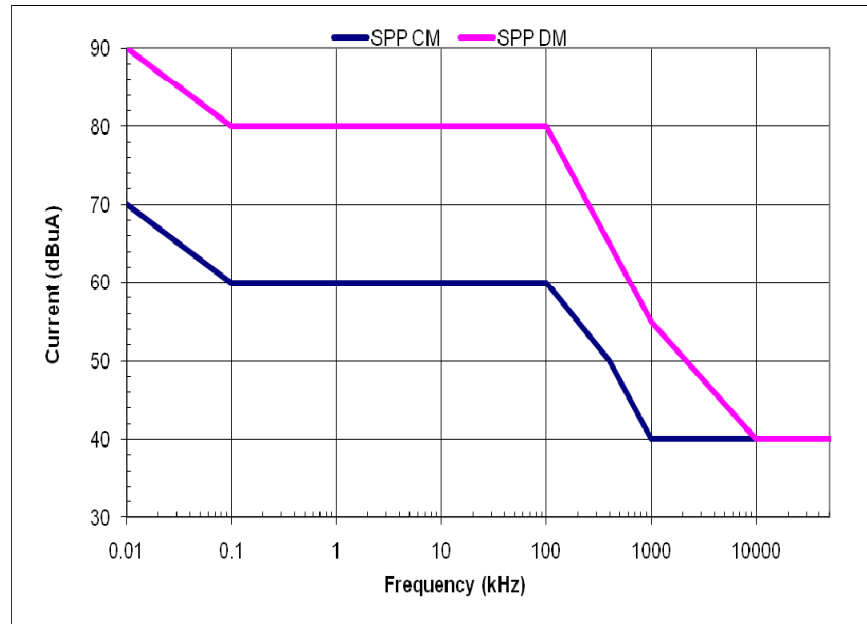
- Requirements from Solar Probe Bus
- Input Specification
 - Operate over bus voltage of 22 to 35 V
 - Survive any standing or fluctuating voltage from 0 to 40 V
 - Meet EMI/EMC
 - Transformer and power inductor far away from wall
 - Power supplies crystal controlled to a frequency window centered at $n \cdot 50$ kHz with $n \geq 3$ and 500 ppm wide over all operating conditions and time.
 - Inrush current limit
 - Primary Secondary isolation > 1 MOhm
 - Overall efficiency $> 70\%$



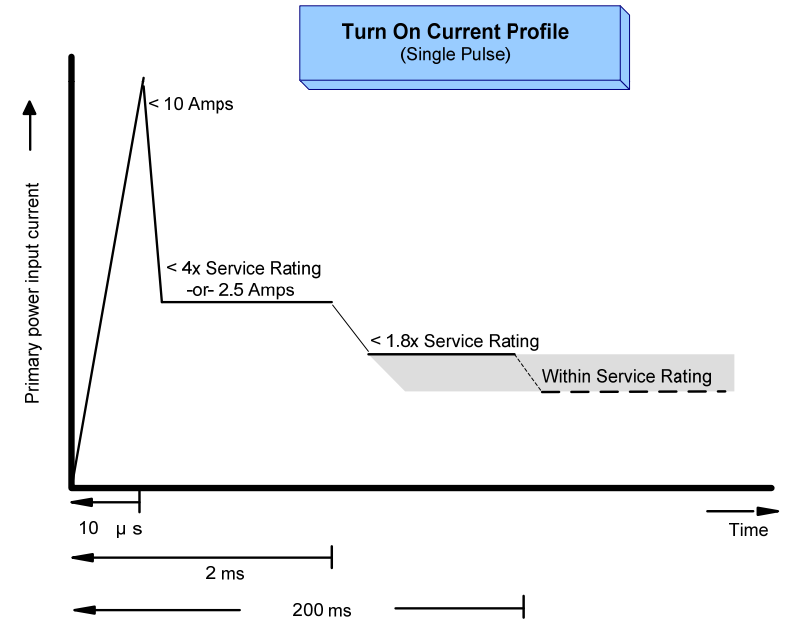
Input Power Requirement



- EMI/EMC
- Inrush Current



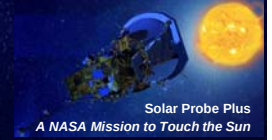
CE01& CE03 Limit



In-Rush Current Limit



Interface

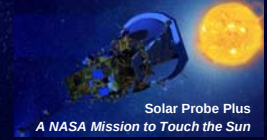


- EPI-Hi
 - Input connector: MWDM2L-9SCBRR2-.110-429
 - Output connector: 891-008-51PSBRT1T-429TH

- EPI-Lo
 - Input connector: MWDM_L-9SSMR
 - Inter board connector: 891-008-51PSBRT1T-429
 - Safing connector: 803-005-07M5-3EN
 - Bias voltage connector: 09-9001-1
 - High voltage: Pig tails



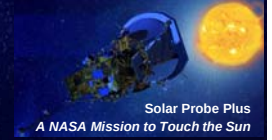
Power Topology



- Common for EPI-Hi and EPI-Lo:
 - Main converter is forward with resonant reset operating at 200 kHz. Efficiency is $>80\%$.
 - Digital voltages are linear regulated.
- EPI-Lo HVPS:
 - Bulk high voltage is set at 3.4 kV.
 - High voltages of up to 3.3 kV are controlled through Optocouplers.
 - Bias voltage is up to 200 V.



Output Requirements

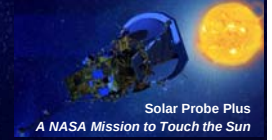


- EPI-Hi:
 - Generate low voltages: +12 V, +6 V, +3.3 V, +1.8 V, +1.5 V & -6 V
 - Primary input current telemetry
 - Temp sensor
 - Provide path for Op-heater voltage

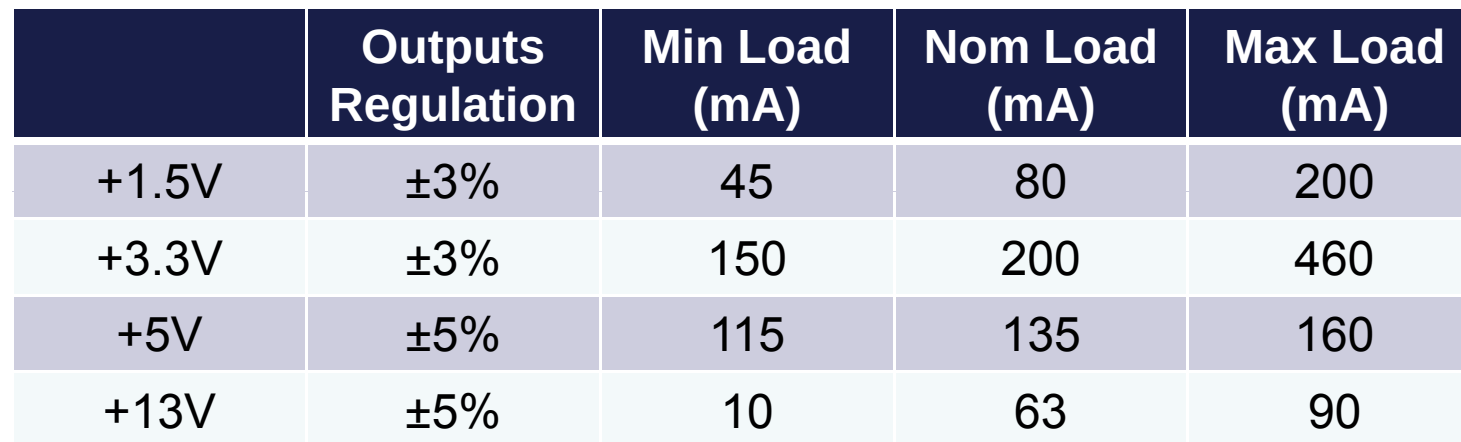
- EPI-Lo:
 - Generate low voltages: +13 V, +5 V, +3.3 V and +1.5 V
 - House keeping through ADC for primary input current, temperature, output currents and output voltages
 - Generate high voltages and bias voltages to sensors
 - Hard and soft high voltage safing



EPI-Hi Output Requirements

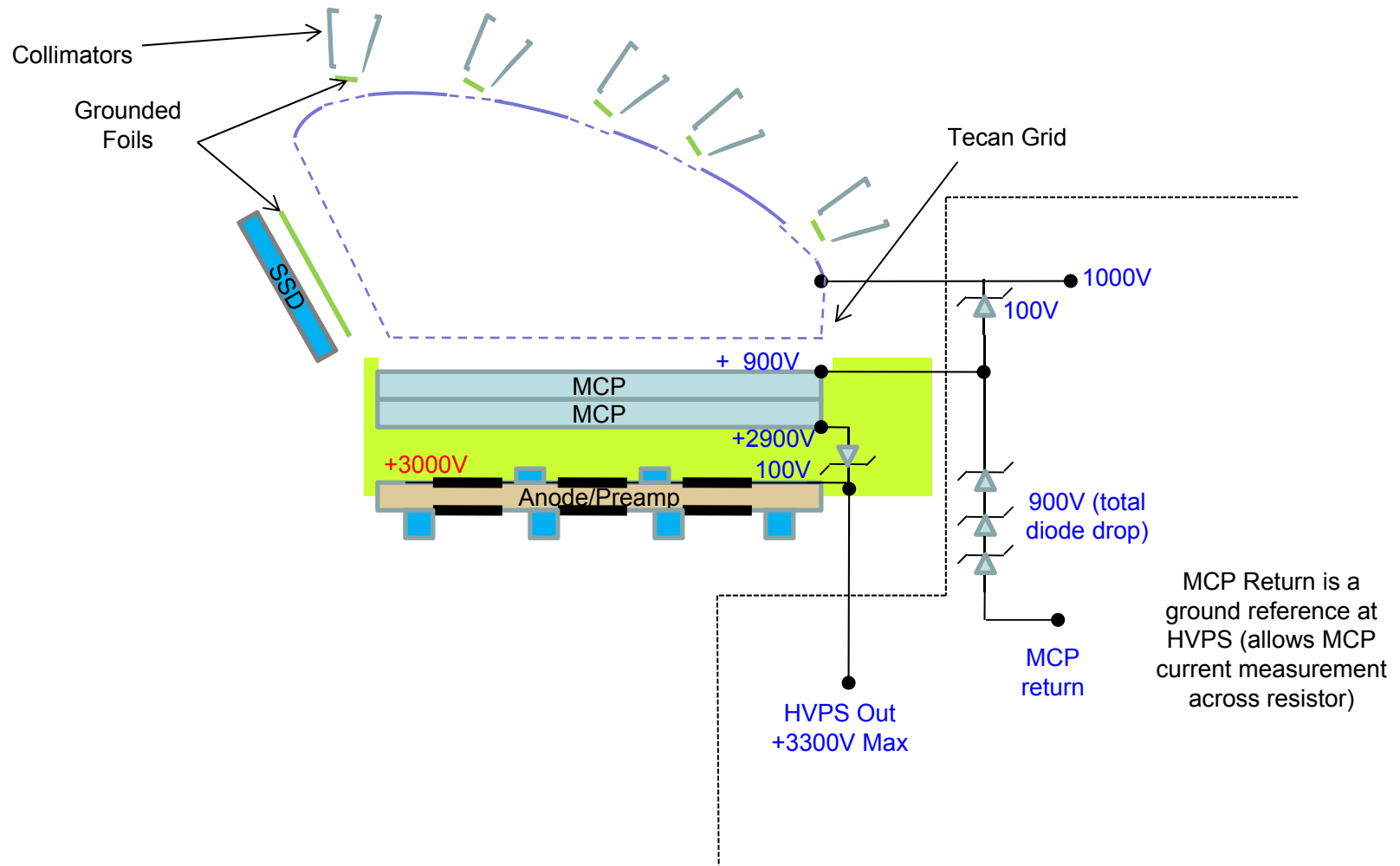
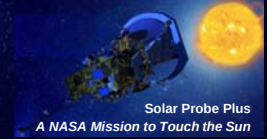


	Output Regulation	Min Load (mA)	Nom Load (mA)	Max Load (mA)
+1.53V	±2.5%	50	100	150
+1.82V	±2.5%	20	40	60
+3.41V	±2.5%	145	287	430
+6V	±7%	79	338	500
+12V	±7%	8	16	64
-6V	±5%	6	12.6	19



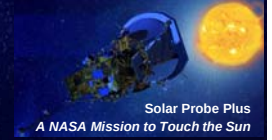


Sensor Voltages

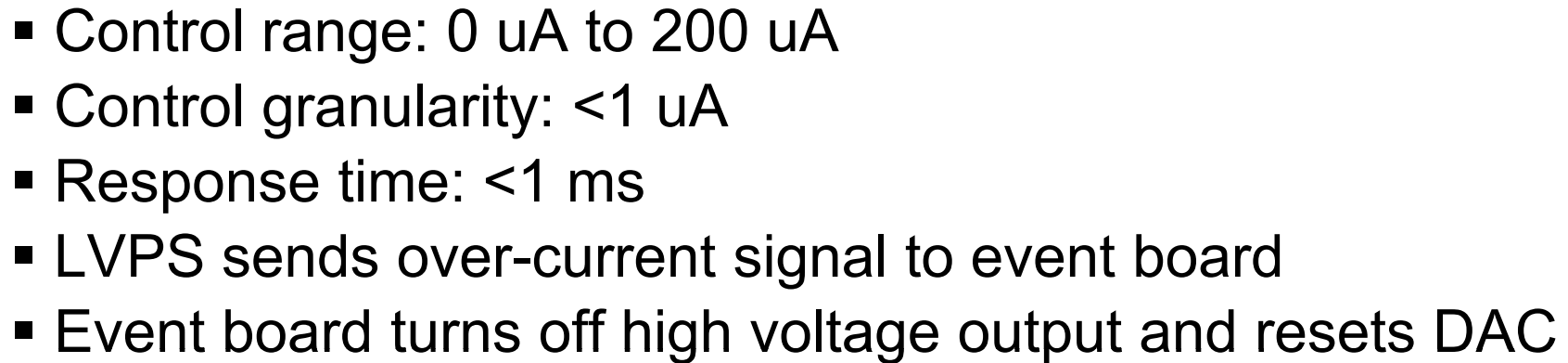




EPI-Lo HVPS Requirements

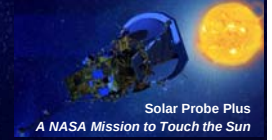


	Max Output Voltage (V)	Min Load (uA)	Max Load (uA)
Bias	200	0	20
Bulk	3400	0	250
HVPS	3300	0	50
Grid	1000	0	1
MCP	900	0	50

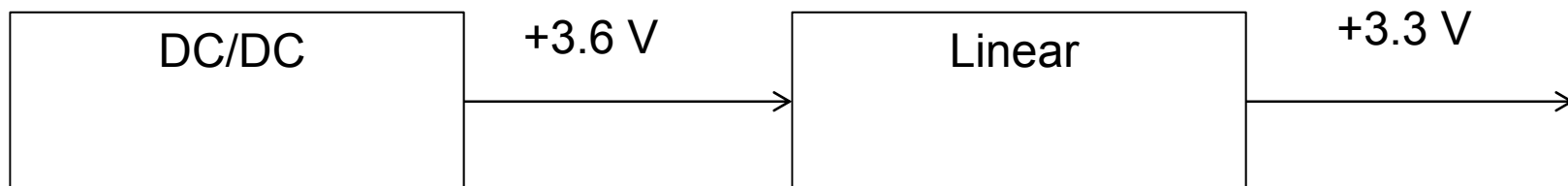




LVDS Fault Mitigation

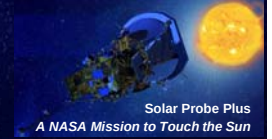


- Transformer: primary and +3.3 V winding is well isolated by +13 V and +6 V windings
- +3.3 V is linear regulated from +3.6 V
- Linear pass transistor is rated for 100 V
- Worse case fault LVPS goes to full duty cycle, which results in +7.5 V output on +3.6 V
- Preliminary thermal analysis shows 33°C rise in linear regulator

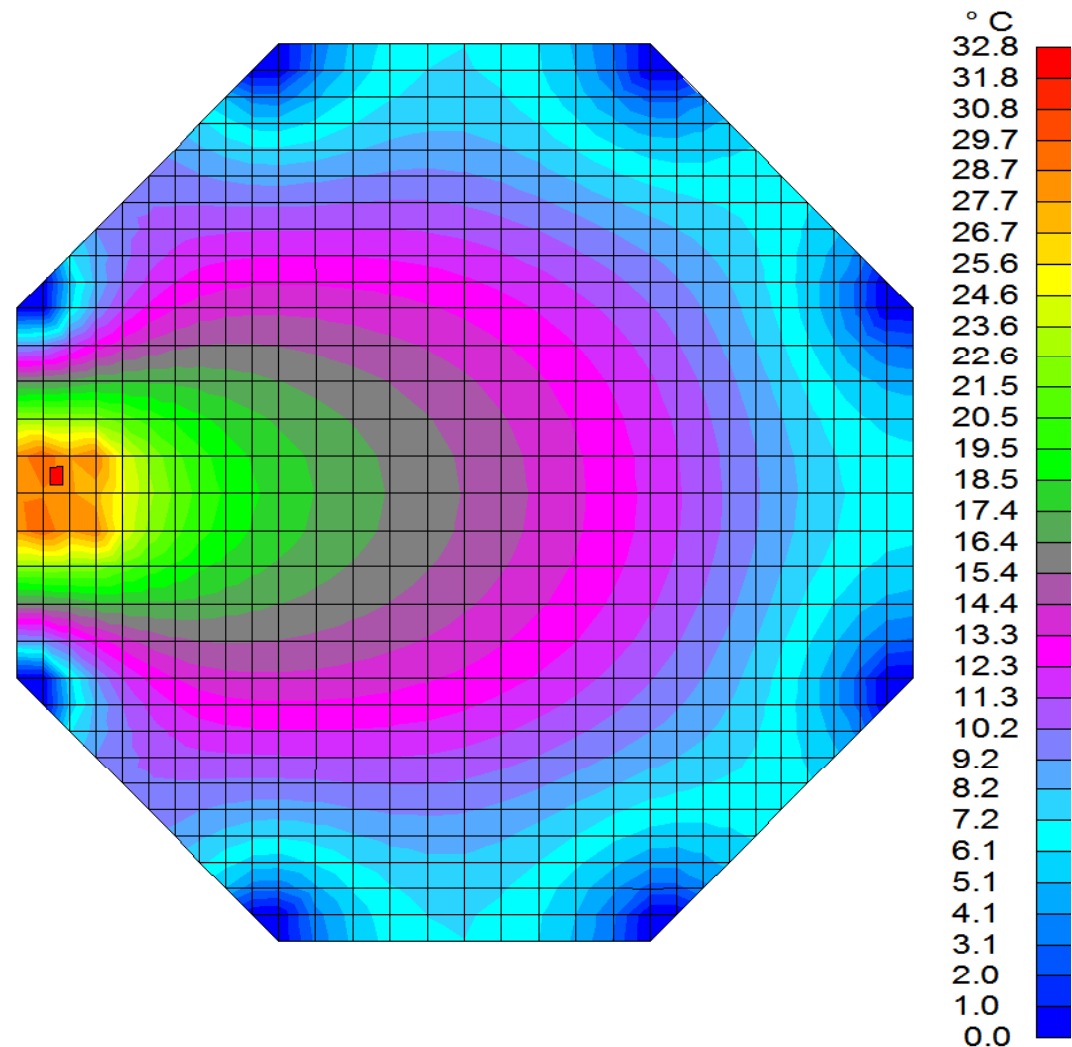




Worst Case Thermal Analysis

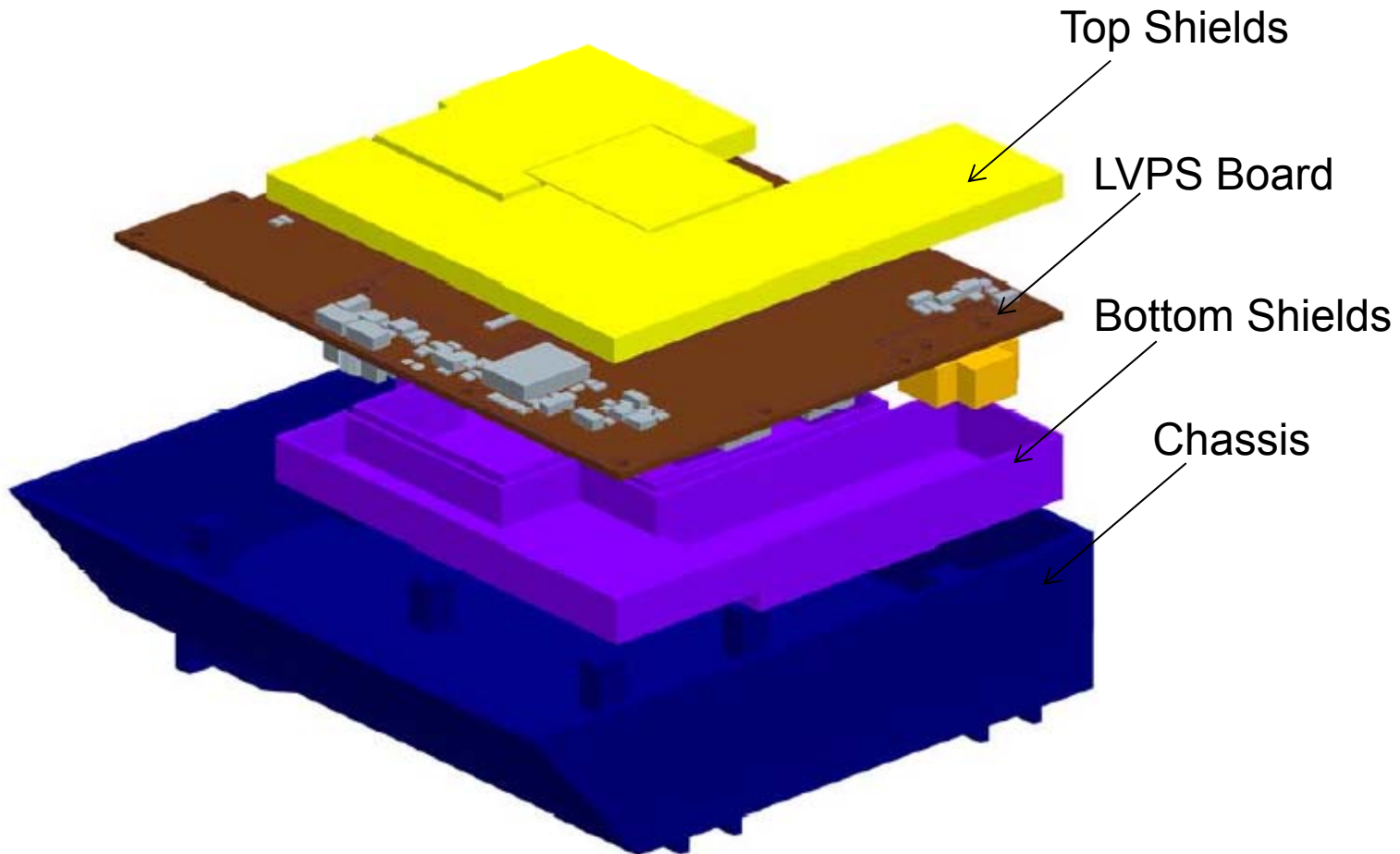
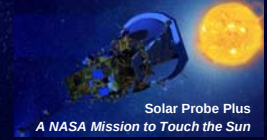


- 6 oz Cu in PWB
- Thermal contours plot shown with 8 W total power dissipation
- Actual power dissipation <2.5 W
- TO-254 temps for 6 oz
 - Junction = 32.8°C
 - Case = 13.2°C



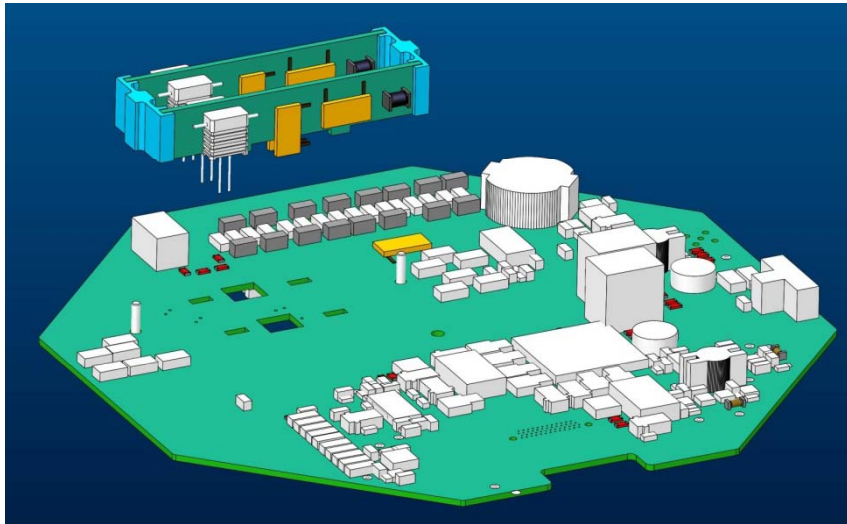
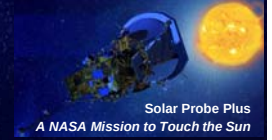


EPI-Hi Package

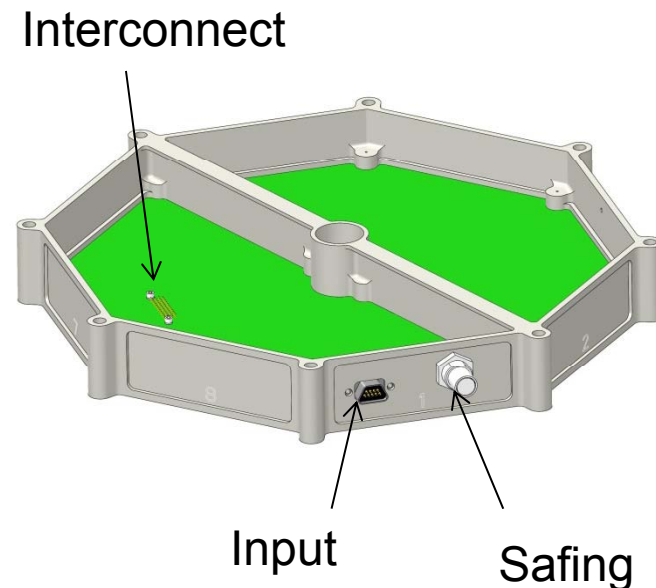




EPI-Lo Packaging

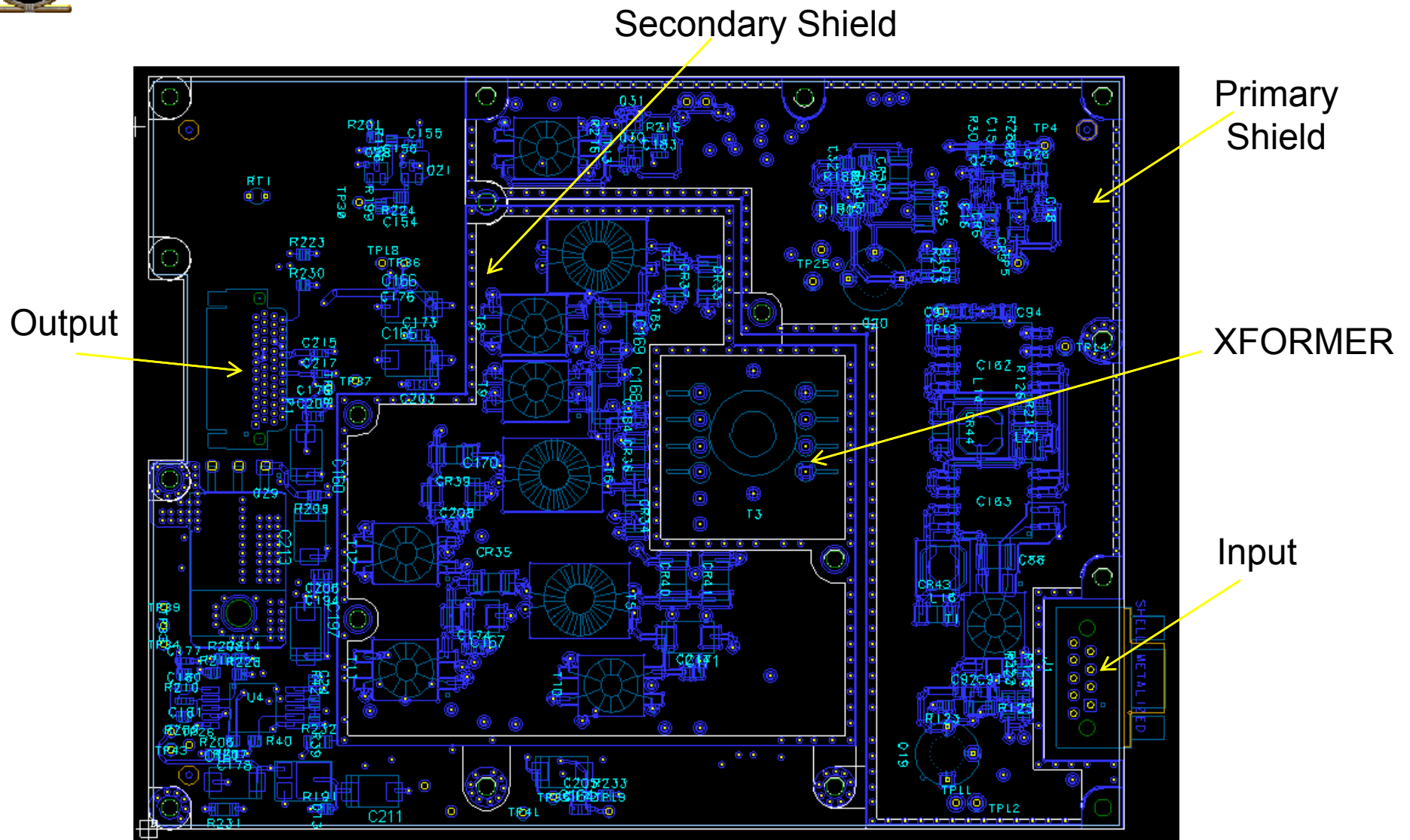
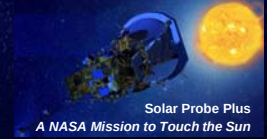


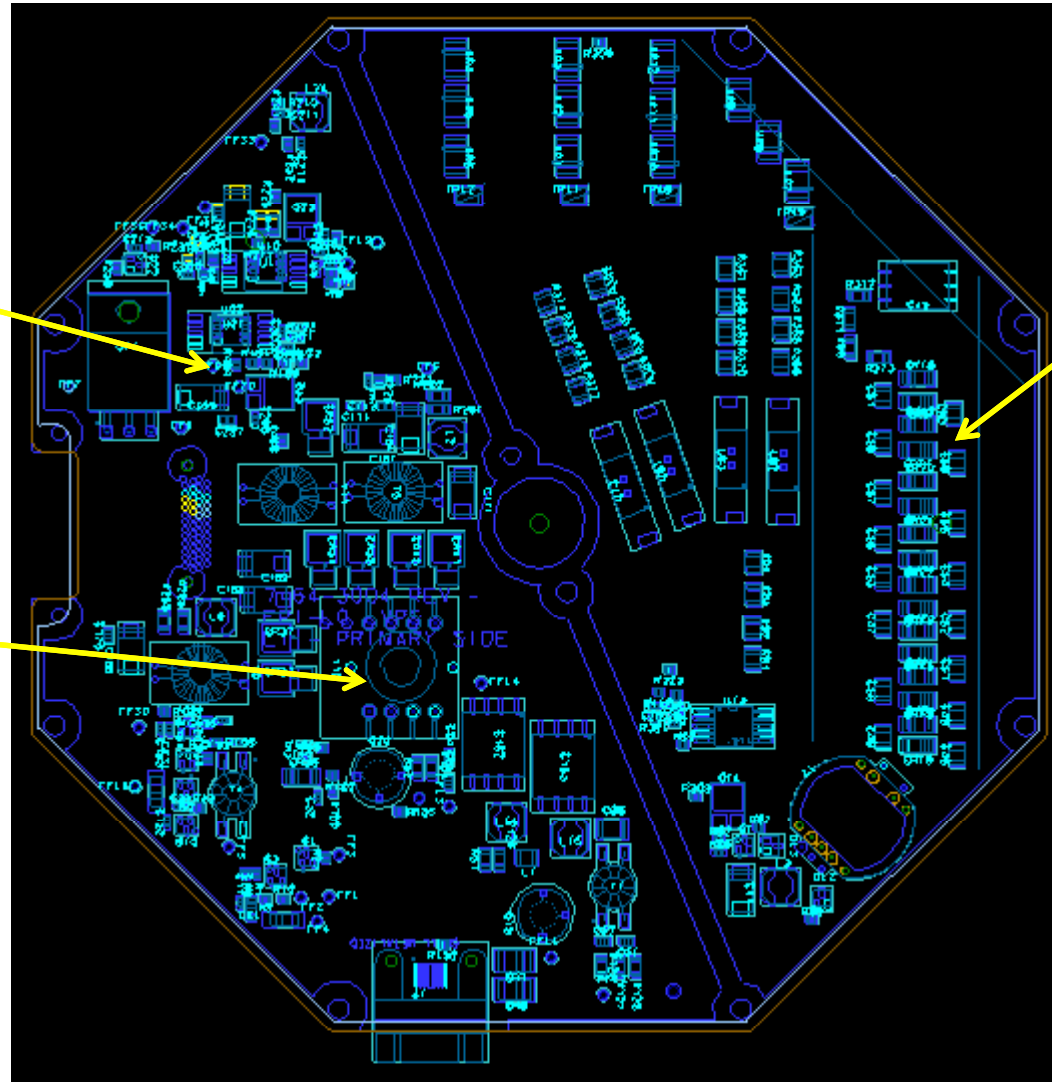
- Packaged in octagon frame
- 2 daughter boards for high voltages
- Stiffener goes across the board
- Power dissipation is estimated $<2.5\text{ W}$





EPI-Hi Board Layout







Nominal Output Regulation and Efficiency

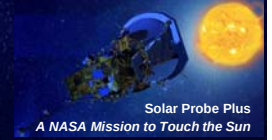


	Load(A)	Regulation(V)	Power(W)
+1.53V	0.14	1.505	0.2107
+3.41V	0.287	3.69*	0.9758
+6V	0.338	5.97	2.01786
+12V	0.016	11.98	0.19168
-6V	0.012	5.95	0.0714
input	0.159	28	4.452
			78%

- *+3.41V shown pre-regulated. Efficiency is calculated using +3.4 V.
- +3.41 V and +1.82V linear regulator have same design as +1.53 V.



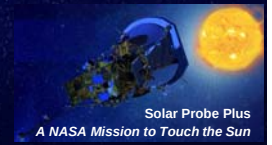
Analysis



- Preliminary EMI completed
- WCA for digital voltages regulation = $\pm 2.3\%$



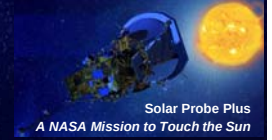
Voltage Regulation WCA Method and Assumptions



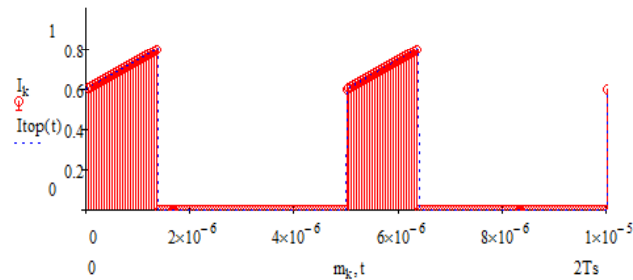
- WCA Method
 - Extreme Value Analysis in Mathcad
- Temperature Range
 - -35°C to $+65^{\circ}\text{C}$ operational
- Resistors Variation
 - K resistors are 100 ppm (0.8%) + 1% initial tolerance + 2% Aging $\approx 4\%$
 - E resistors are 25 ppm (0.2%) + 0.1% initial tolerance + 1% Aging $\approx 1.3\%$
 - Z resistor are 5ppm(0.04%)+ 0.01% initial tolerance 0.16% Aging $\approx 0.2\%$
- RH1078
 - 100 Krad data from datasheet
- PWM5302S
 - 100 Krad data from datasheet



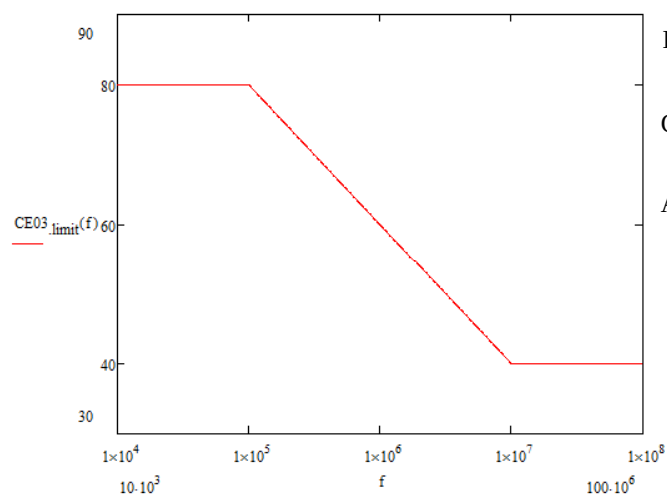
EPI-Lo EMI Analysis



Waveform in time



Primary Current in Discrete Time



CE03 Limit

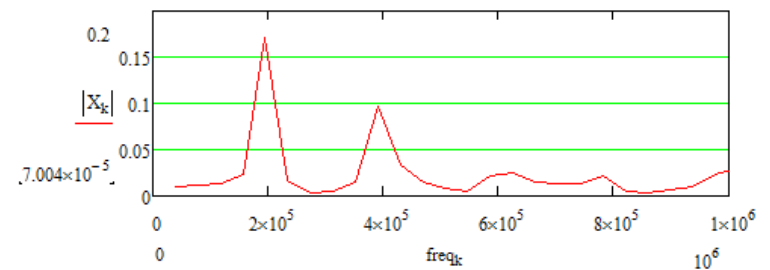
$$I_{in_{dB}} := 20 \log \left(\frac{\text{peak}}{\mu A} \right) = 104.725$$

$$CE03_{limit}(200kHz) = 73.979$$

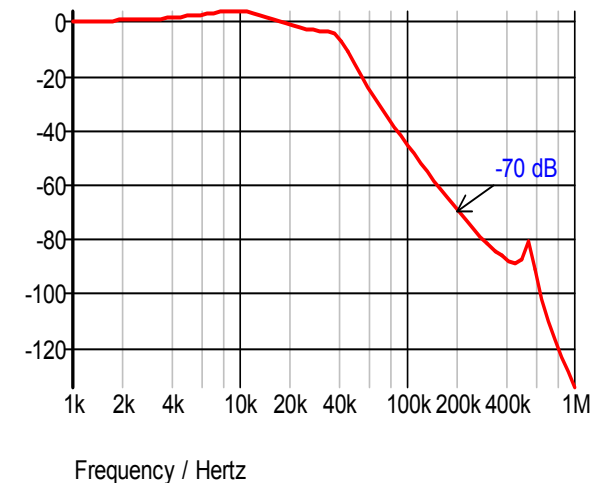
$$A_{ten} := I_{in_{dB}} - CE03_{limit} \left(\frac{1}{T_s} \right) = 30.746$$

dB / dB

CFFT Magnitude



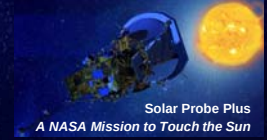
Primary Current in CFFT



EMI Filter Attenuation



Parts

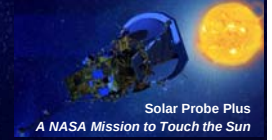


- All parts are rad-hard to >100 krad
- Parts submitted to PCB. No issues expected.

Part Number	Description	Manufacture
PWM3052S	PWM IC	Aeroflex
ADC128S102QML	12 Bit-ADC	TI
RH1009MW	2.5V Reference	Linear Tech
RH1078MW	Low power Opamp	Linear Tech
M49470X01335KBB	Stacked 3.3uF Ceramic	Presidio
IRHNM57110	100V N Channel FET	IR
JANSR1N5811US	100V Schottky Diode	Microsemi
JANSR2N2222AUB	NPN transistor	Microsemi
JANSR2N3501UB	NPN transistor	Microsemi
66353	High voltage opto	Micropac
ADCMP600	Comparator	Analog Devices



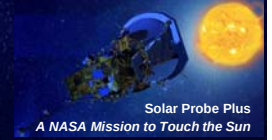
Plans for Testing



- Follows APL manufacturing flow
- Significant highlights:
 - Populate Passive Components with Automatic Measurement.
 - Populate Actives and Install Known Tailors or Tailor Flags
 - Install into Flight Frame
 - Execute Test Procedure to Test and Tailor Entire Board
 - ESS Testing
 - Execute Functional Test Procedure
 - Photograph and Conformal Coat
 - Execute Test Procedure to Calibrate and Characterize Board (over temperature)
 - Release to Next Assembly



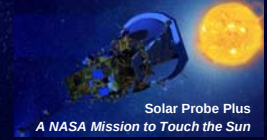
Status Summary



- EPI-Hi
 - EM PWB is being fabricated
- EPI-Lo
 - EM is in placement and layout phase



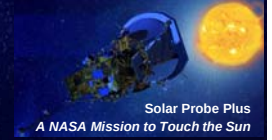
Plan Forward



- EPI-Hi
 - Complete testing EM
 - Fabricate flight
- EPI-Lo
 - Fabricate and complete testing EM
 - Fabricate flight
- Finalize all documentation and procedures for flight build
- Build, tailor, calibrate, and qualify flight units



Peer Reviews



- EPI-Hi LVPS: May 2013, 27 AIs all closed SRI-13-026
- EPI-Lo Power: Aug 2013, 5 AIs all closed SRI-13-029
- Major Action Items:
 - EPI-Hi:
 - Shielding over switching circuits
 - Output loads
 - Output regulations
 - EPI-Lo:
 - MCP voltage accuracy
 - LVDS fault mitigation
 - Bias Voltage Zener diode protection