Power Matters

SSPA Solutions and Space Relays

Microsemi Space Forum Russia – November 2013

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National Sales Manager – Power Management Group

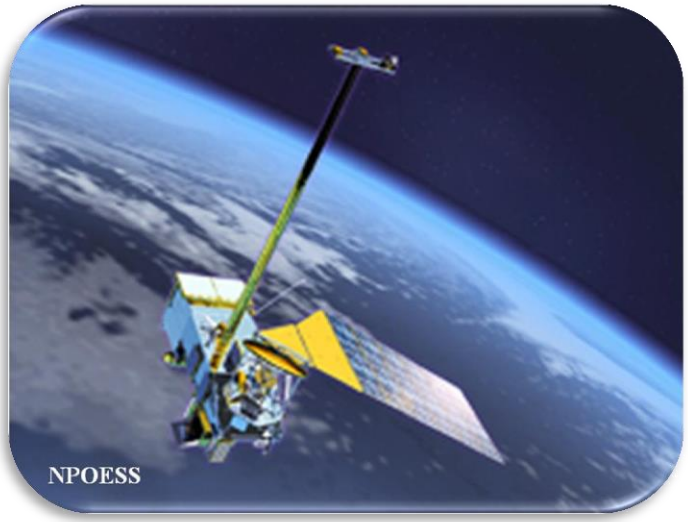
Agenda

- Introduction
- SSPA Overview
- SSPA Architectures
- Architecture Solution
- Space Grade Relays
- Conclusions

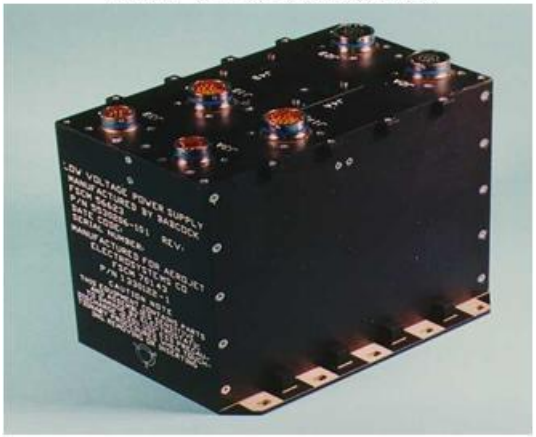
Vivisat Life Extension Concept

Microsemi PMG Core Competencies

- Over 30 years of space heritage
- Power supply and power system designs
- Electrical topologies with inherent SEE Hardening
- Engineering competence
  - Radiation analysis
  - Worst case / EOL analysis
  - Component engineering
  - Mechanical design for space
    - Structural analysis
    - Solid modeling
    - Thermovac design
    - Life / solder fatigue
- AS9100 process qualification



DSP PROGRAM EM291
SSLV POWER SUPPLY



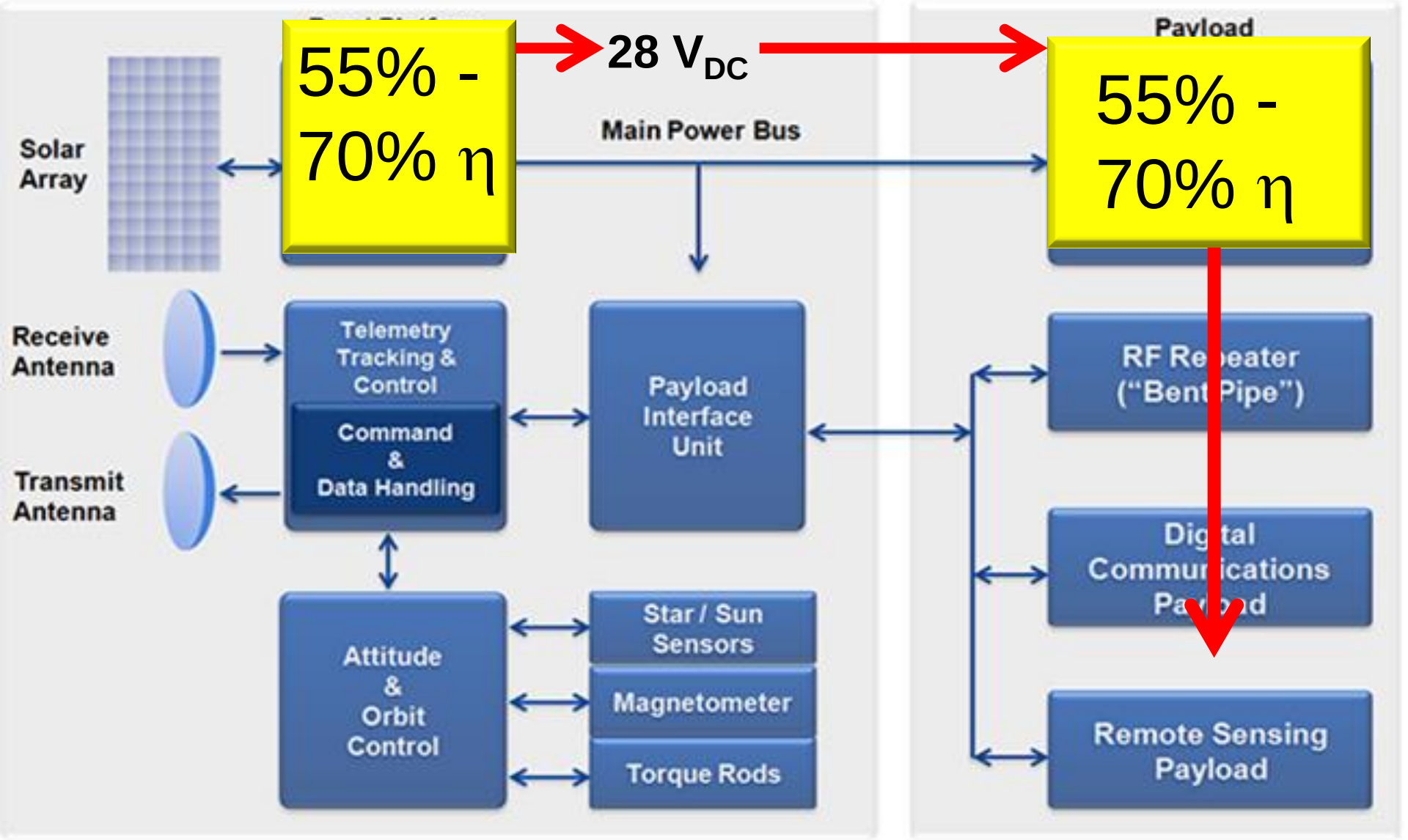
PMG Satellite and Missile Programs

Atlas V Launch Vehicle	MIMU Miniature Inertial Measurement Unit
Ares I-X Launch Vehicle	MUOS
A2100	NEAR Near Earth Asteroid Rendezvous
A2100 OBC	Next View
ABI GOES	NPOESS ATMS
AEHF Advanced Extreme High Frequency	NPOESS Payload
Aries	NPOESS VIIRS
DSP Defense Support Program	Special Programs
E115	Special Programs CTCU
EOS AM Earth Observation Satellite	PAC-3 Patriot Advanced Capability
EOS CHEM Earth Observation Chemistry Mission	RIMU Trident
EOS PM Earth Observation PM Mission	ROCSAT Republic Of China Satellite
Radiation Experimental Satellite	SBI Space Based Interceptor
GeoEye I	SBIRS High Space Based Infrared System
GeoEye II	Sensitive Collection Optical Receiver (SCORE)
GMI	SE2
GPS II	SMIS Space & Missile Tracking System
HMC Health Management Computer	STSS Space Tracking & Surveillance Systems
INDOSTAR Indonesian Satellite	Mission Computer
IUS Inertial Upper Stage	TKE Thermal Knife
KOMPSAT Korean Multi-Purpose Satellite	TRIFOG 3 Axis Fiber Optic Gyro
Mars Lander	Vibe Sensor
MILSTAR Military Communications	

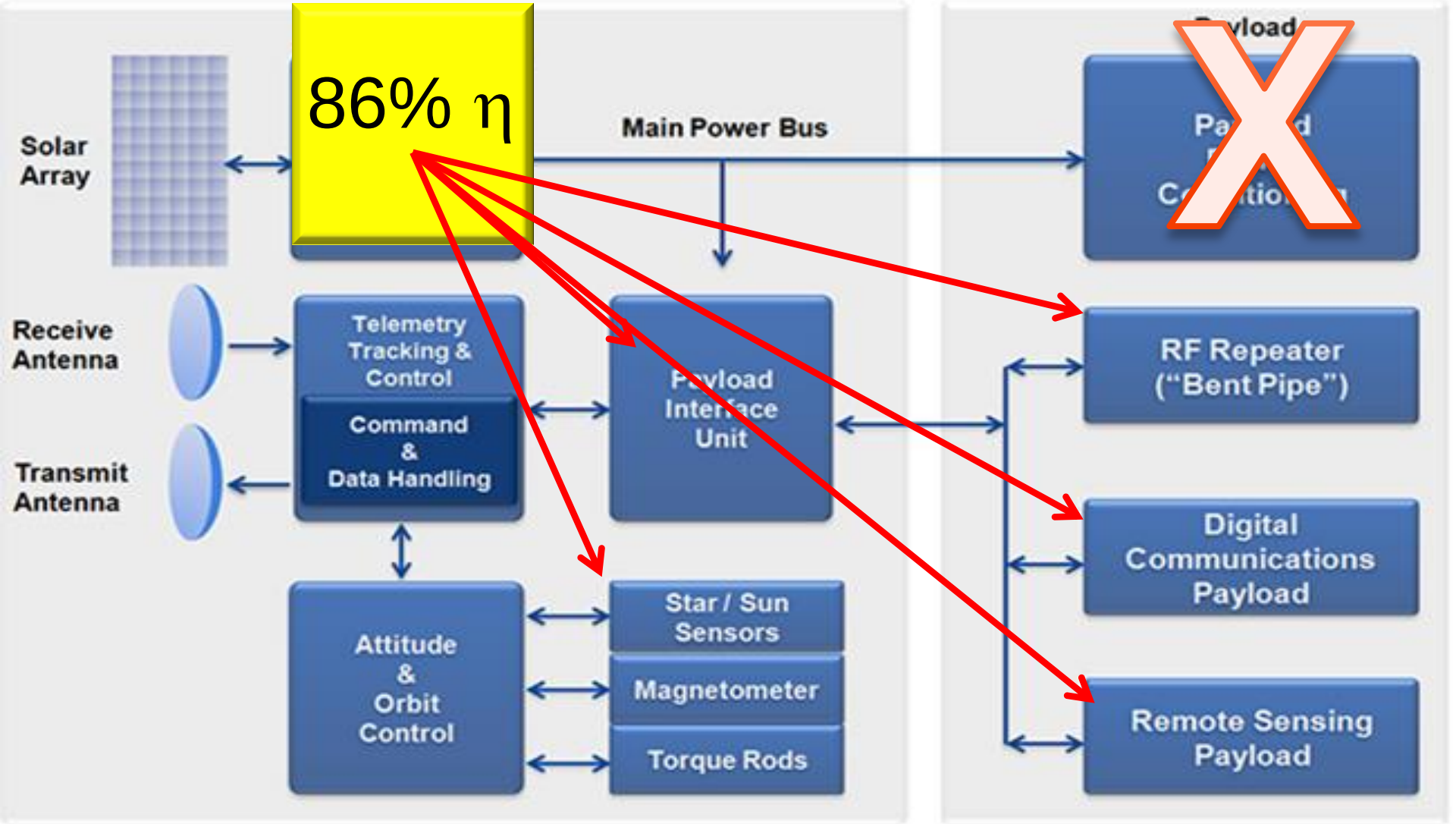
Power Conversion

- The design goal of every modern day satellite is to deliver power as efficiently as possible from the solar panel to the load
- Higher efficiency power conversion reduces the size of the solar panel required to power the load (further reducing weight and cost)
- Higher efficiency power conversion reduces the size of the heat dissipation plate and increases reliability

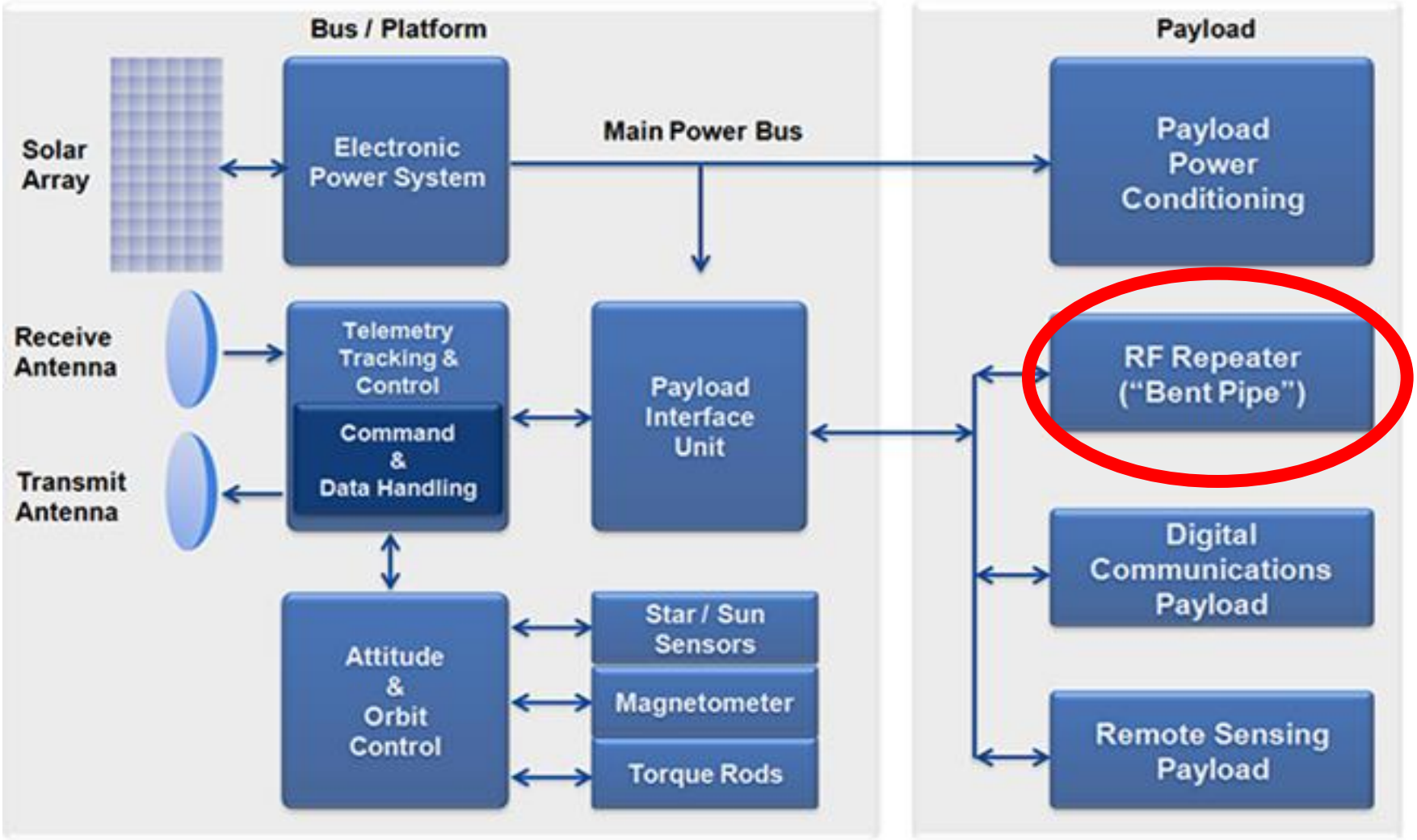
Legacy Architecture Efficiencies



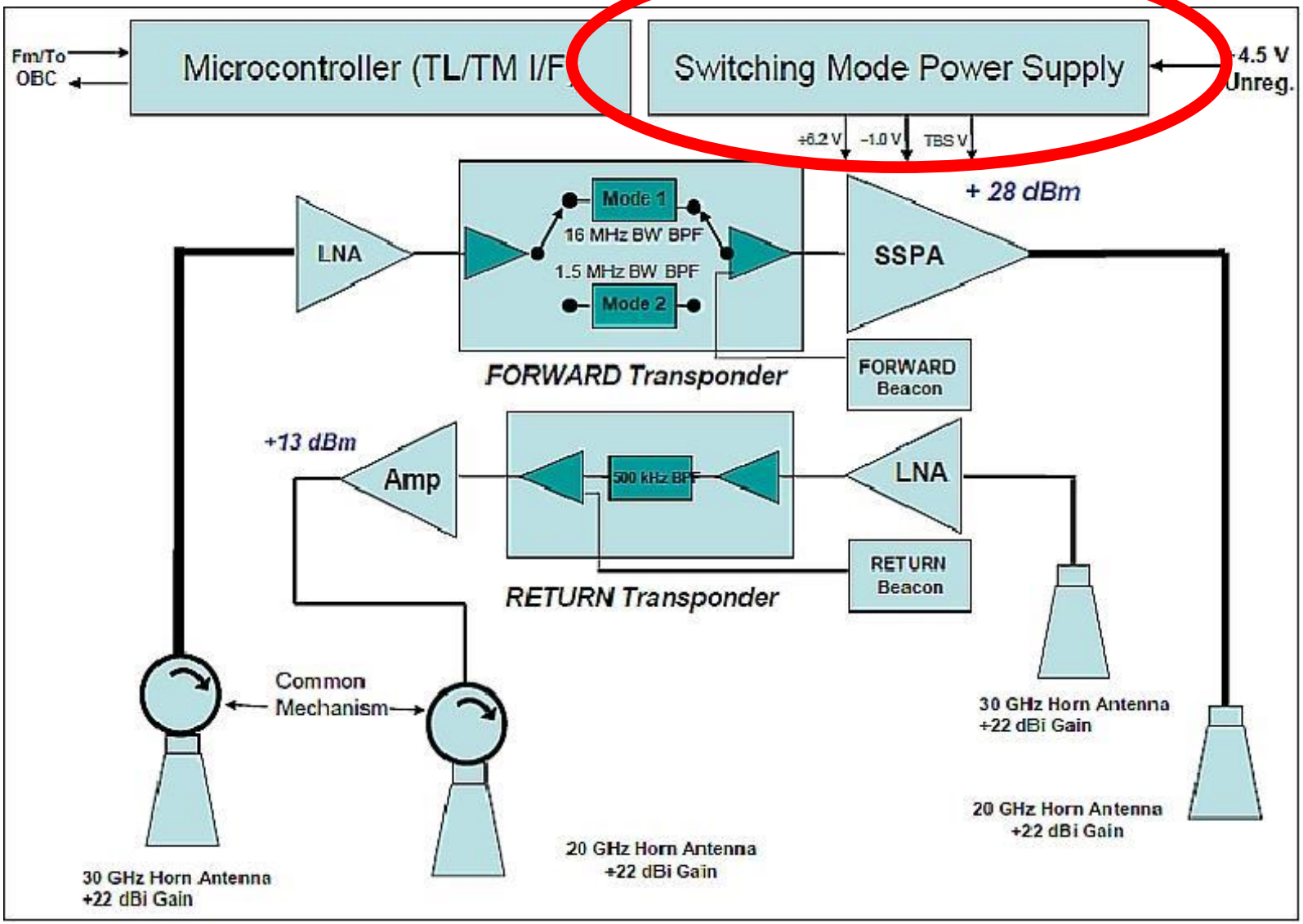
Future Architecture Efficiencies



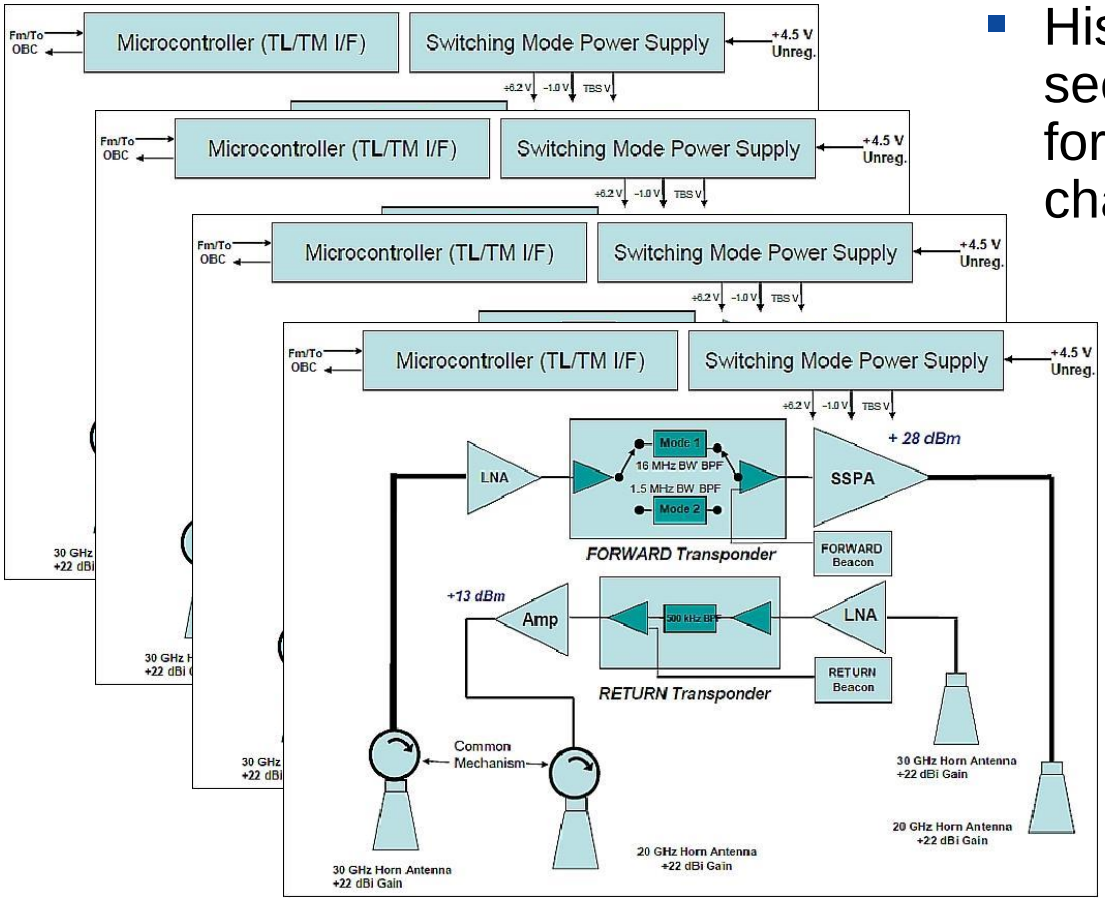
Solid State Power Amplifier Architectures



Solid State Power Amplifier Architectures



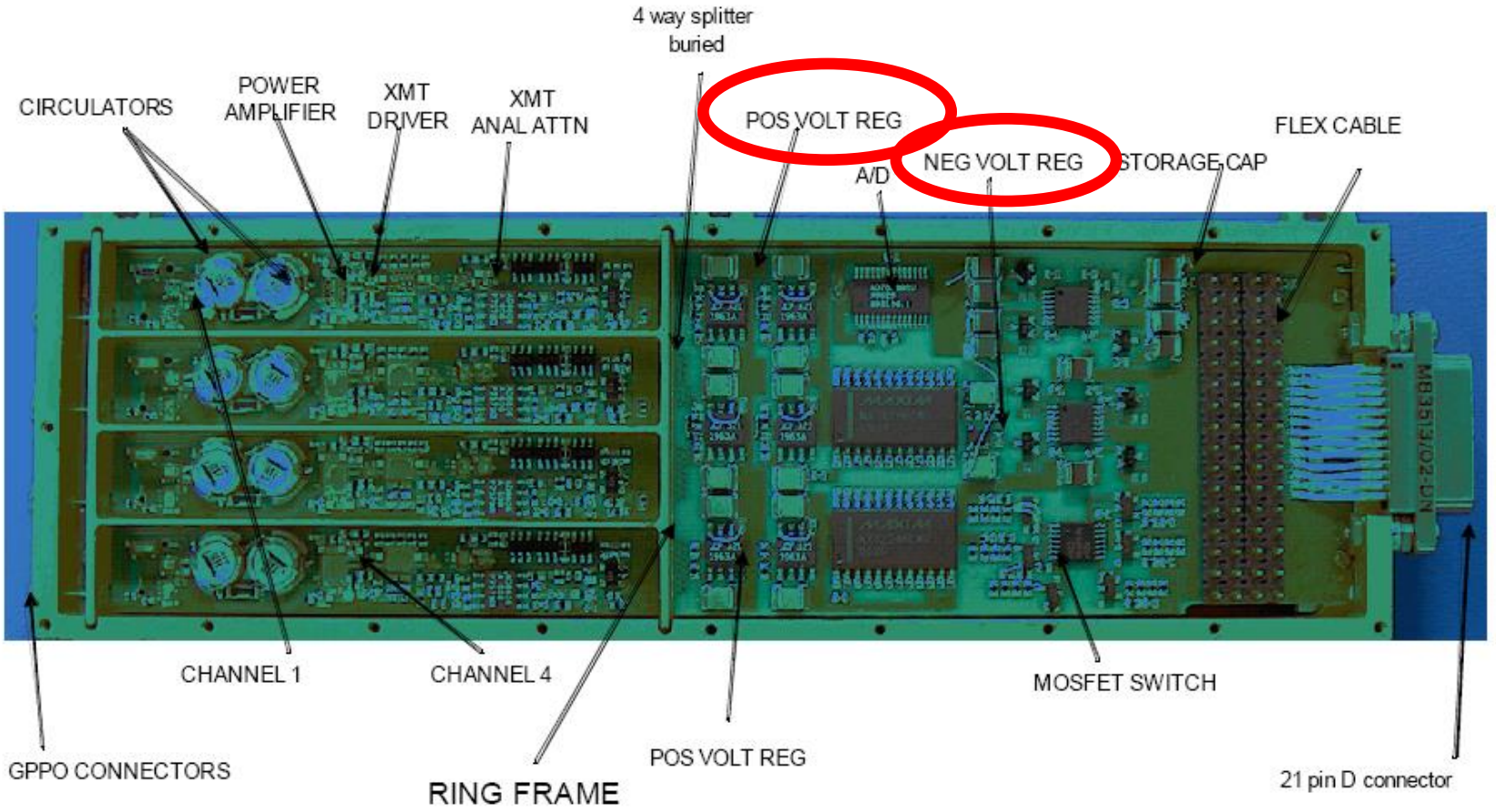
Historical SSPA Architecture



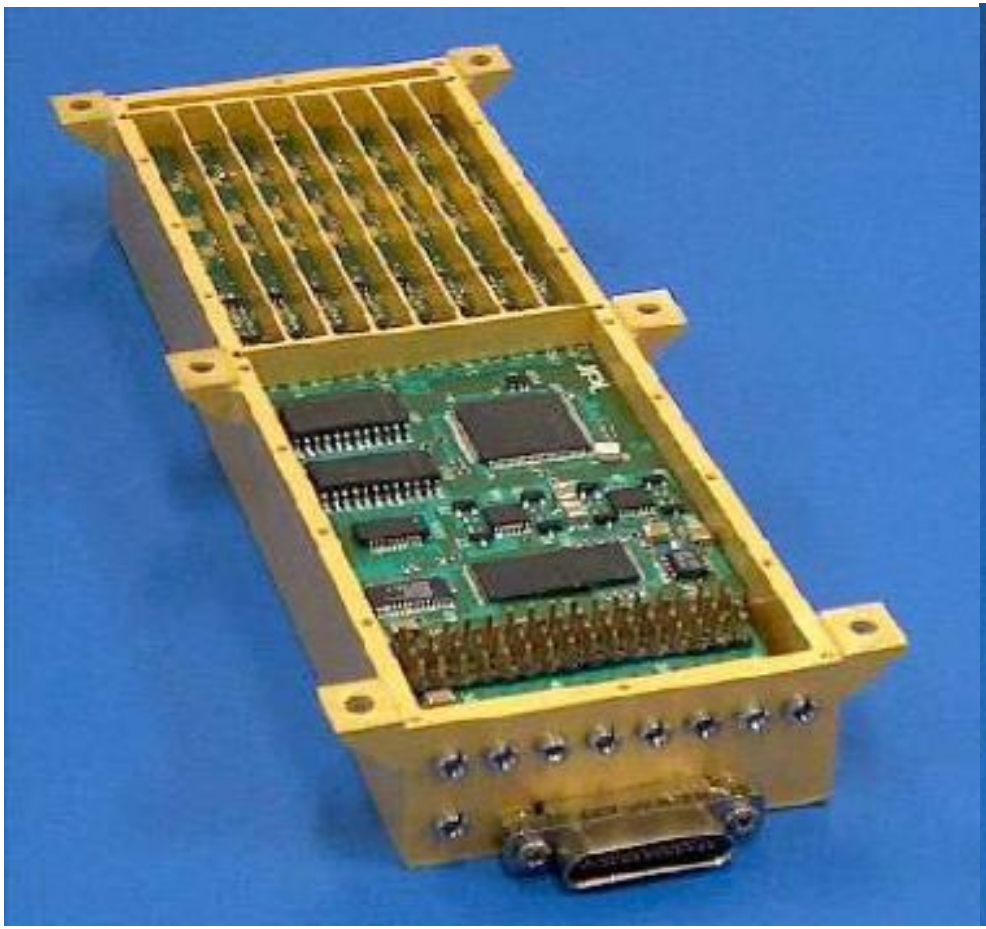
- Historically all blocks of the RF sections were combined to form one Transmit / Receive channel
  - Low Noise Amp
  - Phase locked source
  - TCXO reference
  - Power Output Amp
  - High-Q filter
  - DC/DC Converter
    - If any sub component failed the entire module was shut down

Local On-Board Regulators for Low Noise

TRANSMIT SIDE OF T/R MODULE SHOWING COMPONENTS



Today's SSPA Architectures



Eight Receive Channels

Four Transmit Channels

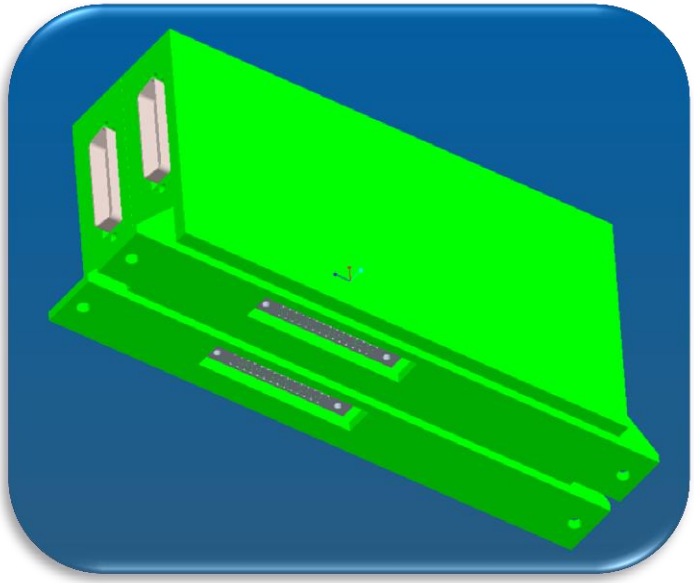
Industry Trends

- Satellites continue to grow – more channels per system
- Typical commercial communications (Satellite TV) use 25KW to 35KW solar panels
- RF front ends can number 32, 64+
- Customers must choose between Modular vs Distributed Power
- Size, weight, efficiency, reliability and cost are driving factors

Specification of SSPA DC to DC Converter

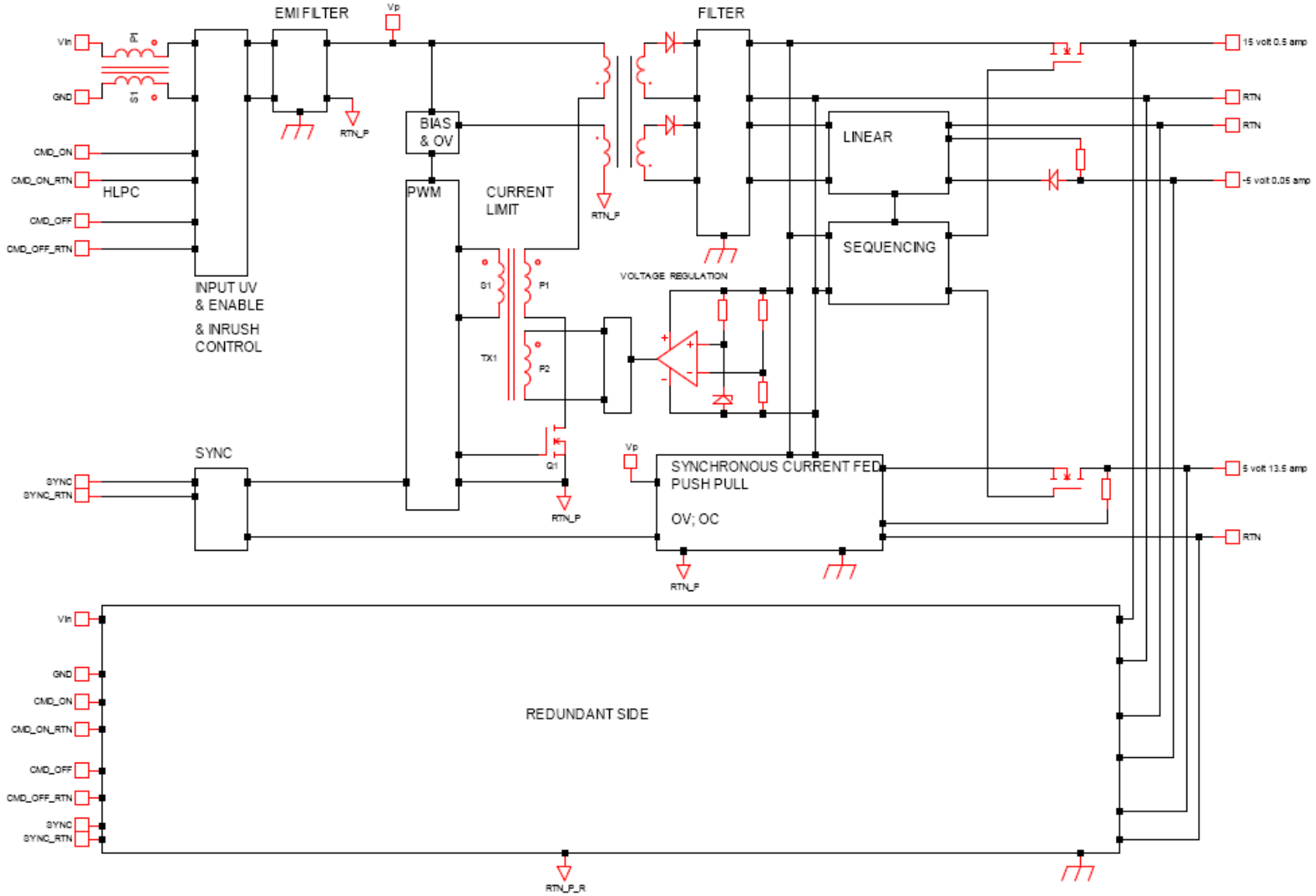
- Design Life of 15 years
- Radiation Total Dose ~100KRad
- Radiation Single Event >80 MeV
- EMI filter on inputs
- Power sequencing control
- Remote controls for Inhibit, Sync, Output ON/OFF
- Inrush Current Limiting
- Multiple Outputs to support both Analog and Digital
- Analog output rails < 5mV ripple (or less!)
- Overvoltage output protection
- Telemetry for power status
- Mass is a key issue but must meet high shock and vibration

Microsemi SSPA Dual Redundant Power Supply



- Direct conversion from Main Satellite Bus
  - 28V, 50V, 100V Versions
- Powering multiple RF sections with a single redundant supply reduces weight, cost & power dissipation.
- Remote telemetry monitors “power good” or actual output voltage and current
- The system switches to a back up supply automatically
- The primary and backup can be ‘wired OR’
- Alternatively, each supply can be turned on with the output enabled via a latching relay
- Multiple redundant supplies are possible

Block Diagram DC to DC Converter



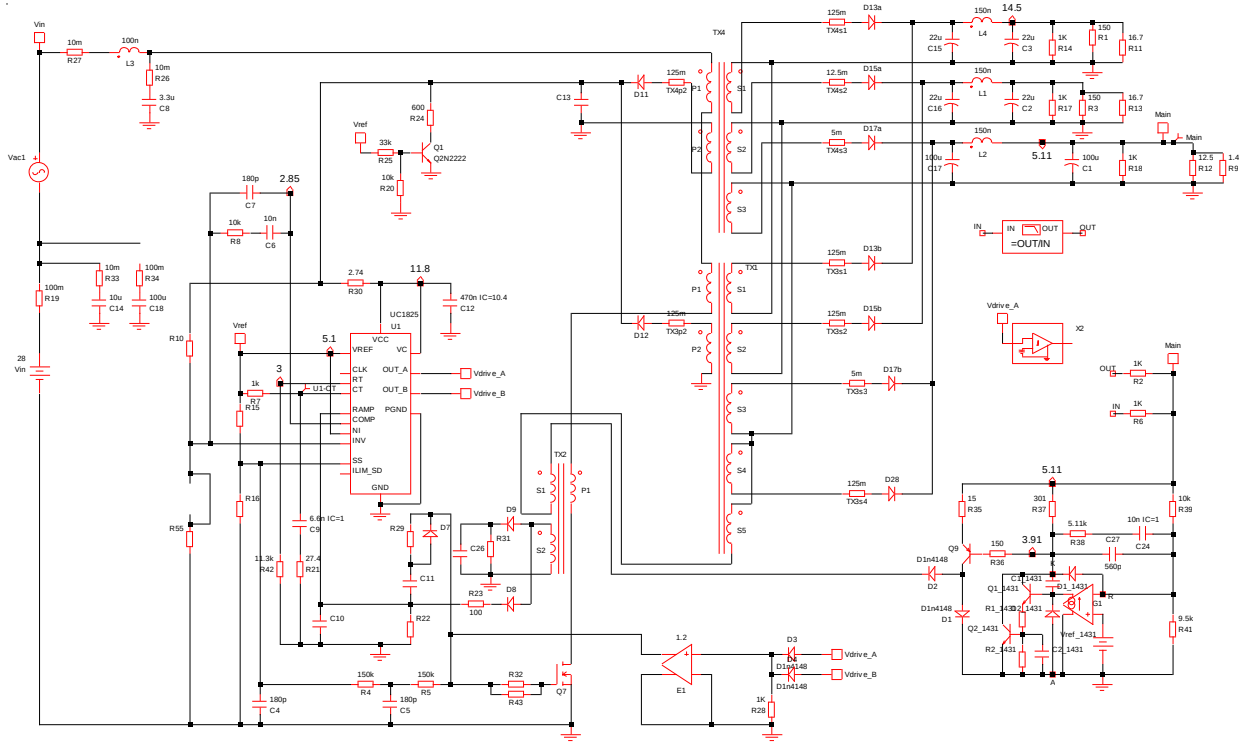
Electrical Design – Heritage Designs

- The converter is based on Microsemi PMG heritage circuitry. The design uses current fed topology that is inherently insensitive to single event caused power stage failures
- Outputs are isolated from inputs and are both isolated from chassis.
- Over Voltage Protection circuits monitor the outputs independent of the normal control loop. Over Current circuits provide constant current profile limiting and protect all outputs from overload including continuous short circuit condition
- Sequencing ensures that the -5 VDC rail is in regulation, prior to raising the positive output rails

Electrical Design – Heritage Designs

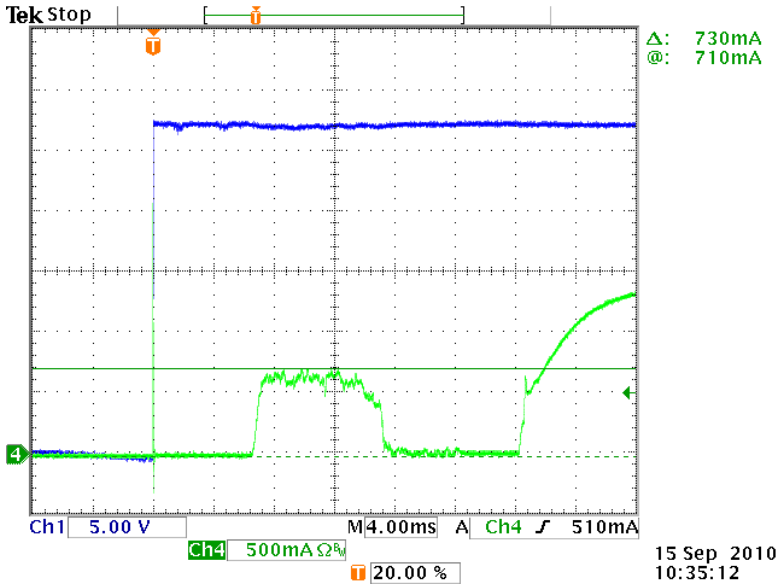
- The input power charges the EMI filter capacitors at a controlled rate through the inrush limiting circuit
- The Power Supply accepts High Level Pulsed Commands to activate its latching relay and turn on or off. The system must command the relay to the OFF mode prior to the application of input power to the Power Supply, for both the Primary and Redundant side
- The 15 VDC output is produced by a flyback converter. This same converter provides the power for the -5 VDC linear regulator and for the internal biasing needs. A high efficiency synchronous current fed converter is used to provide the 5 VDC output
- The Power Supply meets MIL-STD-461 emissions and susceptibility requirements

Electrical Design – Practice

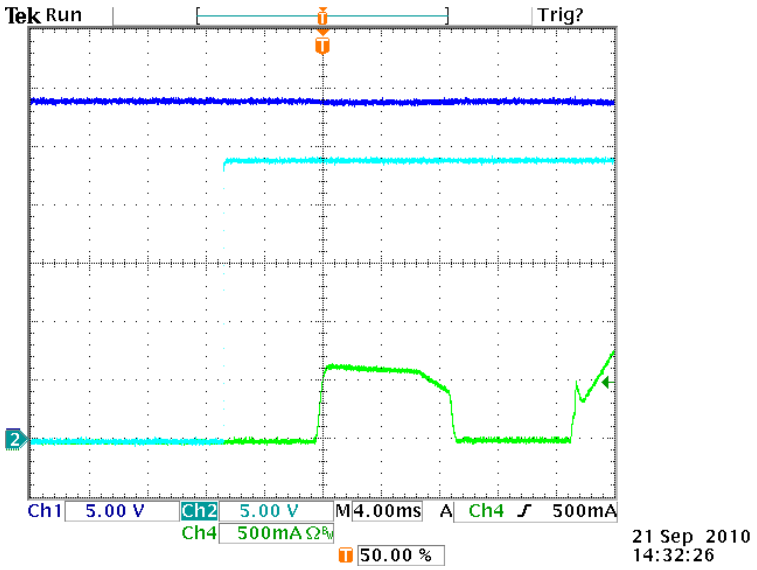


- Magnetics designed in house by PMG
- Spice based simulation of complete power supply (Monte Carlo analysis)
- Extensive use of design tools
  - Mathcad, Simetrix-Simplis, QickField finite element analysis
- Full bread-boarding of Power Supply
  - Fully stocked and equipped engineering lab
  - Automatic test stations
- Thermal imaging

Inrush Current Limiting



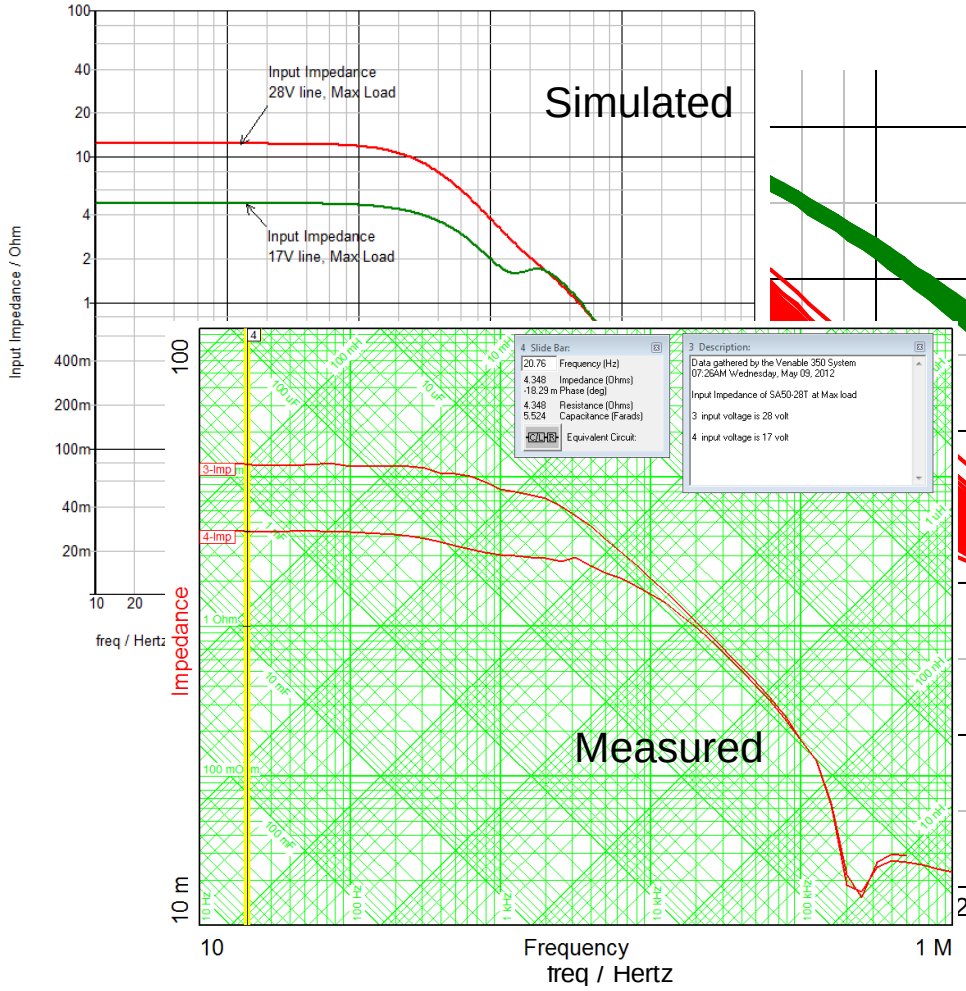
V_{IN} = 0 to 28V



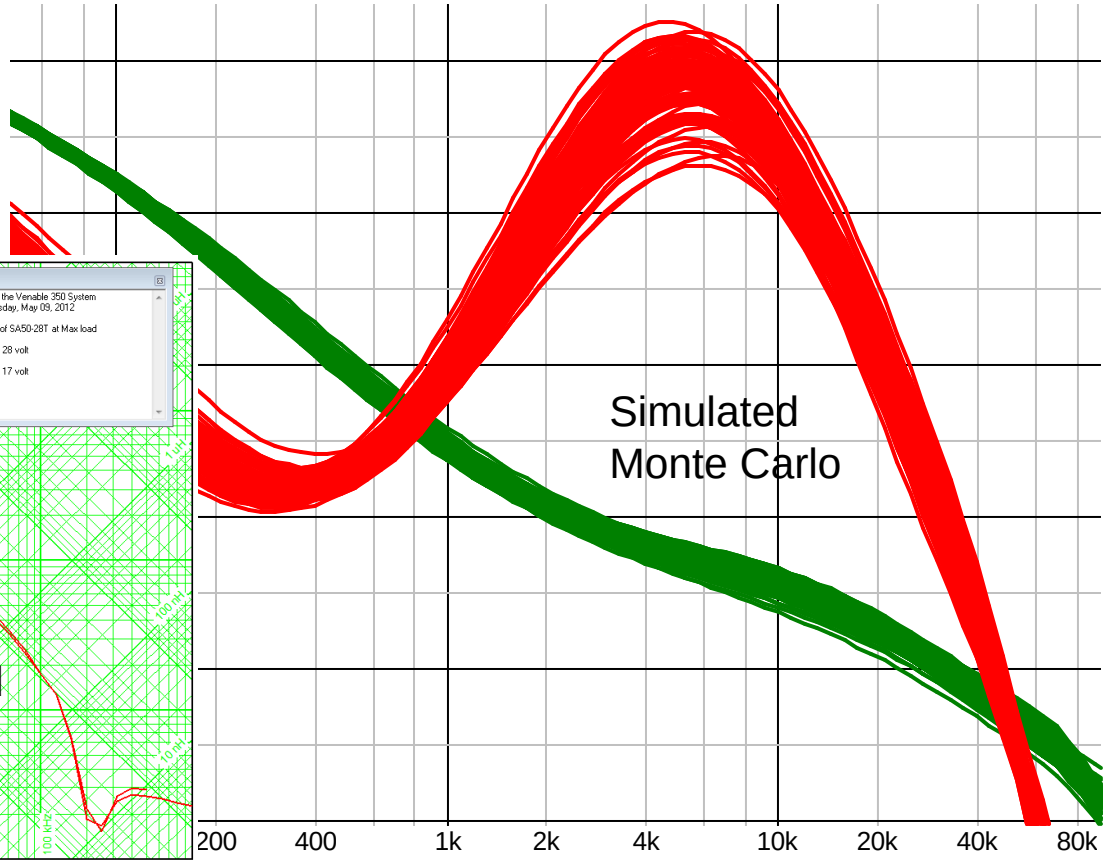
Turn on with Enable Pin

Electrical Design – Practice

- Input impedance

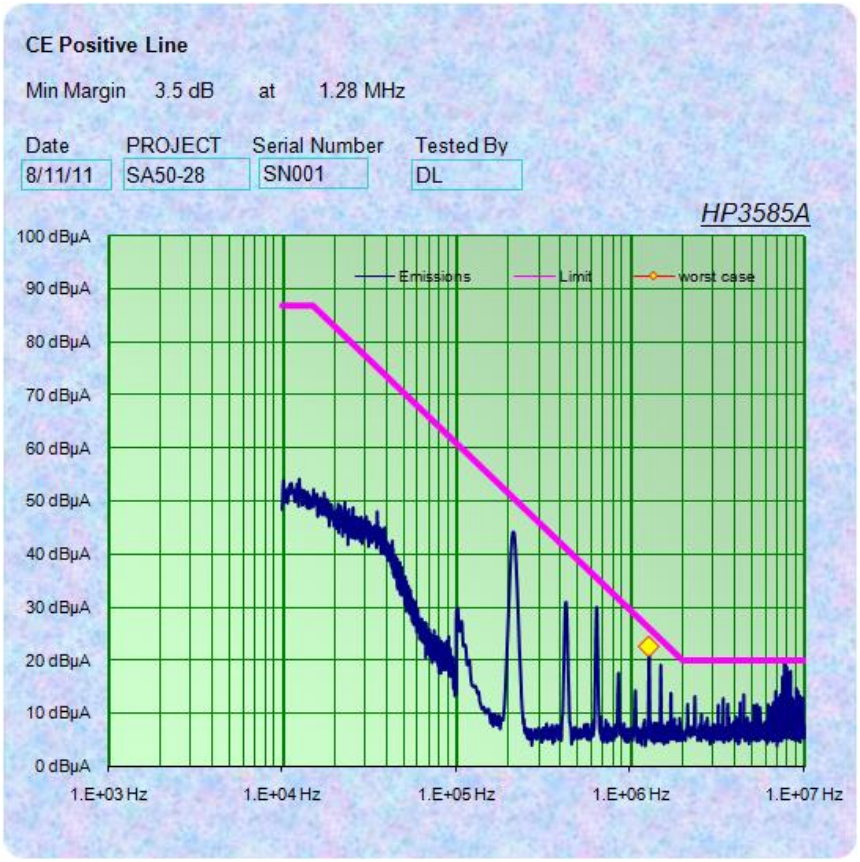


- Control loop
  small signal response

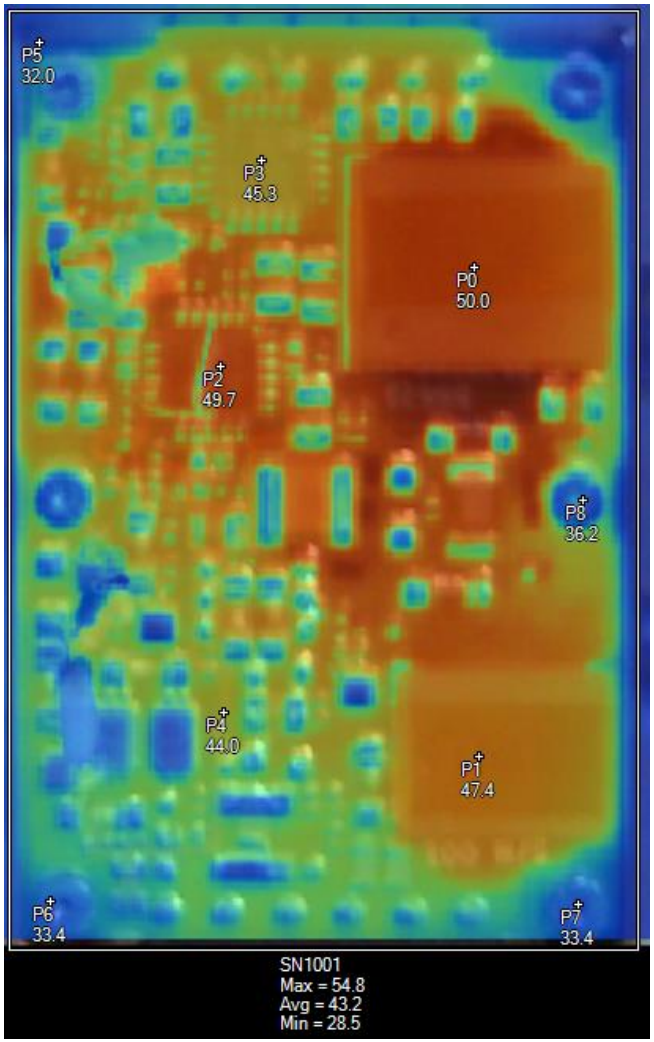


Electrical Design – Practice

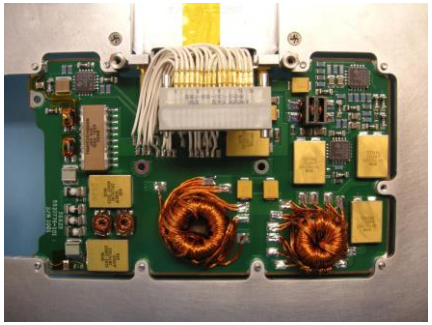
- In house EMI evaluation

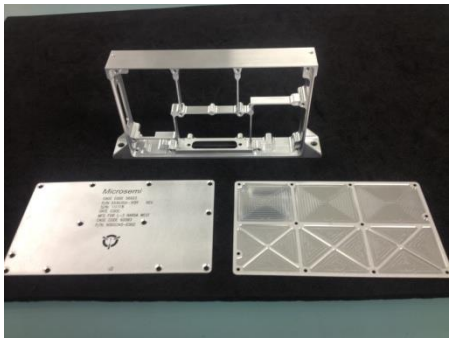


- In house Thermal imaging

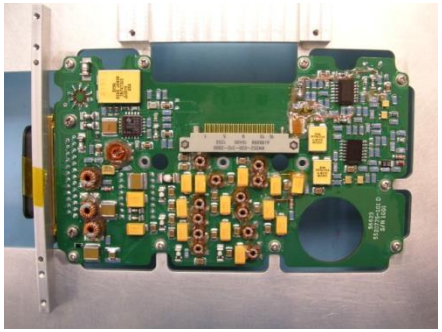


SSPA Power Supply Assembly



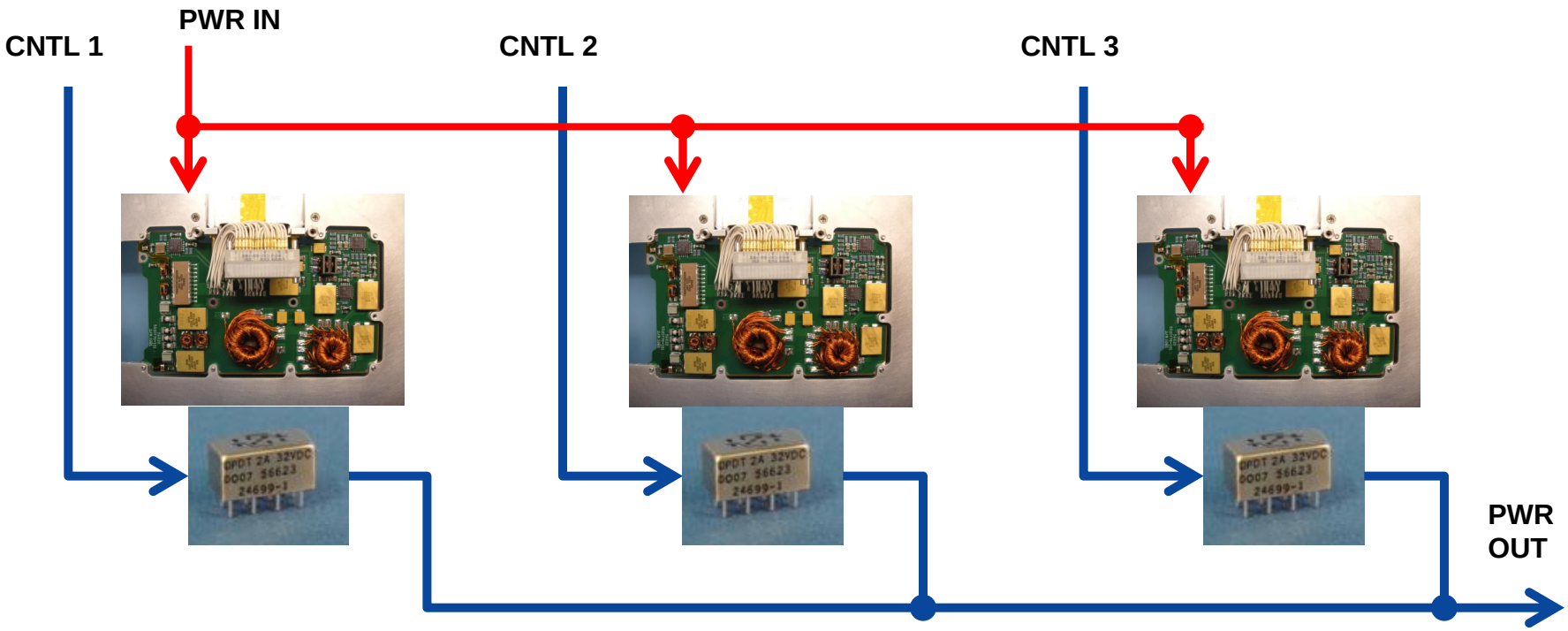


- Back to Back PWAs
  - PWA1 Control & Bias
  - PWA2 Main Power
- Light, Stiff Covers # Frame
  - Thermal Conduction to Base
- Final Unit weight <500gms



Using Latching Relays to Switch Power

- Space Grade Latching Relays enable reliable Power Switching
- Control Electronics provide pulse to latch a relay on or off
- Redundant supplies each have a latching relay for power control



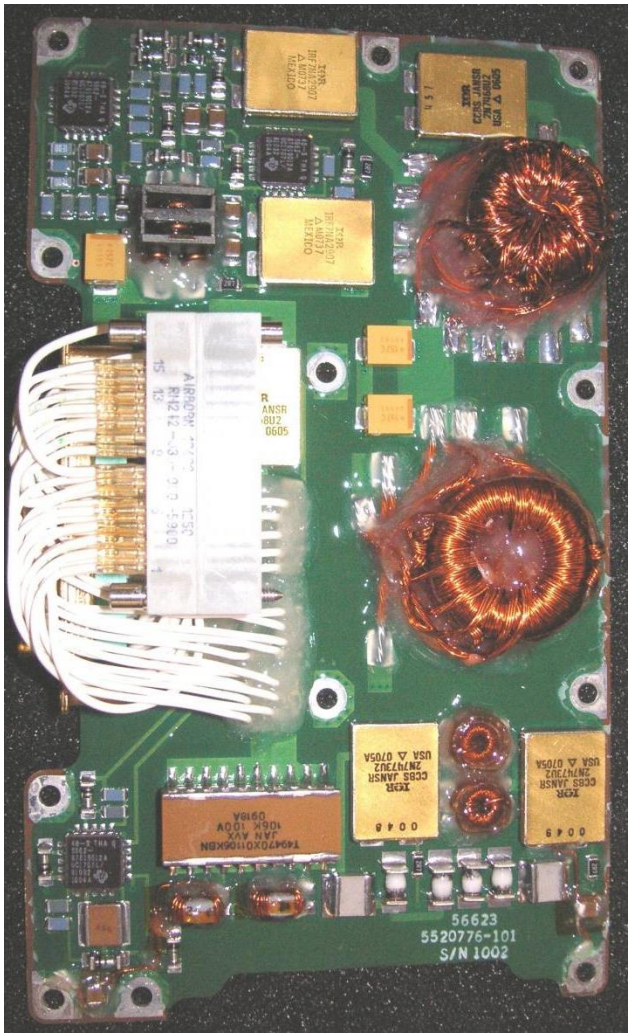
Mechanical Architecture

Customizing the SSPA Power Supply

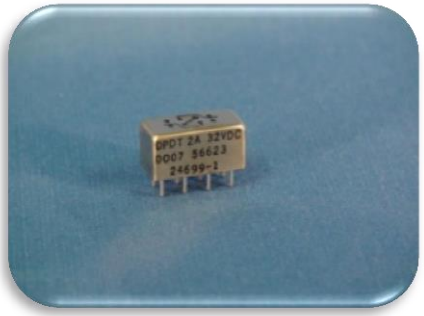
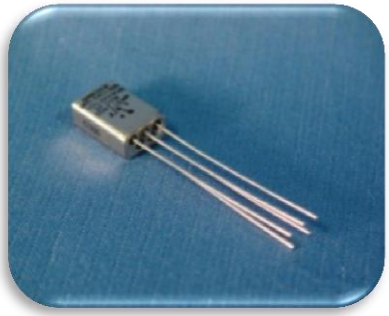
- SSPA power supplies have been designed, tested, qualified and shipped
- Customers seeking solutions don’t have to start at ground zero
- PMG can supply summary data sheets for this application
- Modifications to existing designs mean less cost and shorter delivery times to customers
- Complete analysis and qualification packages can be provided
- PMG will work closely with customers to provide the optimal system solution

Design Reports

- Structural Analysis
- Thermal analysis
- Radiation Analysis
- Worst Case Analysis
- Reliability Analysis
- FMEA
- FA Qualification
- Radiation Test Report
- EMI Performance



Space Grade Relays

- Electromechanical Relays play an important role in satellites
- Variety of coil voltages
- Up to 25 Amp contacts
- Multiple Pole Double Throw configurations
- Latching or non-latching
- Sealed

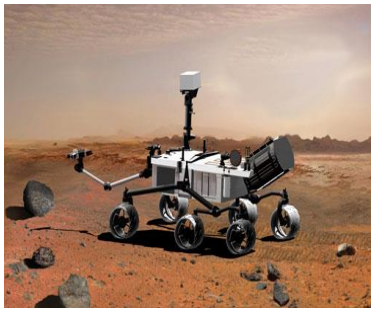
PMGP Electromechanical Products Heritage

Atlas
1947

Delta
1960

Titan 1959-
1963

Mars Observer
1993



Mars Rover
2003

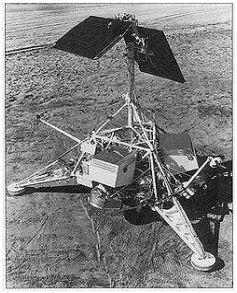
Agena 1960

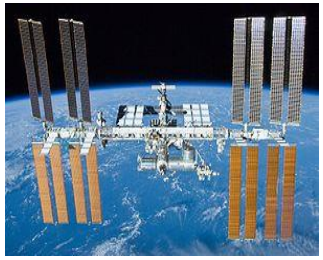
Centaur 1962

Surveyor 1966

International
Space Station
1998

Cygnus
2011





Relays in Space

- Used to switch inductive loads such as motors or actuators
- Used when high isolation is needed
- Used to switch high current loads where low “on” resistance is critical
- Latching relays ‘remember” on/off state
  - Actuated with a pulse, contacts remain in the same state indefinitely
- Some present day satellites use 500+ relays
- Military grade relays & contactors too!

Comparison of Solid State with Electromechanical Relay

	EMR	SSR
Contact Resistance	< 100 mOhms	>10 ohms
Capacitance	< 1 pf	>20 pf
Leakage	Lower across open contacts	Higher due to P-N junction
DC Sensitive	Not DC sensitive Can be used for AC or DC loads	Frequency limit on AC & DC sensitive need isolated bias supply
Response Time	Slow 2-15 mSec	Fast <02ms
Number of Operation	Low >100	High >100 million
Noise Acoustic	High	Low (Silent)
Mechanical Shock & Vibration	30g Vibration	Up to 10 times as much

Relay Key Specs- Performance

Performance

Contact Rating:	1 Amp – 25 Amp
Life:	50,000 – 100,000 activations
Pull-In:	100 mw – 1 w
Operate Time:	3 ms – 15 ms
Contact Bounce:	1 ms – 2 ms

Environmental

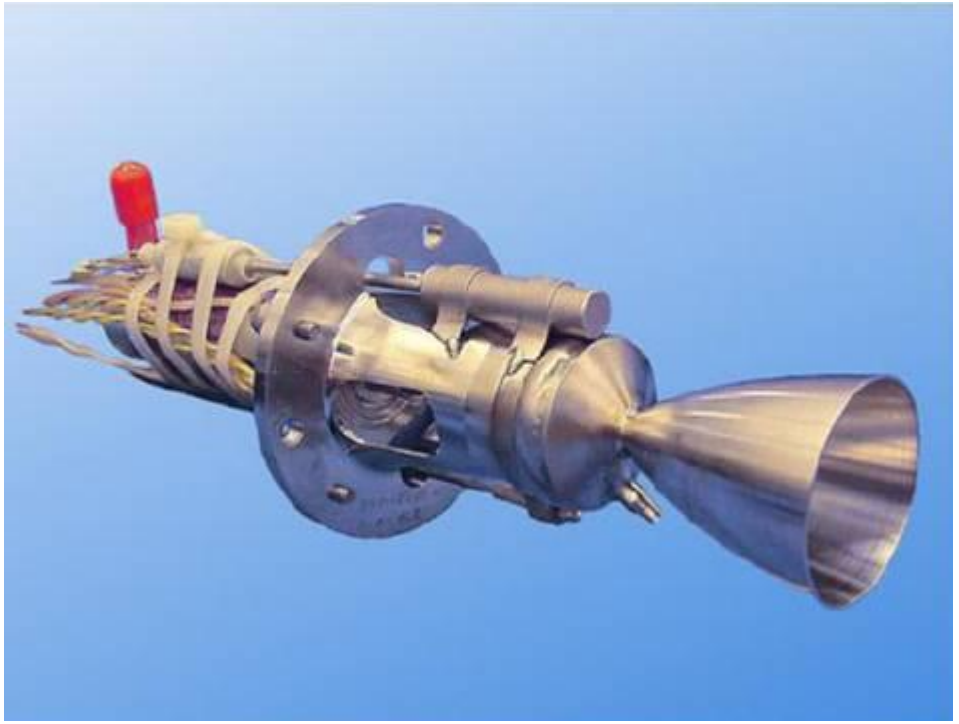
Temperature Range:	-65 ^{o}C to +125 ^{o}C
Vibration:	20 G's 38-2,000 Hz – 30 G's 70-3,000 Hz
Shock:	50 G's 11 ms – 200 G's 6ms

Electrical

Insulation Resistance:	100 MΩ – 10,000 MΩ
Contact to Case:	500 V_{RMS} – 1,250 V_{RMS}
Contact to Coil:	500 V_{RMS} – 1,250 V_{RMS}
Coil to Case:	500 V_{RMS} – 1,000 V_{RMS}
All Points:	250 V_{RMS} – 5000 V_{RMS}

High Voltage Relays

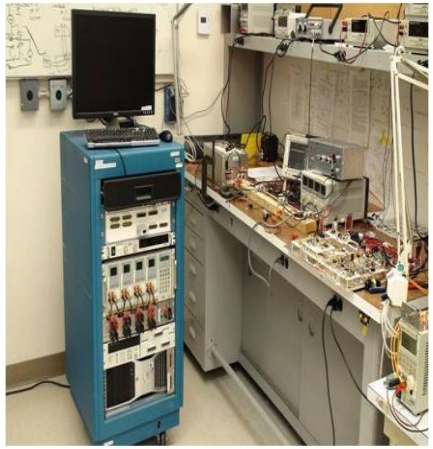
- Space applications require vacuum sealed ultra low leakage rates for HV relays (4KV to 10KV isolation)
- We are interested in supporting customers who manufacture steering thrusters



HV Relays

Reliability Testing

- Vibration (sine-random)
- Chatter
- Shock up to 30,000 Gs
- Thermal shock hot/cold -70 to125 ^{o}C
- Humidity-Moisture
- Pressure
- Terminal strength
- Solder ability
- Electrical Life testing
- Overload
- Rupture
- Inductive
- Motor
- Lamp
- Resistive
- Time current characteristics up to 350 Amp
- Fine leak to X10^{-8}



Microsemi relays are qualified to MIL-PRF-83536, MIL-PRF-39016, MIL-PRF-6106, and MIL-PRF-5757, RPCs are built to MIL-PRF-83383

Summary

- Traditional systems can benefit in reduced cost, weight and size by direct conversion from the solar panel voltage to the payload required voltages
- Additional benefits occur with increased system efficiency and reliability
- Future architectures will power multiple RF modules with redundant power supplies
- Microsemi PMG is ready willing and able to support customer's DC to DC conversion needs
- Relays continue to be a viable switching solution
- Please initiate a discussion with Microsemi PMG with an email or an RFQ

Microsemi

Thank you