SSPA Solutions and Space Relays

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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
## PMG Satellite and Missile Programs

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

Solar Array

Receive Antenna

Transmit Antenna

Telemetry Tracking & Control

Command & Data Handling

Attitude & Orbit Control

Payload Interface Unit

Star / Sun Sensors

Magnetometer

Torque Rods

Payload

Remote Sensing Payload

Digital Communications Payload

RF Repeater ("Bent Pipe")

28 V\text{DC}

55\% - 70\% \eta

55\% - 70\% \eta
Future Architecture Efficiencies

86% $\eta$
Solid State Power Amplifier Architectures
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

- CIRCULATORS
- POWER AMPLIFIER
- XMT DRIVER
- XMT ANAL ATTN
- 4 way splitter buried
- POS VOLT REG
- NEG VOLT REG
- A/D
- STORAGE CAP
- FLEX CABLE
- CHANNEL 1
- CHANNEL 4
- RING FRAME
- MOSFET SWITCH
- GPPO CONNECTORS
- 21 pin D connector

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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
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.
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.
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

$V_{\text{IN}} = 0 \text{ to } 28\text{V}$

Turn on with Enable Pin
Electrical Design – Practice

- Input impedance
  - Simulated
  - Measured

- Control loop small signal response
  - Simulated Monte Carlo

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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
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
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

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

**Temperature Range:** -65 °C to +125 °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

**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 to 125 °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
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.
Thank you