Space Power and Point-of-Load Solutions Product Overview

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Company Overview

- Leading-Edge Semiconductor Solutions Differentiated by:
  - Performance
  - Reliability
  - Security
  - Power

- Solid Financial Foundation
  - FY2016 Revenue: $1.6B
  - 4800 employees today

- Major Focus Products
  - FPGA and ASIC
  - Timing and OTN
  - Mixed-Signal and RF
  - Switches and PHYS
  - Storage Controllers
  - Discretes and integrated power solutions
Microsemi Space Pedigree

Extensive Space Heritage
- Developing space solutions for six decades
- Proven track record of innovation, quality, and reliability

Broad Solutions Portfolio
- Power, mixed-signal, and digital, for bus and payload applications

Expanding our Product Portfolio through Continuous Innovation

Partner for the Long Run
- 60 Year space heritage
Delivering Comprehensive Space Portfolio

| Radiation-Tolerant FPGAs                                                                 | High Performance, High Density, Low Power  
TID up to 300 Krad, SEL Immune  
RTG4 FPGAs up to 300 MHz and 150K LE  
RTProASIC3, RTAX and RTSX-SU QML Qualified |
|---------------------------------|------------------------------------------------------------------------------------------|
| Rad-Hard Mixed Signal Integrated Circuits | Telemetry and Motor Control Space System Managers  
High Side Drivers  
Regulators and PWMs  
Extensive Custom IC Capability |
| Space Qualified Oscillators      | Ovenized Quartz Oscillators  
Hybrid Voltage Controlled and  
Temperature Compensated Crystal Oscillators  
Cesium Clocks |
| Rad-Hard Power Solutions         | Rad-hard JANS Diodes, Bi-Polar Small Signal Transistors, and MOSFETs  
Rad-hard Isolated DC-DC Converter Modules  
Custom Power Supplies 2 W to > 5 KW  
Linear and POL Hybrids  
Electromechanical Relays |
Agenda

- Power Products Overview

- Non-isolated point-of-load and hybrid capabilities

- Isolated bus convertors for satellite bus power rails

- What’s next for SWAP (Size Weight and Power) improvements?
  - Point-of-Load Hybrids
  - Point of Module
Portfolio Breadth: Example Signal Processing Payload

LDO Regulators and Switchers

- Sensor
  - ADC
  - Signal Processing (FPGA, FPGA, FPGA, POL, LX7730)
- Oscillator
- Compression (FPGA, POL, LX7730)
- Storage (FPGA, POL, LX7730)
- Transmit (FPGA, POL, LX7730)
- TWTA or SSPA

Sensor Power Supply
- DC-DC Converter
  - POL, LX7730, FPGA

Motor Control Unit (Gimbals, mirrors, filters, focal plane)
- DC-DC Converter
  - POL, LX7720

Power Distribution Unit (PDU)
- DC-DC Converter
  - POL, LX7730, FPGA

Payload Interface Unit (PIU)
- POL, LX7730, FPGA

Embedded Power Controller (EPC)
- To Spacecraft TT&C / C&DH

www.microsemi.com/applications/landers/instrument-payload

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Portfolio Breadth: Example Signal Processing Payload

- Integrated Power Solutions and Discretes

```
Sensor → ADC → Sensor Power Supply
          |                     | Motor Control Unit
          |                     | (Gimbals, mirrors, filters, focal plane)
          |                     | DC-DC Converter
          |                     | POL  LX7730  FPGA

Oscillator  → Signal Processing → Oscillator
               | FPGA  FPGA  FPGA  POL  LX7730

ADC

Oscillator  → Compression  → Oscillator
               | FPGA  POL  LX7730

Signal Processing

Oscillator  → Storage  → Oscillator
               | FPGA  POL  LX7730

Compression

Storage

Oscillator  → Transmit → Oscillator
               | FPGA  POL  LX7730

Signal Processing

Transmit

Oscillator  → Embedded Power Controller (EPC)
               | FPGA  POL  LX7730

To Spacecraft TT&C / C&DH

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```

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Space Executive Overview

- **60 years of flight heritage** on hundreds of space programs

- **Widest discrete product portfolio** of any space component manufacturer
  - Dominate role in Defense Logistics Agency (DLA) Qualified Manufacturers List: >75% of total slash sheets
  - First company to have diodes qualified to space level (JANS qualification) by DLA (formerly DSCC)
  - Over 95% of the product portfolio is EAR99

- Over 30 years of space power supply design expertise with zero in-flight failures

- Internal **packaging and radiation-hardened by design expertise** for discretes and hybrids

- **Comprehensive** High-Reliability Plastic / Non-hermetic Product Portfolio

- **Superior manufacturing and quality** system ideal for high-reliability applications
  - AS9100/ISO9001, MIL-PRF-38534, MIL-PRF-19500, LEAN processing

- Continue to be a **market leader in space and radiation-hardened applications**
  - Intense focus on system level solutions to meet our customers’ needs today and tomorrow
  - Leverage our breadth of technology and core strengths around packaging, radiation effects and design, quality, and reliability
Satellite Power System (with example payload)

System Architecture Drivers

- Isolated power topologies provide **fault isolation**
- **High voltage** power bus provides significant cost savings through weight reduction
- Long inductance paths between supply and load drive **distributed power topologies**
- Distributed power topologies are often **non-efficient** due to multiple stages
- Point of load solutions take up valuable **real estate** for digital designer
- **Radiation performance** in power supply is critical to avoid single point of failure
# Space Power Products

<table>
<thead>
<tr>
<th>Product Family</th>
<th>Target Application/ Sub-System</th>
<th>Key Differentiation</th>
<th>Key Products</th>
</tr>
</thead>
</table>
| Radiation- Hardened Isolated DC-DC Converters | • Power conditioning unit (PCU)  
• Electronic Power Convertor (EPC)  
• Power distribution unit (PDU)  
• System power bus convertor (DC-DC)  
• Power Processing Unit (PPU)  
• Ion propulsion thrusters | • Highest output power and efficiency  
• Robust SMT construction  
• Hundreds of successful space missions  
• Greatest customization flexibility without added schedule risk  
• Shortest lead times | • SA50 Family - Catalog and semi-custom power solutions w/ EMI filtering  
• 30+years of flight hours with 0 failures  
• Worst-case analysis on hundreds of space programs  
• Custom Power Solutions |

| Radiation- Hardened Power Discretes: JANS Diodes, Bi-Polar Transistors, MOSFETs | • Power conditioning unit (PCU)  
• Electronic Power Convertor (EPC)  
• Power distribution unit (PDU)  
• System power bus convertor (DC-DC)  
• Power Processing Unit (PPU)  
• Ion propulsion thrusters | • Broadest JANS QPL portfolio  
• Low Dose Rate guaranteed bipolar transistors  
• **Largest** glass diode and transistor family in the market  
• Devices on over 75% of the available slash sheets | • Small Signal Glass Diodes, Rectifiers, Schottky Diodes  
• Voltage and Current Regulators  
• Protection Devices  
• Bipolar Transistors |

| Radiation- Hardened Hybrids: Linear and Switching | • Point of Load (POL)  
• Distributed power supplies in payloads | • DLA MIL-PRF-38534-certified facility  
• Highest level of integration to allow for optimal power footprint near digital circuits  
• Optimized for distributed power architectures | • MHP8565A (smallest radiation-hardened, QML-certified 4 A solution on the market—ideal for LEO orbits) |

| High-Voltage Electromechanical Relays | • Power conditioning unit (PCU)  
• Power distribution unit (PDU)  
• System batteries  
• Latching relays  
• High Voltage switching for thrusters | • Vacuum-sealed, ultra-low leakage rates  
• Broad range of High Voltage 4 kV–10 kV  
• Highest reliability  
• Extensive heritage in space | • Several hundred relays are used per satellite in various applications  
• New investments being made in new high voltage |
PBA Surface Mount vs. Hybrid Technology

- SMT vs. Hybrid Processing Capabilities Present Tradeoffs

<table>
<thead>
<tr>
<th></th>
<th>SMT</th>
<th>HYBRID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Process</td>
<td>Automated</td>
<td>Manual/Automated</td>
</tr>
<tr>
<td>Device Attachment</td>
<td>Solder</td>
<td>Eutectic / Epoxy</td>
</tr>
<tr>
<td>Connections</td>
<td>Solder</td>
<td>Wire Bond</td>
</tr>
<tr>
<td>Components</td>
<td>Package pre-screened</td>
<td>Basic Die / KGD</td>
</tr>
<tr>
<td>Semi-custom</td>
<td>Available</td>
<td>Not Available</td>
</tr>
<tr>
<td>Qualification</td>
<td>Same flow down as the rest of the design</td>
<td>MIL-STD-38534</td>
</tr>
</tbody>
</table>

Microsemi has the capability to work to the optimum solution for your application

- SMT modules
  - Quick-turn semi-custom capability
  - Full program requirement flow
  - Offset customer resourcing
- Hybrids
  - Optimal size integration
  - Qualified to MIL-STD-38534
Hybrid Capabilities (Catalog and Custom Design)

- Supporting Aerospace and Defense Markets
- Quality Certification
  - MIL-PRF-38534 Class H and K certified
- Design Capabilities
  - Electrical design (worst-case analysis)
  - Substrate design and fab (thick film)
  - Mechanical and thermal design
  - Power module capability
- Custom Design or Build to Print
  - Total parts management
  - Hybrid assembly and die attach
  - Au and Al gold wire bonding
  - High-temperature assembly
  - Hermetic and non-hermetic package assembly
  - Internal electrical and radiation test
  - Vibration or shock testing available
- Example Custom Products
  - Custom analog and digital devices
  - D/A and A/D converter modules
  - Op-Amp modules
  - Power supplies and drivers
  - Differential amplifiers
  - Resistor ladders
  - Analog switch modules
  - Wide-band amplifier modules
  - Custom rectifier modules
MHP85xx Family
Radiation-Hardened Point-of-Load Hybrids—Optimized for LEO

**Family Features**
- Current mode control
- Enable input pin for power sequencing
- Designed for −55 °C to 125 °C operation
- Peak efficiencies over 87%
- Worst-case accuracy less than 5%
- Simple external soft start circuit
- Nominal 500 kHz switching frequency (583 kHz for MHP8566)
- TID >100 krad(Si) for HDR and LDR
- SEL, SEB, SEGR, and SEFI immune up to 85.5 MeV
- SEU (SET) immune in LEO orbit (up to 58 MeV)

**Device Specific Features**
- **MHP8564** (SMD In Process)
  - Vin = +4.5 V to +12 V (input cap rated for +25 V)
  - Iout = 4 A (parallelable to double output current and reduce ripple)
  - Vout = +1.21 V to +4.5V through external set resistor or fixed out
  - External sync pin and remote voltage sense option
  - Ultra small 16-pin flat pack package
- **MHP8565A** (5962R13236)
  - Vin = +4.5 V to +12 V (input cap rated for +16 V)
  - Iout = 3 A
  - Vout = +1.21 V to +4.5 V through external set resistor
  - Ultra small 5-pin MO-078 package

**Benefits**
- Built-in DLA certified MIL-PRF-38534 facilities (Class H and K)
- Radiation hardness assurance (RHA) approved through DLA
- Several Vin and output current options available based on similar design to minimize component changes
- Optimal solution size through integrated hermetic hybrid design
- TID testing follows MIL-STD-883, Method 1019.6
- High-input Vin allows for operation with sufficient de-rating margin
- SMD already approved on base MHP8565 design

**Point-of-Load Solution**

Smallest radiation tolerant point-of-load solution on the market

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Power Supply Flight Heritage

- 50+ successful programs
- 30+ years experience
  - No in flight failures
- End to end support
  - Design
  - Analysis
  - Qualification
  - Production
- In house production
  - ISO9000 & AS9100C Certified
SA50 Series Isolated DC-DC Features – EAR99

**Features**

- 120 Vin, customizable for 28Vin with internal EMI filter
- Triple, dual, and single output versions (**20+ catalog options**)
- Isolated outputs
- 50 W total combined power output
- Inhibit, remote sense, and remote adjust
- Isolated sync input, 500 kHz
- Less than 1% accuracy over temp and radiation
- **>86% efficient full load at 5 ± 15 V output (T version)**
- 3.055" L × 2.055" W × 0.50" H envelope
- Total dose rating of 100 krad(Si) at LDR
- SEE (all effects) >80 MeV·cm²/mg (H version)
- Thermal resistance= 0.041 °C in²/W (measured at 55 °C)
- NASA outgassing compliant: (TML)= 1% max,(CVCM)= 0.1% max

**Benefits**

- Support for standard satellite bus voltages
- No external EMI filtering needed saving valuable real estate
- Semi-custom solution in half the lead time of a full custom solution
- Patented load sharing techniques to maximize performance
- Optimal output voltage accuracy through internal reference and remote current sense
- Peak efficiency at full load
- Up to 5 modules can be connect in parallel
- Best in class radiation performance and accuracy
- EAR99 Solution

**Design Support Available**

- Radiation analysis
- Worse case analysis
- Reliability analysis
- FEMA
- First article qualification test report
- EMI test report
- Structural analysis
- Stress analysis
- Thermal analysis

**Package**
SA50 Series RH Isolated DC-DC Options

### Standard Types

<table>
<thead>
<tr>
<th>Options</th>
<th>Input voltages: 28 V, 100 V, and 120 V standard, and others custom (for example, 50 V)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single outputs: 3.3 V, 5 V, 12 V, 15 V, and 28 V standard, and others custom</td>
</tr>
<tr>
<td></td>
<td>Dual outputs: Special configurations of triples</td>
</tr>
<tr>
<td></td>
<td>Triple outputs: 3.3 V or 5 V with 12 V or 15 V standard, and others can be available</td>
</tr>
<tr>
<td></td>
<td>Case style: A= leads out the side, B= leads out the top</td>
</tr>
</tbody>
</table>


The following are also available:

- Semi- and full-customized versions
- Filter solutions (such as SF200-28)
Example Configuration using two modules

- 2 x 5V rails to be loaded by >2W each (preload or system load)
- 3 x 12V rails connected in parallel for up to 100W
- 1 x 24V rail connected in cascade with 12V bus for up to 100W
- Power will **AUTOMATICALLY AND DYNAMICALLY** distribute amongst the various loads due to the inherent cross regulation characteristic of the SA50-50-5R5-12T
Efficiency Performance, SA50 120 V Triple

At 86-87% efficiency, SA50 sets a high standard for main-bus to regulated-payload sub bus power conversion.
SA50 Architecture Customization with Microsemi Silicon Carbide (SiC) Diodes
Two Switch Forward Topology

- Problems with freewheeling diodes efficiency prompted substitution of SiC Diodes
  - Promotes high efficiency and reliability
- Multiple secondary's to promote current sharing
  - However not for freewheel current
- IN6674 space qualified silicon diodes for all positions initially
High Power DC-DC Converter benefits from SiC

- Forward voltage drop favors Silicon
- Dominant loss in the topology comes from reverse recovery
- Silicon Carbide a clear winner with close to zero Qrr!!
Microsemi Creates a SiC Space Diode Solution

- Initial proof of concept from a Plastic Package SiC Diode used to verify performance

- Flight Custom solution created
  - SiC Die + High Reliability Screening + Hermetic Package

- Microsemi builds & qualifies a new hermetic SiC diode part in very short order as part of a custom solution

Final efficiency of SiC version meets desired efficiency profile
Microsemi has the ability to solve serious technical issues in real time through strong internal team collaboration of expertise
- Internal capabilities allow for greater potential for program success

SiC diodes can greatly enhance efficiency of high power space DC-DC converters

Current generation SiC diodes appear to require a deep derating of Vrr to reliably withstand SEE
- 650V diode was derated to 250V in this case (38% of rated)
- Derating ratio does not necessarily apply to other Vrr ratings

Surge current screening of SiC diodes should carefully account for the positive Vf characteristic and dynamic heating of the SiC die during the pulse
SWAP Improvement Concepts
Traditional Space Power Distribution

- DC-DC provides isolation
- Distribution is by low-impedance bus over several load modules
- Voltage regulation such that all loads are within limits
  - Static and dynamic regulation
- Regulation issue increases with lower voltage digital loads

Satellite Bus
100 V

5 V Secondary Bus

100Vin to 5Vout
Converter SA50-120-5S
(Isolated)

Point of Load
(MHP85xx)

Non-Isolated Supplies

Point of Load
(MHP85xx)

Point of Load
(MHP85xx)

System Efficiency = SA50 (86%) x MHP85xx (84%) = 72%
FPGA Trends

- Future requirements are for greater flexibility and much higher data capability
- Reduced feature sizes come with lower core voltages, higher currents and greater transient requirements
- Power topologies and design methodologies must adapt to changing requirements
- The system designer needs to understand future requirements in order to effectively assess partitioning of the power system
- Entire power generation and distribution system must be reviewed to maximize the overall system efficiency and effectiveness
Typical Power Supply Challenges

- Per NASA and ESA studies ~30% of the satellite weight is in power distribution

Key Drivers
- Over design for worst-case analysis due to high digital (uC, ASIC, FPGA, etc..) power estimates
- Isolation requirements between the main bus, payloads, and sub-systems
- System efficiencies 55% to 75%
  - Large variation in typical and worst-case power estimates (2-4x)
  - Multiple inefficient power stages vs. one direct conversion stage
- Conduction cooling coupled with inefficacies drive large, heavy thermal relief
- Point of load solutions are often >2.6cmx2.6cm thus requiring >30% of critical real estate on digital cards
- Legacy technology limitations to raise the system bus voltage
  - MOSFET Single Event SOA curves have traditionally been derated higher voltages
Point of Load – RTG4 Commercial Power Evaluation Board

- Typical 6U card size
  - 23cm x 16cm = 368cm^2
- RTG4 Evaluation Board
  - 12 point of load power rails
- Standard space point of load solutions are large
  - ~2.6 cm x 2.6 cm
- >20% board area on a 6U card would be dedicated to point of load power
  - Not including any ADC’s or memory that would potentially need an isolated power rail
### MHP5061
3 Vin–6.3 Vin, 6 A, Synchronous Hybrid Point-of-Load DC-DC Converter

#### Device Features
- **VIN** = 3 V to 6.3 V
- Internal reference (0.8 V)
- Adjustable frequency 100 kHz to 1 MHz
- Parallel operation 180° out of Φ with sync pin
- Internal VREF 1.5% variation over temp and radiation
- Ultra-fast transient response to lower output impedance
- Integrated design (Cin, Cout, and Lswitch)
- External compensation and soft-start
- External enable and output power good
- 95% peak efficiency

#### Benefits
- DLA certified MIL-PRF-38534 facilities
- Optimal solution size—integrated hermetic hybrid design
- **40% smaller than current solutions on the market**
- Radiation hardness assurance (RHA) DLA-approved TID testing follows MIL-STD-883, Method 1019.6
- Minimizes solution size through small package and excellent load transient response with smaller output capacitances
- 12 A current output through current share
- Ease of implementing power sequencing schemes
- Pspice models available

#### Radiation Performance
- TID = 100 krad(Si), radiation hardness assured
- SEL/SEB/SEGR immune to LET 65 MeV at 125 °C
- SEFI/SET onset > LET = 65 MeV

#### Package Size

![Package Diagram](image-url)
Description

- Module POL concept based on SA50 topology
- Designed to support three independent low-voltage digital loads
- Mil Std 461 compliance at the satellite bus
- Input-to-output isolation

Features

- Large step loads or noise are not seen on adjacent rails through independent outputs
- Excellent load-step response
- Power-up/power-down sequencing built in
- Internal and external synchronization to reduce system noise

Benefits

- Each channel has individual current limit
- Regulates with no load on any output (independently regulated)
- Point of load power stage eliminated to improve efficiency and size
- Switching noise frequency can be set externally to optimize system performance
### SB30 Dual Isolated DC-DC Features – EAR99

<table>
<thead>
<tr>
<th><strong>Features</strong></th>
<th><strong>Benefits</strong></th>
</tr>
</thead>
</table>
| - Dual output for digital loads with internal EMI filter  
  - +5 V at 2 A; 10 V at 1 A  
- Input-output isolation  
- 100Vin, 20 W total combined power output  
- Inhibit, remote adjust, power good output  
- Isolated sync input, 500 kHz  
- Better than 1% accuracy over temp and radiation  
- >70% efficient full load all conditions  
- 3.050” L × 2.050” W × 0.625” H envelope  
- Total dose rating of 100 krad(Si) at LDR  
- SEE (all effects) >80 MeV-cm²/mg (H version)  
- Thermal resistance= 0.041 °C in²/W (measured at 55 °C)  
- NASA outgassing compliant: (TML)= 1% max,(CVCM)= 0.1% max  | - Single stage isolated power solution for digital loads  
- No external EMI filtering needed saving valuable real estate  
- Individual PWM control for each load  
- Optimal output voltage accuracy through internal reference  
- Peak efficiency at full load  
- Best in class radiation performance and accuracy  
- EAR99 Solution  
- Flight proven architecture from SA50 |

<table>
<thead>
<tr>
<th><strong>Package</strong></th>
<th><strong>Design Support Available</strong></th>
</tr>
</thead>
</table>
| ![Image](image1.png)  
![Image](image2.png)  | - Radiation analysis  
- Worse case analysis  
- Reliability analysis  
- FEMA  
- First article qualification test report  | - EMI test report  
- Structural analysis  
- Stress analysis  
- Thermal analysis |
SB30 Dual DC-DC (Available)

All SB30 Output Is Externally Trim-able
Each Output Is Adjustable ±10%

- Multistage filter with differential and common mode filtering
- Meets MIL-STD-461 conducted emission requirements
- Effective decoupling between payload modules
SB30 Dual Efficiency Performance

Efficiency at Load and Line combinations

- Efficiency Vin 125 volt
- Efficiency Vin 100 volt
- Efficiency Vin 60 volt

Total Output Power

0 watt 5 watt 10 watt 15 watt 20 watt 25 watt 30 watt
# SB30 Triple Isolated DC-DC Features – EAR99

## Features

<table>
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<th>Feature</th>
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</thead>
<tbody>
<tr>
<td>Input-output isolation</td>
<td>・28, 50, 70, 100, or 120 Vin</td>
</tr>
<tr>
<td>Triple output for digital loads with internal EMI filter</td>
<td>・+5 V at 2 A; +3.3 V at 3 A; +2.5 V at 3 A; customizable</td>
</tr>
<tr>
<td>30 W total combined power output</td>
<td>・30 W total combined power output</td>
</tr>
<tr>
<td>Inhibit, remote adjust, power good output</td>
<td>・Inhibit, remote adjust, power good output</td>
</tr>
<tr>
<td>Isolated sync input, 500 kHz</td>
<td>・Isolated sync input, 500 kHz</td>
</tr>
<tr>
<td>Less than 1% accuracy over temp and radiation</td>
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</tr>
<tr>
<td>&gt;86% efficient full load</td>
<td>・&gt;86% efficient full load</td>
</tr>
<tr>
<td>2” L × 2” W × 0.5” H envelope goal</td>
<td>・2&quot; L × 2&quot; W × 0.5” H envelope goal</td>
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<tr>
<td>Total dose rating of 100 krad(Si) at LDR</td>
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<td>Synchronous rectification minimizes conduction losses</td>
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## Benefits

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<tr>
<td>Single stage isolated power solution for digital loads</td>
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</tr>
<tr>
<td>No external EMI filtering needed saving valuable real estate</td>
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</tr>
<tr>
<td>Individual PWM for each load</td>
<td>・Individual PWM for each load</td>
</tr>
<tr>
<td>Optimal output voltage accuracy through internal reference</td>
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<tr>
<td>Peak efficiency at full load</td>
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## Planned Design Support

- Radiation analysis
- Worse case analysis
- Reliability analysis
- FEMA
- EMI test report
- Structural analysis
- Stress analysis
- Thermal analysis
- First article qualification test report
SB30 Triple DC-DC

All SB30 Outputs are Externally Trim-able
Each Output Is Adjustable ±10%

- Multistage filter with differential and common mode filtering
- Meets MIL-STD-461 conducted emission requirements
- Effective decoupling between payload modules

Pinout

Built-In EMI Filter

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System Efficiency with Next Generation SB30 Triple

- Next generation SB30 with three channels configured as 5 V + 3.3 V + 2.5 V with all outputs at 2 A achieves 86% efficiency (projected)
- Downstream POL would be 5 V converted to range 0.8 V to 1.5 V with efficiencies of 78% to 85%, respectively
- Overall conversion from main bus to POL is in the region of 79% vs 72% for traditional distributed power conversion
- Point of Module converter meets size and efficiency targets for effective integration

**CASE EXAMPLE -- Mixed Signal Payload with Embedded FPGA**

<table>
<thead>
<tr>
<th>Power in</th>
<th>SB30 Eff %</th>
<th>POL Eff %</th>
<th>Power Delivered</th>
<th>Voltage Delivered (V)</th>
<th>Current delivered (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.78</td>
<td>90%</td>
<td>100%</td>
<td>2.50</td>
<td>5.0</td>
<td>0.5</td>
</tr>
<tr>
<td>3.84</td>
<td>86%</td>
<td>100%</td>
<td>3.30</td>
<td>3.3</td>
<td>1.0</td>
</tr>
<tr>
<td>1.52</td>
<td>82%</td>
<td>100%</td>
<td>1.25</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>0.96</td>
<td>90%</td>
<td>87%</td>
<td>0.75</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>10.84</td>
<td>90%</td>
<td>82%</td>
<td>8.00</td>
<td>8.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

**Totals**

<table>
<thead>
<tr>
<th>Power in (kW)</th>
<th>Efficiency POL %</th>
<th>Efficiency SB30 %</th>
<th>Power Delivered (kW)</th>
<th>Voltage Delivered (V)</th>
<th>Current delivered (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.94</td>
<td>15.80</td>
<td>79%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall Efficiency: 79%
Smaller More Efficient Power Distribution Solutions

- **Point of Module advantages for satellite power distribution**
  - Eliminates noise decoupling between payload systems
  - Maximum efficiency by minimizing power conversion stages
  - Excellent fault isolation and fault effects containment
  - Reduction in size, weight, and cost on a system basis
  - SB30 could be taken to a hybrid for further size reduction

- **Point of Load**
  - Ultra small and efficient complete point of load solutions
  - Excellent transient response for dynamic current needs
  - EAR99 solution for ease of use
Summary

- DC to DC and point of load power solutions

- Power bottlenecks and system issues
  - High current, low voltage
  - Size and efficiency

- Increasing SWAP advantages through point of loads and modules

- Next Steps
  - Working with customers on optimization of the SB30
  - Definition of next generation point of loads
Your Partner for Space Technology

- Leadership in space
- Leveraging our product breadth
- Innovative new products
- Focused on system solutions
Thank You

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