Aeroflex Microelectronic Solutions

White Paper:
A Candidate DC-DC Converter for Hi-Rel

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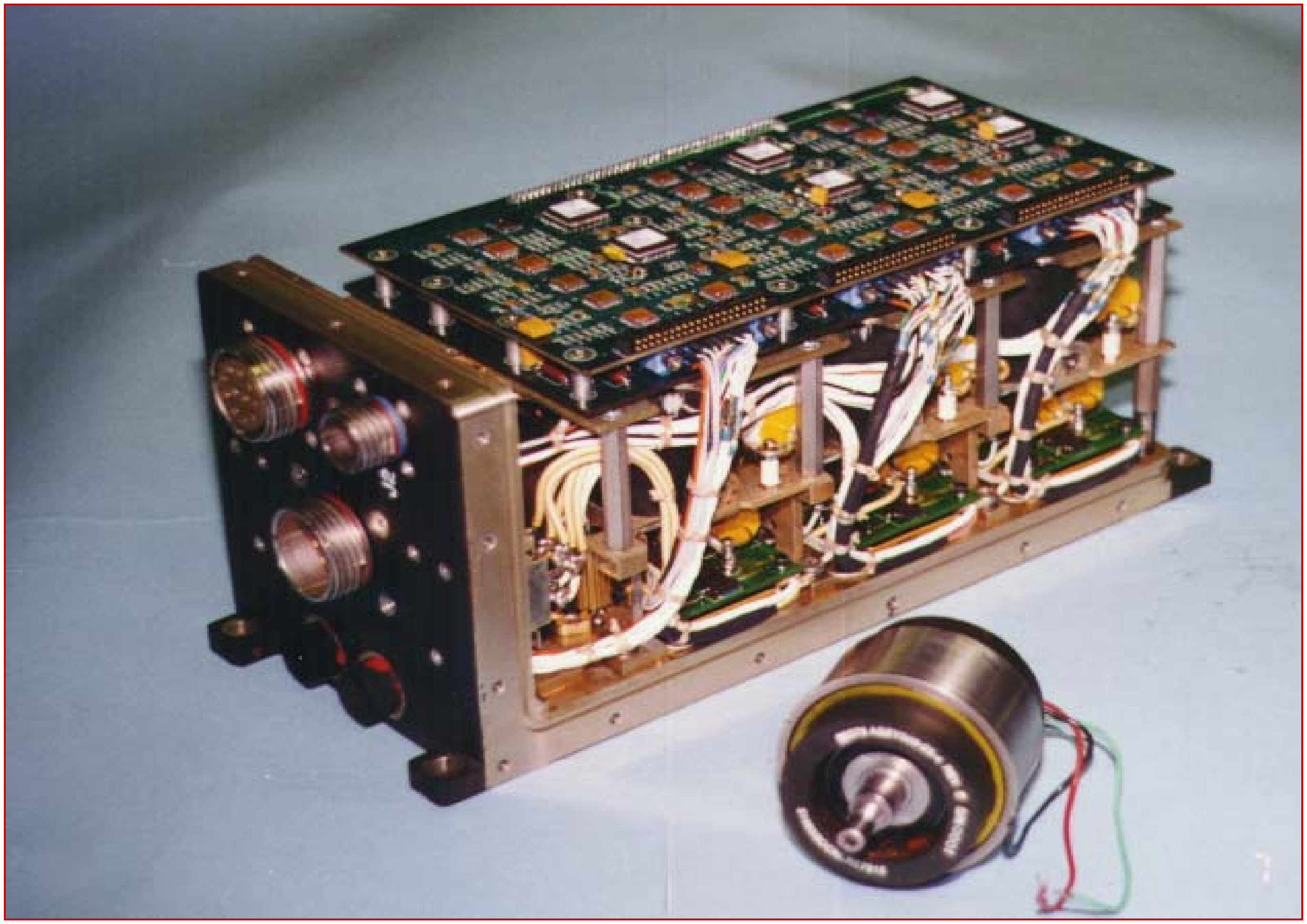
Options for Building a Hi-Rel Military / Space Power Supply

- Three approaches exist for building a Military/Space Qualified Power Supply:
  - Conventional, Discrete construction with screening levels for components dependent on programmatic concerns.
  - Hybrid, where the packaging density of Conventional Discrete is not adequate.
  - Planar Magnetic/Chip-On-Board for greater packaging densities of Conventional Discrete at lower costs and lighter weight than Conventional Discrete.

Conventional Discrete Power Supply

Typical Discrete Power Supply

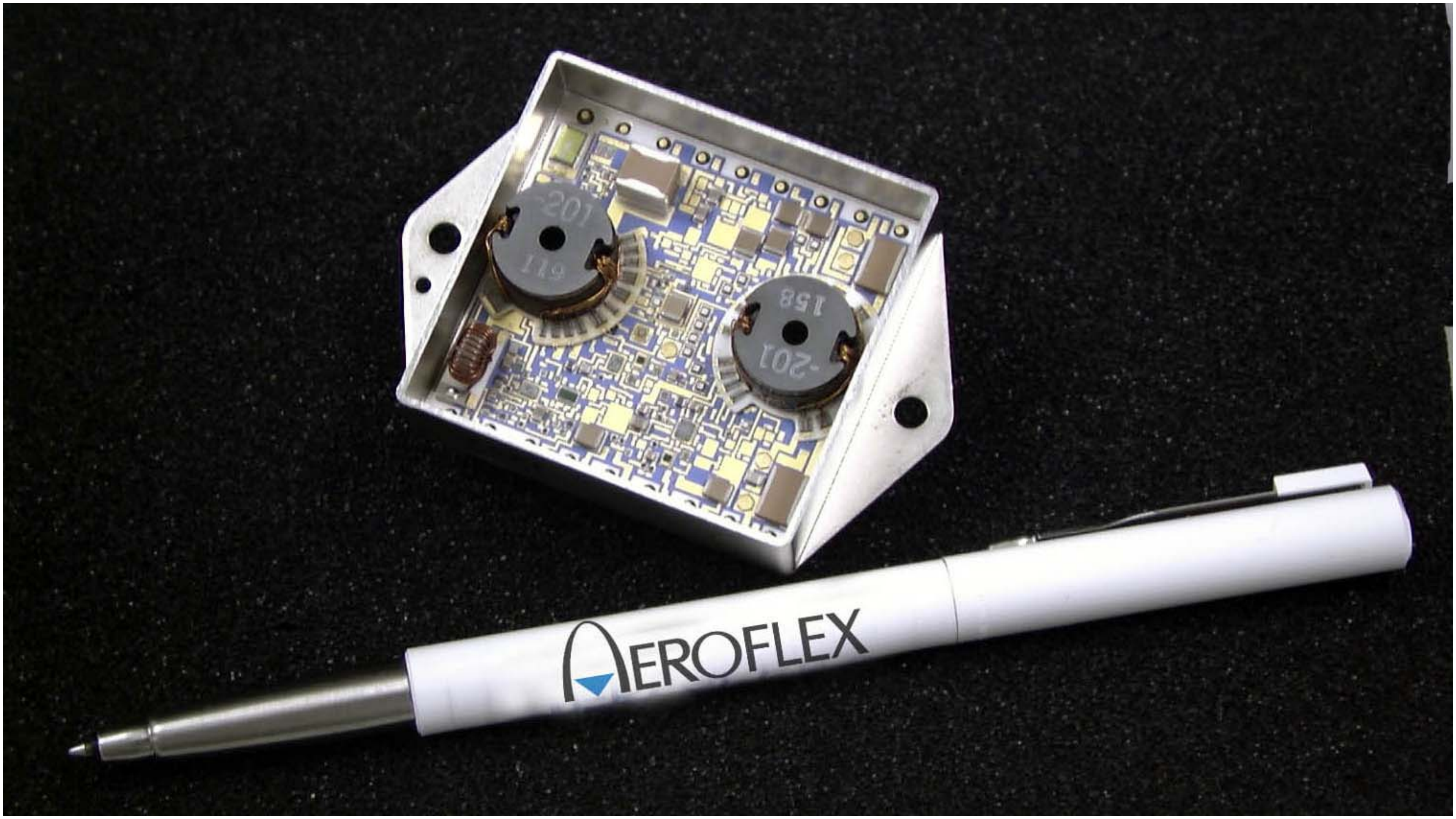


Conventional Discrete Power Supply Advantages and Disadvantages

- Semiconductors packaged by manufacturers, screened to programmatic concerns (i.e. MIL-STD-883, MIL-STD-19500).
- Magnetics separately screened IAW MIL-T-27.
- Advantages -
  - Faster design cycle. The designer relies extensively on major components provided by outside vendors.
  - Components, such as hybrids are individually qualified if necessary.
  - Legacy.
- Disadvantages -
  - Long Procurement Cycle. Component parts screened by outside vendors often have 6 month - 1 year lead-times.
  - High Cost. Each component vendor separately inspects, screens, tests and qualifies each component.

Hybrid Power Supplies

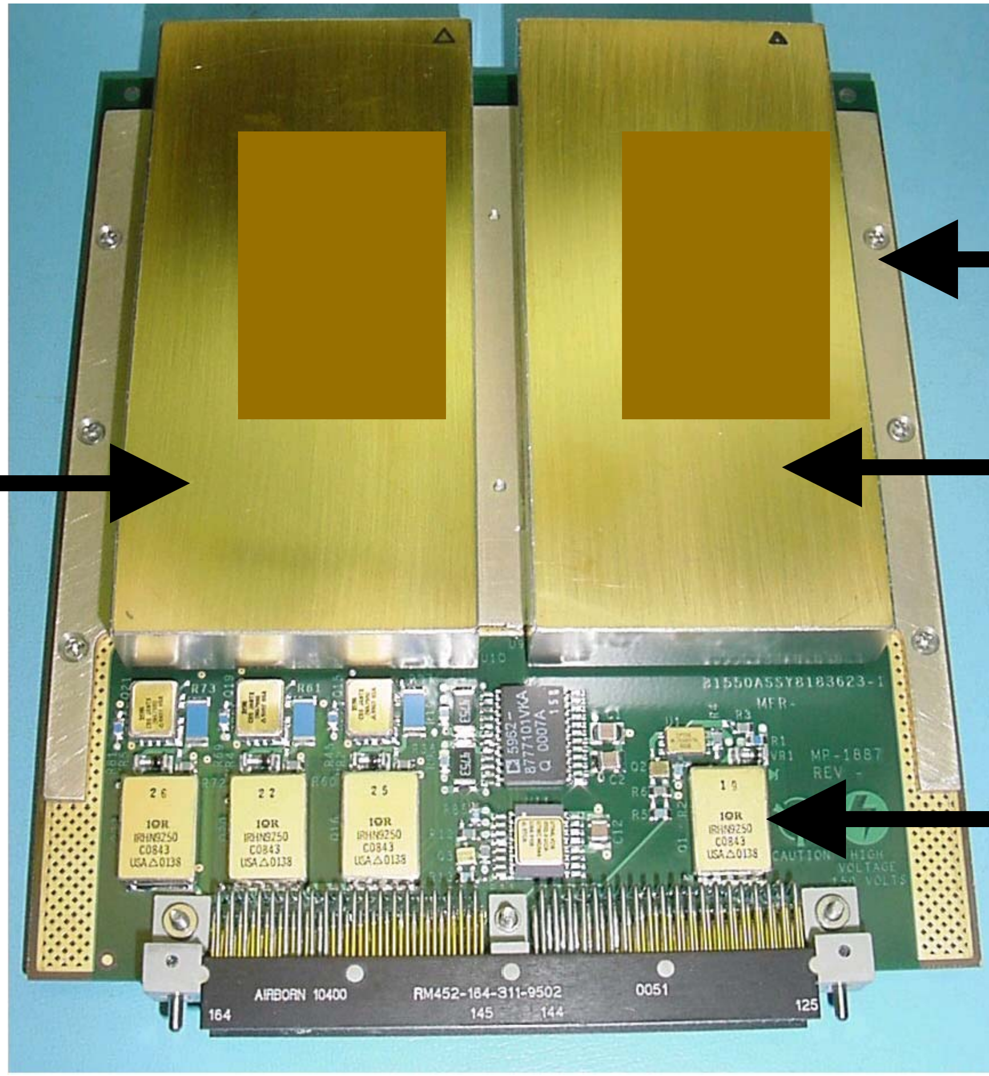
Typical Hybrid Power Supply



Hybrid Power Supplies Advantages and Disadvantages

- Classical thick film hybrids built and screened to programmatic concerns (i.e. MIL-H-35384).
- Advantages -
  - Incredible Power Density. Designer's are often attracted to modules that offer a relatively high watts/cubic inch ratio when compared with other possible solutions.
  - Self contained unit in some cases. i.e. on board power supply
  - A large variety are available as off the shelf components or as "one offs" custom power supplies.
- Disadvantages –
  - The OEM is faced with the task of integrating the hybrids into the next higher level assembly, often times this could be a power supply for a black box subsystem requiring the OEM to perform ESS testing and qualification. For the resource strapped OEM this could present a significant challenge.

Typical Hybrid Based Power Supply



Heatsink

Hybrid #1

Hybrid #2

Multiple HTCC Packages

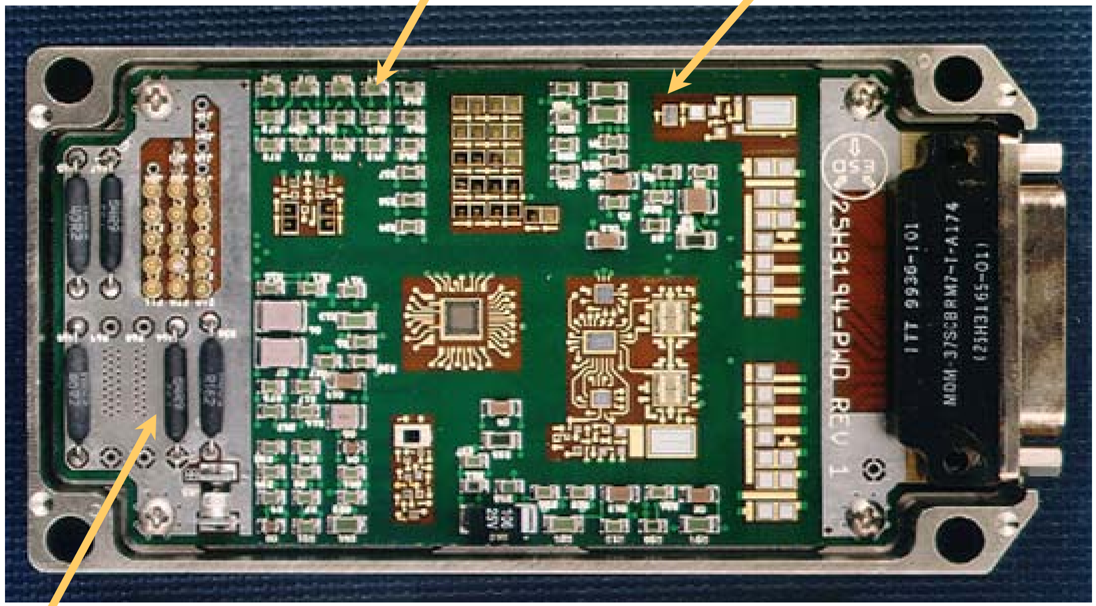
Aeroflex Microelectronic Solutions' COB Packaging

- Aeroflex Plainview has become a leader in the application of Chip-On-Board packaging in the space marketplace.
- COB Packaging Process
  - Conventional surface mount components are re-flowed to a glass fabric polyimide resin Printed Wiring Board (PWB).
  - After cleaning, bare die are bonded to the PWB using epoxy attach.
  - Then the die are wire bonded using either gold or aluminum technologies.

Typical Chip On Board Assembly

SMT Chip Caps
& Resistors

Bare die



Discrete Leaded
Components
and Connectors

MODULE IN FULL SCALE
PRODUCTION >2000 UNITS
SHIPPED TO DATE

COB Encapsulation Materials for Reliability without Hermeticity

- Dexter Electronic Materials Hysol™ Formulations.
- Materials chosen for ease to use, low CTE, high Tg (glass transition temperature), low cure shrinkage and low ionic content.
- Parylene "C" Coating - In house vacuum coating provides supplemental moisture resistance.

"A combination of Parylene and epoxy coatings proved to have superior reliability in providing die protection throughout a rigorous environmental test sequence" [1]

1. *Source: Design, Fabrication, and Qualification of Chip-On-Board Technology for Space Electronics by Binh Q. Le, Richard H. Maurer, Elbert Nhan and Ark Lew of Johns Hopkins University/Applied Physics Laboratory as published in The International Journal of Microcircuits & Electronic Packaging, Volume 22, Number 2, Second Quarter 1999*

Advantages of a Chip On Board Slice vs. a PEM Populated SMT Slice

- Die undergo MIL-PRF-38534 visual inspection, each die is visually inspected after die bonding.
- Die traceability is maintained IAW MIL-PRF-38534.
- Attachment epoxies, wires, encapsulants and coatings are all controlled at a single point MIL-PRF-38534 house versus multiple off shore commercial sources.
- Thermal failures due to electrical overstress are greatly reduced because the PWB layout is designed to accommodate the thermal conditions of the die.
- The housing is optimized with heat risers to match up to the PWB hot spots.

Advantages of a Chip On Board Slice vs. a PEM Populated SMT Slice *cont.*

- Performance can be guaranteed over an extended temperature range without running the risk of violating the manufacturer's data sheet.
- Aeroflex's COB devices are built with a tightly controlled baseline at a single assembly & test site in a ISO-9001-2000 and AS9100 certified site on a MIL-PRF-38534 H & K qualified line.
- Class H & K Products are qualified to a combination of MIL-PRF-38534 and JEDEC Test Standards.

Chip On Board (COB) Qual & QCI Tests

Combination of MIL-PRF-38534 & JEDEC Qual Tests

Qualification & QCI Tests	Class H/K Test Requirements
Group A testing	Group A tests are performed on a 100% basis IAW the detail specification and MIL-PRF-38534, Appendix C, and include all final tests as defined by the detail module specification.
A/R	As a COB Slice Over Temperature
A/R	As a module w/COB Slice mounted into housing. Subjected to Vibration, Thermal Cycle & Vibration
A/R	As a module over temperature

Chip On Board (COB) Qual & QCI Tests

Combination of MIL-PRF-38534 & JEDEC Qual Tests

Group B In Line

Physical dimensions	MIL-STD-883, Method 2016, two COB modules per month.
Resistance to moisture	JESD 22-A110, one coupon sample from each encapsulation lot or a period not to exceed one week; biased HAST 130°C, 85% RH, 24 hours; endpoint electrical.
Susceptibility to leakage and corrosion	JESD 22-A102, one coupon sample from each encapsulation lot or a period not to exceed one week; 2atm, 121 °C, 16 hours, no bias.
Visual and mechanical	MIL-STD-883, Method 2014, one device of each type each month.
Bond strength	MIL-STD-883, Method 2011; precondition sample at 200 °C for 24 hours.
Solderability (for external leads, if applicable)	MIL-STD-883, Method 2003, perform as part of incoming inspection (i.e. substrate or board or other areas where soldering is performed).

Chip On Board (COB) Qual & QCI Tests

Combination of MIL-PRF-38534 & JEDEC Qual Tests

Group C

Subgroup C1 testing	
Visual	At pre-encapsulation modules are inspected IAW IPC-6012, Class 3 for PWB and J-STD-001B for solder connections and any additional inspection criteria included in the detail specification. For encapsulated components, Aeroflex's procedure shall govern. It shall include cover areas, height and touch up requirements and disallow delamination, pin-holes, voids and cracks.
Temperature cycling	MIL-STD-883, Method 1010, Condition B, -55 to +125 °C, 20 cycles.
Vibration	See purchase order or detail specification for requirements, if any.
Mechanical shock	See purchase order or detail specification for requirements, if any.
Resistance to moisture	JESD 22-A110; biased HAST 85 °C, 85% RH, 96 hours

Chip On Board (COB) Qual & QCI Tests

Combination of MIL-PRF-38534 & JEDEC Qual Tests

Group C

Subgroup C1 testing *(cont.)*	
Endpoint electrical	Per detail drawing.
Visual	IPC-6012, Class 3 for PWB and J-STD-001B for solder connections and additional inspection criteria included in the detail specification. For encapsulated components, Aeroflex's inspection procedure shall govern. It shall include cover areas, height and touch up requirements and disallow delaminations, pin-holes, voids and cracks.
COB-CA	See steps listed on next slide.
Subgroup C2 testing	
Steady state life	MIL-STD-883, Method 1005, 1000 hr, BI conditions.
End point electrical	Per detail drawing.

Chip On Board (COB) Qual & QCI Tests

Combination of MIL-PRF-38534 & JEDEC Qual

Group C3 testing

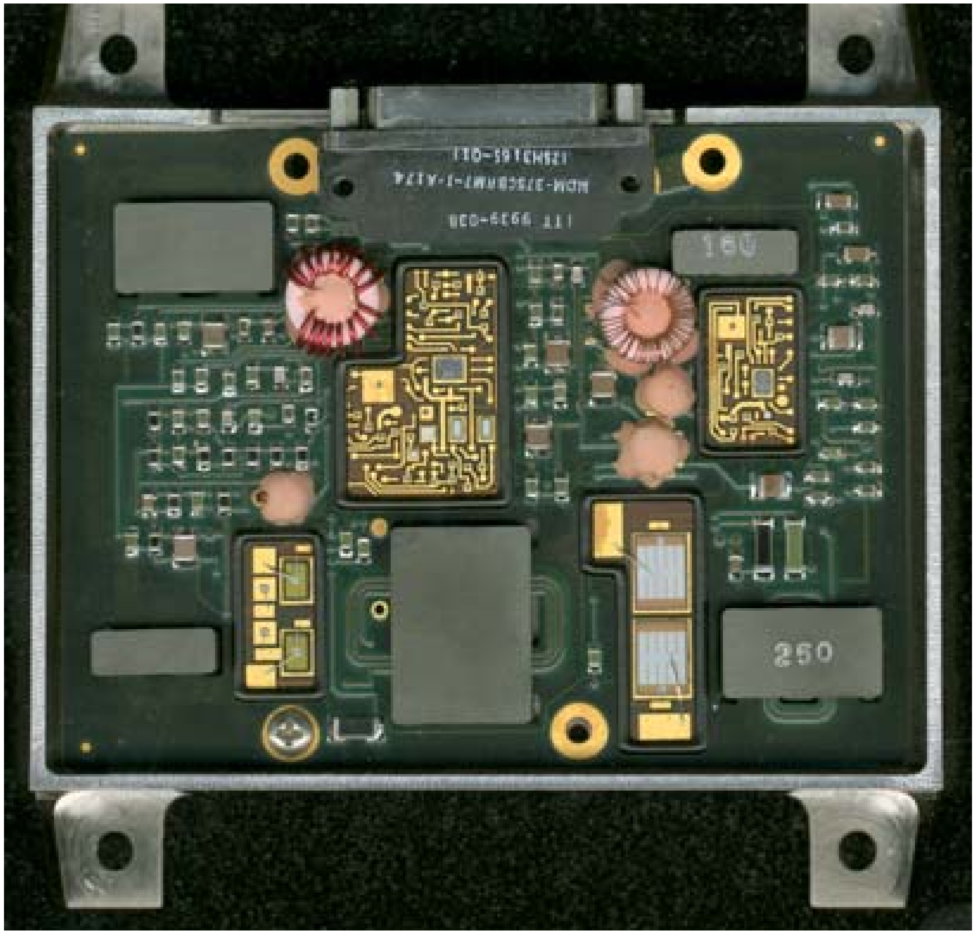
COB construction analysis	Two (2) randomly selected samples selected every 13 weeks of production. Performed by an Independent Lab
Task	**Method**
External Visual	MIL-STD-883, Method 2009
Internal Visual	MIL-STD-883, Method 2010, test condition A, also as applicable methods 2017, 2032, 2013 & 2014 or MIL-STD-750, method 2072 & 2074.3. Inspect all solder connections between SMT devices and the circuit board IAW J-STD-001B.
SEM	MIL-STD-883, Method 2018
Bond Strength Pull Test	MIL-STD-883, Method 2011, Condition D
Design Verification	Via Photo Comparisons
Die Shear Strength Test	MIL-STD-883, Method 2019, performed on all epoxy mounted devices
Prohibited Materials Analysis	Via Energy Dispersive Spectroscopy (EDS) Analysis

Chip-On-Board Combined with Planar Magnetics

- Add to the advantages of COB packaging: Planar Magnetics
- Magnetic Circuitry is now embedded in the circuit card assembly, eliminating the solder joints and windings inherent in conventional magnetics
- The advantages of COB packaging and planar magnetics are directly applicable to hi-rel power supplies.

Planar Magnetic/Chip-On-Board Power Supply Advantages and Disadvantages

Typical Planar Magnetic/Chip-On-Board Power Supply



Planar Magnetic/ Chip-On-Board Power Supply

- This approach uses printed wiring boards containing integrated circuit die, SMT components and planar magnetics.
  - COB packaging surface mount components are re-flowed to a Printed Wiring Board (PWB).
  - Bare die are bonded to the PWB using epoxy attach and are wire bonded using either gold or aluminum technologies.
  - Magnetics are bonded to the PWB.
  - After product testing the wire bonded areas are polymer encapsulated using a material selected for stress minimization of the critical PWB, Die and Bond Wire interfaces.

Planar Magnetic/Chip-On-Board Power Supply Advantages

- Low Profile - the height of a planar magnetic device will be 25% to 50% less than a corresponding wire wound component.
- Higher Power Densities relative to conventional discrete - higher surface-to-volume ratio is more effective at conducting heat and reducing thermal sensitivities.
- Highly Constant Parasitics - highly repeatable placement of conductors greatly reduces lot to lot variability in leakage inductance and capacitance compared to conventional wire wound magnetics.
- Integrated Magnetics improve reliability.
- Since individual component packaging and screening are eliminated, cost is typically half that of a Conventional Discrete.

Planar Magnetic/Chip-On-Board Power Supply Disadvantages

- Disadvantages -
  - Represents a new technology, has limited legacy at this time.
  - Requires the customer to buy into the concept of achieving long term reliability without hermeticity, not every hi-rel market segment in the aerospace world accepts.

Missile Mission Computer (MC) Power Supply

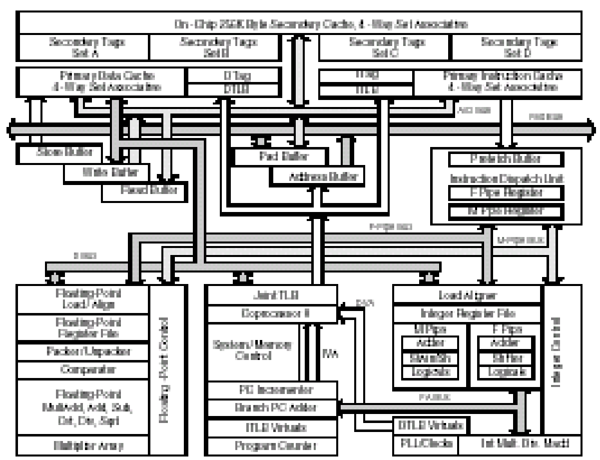
AEROFLEX

ACT 7000SC
64-Bit Superscaler Microprocessor

Features

- Full militarized QED RM7000 microprocessor
- Dual issue symmetric superscalar microprocessor with instruction prefetch optimized for system level price/performance
  - 150, 200, 210, 225 MHz operating frequency. Consult Factory for latest speeds
  - MIPS IV Superset Instruction Set Architecture
- High performance interface (RM52xx compatible)
  - 500 MB per second peak throughput
  - 75 MHz max. freq., multiplexed address/data
  - Supports 1/2 clock multipliers (2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 7, 8, 9)
  - IEEE 1149.1 JTAG (TAP) boundary scan
- Integrated primary and secondary caches - all are 4-way set associative with 32 byte line size
  - 16KB instruction
  - 16KB data: non-blocking and write-back or write-through
  - 256KB on-chip secondary: unified, non-blocking, block writeback
- MIPS IV instruction set
  - Data PREFETCH instruction allows the processor to overlap cache miss latency and instruction execution
  - Floating point combined multiply-add instruction increases performance in signal processing and graphics applications
  - Conditional moves reduce branch frequency
  - Index address modes (register + register)
- Embedded supply de-coupling capacitors and additional PLL filter components
- Integrated memory management unit (ACT52xx compatible)
  - Fully associative joint TLB (shared by I and D translations)
  - 48 dual entries map 96 pages
  - 4 entry DTLB and 4 entry ITLB
  - Variable page size (4KB to 16MB in 4x increments)
- Embedded application enhancements
  - Specialized DSP integer Multiply-Accumulate instruction, (MAD/MADU) and three-operand multiply instruction (MUL/U)
  - Per line cache locking in primaries and secondary
  - Bypass secondary cache option
  - I&D Test/Break-point (Watch) registers for emulation & debug
  - Performance counter for system and software tuning & debug
  - Ten fully prioritized vectored interrupts - 6 external, 2 internal, 2 software
  - Fast Hit-Writeback-Invalidate and Hit-Invalidate cache operations for efficient cache management
- High-performance floating point unit - 600 M FLOPS maximum
  - Single cycle repeat rate for common single-precision operations and some double-precision operations
  - Single cycle repeat rate for single-precision combined multiply-add operations
  - Two cycle repeat rate for double-precision multiply and double-precision combined multiply-add operations
- Fully static CMOS design with dynamic power down logic
  - Standby reduced power mode with WAIT instruction
  - 4 watts typical @ 2.5V Int., 3.3V I/O, 200MHz
- 208-lead CQFP, cavity-up package (F17)
- 208-lead CQFP, inverted footprint (F24), with the same pin rotation as the commercial QED RM5261

BLOCK DIAGRAM

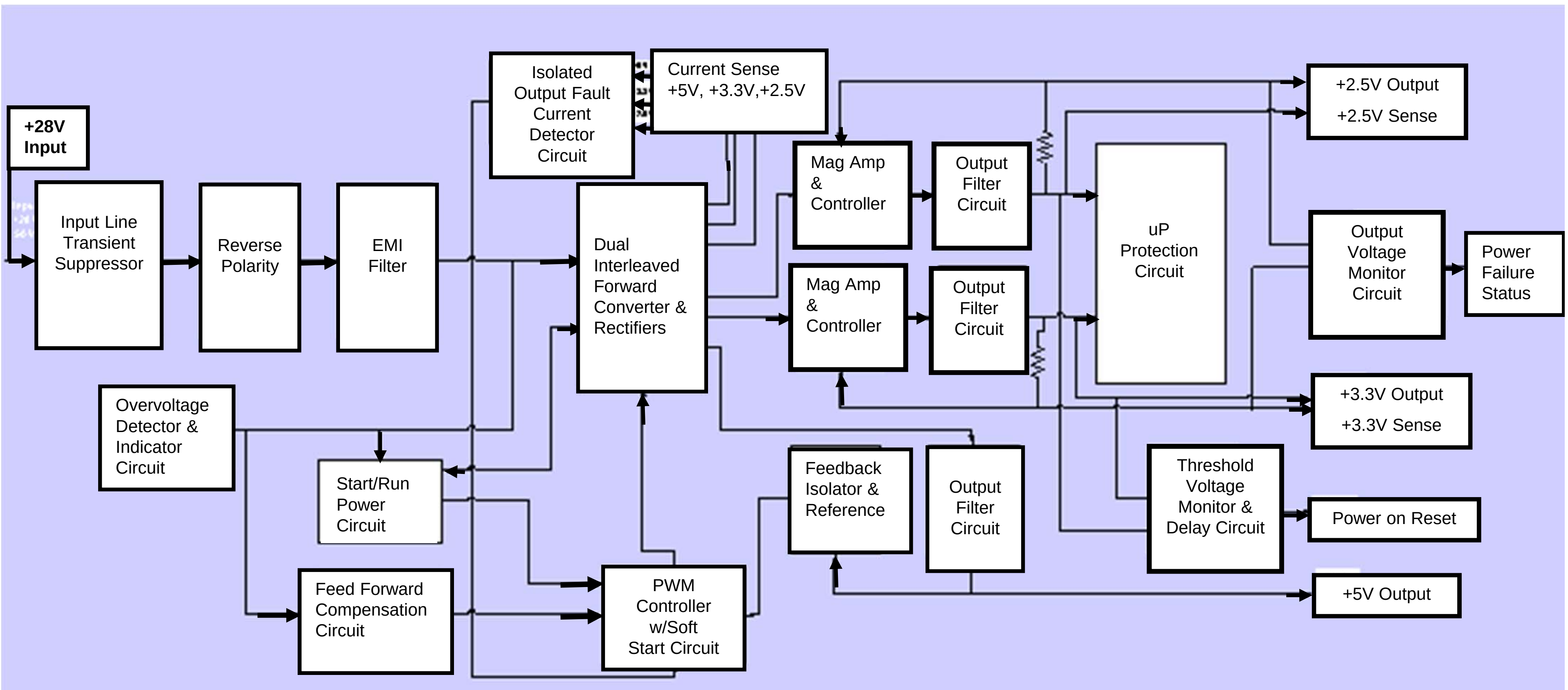


Aeroflex Circuit Technology – MIPS RISC Microprocessors © SCD7000SC REV B 7/30/01

- Task:

  From a +28V Missile Bus powering four Aeroflex ACT7000SC Superscalar Microprocessors, provide:
  - 2A @ +5V, 50mV ripple
  - 11A @ +3.3V, 33mV ripple
  - 10A @ +2.5V, 25mV ripple
  - Graceful power up and power down sequence
  - Built in EMI filtering
  - Built in Over/Under Current/Voltage Protection to facilitate integration into next higher level assembly

Missile MC Power Supply Block Diagram



Missile MC Power Supply, Electrical Features

- Regulation for the +2.5V outputs and +3.3V outputs is provided by magnetic amplifiers.
- The current outputs of each of the three output voltages are sensed by current sense transformers. The secondaries of these current sense transformers are connected to an output current limiter circuit.
- When any one or more of the inputs are overloaded, this output current limiter will feed back to the PWM controller, reducing the output voltages on each output to lower the current to an acceptable level.

Missile MC Power Supply, Electrical Features *cont.*

- Power up sequencing protection is provided by sensing the 2.5V and 3.3V voltages, and driving a MOSFET connected between the two rails to clamp the 3.3V to 2.5V outputs.
- Ancillary circuits provide:
  - Monitoring of the +2.5V and +3.3V outputs to derive the processor reset signal.
  - Monitoring of the +2.5V and +3.3V outputs for Power Supply Integrity.
  - Monitoring of the input bus to provide permanent latching if the input voltage exceeds 45V for 20mS.

Missile MC Power Supply, Electrical Features *cont.*

- The output of the transient suppressor is connected to the input reverse polarity detector.
- The reverse polarity detector prevents reverse voltage from being applied to the unit.
- The reverse polarity detector is followed by the EMI filter. The filter has been designed to retain the converter emissions below the limits specified in MIL-STD-461E with some special limits from MIL-STD-461C.
  - CE101 from 30Hz – 10KHz for the 28V leads, including the returns.
  - CE102 from 10KHz – 10MHz for the 28V leads, including the returns.
  - RE102 from 500KHz to 18GHz
  - CS101 from 30Hz to 150KHz
  - CS116 from 10KHz to 100MHz
  - RS103 from 2MHz to 18GHz

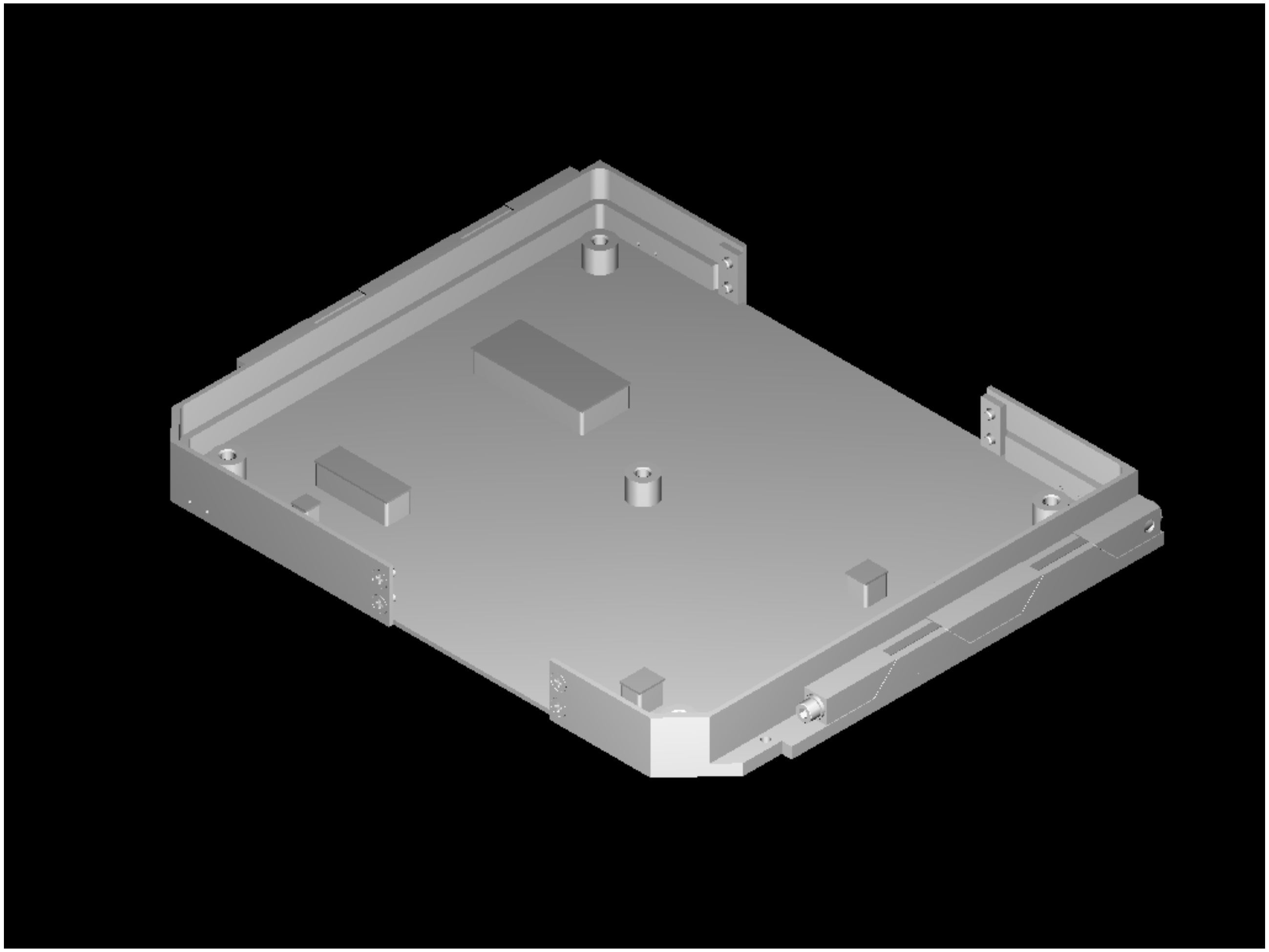
Missile MC Power Supply, Electrical Features *cont.*

- Energy storage for a 100uS input power dropout is provided by capacitors in the EMI filter and local bypassing in the converter.
- The converter topology is an interleaved forward converter, with each side switching at 150 kHz.
- The converter feeds three low pass filters, one for the +2.5V output, one for the +3.3V output, and one for the +5V output.
- Regulation for the +5V output is provided by pulse width modulating the input voltage at the forward converter.

Missile MC Power Supply, Mechanical Features

- The MC LVPS is fabricated as a Chip-On-Board module, in an aluminum housing.
- Bare die are bonded to an organic PWB, wire bonded, and after test, encapsulated using local dam and fill operations to achieve reliability without hermeticity.
- Flex circuits interconnect the I/O connectors with the PWB.
- Magnetics are planar, with windings inherent to PWB and cores epoxy attached to the PWB.

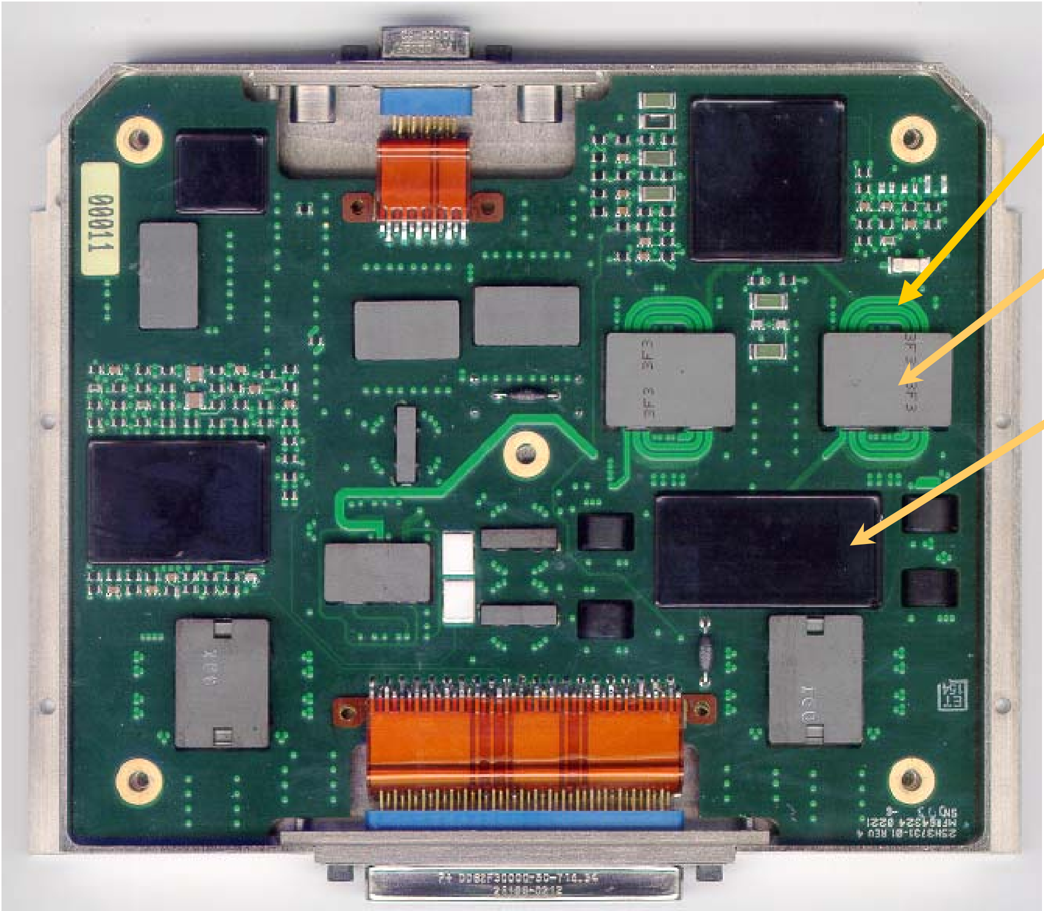
Missile MC Power Supply, Mechanical Features *cont.*



“Hand in Glove”
MC LVPS Chassis With Ribs and Heat Risers

Multiple Output DC-DC Converter

COB combined with Planar Magnetics
Missile Application



Integral Transformer Winding

Planar Magnetics

Chip & Wire Islands

Benefits of a Chip On Board Power Supply

- Planar Magnetics Provide Increased Reliability by Eliminating High Current Interconnects
- Reduced Parasitic Effects Due to Shorter Interconnects between Components & Magnetics
- High Rel Connectors facilitate coupling of increasingly higher currents
- Elimination of Stacked Multi-Layer Ceramic Caps
- Reduced Total Mass by eliminating overhead packaging
- Typically a Lower Recurring Unit Cost vs. a Discrete Solution
- Provides the ability to build low profile units
- Less solder joints equates to lower levels of Pb loaded solder.
- Reduced parts management versus CCAs populated with hybrids and MCMs. Single vendor ownership.

Summary: Options for Building a Military/Space Power Supply

- Three ways to build a Military/Space Power Supply -
  - Conventional Discrete
  - Using hybrids
  - Integrated Planar Magnetics/Chip On Board
- User has to consider
  - Lead time
  - Non-Recurring Costs
  - Recurring Unit Prices
  - Ability of system to absorb overhead packaging
  - Does his organization accept the concept of Long Term Reliability without Hermiticity?
  - Desirability to purchase a ***"plug & play"*** power supply versus an in-house solution based on hybrids or a conventional power supply made up of discrete parts.