Powering Military and Other Hi-Reliability Systems

Meeting todays challenges for Mil/Aerospace Commercial Avionics, Unmanned Systems, Naval, Missile Ground and Space Systems.

Full Mil, Hi-Rel COTS / MIL-COTS isolated and non-isolated Power Conversion products.

Don Laskay
Regional Sales Manager

October 2017

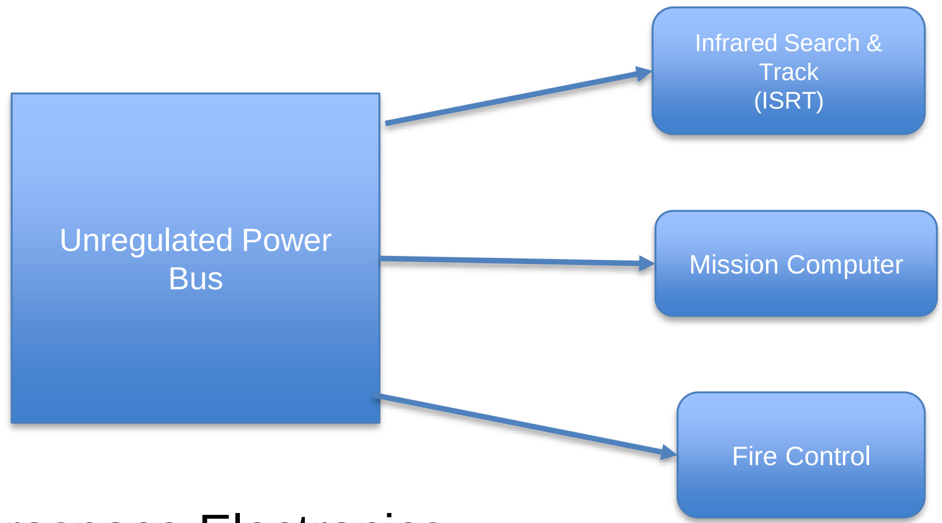
www.vptpower.com

Power Your Critical Mission Today

Power System Requirements

- All systems require reliable bullet proof power
- Many ways to provide power
- Design Considerations
  - Meeting system requirements
    - Processors, FPGA, RF systems, Amplifiers…
  - Size, Weight and Power (SWAP)
  - Reliability
  - cost

Typical System Architecture



– **Applications**

- Military Aerospace Electronics
  - Ground systems, Airborne, Satellite, Launch Vehicle, Weapons or Countermeasures
- Commercial Avionic Systems
  - Data processing, Sensor systems, radar, Navigation
- Space Systems
  - Telemetry, positioning, sensor systems
- Industrial
  - Control Systems

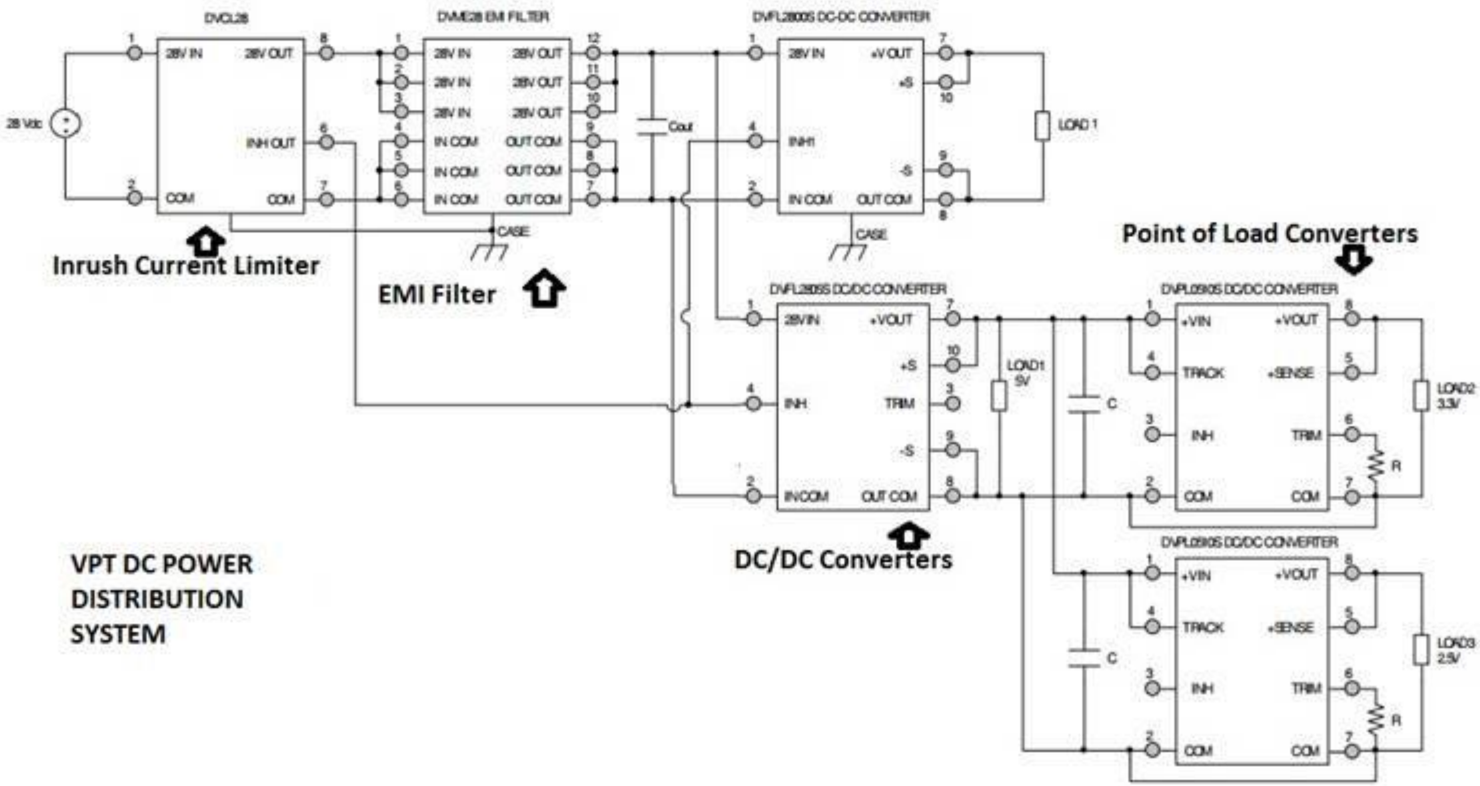
DC Power Requirements

- Modern processors and FPGA’s have demanding power requirements.
- MIL-STD-704 specifies the avionic 28V bus power
- MIL-STD-1275 specifies the ground vehicle 28V bus power
- Neither of these specs are good enough for most electronic systems
  - Additional power conditioning and conversion is required

Power System Requirements

- In Rush Current
- Turn on delay
- Over current protection
- Loop response
- Ripple Voltage
- Input bus variations
- EMI
- Temperature

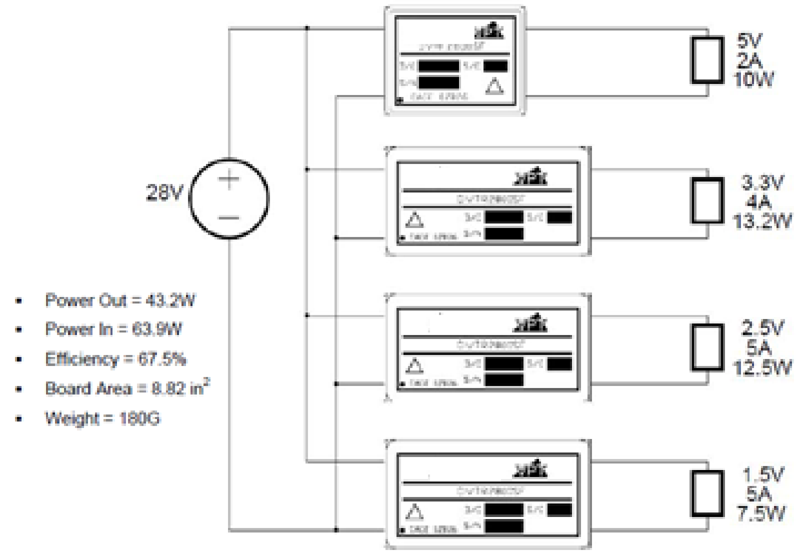
Bus Power Conditioning



VPT DC POWER
DISTRIBUTION
SYSTEM

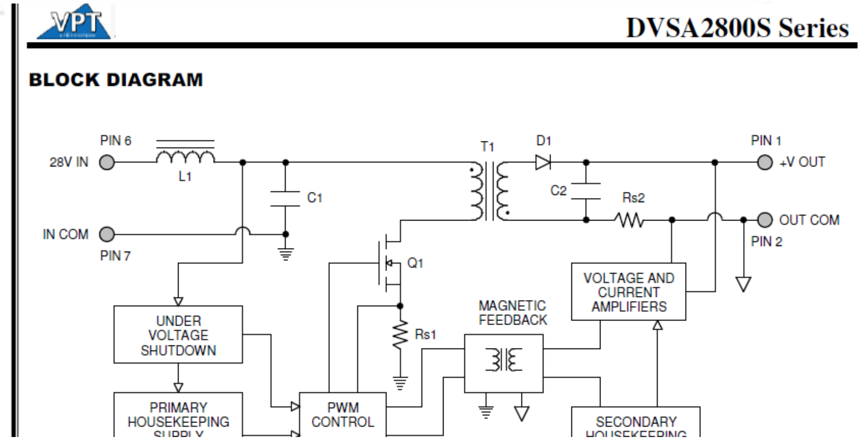
Efficiency Considerations in Distributed Architectures

- Multiple Isolated DC/DC
- Power Out = 43.2W
- Power In = 63.9W
- Efficiency = 67.5%
- Board Area = 8.82 in2
- Weight = 180G



DC/DC Topologies & Efficiency

- VPT Topologies
  - Flyback
    - Efficiency of 30W 75% to 85%



  - Forward, Synchronous
    - Efficiency 90% to 91%

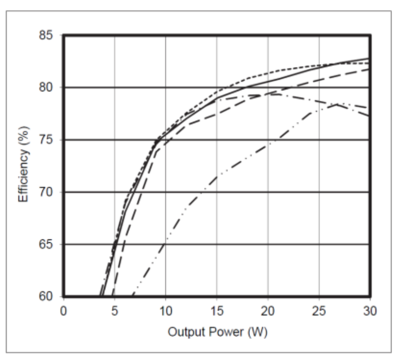
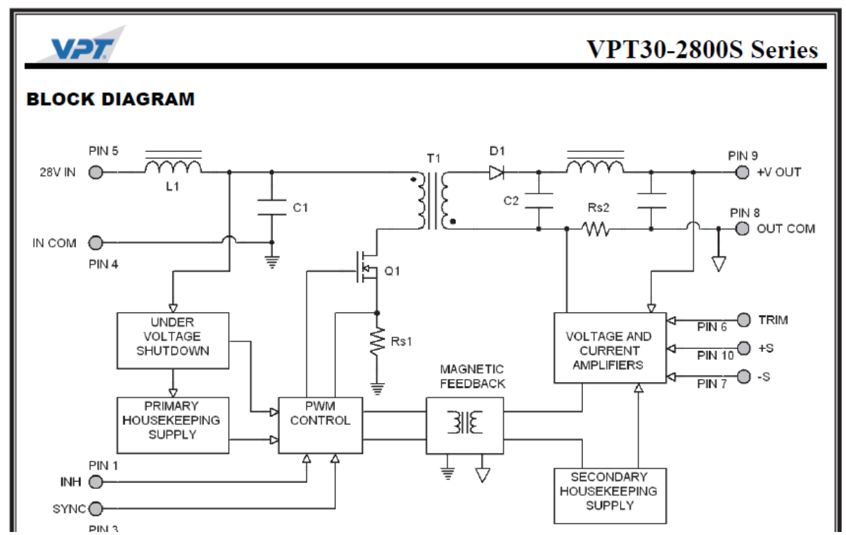


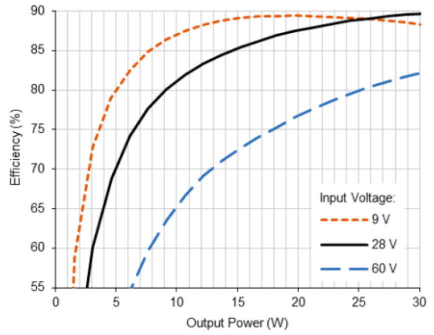
Figure 8 – VPT30-2851515T



DC/DC Topologies & Efficiency

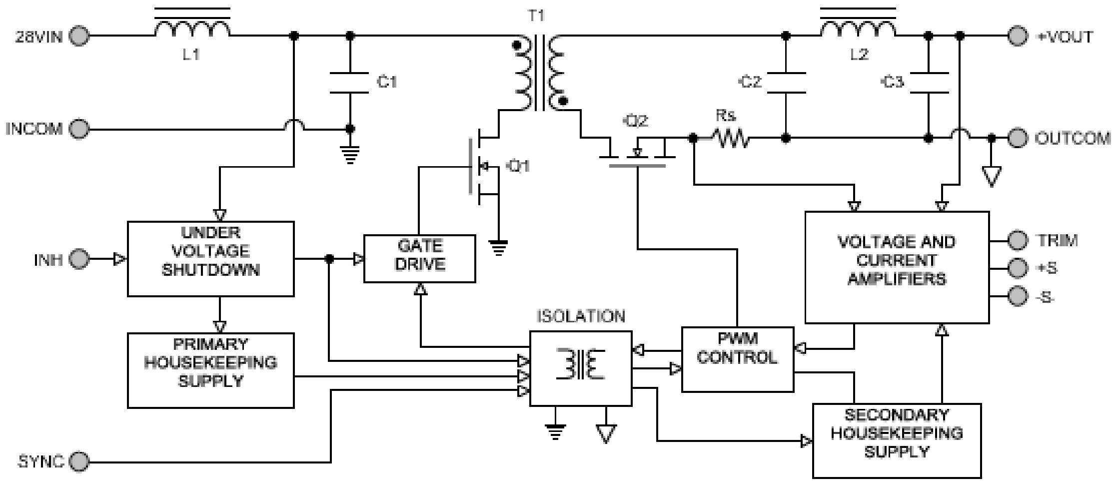
- VXR series Topologies
  - Flyback Synchronous Rectified
    - Efficiency 85% to 90%

4.1.3 VXR30-2807S Efficiency (Typical, 25 °C)



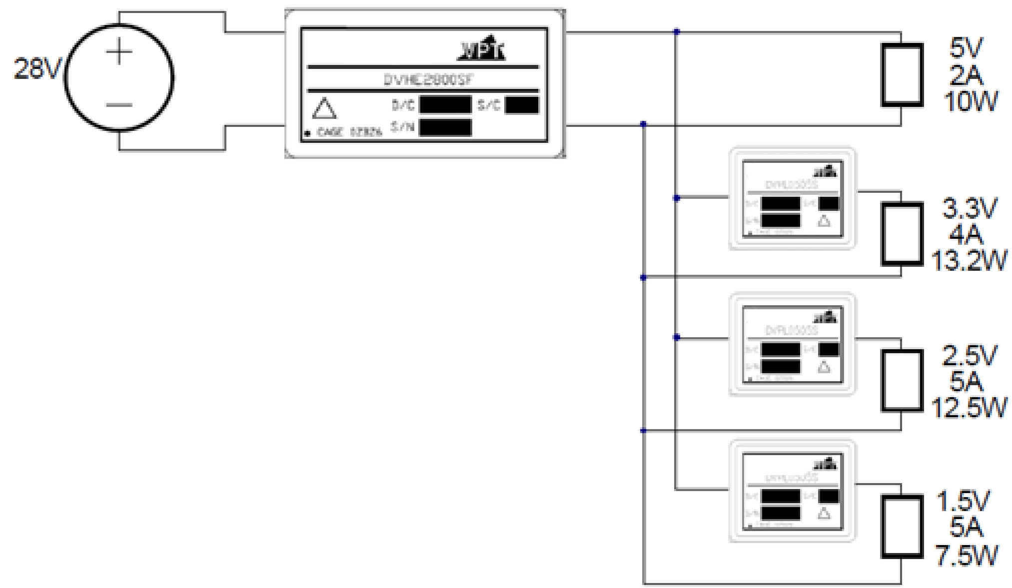
VXR30-2800S SERIES DATASHEET

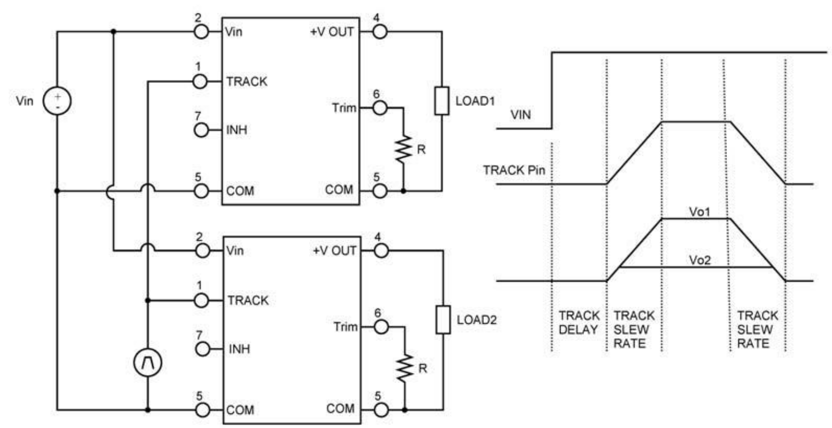
2.1 BLOCK DIAGRAM



Using POL Converters

- Isolation at DC/DC
- Compact POL
  - Placed near FPGA
  - Output trimmable to 0.8V
  - Efficiency to 95%
- Power Out = 43.2W
- Power In = 50W
- System Efficiency = 86.4%
- Board Area = 4.73 in2 (53% reduction
- Weight = 90G (50% lighter)
- Track pin on POL can control rate of rise of multiple input to processors

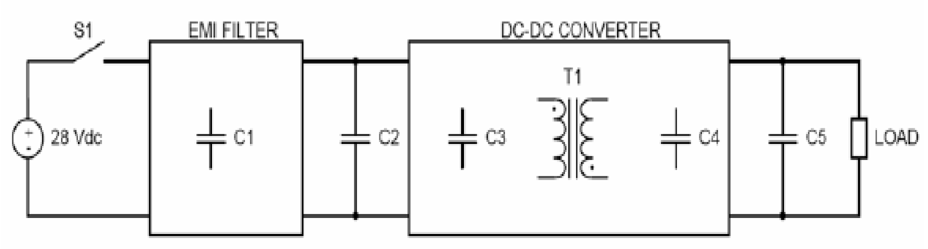




Turn On Considerations – In rush current

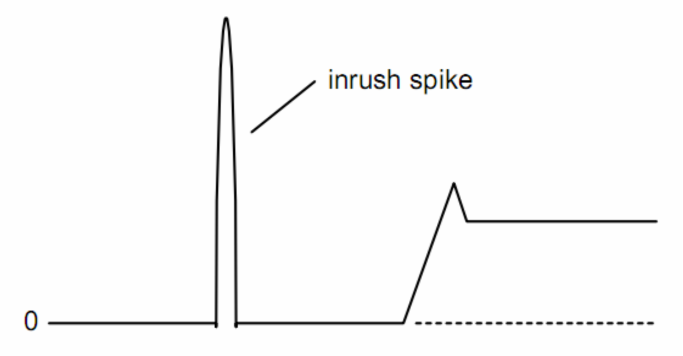
- Typical design has capacitance connected across the input line.

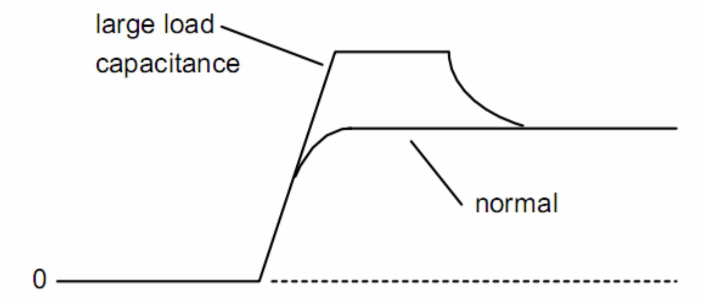
- DC-DC converter capacitance
- load capacitance.



Inrush sources

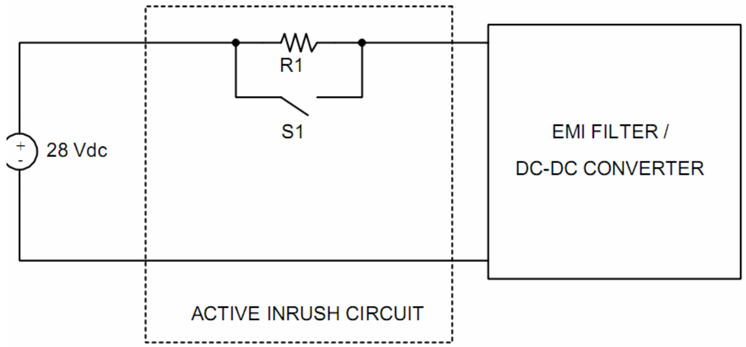
- In rush spike
  - Input source dependent on rise time dv/dt and source impedance
  - EMI magnetics too small to limit peaks
  - Slower rise determined by I=C(dv/dt)
- Turn on Current
  - Second peak occurs when DC/DC turns on
  - Large load capacitance
  - DC/DC Converters have controlled turn on to the load

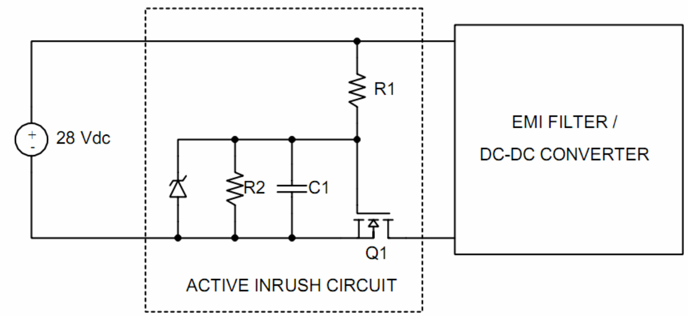




Controlling Inrush

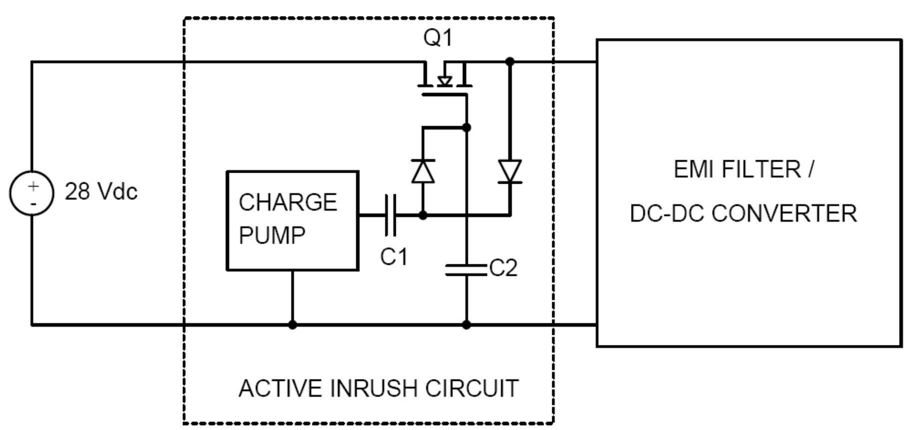
- A resistor with a bypass switch
- An inductor
- Controlled MOSFET

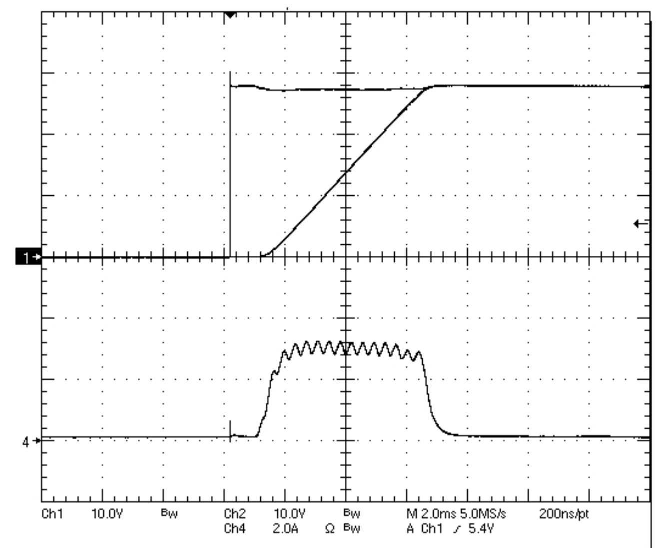




Controlling Inrush Current

- Dedicated inrush current protection module
- Controls the output voltage ramp rate (dv/dt)
- DVCH example shows in rush to a 500 uf Cap load





Handling the MIL-STD-1275E 2J requirement

- +/-250 V (2 Joule) capacitor vendors advise it is of short duration, it will not have any effect on the capacitors.
- Equipment is limited to confirm this- it has not been tested.
- Best to use TVS to clamp this voltage

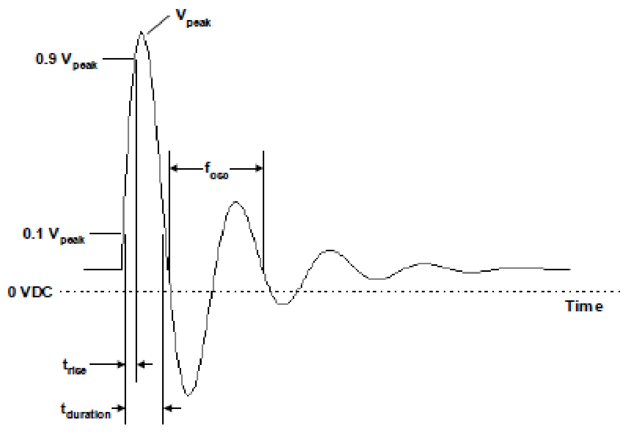


Figure 3. Voltage spike.

MIL-STD-1275E

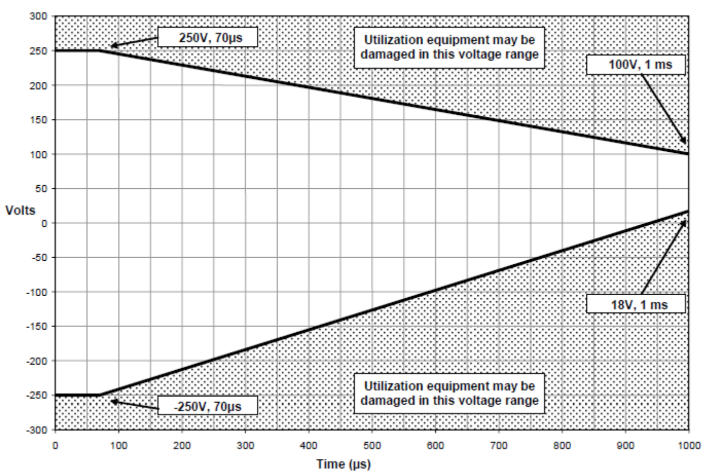
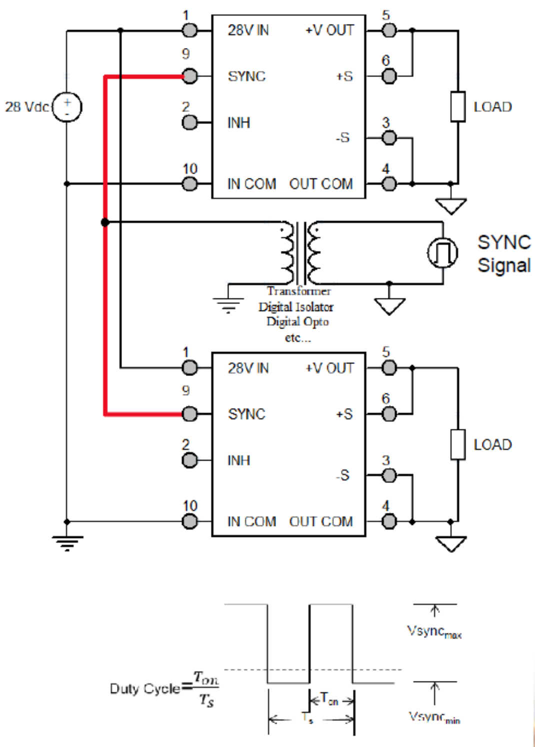


Figure 7. Envelope of spikes for 28VDC systems.

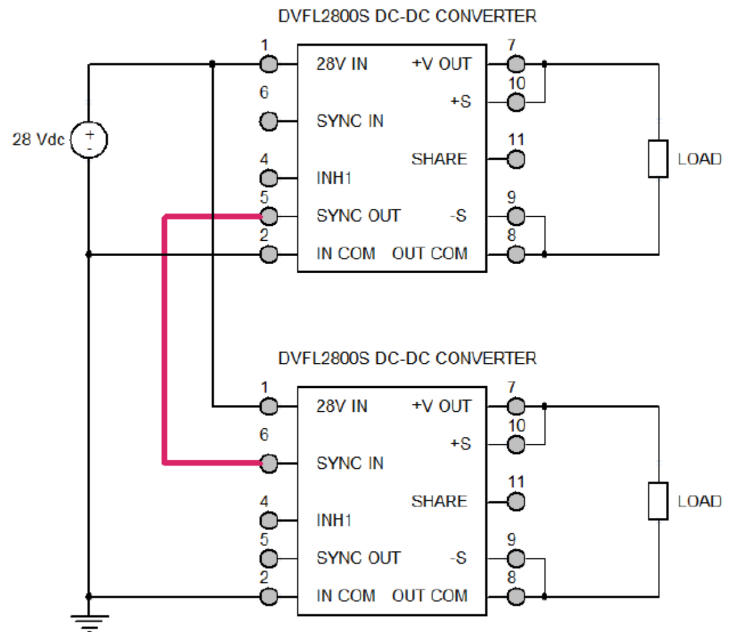
Controlling additional sources of ripple/noise

Sync Capability of internal PWM will help reduce beat frequencies

External Sync

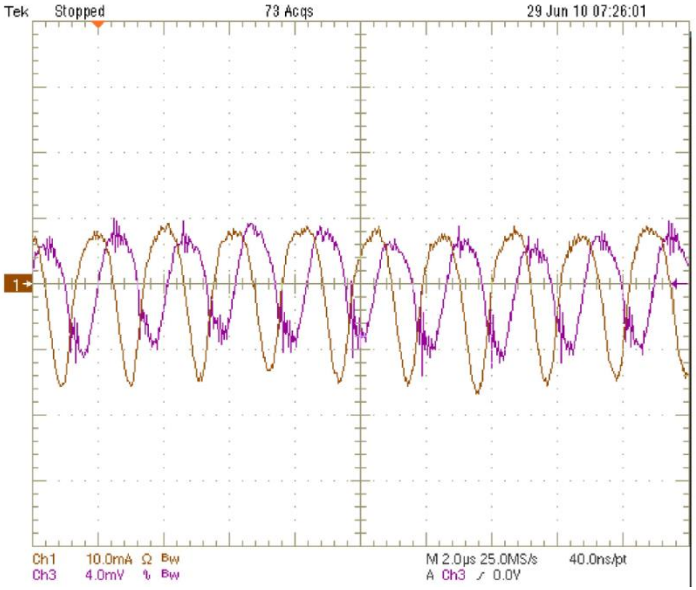


Utilizing Internal Sync



Output Ripple

- DVSA2805S typical output ripple example. 10Mhz BW
  - Vout Ripple is specified at 10 mVp-p typical & 30 mVp-p maximum
  - Measured is purple trace and is 8 mVp-p
  - Reduce output Ripple with Low ESR Ceramic Capacitor.
    - 1 to 10 uf general recommendation
    - 50 to 100 uf for low noise <10 mVp-p
    - If even lower ripple needed, LC can be used



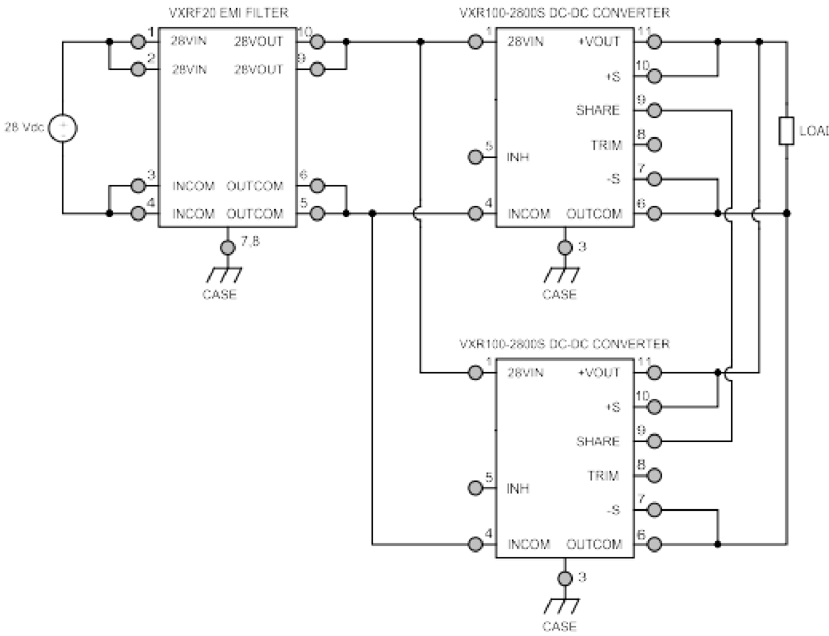
Highly recommend the 5 minute video be watched under “Data Tab”

http://www.vptpower.com/data/vpt-video-labs/#AllVideos-21

Basic Recommendation for any VPT DC to DC converter

Higher Power Requirements

- Current Sharing – parallel connections
- Current is sensed internally and fed into a P/I op-amp which sets one as a master another as a slave
- Ensures equal current and power dissipation
- Can connect multiple devices



Hold Up Voltage Considerations

- Some systems require the processor to remain operable during a power interruption
- This can be accomplished using capacitors
  - Dependent upon system efficiency and load
  - These can be large

$$C_{holdup} \geq \frac{2 \times P_{LOAD} \times t_{HOLDUP}}{\eta \times \left((V_{NOM})^2 - (V_{DROPOUT})^2 \right)}$$

Where
C_{holdup} = Total hold-up capacitance
P_{load} = Output Power Requirement: The total delivered power to the load(s) in Watts
t_{holdup} = Desired holdup time in seconds
V_{nom} = The nominal DC input or DC bus voltage, of the power supply at time of input power loss
$V_{dropout}$ = The low-line, or dropout voltage, of the DC portion of the power supply
η = Efficiency of the power supply

MIL-STD-1275 Transients

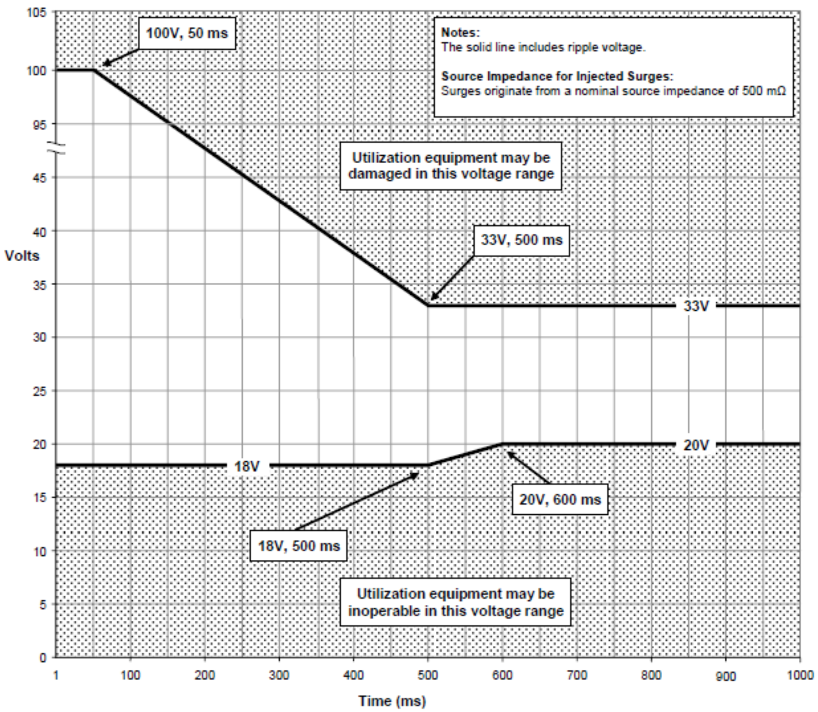
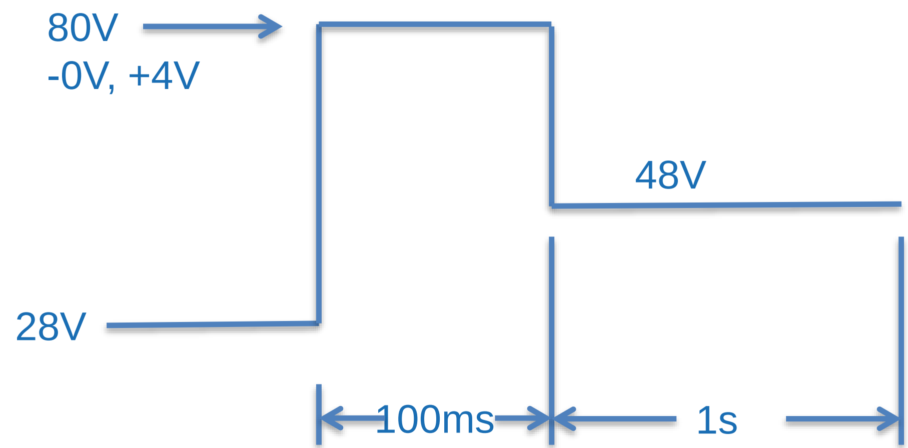


Figure 8. Envelope of surges for 28VDC systems.

MIL-STD-1275 Voltage Surge



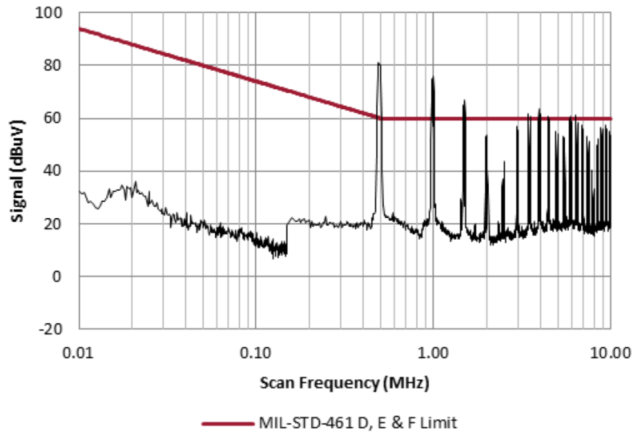
RTCA DO-160 16.6.2.4 Abnormal Voltage surge Category Z equipment

Adding 100V transient capability allows the entire VXR family to pass the MIL-STD-1275 voltage surge and the DO-160 voltage surge without any additional components!

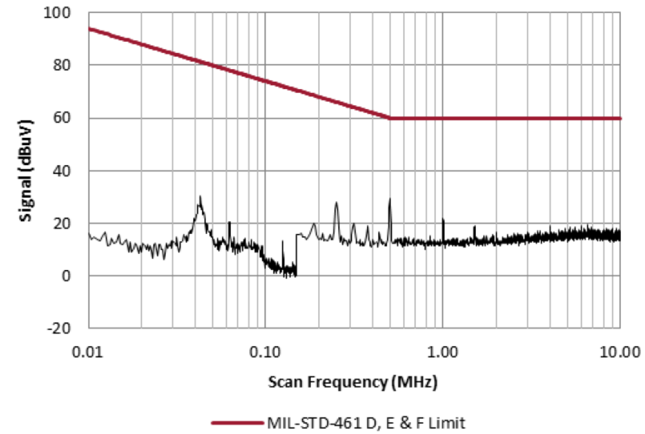
EMI: MIL-461 & DO-160

- EMI Filters Matched to Internal PWM to attenuate Common Mode and Differential noise
- Example Plots

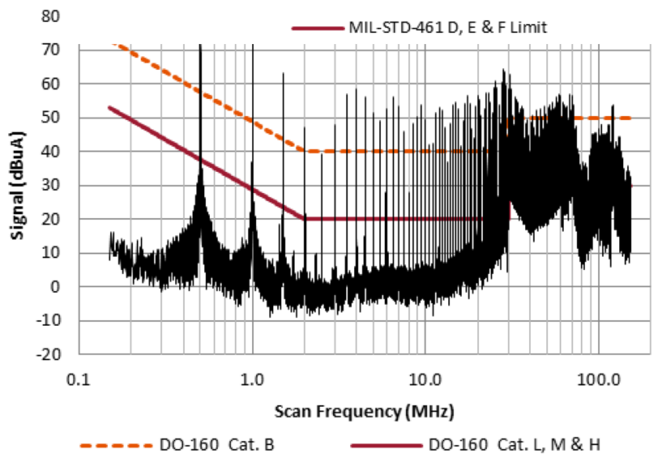
4.1.3 Two VXR30-2800S without EMI Filter

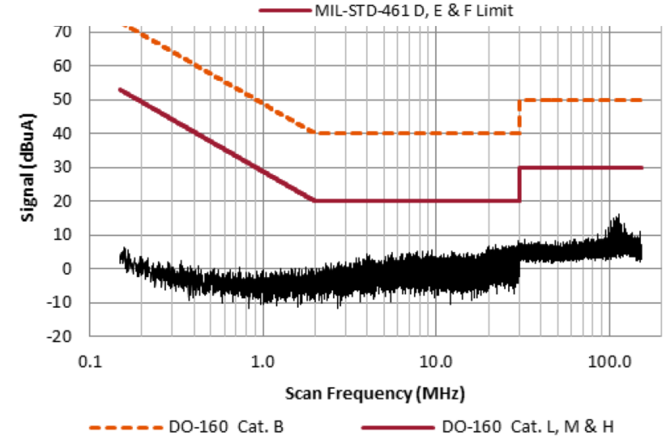


4.1.4 Two VXR30-2800S with EMI Filter



4.1.5 T





Environmental Requirements

- DO-160
  - Aviation Power and electronics environmental screening and procedures
- MIL-STD-461
  - EMI requirements and testing
- MIL-PRF-38534
  - Device level qualification screening and procedures
  - Die level qualification and screening and procedures
  - Space level qualification screening and procedures
  - No Pure Tin. MIL-PRF-38534 specifically prohibits the use of internal and external pure tin finishes

DO 160 Temperature Criteria

Table 4-1 Temperature and Altitude Criteria

Environmental Tests	Category Paragraph 4.3																			
	A				B				C				D			E		F		
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	1	2	3
Operating Low Temp. Degrees C Paragraph 4.5.2	-15	-15	-15	-15	-20	-45	-45	Note (4)	-20	-55	-55	Note (4)	-20	-55	-55	-55	-55	-20	-55	-55
Operating High Temp. Degrees C Paragraph 4.5.4	+55	+70	+70	Note (3)	+55	+70	Note (3)	Note (4)	+55	+70	Note (3)	Note (4)	+55	+70	Note (3)	Note (3)	Note (3)	+55	+70	Note (3)
Short-Time Operating Low Temp. Degrees C Paragraph 4.5.1	-40	-40	-40	Note (3)	-40	-45	Note (3)	Note (4)	-40	-55	Note (3)	Note (4)	-40	-55	-55	-55	-55	-40	-55	-55
Short-Time Operating High Temp. Degrees C Paragraph 4.53	+70	+70	+85	Note (3)	+70	+70	Note (3)	Note (4)	+70	+70	Note (3)	Note (4)	+70	+70	Note (3)	Note (3)	Note (3)	+70	+70	Note (3)
Loss of Cooling Test Degrees C Paragraph 4.5.5	+30	+40	+45	Note (3)	+30	+40	Note (3)	Note (3)	+30	+40	Note (3)	Note (3)	+30	+40	Note (3)	Note (3)	Note (3)	+30	+40	Note (3)
Ground Survival Low Temperature Degrees C Paragraph 4.5.1	-55	-55	-55	Note (3)	-55	-55	Note (3)	-55	-55	-55	Note (3)	-55	-55	-55	-55	-55	-55	-55	-55	-55
Ground Survival High Temperature Degrees C Paragraph 4.5.3	+85	+85	+85	Note (3)	+85	+85	Note (3)	+85	+85	+85	Note (3)	+85	+85	+85	Note (3)	+85	Note (3)	+85	+85	Note (3)
Altitude Thousands of Feet Thousands of Meters Paragraph 4.6.1	15 4.6	15 4.6	15 4.6	15 4.6	25 7.6	25 7.6	25 7.6	25 7.6	35 10.7	35 10.7	35 10.7	35 10.7	50 15.2	50 15.2	50 15.2	70 21.3	70 21.3	55 16.8	55 16.8	55 16.8
Decompression Test Paragraph 4.6.2	Note (1) (4)	Note (1) (4)	Note (1) (4)	Note (1) (4)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overpressure Test Paragraph 4.6.3	Note (2)	Note (2)	Note (2)	Note (2)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note:

1) *The lowest pressure applicable for the decompression test is the maximum operating altitude for the aircraft in which the equipment will be installed.*
2) *The absolute pressure is 170 kPa (-15,000 ft or -4,600 m).*
3) *To be declared by the equipment manufacturer relative to temperature extremes.*
4) *To be declared by the equipment manufacturer and defined in the manufacturer's installation instructions when specific critical criteria exist.*

DO-160 lightning Wavefoms

Level	Waveforms		
	3/3	4/1	5A/5A
	Voc/Isc	Voc/Isc	Voc/Isc
1	100/4	50/10	50/50
2	250/10	125/25	125/125
3	600/24	300/60	300/300
4	1500/60	750/150	750/750
5	3200/128	1600/320	1600/1600

MIL-PRF-38534 Environmental Screening Options for Hybrids

ENVIRONMENTAL SCREENING (100% Tested Per MIL-STD-883 as referenced to MIL-PRF-38534)

Screening	MIL-STD-883	Standard (No Suffix)	Extended /ES	HB /HB	Class H /H	Class K /K
Non-Destructive Bond Pull	Method 2023	•	•	•	•	•
Internal Visual	Method 2017, 2032 Internal Procedure	 •	•	•	•	•
Temperature Cycling	Method 1010, Condition C Method 1010, -55°C to 125°C		 •	•	•	•
Constant Acceleration	Method 2001, 3000g, Y1 Direction Method 2001, 500g, Y1 Direction		 •	•	•	•
PIND	Method 2020, Condition A[2]					•
Pre Burn-In Electrical	100% at 25°C					•
Burn-In	Method 1015, 320 hours at +125°C Method 1015, 160 hours at +125°C 96 hours at +125°C 24 hours at +125°C	 •	 •	 •	 •	•
Final Electrical	MIL-PRF-38534, Group A[1] 100% at 25°C	 •	 •	•	•	•
Hermeticity	Method 1014, Fine Leak, Condition A Method 1014, Gross Leak, Condition C Dip (1×10^{-3})	 •	• •	• •	• •	• •
Radiography	Method 2012[3]					•
External Visual	Method 2009	•	•	•	•	•

Notes:
1. 100% R&R testing at –55°C, +25°C, and +125°C with all test data included in product shipment.
2. PIND test Certificate of Compliance included in product shipment.
3. Radiographic test Certificate of Compliance and film(s) included in product shipment.

MIL-PRF-38534 Component/Die Level Screening

TABLE C-II. Microcircuit and semiconductor dice evaluation requirements.

Subgroup	Class K	Class H	Test	MIL-STD-883 Method	MIL-STD-883 Condition	Quantity (accept number)	Reference paragraph
1	X	X	Element electrical			100 percent	C.3.3.1
2	X	X	Element visual	2010 1/ 2069 1/ 2070 1/ 2072 1/ 2073		100 percent	C.3.3.2
3	X	X	Internal visual	2010 1/ 2069 1/ 2070 1/ 2072 1/ 2073		10 (0)	C.3.3.3 C.3.3.4.2
4	X		Temperature cycling	1010	C	2/ 10 (0)	C.3.3.3
	X		Mechanical shock or Constant acceleration	2002 2001	B, Y1 direction 3,000 g's, Y1 direction		
	X		Interim electrical				C.3.3.4.3
	X		Burn-in	1015	240 hours minimum at +125°C		
	X		Post burn-in electrical				C.3.3.4.3
	X		Steady-state life	1005			
	X	X	Final electrical				C.3.3.4.3
5	X	X	Wire bond evaluation	2011		10 (0) wires or 20 (1) wires	C.3.3.3 C.3.3.5
6	X		SEM	2018 1/ 2077		See method 2018 of MIL-STD-883 or method 2077 of MIL-STD-750	C.3.3.6

1/ MIL-STD-750 methods.
2/ For Class K sample sizes, see C.3.3.4.1.

Capacitor Screening Example

MIL-PRF-32535

NOTE: Inspection for 30% reduction in dielectric thickness for dielectrics less than or equal to 7 microns is not required due to lack of consistent and repeatable measurement.

FIGURE 1. Dielectric parameters.

(2) Undulations in the electrode and dielectric layers shall not be cause for rejection as long as both electrodes and dielectrics follow the same undulating pattern (see figure 2) without distorting the dielectric and the requirement of 3.12b is met.

Hi-Rel Mil COTS
DO-160 Summary

- 22< Vin < 30.3 input voltage range
- Vin=18V for emergency operation
- Ripple voltage less than 4V peak to peak
- Normal surge =50V for 50ms, 12V for 30ms
- Engine starting=10V for up to 35s
- Abnormal surge=80V for 100ms

DLA LAND AND MARITIME SMDs / DRAWINGS

- DLA (Defense Logistics Agency) reviews and approves all qualification tests
  - Provides an SMD number (Standard Microcircuit Drawings) for all devices
  - This saves cost of creating a Source Control Drawing (Spec)
  - Acceptable for all Military and Space requirements

- VPT offers DC/DC converter products qualified to MIL-PRF-38534 Class K and Class H on DLA SMDs, and EMI Filter products qualified to MIL-PRF-38534 Class K and Class H on DLA Land and Maritime Drawings. All SMD and DLA Land and Maritime drawing products are marked with a “Q” on the cover as specified by the QML certification mark requirement of MIL-PRF-38534.

- VPT SMDs and DLA Land and Maritime Drawings are available through the DLA Land and Maritime website or through http://www.vptpower.com/.

VPT Solutions for MIL-COTS / Hi-Rel COTS and Industrial Applications

- What Defines MIL-COTS/ Hi-Rel COTS?
  - Temperature Range
    - -55C to 100C or 105C (family dependent)
  - Ruggedized Design with Qualifications
    - ESD Testing
    - Temperature Cycling & Humidity Testing
    - 1,000 hour Life Test
    - Barometric Testing to 70,000 feet
    - Temperature Cycle, Random Vibration & Shock Testing
  - 100% Production Module Environmental Screening

Test	Condition
Internal Visual	IPC-A-610, Class 3
Stabilization Bake	MIL-STD-883, Method 1008, Condition B, 125°C, 24 hours
Temperature Cycling	MIL-STD-883, Method 1010, Condition B, -55°C to +125°C, 10 Cycles
Burn In	96 hours at +105°C
Final Electrical	100% at 25°C
External Visual	Internal Procedure

Design Trade off Considerations

- "COTs" – cost savings has some risk
  - Component level screening is limited to reduce cost
  - Device level screening and testing
  - Traceability may be limited
    - Component level
    - Device level
  - Failure analysis may be limited at best
    - Potted module analysis a difficult and destructive process ($)
    - Most "COTS" supplier will not provide detailed analysis

Hybrid Highlights & Performance Advantages

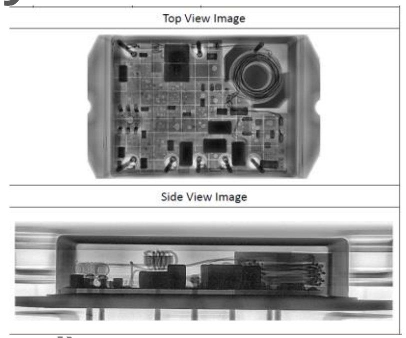
- Single, dual and triple outputs, 1.5 to 120W
- Standard Output Voltages 3.3, 5, 5.2, 12, 15….many other Vouts
- Triple outputs with dual control loops for improved cross regulation
- Metal packages for Low Radiated Emissions
- Companion EMI filters for **MIL-STD-461**
- Wide input voltage range
  - 15 to 50V with 80V transient (**MIL-STD-704A**)
  - 16 to 40V with 50V transient (**MIL-STD-704F**)
  - Magnetic feedback with no optoisolators
- Low input and output noise
- Efficiency ranging from 71% up to 86% module & Vout dependant
- Short Lead Times, with many products in stock
- 100 % Non-Destruct W/B pull Testing (Ultimate in Hi-Reliability SMD's)
- Multiple levels of Environmental Screening Available

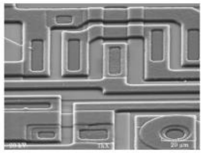
Space Trends

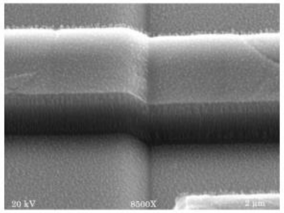
- Industry is changing, more "commercial" competition is focused on reducing costs, BUT there is risk
- Small Satellite market is growing quickly
  - Cost sensitive
  - Limited mission/life
  - Failure rates are high – Various reports indicate up to 50% failure rate within the first month(s)
    - 50% of the failed satellites that has some form of telemetry still functioning indicate a power failure
  - Could be a market bubble due to reliability issues
    - Nonetheless – they are changing the space community

Space Screening

- Additional tests as specified by MIL-PRF-35834
  - Mission dependent
  - May Include the following
    - X-Ray
    - PIND
    - Element Evaluation (component level)
    - Group C testing (device level)
    - Worst Case Analysis
    - SEM analysis – component lot level screening
  - Radiation tests and reports
    - TID, SEU, ELDRS







Industrial Applications

- What Defines an Industrial Product?
  - Temperature Range
    - -40C to 100C
    - Metal Package only
  - Mature Product with Limited Screening
    - Reduced component screening
    - Reduced module Environmental Screening
    - Reduced Failure Analysis Support
  - 100% Production Module Environmental Screening

Screening	Condition
Internal Visual	IPC-A-610, Class 3
Final Electrical	100% at 25 °C
External Visual	Internal Procedure

Access to Video Labs & White Papers

- On Line Technical Resources
  - SMD Advantages http://www.vptpower.com/data/vpt-video-labs/#AllVideos-16
  - MIL-PRF-35834 http://www.vptpower.com/data/vpt-video-labs/#AllVideos-24
  - EMI MIL-STD-461 http://www.vptpower.com/data/vpt-video-labs/#AllVideos-25\
  - MiL-STD-1275, 704A http://www.vptpower.com/data/vpt-video-labs/#AllVideos-19
  - Converter Protection Features http://www.vptpower.com/data/vpt-video-labs/#AllVideos-126
  - DC/DC Output ripple http://www.vptpower.com/data/vpt-video-labs/#AllVideos-21
- Application notes
  - http://www.vptpower.com/data/application-notes/#.WImYSxsrLD4

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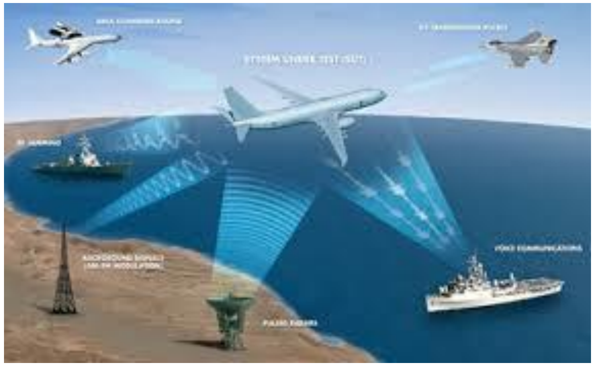
Mil/Aerospace Heritage

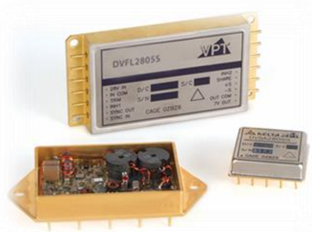
- On board 100’s of Mil/Aerospace Platforms
  - http://www.vptpower.com/programs/programs-supported/
  - Husky GPR, Navy Nuclear Fleet, Commercial & Military Avionics, PAC-3, Predator UAV
  - JSF, F-16, F-15, F-22, Multiple Airbus & Boeing Aircraft, C919



Thank you !

- www.vptpower.com

Catalogs



Products

Datasheets
Application
Notes

Technical
Videos