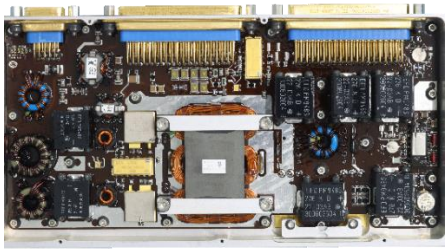
EBS-Series

Datasheet & EBS Design Envelope

Part Number: 12192



Preliminary Data Sheet

The EBS is a series of high reliability single output, high power DC/DC converters designed for space applications. The EBS is designed for hot redundant operation with multiple units operating in parallel for greater power levels without compromising single point failure free requirements of the common output rail. Current sharing between multiple units is implemented.
The design lifetime is 18 year and the converter is designed for radiation environments encountered by geostationary earth orbit satellites, deep space probes and communication systems.
It offers good tolerance to total ionizing dose, single event effects, and environmental stresses such as temperature extremes, mechanical shock and vibration. All components are derated to meet the requirements of EEE-INST-002 (NASA) and ECSS-Q-30-11A (ESA).
Features include isolated telecommand and status telemetry interface, internal EMI filter and input under voltage protection (UVP), output OR-ing and output over voltage protection (OVP) and the design can be tailored to fit most major satellite platforms.
The hot (n for m) redundant capability and protection features combined with a wide input range makes the EBS-series well suited for use as low voltage bus converter.
Each converter is provided as a complete equipment in a closed chassis for installation onto the satellite panel but can also be provided as an open board since all parts and circuits are mounted to a single PCB.
Extensive documentation including worst case analysis, radiation susceptibility, thermal analysis, stress analysis and reliability analysis is available

Features

General

- Single output, fixed in the range +20V to +32V, up to 11A or 350W
- Input ranges can be accommodated within an overall range from 20VDC to 100VDC
- Short circuit and overload protection
- Input under-voltage protection
- Output OR-ing and hot redundant operation
- Current sharing between multiple units
- Galvanic isolation, 100VDC @ >10MΩ

Telecommand/Telemetry

- Isolated On/Off control via high level pulse command (latching relay)
- On/Off Status telemetry (relay contact type)
- Input current telemetry (analog)
- Temperature telemetry (NTC)
- Output overvoltage telemetry (switch closure)
- Output OR-ing and hot redundant operation
- Current sharing between multiple units
- Galvanic isolation, 100VDC @ >10MΩ

Applications

- Low voltage bus converter
- High power, hot redundant systems

EMC

- Output Ripple: <20mVrms (100Hz – 50MHz)
- CS rejection input to outputs: > 35dB (50Hz – 1MHz)
- Internal EMI filter: Meets conducted emission requirements of major satellite power buses

Radiation

- TID Rating: 100krad(Si)
- SEE Rating: 60 MeV·cm2/mg

Quality

- Meets derating requirements of EEE-INST-002 and ECSS-Q-30-11A
- Workmanship per J-STD-001 with space addendum J-STD-001FS
- FIT: <250 @ 35°C, SF env. (MIL-HDBK-217Fn2)
- Design life: 18 years

Mechanical

- Board dimensions: 190x92.05x29mm (LxBxH)
- Chassis dimensions: 227x99x32mm (LxBxH)
- Vibration and shock resistant
- Mass incl. chassis: < 910g (board < 500g)
- Board is coated with NuSil CV6-1144

Revision History

Revision	Description	Release Date

Table of Contents

List of Figures

List of Tables

1.0 Specifications

Section 2 and the front page of this datasheet presents the generic design envelope, while this section present the data for the specific part number 12192.

Table 1. Absolute Maximum Ratings	
Input Voltage Range (note 9)	-0.5Vdc to 110V
Output Power	Internally Limited
Operating Mounting Point Temperature (note 9)	-55°C to +100°C
Storage Temperature (note 9)	-55°C to +125°C

Table 2. Recommended Operating Conditions	
Input Voltage Range	+65Vdc to +105Vdc
Output Power	0 to 350W
Operating Mounting Point Temperature	-35°C to +65°C*
Storage Temperature	-40°C

* *The DC/DC converter will keep derating as per EEE-INST-002 and ECSS-Q-30-11A. In order to respect the required component temperatures, the host chassis must provide a good thermal conductive path through the fixation screws.*

1.1 Performance Characteristics – EBS10032R5S, PN12192

Table 3. Fundamental Characterisitics						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Primary Input Voltage (Vin)			65	100	105	V
Output Voltage (V_{OUT1})		Note 1				
	1	0% ≤ IOUT ≤ 100% rated load	32.35	32.40	32.45	V
	2	0% ≤ IOUT ≤ 100% rated load	32.30	32.40	32.50	V
	3	0% ≤ IOUT ≤ 100% rated load	32.20	32.40	32.60	V
Output Power (P_{OUT1})	1,2,3				350	W
Output Current (I_{OUT1})	1,2,3	Note 1	0		11	A
Current Limit Point (CL_{OUT1})	1,2,3	Note 1				
		With droop regulation enabled	11.0		12.0	A
		With droop regulation	12.3		15.9	A
Input Current (I_{IN})	1,2,3	Maximum load current		5.9	6.1	A
		Failure mode (output overload / current limit)		8.2	9.2	A
Idle Loss (P_{IDLE})	1,2,3	Input under voltage protection active		80	150	mW
		Commanded Off		0.95	2.5	W
		Commanded On, I_{OUT} = 0		6.65	8.0	W
Switching Frequency (F_S)	1,2,3	Note 1, Note 7	117	130	143	KHz

Table 3. Fundamental Characteristics Cont.						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Efficiency (Eff)	1,2	¼ Load	83	88		%
	1,2	½ Load	86	91		
	1,2	¾ Load	91	92		
	1,2	Full Load	91	92		
	3	Full Load, EOL	91	91		

Table 4. Detailed Output Characterisitics						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Line Regulation (VR_{LINE})	1,2,3	Across full input voltage range	-5		+5	mV
Load Regulation (VR_{LOAD})	1,2,3	Across full output load range	-50		+50	mV
Output Ripple (V_{RIP})		Notes 1,2				
	1	Frequency domain 100Hz – 50MHz		5	20	mVrms
	1,2	Time domain 100Hz – 50Mz		250	500	mVpp
Output Response, Step Load Changes (V_{TLD})	1,2,3	20% to 100% load Notes 3,4		1150	1300	mVpk
Recovery Time, Step Load Changes (T_{TLD})	1,2,3	20% to 100% load Notes 3,4			2.5	ms
Output Response, Single Event Transients	1,2,3	In 20% to 100% load range Note 3			2000	mVpk
Recovery Time, Single Event Transients	1				200	us
Turn-On Response Overshoot	1,2,3	Note 5			50	mV
Turn-On Delay			1		5	ms
Turn-Off Delay	1,2,3	During command off	145		225	ms
Capacitive Load	1,2,3	Max capacitive load, each output Notes 1,6			100	µF

Table 5. Telemetry & Telecommand (TM & TC)						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Telecommand I/F ON command pulse Neg. Pulse Voltage Pulse duration	1,2,3	Note 10	+23	26	+32.6	V
			-40		0.5	V
			10		1000	ms
Status Telemetry Converter On Converter Off	1,2,3	Note 10				
		Closed contact			500	Ohm
		Open contact	1			MOhm
Input Current Telemetry	1,2,3	Note 1				
		Gain at Vin = 100V		1		V/A
		Telemetry voltage range	0		5.5	V

Table 5. Telemetry & Telecommand (TM & TC) Cont.						
Parameter	Conditions	Notes / Comments	Limits			Unit
			Min	Nom	Max	
Output Voltage Telemetry	1,2,3	Note 1				
		Gain		119		mV/V
		Telemetry voltage range	0		5.5	V
Output Over Voltage Telemetry	1,2,3	Note 1				
		Normal operation			500	Ohm
		Over voltage protection engaged	950			kOhm
		Telemetry reset time	245		380	ms

Table 6. Under Voltage Protection (UVP)						
Parameter	Conditions	Notes / Comments	Limits			Unit
			Min	Nom	Max	
Under Voltage Protection Trig Level – Turn On	1,2,3	UVP is non-latching and restarts automatically when the turn on threshold is reached 0% ≤ Iout ≤ 100% of rated load	56.4	58.1	59.8	V
Under Voltage Protection Hysteresis	1,2,3	0% ≤ Iout ≤ 100% of rated load	0.73	1.58	2.55	V

Table 7. Over Voltage Protection (OVP)						
Parameter	Conditions	Notes / Comments	Limits			Unit
			Min	Nom	Max	
Over Voltage Protection	1,2,3	Note 1				
Trig level			33.609	33.950	34.350	V
Peak voltage		Peak duration < 5 us			34.650	V
Restart Time	1,2,3	Note 1	150	190	235	ms

Table 8. Electromagnetic Compatibility (EMC)						
Parameter	Conditions	Notes / Comments	Limits			Unit
			Min	Nom	Max	
Conducted Emission (CE) On Output	1,2,3				109	dBuVrms
EMC Conducted Susceptibility (Line Rejection)	1,2,3	For VIN = 100V with sine wave injection of 2Vp-p, 100Hz to 1MHz	35	50		dB
Electromagnetic Interference (EMI), Conducted Emission (CE) On Input	1	For VIN = 100V measured at switch frequency See also section 1.3		85	92	dBuArms

Table 9. Mechanical Characteristics						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Board Dimensions Length Width Height	1,2,3	See also section 2.4 Excl. protruding connectors		190.0 84.5	190.1 84.6 29.0	mm
Chassis Dimensions Length Width Height	1,2,3	See also section 2.4 Excl. protruding connectors		227.0 92.9 32.0	227.2 93.1 32.2	mm
Mass	1,2,3	Open board excl. mounting screws			500	g
		In chassis excl. mounting bolts			910	
Vibration	1,2	See also section 2.4.1			9.42	grms
Shock	1,2	See also section 2.4.1			4200	G

Table 10. Radiation						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Total Ionizing Dose (TiD)	1,2,3		100			krad
Single Event Effect Tolerant (SEE)	1,2,3	SEE rating in general A single component has SEL at added failure rate is calculated to be 0.1 FIT	60 43			MeV·cm^2/mg

Table 11. Other Characteristics						
Parameter	**Conditions**	**Notes / Comments**	**Limits**			**Unit**
			Min	**Nom**	**Max**	
Isolation	1,2,3	Input to Output, any potential to telecommand input and any potential to telemetry output, test @ 100VDC See also section 0	10			MΩ
Failure Rate		MIL-HDBK-217 Notice 2, SF, 35°C, note 8			250	FITs

Performance Characteristics Notes:

General: All parameters are specified within recommended operating conditions unless otherwise stated.

1. Parameter is analyzed and tested.
2. Guaranteed for a DC to 50MHz bandwidth. Tested using a 10.7MHz bandwidth.
3. Load step transition time ≥ 10 µSec.
4. Recovery time is measured from the initiation of the transient to where VOUT1 has returned to within 90% of its steady state value.
5. Turn-on delay time from application of telecommand pulse to the point where VOUT1 >90% of nominal output voltage
6. Capacitive load may be any value from 0 to the maximum limit without compromising the performance. A capacitive load in excess of the maximum limit may influence the performance and start-up time, but the converter operation and dc performance will remain intact
7. The switching frequency and 1st harmonic of the input ripple is tested on every unit

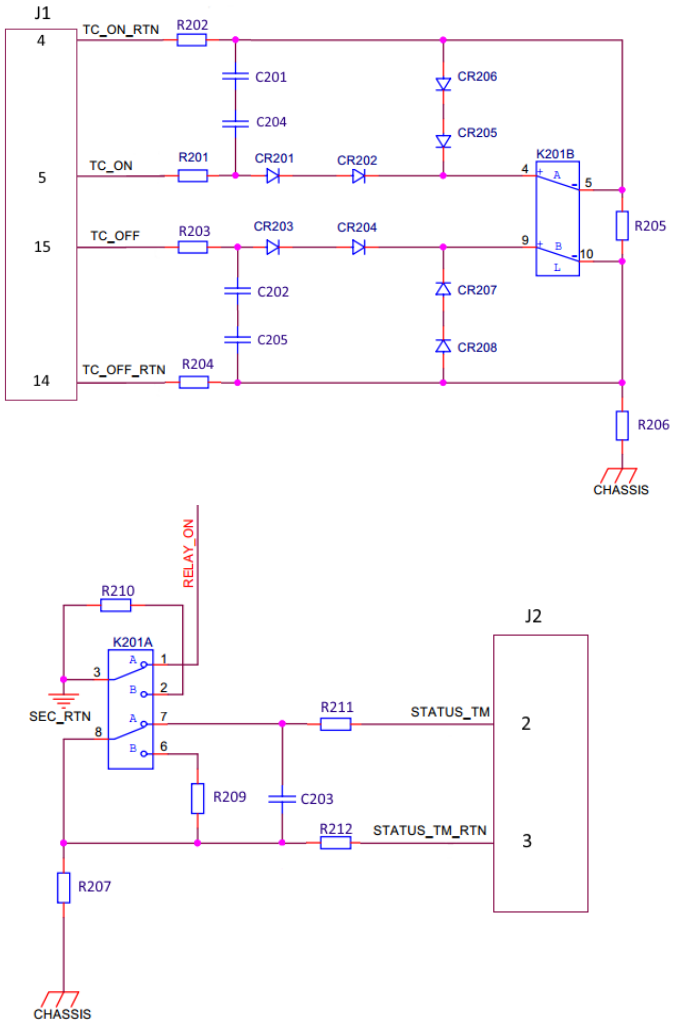
8. MIL-HDBK-217Fn2 stress-dependent method is used with 4 exceptions: For soldering a fixed failure rate at 0.035FIT is used and for power MOSFETs the dissipated power (instead of rated power) is used for the Pr parameter. For connectors and transformers MIL-HDBK-217Fn1 is used. 1 FIT is 1 failure in 10E9 hours.
9. The converter meets full derating per EEE-INST-002 and ECSS-Q-30-11A with the following exception: For Schottky diode JANS1N5819 a maximum derated junction temperature of +110°C. For EEE-INST-002 it is required that ceramic capacitors with a voltage stress below 10V shall be rated for minimum 100V – in the design such capacitors is rated for 50V minimum
10. Generic TM/TC circuit and configuration for specific part number is presented in section 2.2.3

Table 12. Electrical Performance Characteristics - Definition of Conditions

Condition	Definition	Comment
1	BOL at +25°C interface temperature	Initial setting
2	BOL at -35°C to +65°C interface temperature	Initial setting and worst-case temperature variation
3	EOL at -35°C to +65°C interface temperature	Worst-case performance including initial setting, temperature variation, ageing and radiation degradation

1.2 Telecommand Interface Schematic

The telecommand interface can be tailored to fit all major satellite platforms. Figure 1. show the generic schematic and the table gives the specific configuration for part number 12192.



RefDes	PN12192
C203	100 pF, 100V, SMD0805
C201	Not fitted, SMD0805
C202	Not fitted, SMD0805
C204	Not fitted, SMD0805
C205	Not fitted, SMD0805
CR201	1N6640US, 0.3A, 75V
CR202	1N6640US, 0.3A, 75V
CR203	1N6640US, 0.3A, 75V
CR204	1N6640US, 0.3A, 75V
CR205	1N6640US, 0.3A, 75V
CR206	1N6640US, 0.3A, 75V
CR207	1N6640US, 0.3A, 75V
CR208	1N6640US, 0.3A, 75V
J1	SDD15M400T2G
J2	SDD78M400T2G
K201	J422-26M
R211	422 ohm, SMD1206
R201	100 ohm, SMD1206
R203	100 ohm, SMD1206
R206	Not fitted, SMD1206
R207	Not fitted, SMD1206
R209	0 ohm, SMD0603
R210	0 ohm, SMD0603
R202	0 ohm, SMD1206
R204	0 ohm, SMD1206
R205	0 ohm, SMD1206
R212	0 ohm, SMD1206

Figure 1. TM/TC Circuit Implemented on PCB.

Note: not all components are to be mounted at the same time, but can be mounted or left out according to requirements. Actual configuration for a specific part number is shown in the table.

1.3 EMI Performance, EBS10032R5S, PN12192

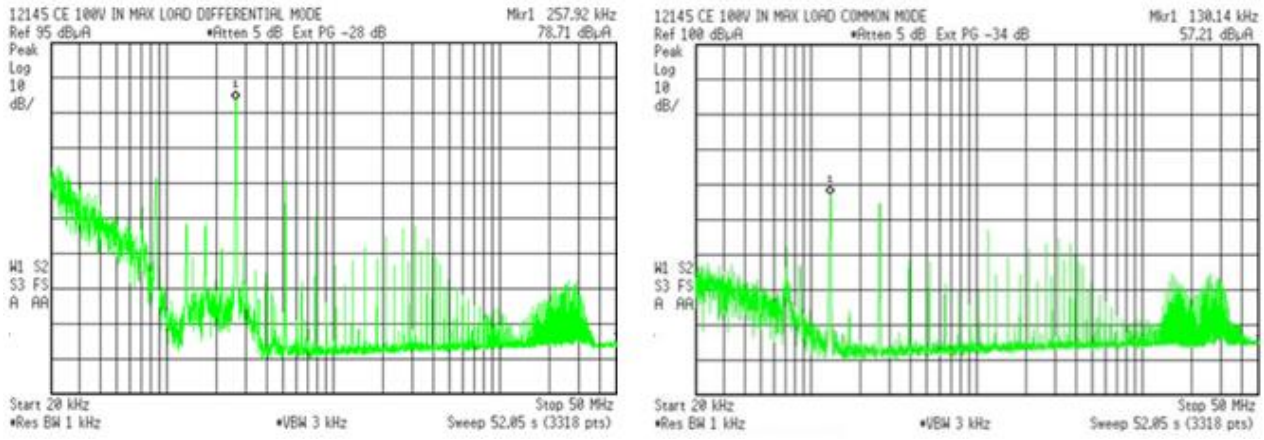


Figure 2. Conducted Emission Input

The EBS series has an integrated EMI filter.
Conducted emission on input line - typical performance – full load. Left: Differential mode, Right: Common mode

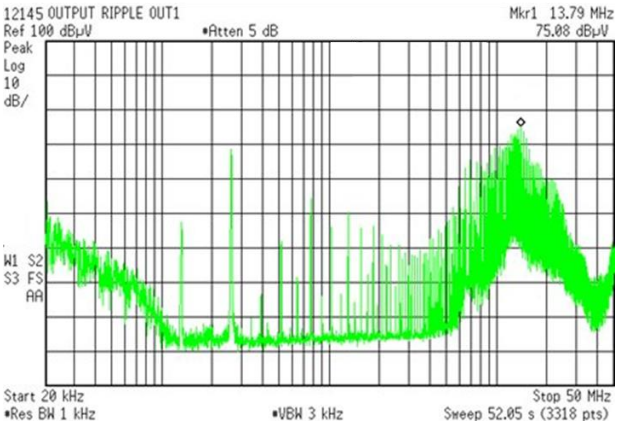


Figure 3. Conducted Emission Output

Conducted emission, differential mode - typical performance – full load.

2.0 EBS Series

Section 1 in this datasheet presents the data for part number 12192. This section with subsections presents the generic design envelope, for which the EBS series can be tailored by changing parts but re-using the generic printed circuit board.

2.1 General

The EBS-Series consists of two switching DC/DC converters. A low power Fly-back converter provides the internal supply voltages and a high power Hy-bridge converter supplying the output voltage. Both converters provide galvanic isolation from the primary side to the secondary side.

The Hy-Bridge converter directly senses the output voltage upstream the active OR-ing circuit. Compensation for the load dependent voltage drop across the OR-ing device ensures an accurate output voltage at the terminals.

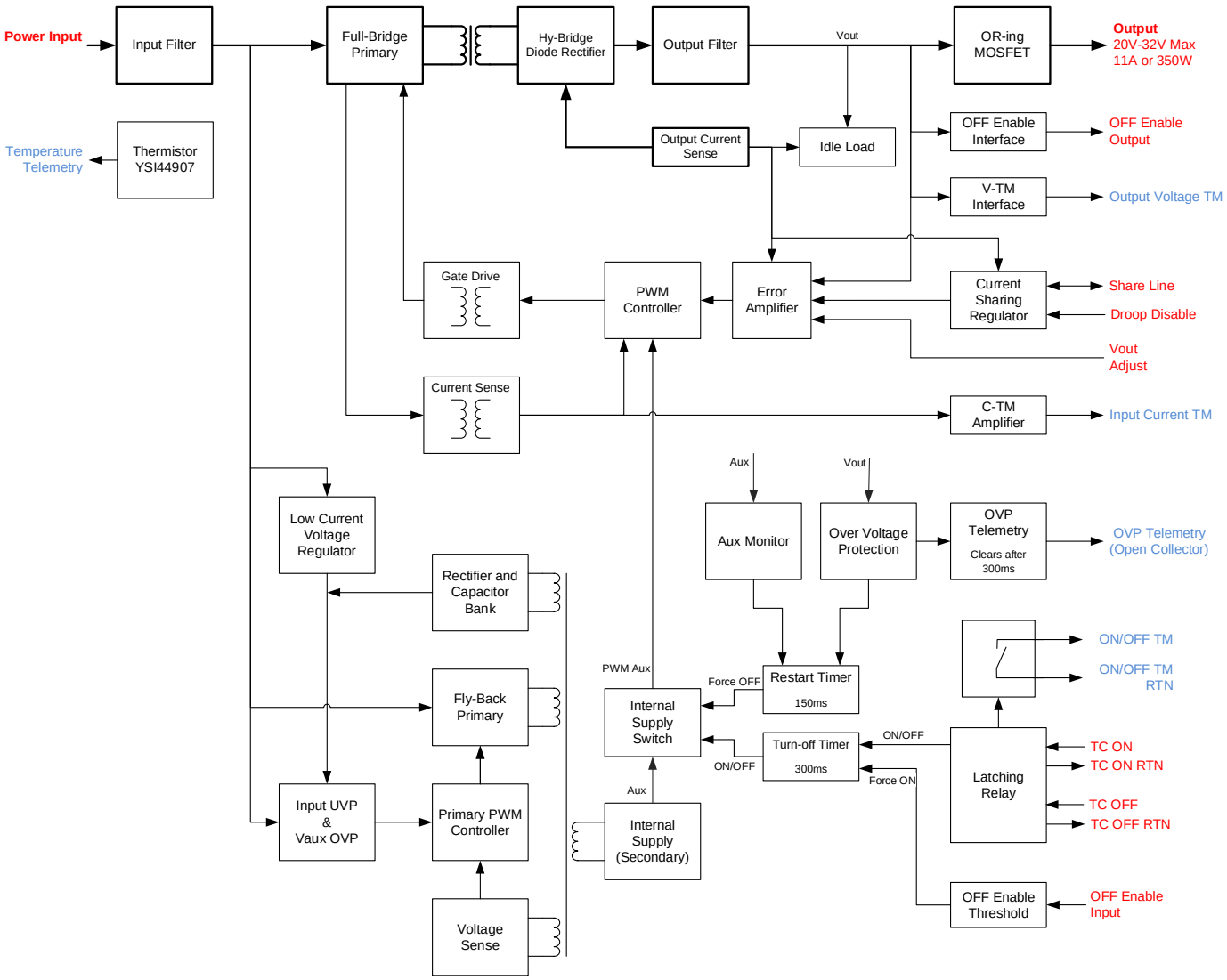


Figure 4. Block Diagram

2.2 Design Envelope

2.2.1 Input Bus Voltage Range

The input voltage range can be configured for different satellite power busses. Best performance is achieved when the input voltage has a small range between minimum and maximum input voltages such as 100±5V or 50±3V busses. The EBS can also be configured to low voltage busses such as 28±8V. In general, the input voltage range is configurable from 20V to 100V, however the full input range cannot be accommodated in one single design as this will sacrifice performance and derating requirements. Instead the primary side of the design must be adjusted from project to project.

2.2.2 Output Voltage Range and Power

The EBS has a total output capability of max 11A or 350W, whichever is greater.
The output can in be configured in the range from +20V to +32V.

2.2.3 Telecommand & Status Telemetry

The EBS series includes telecommand and telemetry options. The interfaces can be tailored to fit most major satellite platforms.

Telecommand Interface:

- TC voltage: can be customized to fit 12V-17V or 22V-34V command voltage ranges
- Freewheeling diodes/inductive kick back protection on TC lines are optional
- Telecommand pulse length: >10ms
- Telecommand interface is galvanically isolated from other circuits
- Telecommand ON return and OFF return can be isolated from each other or tied together
- Circuit concept is based on a latching relay

Status Telemetry Interface:

- Switch closure acquisition with closed (or specific impedance) or open contact
- Status TM circuit is galvanically isolated from other circuits
- Circuit concept is based on a latching relay.

2.2.4 Telecommand & Status Telemetry

The output voltage telemetry is derived directly from the output voltage and will be proportional with this the telemetry voltage cannot exceed the output voltage, but can be similar or divided down. Normally the output voltage is divided as to not exceed 5V on the telemetry interface.
The input current telemetry is derived from the primary side switch current also used for the PWM control scheme. The current is low-pass filtered and scaled using an op-amp to give an appropriate gain and output level typically limited to 5V.
The OVP telemetry provides an open collector as interface and will be high impedance during normal operation and low impedance when an over voltage has been detected and the output shit down. If the overvoltage condition clear and the output comes back to normal operation, the telemetry will clear automatically after a short time. An external pull-up resistor can be connected to the telemetry as needed.

2.2.5 Under-Voltage Protection (UVP)

- The Under-Voltage Protection circuit is non-latching and will automatically restart the converter when the input bus voltage is above the threshold level.
- The threshold level can be adjusted to comply with all major satellite platforms.

2.2.6 Overload and Short Circuit Protection

The EBS series uses peak current mode control which inherently provides a cycle-by-cycle output current limiter without dissipating excessive power internal to the converter. The characteristic of the output is a near ideal voltage source when the output current is below the current limit threshold and a near ideal current source when the threshold is exceeded. This means that if the load current is increased above the threshold the output voltage will droop and thereby limit the power supplied to the load. The current limiter is non-latching and when the overload condition is removed the output will automatically return to nominal voltage.

2.2.7 Packaging

A number of features are included to ensure single point failure free operation in a hot redundant system consisting of multiple EBS converters running in parallel.

- **Output OR-ing,** protect the common rail from failures internal to the EBS. The OR-ing circuit turns on when the converter is supplying current to the common rail and automatically blocks current from flowing into the output of the EBS.
- **Diode Rectification,** ensures that if the OR-ing fails short the common rail is not discharged
- **Overvoltage Protection,** protects the common rail from excessive voltage levels originating from the EBS in case of an internal failure. The OVP is non-latching and will automatically try to restart after a short time and will continue to restart until the overvoltage condition clears or the converter is turned off.
- **Current Sharing,** ensures that all EBS running in parallel share the load current and are kept in voltage regulation. Two options exist:
    1. Current sharing can be obtained by drooping the output voltage as a function of output current. The slope and droop engage point can be customized by changing component values to match the customer requirements.
    2. Active current sharing using a common average output current signal which is shared between converters. This average current signal is formed by resistive voltage division between the output current measurement signals from each converter. Internal to each converter the average signal is compared to the individual output current signal and this is used to adjust the output voltage slightly until the output current is equal to the average output current of converters. Active current sharing only needs one signal to be connected between the converters and the corresponding return line (two wires in total).
- **OFF Enable,** allows cross strapping of EBS units to ensure automatic turn ON if all command relays are in the OFF position. This feature overrides the relay and forces the EBS on whenever the OFF Enable signal is not present. This feature can be omitted if not required.
- **Turn Off Timer,** delays output turn OFF to allow time for a crossed strapped unit to automatically turn ON in order to avoid voltage dropouts. The timer is bypassed in case of OVP shutdown

2.3 Grounding Isolation

Table 13. Grounding & Isolation	
Parameter	**Performance**
Isolation Primary to Secondary: Secondary to Chassis:	 > 10Mohm // < 200nF with option for antiparallel diodes across primary and secondary barrier > 10Mohm // < 300nF
Telecommand	Floating / Galvanically isolated
Status TM	Floating / Galvanically isolated
Grounding	Primary, Secondary and Chassis are separate but can be tied together inside the EBS as follows if needed: Chassis tied to secondary return Primary return tied to secondary return.

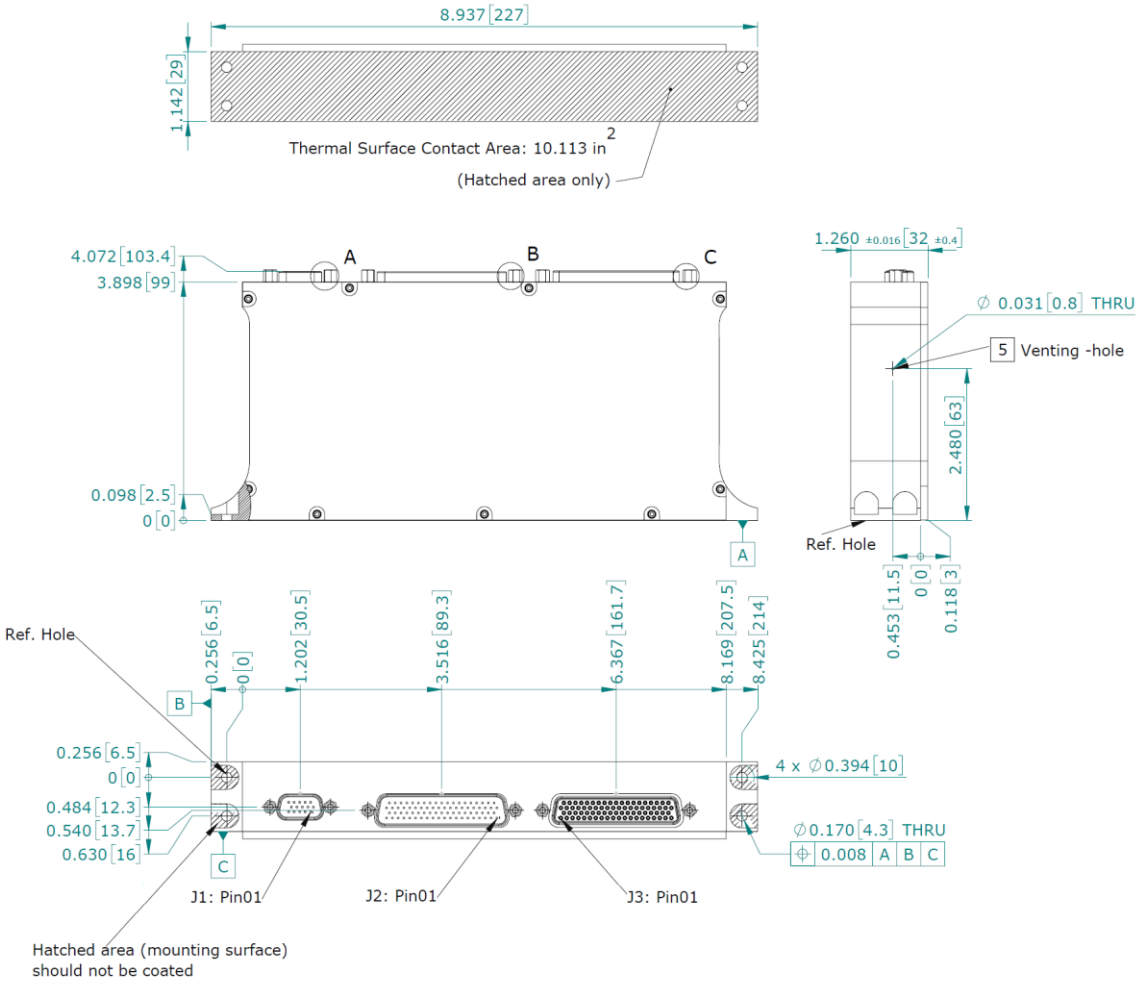
2.4 Mechanical Design

The EBS power supply is considered a platform equipment in chassis but can also be supplied as an 'open PCB board' ready for installation into the host equipment housing.

A single PCB holding all components and connectors is mounted into the chassis or host mechanics. The screws act as both mechanical fixation and thermal path. Hence, the screw positions is a result of the mechanical and thermal design.

- Input terminals: High density D-SUB15 male
- Power Output Terminals: High Density D-SUB78 female
- Power Return and Signal: High Density D-SUB78 male
- Chassis Mounting: 4 pcs 6-32 screws or equivalent
- The PCB is conformal coated with Arathane 5750 (except on mating surfaces and terminals)

Dimensions are outlined below and the Interface control drawing (ICD) with detailed terminal information and dimensions can be delivered upon request.



Input Connector	
J1 Input – D-SUB SDD15 MALE	
Pin	**Function**
1	100V
2	N/C
3	100V RETURN
4	PULSE_RETURN
5	PULSE_ON
6	100V
7	100V
8	N/C
9	100V RETURN
10	100V RETURN
11	100V
12	N/C
13	100V RETURN
14	PULSE_RETURN
15	PULSE_OFF

Input Connector	
J2 Input – D-SUB SDD78 FEMALE	
Pin	**Function**
1	OUTPUT_OVP_TLM
2	STATUS_TM
3	STATUS_TM_RTN
4	VOUT ADJUST
5-20	RETURN
21	I_SHARE
22	I_SHARE_RTN
23	TEMP_1
24	TEMP_RTN
25-39	RETURN
40	I_IN_TLM
41	V_OUT_TLM
42	ANALOG_TM_RTN
43	DROOP DISABLE
44-59	RETURN
60	OFF_EN_INPUT
61	OFF_EN_OUTPUT
62	OFF_EN_RTN
63	RETURN

Input Connector	
J2 Input – D-SUB SDD78 FEMALE	
Pin	**Function**
1-78	POWER

Figure 5. Mechanical Interface of Chassis

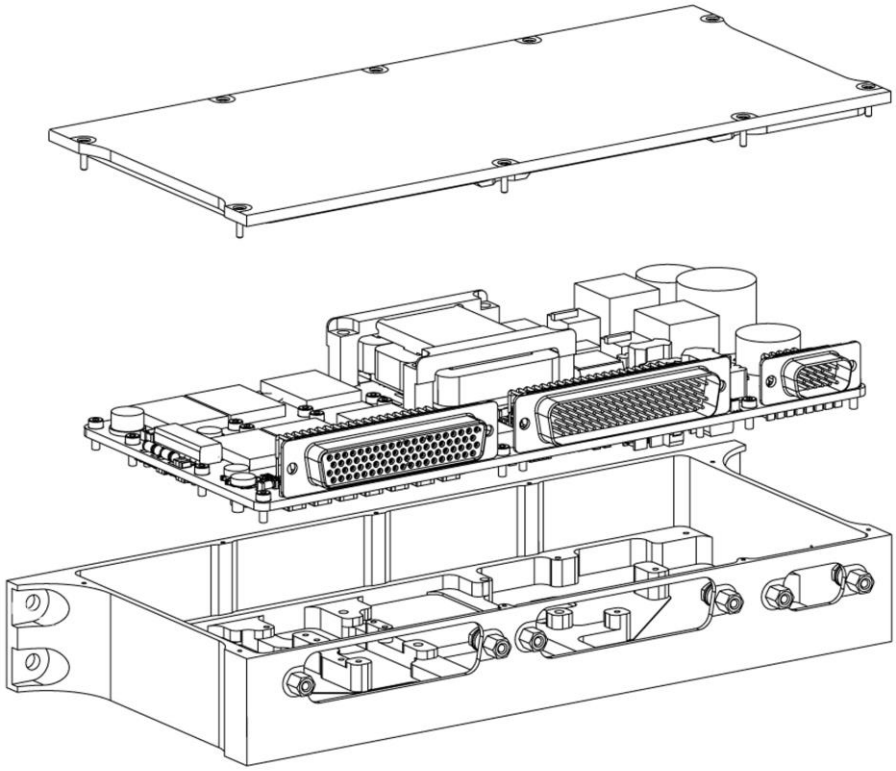


Figure 6. Exploded View of Chassis and PCB Assembly

2.4.1 Vibration and Mechanical Shock

1st resonance frequency is approximately 540Hz. Critical components are supported by staking.

The EBS is qualified to the following vibration and shock levels:

Table 14. Random Vibration		
Axis	**Frequency (Hz)**	**Level**
All	20 – 50	+6.0 dB/oct
	50 – 600	0.08 g^2/Hz
	600 - 2000	-4.5 dB/oct
Overall Level: 9.42Grms		

Table 15. Mechanical Shock (SRS, Q = 10)	
Frequency (Hz)	**Level (G) [1]**
200	140
2200	2200
4000	4200
10000	4200

Note 1. Relay might change state during exposure, but will not be damaged or degraded

3.0 Documentation

3.1 Standard Documentation

Each converter is delivered with the following documentation:

- Interface Control Drawing
- User's Manual
- End Item Data Package with CoC, applicable configuration, MIP photo and acceptance test results

3.2 Design Justification Documentation

The following documentation can be made available upon request:

- Worst Case Analysis
- Parts Stress Analysis
- Thermal Analysis
- Mechanical Analysis
- FMECA
- Reliability Assessment
- Declared Components List
- Declared Materials List
- Declared Process List

4.0 Ordering Information

This datasheet covers the specific part number 12192 which can be ordered through Micross sales team. The EBS platform is highly customizable on the input and output side and can be adapted for most satellite platforms. For adaptation request please contact Micross sales and marketing.

Table 16. Ordering Information

Part Number	Description
12192EM	Engineering Model
12192QM	Qualification Model
12192FM	Flight Model

Table 17. Model Testing

Part Number	12192EM	12192QM	12192FM
Temperature Cycling	No	Optional	Optional
Electrical Acceptance Test in Temperature, Note 1	Yes, Q-Level	Yes, Q-Level	Yes, A-Level
Thermal Vacuum	No	Optional	Optional
EMC, Note 2	Optional (CE & CS Only)	Optional	No
Vibration	No	Optional (sine, random)	Optional (random only)
Mechanical Shock	No	Optional	No

Note 1: A-Level Temperatures corresponds to Recommended Operating mounting point temperatures defined in section 0. Q-Level temperatures are 5°C higher at hot and 5°C lower at cold, compared to A-Level.

Note 2: The electrical acceptance test includes limited EMC characterization (e.g. CE for power input and power output)

Table 18. Model Build Standard	
EM: Engineering Model	The EM is foreseen to be used to confirm electrical compatibility with the host equipment and is typically delivered at an early stage of the design phase and may deviate from the final EQM and FM-configuration on several points including PCB layout. The EM meets the functional electrical requirements and is representative for normal operating conditions. Final tuning and optimization may not be completed and minor deviations from the specification shall be acceptable. The manufacturing processes used for EM are different from the processes used for EQM and FM units. The EM is a PCB that is hand soldered by the engineering group and the workmanship is checked by a certified inspector. Components are glued and staked. The PCB is conformal coated and magnetics are impregnated. Minor deviations in workmanship shall be allowed. If possible, the same type of EEE parts as intended for flight is used. However, lower quality grades and different types (incl. commercial and automotive grade) with same basic characteristics may be used. Mechanical relays are shock resistant, same type as used for flight models The EM is suitable for full environmental testing and can be used for qualification at equipment level.
QM: Qualification Models	Manufactured as a normal flight model, except that testing follows the qualification flow (e.g. extended levels for Temperature and Vibration, TVAC, Mechanical Shock, EMC and ESD).
FM: Flight Model	Flight standard for materials, processes and parts.