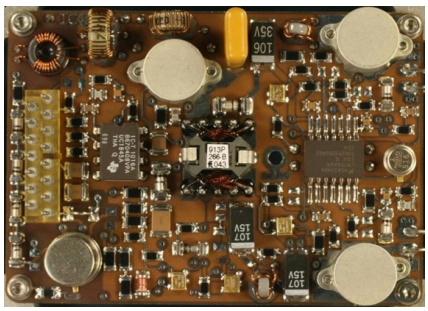
International
IOR Rectifier

PD-97806

HIGH RELIABILITY RADIATION HARDENED LOW POWER DC-DC CONVERTER

ML1000605D

100V Input, Dual Output



Description

The ML-Series of isolated DC-DC converters for space applications are low power radiation hardened high reliability devices designed for hostile radiation environments such as those encountered by geostationary earth orbit satellites, deep space probes and communication systems. Features include small size, high efficiency, low weight, and a good tolerance to total ionizing dose, single event effects, and environmental stresses such as temperature extremes, mechanical shock, and vibration. All components are fully derated to meet the requirements of EEE-INST-002 (NASA) and ECSS-Q-30-11A (ESA). Extensive documentation including worst case analysis, radiation susceptibility, thermal analysis, stress analysis, and reliability analysis are available.

The ML-Series converter has two outputs – one positive and one negative - each is independently regulated via linear post regulators. The outputs are sequenced during turn-on and turn-off such that negative output comes up first at turn-on and stays up at turn-off until the positive output has decreased. The ML-series converters incorporate a fixed frequency flyback power converter and internal EMI filter that meets the requirements for most major satellite power buses. The converter includes isolated On/Off telecommand with associated status telemetry. The converter also includes input under voltage shut-down functionality.

Due to the linear post regulation of the outputs, the ML-Series is well suited for use in RF-applications where low noise, high output voltage accuracy, and high CS attenuation is required.

Each converter is provided as a complete board assembly for installation into the host equipment chassis. The board is conformal coated (except for mating surfaces) and is mounted in the host chassis using screws. The board outline is L x W x H: 70mm x 50mm x 18mm. The weight is less than 50 grams.

Features

- Total Dose > 100 krad(Si)
- SEE > 82 MeV.cm²/mg
- Low Weight < 50 grams
- 97V to 103V DC Input Range
- O/P 1: +6.0V (up to 500mA)
- O/P 2: -5.0V (up to 100mA)
- Output Ripple: < 1mVrms (100Hz - 50MHz)
- CS Rejection Input to Outputs: > 90dB (50Hz - 1.0MHz)
- 10MΩ @ 100VDC Isolation
- Input Under-Voltage Protection
- Meets Conducted Emission Requirements of Major Power Buses:
  100Hz - 100kHz: 80dBuArms
  100kHz - 10MHz: -20dB/decade
  10MHz - 50MHz: 40dBuArms
- Short Circuit and Overload Protection
- Meets Derating Requirements of EEE-INST 002 and ECSS-Q-30-11A
- Isolated On/Off Control via High Level Pulse Command (Latching Relay)
- Status Telemetry (Relay Contact Type)
- Workmanship Per IPC-A610 Class 3
- Board is Coated with ARATHANE-5750

Applications

- Low Power RF Systems (like LNA) on-board Satellites

Non-flight versions of the ML-Series converters are available for system development purposes. Variations in electrical specifications and screening to meet custom requirements can be accommodated.

Circuit Description

The ML-Series converters utilize two-stage regulation with a flyback topology with a switching frequency of 140kHz for primary regulation and linear post regulation for each of the outputs.

The Output power is limited under any load fault condition to approximately 120% of rated output. An overload condition on the positive output causes the converter output to behave like a constant current source with the output voltage dropping below nominal. An overload condition at the negative output causes the positive output to shut-down in order to protect RF-transistors in the load. The converter will resume normal operation when the load current is reduced below the current limit point.

An under-voltage protection circuit prohibits the converter from operating when the line voltage is too low for safe operation. In case of an under voltage event the converter will not start when the input voltage returns to its nominal level before an Off-command followed by an On-command has been issued.

The isolated On/Off telecommand is made with a latching relay and is intended for use with a 26V pulse command. A status telemetry derived from a spare set of contacts in the relay is used for status telemetry.

For further information please refer to the ML-Series generic description available at www.irf.com.

Design Methodology

The ML-Series is developed using a proven conservative design methodology, which includes selecting radiation tolerant, and established reliability components and full derating to the requirements of EEE-INST-002 and ECSS-ST-11A.

Specifications

Absolute Maximum Ratings		Recommended Operating Conditions	
Input voltage range	-0.5Vdc to +120Vdc	Input voltage range (Note 9)	+97Vdc to +103Vdc
Output power	Internally limited	Output power	0 to Max. Rated
Operating mounting point temperature (Note 10)	-55°C to +100°C	Operating mounting point temperature (Note 9)	-40°C to +75°C *
Storage temperature	-55°C to +125°C	Cold start temperature	-55°C

* Meets full derating

Electrical Performance Characteristics

Parameter	Condition	Conditions -40°C ≤ Tc ≤ +75°C V_{IN} = 100V DC ± 0.5%, C_L = 0µF unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Primary Input Voltage			97	100	103	V
Output voltage (V_{OUT}) (O/P 1, O/P 2) +6.0V -5.0V	 1 1	Note 1 0% ≤ I_{OUT} ≤ 100% of rated load	 +5.970 -4.975	 +6.00 -5.00	 +6.030 -5.025	V
+6.0V -5.0V	2 2	0% ≤ I_{OUT} ≤ 100% of rated load	+5.940 -4.950		+6.060 -5.050	V
+6.0V -5.0V	3 3	0% ≤ I_{OUT} ≤ 100% of rated load	+5.880 -4.900		6.120 5.100	V
Output power (P_{OUT}) (O/P 1, O/P 2) +6.0V -5.0V	 1,2,3	 V_{IN} = 97, 100, 103V			 3.0 0.5	W
Output current (I_{OUT}) (O/P 1, O/P 2) +6.0V -5.0V	 1,2,3	 V_{IN} = 97, 100, 103V	 0 0		 500 100	mA
Line regulation (VR_{LINE}) Each output	1,2,3	V_{IN} = 97, 100, 103V I_{OUT} = 10%, 50%, 100% rated	-1.0		1.0	mV
Load regulation (VR_{LOAD}) Each output	1,2,3	I_{OUT} = 10%, 50%, 100% rated V_{IN} = 97, 100, 103V	-1.0		1.0	mV
Cross regulation (VR_{CROSS})	1,2,3	V_{IN} = 97, 100, 103V, Note 1			1.0	mV
Input current	1,2,3	I_{OUT} = 0, commanded On Commanded Off		10	15 2.0	mA
Switching frequency (F_S)	1,2,3	Notes 1, 7	126	140	154	kHz
Input under voltage Trig level	1,2,3	0% ≤ I_{OUT} ≤ 100% of rated load	85		95	V
Output Sequencing Turn-on delay O/P 2 to O/P 1 Turn-off delay O/P1 to O/P 2	1,2,3	 I_{OUT} ≥ 20% for Output 1	 2.0 1.0		 12 8.0	ms

For Notes to Specifications, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Condition	Conditions -40°C ≤ Tc ≤ +75°C V_{IN} = 100V DC ± 0.5%, C_L = 0µF unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Output ripple (V_{RIP}) Each output +6.0V -5.0V +6.0V -5.0V	 1 1,2	V_{IN} = 97, 100, 103V I_{OUT} = 100% rated load Frequency domain 100Hz – 50MHz Note 1 Time domain 100Hz – 50MHz Notes 1, 2			 1.0 1.0 30 30	 mVrms mVpp
Efficiency (E_{FF}) For combined output power of 0.70W 1.75W 3.50W	1,2,3	I_{OUT} = 20% rated load I_{OUT} = 50% rated load I_{OUT} = 100% rated load	37 52 60	38 54 62		% %
Telecommand I/F Pulse Voltage high Pulse Voltage low Pulse duration	1,2,3	Note 1	 +22 -40 10		 +30 0.5 1000	 V V ms
Telemetry Converter On Converter Off	1,2,3		 400 1.0	 422	 450	 ohm Mohm
Current Limit Point Each output +6.0V -5.0V	 1,2,3	V_{OUT} = 100mV below Nominal	 550 110		 700 150	 mA
Output response to step load changes (V_{TLD}) +6.0V -5.0V	 1,2,3	 20% to / from 100% Load, Note 3	 -70 -50		 70 50	 mV pk
Recovery time, step load changes (T_{TLD}) +6.0 -5.0	 1,2,3	 20% to / from 100% Load , Notes 3, 4			 2.5 2.5	 ms
Turn-on Response Overshoot (V_{OS}) +6.0V -5.0V Turn-on Delay	 1,2,3	 10% Load, Full Load Note 5	 2.0		 60 50 10	 mV ms
Capacitive Load (C_L) +6.0V -5.0V	 1	 I_{OUT} = 100% rated load No effect on DC performance Notes 1, 6 Each output			 100 100	 µF

For Notes to Specifications, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Condition	Conditions -40°C ≤ Tc ≤ +75°C V_{IN} = 100V DC ± 0.5%, C_L = 0µF unless otherwise specified	Limits			Unit
			Min	Nom	Max	
EMC conducted susceptibility (Line rejection)	1	I_{OUT} = 100% rated load Primary power sine wave injection of 2Vp-p, 100Hz to 1MHz, Note 1	96	110		dB
Electromagnetic Interference (EMI), conducted emission (CE)	1	I_{OUT} = 100% rated load, Notes 1, 7	Limits per Figures 4 and 5			
Isolation	1	Input to Output, any potential to telecommand input and any potential to telemetry output, test @ 100VDC	10			MΩ
Device Weight					50	g
Failure Rate		MIL-HDBK-217F2, SF, 35°C, Note 8			60	FITs

Notes: Specification and Electrical Performance Characteristics Tables

1. Parameter is tested as part of design characterization or after design changes. Thereafter, parameter shall be guaranteed to the limits specified.
2. Guaranteed for a D.C. to 50MHz bandwidth. Tested using a 10.7MHz bandwidth.
3. Load current step transition time ≥ 10 µs.
4. Recovery time is measured from the initiation of the transient to where V_{OUT} has returned to within ±1% of its steady state value.
5. Turn-on delay time from application of telecommand pulse to the point where Output 2 = 98% of nominal output voltage.
6. Capacitive load may be any value from 0 to the maximum limit without compromising the output sequencing performance. A capacitive load in excess of the maximum limit may influence the output sequencing performance and start-up time, converter operation and dc performance will remain intact.
7. The switching frequency and 1st and 2nd harmonic of the input ripple is tested on every unit.
8. MIL-HDBK-217F2 stress-dependent method is used with 2 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. 1 FIT is 1 failure in 10^9 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 product such capacitors is rated for 50V minimum.
10. Although operation temperatures between -55°C to +100°C and -40°C to+75°C is guaranteed, no parameter limits are specified.

Electrical Performance Characteristics - Definition of Conditions

Condition	Definition	Comment
1	BOL @ +25°C interface temperature	Initial setting
2	BOL @ -40°C to +75°C interface temperature	Initial setting and worst case temperature variation
3	EOL @ -40°C to +75°C interface temperature	Worst case performance including initial setting, temperature variation, aging and radiation degradation

Model Definition and Test Plans

Model Definition

Model	Description	Build Standard
EBB	The EBB is an electrical representative model. The EBB is intended to be used by customers in their proto type at equipment level. EBB models are built at IR's Danish Design Center.	The PCB will be hand soldered by the engineering group. No staking and conformal coating is foreseen Preferably same type of EEE parts as intended for flight, but lower grade will be used for convenience. For resistors and capacitors different types with same basic characteristics may be used
EQM	The EQM is an electrical and mechanical representative model. The EQM is intended to be used by customer in their EQM at equipment level.	Flight standard for processes. Same type of EEE parts as intended for flight, but lower grade may be used for convenience.
FM	Flight standard models.	Full flight standard

Test Plan - A

The EBB must pass the following tests:			
Test No.	**Type of Test**	**Location***	**Remarks**
1	Electrical performance test, room temperature incl. Limited EMC test (CE 50kHz-1MHz)	IRD	Acceptance Test Procedure
2	Electrical performance test in temperature (Q-level)	IRD	Acceptance Test Procedure
3	Electrical performance test, room temperature incl. Limited EMC test (CE 50kHz-1MHz)	IRD	Acceptance Test Procedure
4	Final Inspection	IRD	General inspection Procedure

Test Plan - B

The EQM must pass the following tests:			
Test No.	**Type of Test**	**Location***	**Remarks**
1	Electrical performance test, room temperature incl. Limited EMC test (CE 50kHz-1MHz)	IRSJ	Acceptance Test Procedure
2	Thermal cycling with electrical monitoring of input and outputs (Q-level)	IRSJ	Acceptance Test Procedure 10 cycles
3	Electrical performance test in temperature (Q-level)	IRSJ	Acceptance Test Procedure
4	Random Vibration test in (Q-level)	External test house	Vibration Test Procedure
5	Electrical performance test, room temperature incl. Limited EMC test (CE 50kHz-1MHz)	IRSJ	Acceptance Test Procedure
6	Mechanical Measurements	IRSJ	Acceptance Test Procedure
7	Final Inspection	IRSJ	General inspection Procedure

Test Plan - C

The FM must pass the following tests:			
Test No.	**Type of Test**	**Location***	**Remarks**
1	Electrical performance test, room temperature incl. Limited EMC test (CE 50kHz-1MHz)	IRSJ	Acceptance test procedure
2	Electrical performance test in temperature (A-levels)	IRSJ	Acceptance test procedure
3	Electrical performance test, room temperature incl. Limited EMC test (CE 50kHz-1MHz)	IRSJ	Acceptance test procedure
4	Electrical performance test, room temperature	IRSJ	Acceptance Test Procedure
5	Mechanical Measurements	IRSJ	Acceptance test procedure
6	Final Inspection	IRSJ	General inspection procedure

Note:
Location* - IRD: IR's Danish Design Center, Skovlunde, Denmark
- IRSJ: IR's Site in San Jose, California, USA

Radiation Performance

TID

The TID radiation performance is guaranteed by worst case analysis with radiation degradation data for each radiation sensitive component used in the DC-DC converter. For TID radiation verification testing (RVT) for each wafer lot for all sensitive components is part of the EEE parts requirements per table below.

TID RVT Plan Table

Component Type	RVT Plan (applicable to all flight lots)
JANS2N2222A	LDRS 0.01 to 0.1 rad up to 200 krad per IR RVT plan
JANS2N2907A	LDRS 0.01 to 0.1 rad up to 200 krad per IR RVT plan
JANSR2N7492T2	RVT by Manufacturer (HDR)
IRHF57214SESCS	RVT by Manufacturer (HDR)
IRHLUB770Z4SCS	RVT by Manufacturer (HDR)
IRHLUB7970Z4SCS	RVT by Manufacturer (HDR)
LM124AWR	RVT by Manufacturer (ELDRS)
IS2-1009RH	RVT by Manufacturer (HDR) LDRS 0.01 to 0.1 rad up to 100 krad per IR RVT plan
UC1845A	LDRS 0.01 to 0.1 rad/s up to 100kRad per IR RVT plan

SEE

The SEE radiation performance is guaranteed by a combination of derating and mitigation at circuit level. For mitigation at circuit level both theoretical analysis and testing with imposed SEE effects are performed. The applicable SEE and mitigation concept is presented in table below.

The maximum output perturbation is 5% of the nominal output voltage during any SEE.

Applicable SEE and Mitigation Methods Table

Component Type	Applicable SEE	Mitigation Concept
RH MOSFET	SEGR	Vds derating in combination with SEE SOA curves from manufacturer data sheet
Op-Amp	SET, 15us perturbation to rail	Mitigation at circuit level (filtering)
Voltage reference	SET, 10us perturbation to rail	Mitigation at circuit level (filtering)
PWM	SET, 15us perturbation to rail	Mitigation at circuit level (filtering)
	Double Pulses	Mitigation at circuit level (filtering, no saturation of magnetic parts)
	Missing Pulses	Mitigation at circuit level (filtering, no saturation of magnetic parts)

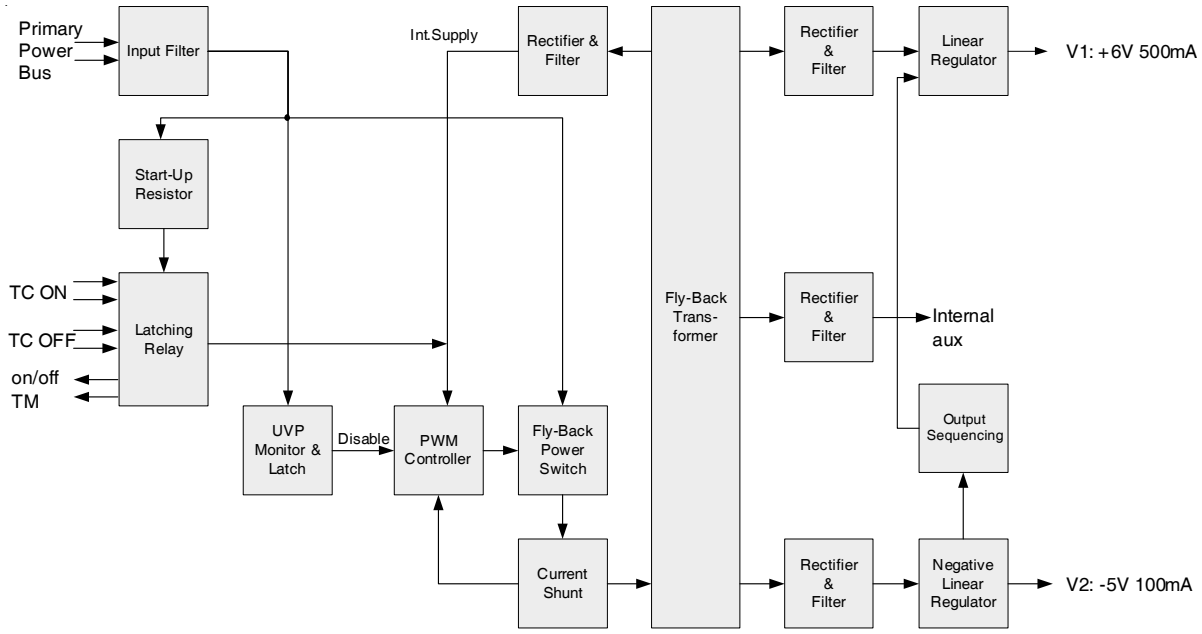
EEE Parts Technical Standard

For component screening and DPA rules, refer to the generic ML-Series data sheet at www.irf.com.

Random Vibration

Axis	Frequency Range (Hz)	Level	PSD Level (g_{rms})	Duration (S)
X, Y, Z	20-100	+6 dB/oct	29.9	180
	100-1600	0.5 SQR(g)/Hz		
	1600-2000	-12 dB/oct		

Fig 1- Block Diagram

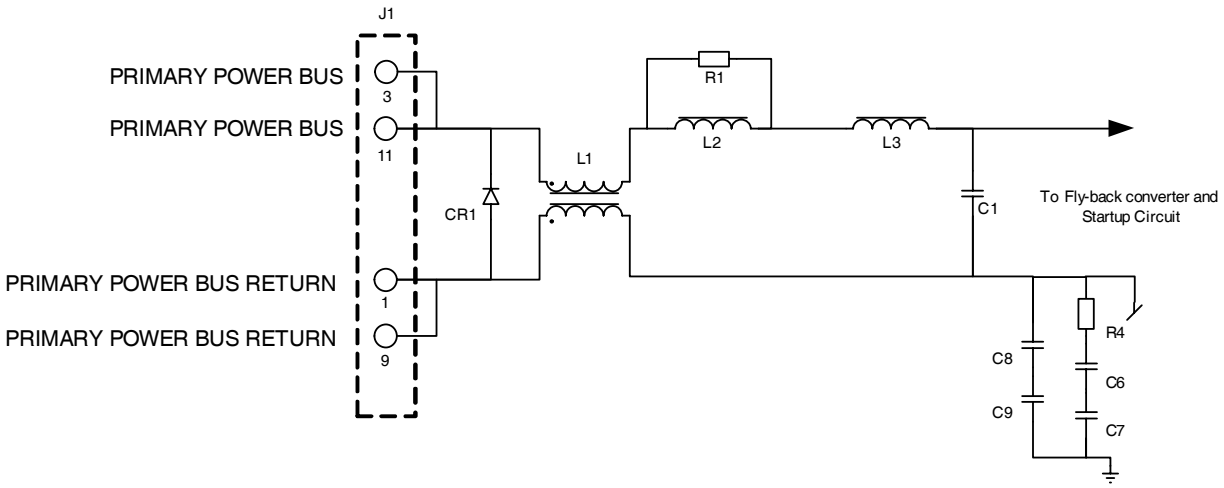


Grounding and Isolation Scheme

Parameter	Grounding & Isolation Performance
Isolation: Primary to Secondary: Telecommand: Status TM:	 > 10 MOhm // < 50nF Floating Floating
Grounding:	Secondary return bound to chassis via multiple screw connections

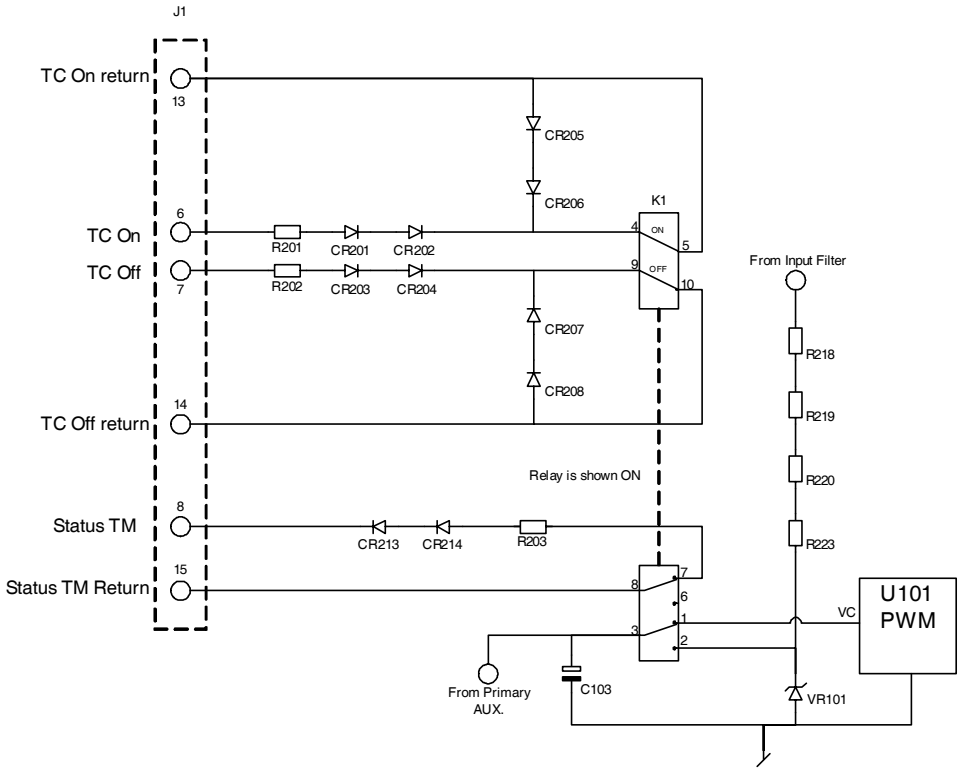
Interface Schematics

Fig 2 - Power Input:



Component	Component Type	Package	Value	Voltage (V)
C1	BR40 II	RADIAL	0.56µF	200
C6	CDR33BX	SMD 1210	27nF	100
C7	CDR33BX	SMD 1210	27nF	100
C8	CDR33BX	SMD 1210	27nF	100
C9	CDR33BX	SMD 1210	27nF	100
CR1	1N5806US	A- MFLF	2.5A	150
L1	R6.3	TOROID	2 X109.8µH	
L2	HIGH FLUX	TOROID	90µH	
L3	HIGH FLUX	TOROID	30µH	
R1	RWR81S	RWR	9.09ohms	500
R4	RM1206B	SMD 1206	21.5ohms	100

Fig 3 - TM / TC Interface:



Component	Component Type	Package	Value	Voltage (V)
CR201	1N6640US	D-5D	0.3A	75
CR202	1N6640US	D-5D	0.3A	75
CR203	1N6640US	D-5D	0.3A	75
CR204	1N6640US	D-5D	0.3A	75
CR205	1N6640US	D-5D	0.3A	75
CR206	1N6640US	D-5D	0.3A	75
CR207	1N6640US	D-5D	0.3A	75
CR208	1N6640US	D-5D	0.3A	75
CR213	1N6640US	D-5D	0.3A	75
CR204	1N6640US	D-5D	0.3A	75
C103	CWR29	SMD H	33μF	25
K201	J422-26M SHOC	TO-5		26.5
R118	RM1206B	SMD 1206	21.5kohms	100
R119	RM1206B	SMD 1206	21.5kohms	100
R120	RM1206B	SMD 1206	21.5kohms	100
R123	RM1206B	SMD 1206	21.5kohms	100
R201	RM1206B	SMD 1206	215ohms	100
R202	RM1206B	SMD 1206	215ohms	100
VR101	1N4109UR-1	DO-213AA		15

EMI Performance

Fig 4 - Typical Conducted Emission Performance at Power Input:

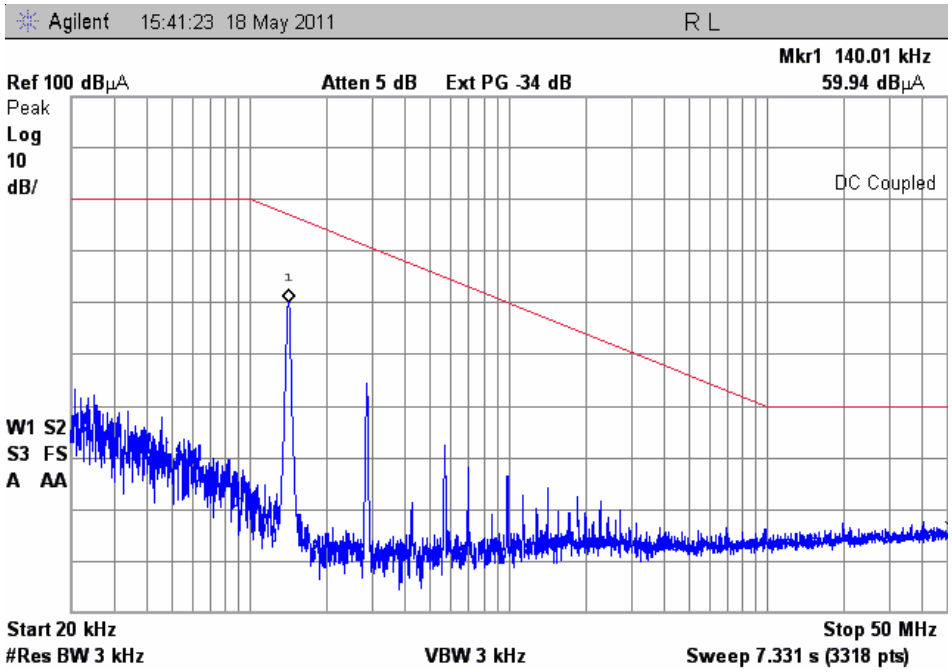
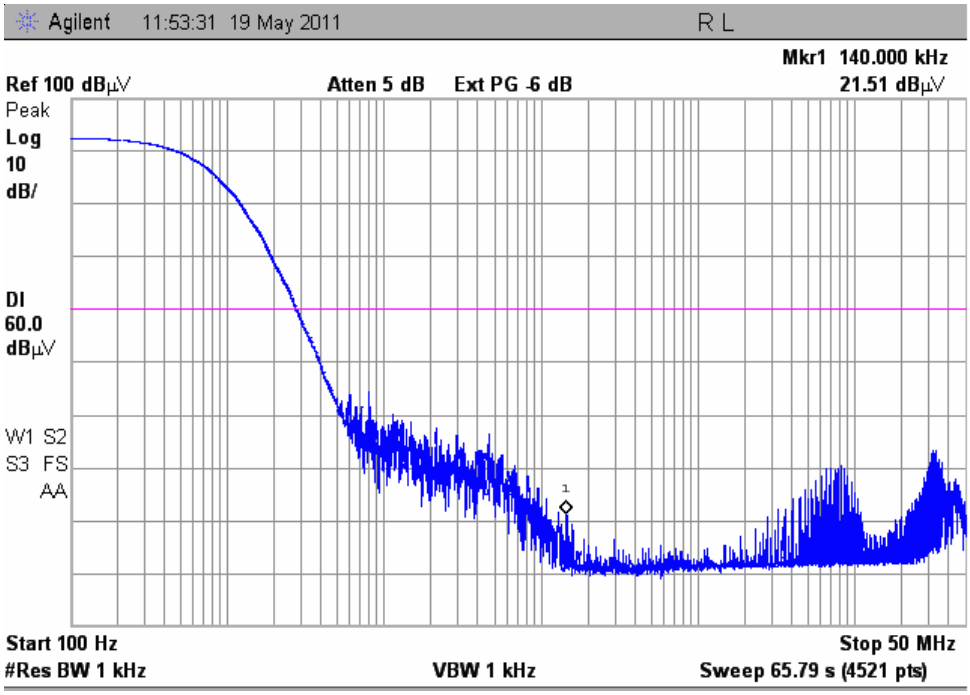
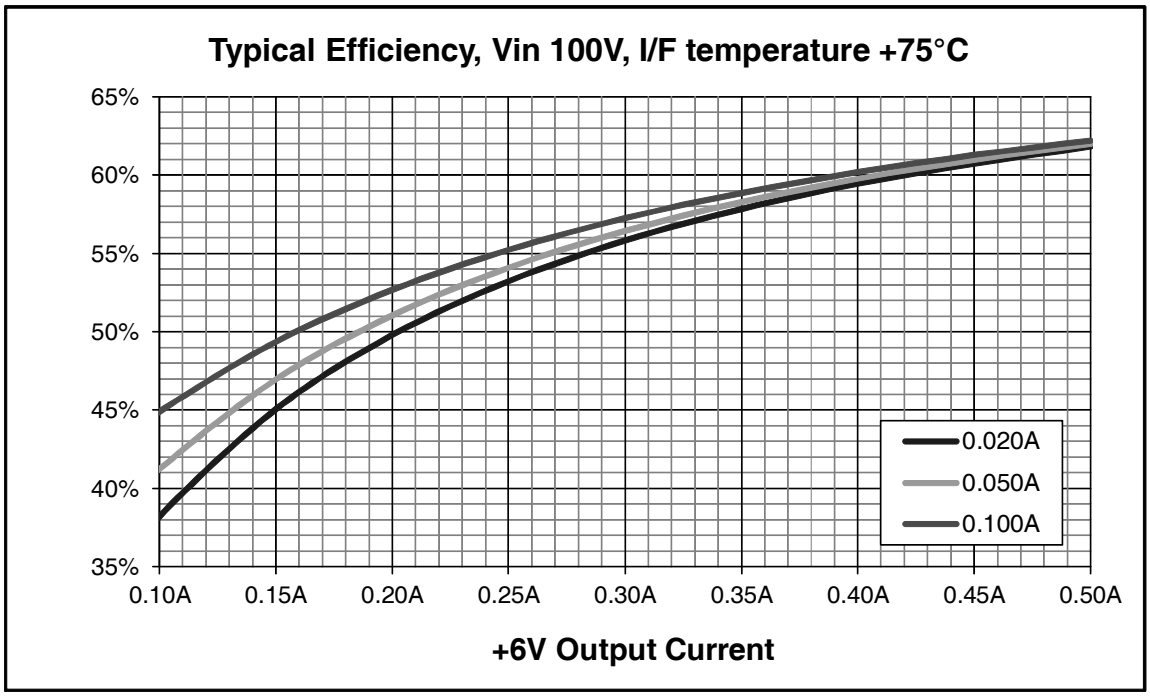


Fig 5 - Typical Conducted Emission Performance at Output 1:



Power Conversion Efficiency

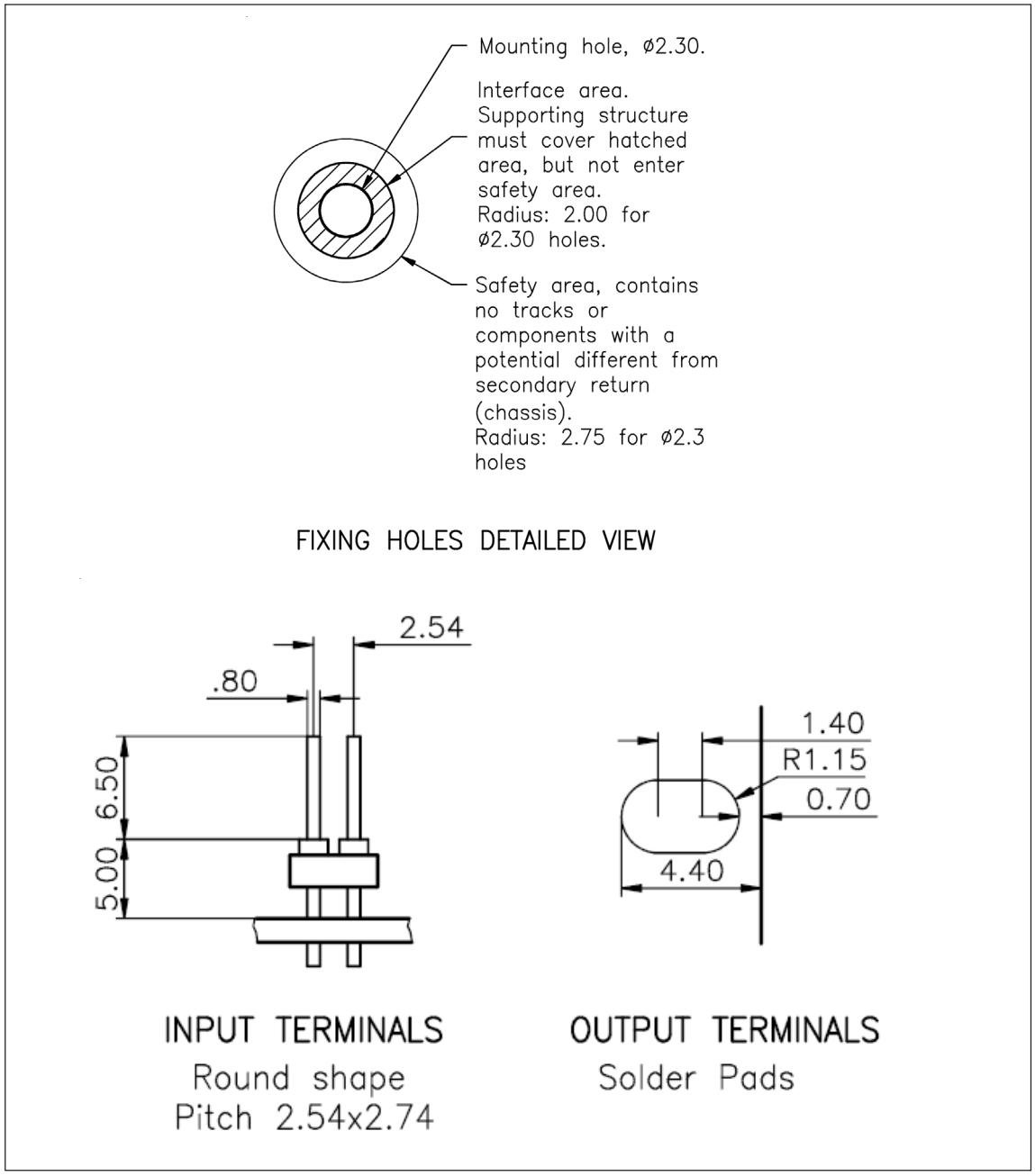
Fig 6 - Typical Power Conversion Efficiency Vs +6V Output Current Parametric with -5V Output Current



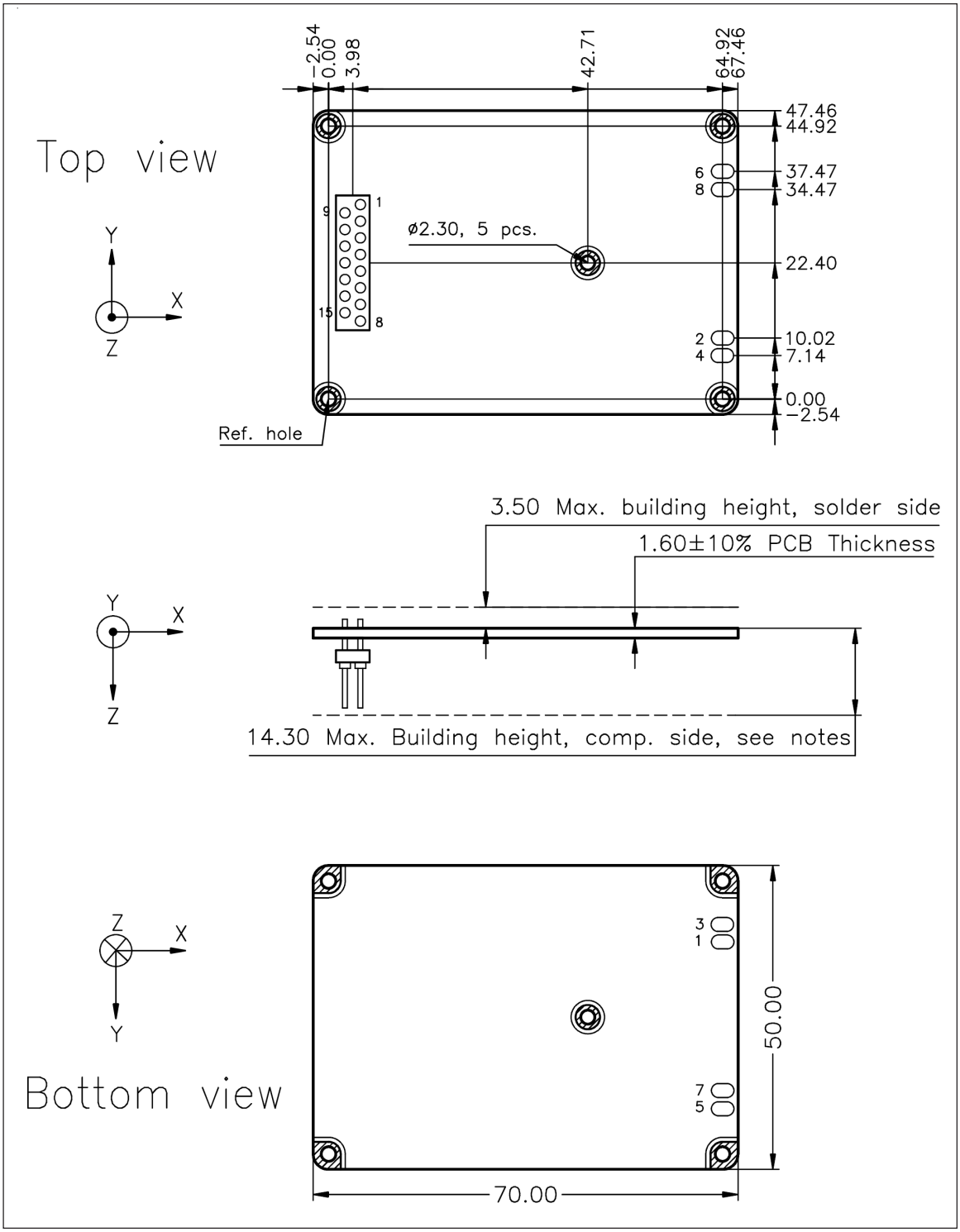
Recommended Mounting Stud Design

It is foreseen with a mounting stud design with circular mounting studs made out of aluminum with a diameter of 4.0mm and a treaded hole support mounting with M2 screws.

5pcs M2 screws are used for mounting the board. Mounting torque shall be 30Ncm ± 5.0Ncm.



Mechanical Interface



Pin Designation Tables

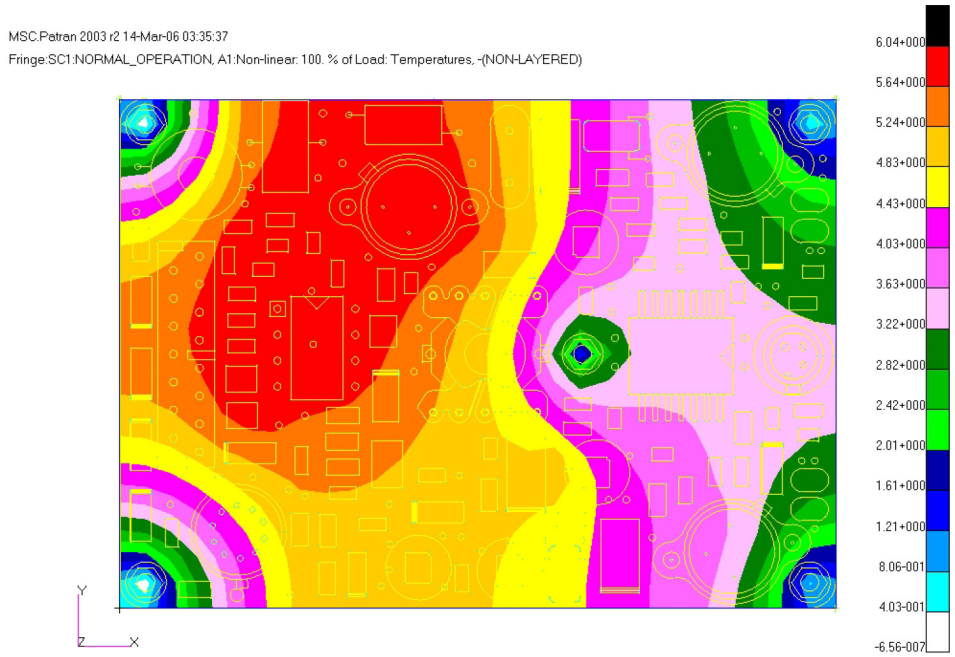
Input Terminals Assignment List		
Indent.: Input Terminals (Solder, Pins, Straight)		
Pin #	**Pin #**	**Function**
	1	Input Power Return
9		Input Power Return
	2	Rerserved
10		Rerserved
	3	Input Power
11		Input Power
	4	Chasis (Ground)
12		Voltage TM
	5	Chasis (Ground)
13		TC On Return
	6	TC On
14		TC Off Return
	7	TC Off
15		TM Status Return
	8	TM Status

Output Terminals Assignment List		
Indent.: Output Terminals (Solder Pads)		
Pin #	**Pin #**	**Function**
1	2	V1 (Positive Output)
3	4	Chasis (Ground)
5	6	Chasis (Ground)
7	8	V2 (Negative Output)

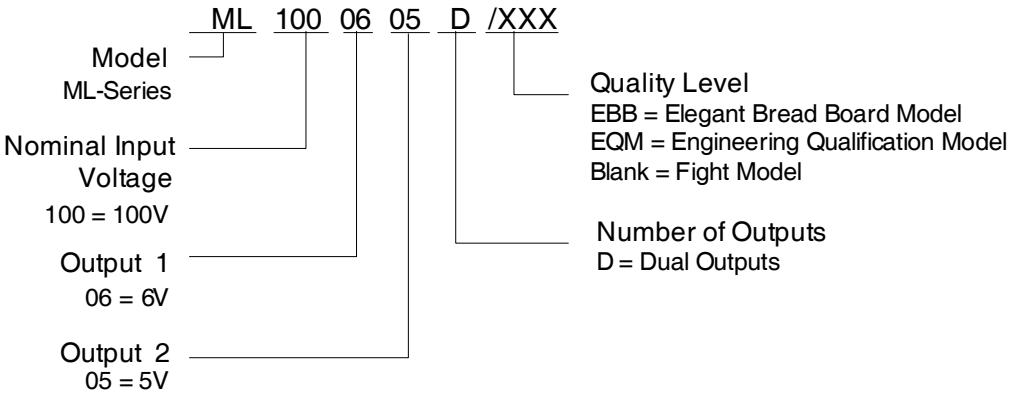
Thermal Design Information

The thermal design for the ML-Series is solely based on heat conduction through the mounting interfaces/mounting screws into the host equipment chassis.

The maximum power loss during normal operation is 2.0W. The temperature profile for the board based on all screw mounting points kept at isothermal level is given below.



Part Numbering



Application Information

Standard Documentation

- Interface Control Drawing
- User's Manual
- End Item Data Package with CoC, Applicable Configuration, MIP Photo and Test Results

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

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