# XMM Optical Monitor

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## MSSL XMM OM TMPSU Requirements~~TMPSU Requirements~~

DOCUMENT: XMM-OM/MSSL/SP/0121.05~~XMM-OM/MSSL/SP/0121.04~~

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| | | | |
|---|---|---|---|
| Author: | N R Bray | Date: | 4 Dec 96 |
| OM Project Office | | Date: | |
| Distributed: | | Date: | |

| Issue | Date | Changes |
|---|---|---|
| 1 | 9-Sep-96 | |
| 2 | 16 Oct 96 | 1. Section 4.2 should read J02<br>2. Section 5.3 should read 1.2A<br>3. Section 5.7 shared with DEM, so resistances 1MOhm -> 2MOhm (twice) and capacitance 20nF -> 10nF.<br>4. Section 11.1.1 Figure changed to Fig. 5.9.4.1.1-1 in EID-A.<br>5. pos5.3 and neg5.3 regulation is ±1%<br>6. Section 7.2 regulation range in table applies over ±20% of nominal output current else ±2% regulation applies to all except pos25.<br>7. Section 11 (was 10.1) current measurement accuracy 5% |
| 3 | | 1) Section 4.1.1 37 way male D-type to ESA/SCC specification approved by ESA to be compatible with Framatone type 3401 002 01 BDCMA 37S NMB FO<br>2) Section 4.1.1 50 way female D-type to ESA/SCC specification approved by ESA to be compatible with Framatone type 3401 002 01 BDDMA 50P NMB FO<br>3) Section 5.3 …less 3.2A.<br>4) Section 5.5 …set between 5V and 25V. This level shall be stable within 2V over all load and environmental conditions.<br>5) Section 5.7 Isolation main power to structure 1M, 20n applies to the two combined flight units. Main power to secondary 1M.<br>6) Section 7.1 and 7.2 Regulation ±1% for pos5.3 and neg 5.3, pos25 ±5% outside regulation range.<br>7) Section 12.2.1 30Hz to 50MHz<br>8) Section 12.2.2 E=28V |
| 4 | | 1. Section 5.7 removed "* Only applicable to 1 unit" |
| 5 | 16 Jun 97 | Updated sections 7.1, 7.4, and 7.5 in line with ± 15V requirements |

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|---|---|
| Machine File-System Directory: | \\mssli7\data\projects\XMM-OM/MSSL/SP/0121.05~~XMM-OM/MSSL/SP/0121.04~~ |
| Document File Name: | TMPSU Requirements.doc~~TMPSU Requirements.doc~~ |
| Application: | MS Word 7 |
| Included files: | |
| Print Date (this): | 14-Apr-98 @ 15:34~~17-Jun-97 @ 10:46~~~~13-Dec-96 @ 13:23~~ |
| Printer: | Postscript |

## 1. Scope

This document contains a definition of the requirements of the EM/QM/FM TMPSU for Optical Monitor aboard the XMM spacecraft.

The TMPSU is a multiple output power converter with a digital control interface and switched outputs for driving heaters and motors.

## 2. Applicable Documents

[1~~11~~] XMM Experiment Interface Document Part A, ESA, RS-PX-0016, Issue 6, 29-Feb-96
[2~~22~~] Product Assurance Requirements for XMM Experiments, ESA, PX-RS-0017, Issue 2
[3~~33~~] Mechanical Interface Drawing for XMM-OM TMPSU, MSSL, A2/SK/1142, Issue 2
[4~~44~~] Modular Attitude Control System Handbook, Matra/ESA, Issue 2
[5~~55~~] MSSL XMM-OM Electrical Interfaces Specification, XMM-OM/MSSL/SP/0007, Issue 7, 31-May-96

## 3. Design and Construction Requirements

### 3.1.1 Measurement Standards

Drawings, specifications and engineering data shall use the International System (SI) metric standard. Dimensions shall be in millimetres and angles in degrees.

## 3.2 Design Requirements

All designs shall comply with space industry standards and practices, and shall comply with the design specifications and standards as defined in [222]~~[22]~~[22] and its applicable documents.

A full set of design documentation shall be provided for each model. Any differences in documentation or manufacture between the EM, QM and FM models shall be subject to formal change control and approval from MSSL.

## 3.3 Product Assurance Requirements

EM units shall follow specifications and standards as defined in [222]~~[22]~~[22] and its applicable documents in so far as is necessary to meet the functional and EMC requirements.

QM units shall follow specifications and standards as defined in [222]~~[22]~~[22] and its applicable documents in so far as is necessary to meet the functional, EMC, mechanical, thermal, and cleanliness requirements.

FM and FS units shall fully comply with the specifications and standards as defined in [222]~~[22]~~[22] and its applicable documents.

## 3.4 Materials

They shall have low outgassing (≤0.1% total material loss and ≤0.01% collected vaporised condensable material).

All materials used in the devices shall be capable of being identified and traced to their source documentation.

## 3.5 Electronic Components

Parts used in EM units shall meet the TMPSU requirements in so far as is necessary to meet the functional and EMC requirements.

Parts used in QM units shall meet the TMPSU requirements in so far as is necessary to meet the functional, EMC, mechanical, thermal, and cleanliness requirements.

Parts used in FM and FS units shall fully comply with TMPSU requirements.

## 3.6 Reliability requirements

### 3.6.1 Interface Failure

The equipment shall be designed in such a way that any single failure cannot be propagated towards other equipment, through the electrical harness or by thermal or mechanical effects.

### 3.6.2 Internal Failure

The equipment shall be designed in such a way that any single failure cannot be propagated inside the unit.

## 3.7 Radiation tolerance

The unit shall remain inside specification for a radiation dose of 50krad spread over 10 years. This figure takes into account shielding due to other instrument and spacecraft parts. The supplier shall demonstrate a compliance with this requirement for every component.

# 4. Interfaces and Resources

## 4.1 Connectors and Pin-Out

The interface requirements for the signal lines defined below are given in the subsequent sections.

### 4.1.1 Main power (MNPWR-1/2)

Connector J01 shall be a 37 way male D-type to ESA/SCC specification approved by ESA to be compatible with Framatone type 3401 002 01 BDCMA 37S NMB FO.

| Pin | Line Name | Wire Type |
|---|---|---|
| | TMPSU-J01 | |
| 1 | MNPWR_PWR_goA | SPL21-20 twist 2 |
| 2 | MNPWR_PWR_retA | twist 1 |
| 3 | SCN_PWRA | around 1, 2 |
| 4 | MNPWR_PWR_goB | SPL21-20 twist 5 |
| 5 | MNPWR_PWR_retB | twist 4 |
| 6 | SCN_PWRB | around 4, 5 |
| 7 | MNPWR_SYNC_pos | SPL21-28 twist 8 |
| 8 | MNPWR_SYNC_neg | twist 7 |
| 9 | SCN_SYNC | around 7, 8 |
| 11 | ICB_Clock_true | SPL21-28 twist 12 |
| 12 | ICB_Clock_inv | twist 11 |
| 13 | SCN_ICB_Clock | around 11, 12 |
| 14 | ICB_Data_true | SPL21-28 twist 15 |
| 15 | ICB_Data_inv | twist 14 |
| 16 | SCN_ICB_Data | around 14, 15 |
| 18 | 0V_1 | SPL10-26 |
| 19 | 0V_2 | SPL10-26 |
| 21 | HTR1_go | SPL21-24 twist 22 |
| 22 | HTR1_ret | twist 21 |
| 23 | HTR2_ go | SPL21-24 twist 24 |
| 24 | HTR2_ret | twist 23 |
| 25 | HTR3_ go | SPL21-24 twist 26 |
| 26 | HTR3_ret | twist 25 |
| 27 | HTR4_ go | SPL21-24 twist 28 |
| 28 | HTR4_ret | twist 27 |
| 29 | HTR5_ go | SPL21-24 twist 30 |
| 30 | HTR5_ret | twist 29 |
| 37 | SCN_Overall | |

SCN_PWRA/B, SCN_SYNC, SCN_ICB_Clock, SCN_ICB_Data, and SCN_Overall shall be internally connected to the box structure.
The OV_1/2 signals shall be connected to the PWR_pos5.3_ret signal.

## 4.2 Conditioned Power Filters and Heaters for BL1 and BL2

Connector J02 shall be a 50 way female D-type to ESA/SCC specification approved by ESA to be compatible with Framatone type 3401 002 01 BDDMA 50P NMB FO.

| Pin Number | TMPSU1-BL1 | |
|---|---|---|
| | Line Name | Wire Type |
| 1 | PWR_pos25-go | SPL21-24 twist 2 |
| 2 | PWR_pos25_ret | twist 1 |
| 3 | PWR_pos15_go | SPL21-28 twist 4 |
| 4 | PWR_pos15_ret | twist 3 |
| 5 | PWR_pos11_go | SPL21-28 twist 6 |
| 6 | PWR_pos11_ret | twist 5 |
| 7 | PWR_pos5.3-go | SPL20-22 twist 8 |
| 8 | PWR_pos5.3_ret | twist 7 |
| 9 | PWR_neg5.3-go | SPL20-22 twist 10 |
| 10 | PWR_neg5.3_ret | twist 9 |
| 11 | PWR_neg15-go | SPL21-28 twist 12 |
| 12 | PWR_neg15_ret | twist 11 |
| 13 | CONPWR_SCN | |
| 15 | FWMTR_ph1 | SPL21-28 twist 16 |
| 16 | FWMTR_ph3 | twist 15 |
| 17 | FWMTR_13ret | around 15, 16 |
| 18 | FWMTR_ph2 | SPL21-28 twist 19 |
| 19 | FWMTR_ph4 | twist 18 |
| 20 | FWMTR_24ret | around 18, 19 |
| 21 | FWPK_tx | SPL21-28 twist 22 |
| 22 | FWPK_rx | twist 21 |
| 23 | FWPk_ret | around 21, 22 |
| 24 | DMTR_ph1 | SPL21-28 twist 25 |
| 25 | DMTR_ph3 | twist 24 |
| 26 | DMTR_13ret | around 24, 25 |
| 27 | DMTR_ph2 | SPL21-28 twist 28 |
| 28 | DMTR_ph4 | twist 27 |
| 29 | DMTR_24ret | around 27, 28 |
| 50 | SCN_Overall | |

CONPWR_SCN, and SCN_Overall shall be internally connected to the box structure.

## 4.3 Temperature

Operating:
-20 to +50 °C  The TMPSU shall meet all of its requirements in this range.
Non-operating:
-35 to +55 °C  The TMPSU shall survive switch-on in this range.

## 4.4 Mass

The Mass of the TMPSU shall not exceed 2.2kg.

# 5. Main Power Input

## 5.1 Signal Definitions

The power input to the TMPSU comprises the Main Power Bus as characterised in [111]~~[11][11]~~ Section 5.8.1. Note that the Keep Alive Line is not applicable.
The Power Bus is delivered to the TMPSU on the signal lines MNPWR_PWR_goA, _goB, _retA, _retB. The _goA/B lines are line redundant as are the _retA/B lines.

## 5.2 Steady State Requirements

The converter shall operate within specification over the input voltage range 25.7 - 30V

## 5.3 Transient Requirements

Inrush current on switch-on with any load from the specified minimum to full shall be controlled to less than 3.2A. The duration of the inrush peak shall be less than 500µs, with a rate of rise of less than 1A $\mu s^{-1}$.

## 5.4 Overload Requirements

The unit shall survive a momentary input lasting for up to 1ms of +45V, repeated every 10s, without damage.

The unit shall survive an input voltage of 0 to +35V for at least 24 hours without damage and with the outputs being back in specification within 1 minute of the supply being restored to normal.

### 5.5 On/Off Threshold

There shall be a unit on/off threshold set between 5V and 25V. This level shall be stable within ±2V over all load and environmental conditions.
The on threshold shall be 2V greater than the off threshold. (2V Hysteresis)

### 5.6 Switch-On and Switch-Off Profile, Nominal and Overload

The unit shall survive an instantaneous short circuit on the input power line at any time .

### 5.7 Isolation

Main Power Input to structure, breakdown voltage: > 100V
Main Power Input to structure, resistance: > 1MΩ
Main Power Input to structure, capacitance: < 20nF
Main Power Input to secondary, resistance: > 1MΩ
Main Power Input to secondary, capacitance: < 1nF
Main Power Input to synchronisation input: as Main Power Input to structure
A static shield shall be implemented between Main Power Input and secondary windings and attached to the unit mounting frame.
Secondary is defined as any interface signal from the TMPSU that is derived from converted Main Power. For instance all heater, ICB and output signals but not the synchronisation input or heater outputs.

## 6. Synchronisation

The MNPWR_SYNC signal is derived from _pos and _neg lines on the connector.
Normal frequency of operation is 65 536Hz locked to a synchronisation signal at 131 072Hz ±0.1%. The signal is a 5V square-wave provided from a transformer - coupled source. If there is no synchronisation signal, or it is corrupted so as to be unusable, the converter shall run at 65 536Hz ±10%. The converter input impedance shall be 10kΩ ±20% in parallel with 10pF ±20%.

## 7. Voltage Outputs

### 7.1 Signal Definitions

| Signal PWR_ | Nominal Voltage /V | Regulation | Output Current /mA nominal | Output Current /mA maximum | Output Ripple /mV |
|---|---|---|---|---|---|
| pos25 | +25 | ±4% | 36 | 50 | 50 |
| pos15 | +15 | ±1% | 75~~25~~ | >83~~50~~ | 20 |
| pos11 | +11 | ±1% | 237 | 290 | 50 |
| pos5.3 | +5.3 | ±1% | 1457 | 1750 | 50 |
| neg5.3 | -5.3 | ±1% | 490 | 590 | 50 |
| neg15 | -15 | ±1% | 89~~9~~ | >98~~20~~ | 20 |

For each signal there shall be two lines _go _ret at the interface connector carrying the go and return currents.

### 7.2 Voltage Range

All the voltages shall be within the regulation range defined in the table over the range ±20% of nominal output current.
All the voltages except pos25 shall be regulated to within ±2% outside the above range between zero and maximum output current.
The pos25 shall be regulated to within ±5% outside the above range between zero and maximum output current.
This shall be measured with worst case: power input, output load, and environmental conditions.

### 7.3 Noise limits

Spikes measured across a load resistance of 1MΩ and over a bandwidth of 0 to 50MHz shall not exceed 100mV pk-pk on any output. This shall be measured with worst case: power input, output load, and environmental conditions.

Output Ripple is defined as the maximum allowable amplitude of repetitive signals in the frequency range of 100Hz to 10MHz measured in a 30Hz bandwidth. This shall be measured with worst case: power input, output load, and environmental conditions.

## 7.4 Overload

TMPSU current limiting on the +15V rail shall be set at a level above 83mA and on the -15v rail above 98mA
All outputs shall withstand a continuous overload or short circuit for at least 24 hours without damage and with the outputs being back in specification within 1 minute of loads being restored to normal. This shall be measured with worst case: power input, output load, and environmental conditions.
An excessive load on any combination of outputs shall not cause any other output to exceed its maximum allowable voltage. An excessive load is defined as one which draws greater than the maximum output current at nominal voltage.

## 7.5 Power Consumption

Nominal output power is 16~~4~~.3W. Input power shall not exceed 24.8~~2~~W when all output currents are at their nominal values, and motors and heaters are not being driven.
This is calculated on the basis of a conversion efficiency of 72% and an additional 2.1W allowed for additional circuitry.
The TMPSU shall meet its EMC and Thermal requirements with any combination of output currents giving a total output power between 14.3W and 16.3W.

## 7.6 Output Isolation

Breakdown voltage from any output signal line and structure shall be > 100V
Resistance between any output signal line and structure shall be > 10MΩ
Capacitance between any output signal line and structure shall be < 1nF

## 7.7 Grounding

The TMPSU shall meet its requirements with all of its output return lines connected together externally.

## 7.8 Off State

In the off state following switch on or an off command, all the voltage outputs shall have less than 100mV and source or sink no more that 100uA.
The outputs will be in their off-state following switch on of the Main Power as defined in section 5.5~~5.5~~5.5.

## 7.9 Controlled On-Off Characteristics

There shall be a single unique ICB send operation not shared with any other function that will control the outputs to switch on and off.

# 8. Control

## 8.1 ICB Interface

The ICB is defined in [444]~~[44]~~[44] with the following restrictions.
There shall be a single non-redundant MACS channel using the signals ICB_Clock_true/_inv, ICB_Data_true/_inv.
The TMPSU shall be implemented as a slave unit which recognises TI and RD instruction protocols and ignores the value of the source address.
The supplier may define unused pins on the J01 connector for the purpose of configuring the equipment destination address.
Such configuration shall be limited to wire connections between pairs of pins.
The TMPSU shall otherwise be manufactured with an equipment destination address of 00111.

## 8.2 Protocol Definition

An ICB send command is defined as a TI instruction word and one data word transmitted to the TMPSU. The sub-address field shall only be used to identify the function being commanded. The data field shall only be used to provide control information.
An ICB acquire command is defined as a RD instruction word to and one data word from the TMPSU. The sub-address field shall only be used to identify the function being acquired. The data field shall only be used to return TMPSU state information.

# 9. Motor Interface

The TMPSU shall provide two stepper motor drives, and one position sensor interface.

The characteristics of the motors and sensor are defined in [555][55][55].

## 9.1 Signal Definitions

Filter Wheel: FWMTR_ph1, _ph3, _13ret, _ph2, _ph4, _24ret
Position sensor: FWPK_tx, _rx, _ret
Dichroic: DMTR_ph1, _ph3, _13ret, _ph2, _ph4, _24ret

For each motor, internal to the TMPSU the _ret lines shall be connected together and to a ballast resistor that matches the DC resistance per phase of the motor.

## 9.2 Motor Drives

Each phase shall be driven with a switched secondary 28V source through the ballast resistor.
The rise-time shall not exceed 28V/ms. The drive signal shall not overshoot greater than 28V or undershoot less than -1V with the load connected.
It shall be possible to drive the filter wheel at 450 steps/sec, the dichroic at 100 steps/sec, in mode A, each energised phase being stable at 28V for at least 60% of the step period.
All phases will be in their off-state following switch on of the Main Power as defined in section 5.55.55.5.

## 9.3 Position Sensor

The FWPK_tx signal shall be driven on command by a current source that is controlled between 0 to 105mA at equally spaced 7mA steps.
The FWPK_rx signal shall be detected as true / false with the threshold set with the transmitter at 4mA and 30% reflected onto the receiver using the OM mechanical dimensions.

## 9.4 Commanding

There shall be an ICB send operation that will control the individual filter wheel motor drive phases.
There shall be an ICB send operation that will control the individual dichroic motor drive phases.
There shall be an ICB send operation that will control the FWPK_tx current.
There shall be an ICB acquire operation that will monitor the FWPK_rx state.

# 10. Heater Switching

The heater signals are defined as:

HTR1_go/_ret, HTR2_go/_ret, HTR3_go/_ret, HTR4_go/_ret, HTR5_go/_ret.

Each heater output shall be switched from the Main Power Input.
The heater characteristics are given below:

| Heater | Nominal Resistance /Ω | Minimum Resistance /Ω |
|---|---|---|
| HTR1 | 44 | 39 |
| HTR2 | 28 | 25 |
| HTR3 | 157 | 140 |
| HTR4 | 261 | 234 |

The heaters will be switched on and off once every 10 seconds. The average power dissipation of the heaters over 1 hour will not exceed 27W.
The TMPSU shall meet its EMC tests when connected to nominal heater resistance.
The TMPSU shall meet its Thermal / Vacuum tests when connected to maximum heater resistance.
There shall be a maximum voltage drop of 0.5V between that across a heater and the Main Power input.
There shall be an ICB send operation that will control the individual heater switches.

# 11. Current Monitoring

The current drawn from external loads on the voltage outputs shall be monitored by the TMPSU.
Each current monitor shall have an anti-aliasing filter with a 1 second first order time constant.
There shall be an ICB send operation that selects and initiates AtoD conversion of a specific current signal.
There shall be an ICB acquire operation that will return the measured current.
The measured current shall be monotonic and accurate to 5% of maximum.
It shall be possible to acquire all the measured currents consecutively to the defined accuracy within 2ms.

# 12. Electro-Magnetic Compatibility

All the following parameters apply to ANY combination of load or supply conditions within the nominal specification. The TMPSU noise emissions shall not be affected by the rise or fall times of the converter synchronisation signal.

## 12.1 Conducted Emissions

#### 12.1.1 Differential mode

The noise appearing on any primary power or return wire shall not exceed the limits of Fig. 5.9.4.1.1-1 from [111]~~[11]~~[11].

#### 12.1.2 Common mode

The noise appearing on the power line together with the return shall not exceed 100µA peak from 30Hz to 50MHz.

### 12.2 Conducted Susceptibility

For all continuous injected signals, the injected current shall be limited to a maximum of 1A peak.
The TMPSU shall not go outside specification when subject to any of the following conditions.

#### 12.2.1 Differential mode

Continuous sinewave sweep at 1 octave in 90s from 30Hz to 50MHz.
Signal injection: Main power. Level: 1V rms

Continuous squarewave sweep at 1 octave in 90s from 30Hz to 50MHz. Risetime <1µs for f <50kHz, <100ns for f > 50kHz, duty cycle 50%.
Signal injection: Main power. Level: 2V p-p

Voltage transient of trapezoidal shape as shown in Fig. 2, with rise time < 4µs.
At least 10 pairs of pulses, one positive and one negative, shall be applied at a rate of 5Hz, with the supplies set to the upper voltage limit (30V).
The test shall then be repeated at the lower voltage limit (25.7V).
Signal injection: Main power. Transient parameters: E = 3V t = 800µs

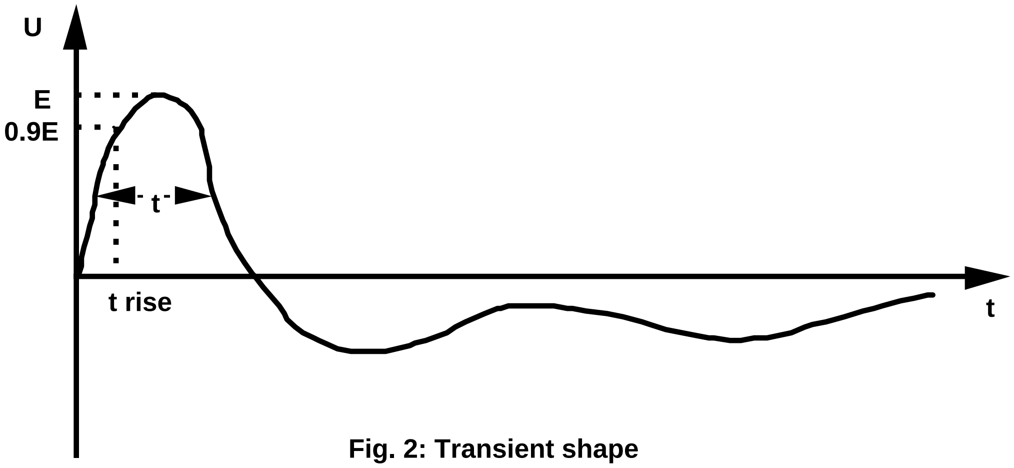



**Fig. 2: Transient shape**

#### 12.2.2 Common mode

The noise signal shall be injected between the power return wire and the unit case.

Continuous squarewave sweep at 1 octave in 90s from 30Hz to 1MHz. Risetime < 5% of the period, duty cycle 50%, amplitude 4V p-p.

Voltage transient of trapezoidal shape as shown in fig. 2, with rise time < 4µs.
At least 10 pairs of pulses, one positive and one negative, shall be applied at a 5Hz rate.
Transient parameters: E = 2 8V t <150ns t rise <10ns

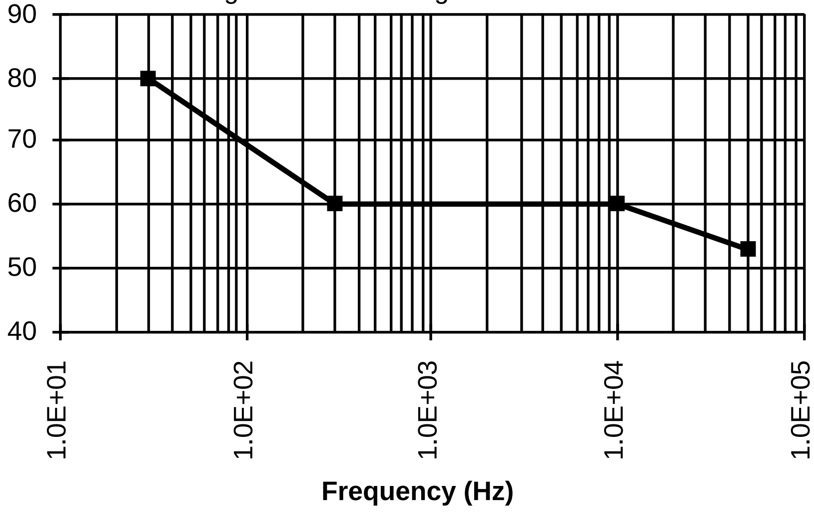
### 12.3 Radiated Emissions

#### 12.3.1 Magnetic field

The emissions shall not exceed the following:

| | |
|---|---|
| DC: | 106dBpT (200nT) at 1m distance |
| 30Hz to 50kHz: | see fig. 3 |

Fig. 3: Radiated magnetic fields




### 12.3.2 Electric field

This section is dependent on the overall enclosure and is provided for information only.
The power system emissions shall not exceed:

| | |
|---|---|
| DC: | zero |
| 14kHz to 10GHz: | see fig. 4 and 5 |

Fig.4: Radiated electric field, broadband

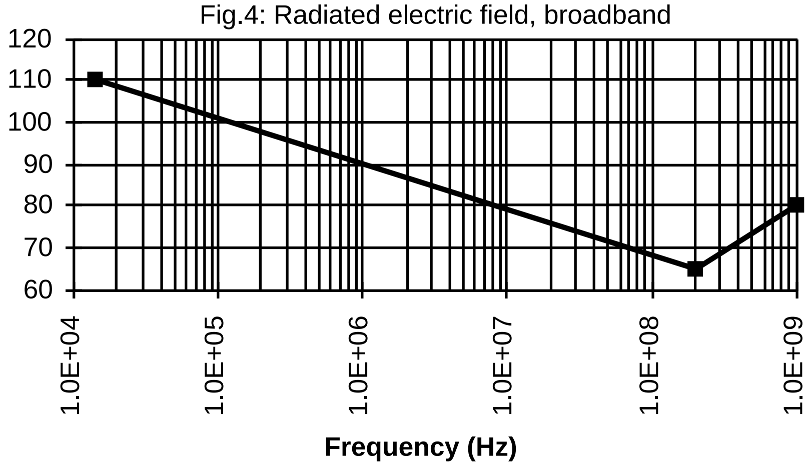
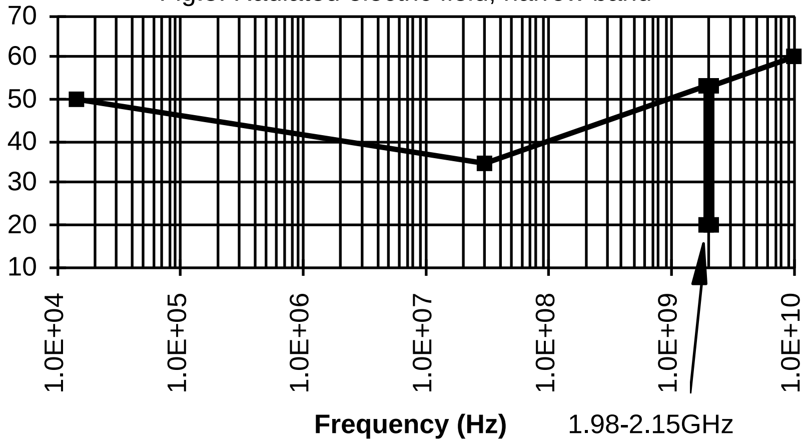



Fig.5: Radiated electric field, narrow band



## 12.4 Radiated Susceptibility

### 12.4.1 Magnetic field

The TMPSU shall be inside the specification when subject to:

| | |
|---|---|
| DC: | 170dBpT (300µT) |
| 30Hz to 50kHz: | 130dBpT rms |

The alternating magnetic field shall be swept at 1 octave in 90s along each orthogonal axis.

### 12.4.2 Electric field

The power system shall be inside the specification when subject to:

| | |
|---|---|
| 14kHz to 10GHz: | $1Vm^{-1}$ |
| 2.1 to 2.4GHz: | $5Vm^{-1}$ |

The source shall be swept at 1 octave in 90s and 30% amplitude modulated by a 1kHz squarewave.

## 12.5 Electrostatic Discharge

The TMPSU shall be inside the specification when subject to:

### 12.5.1 Conducted electrostatic discharge

Current injected into the box of the TMPSU

| | |
|---|---|
| Imax: | 25A |
| t rise: | < 5ns (10 - 90 %) |
| duration: | 30ns (between 50% points) |
| repetition rate | 0.1Hz to 10Hz |

### 12.5.2 Radiated electrostatic discharge

Spark gap discharge at a distance of 30cm from the power system

| | |
|---|---|
| energy: | 15mJ |
| voltage: | 10kV |
| repetition rate: | 0.1Hz to 10Hz |

## 12.6 Bandwidth Definitions

The following receiver bandwidths shall be used for the measurements:

| Frequency Range | NB Bandwidth | BB Bandwidth |
|---|---|---|
| 30Hz - 10kHz | 30Hz | – |
| 10kHz - 2.5MHz | 300Hz | 3kHz |
| 2.5MHz - 25MHz | 3kHz | 30kHz |
| 25MHz - 1GHz | 30kHz | 300kHz |
| 1GHz - 10GHz | 300kHz | – |

# 13. Vibration

The unit shall be in specification after the following vibration tests in all three axes:

## 13.1 Sine Vibration

Qualification levels

| Frequency (Hz) | Level | Sweep Rate |
|---|---|---|
| 5 - 22 | ±11mm | 2 octave / min |
| 22 - 100 | ±22.5g | 2 octave / min |

Acceptance levels (qualification divided by 1.5)

| Frequency (Hz) | Level | Sweep Rate |
|---|---|---|
| 5 - 22 | ±7.3mm | 4 octave / min |
| 22 - 100 | ±15g | 4 octave / min |

## 13.2 Random Vibration

Qualification levels:

| Frequency (Hz) | Level | g (rms) | Duration |
|---|---|---|---|
| 20 - 100 | +6dB / octave | 12.7 | 2 min per axis |
| 100 - 500 | $0.2g^2$ / Hz | | |
| 500 - 2000 | -6dB / octave | | |

Acceptance levels (qualification divided by 2.25):

| Frequency (Hz) | Level | g (rms) | Duration |
|---|---|---|---|
| 20 - 100 | +6dB / octave | 5.64 | 1 min per axis |
| 100 - 500 | $0.089g^2$ / Hz | | |
| 500 - 2000 | -6dB / octave | | |

# 14. Thermal / Vacuum

The unit whilst operating, fully loaded and in a vacuum shall survive 6 cycles of -35 – +65 °C at a rate of change of 0.1 -> 1°C per minute at a pressure less than 1.3 x $10^{-3}$ Pa (1.33 x $10^{-5}$ mbar), and be within specification whilst in the range -20 –> + 50 °C during the test and afterwards.

# 15. Cleanliness

Molecular contamination levels of the external surfaces of all the TMPSU shall be not greater than $1.5x10^{-8}$ g/cm$^2$.
Particular contamination levels of the external surfaces of all the TMPSU shall be not greater than 45 ppm (particulate).
Evidence to demonstrate the level of cleanliness shall be provided.

# 16. Testing Requirements

## 16.1 Verification

All units shall undergo verification tests sufficient to demonstrate full functional compliance.

## 16.2 Vibration

QM, units shall undergo testing to qualification level
FM and FS units shall undergo testing to acceptance level

## 16.3 Thermal / Vacuum

QM, units shall undergo testing to qualification level as defined in [111]~~[11]~~~~[11]~~.
FM and FS units shall undergo testing to acceptance level as defined in [111]~~[11]~~~~[11]~~.

## 16.4 EMC

All units shall undergo testing as defined in [111]~~[11]~~~~[11]~~.

## 16.5 Baseline

On delivery to MSSL all units shall undergo baseline tests sufficient to demonstrate that the major functionality is operational.
Any non-standard laboratory equipment needed for baseline tests shall be provided until the unit is successfully integrated into the OM.
Baseline tests shall be conducted separately and independently of OM units or the OM System EGSE.

# 17. Documentation

The following shall be supplied with the EM TMPSU.

- design document , containing architectural description, detailed description and full circuit diagrams
- users guide
- mechanical, electrical and thermal interface control drawings
- declared parts processes and components lists
- parts approval documents (approvals to be obtained by supplier from MSSL)
- detailed test plans: vibration, thermal/vacuum, EMC, baseline
- failure modes effects and criticality analyses
- compliance document
- test reports

Configuration control shall be applied to the above delivered documentation. Change requests shall be submitted to MSSL for review.
The following shall be supplied with each QM, FM and FS TMPSU.

- test reports
- change requests
- updated documents from approved change requests

# 18. Marking

Each unit shall be engraved with at least the manufacturer’s name, model type and a serial number.

# 19. Deliverables

- EM (1)
- QM (2)
- FM (2)
- FS (1)

# 20. Transportation

## 20.1 Containers

The supplier shall provide a container for each unit of sufficient quality to ensure transport and storage for up to 1 month without damage. These containers shall be robust and reusable. The packaging shall ensure that cleanliness is maintained.

## 20.2 Transit

The supplier shall insure that the units arrive at MSSL undamaged.