Electrical Interface Control Document (ICD) for ICU_OBM

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1 INTRODUCTION

1.1 Scope

This document defines the electrical interface requirements between the ICU and the OBM for the EarthCARE MSI instrument.

1.2 Applicable Documents

Applicable Documents identified in the following text are identified by **AD-n**, where “n” indicates the actual document, from the following list:

AD#	Title	Doc No.	Issue	Date
AD1	ICU Technical Specification	EC.RS.SSTL.MSI.00012	007	09/08/10
AD2	FEE Technical Specification	EC.RS.SSTL.MSI.00032	1	21/09/09
AD3	Electrical Interface Control Document (ICD) for FEE to Detectors	EC.ICD.SSTL.MSI.00011	1	28/08/09

The ICU supplier only needs to refer to AD1 while the FEE supplier only needs to refer to AD2

1.3 Reference Documents

Documents referenced in the following text, are identified by **RD-n**, where “n” indicates the actual document, from the following list:

RD#	Title	Doc No.	Issue	Date
RD1	Ulis datasheet	UL 03 04 1/27.08.07/UP/DVM/NTC07012-6	Rev 6	
RD2	FEE Register List	EC.LI.SSTL.MSI.00038	5	17/12/12
RD3	Slotted Optical Switch OPB870	http://www.optekinc.com/datasheets/OPB355-360TO390-820-860TO890.PDF	A.8	05/09
RD4	(VNS) External Interface Control Document	EC.ICD.TNO.MSI.00281	3.2	11/01/10

1.4 Acronyms and Abbreviations

The following abbreviations are used within this document

ADC	Analogue to Digital Converter
AN2	Analogue acquisition 0V to 5V
ANP	Analogue temperature acquisition PRT
ANY	Analogue temperature acquisition YSI-44907/44908
BB	Black Body
BOL	Beginning of Life
CBB	Calibration Black Body
CCSDS	Consultative Committee for Space Data Systems
CRC	Cyclic Redundancy Check
EOL	End of Life
FEE	Front end electronics
GDIR	General Design and Interface requirements
ICU	Instrument Control Unit
LBR	Measurement Data Interface (Low Bit Rate)
MSI	Multi Spectral Imager
NIR	Near Infrared
OB	Optical bench
OBC	On-Board Computer
OBM	Optical Bench
PRT	Platinum Resistance Thermometer
RD	Receive data Line
SBDL	Standard Balanced digital Line
SSTL	Surrey Satellite Technology Limited
SWIR	Short Wave Infrared
TBC	To Be Confirmed
TBD	To Be Defined
TD	Transmit Data Line
TEC	Thermal Electric Cooler
TIR	Thermal infrared
TIROU	Thermal infrared optical unit
UART	Universal Asynchronous Receiver Transmitter
USL	Serial UART interface
VIS	Visible
VNS	Visual Near infrared Short wave infrared
VNSOU	Visual Near infrared Short wave infrared optical unit

1.5 Definitions

1.5.1 Redundancy

ICU_OBM-SSTL-15 / Information
The ICU and the OBM are internally redundant.
The FEE is internally redundant up to the detector interface.
The thermal control and mechanism interfaces of the OBM connected via the OB are also redundant.
The detectors are not redundant and the FEE is responsible for driving the detector from either its nominal or redundant section.

1.5.2 Applicability

ICU_OBM-SSTL-203 / R
The requirements in this document shall apply both sections of the ICU (ICU-A and ICU-B) and OBM (FEE-A and FEE-B and OB-A and OB-B).

1.5.3 Interface description

ICU_OBM-SSTL-204 / R, T
The interfaces are described for one ICU to OBM interface and the interfaces shall be duplicated for the other ICU to OBM interface.

2 DESIGN RULES

ICU_OBM-SSTL-17 / R

In all cases, except when a restriction is clearly mentioned, the requirements shall be considered as "End of Life (EOL) and In Orbit" requirements. As a consequence, the subcontractor shall define "On-Ground Beginning Of Life (BOL)" success criteria compatible with the as mentioned EOL requirements.

ICU_OBM-SSTL-18 / T

The design of any signal interface shall ensure that the interface is not susceptible to the noise specified and that the noise it generates is compatible with the emissions requirement.

ICU_OBM-SSTL-19 / T

Two wire interfaces shall be used. All electrical links between the ICU and the Front end electronics and optical bench of the Optical bench module (OBM) shall be performed either differentially, or using galvanic isolated interfaces. Unless explicitly specified, the use of a common return for several links is not allowed.

ICU_OBM-SSTL-205 / T

Data truncation within the ICU shall make use of the least significant 16 bits of the 24 bits supplied by the MSI FEE.

3 INTERFACE DEFINITION, DESCRIPTION AND ARCHITECTURE

3.1 Interface Overview.

ICU_OBM-SSTL-22 / Information
The Optical Bench module (OBM) consists of the following sub assemblies: the Optical bench (OB), Thermal infrared optical unit (TIROU), Visible/Near Infrared/Short wave infrared optical unit (VNSOU) and Front end electronics (FEE).

ICU_OBM-SSTL-23 / Information
The ICU interface to the OBM will be via the OB and FEE. The OB will then distribute the interface connections to the TIROU and VNSOU for thermal and mechanism signals. The FEE will connect to the detectors in the OBM.

ICU_OBM-SSTL-24 / R
The ICU interface to the FEE and OB of the OBM shall consist of the minimum number of connectors compliant with the GDIR connector requirements listed in Chapter 5 of AD1.

ICU_OBM-SSTL-25 / Information
The electrical interface between the ICU and the OBM consists of:

For FEE
- Master clock from ICU to FEE
- Timing pulse from ICU to FEE.
- Measurement data from FEE to ICU (LBR).
- Command and monitoring bi-directional (USL).
- Secondary power from ICU to FEE.
- Temperature monitoring.
- Thermal control for TIR detector TEC
- Analogue voltage monitoring Interface (used for detector temperature monitoring)
- Survival heater

For Optical Bench
- Temperature monitoring
- Thermal control
- Survival heater

For TIROU via OB
- Temperature monitoring
- Thermal control
- Mechanisms control and drive
- Survival heater

For VNSOU via OB
- Temperature monitoring
- Thermal control
- Mechanisms control and drive
- Survival heater

3.2 Redundancy architecture

ICU_OBM-SSTL-27 / T
The ICU is operated in cold redundancy. The FEE of the OBM is operated in cold redundancy.

ICU_OBM-SSTL-28 / Information
Each of the redundant sections of the ICU interface to the corresponding redundant sections of the FEE without cross strapping.

ICU_OBM-SSTL-29 / Information
The FEE operates in cold redundancy while driving a non-redundant detector.

ICU_OBM-SSTL-30 / T
The TIR detector TEC and thermal measurement are not redundant so the ICU shall present a high impedance interface connection to these items when turned off.

ICU_OBM-SSTL-31 / T
ICU-A shall interface to FEE-A and OB-A. ICU-B shall interface to FEE-B and OB-B.

3.3 FEE States

ICU_OBM-SSTL-33 / T
The ICU shall support the FEE in all of its operational States.

ICU_OBM-SSTL-34 / Information
The FEE will support the States listed in Subsections 3.3.1, 3.3.2, 3.3.4, 3.3.6 and their associated Sub-States listed in Subsections 3.3.3 and 3.3.5.

3.3.1 Powered State

ICU_OBM-SSTL-34 / Information
The secondary power supplies are on. There is no master clock signal present. The FEE will not respond on the command and monitoring interface and no readout of the detector is possible. The detector supplies will be in safe mode (turned off) so no damage to the detectors is possible. If the FEE was operational and the master clock is lost the FEE will return to this State. This is not a normal State and is only entered on power up with no master clock present or on loss of master clock.

3.3.2 Idle State

ICU_OBM-SSTL-38 / Information
Idle State is entered if the secondary power supplies are on and the master clock signal is present. The timing signal can be in any state. The FEE will not read out the detector and the detector supplies will be in safe mode (turned off) so no damage to the detectors is possible. The command and monitoring interface will be active waiting for commands or monitoring requests. This State will be used to allow the download of the bad pixel table and ICU monitoring of the registers and memory. This State is entered on power up with the master clock present, which is preferred. If the master clock is lost then Powered State is selected.

3.3.3 Idle State with memory test

ICU_OBM-SSTL-40 / Information
This is a sub State of Idle State where the memory of the FEE is tested by the ICU. Memory problems are reported using the relevant PUS service. The format of the test and the reporting are TBD. The memory test will be disabled if not in Idle State.

3.3.4 Normal State

ICU_OBM-SSTL-43 / Information

Normal State is entered if the secondary power supplies are on, the master clock signal is present, the timing signal is active and the State has been commanded. The detector data is readout using the timing signal to start each ground line. The detector supplies will be powered up if commanded in the correct sequence (if any) and after any inrush period the latch up detection will be enabled. The detector data will be processed. The data sent to the ICU will be CCSDS packets of ground pixel data with 24bits/pixel. If enabled CCSDS packets of raw pixel data will also be sent to allow algorithm checking of a ground pixel. If the timing signal is lost then Idle State is selected. If the master clock is lost then Powered State is selected.

3.3.5 Normal State with test pattern

ICU_OBM-SSTL-45 / Information

This is a sub State of normal State where the detector pixel data from the ADC(s) is replaced with a known test pattern. This State is used to test that the algorithm is operating correctly.

3.3.6 Raw State

ICU_OBM-SSTL-47 / Information

Raw state is used for checking all the detector pixels for correct operation (bad pixel detection). The raw pixel data used for algorithm checking is collected during normal state so a direct comparison between unprocessed pixel data and a processed pixel can be made.

ICU_OBM-SSTL-48 / Information

Raw State is entered if the secondary power supplies are on, the master clock signal is present, the timing signal is active and this State has been commanded. The detector is readout continuously as for normal State. The detector supplies will be powered up if commanded in the correct sequence (if any) and after any inrush period the latch up detection will be enabled. The raw data is processed by storing the digitised pixel values from at least one complete detector readout into RAM. This is then sent to the ICU at the normal data rate in the same format as processed data but with the data identified as raw data. When the RAM is empty the next detector readout is stored and sent. If the timing signal is lost then Idle State is selected. If the master clock is lost then Powered State is selected.

3.4 Error handling - Receipt of Status Register

ICU_OBM-SSTL-50 / Information

The FEE will update the status if there is a fault in the FEE.

ICU_OBM-SSTL-51 / T

The ICU shall monitor the status register and forward the FEE status to ground if there are any errors. The ICU will decode the status bits to determine the fault and act accordingly.

ICU_OBM-SSTL-52 / Information

The latch-up status bits will remain set until cleared by writing a 1 to the active bit in the status register. This allows the status register to be re-read if required.

3.4.1 Bad command

ICU_OBM-SSTL-54 / T

The ICU shall repeat the command a number of times. A permanent fault with the FEE command system should then be reported to ground to allow change over to the redundant ICU and therefore FEE. The number of repeats should be settable from ground.

3.4.2 Detector power supply latch up

ICU_OBM-SSTL-56 / Information

The detectors are prone to latch up. If latch up is detected by the FEE then the FEE will turn off the detector by clearing the detector on bit in the State register and the status register will be updated with the latchup error.

ICU_OBM-SSTL-57 / T

The ICU shall report the latch up via the main telemetry system. The ICU shall then power up the detector by resetting the detector on bit in the State register to get the FEE back to its previous operating state. The ICU must wait a minimum of 1s before resending the commands to allow the detector to recover from latch up.

4 SURVIVAL HEATER LINES

ICU_OBM-SSTL-59 / T

The ICU shall pass the survival heater supply on to the FEE and OB of the OBM. The OB will distribute the survival heater line to the survival heaters of the TIROU and VNSOU.

ICU_OBM-SSTL-60 / R

The survival heater interface shall be dimensioned by considering:

- the mean operating voltage of 28 V at the heater input leads,
- a maximum current of 1.5 A and
- a duty cycle of 70%.

5 THERMAL CONTROL HEATERS AND TEC LINES

ICU_OBM-SSTL-62 / T
The ICU is required to drive two types of thermal control elements: Normal resistive heaters and a thermal electric cooler (TEC), which can be used to both heat and cool.

ICU_OBM-SSTL-63 / T
The thermal controller shall operate in a linear mode with proportional control (PID loop not bang/bang). If a PWM output driver is used the filtering must be such that the noise on the output is < 1% TBC of the average drive voltage or current.

ICU_OBM-SSTL-64 / T
The TEC driver shall be current controlled with the capability to set a fixed current if commanded.

ICU_OBM-SSTL-65 / T
The resistive heaters can be either voltage or current controlled. There shall be the ability to set a fixed level power level (assuming a constant resistance of the heater).

ICU_OBM-SSTL-66 / T
The thermal control module has to drive

TIROU detector TEC	1 off via the FEE
OB heater	1 off
TIROU resistive heaters	2 off via the OB
VNSOU resistive heaters	4 off via the OB
VNSOU decontamination heater	1 off via the OB

5.1 TEC controllers

5.1.1 TIROU TEC controllers

ICU_OBM-SSTL-69 / T
The ICU shall drive the TIROU TEC as indicated in the table below

	Current range		**Compliance voltage**		**Temperature**
Channel	**Min**	**Max**	**Min**	**Max**	**resolution**
A	-250 mA	250 mA	-3.5 V	3.5 V	10 mK

ICU_OBM-SSTL-70 / T
The temperature measurement is from the TIR detectors VTEMP output. The VTEMP output is only valid when the FEE is powered and the detector is operating. The temperature controller shall switch to constant current mode when VTEMP is invalid. VTEMP characteristics are provided in paragraph 7.2.

ICU_OBM-SSTL-71 / T
The controller shall also monitor a temperature sensor, which is monitoring the TEC hot side temperature. The TEC supply shall be turned off if the hot side temperature rises above a commandable threshold level.

ICU_OBM-SSTL-72 / T
The set point temperature shall be settable over the temperature range -10ºC (263 K) to 50ºC (323 K) with a resolution of 10 mK. The controller shall also be able to operate in constant current mode with a settable current with a resolution of 0.01 mA.

ICU_OBM-SSTL-73 / T
The ICU shall have high impedance outputs to the TEC when turned off as there is a direct connection via the non-redundant TEC to the redundant ICU.

5.1.2 Heaters

ICU_OBM-SSTL-75 / T

The ICU shall be able to drive the Resistive heaters as indicated in the table below.

Heater	Power range Min	Max	Temperature resolution
Optical Bench heater (spread out)	0 W	15 W	10 mK
TIROU heater 1 (Base Plate)	0 W	10 W	10 mK
TIROU heater 2 (Rear optics)	0 W	5 W	10 mK
VNSOU heater 1 (SWIR 2 Cold finger)	0 W	5 W	10 mK
VNSOU heater 2 (SWIR 2 Barrel)	0 W	5 W	10 mK
VNSOU heater 3 (Optical unit)	0 W	10 W	10 mK
VNSOU heater 4 (Calibration unit)	0 W	8 W	10 mK
VNSOU decontamination	0 W	42 W	threshold 27ºC

Note 1 – No decontamination heater is required for the TIROU as it is operating at 300 K and there is a cold trap in the vicinity of the TIROU. The temperature measurement is from a thermistor with 2.5 mK resolution.

ICU_OBM-SSTL-206 / T

The heaters' supply line shall be specified by the ICU supplier. SSTL prefers that they be powered from the primary supply. In the event that they are powered from the secondary supply, the ICU supplier shall provide the voltage range of the secondary to SSTL.

ICU_OBM-SSTL-79 / T

The temperature measurement is from a thermistor with 2.5 mK resolution. It shall be possible to use any of the local thermistors in the OBM to control the heaters (minimum of two thermistors).

ICU_OBM-SSTL-80 / T

The set point temperature shall be settable over the temperature range 220 K to 320 K with a resolution of 100 mK. The controller shall also be able to operate in constant power mode with a settable power with a resolution of 1 mW.

5.2 Operation of PID loops

ICU_OBM-SSTL-208 / R

The ICU supplier shall detail the operation of the PID loop.

ICU_OBM-SSTL-209 / Information

The main operational requirements of the PID loop are given below.

ICU_OBM-SSTL-210 / T

The PID loops shall have a mode of operation register that has a least the following modes which are settable by telemetry command.

- Off
- On PID in operation
- On Constant power

ICU_OBM-SSTL-211 / T

The three PID terms: Proportional, Integral and Differential shall be settable by telemetry command.

ICU_OBM-SSTL-212 / T

The settings shall give smooth operation in preference to fast settling speed with a response speed able to deal with the orbit changes.

ICU_OBM-SSTL-213 / T

The operation history shall be recorded and reported when requested. This is very important for the TEC PID as if the Vtemp TIR detector output fails, the PID loop will need to be operated in constant current mode and the setting level will need to be calculated from past operating current when operated in PID mode.

5.2.1 Heater PID loops

ICU_OBM-SSTL-215 / T
Each loop shall have two temperature sensors allocated from all of the possible temperature sensors.

ICU_OBM-SSTL-216 / T
The main temperature sensor shall be used as the control temperature.

ICU_OBM-SSTL-217 / T
The second temperature sensor shall be monitored only.

ICU_OBM-SSTL-218 / T
If the main temperature sensor goes open circuit or short circuit then the software shall change to using the second sensor and report the change over.

ICU_OBM-SSTL-219 / T
If the second sensor goes open circuit or short circuit then the software shall report the condition.

ICU_OBM-SSTL-220 / T
If both sensors go open circuit or short circuit then the heater shall be turned off and reported.

ICU_OBM-SSTL-221 / T
If the temperature difference between the main sensor and the second sensor is greater than a selectable limit, then the difference shall be reported. This is to allow the ground station to work out which sensor is in error by looking at the overall instrument temperatures and then to change the allocation of sensors.

ICU_OBM-SSTL-222 / T
The mode of operation shall be selectable between PID loop and constant power by command.

ICU_OBM-SSTL-223 / T
The constant power level shall be settable by telemetry command.

5.2.2 TEC PID loop

ICU_OBM-SSTL-225 / Information
This loop has only one sensor input Vtemp from the TIR detector.

ICU_OBM-SSTL-226 / T
If the main temperature sensor goes open circuit or short circuit then the software shall switch off the TEC power and report the switch off. It will then be up to the ground station to recover the instrument.

ICU_OBM-SSTL-227 / T
The mode of operation shall be selectable between PID loop and constant current by telecommand.

ICU_OBM-SSTL-228 / T
The constant current level shall be settable by telecommand.

6 TEMPERATURE MONITORING LINES

ICU_OBM-SSTL-82 / T
The ICU shall monitor (check that value is within FDIR limits) and report the temperatures as specified below in Subsections 6.1, 6.2 and 6.3.

6.1 Thermistor channels

ICU_OBM-SSTL-83 / Information
The TIROU thermistor channel temperatures are listed in the following table:

TIROU temperature 1	Detector hot side temperature sensor via FEE
TIROU temperature 2	Optical Bench / Base Plate PID sensor 1
TIROU temperature 3	Optical Bench / Base Plate PID sensor 2
TIROU temperature 4	Rear Optics PID sensor 1
TIROU temperature 5	Rear Optics PID sensor 2
TIROU temperature 6	Mask Top
TIROU temperature 7	Mask Bottom
TIROU temperature 8	Lens 2
TIROU temperature 9	Reference Blackbody (RBB)
TIROU temperature 10	Satellite monitored

ICU_OBM-SSTL-232 / Information
The VNSOU thermistor channel temperatures are listed in the following table:

VNSOU temperature 1	SWIR 2 Barrel PID sensor 1
VNSOU temperature 2	SWIR 2 Barrel PID sensor 2
VNSOU temperature 3	Optical unit PID sensor 1
VNSOU temperature 4	Optical unit PID sensor 2
VNSOU temperature 5	Satellite monitored
VNSOU temperature 6	Calibration Mechanism sensor 1
VNSOU temperature 7	Calibration Mechanism sensor 2

ICU_OBM-SSTL-233 / Information
The OB thermistor channel temperatures are listed in the following table:

OB temperature 1	Optical Bench PID sensor 1 and thermal reference
OB temperature 2	Optical Bench PID sensor 2
OB temperature 3	Satellite monitored

ICU_OBM-SSTL-234 / Information
The FEE thermistor channel temperatures are listed in the following table:

FEE temperature 1	FEE box temperature sensor

6.2 PT1000 channels

ICU_OBM-SSTL-231 / Information
The VNSOU PT1000 channel temperatures are listed in the following table:

VNSOU temperature 1	SWIR 2 Cold finger PID sensor 1
VNSOU temperature 2	SWIR 2 Cold finger PID sensor 2

ICU_OBM-SSTL-235 / Information
The VNS Radiator PT1000 channel temperatures are listed in the following table:

VNS Radiator temperature 1	Decontamination PID sensor 1

VNS Radiator temperature 1	Decontamination PID sensor 2	see Note 2

ICU_OBM-SSTL-236 / Information
NOTE 2 - We are considering changing the VNS Radiator decontamination heater to a simple on/off heater with local over temperature protection. Decontamination PID sensor 2 would then be removed. Combining the decontamination heater with the survival heater is also being considered.

ICU_OBM-SSTL-84 / T
Two spare temperature channels shall be made available at the ICU connectors.

ICU_OBM-SSTL-85 / T
For the thermistors, the interface shall be of type ANY (calibrated channels) but with increased resolution of at least 2.5 mK for the temperature range 0ºC (273 K) to 40ºC (313 K).

ICU_OBM-SSTL-86 / T
For the PT1000s the interface shall be type ANP (calibrated channels) but with increased resolution of at least 2.5 mK for the temperature range -55ºC (218 K) to -20ºC (253 K)and a minimum measurable temperature of -70ºC (203 K).

ICU_OBM-SSTL-87 / Information
The thermistors will normally be of the standard type YSI 44908.

ICU_OBM-SSTL-88 / Information
For the PID controllers where possible there are multiple local sensors allocated as the reference sensor (minimum of two as required by the GDIR, Chapter 5 of AD-1). Any of the local sensors shall be used to control the PID controller.

6.3 Calibration Black Body

ICU_OBM-SSTL-237 / Information
The calibration black body is not directly temperature controlled. It is thermally connected to the TIROU and assumes the same temperature as the TIROU with a small offset.

ICU_OBM-SSTL-90 / Information
For the calibration black body temperature sensor the interface will be of type to be defined by the Black Body supplier which and have a resolution of at least 2.5 mK for the temperature range 0ºC (273 K) to 40ºC (313 K).

ICU_OBM-SSTL-91 / T
The absolute accuracy shall be 25 mK. For absolute accuracy the ICU supplier shall assume a perfect temperature sensor.

ICU_OBM-SSTL-92 / Information
The temperature sensor type will be 4 wire 2kΩ Goodrich PT2000 PRTs for the MSI TIR-BB PFM and 4 wire 2kΩ NTH4G thermistors for the MSI TIR-BB EQM.

ICU_OBM-SSTL-93 / T
Channels required are listed below

TIR Calibration Black Body	Calibrated sensor 1 Nominal
TIR Calibration Black Body	Calibrated sensor 2 Nominal
TIR Calibration Black Body	Calibrated sensor 1 Redundant
TIR Calibration Black Body	Calibrated sensor 2 Redundant

7 VOLTAGE MONITORING LINES

ICU_OBM-SSTL-95 / T
The FEE will monitor the voltages as specified below in Sections 7.1 and 7.2. The voltage will be reported by the FEE to the ICU via the registers within the FEE. The registers will contain the 12 bit ADC reading without any calibration.

ICU_OBM-SSTL-238 / Information
NOTE – It may be possible to just report the ADC values with the conversion to volts performed on ground.

7.1 FEE internal supply monitoring

ICU_OBM-SSTL-97 / Information
For voltage monitoring the interface will be via Command and monitoring bi-directional interface (USL). The monitoring ADC will have an input range of 0 to 3.3V.

ICU_OBM-SSTL-98 / Information
The OBM FEE will condition the voltages to ensure they are within the monitoring range. The conditioning will be a simple factor of 1 or 2.

ICU_OBM-SSTL-99 / T
The ICU shall report the correct voltage taking into account the conditioning of the OBM FEE and calibration information that will be supplied. The ADC Ref inputs are from a stable Video ADC reference and are included to allow conformation of the monitoring ADC calibration as the monitoring ADC uses the supply as the ADC reference.

7.1.1 FEE VNS Section

ICU_OBM-SSTL-239 / Information
The FEE VNS section voltages are listed in the following table:

ICU_OBM-SSTL-101 / Information

Supply	Nominal Voltage	
VIS VDD	5 V	Note 1
VIS VDET/REF	3 V	
VIS Vvideo	6V	Note 1
Spare		Note 1
NIR VDDA	5 V	Note 1
NIR VDET/REF	3 V	
NIR Vvideo	6V	Note 1
ADC Ref	1.25 V	
SWIR 1 VDD	5 V	Note 1
SWIR 1 VDET/REF	3 V	
SWIR 1 Vvideo	6V	Note 1
TIR_Vvideo	1.25 V	
SWIR 2 VDDA	5 V	Note 1
SWIR 2 VDET/REF	3 V	
SWIR 2 Vvideo	6V	Note 1
ADC Ref	1.25 V	

7.1.2 FEE TIR Section

ICU_OBM-SSTL-240 / Information
The FEE TIR section voltages are listed in the following table:

ICU_OBM-SSTL-103 / Information

Supply	**Nominal Voltage**	
TIR VDDA	5 V	Note 1
TIR VDDL	3.3 V	Note 1
TIR VBUS	3.2 V	Note 1
TIR VFID	variable 0.65 V to 5 V	Note 1
TIR VSKIMMING	variable 2 V to 5.5 V	Note 1
TIR VEB	2.2 V	
TIR ADC P	6V	
ADC Ref	1.25 V	

ICU_OBM-SSTL-241 / Information
Note 1: These supplies will have a potential divider halving the nominal voltage.

7.2 Detector VTEMP

7.2.1 TIROU detector VTEMP

ICU_OBM-SSTL-105 / Information
For the TIR detector VTEMP the interface will be AN2 type with a modified input range of 1.5 V to 2 V with a resolution that gives a temperature resolution of 2.5 mK.

ICU_OBM-SSTL-106 / T
The ICU shall have high impedance inputs from the VTEMP signal when turned off as there is a direct connection via the non-redundant detector to the redundant ICU.

ICU_OBM-SSTL-107 / Information
The TIR detectors on-chip temperature output provides an analogue output voltage VTEMP related to detector temperature. VTEMP output is provided on one pin of the detector and its sensitivity is around - 6.45 mV/K. VTEMP is about 1.73 V for a detector temperature of 27ºC (300 K). The relation between VTEMP and the FPA temperature is shown in Figure 7-1.

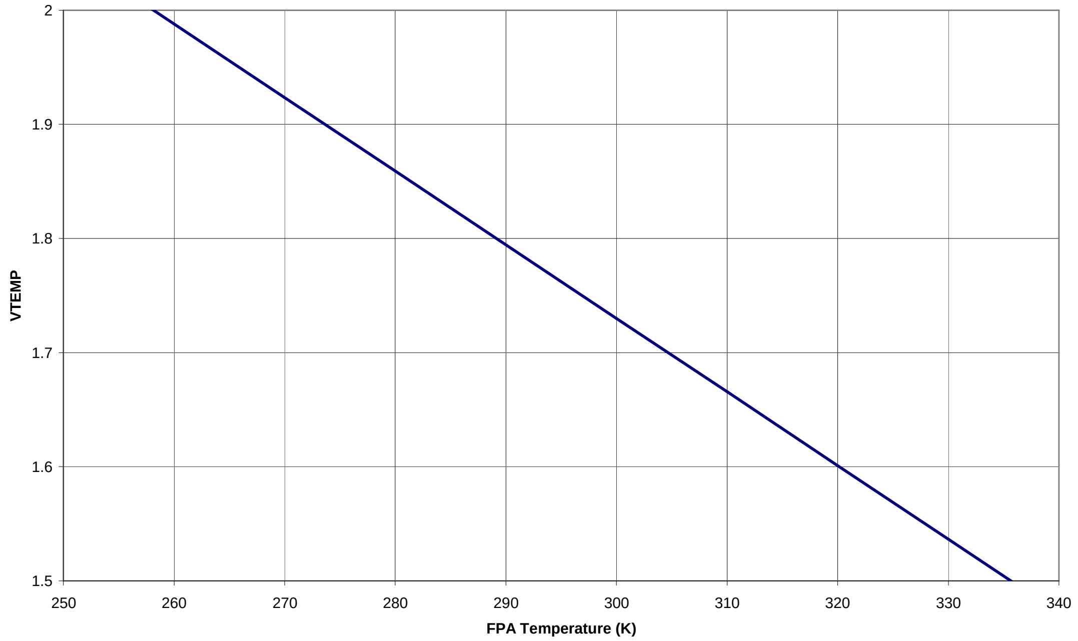


Figure 7-1 : Typical TIR VTEMP temperature sensor characteristics

ICU_OBM-SSTL-196 / Information
See [AD3] for further information on the detector interface details.

7.2.2 VNSOU detector VTEMP

ICU_OBM-SSTL-110 / Information
For the VNS detector VTEMP the interface will be AN2 type with a modified input range of 780 mV to 980 mV with a resolution that gives a temperature resolution of 2.5 mK.

ICU_OBM-SSTL-111 / Information
There are 4 detectors in the VNS. Each detector has one VTEMP output. The temperature sensor will be used for monitoring only and will not be used for thermal control.

ICU_OBM-SSTL-112 / T
The ICU shall have high impedance inputs from the temperature signal when turned off as there is a direct connection via the non-redundant detector to the redundant ICU.

ICU_OBM-SSTL-113 / Information
The VNS detectors on-chip temperature output provides an analogue output voltage VTEMP related to detector temperature. VTEMP output is provided on one pin of the detector and its sensitivity is tabled below. The relation between VTEMP and the FPA temperature is shown Figure 7-2.

ICU_OBM-SSTL-114 / Information

FPA Temperature (K)	VTEMP (mV)
223.15	923
233.15	909
243.15	894
253.15	881
263.15	868
268.15	861
273.15	854
278.15	847
283.15	840
288.15	833
293.15	826
298.15	819
303.15	812
308.15	804
313.15	798
318.15	790
323.15	783

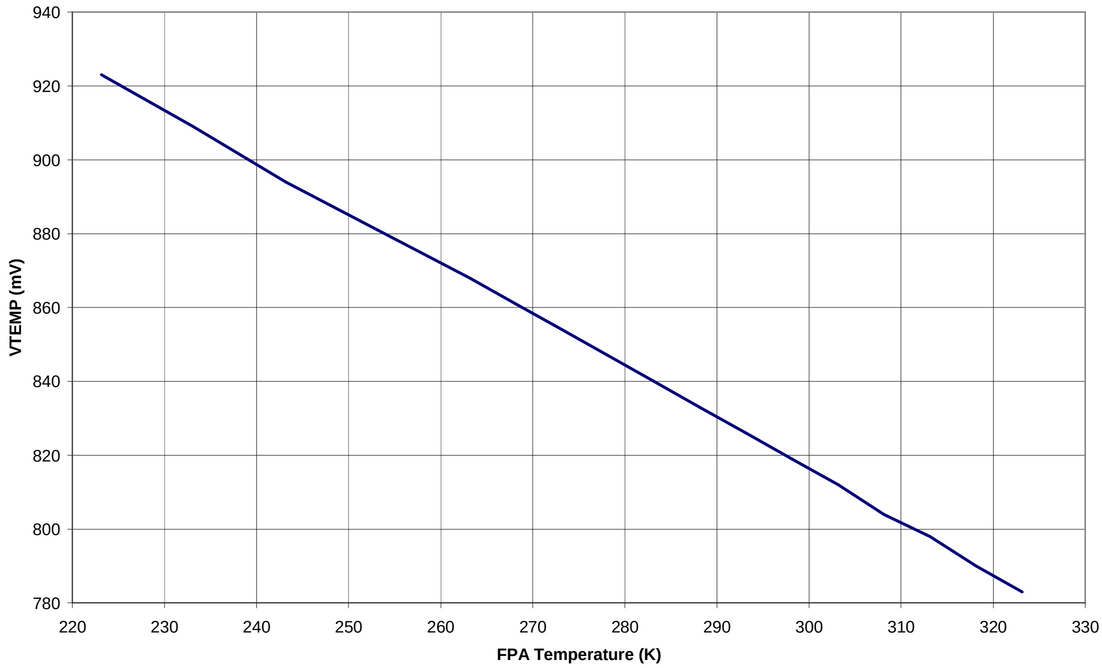


Figure 7-2 : Typical VNS VTEMP temperature sensor characteristics

ICU_OBM-SSTL-244 / Information
See [AD3] for further information on the detector interface details.

8 SECONDARY SUPPLY VOLTAGES

ICU_OBM-SSTL-116 / T
The ICU shall provide the single FEE with 2 voltages as specified below in Subsection 8.1.

ICU_OBM-SSTL-117 / T
The ICU shall not create a voltage higher than the maximum for all conditions.

ICU_OBM-SSTL-118 / Information
The FEE shall operate correctly for all voltages from minimum to maximum.

ICU_OBM-SSTL-119 / Information
The FEE shall not create a current higher than the maximum specified except at start-up during the inrush interval and during failure.

ICU_OBM-SSTL-120 / T
The ICU shall limit the current to the maximum specified without fold back.

ICU_OBM-SSTL-121 / T
Any permanent short circuit of any supply and its return or any supply and ground will not affect any of the other supplies. The ICU shall not be damaged by any short-circuit condition.

8.1 FEE

ICU_OBM-SSTL-124 / Information
The FEE supply voltages are listed in the following table:

	Minimum	**Typical**	**Maximum**	
Detector supply				
Voltage	6.7 V	7 V	9 V	
Voltage noise			10 mV rms	Note 1
DC output resistance	100 mR			TBC
AC output impedance				TBC
Current	0 mA	550 mA	800 mA	TBC
Electronics Supply				
Voltage	3.8 V	4 V	7 V	
Voltage noise			10 mV rms	Note 1
DC output resistance	100 mR			TBC
AC output impedance				TBC
Current	350 mA	675 mA	1000 mA	TBC

ICU_OBM-SSTL-245 / R
Note 1 – The ICU supplier is to advise the noise level that is achievable without the use of extra linear regulators on the outputs.

ICU_OBM-SSTL-125 / T
The electronics supply shall be able to cope with the start up current requirements of the FPGA within the FEE. The FPGA is of type RTAX1000S-CGS624.

8.1.1 FEE Interface Diagrams

ICU_OBM-SSTL-249 / Information
The circuit diagrams of the interface sections for the FEE supplies are provided below.

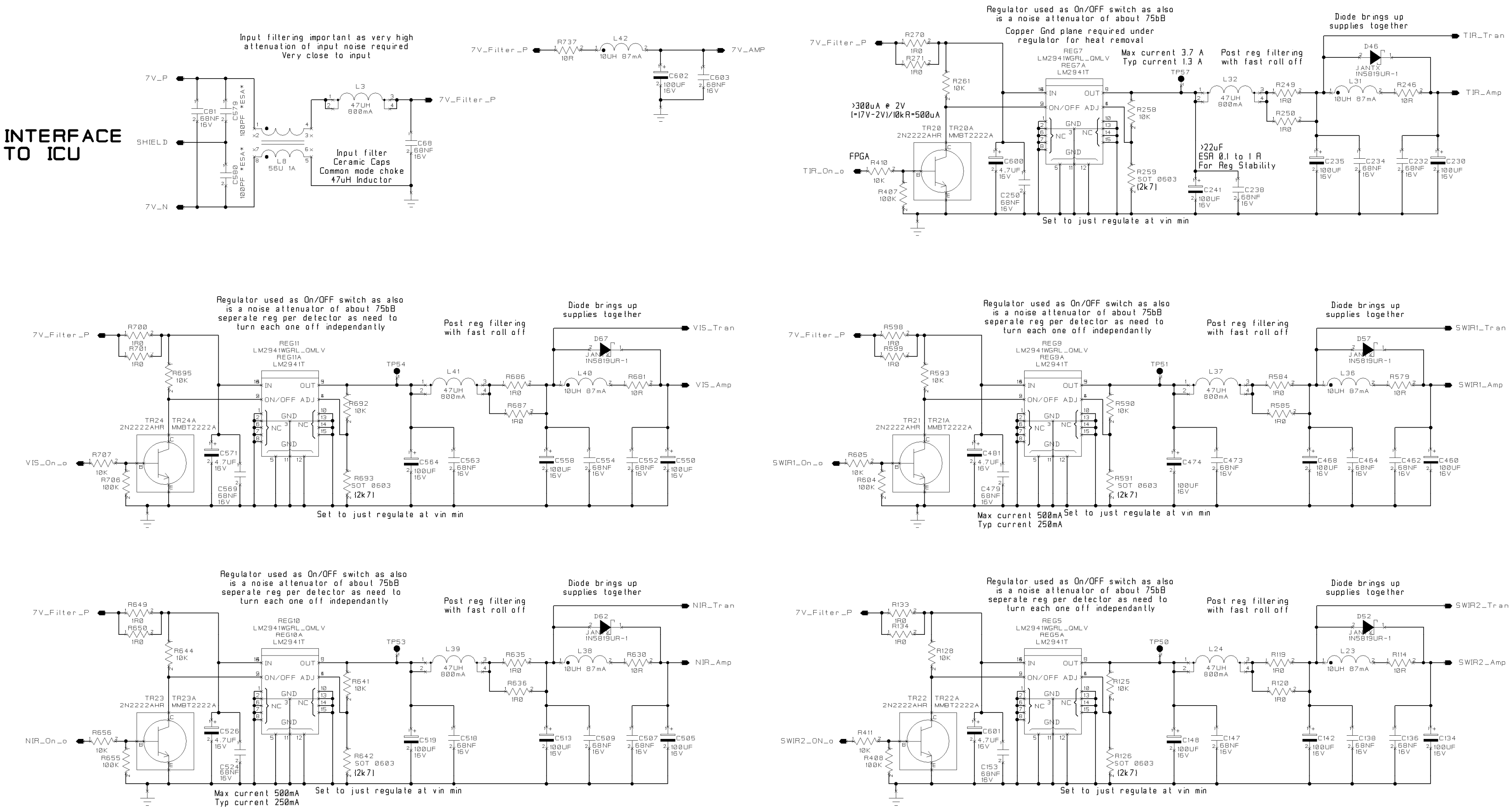


Figure 8-1 : FEE 7V supply interface circuit diagram.

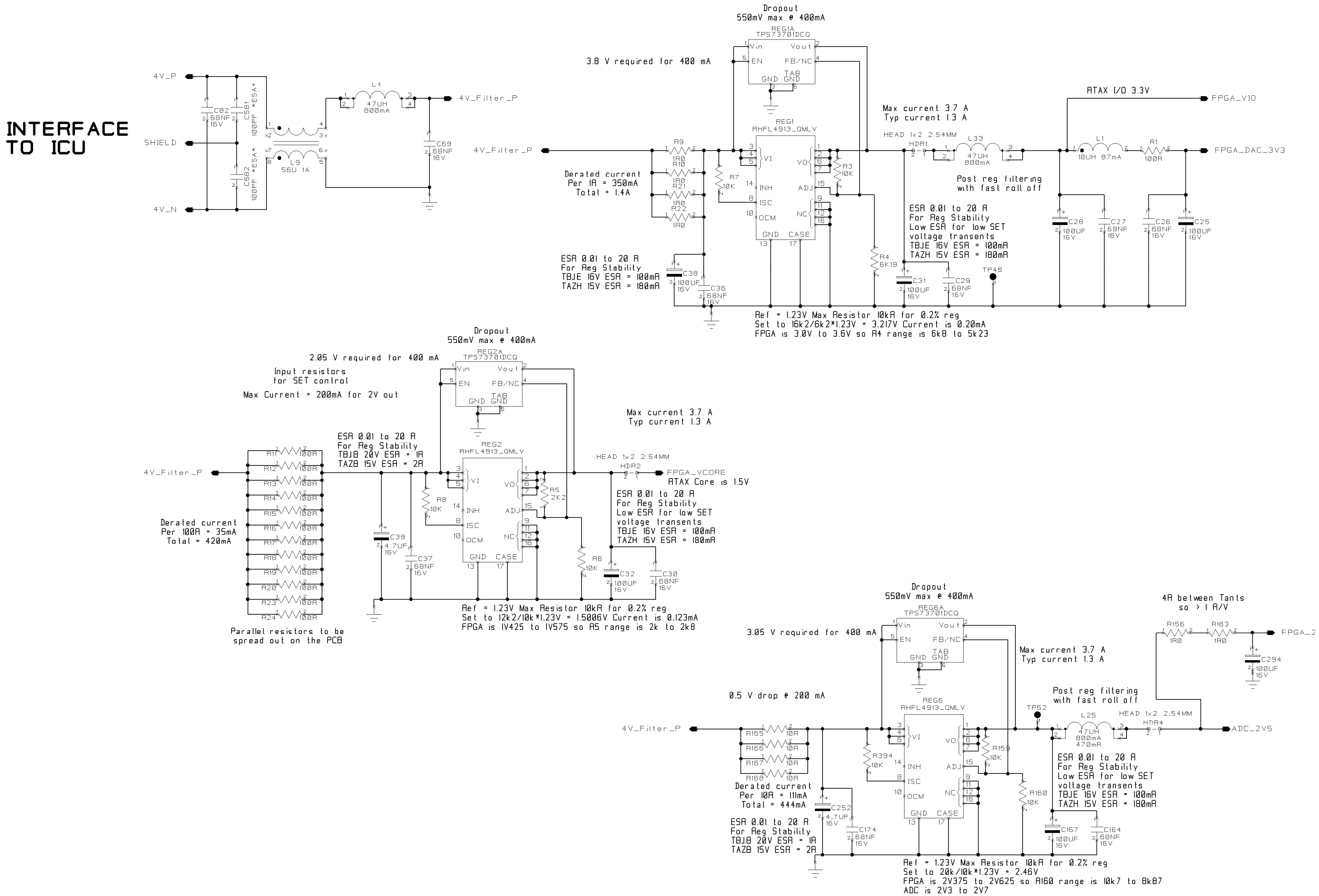


Figure 8-2 : FEE 4V supply interface circuit diagram.

9 SERIAL LINK

ICU_OBM-SSTL-127 / T
Command and Monitoring for the FEE by the ICU will be via a USL interface using SBDL (RS422 based) physical interface. See paragraph 14 for further details of the USL interface.

ICU_OBM-SSTL-128 / T
The baud rate shall be 65,536 bauds, which is not standard.

ICU_OBM-SSTL-129 / Information
The FEE will store configuration and status information in registers accessible via the USL interface using the protocol detailed below.

ICU_OBM-SSTL-130 / T
The ICU shall set and monitor the FEE registers using the protocol detailed below.

ICU_OBM-SSTL-131 / T
Command messages sent by the ICU to the FEE and Monitoring Messages received by the ICU from the FEE shall be transmitted in continuous blocks without time gaps between the bytes of a block. A small interval of 8 bits TBC between bytes will be taken as a continuous set of bytes.

ICU_OBM-SSTL-132 / T
The command message consists of 40 bits (5 octets/bytes) in the following format
(Byte 0 contains bits 00 to 07, byte 1 contains bits 08 to 15...byte 4 contains bits 32 to 39)

Bit 00 (MSB)	Write/read flag, 1 for Write, 0 for read. FEE always uses 0.
Bits 01 to 07	Register address for 1 to 128 registers in the FEE.
Bits 08 to 31	Register Data, 24 bits long, used for writes only.
Bits 32 to 39	CRC 8bits.

ICU_OBM-SSTL-133 / T
The message will be sent most significant byte first (byte 0) and most significant bit first (bit 00).

ICU_OBM-SSTL-134 / T
The CRC-8 format is CCITT standard (10000111b) with initial value of all 1s.

ICU_OBM-SSTL-135 / Information
If the message is a write message (bit 00 is 1) then the FEE will update the register if the message is decoded correctly. The FEE will then respond with the value read back from the register in the same format given above. If the message from the ICU is a read message (bit 00 is 0) then the FEE will again respond with the value read back from the requested register in the same format given above. If an error is detected the FEE will respond by sending the Status register (address 0). This register contains message error status bits indicating the type of error. The ICU can tell that there was a problem as the returned message address will be 0.

ICU_OBM-SSTL-250 / Information
The FEE will be able to receive a message at the same time as it is transmitting a message.

ICU_OBM-SSTL-136 / T
The ICU shall monitor the contents of the state register by reading the register at a nominal rate of once per second. The sampling rate shall be programmable by telecommand. Any errors shall be reported to the Satellite by using Service 5: Event Reporting service TBC.

9.1 Message error recovery

ICU_OBM-SSTL-138 / T
If a status register message is received during communication with another register or the top bits of the status register are 1 when reading or writing the status register then the appropriate recovery actions should be performed.

ICU_OBM-SSTL-139 / Information
Framing Error (bit 19)
The command message was received with 1 or more framing errors. A framing error is an incorrect stop bit value or a data value change close to the central sampling point.

ICU_OBM-SSTL-140 / Information
Checksum (bit 20)
The command message was received with an incorrect CRC byte.

ICU_OBM-SSTL-141 / Information
Incomplete (bit 21)
The command message was received with a larger than allowed gap between the 5 bytes of the message.

ICU_OBM-SSTL-142 / T
For the above 3 errors the command message shall be repeated up to the defined number of times. If after all attempts there are still errors a message shall be sent to ground and the command message abandoned.

ICU_OBM-SSTL-143 / Information
Address Write (bit 22)
The command write message failed to write to the register.

ICU_OBM-SSTL-144 / Information
Address Read (bit 23)
The command read message failed to read the register.

ICU_OBM-SSTL-145 / T
For the above 2 errors the command message shall be abandoned and a message shall be sent to ground. There is no need to repeat this command as it is due to an incorrect register address.

9.2 Status register error recovery

ICU_OBM-SSTL-147 / T
If the status register is read successfully and any of the bottom bits (bits 0 to 17) are set to 1 then a detector latch-up recovery action shall be undertaken.

ICU_OBM-SSTL-148 / T
The error shall be reported to ground.

ICU_OBM-SSTL-149 / T
After a 1 second wait the status register shall be written with a 1 in the bits that where 1 on the previous read, this will clear the status register bits and then checked. If the same bits are still 1 then the permanent error shall be reported. If different bits are set to 1 then another wait of one second shall be taken and the status clearing tried again. When the status register has been successfully cleared the state register shall be written with the value previous used.

ICU_OBM-SSTL-150 / Information
Note - The register value can be stored in a command block which is used to put the FEE into normal operating state. This will allow multiple register to be written if required. The block would also be used for setting the FEE to normal state.

ICU_OBM-SSTL-151 / T
If the status register is read successfully and the EDAC double error bit (bit 18) is set then the INT_RAM_EDAC registers (registers 12 to 15 hex) shall be read and reported to ground.

9.3 Registers

ICU_OBM-SSTL-253 / T
The FEE control and monitoring is performed by a set of register in the FEE. The USL interface is used to access these registers. The registers are nominally 24 bits but not all bits are implemented in all registers, Un-used bits will be returned as 0. The ICU shall write unused bits as 0 (the FEE will ignore the value in unused bits).

ICU_OBM-SSTL-254 / T
There should be the ability to send a block of command messages to the FEE for configuration. The block should hold about 64 commands TBC. To allow variable number of commands to be sent the address 127 will not be used so an all ones command message can be used as an end of command list.

ICU_OBM-SSTL-255 / T
During block commanding the ICU shall test the reply against the data value of the command message and report if there is an error.

9.4 ADC monitoring registers

ICU_OBM-SSTL-256 / T
The ADC monitoring registers (registers 20 to 2B hex) shall be read at regular intervals and the ADC values used to update the relevant telemetry data value. The interval shall be commandable from ground.

9.5 Power up of FEE

ICU_OBM-SSTL-258 / T
On power up all registers will be initialised to zero. The ICU shall test that all register that give a consistent output (EDAC and ADC monitoring registers have variable values) are zero. The ICU shall then test the registers with all 1s (except register where this will cause problems such as detector turn on) and then load the working values and confirm correct loading.

ICU_OBM-SSTL-259 / Information
Note – this can be accomplished by having 3 command message blocks in the ICU. An all zero block (filled with read commands for the registers to be tested), an all 1s block (filled with write commands for the registers to be tested) and an operating values block (filled with write commands for registers to be set for operation) and send each block in turn.

ICU_OBM-SSTL-260 / T
After the register test a memory test shall be performed.

ICU_OBM-SSTL-261 / T
The 1 Mword of external memory is tested using the EX_RAM registers 10 and 11 hex. The EX_RAM_address register (register 10 hex) is set to zero with the inc bit (bit 23) set to 1. A pseudo random sequence of 24 bit data values are then written to the EX_RAM_Data register (register 11 hex). The EX_RAM_Data reply shall be tested against the value written and any error reported to ground. The address will automatically be incremented to the next RAM location. When all of the RAM has been written the EX_RAM_Address register is reset to zero with the Inc bit set to 1 and the EX_RAM_Data register read and tested against the same pseudo random sequence. Any error shall be reported then retested by writing the EX_RAM_Address register with the failed address and rewriting the data value and testing the reply to check that the error is not a SEU.

ICU_OBM-SSTL-262 / T
The internal 4 kWords of internal memory shall be tested using the INT_RAM register 12 to 17 hex. The INT_RAM_EDAC_Counters register shall first be written to have all zeros. The INT_RAM_address register (register 12 hex) is set to zero with the inc bit (bit 23) set to 1. A pseudo random sequence of 24 bit data values are then written to the INT_RAM_Data register (register 13 hex). The INT_RAM_Data reply shall be tested

against the value written and any error reported to ground. The address will automatically be incremented to the next RAM location. When all of the RAM has been written the INT_RAM_Address register is reset to zero with the Inc bit set to 1 and the INT_RAM_Data register read and tested against the same pseudo random sequence. Any error shall be reported then retested by writing the INT_RAM_Address register with the failed address and rewriting the data value and testing the reply to check that the error is not a SEU.

ICU_OBM-SSTL-263 / Information
After these test the FEE is ready for normal operation. The FEE will be in the Idle state with the detectors off.

ICU_OBM-SSTL-264 / Information
When required the FEE can be changed to the normal state by writing to the state register. This can come from a command block which can then be used to recover from a latch-up see above.

9.6 Day and Night operation

ICU_OBM-SSTL-266 / Information
The difference between day and night operation is that the VNS CCSDS output will be disabled. This requires writing to the State register (register 1 hex). Clearing the B1 (bit 3) to B4 (bit 6) bits of the register will disable the VNS CCSDS packet output.

ICU_OBM-SSTL-267 / Information
Note – It may be necessary to write to other registers to perform the day to night transition so using two command blocks for day and night operation would be more flexible.

9.7 Register details

ICU_OBM-SSTL-269 / Information
The register details are contained in EC.LI.SSTL.MSI.00038 (RD2).

10 MEASUREMENT DATA INTERFACE

ICU_OBM-SSTL-153 / Information
The ICU shall receive science data from the FEE via a measurement data interface (LBR).

ICU_OBM-SSTL-154 / T
There shall be one measurement data interfaces (LBR) for the FEE.

ICU_OBM-SSTL-155 / T
The FEE is the data packet source for this interface.

ICU_OBM-SSTL-156 / T
The implementation of the measurement data interface (LBR) shall be according to the GDIR. The data clock rate of the measurement data link (LBR) will be 2.7962 MHz.

ICU_OBM-SSTL-157 / T
The FEE will send the data to the ICU in CCSDS format. The CCSDS format is given in section 16 of this document. The ICU shall be able to accept this data.

ICU_OBM-SSTL-158 / Information
The packet transmission will start within a commandable time interval from the start signal negative edge.

ICU_OBM-SSTL-159 / T
The packets will be spaced out by inserting an idle period between the packets. The idle period shall be settable from a register in the FEE.

ICU_OBM-SSTL-160 / T
The ICU will decode the CCSDS packet headers and

a) Time stamp the packet
b) Perform the correct post processing

11 MASTER CLOCK

ICU_OBM-SSTL-164 / T
The ICU shall supply a master clock signal to the FEE.

ICU_OBM-SSTL-165 / T
There shall be one master clock signals for the FEE.

ICU_OBM-SSTL-166 / Information
The master clock frequency is 16.777216 MHz (2^24 cycles per second).

ICU_OBM-SSTL-167 / Information
This frequency is compatible with the clock needed for the time system in the ICU.

ICU_OBM-SSTL-168 / T
The interface standard used for this interface shall be LVDS.

12 TIMING PULSE

ICU_OBM-SSTL-170 / T
The ICU shall supply a timing pulse signal to the FEE.

ICU_OBM-SSTL-171 / T
There shall be one timing pulse signals for the FEE.

ICU_OBM-SSTL-172 / T
The timing pulse signal shall indicate the start of each ground line (about 70ms interval).

ICU_OBM-SSTL-173 / T
The ICU shall generate a timing signal for the FEE indicating the start of the next ground line interval.

ICU_OBM-SSTL-174 / T
The ICU shall make the timing interval commandable in steps of 119.21 ns (1/(2^23) of a second) over the range 60 ms to 80 ms TBC. The interval will need to be changed manually with orbit position. The number of master clock cycles making up the time interval shall be dividable by 24.

ICU_OBM-SSTL-175 / T
The ICU shall record the time to the nearest time count (119.21 ns) that the timing pulse is sent. All measurement data CCSDS packets that have started to be received by the ICU shall be time stamped with this recorded time.

ICU_OBM-SSTL-176 / T
The FEE shall use this timing pulse to start the detector readout for the next ground line.

ICU_OBM-SSTL-177 / T
The physical interface shall be SBDL.

ICU_OBM-SSTL-178 / T
The falling edge of the true line is used as the timing reference. The pulse width shall be greater than or equal to 4 ms and less then 50 ms.

13 MECHANISMS CONTROL AND DRIVE

ICU_OBM-SSTL-180 / T
The ICU shall be responsible for the drive and control of two mechanisms on the MSI OBM used for calibration. Each mechanism has its own motor and set of position encoders, which the ICU is responsible for driving and monitoring respectively.

ICU_OBM-SSTL-181 / T
The ICU shall switch off the mechanisms control and drive section of the ICU when not calibrating.

ICU_OBM-SSTL-182 / Information
The two mechanisms have the following characteristics, given in Subsections 13.1, 13.2.8 and 13.4.

13.1 TIROU calibration mechanism

ICU_OBM-SSTL-185 / Information
The TIROU calibration mechanism characteristics are listed in Table 13-1:

Motor Type:	Internally redundant two phase stepper motor
Motor Voltage:	24 V minimum
Motor Current:	Constant current drive adjustable between 0 A to 0.6 A in steps of 10 mA TBC
Controller type	Speed ramping and micro Step capable with loadable acceleration profile.
Positions:	3 positions (Earth view, Cold space, Calibration black body)
Maximum Step Rate:	512 steps/s (see 13.2.5)
Minimum Step Rate:	16 steps/s (see 13.2.5)
Aperture closed Position:	Calibration Black Body

Table 13-1: TIROU Calibration Mechanism Characteristics

ICU_OBM-SSTL-187 / T
It shall be possible to operate the motor at two different settable currents:

- Nominal current 0.2A
- Recovery current 0.6A

ICU_OBM-SSTL-270 / T
Nominal current shall be used for all normal moves. Recovery current shall be used for recovery moves and the EQ_SOL operation.

ICU_OBM-SSTL-271 / Information
The TIROU calibration mechanism has a prime and redundant connector, which is the only interface from the mechanism to the OBM and is included here as a reference for the connections. Both connectors are 26-way male D-types (22 gauge), both with matching pin designations as defined in Table 13-2, based on the pin numbering in Figure 13-1.

Pin Number	Item
1	LED POWER +
2	LED POWER -
10	ENCODER 1 +
11	ENCODER 1 -
19	ENCODER 2 +
20	ENCODER 2 -
23	MOTOR PHASE A +
24	MOTOR PHASE A -
25	MOTOR PHASE B +
26	MOTOR PHASE B -
8	APERTURE CLOSED P
9	APERTURE CLOSE N

Table 13-2: TIROU Calibration Mechanism Connector Pin Designation

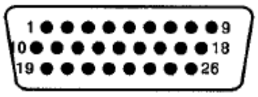


Figure 13-1: TIROU Calibration Mechanism Interface Connector Pin Numbering

ICU_OBM-SSTL-274 / Information
The mechanism's position encoder has prime and redundant channels. Each encoder channel consists of two optical detectors shown in Figure 13-2. Each optical detector comprises a LED and a photo-transistor optical detector (P-T) with logic level output. The encoder works in conjunction with a shuttered encoder disc (Figure 13-3), which rotates to give the output states defined in Table 13-3, with reference to the 3 required positions (Figure 13-4).

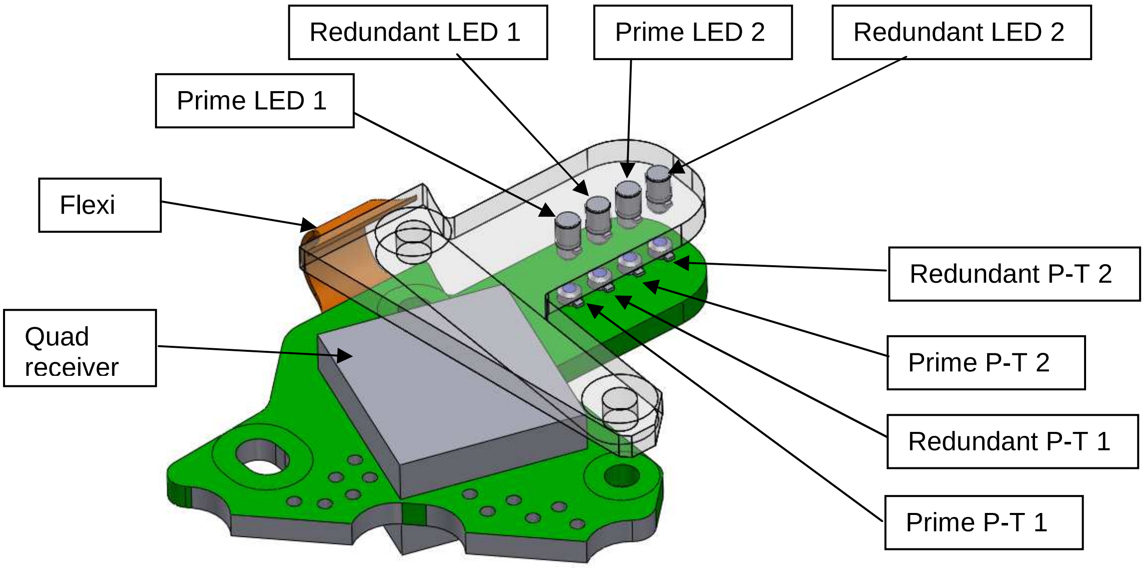
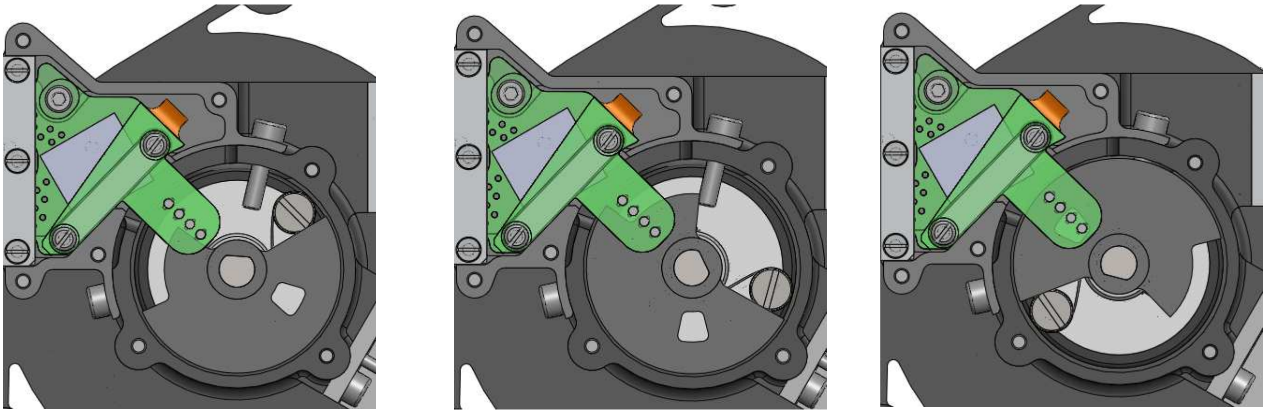


Figure 13-2: Optical Encoder PCA (top board transparent)

Figure 13-3: Shuttered encoder disc



a) Earth view b) Cold Space view c) Black body view

Figure 13-4: Position encoder configuration at each required position (viewed from below with upper sensor board transparent)

Position	Sensor 1	Sensor 2	Rotation
At Earth view	1	1	N/A
Between Earth view and Cold space	1	0	Clockwise (from below)
At Cold space	1	0	Clockwise (from below)
Between Cold space and Black body	0	0	Clockwise (from below)
Calibration Black Body (also safe position for EQ-SOL)	0	1	Clockwise (from below)
Over travel past Black body (not normally used)	0	1	Clockwise (from below)

Table 13-3: Sensor truth table

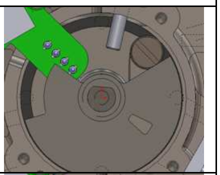
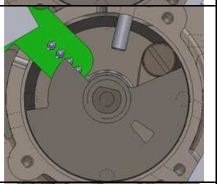
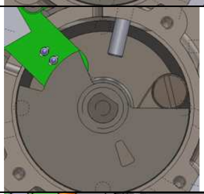
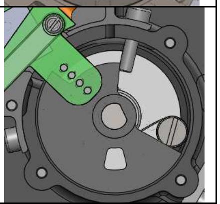
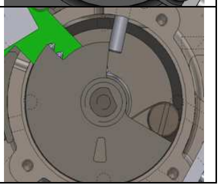
ICU_OBM-SSTL-279 / Information

The reverse sequence described in Table 13-3 is obtained for anti-clockwise motion.

ICU_OBM-SSTL-280 / Information

The shuttered encoder disc is mounted on the mirror shaft, and rotates synchronously with the calibration mirror. The motor drives a 20:1 gearbox which actuates a spring assembly. The spring assembly ‘pulls’ the mirror shaft around in the anti-clockwise drive direction (from below); and pushes the mirror shaft around in the clockwise drive direction. The spring assembly allows the motor to over-drive beyond the Earth view position, whilst the mirror shaft (and therefore encoder disc) is held firmly against a mechanical end stop. This is desirable since the spring winds up to provide a force which holds the mirror shaft in an accurate and repeatable position at Earth view. The nominal over-driven position of the motor to wind up the spring is 60 full motor steps beyond Earth view (anti-clockwise from bottom). A safety mechanical end stop is present at 130 full motor steps beyond Earth view position (i.e. 70 beyond the wind-up position of the overdrive spring). This safety end stop is present in case control is lost and thus to prevent potential excessive over-drive causing the spring to come off. Since the spring deflects independently from the mirror shaft (which is held against its end stop), then the mirror shaft does not experience rotation, and hence over-driven positions are referred back to motor level.

ICU_OBM-SSTL-281 / Information
In the other extreme of the mirror shaft rotation, there is an end stop 10° beyond the clockwise direc tion beyond black body rotation. A summary of the positions is given in Table 13-4, with rotations referred to mirror shaft level unless stated otherwise. The mechanism shall be calibrated during build of the TIROU, and thus slight variation of the angles stated may occur. The visual of the mirror shaft position and associated encoder response is also presented. The mechanism's gearbox means that clockwise direction of the motor, equates to clockwise direction of the mirror shaft as viewed from below.

Position	Angle	Comment	Encoder Feedback		Visual (from below)
			S1	S2	
Safety end stop to prevent spring loss and encoder clash	-130 full motor steps	Protects spring. Will cause motor miss-stepping	1	1	N/A
Spring wind up position for desired accurate Earth view pointing	-60 full motor steps	Desired static position	1	1	N/A
Earth view pointing – but without spring tension	0°	Dynamic position. Reduced anticlockwise speed at the start of spring wind up	1	1	
Encoder 11 to 10 transition (in clockwise direction)	8°	Dynamic position	1	0	
Rotation move between Earth view and Cold Space	8°< x < 60°	Dynamic position	1	0	
Cold Space view – Encoder transition 10 to 00 (in clockwise direction)	60°	Static position	1	0	
Datum position	68°	Static position and used as datum edge when rotate anti-clockwise	0	0	

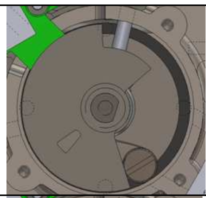
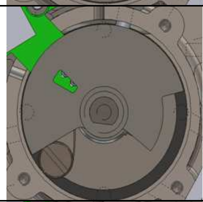
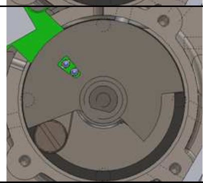
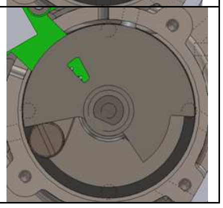
Rotation move between Cold Space and Black Body	68°< x < 182°	Dynamic position	0	0	
Encoder transition 00 to 01 (in clockwise direction)	182°	Dynamic position	0	1	
Calibration black body viewing	190°	Static position	0	1	
Safety end stop beyond black body rotation to prevent encoder clash	200°	Can be used for EQ-SOL safe position. Will cause motor miss-stepping	0	1	

Table 13-4: Significant Rotation Angles (rotation at mirror shaft unless otherwise stated)

13.2 Mechanism operation

13.2.1 Overall operation suggestion

ICU_OBM-SSTL-285 / T

The calibration sequence shall be controlled by a sequence of commands (drive profiles). One drive profile shall commence once the previous one has completed. The first command shall be a timed command, so that the sequence can be queued.

ICU_OBM-SSTL-286 / T

The ICU shall hold a table with an entry for each move – to control the motor and mechanism operation. Each entry shall have the number of steps, the number of steps before deceleration, whether the move should look for an encoder change to stop the move, and the expected encoder value at the end of the move.

ICU_OBM-SSTL-287 / T

The ICU shall remember the motor mechanism position between operations. The positions are:

- Unknown Encoder 11
- Unknown Encoder 10
- Unknown Encoder 00
- Unknown Encoder 01
- Encoder 11 to 10 transition
- Encoder 10 to 00 transition
- Encoder 00 to 01 transition
- Datum (Encoder 00 to 01 transition when approached anti-clockwise)
- Datum plus 25 full motor steps
- Earth view
- Cold space view
- Calibration black body view

ICU_OBM-SSTL-288 / Information

The convention used is positive number equates to clockwise move, and negative number to an anti-clockwise move. The term 'step' refers to a full motor step, in respect of the motor being micro stepped. The conversion from steps to micro steps can be undertaken once the micro step to step ratio is fixed.

ICU_OBM-SSTL-289 / T

The encoder value shall be checked after every move and confirmed that the correct value is found. If an error is detected then a position recovery must be performed as detailed below.

Value	Service Sub Type
0	<Invalid>
1	Earth View
2	Moving
3	VNS Dark
4	VNS Diffuser 1
5	VNS Diffuser 2
6	TIR Calibration Black Body
7	TIR Space
8	VNS Dark Flat Field Offset Data being Generated
9	TIR Space Flat Field Offset Data being Generated

ICU_OBM-SSTL-290 / T

The overall operation when the datum has been found and the mechanism is in the normal Earth view position is as follows. The ICU shall enable the MSI to carry out these operations during a calibration cycle.

- The motor mechanism is powered on. The LBR data is flagged as Moving (in Service Sub Type field of the LBR header) and mechanism is moved from Earth View to Cold space view. The motor mechanism is powered off.
- On completion of the move the LBR data is left at Moving for the TDI clearance time (nominally 20 ground line intervals) and then flagged as TIR space for the calibration data collection time (normally 64 ground lines but may be selected as 32, 64, 128 and 256 ground lines). During the calibration collection time the ICU may also be requested to build a new offset data table in which case the LBR is flagged as TIR Space Flat Field Offset data being generated.
- On completion of the data collection the LBR data is flagged as Moving. The motor mechanism is powered on and mechanism is moved from Cold space View to Calibration Black Body view. The motor mechanism is powered off.
- On completion of the move LBR data is left at Moving for the TDI clearance time (nominally 20 ground line intervals) and then flagged as TIR Calibration Black Body for the calibration data collection time (normally 64 ground lines but may be selected as 32, 64, 128 and 256 ground lines).
- On completion of the data collection the LBR data is flagged as Moving. The motor mechanism is powered on and mechanism is moved from Calibration Black Body view to Earth view. The motor mechanism is powered off.
- On completion of the move the LBR data is left at Moving for the TDI clearance time (nominally 20 ground line intervals) and the LBR data is then set back to Earth View.
- This completes a typical calibration cycle.

ICU_OBM-SSTL-291 / T

On power up the mechanism shall be moved to the safe position (CBB view). When the first move command sequence is requested a find datum shall be performed before the first requested move.

13.2.2 Datum Search

ICU_OBM-SSTL-293 / T

When the ICU is first commanded to move the mechanism or when an error in the operation is found; a datum search operation shall be performed. The action performed depends on the encoder value at the start. Ultimately, the transition from 00 to 10 in the anticlockwise direction is used (the encoder edge) to define the datum. This encoder transition is performed at a reduced rotation speed to provide refined accuracy. The required move commands for each Encoder Value at ICU turn-on or error are shown in Table 13-5.

Encoder Feedback at ICU Turn-On or Following Error	Required Commands
Encoder Value 11	1. Perform the clockwise move 'Unknown Encoder 11' to next encoder change 2. Perform the clockwise move from 'Encoder 11 to 10 transition' to 'Datum plus 60 steps'. 3. Perform the action for 'Encoder Value 00'.
Encoder Value 10	1. Perform the clockwise move 'Unknown Encoder 10' to next encoder change. 2. Perform the clockwise move 'Encoder 10 to 00 transition' plus 60 steps. 3. Perform the action for 'Encoder Value 00'.
Encoder Value 00	1. Perform the anticlockwise move 'Unknown Encoder 00' to next encoder change at the desired reduced speed. 2. Record the position of the encoder change as the Datum Position.
Encoder Value 01	1. Perform the anticlockwise move 'Unknown Encoder 01' to next encoder change. 2. Perform the anticlockwise move 'Encoder 01 to 00 transition' to next encoder change. 3. Perform the clockwise move 'Encoder 10 to 00 transition' plus 60 steps. 3. Perform the action for 'Encoder Value 00'.

Table 13-5: Required Action to Perform Datum Search for Each Starting Position

13.2.3 Position Recovery

ICU_OBM-SSTL-296 / T
On finding an incorrect encoder value at the end of a move a position recovery shall be performed. The error shall be reported and a flag shall be set indicating that the mechanism is in position recovery.

ICU_OBM-SSTL-297 / T
The motor current shall be changed from nominal operating current to recovery operating current. A datum find shall then be performed. The mechanism shall then be moved to the position that caused the error. The sequence shall be completed with the recovery operating current setting.

ICU_OBM-SSTL-298 / T
If another incorrect encoder value is found while in position recovery indicated by the in position recovery flag being set then a move to safe position shall be performed and the error reported. The mechanism shall then be turned off.

13.2.4 EQ-SOL

ICU_OBM-SSTL-300 / Information
On receiving the EQ_SOL signal the mechanism will be moved to the Aperture closed position by performing a Go to safe position move at recovery current. No processor interaction will be required to perform this move.

13.2.5 Mechanism moving

ICU_OBM-SSTL-302/ T
The move command will be converted to the distance to move in steps, and the number of steps until the deceleration is performed and whether to monitor the encoder for changes. This will allow the different profiles to be generated.

ICU_OBM-SSTL-303 / T
The motor shall be moved by command. For each move, the stepper motor shall be started at the minimum speed. The speed is then increased at the acceleration rate until top speed is reached. After the number of steps set in the deceleration start value of the command has been reached, the speed is then decreased at the deceleration rate until the minimum speed is reached. The motor is then stopped when the number of steps set in the total distance to travel value of the command is reached.

ICU_OBM-SSTL-304/ T
The acceleration rate and deceleration rate will be the same.

ICU_OBM-SSTL-305/ T
If the deceleration start value of the command is set to 0, the move will be at constant minimum speed. If it is set to total distance to travel minus the deceleration time, then there will be no minimum speed section.

ICU_OBM-SSTL-306 / T
The motor move command shall have the possibility to enable an early stop if the encoder value changes.

ICU_OBM-SSTL-307/ T
The maximum number of steps for each move must allow for the move Earth view to safe position (Aperture closed) in one operation.

ICU_OBM-SSTL-308 / T
The ICU shall hold the following values to control the moving of the mechanism:

Acceleration rate and deceleration rate:	From min to max in a 32 step period TBC
Minimum motor speed:	16 steps/s
Maximum motor speed:	512 steps/s

ICU_OBM-SSTL-309 / T
The min and maximum speed shall be able to be commanded from ground. The minimum value will be no lower than16 steps/s. Although the speed profile is shown in Figure 13-5 has a linear acceleration profile other acceleration profiles may be acceptable. The acceleration profile may have discrete steps as long as the impact on micro vibrations is within limits.

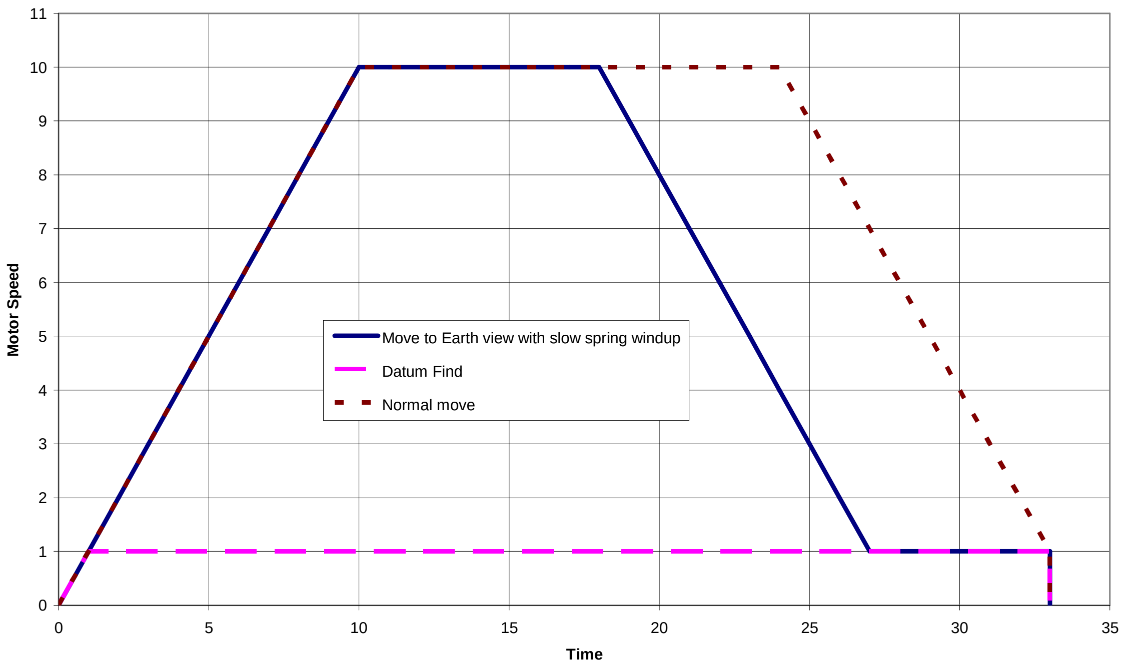


Figure 13-5: Graph showing possible move profiles in arbitrary units

13.2.6 Mechanism Moves

ICU_OBM-SSTL-312 / T

Table 13-6 gives the possible moves that the mechanism shall perform. The table shall be loadable from ground. Room for more moves shall be allocated.

Move	Number of Steps	Deceleration	Stop on Change	Encoder Expected Value
Unknown Encoder 11 to next encoder change	TBC	TBC	Yes	10
Unknown Encoder 10 to next encoder change	TBC	TBC	Yes	00
Unknown Encoder 00 to next encoder change	TBC	TBC	Yes	10
Unknown Encoder 01 to next encoder change	-TBC	TBC	Yes	00
Encoder 11 to 10 transition to Datum plus 25	TBC	TBC	No	00
Encoder 10 to 00 transition to Datum plus 25	25	12 TBC	No	00
Encoder 01 to 00 transition to Datum plus 25	-TBC	TBC	No	00
Datum to Earth view	-TBC	TBC	No	11
Datum to Cold space view	-TBC	TBC	No	10
Datum to Calibration black body	TBC	TBC	No	01
Earth view to Cold space view	TBC	TBC	No	10
Earth view to Calibration black body view	TBC	TBC	No	01
Cold space view to Calibration black body view	TBC	TBC	No	01
Cold space view to Earth view	-TBC	TBC	No	11
Calibration black body view to Cold space view	-TBC	TBC	No	10
Calibration black body view to Earth view	-TBC	TBC	No	11
Go to safe position (Aperture closed)	TBC	TBC	No	01

Table 13-6: Possible Mechanism Moves

13.2.7 Encoder electrical interface

ICU_OBM-SSTL-315/ Information
The encoder consists of 2 LEDs, 2 photo-transistors and a quad LVDS receiver.

ICU_OBM-SSTL-316/ T
The encoder requires a 5V supply @ 50 mA supply

ICU_OBM-SSTL-317/ Information
The encoder output 2 single ended 0 to 5V logic signal representing the opto-transistor state. The output is from an UT54LVDS032 LVDS receiver on the 5V supply used as a comparator. This gives a well defined operating transition for the encoder disk position. The output has a 56 R series output resistor. See Figure 13-6.

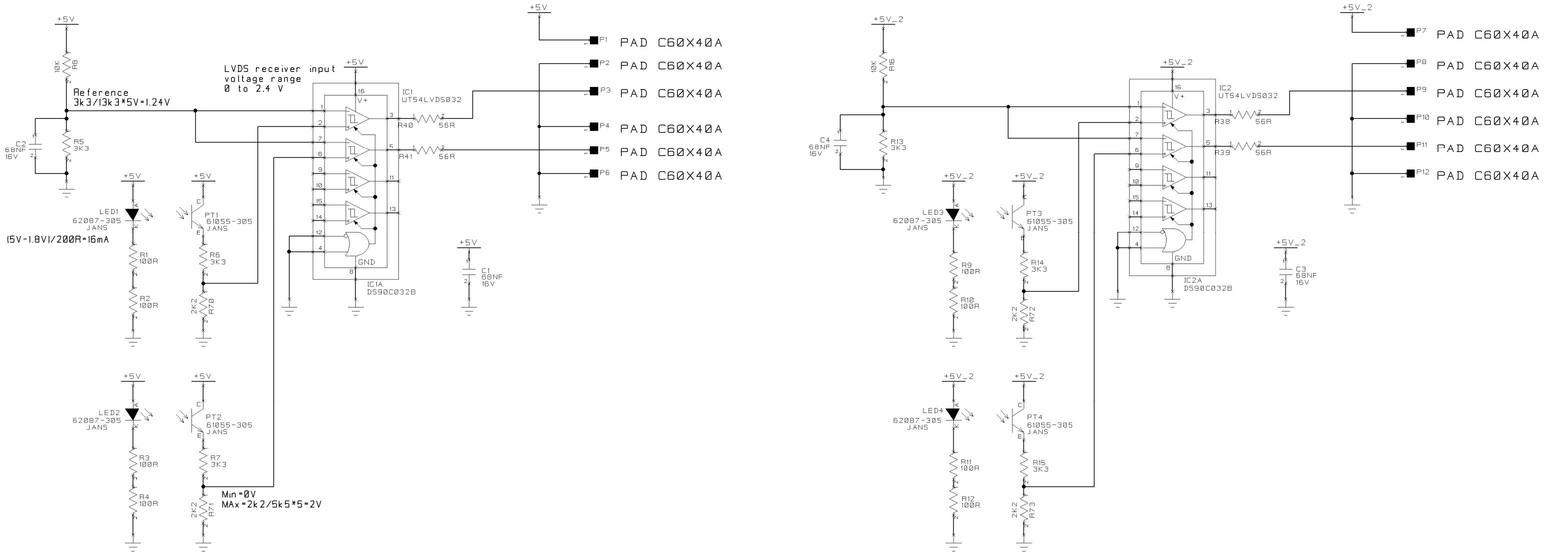


Figure 13-6: Optical Encoder Circuit Diagram

13.2.8 Connections

ICU_OBM-SSTL-321/ Information

The motor winding connections are listed below:

Motor winding A	Shielded twisted pair	No winding centre tap is provided.
Motor winding B	Shielded twisted pair	

ICU_OBM-SSTL-322/ Information

The encoder connections are listed below:

Encoder power	Shielded twisted pair	Powers the LEDs and the optical detectors. Isolated ground.
Encoder A	Shielded twisted pair	Ground connected to Encoder power ground only.
Encoder B	Shielded twisted pair	Ground connected to Encoder power ground only.

13.3 VNSOU Calibration Mechanism

ICU_OBM-SSTL-189/ Information

The VNSOU calibration mechanism characteristics are listed in the following table:

Motor Type:	Internally redundant two phase stepper motor
Motor Voltage:	24 V minimum
Motor Current:	Constant current drive adjustable between 0 A to 0.6 A in steps of 10 mA TBC
Controller type	Speed ramping and micro Step capable with loadable acceleration profile.
Positions:	3 position -
Maximum Step Rate:	TBA
Aperture Closed Position:	Dark Calibration position

ICU_OBM-SSTL-190/ Information

The encoder details for this mechanism are described in EC.ICD.TNO.MSI.00281 Issue 3, see Appendix 1.

ICU_OBM-SSTL-191/ Information

The motor winding connections are listed in the following table:

Motor winding A	Shielded twisted pair
Motor winding B	Shielded twisted pair

ICU_OBM-SSTL-192/ Information

The encoder connections are listed in the following table:

Encoder power	Shielded twisted pair	Powers the LED.
Encoder A	Shielded twisted pair	Direct connection to the opto-transistor

ICU_OBM-SSTL-323/ Information
The encoder is type OPB870T11. See RD3.

ICU_OBM-SSTL-324/ Information
The Encoder has an accuracy of

Sensor uncertainty	= ±5 mrad (0.25 mm @ a radius of 50 mm)
Alignment of sensor to carousel	= ±2 mrad (0.10 mm @ a radius of 50 mm)

ICU_OBM-SSTL-325/ Information
The Encoder transition region will be set to the mid point between stepper motor detent positions with the above accuracies.

ICU_OBM-SSTL-326/ T
The ICU shall have the capability to include the LED current limit resistors in the encoder power supply.

13.4 Aperture Close

ICU_OBM-SSTL-326/ Information
Both the TIR Calibration Mirror Assembly and the VNS Calibration mechanism have aperture close switches. The switches are connected in series to give the MSI aperture close signal. The contacts are close when the mechanisms are in the closed position.

Aperture close	Shielded twisted pair	Direct connection to switch contacts.

ICU_OBM-SSTL-329/ T
The ICU shall relay the Aperture close signal to the satellite.

14 UART SERIAL LINK (USL)

ICU_OBM-SSTL-194/ T

The UART serial interface is as specified in section 5 of the ICU specification with the exception of the baud rate. The Data Rate (each link): 65,536 bauds.

ICU_OBM-SSTL-195/ Information

Note: normal baud rate are 19.2k / 38.4k / 57.6k / 76.8k Bauds. The non standard baud rate has been selected to enable the master clock to be compatible with the timing section clock of the ICU.

15 FDIR

ICU_OBM-SSTL-331/ T
Monitoring for Low Severity Errors shall adopt the following limits:

FEE Register	Resulting Mode	Nominal	Low Limit	High Limit	Comment
FEE Status Register (bit 0 to 15)	-	N/A	N/A	N/A	Digital check

VNSOU Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
N/A					

TIROU Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
TIROU Temp1 (Detector hot side temperature sensor)	-	299 K	289 K	319 K	
TIROU Temp6 (Filter Mask Top)	-	288 K	268 K	308 K	
TIROU Temp7 (Filter Mask Bottom)	-	288 K	268 K	308 K	
TIROU Temp8 (Ge Lens 2)	-	287 K	267 K	307 K	
TIROU Temp9 (Internal Reference BB)	-	293 K	273 K	313 K	

OB Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
N/A					

Black Body Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
TIROU CBB Temp1 (Calibration BB 1)	-	288 K	273 K	313 K	Limits from ICU_OBM-SSTL-90

TIROU CBB Temp2 (Calibration BB 2)	-	287 K	273 K	313 K	Limits from ICU_OBM-SSTL-90

VNS Voltages	Resulting Mode	Nominal	Low Limit	High Limit	Comment
VIS DDA	-	5 V	4.7 V	5.3 V	
VIS VDET	-	3 V	2.7 V	3.3 V	
VIS Vvideo	-	6.2 V	5.8 V	6.6 V	
VIS ADC Ref	-	0 V	0 V	6.6 V	If ADC Ref is out of range then potentially all VIS voltages are wrong and this becomes a high severity event.
NIR DDA	-	5 V	4.7 V	6.6 V	
NIR VDET	-	3 V	2.7 V	5.3 V	
NIR Vvideo	-	6.2 V	5.8 V	6.6 V	
NIR ADC Ref	-	1.22 V	1.12 V	1.32 V	If ADC Ref is out of range then potentially all NIR voltages are wrong and this becomes a high severity event.
SWIR1 DDA	-	5 V	4.7 V	5.3 V	
SWIR1 VDET	-	3 V	2.7 V	3.3 V	
SWIR1 Vvideo	-	6.2 V	5.8 V	6.6 V	
SWIR1 ADC Ref	-	6.2 V	5.8 V	6.6 V	If ADC Ref is out of range then potentially all SWIR1 voltages are wrong

					and this becomes a high severity event.
SWIR2 DDA	-	5 V	4.7 V	5.3 V	
SWIR2 VDET	-	3 V	2.7 V	3.3 V	
SWIR2 Vvideo	-	6.2 V	5.8 V	6.6 V	
SWIR2 ADC Ref	-	1.22 V	1.12 V	1.32 V	If ADC Ref is out of range then potentially all SWIR2 voltages are wrong and this becomes a high severity event.

TIR Voltages	Resulting Mode	Nominal	Low Limit	High Limit	Comment
TIR VDDA	-	5 V	4.7 V	5.3 V	
TIR VDDL	-	3.3 V	3 V	3.6 V	
TIR VBUS	-	3.2 V	2.9 V	3.5 V	
TIR VFID	-	3.6 V	2.9 V	4.2 V	
TIR VSKIMMING	-	5.3 V	5.1 V	5.5 V	
TIR VEB	-	2.2 V	1.9 V	2.5 V	
TIR Vvideo	-	1.65 V	0 V	3.3 V	
TIR ADC Ref	-	1.22 V	1.12 V	1.32 V	

VTEMP	Resulting Mode	Nominal	Low Limit	High Limit	Comment
VNS VIS Detector Temperature		297 K	TBD	TBD	low limit only
VNS NIR Detector Temperature		297 K	TBD	TBD	low limit only
VNS SWIR1 Detector Temperature		297 K	TBD	TBD	low limit only
VNS SWIR2 Detector Temperature		230 K	TBD	TBD	low limit only

TIR Detector Temperature	299 K	TBD	TBD	low limit only

ICU_OBM-SSTL-332/ T
Monitoring for Medium Severity Errors shall adopt the following limits:

FEE Register	Resulting Mode	Nominal	Low Limit	High Limit	Comment
FEE register value mismatch	IDR	N/A	N/A	N/A	TM(5,3)
FEE Detector Latchup	IDR	N/A	N/A	N/A	TM(5,3)
FEE Detector Latch Not Cleared	IDR	N/A	N/A	N/A	TM(5,3)
FEE EDAC Double Error	IDR	N/A	N/A	N/A	TM(5,3)
FEE Command Failed	IDR	N/A	N/A	N/A	TM(5,3)

ICU_OBM-SSTL-333/ T
Monitoring for High Severity Errors shall adopt the following limits:

FEE Secondary Supply Voltages	Resulting Mode	Nominal	Low Limit	High Limit	Comment
FEE_V_Detector (FEE_7V_Detector Monitor)	SBR	7 V	6.7 V	9 V	Detector Supply 15% limit
FEE_I_Detector	SBR	1.0 A	0.0 A	2.0 A	15% limit
FEE_V_Electronics (FEE_4V_Electronics Monitor)	SBR	4 V	3.8 V	7 V	Electronics Supply 15% limit
FEE_I_Electronics	SBR	0.0 A	1.5 A	3.0 A	15% limit

VNSOU Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
VNSOU Temp1 (SWIR 2 barrel 1)	SBR		Closed	Open	open/closed circuit
VNSOU Temp2 (SWIR 2 barrel 2)	SBR		Closed	Open	open/closed

					circuit
VNSOU Temp3 (Optical Unit)	SBR		Closed	Open	open/closed circuit
VNSOU Temp4 (Calibration Mechanism)	SBR		Closed	Open	open/closed circuit
VNS Cal Thermistor 1	SBR		Closed	Open	open/closed circuit
VNS Cal Thermistor 2	SBR		Closed	Open	open/closed circuit
VNSOU Temp5 (SWIR 2 Cold Finger)	SBR		Closed	Open	open/closed circuit
VNSOU Temp6 (SWIR 2 Radiator)	SBR		Closed	Open	open/closed circuit
VNS Radiator Temperature 1	SBR		Closed	Open	open/closed circuit

TIROU Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
TIROU Temp2 (TIR Bench 1)	SBR	TBD	Closed	Open	open/closed circuit
TIROU Temp3 (TIR Bench 2)	SBR	TBD	Closed	Open	open/closed circuit
TIROU Temp4 (Rear Optics 1)	SBR	TBD	Closed	Open	open/closed circuit
TIROU Temp5 (Rear Optics 2)	SBR	TBD	Closed	Open	open/closed circuit

OB Temperatures	Resulting Mode	Nominal	Low Limit	High Limit	Comment
OB Temp1	SBR	TBD	Closed	Open	open/closed circuit

OB Temp2	SBR	TBD	Closed	Open	open/closed circuit

Black Body Temperature	Resulting Mode	Nominal	Low Limit	High Limit	Comment
TIROU CBB Temp1 (Calibration BB 1)	SBR	288 K	Closed	Open	open/closed circuit
TIROU CBB Temp2 (Calibration BB 2)	SBR	287 K	Closed	Open	open/closed circuit

FEE Temperature	Resulting Mode	Nominal	Low Limit	High Limit	Comment
FEE Temp1	SBR	TBD	TBD	TBD	10% limit

VNS Voltages	Resulting Mode	Nominal	Low Limit	High Limit	Comment
VIS DDA	SBR	5 V	4.7 V	5.3 V	High severity only if all limits are exceeded simultaneously.
VIS VDET	SBR	3 V	2.7 V	3.3 V	
VIS Vvideo	SBR	6.2 V	5.8 V	6.6 V	
VIS ADC Ref	SBR	0 V	0 V	6.6 V	If ADC Ref is out of range then potentially all VIS voltages are wrong
NIR DDA	SBR	5 V	4.7 V	6.6 V	High severity only if all limits are exceeded simultaneously.
NIR VDET	SBR	3 V	2.7 V	5.3 V	
NIR Vvideo	SBR	6.2 V	5.8 V	6.6 V	
NIR ADC Ref	SBR	1.22 V	1.12 V	1.32 V	If ADC Ref is out of range then

					potentially all NIR voltages are wrong
SWIR1 DDA	SBR	5 V	4.7 V	5.3 V	High severity only if all limits are exceeded simultaneously.
SWIR1 VDET	SBR	3 V	2.7 V	3.3 V	
SWIR1 Vvideo	SBR	6.2 V	5.8 V	6.6 V	
SWIR1 ADC Ref	SBR	6.2 V	5.8 V	6.6 V	If ADC Ref is out of range then potentially all SWIR1 voltages are wrong
SWIR2 DDA	SBR	5 V	4.7 V	5.3 V	High severity only if all limits are exceeded simultaneously.
SWIR2 VDET	SBR	3 V	2.7 V	3.3 V	
SWIR2 Vvideo	SBR	6.2 V	5.8 V	6.6 V	
SWIR2 ADC Ref	SBR	1.22 V	1.12 V	1.32 V	If ADC Ref is out of range then potentially all SWIR2 voltages are wrong

TIR Voltages	Resulting Mode	Nominal	Low Limit	High Limit	Comment
TIR VDDA	SBR	5 V	TBD	TBD	10% limit
TIR VDDL	SBR	3.3 V	TBD	TBD	10% limit
TIR VBUS	SBR	3.2 V	TBD	TBD	10% limit
TIR VFID	SBR	3.6 V	TBD	TBD	10% limit
TIR VSKIMMING	SBR	5.3 V	TBD	TBD	10% limit
TIR VEB	SBR	2.2 V	TBD	TBD	10% limit
TIR Vvideo	SBR	1.65 V	TBD	TBD	10% limit

TIR ADC Ref	SBR	1.22 V	TBD	TBD	10% limit

VTEMP	Resulting Mode	Nominal	Low Limit	High Limit	Comment
VNS VIS Detector Temperature	SBR	297 K	TBD	TBD	10% limit
VNS NIR Detector Temperature	SBR	297 K	TBD	TBD	10% limit
VNS SWIR1 Detector Temperature	SBR	297 K	TBD	TBD	10% limit
VNS SWIR2 Detector Temperature	SBR	230 K	TBD	TBD	10% limit
TIR Detector Temperature	SBR	299 K	TBD	TBD	10% limit

16 PACKET FORMAT

ICU_OBM-SSTL-335/ Information
The packet formats for the ICU sourced packet that go to the Satellite and the FEE sourced packets that go to the ICU are given below. The FEE packet format is based on the ICU packet format so the packet header decoding is the same.

16.1 ICU sourced packets

ICU_OBM-SSTL-337/ Information
There are 4 packet types which are Normal, Raw and Ancillary.

Instrument Source Packet					
Field Name	**Bits**	**Bytes**	**Value**	**Notes**	**Source**
Packet Information (Not part of sent packet)					
Total packet length	**6464**	**808**			
Packet Header					
Packet Identification					
Version Number	3	2	0		ICU
Type	1		0		ICU
Data Field Header Flag	1		1		ICU
PID	7		0x44		ICU
PCAT	4		See PCAT table	1	ICU
Packet Sequence Control					
Segmentation flag	2	2	0b11		ICU
Source Sequence Count	14		Incremental count		ICU
Packet length					
Packet length	16	2	801		ICU
Packet Data Field					
PUS Data Field Header					
Spare	1	1	0		ICU
PUS Version Number	3		1		ICU
Spare	4		0		ICU
Service Type	8	1	See Service Type table	2	ICU
Service Sub Type	8	1	1	3	ICU
Destination ID	8	1	0	4	ICU
Time				5	
Time Coarse	32	4	Coarse time value	6	ICU
Time Fine	24	3	Fine time value	7	ICU
Time Quality					
Spare	3	1	0		ICU
Time Type	1		0 = ET ; 1 = OBT		ICU
Sync Source	1		0 = Int ; 1 = Ext		ICU
Ext Sync. Source Detail	1		0 = 1 Hz Pulse ; 1 - MIL-Bus		ICU
Sync Status	1		0 = NoSync ; 1 = Sync		ICU
Synchronisation	1		0 = Disabled ; 1 = Enabled		ICU

	Instrument Data Field							
		Instrument Data Field header						
			S/C Quality Vector	32	4	As received from the S/C		ICU
			ISP Format Version	16	2	Fixed version number		ICU
		Instrument Data Field header extension						
			Data Source	5	1	See Data Source table	8	FEE/ICU
			Test data type	3		See Test data type table		FEE
			Spare	8	1	0	9	FEE
			MSI Quality vector	16	2	MSI Quality Value	10	FEE
			Spare	7	2	0	11	FEE
			Raw Line	9		Detector row or column	12	FEE
			Instrument Mode	8	1	Current instrument Mode		ICU
			Instrument Sub Mode	8	1	Current Instrument Sub Mode	13	ICU
			VNS Pointing Direction	3	1	See VNS Direction Table		ICU
			VNS Flat Field Offset Identifier	5		Offset Table ID	14	ICU
			TIR Pointing Direction	3	1	See TIR Direction Table		ICU
			TIR Flat Field Offset Identifier	5		Offset Table ID	15	ICU
			B1 Truncation Factor	3	3	See Truncation Table	16	ICU
			B2 Truncation Factor	3				ICU
			B3 Truncation Factor	3				ICU
			B4 Truncation Factor	3		Moved		ICU
			B7 Truncation Factor	3				ICU
			B8 Truncation Factor	3				ICU
			B9 Truncation Factor	3				ICU
			Ref Truncation Factor	3				ICU
			Spare	8	1	0	17	ICU
		Data						
			Pixel Values (384x16bits)	6144	768	16 bit Pixel/Ancillary Data		ICU
		CRC						
			CRC	16	2	Calculated CRC Value		ICU

Key:
- (green) ICU Software sets up this value
- (yellow) ICU hardware produces it
- (blue) FEE supplied information which is preserved

NOTES:

1 PCAT may be fixed at 12 for all packet types. SSTL in discussion with Astrum
2 Service type changes with Instrument sub mode changing from INS-NOM-OBS to INS-NOM-RAW
3 Always 1- Process data
4 Always for Ground
5 Time shall be captured as the Start pulse falling edge is sent to the FEE
6 LSB is 1 second
7 LSB is 1/16777215 of a second
8 Value filled in by FEE for all except Ancillary. ICU will over write when sending ancillary packet
10 Number of ADC readings over or under range
11 8 bits of Spare for FEE
12 Row is 0 to 287 for Raw data, Column is 0 to 383 for TIR Aux

13 When ICU is in OBS Sub Mode only B1,B2,B3,B4,B7,B8,B9,TIR Aux and Ancillary packets are generated.
When ICU is in RAW Sub Mode only VIS Raw, NIR Raw, SW1 Raw, SW2 RAW and TIR Raw packets are generated.
14 Number of the offset buffer used for the processing of VNS data.
15 Number of the offset buffer used for the processing of TIR data.
16 Expecting no truncation (0). Would be used if data truncation is required after offset subtraction to get data to fit 16 bits
17 8 bits spare for ICU may be used as Truncation factor extension if 4 bits used for each section

16.2 FEE sourced packets

ICU_OBM-SSTL-343/ Information
There is 1 packet type received from the FEE.

FEE Source Packet				
Field Name	**Bits**	**Bytes**	**Value**	**Notes**
Packet Information (Not part of sent packet)				
Total packet length	**9536**	**1192**		
Packet Header				
Packet Identification				
Version Number	3		0	
Type	1		0	
Data Field Header Flag	1	2	1	
PID	7		0x44	
PCAT	4		See PCAT table	
Packet Sequence Control				
Segmentation flag	2	2	0b11	
Source Sequence Count	14		Incremental count	
Packet length				
Packet length	16	2	1185	
Packet Data Field				
PUS Data Field Header				
Spare	1		0	
PUS Version Number	3	1	1	
Spare	4		0	
Service Type	8	1	See Service Type table	1
Service Sub Type	8	1	1	2
Destination ID	8	1	0	3
Time				4
Time Coarse	32	4	Coarse time value	5
Time Fine	24	3	Fine time value	6
Time Quality				
Spare	3		0	
Time Type	1		0	
Sync Source	1		0	
Ext Sync. Source Detail	1	1	0	
Sync Status	1		0	
Synchronisation	1		0	

Instrument Data Field				
Instrument Data Field header				
S/C Quality Vector	32	4	FEE version information	13
ISP Format Version	16	2	FEE version information	13
Instrument Data Field header extension				
Data Source	5	1	See Data Source table	7
Test data type	3		See Test data type table	
Spare	8	1	0	12
MSI Quality vector	16	2	MSI Quality Value	8
Spare	7	2	0	
Raw Line	9		Detector row or column	9
Instrument Mode	8	1	FEE mode	13
Instrument Sub Mode	8	1	0	
VNS Pointing Direction	3	1	0	
VNS Flat Field Offset Identifier	5		0	
TIR Pointing Direction	3	1	0	
TIR Flat Field Offset Identifier	5		0	11
B1 Truncation Factor	3	3	0	10
B2 Truncation Factor	3		0	
B3 Truncation Factor	3		0	
B4 Truncation Factor	3		0	
B7 Truncation Factor	3		0	
B8 Truncation Factor	3		0	
B9 Truncation Factor	3		0	
Ref Truncation Factor	3		0	
Spare	8	1	0	12
Data				
Pixel Values (384x24bits)	9216	1152	24 bit Pixel Data	
CRC				
CRC	16	2	Calculated CRC Value	

NOTES:

1 Private packet sent from FEE to ICU. Format same a ICU packet except data is 24 bits Service type changed to 235 to identify data is 24 bits
2 Always 1- Process data
3 Always for Ground
4 Time is captured as the Start pulse falling edge is sent to the FEE. Time from FEE power up
5 LSB is 1 second
6 LSB is 1/16777215 of a second
7 All values except Ancillary
8 Number of ADC readings over or under range
9 Row is 0 to 287 for Raw data, Column is 0 to 383 for TIR Aux
10 Moved to before spare
11 Number of the offset buffer used for the data processing.
12 8 bits moved
13 FEE Private data to be discarded by the ICU

16.3 Value Table

ICU_OBM-SSTL-350/ Information

The values for the fields are given below.

Value	PCAT
12	Nominal
13	Raw

Value	Service Type
235	MSI Science Data Service

Value	Service Sub Type
1	Processed Data
65	Raw Data

ICU_OBM-SSTL-354/ Information
Service sub type used to define the pointing of the two instruments. During calibration the ICU will have to update this field as the mechanism is moved. This will require updating within a ground line interval as only one instrument will be in the calibration cycle while the other is on Earth view. The VNS dark and TIR space packets will contain the data used for offset table generation if requested.

Value	Instrument Mode	Description
0	<Invalid>	Never used
1	INS-OFF	Instrument off
2	INS_LAU	Launch Instrument (will be off)
3	INS-INI	Initialise
4	INS-SBY	Standby
5	INS-SBR	Standby Refuse
6	INS-IDLE	Idle
7	INS-IDR	Idle Refuse
8	INS-NOM	Normal
9	INS-DEC	Decontamination

Value	Instrument Sub Mode
0	<Invalid>
1	INS-NOM-OBS
2	INS-NOM-RAW
3	INS-NOM-OBS-TNADIR
4	INS-NOM-OBS-TCS
5	INS-NOM-OBS-TBB
6	INS-NOM-OBS-VNADIR
7	INS-NOM-OBS-VSD1
8	INS-NOM-OBS-VSD2
9	INS-NOM-OBS-VDK

Value	Data Source
0	<Invalid>
1	Band 1
2	Band 2
3	Band 3
4	Band 4

5	Band 7
6	Band 8
7	Band 9
8	Reference
9	Aux Raw
10	VIS Raw
11	NIR Raw
12	SW1 Raw
13	SW2 Raw
14	TIR Raw

ICU_OBM-SSTL-358/ Information
The data source has separate values for the processed and unprocessed raw data for example Band 1 normal data and VIS Raw both come from the VIS detector. This allows the FEE to indicate the data source fully by only using this field. A 5 bit field is allocated allowing 31 data sources to be defined.

ICU_OBM-SSTL-359/ Information
There are the following restrictions.

PCAT Nominal	Data source values are 1 to 9
PCAT Raw	Data source values are 10 to 14

ICU_OBM-SSTL-360/ T
Aux Raw is used to confirm that the FEE is processing the pixel data correctly by allowing the independent calculation of some of the process pixel values. It is included in PCAT Nominal as the Band and reference data will be required to do the comparison. The ICU shall handle Aux Raw when commanded.

ICU_OBM-SSTL-361/ Information
Vis Raw, NIR Raw, SW1 Raw, SW2 Raw and TIR Raw data is used to check detector performance and look for bad pixels on the TIR detector and is designated as Raw.

Value	**Test**
0	Normal data
1	Test pattern LBR Incremental
2	Test pattern LBR Pseudo random sequence
3	Test pattern Detector Incremental
4	Test pattern Detector Pseudo random sequence

ICU_OBM-SSTL-363/ T
There are up to 7 Test patterns allowed. The FEE will set this field when test pattern output is requested by setting the associated FEE register. The ICU shall be able to write to this register.

Value	**Truncation Factor**
0	0
1	2
2	4
3	8
4	16
5	32
6	64
7	128

ICU_OBM-SSTL-365/ Information
This field gives the amount the data has been divided by to truncate the data to fit 16 bits. The value is expected to be 0 as no truncation is expected. A 3 bit field is allocated allowing 8 values.

ICU_OBM-SSTL-366/ T
Flat Field Offset Identifier ID is a number in the range 0 to 31 which identifies the Flat field used. The ICU shall provide the ability to handle this Flat Field Offset.

ICU_OBM-SSTL-367/ Information
For the Instrument Source Packet - Normal Data it is the Flat Field Offset table identifier used to generate the 16 bit pixel data.

ICU_OBM-SSTL-368/ Information
For the Instrument Source Packet - Offset Data it is the Flat Field Offset table identifier for the data in the packet, which along with the Data Source value uniquely identified the data.

APPENDIX 1 –

Extracted pages from EC.ICD.TNO.MSI.00281 Issue 4.1 Motor and position sensor information

5.7 Electrical power

5.7.1 Calibration mechanism actuator

5.7.1.1 Motor electrical information

The Calibration mechanism actuator receives its power from the MSI ICU. The actuator is an internally redundant two phase stepper motor of type: PHYTRON VSS43.200.0.6.

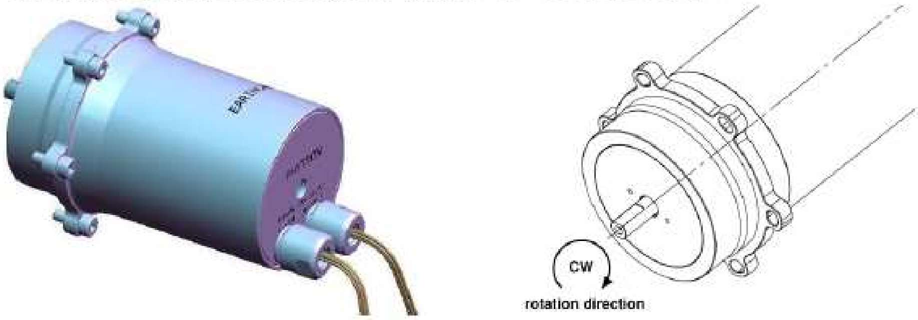


figure 5-12: Phytron VSS43 actuator

Important: The MSI stepper control shall be able to deliver > 0.6A at any circumstance

Table 5-3: Typical Voltage and load characteristics

Performance (electrical)	Value
Motor type	Two-phase stepper
Motor drive current	0.6A
Coil back-emf	20Hz / ½ step → 3.6V – 7,7…8.6 mA
Coil inductance / phase	46 ±20%[mH]
Coil resistance / phase[Ohm]	19 ±10%[Ohm]
Dielectric strength (between cage and windings)	>500V at 50Hz
Dielectric strength (between windings)	>500V at 50Hz
Isolation (between cage and windings)	>100 MΩ at 250V
Magnetic moment	<0.1 Am²
Phase capacity	Typical<500pf
Pulse frequency (half step mode)	20 Hz
Driving mode	Micro stepping (1/16 or 1/32 step)
Maximum step rate	TBD
Electrical redundancy	Yes
Minimum Motor Voltage	24.0V
Controller type	Speed ramping and micro Step capable with loadable acceleration profile.

Detailed information can be found in phytron EIDP's [RD-26] [RD-27] [RD-28] [RD-29]

5.7.1.2 Motor Phase information

Normal (main) motor is connected to J21(JV3):
pin 6 attached to A
pin 7 attached to E
pin 8 attached to F
pin 9 attached to D

Redundant motor windings are connected to J22(JV4):
pin 6 attached to G
pin 7 attached to B
pin 8 attached to C
pin 9 attached to H

According to the phytron ICD this means:

sequence table normal motor					sequence table redundant motor				
CW	A yellow	E black	F white	D green	CW	G brown	B red	C blue	H violet
Step	A+	A-	B+	B-	Step	A+	A-	B+	B-
1	+	-	+	-	1	+	-	+	-
2	+	-	-	+	2	+	-	-	+
3	-	+	-	+	3	-	+	-	+
4	-	+	+	-	4	-	+	+	-
	Phase-1		Phase-2			Phase-1		Phase-2	

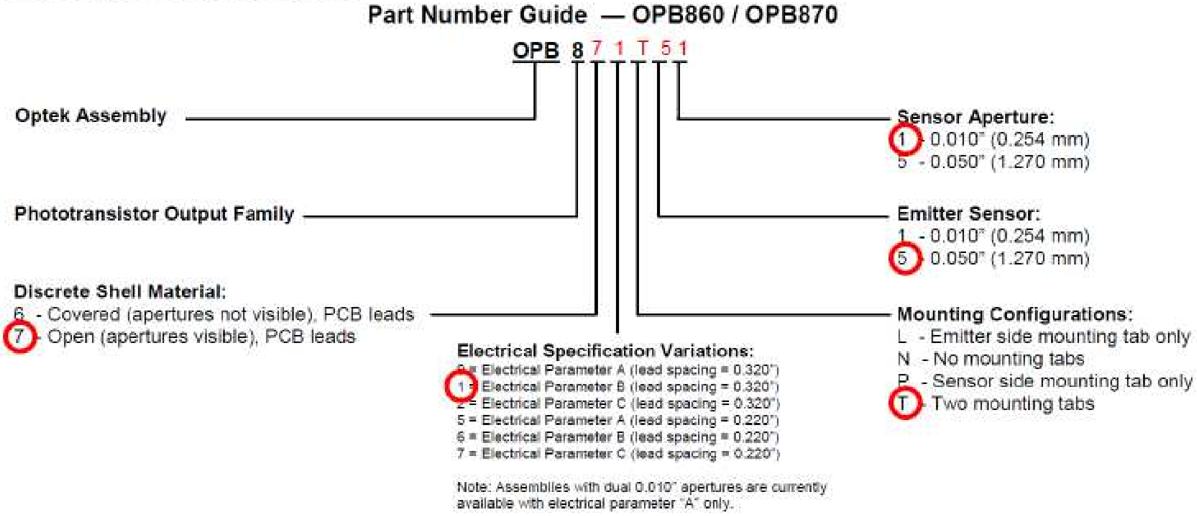
5.7.2 Position sensors

Table 5-4: CMA position sensors

Description	Manufacturer	Part number	Reference specification
Micro switch	Honeywell	JS-151 (RA.1604.001.11)	RD-25
Optical switch	OPTEK	OPB871 T 51 TXV	ANNEX II OPTEC Optical slotted switch OPB871

ANNEX II OPTEC Optical slotted switch OPB871

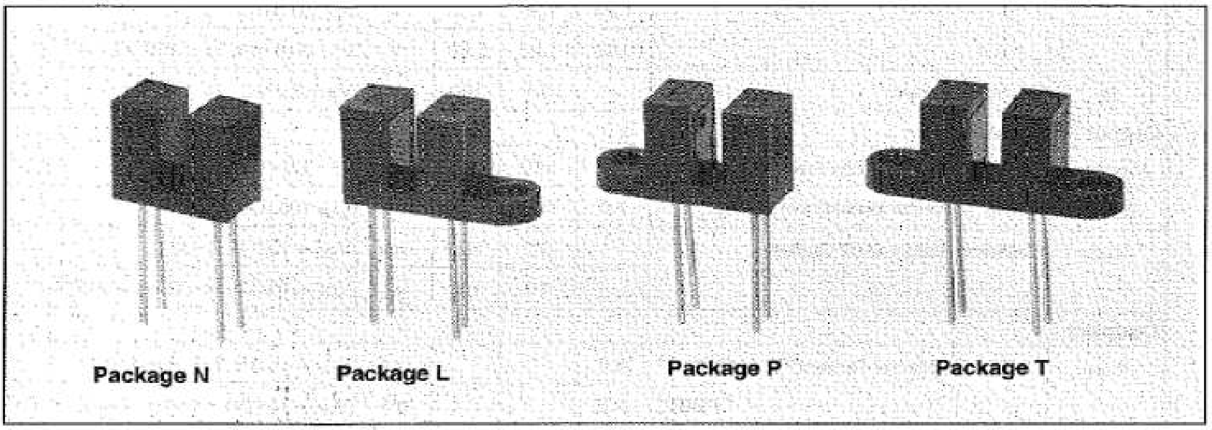
The OPTEC datasheet is a common one for the OPB870-series. By filling in the x-es one can choose for a dedicated type:



On the following pages screenshots from a datasheet stemming from 1996:
http://www.optekinc.com/datasheets/OPB871T51TXV.pdf

Product Bulletin OPB870
September 1996

Hi-Rel Slotted Optical Switches
Types OPB870N, OPB870L, OPB870P, OPB870T Series



A more recent version containing generic 870-data is found at:
http://www.optekinc.com/datasheets/OPB859.pdf

Features

- Non-contact switching
- Choice of apertures
- Choice of minimum $I_{C(ON)}$
- Hermetically sealed components
- Components processed to Optek's screening program patterned after MIL-PRF-19500 for TX and TXV devices
- S level processing available
- Plastic meets NASA publication 1124

Description

The OPB870 series slotted optical switch consists of a gallium aluminum arsenide LED and a silicon phototransistor soldered into a printed circuit board then mounted in a high temperature plastic housing on opposite sides of a 0.125 inch (3.18 mm) wide slot. Phototransistor switching takes place whenever an opaque object passes through the slot. Options include phototransistor aperture widths of 0.050 inches (1.27 mm) or 0.010 inches (0.25 mm) for high resolution positioning sensing.

The OPB870 hi-rel series uses optoelectronic components that have been processed and tested as either TX or TXV components per MIL-PRF-19500. Typical screening and lot acceptance tests are provided on page 13-4.

Absolute Maximum Ratings ($T_A = 25^\circ$ C unless otherwise noted)

Operating Temperature Range .... -65° C to +125° C
Storage Temperature Range .... -65° C to +150° C
Lead Soldering Temperature [1/16 inch (1.6 mm) from case 5 sec. with soldering iron] .... 240° C

Input Diode

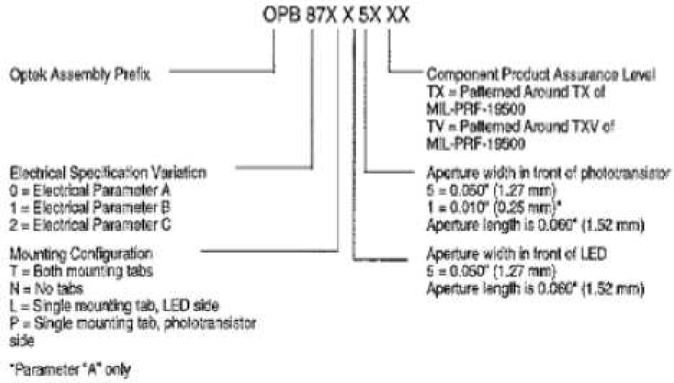
Forward DC Current .... 50 mA
Reverse Voltage .... 2.0 V
Power Dissipation .... 100 mW[2]

Output Phototransistor

Collector-Emitter Voltage .... 50 V
Emitter-Collector Voltage .... 7.0 V
Power Dissipation .... 100 mW[2]

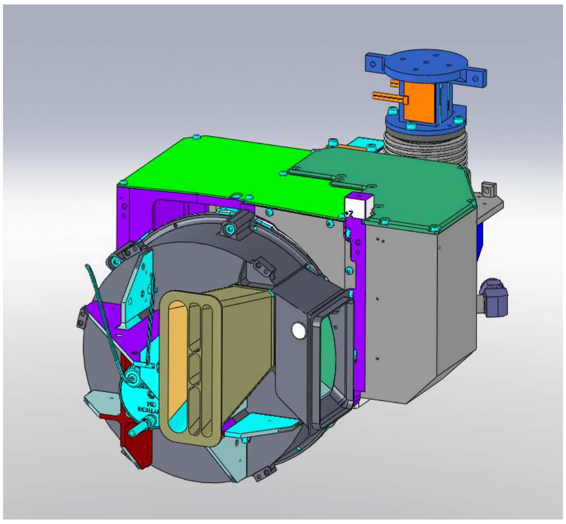
Notes:
(1) Duration can be extended to 10 sec. max. when flow soldering.
(2) Derate linearly 1.00 mW/° C above 25° C.
(3) Methanol or isopropanol are recommended as cleaning agents.

Part Number Guide

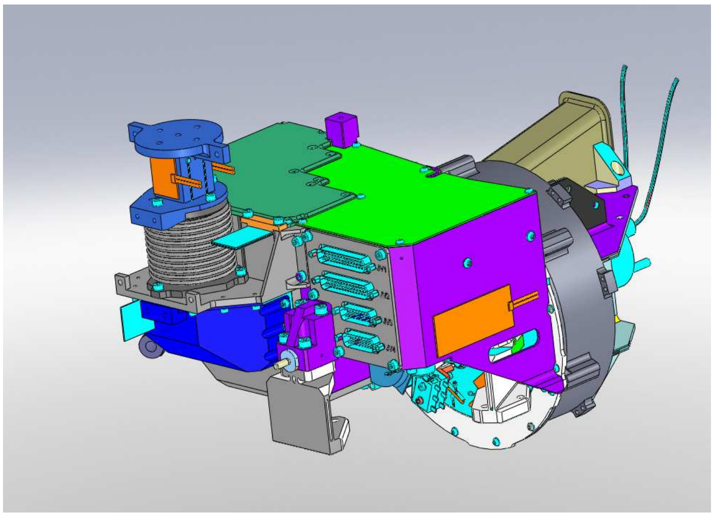


Extracted pages from EC.ICD.TNO.MSI.00281 Issue 4.1 Encoder information

The VNS encoder is part of the calibration mechanism assembly (VNS CMA). Below are two illustrations of the VNS

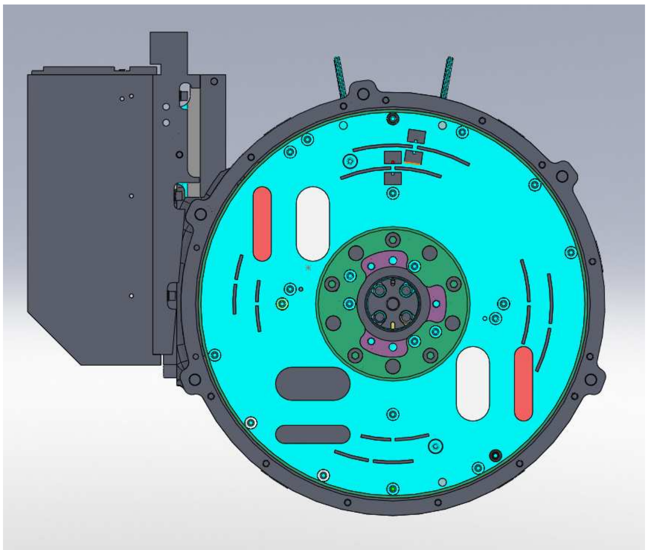


VNS viewed from Earth



VNS viewed from anti-Earth side

The VNS Z-axis definition is positive towards nadir (Earth), so the following sectioned figure is defined viewed from the anti-Earth side. This is applicable to Fig 5-24 from the TNO document extracts.



+Z in to plane of diagram

5.12 Calibration Mechanism Position Control Interface

5.12.1 Operation

Two cycles are implemented to prevent reference calibration diffusers to be exposed to space more than 1 time a month.

- Cycle 1 performed every orbit: A-B-C-A
- Cycle 2 performed once a month: A-D-C-A

Detectable orientations
A) Nadir open
B) Daily calibration
C) Nadir closed (dark calibration)
D) Monthly calibration

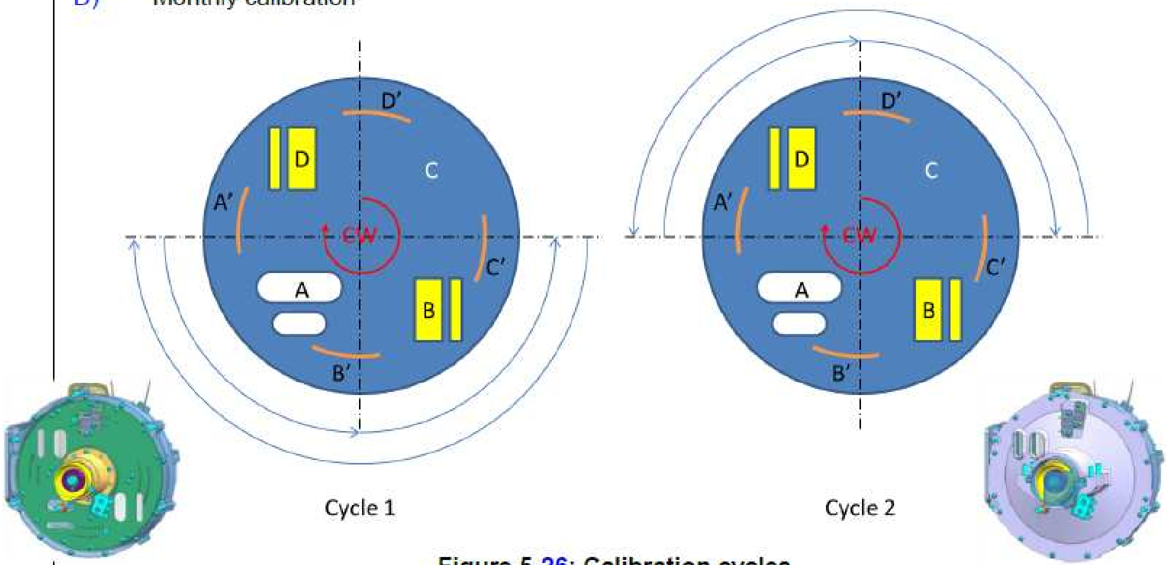


Figure 5-26: Calibration cycles

Table 5-12: Cycle steps

Cycle 1

Step	Movement	Duration
1.	A to B (+90°)	5 seconds
2.	Stop at B	10 minutes
3.	B to C (+90°)	5 seconds
4.	Stop at C	20 minutes
5.	C to A (-180°)	10 seconds
6.	Stop at A	60 minutes

Cycle 2

Step	*Movement*	*Duration*
1.	*A to D (-90°)*	*5 seconds*
2.	*Stop at D*	*10 minutes*
3.	*D to C (-90°)*	*5 seconds*
4.	*Stop at C*	*20 minutes*
5.	*C to A(+180°)*	*10 seconds*
6.	*Stop at A*	*60 minutes*

Position Control by the ICU - Clockwise rotation from A to B gives 6 sensor pulses followed by 7 pulses

5.12.2 Position control by the ICU

The position of the VNS calibration carousel is determined by using one main and one redundant optical switch. These optical switches look through two concentric segmented rings, one optical switch per ring.(Daily calibration is also referenced as orbital calibration)

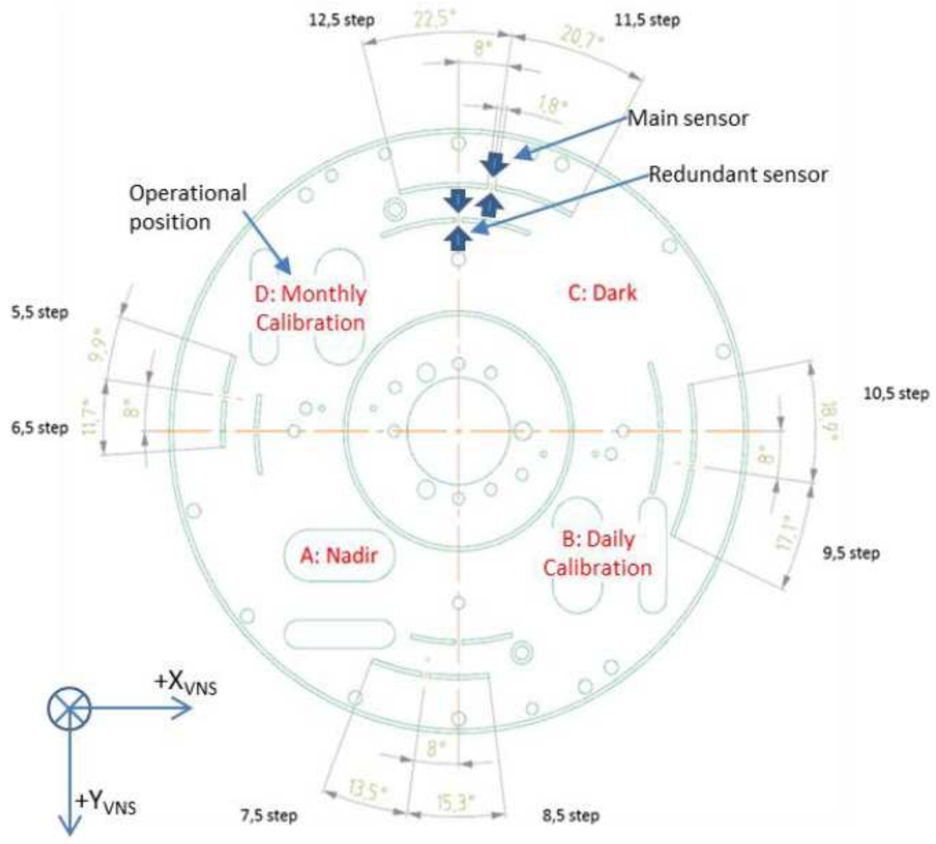


Figure 5-27: Segmented rings and optical switches

5.12.3 Design parameters

Design parameter	*Value*
Actuator full steps #	200 / revolution
Actuator full step size	1.8 deg = 2 mm @ radius for the main ring
Main segmented ring diameter	119 mm
Redundant segmented ring diameter	102 mm
Optical switch	1 main, 1 redundant
Angular position accuracy	0.5 degrees

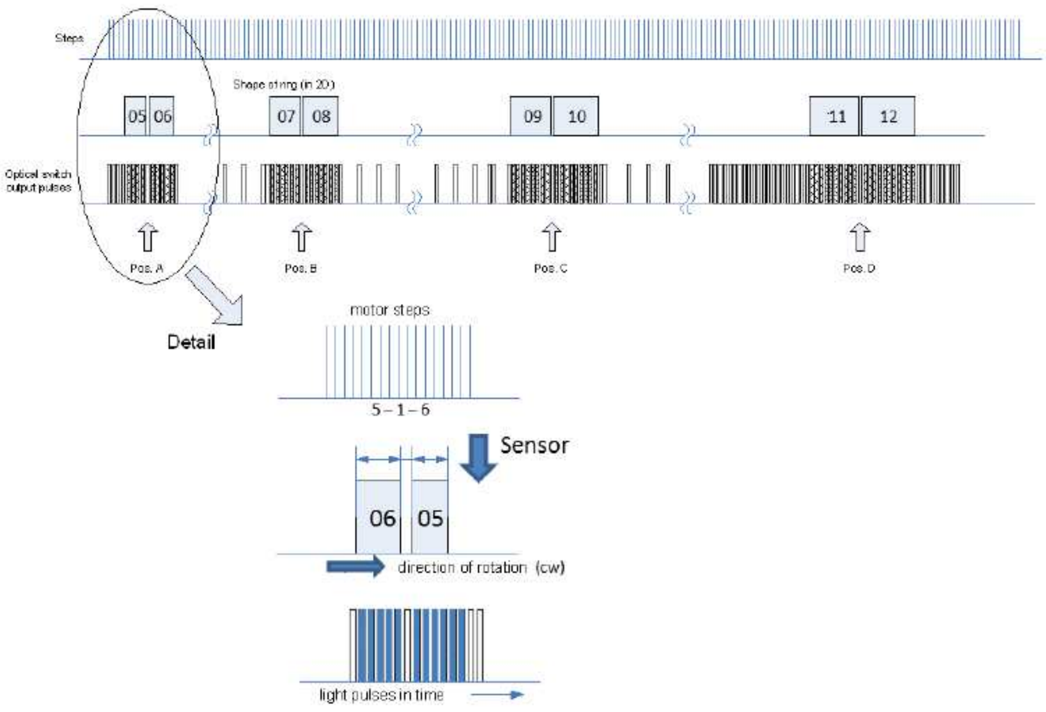


Figure 5-28: Shape of the main segmented ring and visualization of the light pulses

5.12.4 Sensing functions

- Count steps and sense amount of light-dark sequences
- Determine position based on logic
- Adapt orientation to final position (at full step)
- Detection of number of dark pulses to position can be used to verify the direction of rotation (1 ≤ n ≤ 4):
  - Clockwise rotation: 3 + n x 2
  - Counter clockwise: 4 + n x 2

5.12.5 Micro-stepping

The slot is one step wide, micro-stepping minimizes the chance that a target position is missed.

5.12.6 Redundancy

When the redundant optical switch is active, different circle sections must be read out as the redundant optical switch is located on a different position as the main one. These sections have the same angular width, but are placed on a different radius, preventing an off-set error between the main and the redundant optical switch signals.

5.12.7 Position measurement by the S/C

When the VNS is not active, S/C must be able to assess the position of the calibration mechanism. For this purpose two micro switches (one main and one redundant) are installed.

- The micro switches are operated by a detent placed on a shaft. Refer to Figure 1 3.
- The micro switches are not used during nominal operation of the VNS and do not require an I/F with the ICU.
- The detent marks the safe position (Nadir closed). In that position, the micro switches are closed, giving a positive indication of the safe state of the VNS calibration mechanism.
- The micro-switch shows a difference in friction depending on the rotational direction.

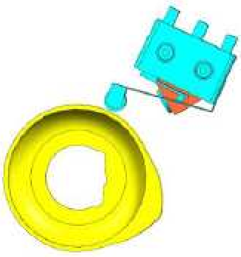


Figure 5-29: Shaft with micro switches