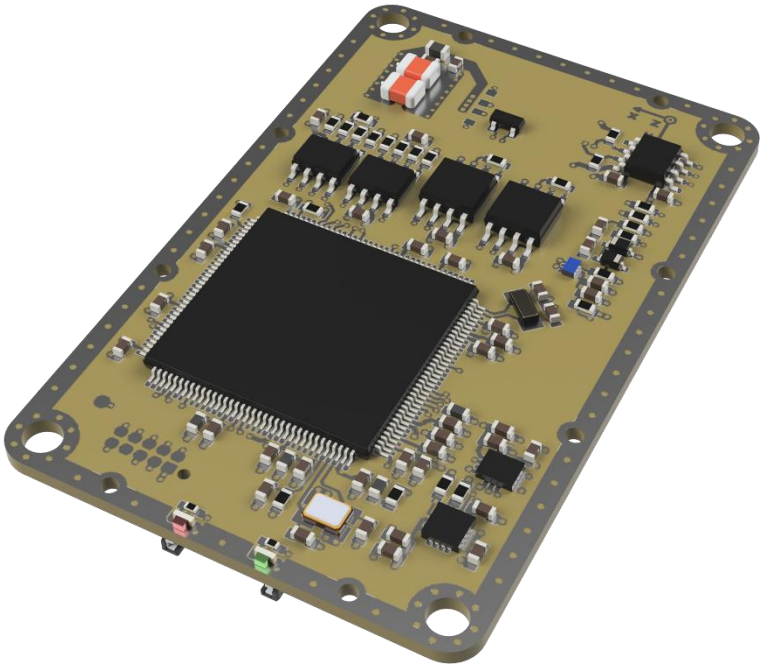

DEEP THOUGHT OBC

DATASHEET

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GLOSSARY

CAN	Controller Area Network
CDHS	Command Data Handling System
CSP	Cubesat Space Protocol
FRAM	Ferroelectric RAM
IC	Integrated Circuit
I^2C	Inter Integrated Circuit
KISS	"Keep It Simple, Stupid" (popular radio amateur protocol)
MCU	Micro Controller Unit
OBC	On-Board Computer
RS485	Differential bus standard
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter

1 PRODUCT OVERVIEW

Deep Thought an On-Board Computer suitable for small satellite applications in role of main satellite computer or as a specific payload computer. The module is based on Microchip SAMV71Q21 32-bit Arm Cortex M7 based micro-controller. This micro-controller is compatible with various RTOS systems. The module also integrates an on-board gyroscope, accelerometer and magnetometer sensors. Besides MSU's FLASH memory for program itself two external memory systems are integrated on-board the module. A Flash based memory array consisting of 4x 32MiB ICs, and an FRAM based memory array consisting of 3x 1MiB ICs.

Two options are available:

- Engineering model integrating consumer grade MCU
- Flight model integrating radiation tolerant MCU (SAMV71Q21**RT**)

Flight heritage on 10+ missions (e.g. LASARsat, CroCube, Planetum-1 and external customers).

2 TECHNICAL SPECIFICATION

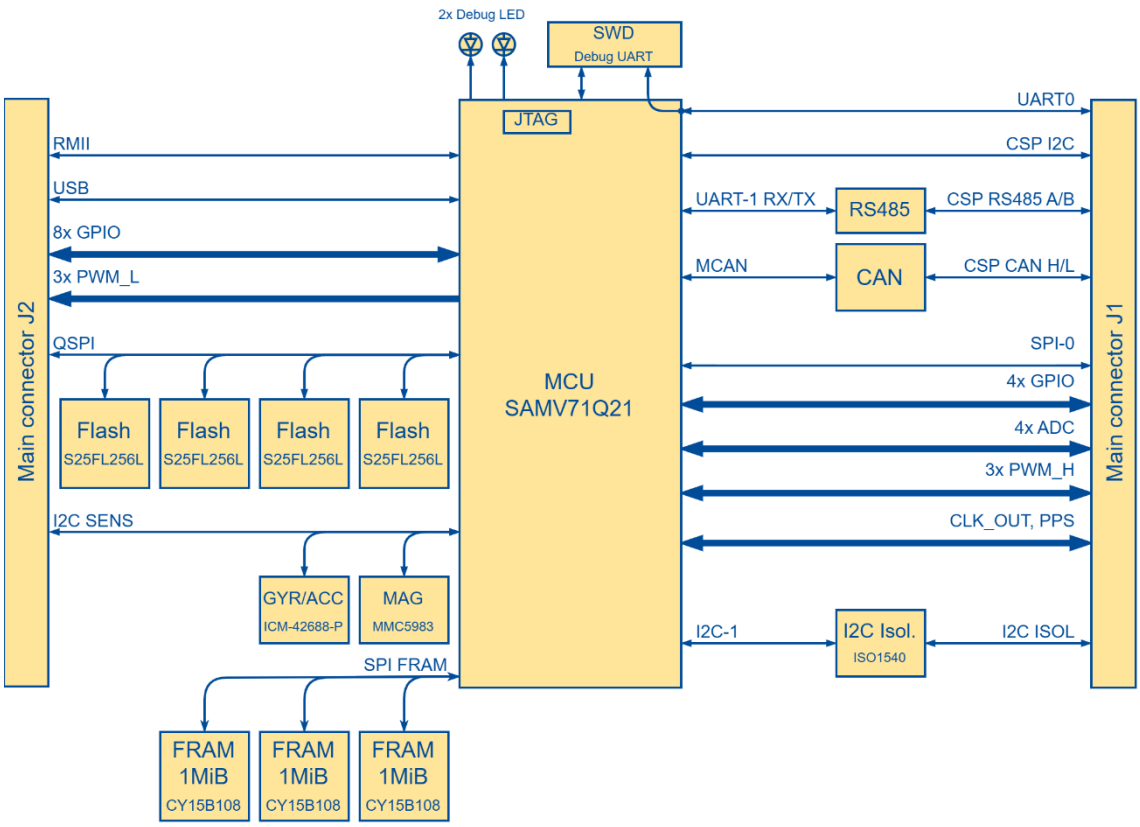

Figure 2-1: DeepThought OBC v2b block diagram

Table 2-1: Technical specification

Parameter	Value	Unit
Operating Temperature	-40 to +85	°C
Dimensions	67 x 42 x 7	mm
Mass	25	g
Power Supply	3.3V	V
Power Consumption - average	330	mW
Power Consumption - peak	<500	mW

Note: Power consumption is directly proportional to implemented software. Presented specification represents typical usage in Spacemanic applications on CSP based satellite buses.

Table 2-2: Key OBC parameters

Parameter	Value	Unit
MCU	SAMV71Q21	
HF Crystal	16	MHz
LF Crystal	32.768	kHz
Data storage external FRAM	3 x 1	MiB
Data storage external Flash	4 x 32	MiB
Operating system	FreeRTOS (alt. Custom)	
On-board magnetometer	MMC5983	
On-board gyroscope & accelerometer	ICM-42688-P	

Table 2-3: Overview of interfaces

Interface	Description
UART-0	Typically implements plain text CLI. Available on both debug and main connectors.
CSP I^2C	CSP over I^2C bus. Speed up to 400 kHz
CSP RS485	CSP over RS485 KISS. Speed up to 115200 Baud rate. Higher speeds possible with software optimizations.
CSP CAN	CSP over CAN. Speed up to 1 Mbit/s
I^2C-SENS	Connects to on-board sensors. Speed up to 400kHz
SPI-MEM	Internal only. Connects to on-board FRAM memories. Typical speed is 40 MHz. Higher possible with software optimization.
QSPI-MEM	Connects to on-board Flash memories. Typical speed is 40 MHz. Higher possible with software optimization.
I^2C-ISOL	Isolated plain I^2C bus, typically used for external sensors. Speed up to 400 kHz.
SPI-0	External SPI for sensor interfacing. Typical speed is 40 MHz. Higher possible with software optimization.
ADC	>5 x 12bit with 3.3 V range. (See pin table)
PWM	3 x 3.3 V range available as High or Low signal.
GPIO	Up to 18 x 3.3 V range. Shares pins with SPI-0, ADC, PWM.

3 INTERFACES

3.1 ELECTRICAL

Table 3-4: Electrical characteristics

Parameter	Min.	Typ.	Max.	Unit
Power Input	3.0	3.3	+3.6	V
Current draw (3.3 V)	-	100	120	mA
Current draw (5 V)	-	-	-	mA
GPIO Level (including comm. Buses)	-0.2	3.3	+3.6	V

Note: Since most communication buses and GPIO are connected directly to the MCU, for more details on ratings refer to SAMV71Q21 documentation and main connectors J1 & J2 documentation.

3.1.1 PROGRAMMING AND DEBUG INTERFACE

Programming is done by a SWD/JTAG interface on the front facing debug connector. Also present is Debug UART (UART-0).

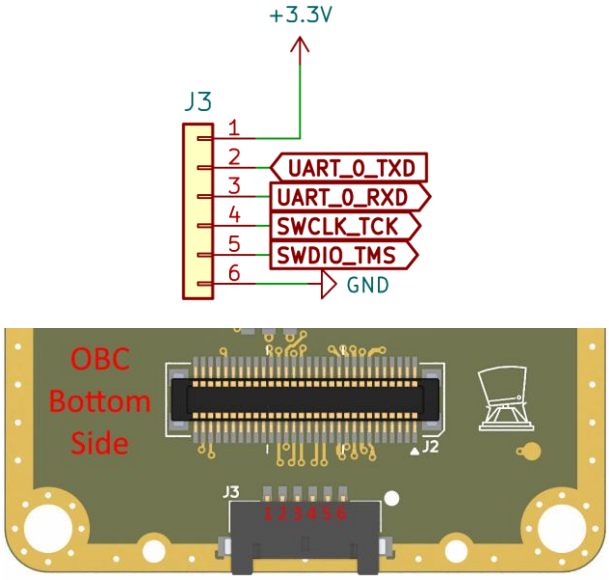

Figure 3-2: Programming connector

Table 3-5: Main connector reference

Connector	Type
Programming (on module)	Molex PicoLock 503763-0691
Programming (on motherboard)	Molex PicoLock 503764-0601 (crimp housing)

It is **NOT** recommended to use the programming connector as the power supply of the OBC module.

3.1.2 MAIN CONNECTORS

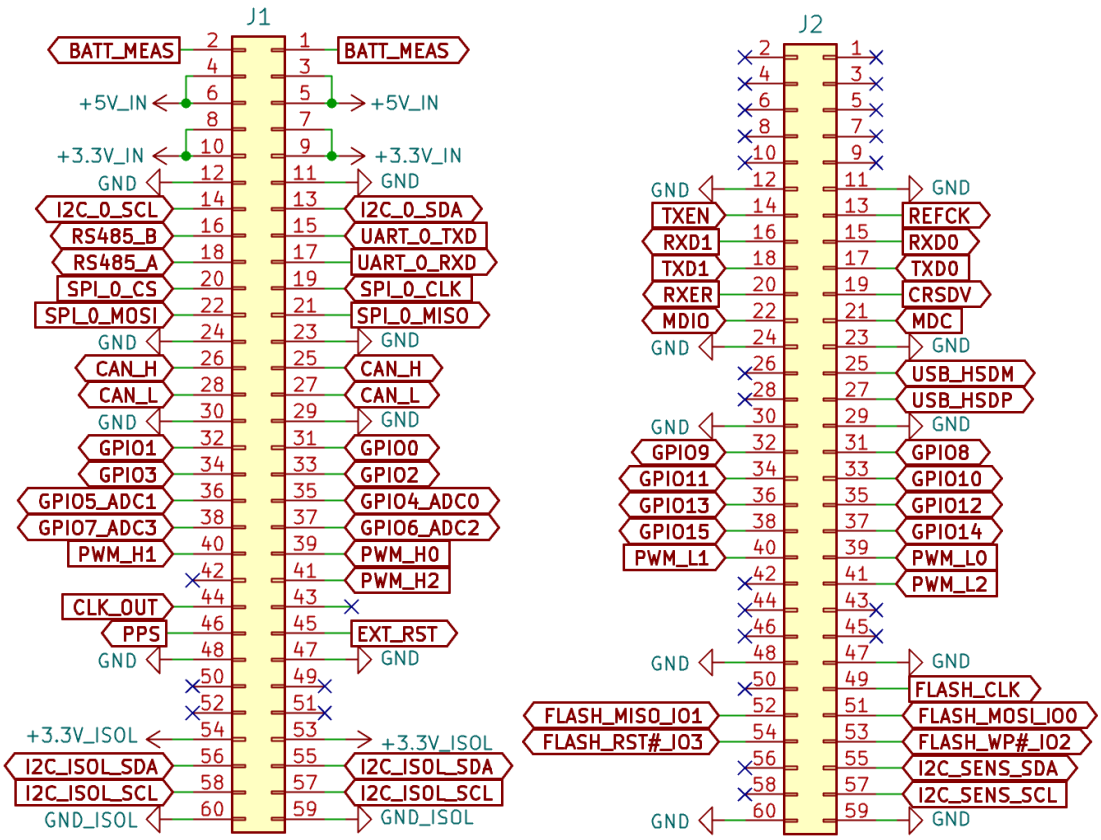

Figure 3-3: Main connectors (J1 & J2)

Table 3-6: Main connector reference

Connector	Type
Main J1 (on module)	Molex SlimStack 55650-0688
Main J1 (on motherboard)	Molex SlimStack 54363-0689

Table 3-7: Pin description of the main DeepThought connector J1

PN	Schematic name	Alt. functions	Pin attributes *	Notes
1	BATT_MEAS	GPIO Analog In PWM	PC0 AFE1_AD9 PWMC0_PWML0	Reserved for battery measurement. Analog input in 0-3.3V range.
2	BATT_MEAS	GPIO Analog In PWM	PC0 AFE1_AD9 PWMC0_PWML0	See PN 1.
3	+5V_IN	-	-	Not connected
4	+5V_IN	-	-	See PN 3.
5	+5V_IN	-	-	See PN 3.
6	+5V_IN	-	-	See PN 3.
7	+3.3V_IN	-	-	Board power supply.
8	+3.3V_IN	-	-	See PN 7.
9	+3.3V_IN	-	-	See PN 7.
10	+3.3V_IN	-	-	See PN 7.
11	GND	-	-	
12	GND	-	-	
13	I2C_0_SDA	-	PA3 TWD0	Intended as main communication bus, e.g. CSP.
14	I2C_0_SCL	-	PA4 TWCK0 WKUP3 TCLK0 UTXD1	Intended as main communication bus, e.g. CSP.
15	UART_0_TXD	-	PA10 UTXD0 PWMC0_PWMEXTRG	Shared with Debug/Programming connector.
16	RS485_B	-	-	Intended as main communication bus, e.g. CSP.
17	UART_0_RXD	-	PA9 URXD0 WKUP6 PWMC0_PWMFI0	Same as Programming and Debug connector.
18	RS485_A	-	-	Intended as main communication bus, e.g. CSP.
19	SPI_0_CLK	GPIO	PWMC0_PWMH2 SPI0_SPCK TIOB11	
20	SPI_0_CS	GPIO	PWMC0_PWML1 SPI0_NPCS1 URXD2	
21	SPI_0_MISO	GPIO	PWMC0_PWMH0 SPI0_MISO	
22	SPI_0_MOSI	GPIO	PWMC0_PWMH1 SPI0_MOSI TIOA11	
23	GND	-	-	
24	GND	-	-	
25	CAN_H		-	

PN	Schematic name	Alt. functions	Pin attributes *	Notes
26	CAN_H		-	
27	CAN_L		-	
28	CAN_L		-	
29	GND		-	
30	GND		-	
31	GPIO0		PC16	
32	GPIO1	PWM UART	PB13 WKUP4 PWMC1_PWML3 URXD1	
33	GPIO2	PWM	PC18 PWMC0_PWML1	
34	GPIO3	UART	PA6 UTXD1	
35	GPIO4_ADC0	GPIO	PA18 AFE0_AD7 PWMC1_PWMEXTRG	
36	GPIO5_ADC1	GPIO PWM	PA19 AFE0_AD8 WKUP9 PWMC0_PWML0	
37	GPIO6_ADC2	GPIO	PA21 AFE0_AD1 PWMC1_PWMFI0	
38	GPIO7_ADC3	GPIO PWM	PA20 AFE0_AD9 WKUP10 PWMC0_PWML1	
39	PWM_H0	GPIO	PA23 PWMC0_PWMH0 PWMC1_PWML2	
40	PWM_H1	GPIO	PA24 PWMC0_PWMH1	
41	PWM_H2	GPIO	PA25 PWMC0_PWMH2	
42	-	-	-	
43	-	-	-	
44	CLK_OUT	GPIO	PA1 WKUP1 PWMC0_PWML0 TIOB0	
45	EXT_RST		-	Reserved for future use. Do not connect.
46	PPS	GPIO	PE4 AFE0_AD4 TIOB10	Reserved for use as 1 pulse per second input for time synchronization, when using with Spacemanic Celeste GNSS module.
47	GND		-	
48	GND		-	
49	-		-	
50	-		-	
51	-		-	

PN	Schematic name	Alt. functions	Pin attributes *	Notes
52	-		-	
53	+3.3V_ISOL		-	Needs to be powered externally for the I2C isolator to work!
54	+3.3V_ISOL		-	Needs to be powered externally for the I2C isolator to work!
55	I2C_ISOL_SDA		-	Reserved for non-CSP use, can be reconfigured at the cost of losing secondary I2C bus (GPIO open drain to GND, pulled high, input/output)
56	I2C_ISOL_SDA		-	Reserved for non-CSP use, can be reconfigured at the cost of losing secondary I2C bus (GPIO open drain to GND, pulled high, input/output)
57	I2C_ISOL_SCL		-	Reserved for non-CSP use, can be reconfigured at the cost of losing secondary I2C bus (GPIO open drain to GND, pulled high, input/output)
58	I2C_ISOL_SCL		-	Reserved for non-CSP use, can be reconfigured at the cost of losing secondary I2C bus (GPIO open drain to GND, pulled high, input/output)
59	GND_ISOL		-	Needs to be grounded externally for the I2C isolator to work!
60	GND_ISOL		-	Needs to be grounded externally for the I2C isolator to work!

* (MCU datasheet https://ww1.microchip.com/downloads/aemDocuments/documents/MCU32/ProductDocuments/DataSheets/SAM-E70-S70-V70-V71-Family-Data-Sheet-DS60001527.pdf)

Color coding:

Reserved for payload, free to use and reconfigure.

Reserved for specified use, can be reconfigured if needed.

Not configurable, specified by hardware.

Table 3-8: Pin description of the extension DeepThought connector J2

PN	Schematic name	Alternative functions	Pin attributes *	Notes
1	-	-	-	
2	-	-	-	
3	-	-	-	
4	-	-	-	
5	-	-	-	
6	-	-	-	
7	-	-	-	
8	-	-	-	
9	-	-	-	
10	-	-	-	
11	GND	-	-	
12	GND	-	-	
13	REFCK	GPIO DAC PWM	PD0 DAC1 GTXCK, PWMC1_PWML0 SPI1_NPCS1	GMAC peripheral (Ethernet) with external transceiver circuitry.
14	TXEN	GPIO PWM	PD1 GTXEN, PWMC1_PWMH0	GMAC peripheral (Ethernet) with external transceiver circuitry.
15	RXD0	GPIO PWM	PD5 GRX0, PWMC1_PWMH2	GMAC peripheral (Ethernet) with external transceiver circuitry.
16	RXD1	GPIO PWM	PD6 GRX1, PWMC1_PWML3	GMAC peripheral (Ethernet) with external transceiver circuitry.
17	TXD0	GPIO PWM	PD2 GTX0 PWMC1_PWML1	GMAC peripheral (Ethernet) with external transceiver circuitry.
18	TXD1	GPIO PWM	PD3 GTX1, PWMC1_PWMH1	GMAC peripheral (Ethernet) with external transceiver circuitry.
19	CRSDV	GPIO PWM	PD4 GRXDV PWMC1_PWML2	GMAC peripheral (Ethernet) with external transceiver circuitry.
20	RXER	GPIO PWM	PD7 GRXER, PWMC1_PWMH3	GMAC peripheral (Ethernet) with external transceiver circuitry.
21	MDC	GPIO	PD8 GMDC PWMC0_PWMFI1	GMAC peripheral (Ethernet) with external transceiver circuitry.
22	MDIO	GPIO	PD9 GMDIO PWMC0_PWMFI2 AFE1_ADTRG	GMAC peripheral (Ethernet) with external transceiver circuitry.
23	GND	-	-	
24	GND	-	-	

PN	Schematic name	Alternative functions	Pin attributes *	Notes
25	USB_HSDM	-	-	
26	-		-	
27	USB_HSDP	-	-	
28	-	-	-	
29	GND	-	-	
30	GND	-	-	
31	GPIO8	PWM	PWMC0_PWML2	
32	GPIO9	CAN	TCLK8 CANTX1	
33	GPIO10	Analog In UART	AFE0_AD10 RTCOUT0 PWMC0_PWMH0 RXD0	
34	GPIO11	Analog In CAN	AFE1_AD3 TIOB8 CANRX1	
35	GPIO12	Analog In UART	AFE1_AD0 RTCOUT1 PWMC0_PWMH1 TXD0	
36	GPIO13	PWM	WKUP7 PWMC0_PWMH0 PWMC1_PWML0	
37	GPIO14	DAC PWM	DAC0 PWMC0_PWML2	
38	GPIO15	PWM	WKUP2 PWMC0_PWMH1	
39	PWM_L0	GPIO	PC1 PWMC0_PWML1	Reverse polarity of PWM_H0. See J1-39.
40	PWM_L1	GPIO	PC2 PWMC0_PWML2	Reverse polarity of PWM_H1. See J1-40.
41	PWM_L2	GPIO	PC3 PWMC0_PWML3	Reverse polarity of PWM_H2. See J1-41.
42	-	-	-	
43	-	-	-	
44	-	-	-	
45	-	-	-	
46	-	-	-	
47	GND	-	-	
48	GND	-	-	
49	FLASH_CLK	-	PA14 QSCK	SPI/QSPI bus to on-board memories
50	-	-	-	
51	FLASH_MOSI_IO0	-	PA13 QIO0	SPI/QSPI bus to on-board memories
52	PLASH_MISO_IO1	-	PA12 QIO1	SPI/QSPI bus to on-board memories

PN	Schematic name	Alternative functions	Pin attributes *	Notes
53	FLASH_WP#_IO2	-	PA17 QIO2	SPI/QSPI bus to on-board memories
54	FLASH_RST#_IO3	-	PD31 QIO3	SPI/QSPI bus to on-board memories
55	I2C_SENS_SDA	-	PB4 TWD1	I2C bus to on-board sensors
56	-	-	-	
57	I2C_SENS_SCL	-	PB5 TWCK1	I2C bus to on-board sensors
58	-	-	-	
59	GND	-	-	
60	GND	-	-	

* (MCU datasheet https://ww1.microchip.com/downloads/aemDocuments/documents/MCU32/ProductDocuments/DataSheets/SAM-E70-S70-V70-V71-Family-Data-Sheet-DS60001527.pdf)

Color coding:

Reserved for payload, free to use and reconfigure.

Reserved for specified use, can be reconfigured if needed.

Not configurable, specified by hardware.

3.1.3 DEBUG UART (UART-0)

Table 3-9: Debug UART (UART-0) pin reference

Signal	J1 Pin	Debug pin	MCU Pin
TX	15	2	PA10
RX	17	3	PA9

The Debug UART is also connected to the Debug/Programming connector. The connection is directly to MCU pins.

3.1.4 CSP I2C (I2C-0)

Table 3-10: CSP I^2C (I2C-0) pin reference

Signal	J1 Pin	MCU Pin
SDA	13	PA3
SCL	14	PA4

This I^2C bus is directly connected to the controller and does not include any pull-up resistors. User is advised to use external 3.3 kΩ pull-up resistors to 3.3 V level.

If the module is to be turned OFF while still connected to an actively used I^2C bus, an I^2C separator is recommended (e.g. *NXP PCA9507* or *TI ISO1540)*.

3.1.5 CSP RS485 (UART-1)

Table 3-11: Debug UART (UART-0) pin reference

Signal	J1 Pin	MCU Pin
TX	-	PD16
RX	-	PD15
DE /RE	-	PD18
A	18	-
B	16	-

The RS485 interface connects MCU UART and direction controlling GPIO to an RS485 differential bus driver. This circuit includes outside facing 10 Ω serial resistors and not populated termination and bias resistors. It is recommended to implement termination and bias on module's motherboard.

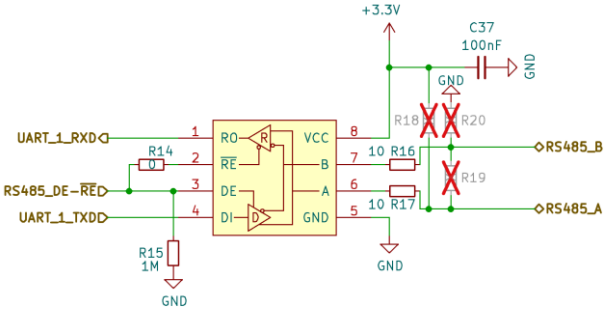

Figure 3-4: RS485 driver circuit

3.1.6 CSP CAN (MCAN-0)

Table 3-12: CSP CAN pin reference

Signal	J1 Pin	MCU Pin
H	55/56	-
L	57/58	-
CAN TX	-	PB2
CAN RX	-	PB3
CAN LBK	-	PC5

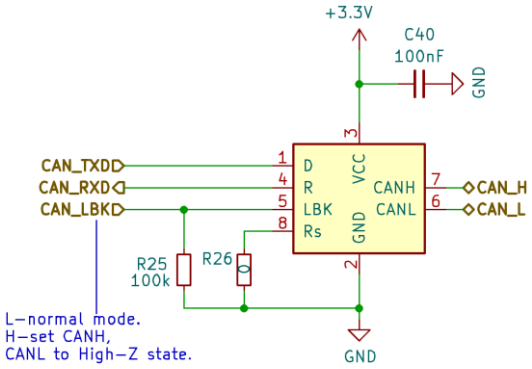

Figure 3-5: CAN driver circuit

The CAN BUS interface is realized using a CAN driver XXX. There is no termination or serial resistors on-board.

3.1.7 ISOLATED I2C (I2C-1)

Table 3-13: ISOL I²C (I2C-1) pin reference

Signal	J1 Pin	MCU Pin
SDA	55/56	PD27
SCL	57/58	PD28

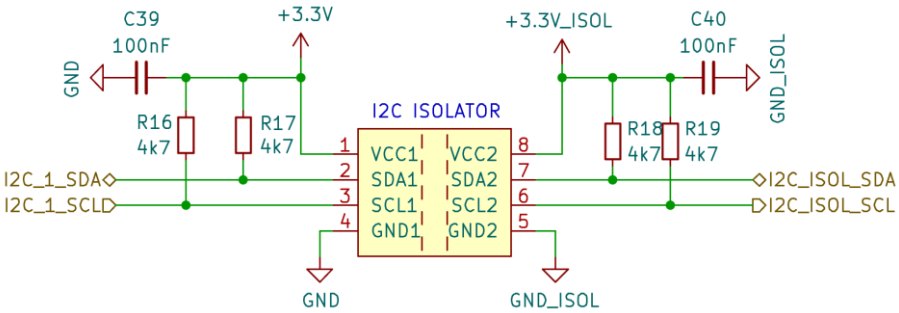

Figure 3-6: ISOL I²C (I2C-1) circuit

This I²C bus is connected to an isolator IC. For this interface to function an external power and ground needs to be connected to +3.3V_ISOL and GND_ISOL. It is recommended to use 3.3V power, but up to 5.5 V can be used. The outside facing I2C voltage level is directed by the externally connected power supply.

The outside facing side of the isolator already implements 4.7 kΩ pull-up resistors connected to the +3.3V_ISOL line.

3.1.8 SENSOR SPI (SPI-0)

Table 3-14: GPIO, ADC, PWM pin reference

Signal	J1 Pin	MCU Pin
CLK	19	PD22
CS	20	PD25
MISO	21	PD20
MOSI	22	PD21

SPI interface on the main connector is available for any user application. Pins are connected directly from the MCU to the connector. Typical SPI speed is 40 MHz. Performance is dependent on software implementation.

Alternatively, all four pins may be used as GPIO.

3.1.9 GPIO, ADC, PWM

Table 3-15: GPIO, ADC, PWM pin reference (J1)

Signal	J1 Pin	MCU Pin
GPIO0	31	PC16
GPIO1	32	PA5
GPIO2	33	PC18
GPIO3	34	PA6
GPIO4 / ADC0	35	PA18
GPIO5 / ADC1	36	PA19
GPIO6 / ADC2	37	PA21
GPIO7 / ADC3	38	PA20
PWM_H0	39	PA23
PWM_H1	40	PA24
PWM_H2	41	PA25
CLK_OUT	44	PA1
PPS	46	PE4
BATT_MEAS	1/2	PC0

Table 3-16: GPIO, ADC, PWM pin reference (J2)

Signal	J2 Pin	MCU Pin
GPIO8	31	PD26
GPIO9	32	PC14
GPIO10	33	PB0
GPIO11	34	PC12
GPIO12	35	PB0
GPIO13	36	PA11
GPIO14	37	PB13
GPIO15	38	PA2
PWM_L0	39	PC1
PWM_L1	40	PC2
PWM_L2	41	PC3

The OBC exposes a number of pins directly connected from the MCU for use as general purpose I/O, Analog measurement input, PWM output or special functions. Refer to MCU documentation for the exact usage via software.

Extra GPIO:

- **CLK_OUT**: legacy name, no special function implemented.
- **PPS**: extra GPIO reserved for use as Pulse-Per-Second input if implemented in software.
- **BATT_MEAS**: extra ADC input meant for analog battery measurement. It does NOT implement any scaling or protection circuits. It is connected directly to the MCU.

3.1.10 RMII

Table 3-17: GPIO, ADC, PWM pin reference (J1)

Signal	J2 Pin	MCU Pin
REFCK	13	PD0
TXEN	14	PD1
RXD0	15	PD5
RXD1	16	PD6
TXD0	17	PD2
TXD1	18	PD3
CRSDV	19	PD4
RXER	20	PD7
MDC	21	PD8
MDIO	22	PD9

Reduced media-independent interface I/O is exposed directly from the MCU. The module does NOT implement any PHY for the Ethernet interface.

3.1.11 SENS I2C AND INTERNAL SENSORS

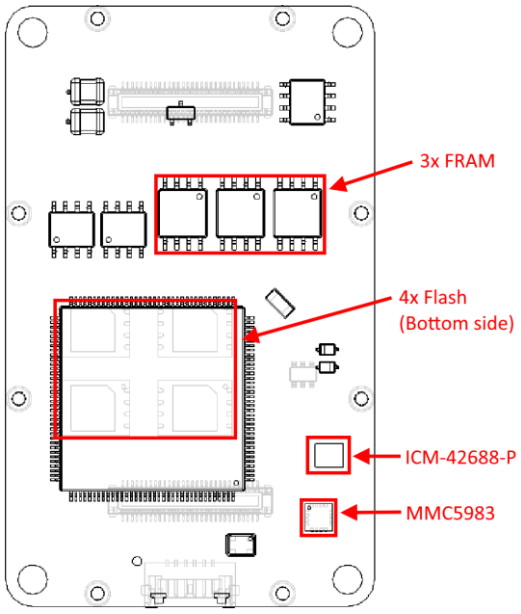

Figure 3-7: Internal sensor and memory placement

Table 3-18: SENS I²C pin reference

Signal	J2 Pin	MCU Pin
SDA	55	PB4
SCL	57	PB5
MAG SENS INT	-	PE0
GYR SENS INT1	-	PE1
GYR SENS INT2	-	PE2

This I²C bus is connected internally to on-board magnetometer and gyroscope & accelerometer sensors including their respective interrupt signals. This bus is not accessible outside of the module. The bus is exposed on J2 connector for possible extension by additional sensors by the user implemented on module's motherboard.

MAGNETOMETER

The DeepThought OBC module integrates a three-axis MEMS magnetometer (MMC5983). The sensor also includes temperature information. Refer to manufacturer documentation for details or the example software for basic usage.

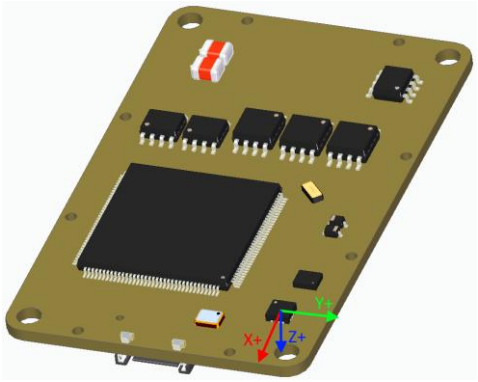

Figure 3-8: Magnetometer coordinate system (left-handed)

GYROSCOPE & ACCELEROMETER

The DeepThought OBC module integrates a three-axis MEMS gyroscope & accelerometer sensor (ICM-42688-P). The sensor also includes temperature information. Refer to manufacturer documentation for details or the example software for basic usage.

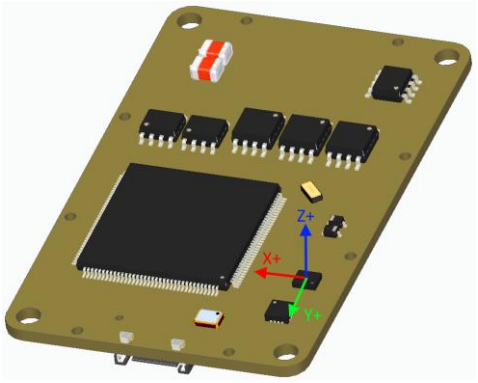

Figure 3-9: Gyroscope & accelerometer coordinate system

3.1.12 FRAM SPI

The module integrates 3 FRAM memory ICs (CY15B108QN), each with 1 MiB data capacity. All are available for user implementation into mission specific software. Typical SPI speed is 40 MHz. Performance is dependent on software implementation.

Table 3-19: FRAM SPI pin reference

Signal	Jn Pin	MCU Pin
FRAM SPI MOSI	-	PC27
FRAM SPI MISO	-	PC26
FRAM SPI SCK	-	PC24
FRAM 1 CS	-	PC31
FRAM 2 CS	-	PC30
FRAM 3 CS	-	CP29

3.1.13 QSPI AND FLASH MEMORIES

Alongside FRAM, the module integrates 4 Flash memory ICs (S25FL256L), each with 32 MiB data capacity. All are available for user implementation into mission specific software. Maximum QSPI speed is 40 MHz. This is driven by attached Flash memory chips. The QSPI bus is exposed on J2 connector for possible extension by additional SPI/QSPI devices by the user implemented on module's motherboard. CS signals of these additional devices need to make use of module's GPIO available on J1 and J2 connectors.

Table 3-20: Flash QSPI pin reference

Signal	J2 Pin	MCU Pin
FLASH_CLK	49	PA14
FLASH_MOSI_IO0	51	PA13
FLASH_MISO_IO1	52	PA12
FLASH_WP#_IO2	53	PA17
FLASH_RST#_IO3	54	PD31
Flash 1 CS	-	PC20
Flash 2 CS	-	PC21
Flash 3 CS	-	PC22
Flash 4 CS	-	PC23

3.2 SOFTWARE

The OBC is fully programable and reprogrammable by the user using the programming/debug connector via supported SWD/JTAG tools.

Spacemanic offers an open-source software example project available at:

https://gitlab.com/spacemanic-public/dt-fw-example

This software is available as-is without any warranty. For extensive software support and development support contact Spacemanic directly.

3.3 MECHANICAL

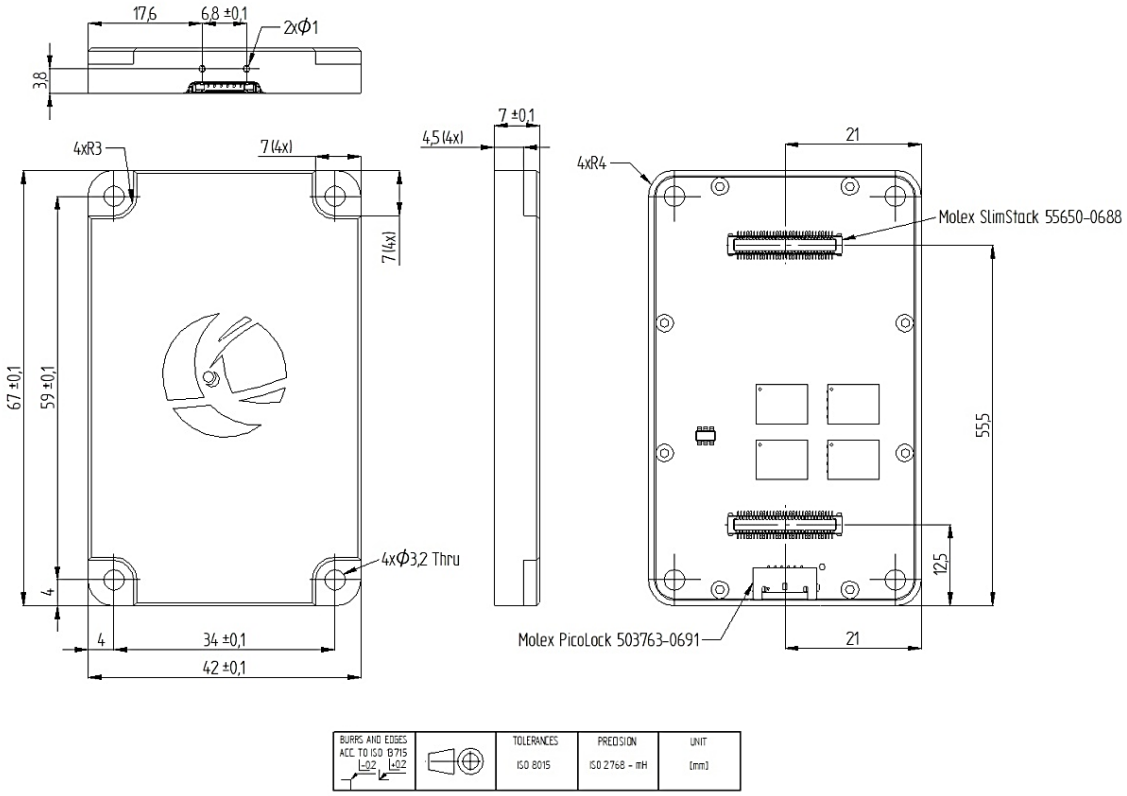

Figure 3-10: Mechanical Interface of the Deep Thought Module

It is recommended to mount the module using four ISO 14579 M3x6 socket head hexalobular TX titanium grade 5 screws against 2.1 mm M3 spacers on the motherboard.

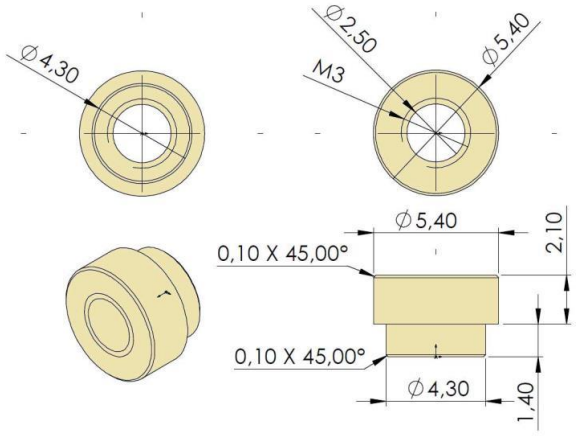

Figure 3-11: Recommended Mounting Spacer (brass)

4 DELIVERABLES

Table 4-1: Deliverables

Type	Item	Note
Mechanical Part	Aluminium cover	
Mechanical Part	USS module standoffs	
Interface	USS module V2b	
Wiring	Debug cable	503764-0601 ~15cm terminated to female 2.54mm header
Support	Engineering support: 1 hour	

5 RELATED PRODUCTS

You may be also interested in:

- Eddie OBC
- 1-16U CubeSat Platforms / Complete Mission

6 DISCLAIMER

Spacemanic shall not be liable for any damages, losses, delays, or other consequences arising from improper use, unauthorized modifications, or incompatibility of the product with other systems, even in cases where these products are deployed in demanding environments such as satellite or space applications. The product is designed for specific use according to the technical specifications outlined in the official documentation, and the company is not responsible for any issues arising from usage beyond this scope.

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