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DS-011 Pixhawk Autopilot v5X Standard

Revision: 0.8.0
Revision date: Dec 07, 2022

Abstract

This document is the formal version of the Pixhawk industry standard that includes all aspects of the hardware standard required to build compatible autopilots.

Table of contents

Document Revisions

Revision	Date	Editor	Reviewer	Comments
0.1.0		Lorenz Meier	David Sidrane	Initial specification
0.2.0		Lorenz Meier	David Sidrane	Addition of FMUv6X draft
0.3.0		Lorenz Meier	David Sidrane	Split up into focused documents
0.4.0		Michael Schaeuble	David Sidrane	Correct IO processor type in diagram on page 6
0.5.0		Michael Schaeuble	Lorenz Meier	Update v5X block diagram, sensor description and pinout, Ethernet Phy specification
0.6.0		Lorenz Meier	David Sidrane	Removed the requirement for temperature calibration
0.7.0		Ramón Roche	David Sidrane	Verify the sensor sets match design files and pinouts, update sensor location diagram, and add power requirement specifications
0.8.0	12/7/22	David Sidrane	Ramón Roche	Added VxX IMU pinout, and Mechanical design considerations

Contact and Public Developer Call

This standard is being developed on a public developer call.
For further questions, please contact the maintainer of the standard, lorenz@px4.io.

Trademark Guideline

Pixhawk is a registered trademark and is used to mark and protect the consistent use of this standard. The requirements for this are covered in this document: Trademark Guideline

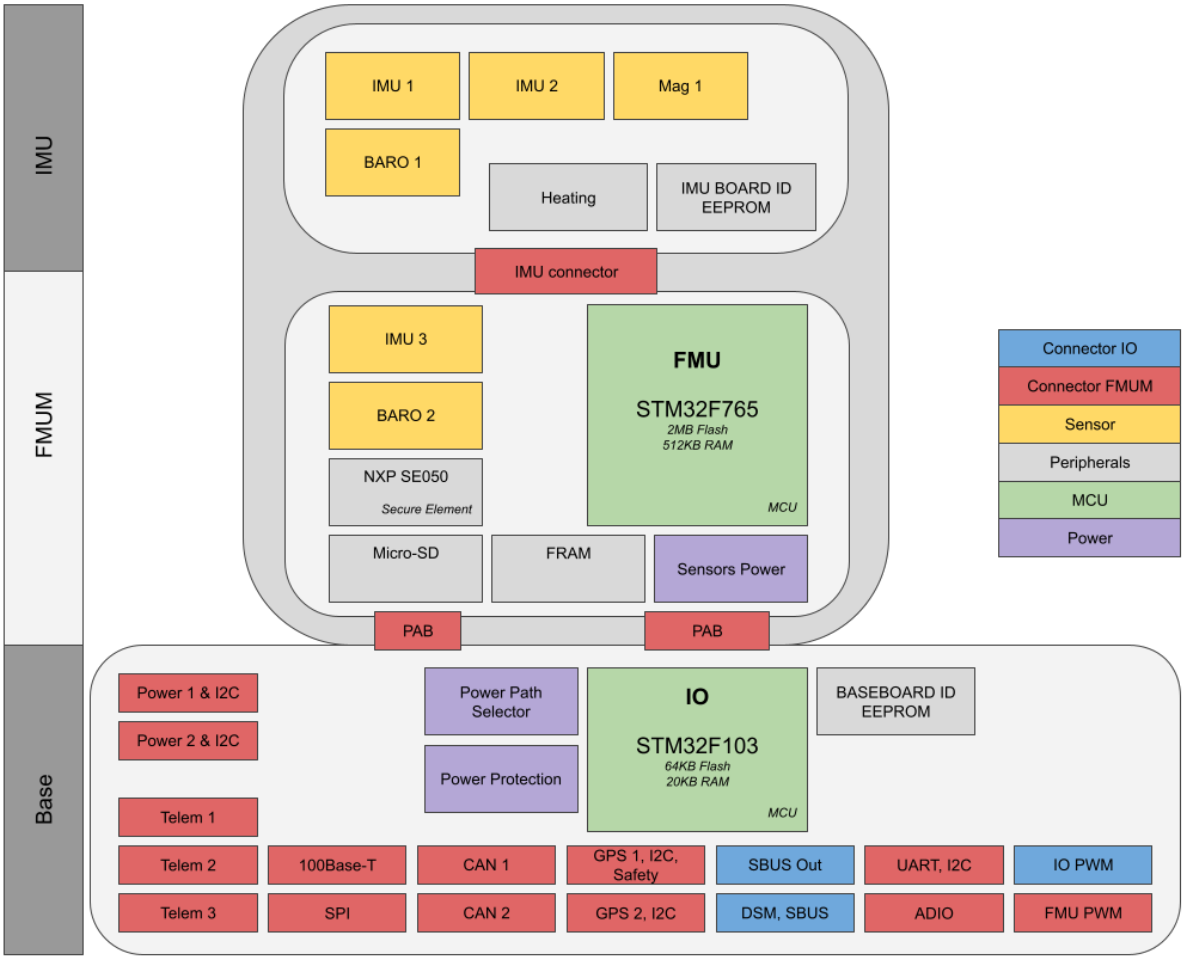
License and Disclaimer

Related Standards

- DS-009 Pixhawk Connector Standard
- DS-010 Pixhawk Autopilot Bus Standard

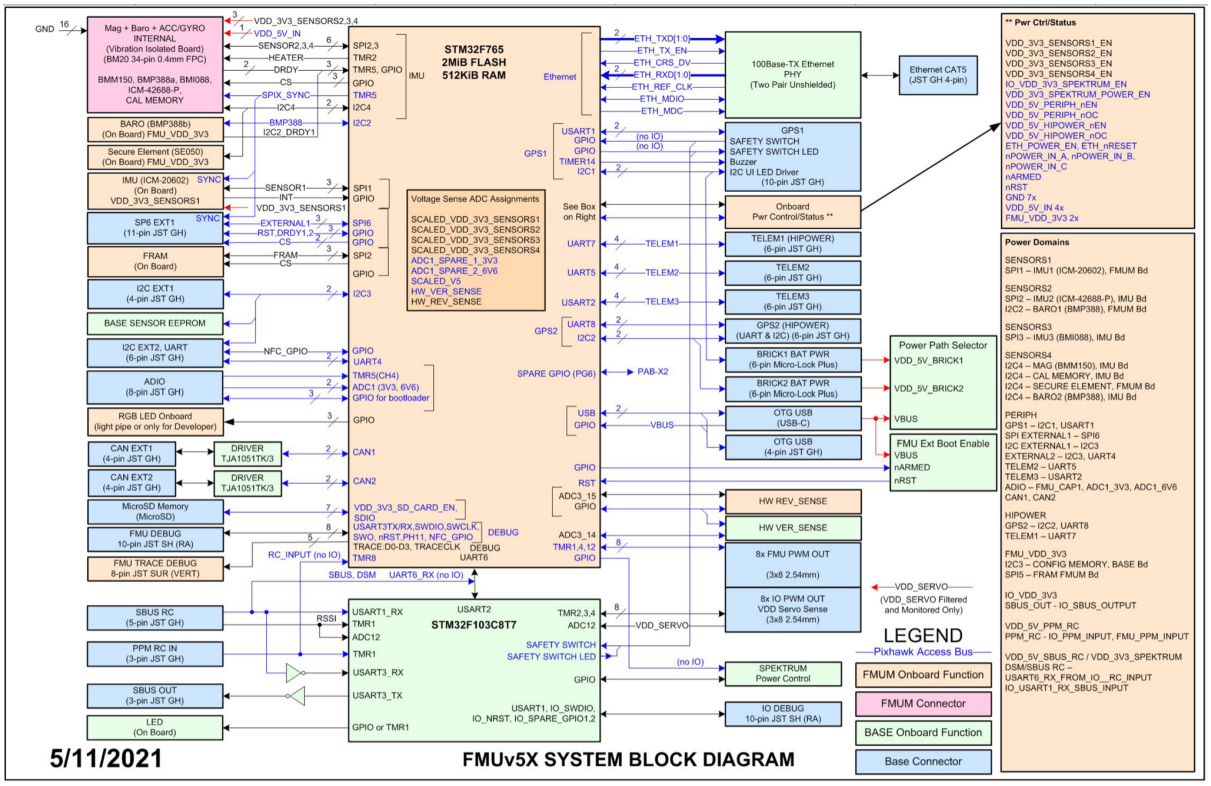
FMUv5X Summary

Overview



Note: Please refer to the Sensor Set section for accurate sensor parts

Detailed Block Diagram



The FMUv5X generation brings the proven features from FMUv5 to a hardened form factor.

- Secure element for secure authentication of the drone (SE050)
- Ethernet interface for high-speed mission computer integration
    - Ethernet PHY: Microchip LAN8742AI-CZ-TR
- Three redundancy domains: Completely isolated sensor domains with separate buses and separate power control.
- It has redundant sensors on separate buses, allowing parallel and continuous operation even in the event of a hardware failure.
    - Some of the possible sensor configurations:
    - Bosch BMI088 accelerometer (vibration isolated)
    - Invensense ICM-20602
    - TDK Invensense ICM 42688-P
    - Bosch BMM150 compass (vibration isolated)
    - Two Bosch BMP388 pressure sensors
    - GPS external mag + baro #1
    - GPS external mag + baro #2
    - Calibration EEPROM for baseboard sensors
    - On-IMU calibration EEPROM memory for high-accuracy sensors
- Automated sensor calibration eliminating varying signals and temperature
- FRAM memory for configuration data
- Operating temperature -40 to +85°C

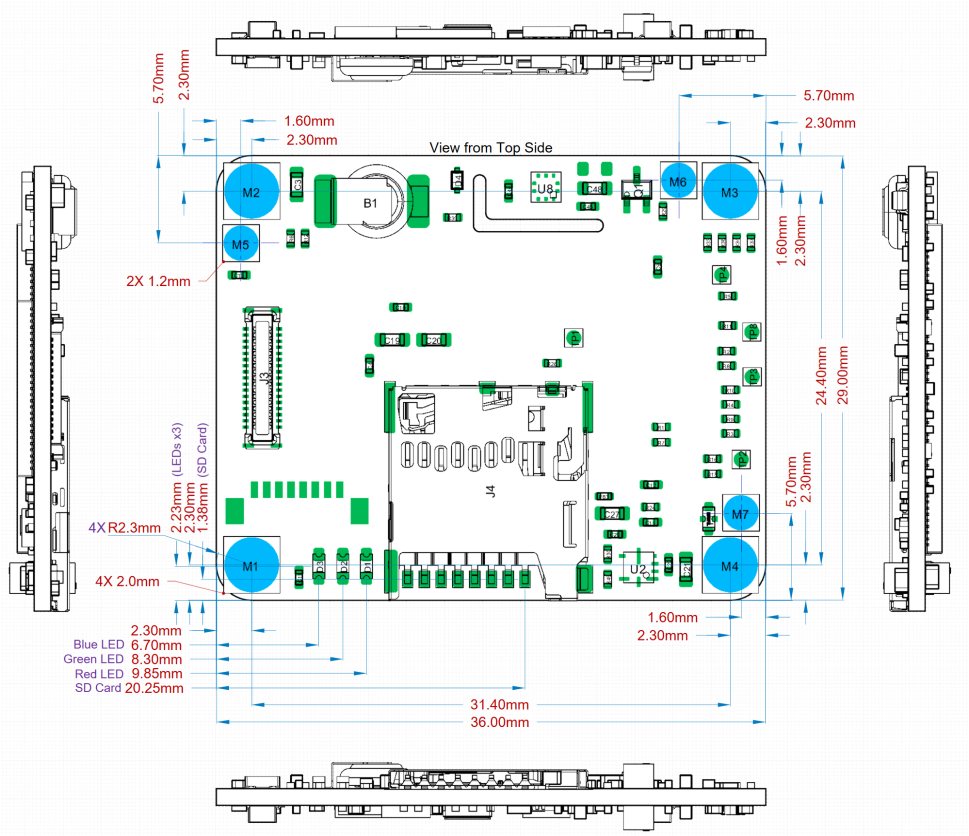
- Extensive power monitoring
    - Two smart batteries on SMBus or more on UAVCAN
    - 5V rail monitoring
    - 3.3V rail monitoring for CPU
    - 3.3V rail monitoring for each sensor domain
- External sensor bus (SPI6)
- Redundant power supply: The autopilot can be powered from up to two power sources and every sensor set is powered by an independent LDO with independent power control
- Battery-backed real time clock for running security applications without GPS coverage
- For NFC one external I2C port needs to have an additional GPIO line and 5V to supply the external NFC reader.

Mechanical Design

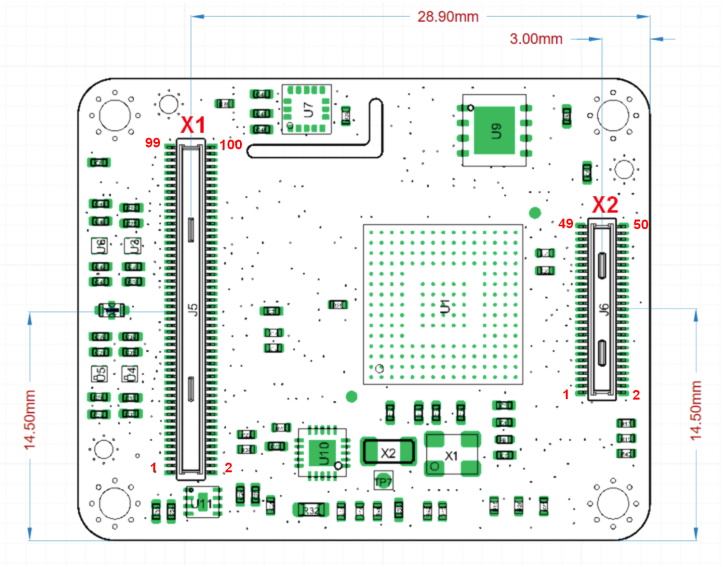
For mechanical compatibility across vendors the following is advised. Locate centers of Red, Green, and Blue LEDs and SD Card connector pin 1 as shown in the Top View FMUM above.

For mechanical case compatibility across vendors the following is advised. The outer case dimensions shall be **no greater than 31.8mm x 38.8mm**. This allows a total of 1.4mm to be used for case wall thickness and clearance to FMUM pcb. It is necessary to provide heat sinking of the FMUM microprocessor. This can be accomplished by using a metal top case that thermally interfaces to the FMUM microprocessor.

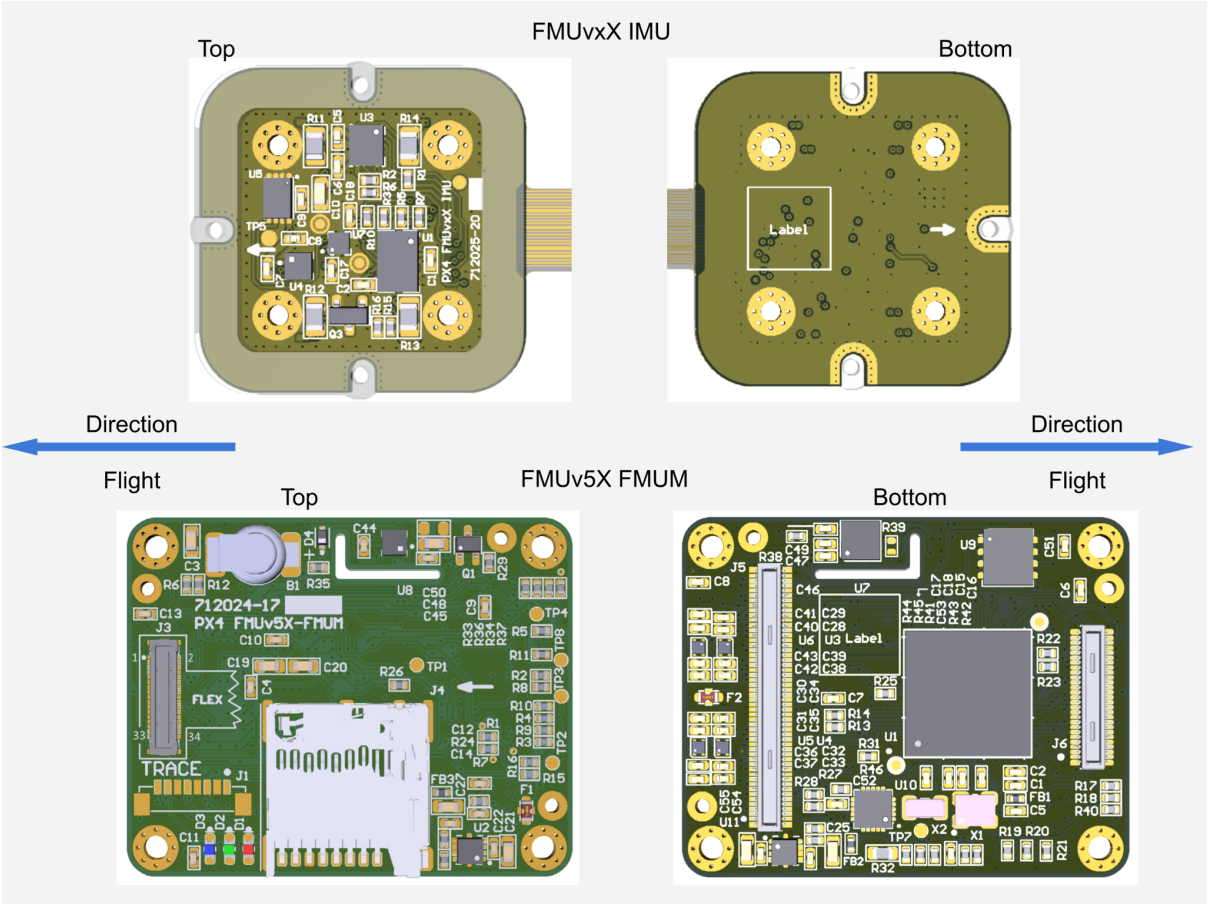
Top view of FMUM



Bottom view of FMU SOM



Sensors Locations



Sensor Sets

Sensor sets comprised an FMU set of sensors and an IMU set of sensors. These are revisioned in pairs. (Rev 1, Rev 2, Rev 3)

Sensor Set (Rev 1)

FMU Sensor Set (Rev 1)

FMU Board

Name	Sensor Type	Bus	Chip Select/ 7 Bit Addr	DRDY	Power Domain
U7 (IMU3)	ICM20602	SPI1	CS1	DRDY1	1
U8 (BARO2)	BMP388	I2C2	0x76 @00=0x50	DRDY1	2
U9 (FRAM)	FM25V02A-DG	SPI5	CS1	NA	FMU VDD 3.3
U10 (SE)	SE050C1HQ1/Z01SCZ	I2C4	0x48	NA	4

IMU Sensor Set (Rev 1)

IMU Board

Name	Sensor Type	Bus	Chip Select/ 7 Bit Addr	DRDY	Power Domain
U1 (IMU1)	BMI088 ACCEL	SPI3	CS1	NA	3
U1 (IMU1)	BMI088 GYRO	SPI3	CS2	DRDY2 INT3	3
~~U2 (MAG2) Not installed~~	~~LIS2MDLTR **DNP**~~	~~I2C4~~	~~0x1e~~	~~NA~~	~~4~~
U3 (IMU2)	ICM-42688-P	SPI2	CS1	DRDY2 INT2	2
U4 (BARO1)	BMP388	I2C4	0x77 @00=0x50	NA	4
U5	EEPROM	I2C4	0x50	N/A	4
~~U6 (IMU2) Not installed~~	ICM20602 **DNP**	SPI2	CS1	DRDY2 INT2	2
U7 (MAG1)	BMM150	I2C4	0x10	NA	4

Sensor Set (Rev 2)

FMU Sensor (Rev 1)

See above.

IMU Sensor Set (Rev 2)

IMU Board

Name	Sensor Type	Bus	Chip Select/ 7 Bit Addr	DRDY	Power Domain
U1 (IMU1)	ICM20649 ACCEL	SPI3	CS1	DRDY2 INT3	3
~~U2 (MAG2)~~	~~VCM5883 **DNP**~~	~~I2C4~~	~~0x0C~~	~~NA~~	~~4~~
U3 (IMU2)	ICM-42688-P	SPI2	CS1	DRDY2 INT2	2
U4 (BARO1)	BMP388	I2C4	0x77 @00=0x50	NA	4
U5	EEPROM	I2C4	0x50	N/A	4
~~U6 (IMU2) Not installed~~	~~ICM20602 **DNP**~~	~~SPI2~~	~~CS1~~	~~DRDY2 INT2~~	~~2~~
U7	BMM150	I2C4	0x10	NA	4

Sensor Set (Rev 3)

FMU Sensor (Rev 1)

See above.

IMU Sensor Set (Rev 3)

IMU Board

Name	Sensor Type	Bus	Chip Select/ 7 Bit Addr	DRDY	Power Domain
U1 (IMU1)	BMI088 ACCEL	SPI3	CS1	NA	3
U1 (IMU1)	BMI088 GYRO	SPI3	CS2	DRDY2 INT3	3
U2 (MAG1)	RM3100	I2C4	0x20	NA	4
U3 (IMU2)	ICM-42688-P	SPI2	CS1	DRDY2 INT2	2
U4 (BARO1)	DPS310	I2C4	0x76 @0x0D=0x10	NA	4
U5	EEPROM	I2C4	0x50	N/A	4
~~U6 (IMU2) Not installed~~	~~ICM20602 DNP~~	SPI2	CS1	DRDY2 INT2	2
~~U7~~ (MAG2) ~~Not Installed~~	~~BMM150 DNP~~	I2C4	0x10	NA	4

Sensor Set (Rev TBD)

FMU Sensor (Rev 1)

See above.

IMU Sensor Set (Rev TBD)

IMU Board

Name	Sensor Type	Bus	Chip Select/ 7 Bit Addr	DRDY	Power Domain
U1 (IMU1)	ICM-42688-P IMU	SPI3	CS1	NA	3
N/A	BMI088 GYRO	SPI3	CS2	DRDY2 INT3	3
~~U2 (MAG2) Not installed~~	LIS2MDLTR **DNP**	I2C4	0x1e	NA	4
U3 (IMU2)	ICM-42688-P	SPI2	CS1	DRDY2 INT2	2
U4 (BARO1)	ICP-10110	I2C4	0x63 CMD=0xEFC8	NA	4
U5	EEPROM	I2C4	0x50	N/A	4
~~U6 (IMU2) Not installed~~		SPI2	CS1	DRDY2 INT2	2
U7	BMM150	I2C4	0x10	NA	4

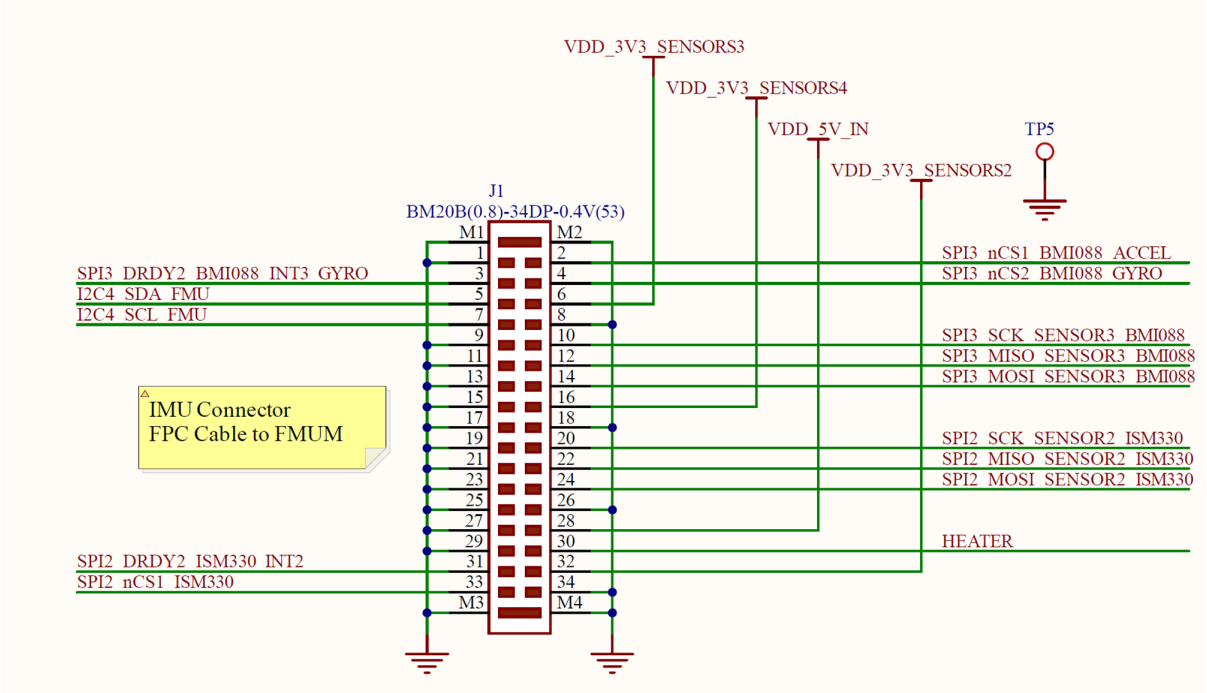
Note: When referring to the pinout chart the CS Names are formed by BUS**n**_CS**n**_DEVICE: SPI**1**_nCS**1**_ICM20602
DRDY Names are formed by BUS**n**_DRDY**n**_DEVICE_INT**n**: SPI**2**_DRDY**2**_ISM330_INT**2**

Note: device names may reflect legacy devices names. What matters is the BUSn,CSn,DRDYn and the INTn.

IMU Pinout of FMUM's IMU connector (FMUvxX)

The signal's name device type (I.E BMI088_xxx) are for reference only. See Sensor Sets for the devices located on a designated bus.

Pin 1 location and direction of flex cable can be seen in FMUv5X Sensors Locations section.



Power Requirements

Voltage

Parameter	Min	Typ	Max	Unit
VDD_5V_IN	4.6	5.3	5.4	V

Current

Parameter	Min	**Typ** @ 5.3V	**Max** @ 4.6V	Unit
V5X baseT + FMUM + IMU	-	3.88	4.40	A
V5X baseT	-	3.44	3.82	A
FMUM w/o IMU	-	0.21	0.36	A
FMUM w/ IMU	-	0.44	0.58	A

Note: Where IMU is listed, the IMU heater is assumed to be on 100% accounting for 0.184-0.214 A on VDD_5V_IN

Full FMUv5X Pinout

At the time of the release of this document the reference pinout was version **RC17**. The current release of the reference pinout is found in this pinout sheet link.

FMUV5X_stm32_pinout - RC17

NOTE: The information contained below is for reference only. See the link above for the complete pinout reference.

			176-pin STM32F765IIK Signal		FMUV5X RC04 USAGE
0	PA	0	ADC1_IN0	A	SCALED_VDD_3V3_SENSORS1
1	PA	1	ETH_REF_CLK	E	ETH_REF_CLK
2	PA	2	ETH_MDIO	E	ETH_MDIO
3	PA	3	USART2_RX	U	USART2_RX_TELEM3
4	PA	4	ADC1_IN4	A	SCALED_VDD_3V3_SENSORS2
5	PA	5	SPI1_SCK	S	SPI1_SCK_SENSOR1_ICM20602
6	PA	6	SPI6_MISO	S	SPI6_MISO_EXTERNAL1
7	PA	7	ETH_CRS_DV	E	ETH_CRS_DV
8	PA	8	TIM1_CH1	T	FMU_CH4
9	PA	9	USB_OTG_FS_VBUS	B	VBUS_SENSE
10	PA	10	TIM1_CH3	T	FMU_CH2
11	PA	11	USB_OTG_FS_DM	B	USB_D_N
12	PA	12	USB_OTG_FS_DP	B	USB_D_P
13	PA	13	SWDIO	D	FMU_SWDIO
14	PA	14	SWCLK	D	FMU_SWCLK
15	PA	15	PA15	G	SPI6_nCS2_EXTERNAL1
16	PB	0	ADC1_IN8	A	SCALED_VDD_3V3_SENSORS3
17	PB	1	ADC1_IN9	A	SCALED_V5
18	PB	2	SPI3_MOSI	S	SPI3_MOSI_SENSOR3_BMI088
19	PB	3	SPI6_SCK	S	SPI6_SCK_EXTERNAL1
20	PB	4	SPI1_MISO	S	SPI1_MISO_SENSOR1_ICM20602
21	PB	5	SPI1_MOSI	S	SPI1_MOSI_SENSOR1_ICM20602
22	PB	6	CAN2_TX	C	CAN2_TX
23	PB	7	I2C1_SDA	I	I2C1_SDA_BASE_GPS1_MAG_LED_PM1
24	PB	8	I2C1_SCL	I	I2C1_SCL_BASE_GPS1_MAG_LED_PM1
25	PB	9	UART5_TX	V	UART5_TX_TELEM2
26	PB	10	TIM2_CH3	T	HEATER
27	PB	11	ETH_TX_EN	E	ETH_TX_EN
28	PB	12	CAN2_RX	C	CAN2_RX

29	PB	13	ETH_TXD1	E	ETH_TXD1
30	PB	14	USART1_TX	U	USART1_TX_GPS1
31	PB	15	USART1_RX	U	USART1_RX_GPS1
32	PC	0	ADC1_IN10	A	ADC1_6V6
33	PC	1	ETH_MDC	E	ETH_MDC
34	PC	2	ADC1_IN12	A	SCALED_VDD_3V3_SENSORS4
35	PC	3	ADC1_IN13	A	ADC1_3V3
36	PC	4	ETH_RXD0	E	ETH_RXD0
37	PC	5	ETH_RXD1	E	ETH_RXD1
38	PC	6	USART6_TX	U	USART6_TX_TO_IO__NC
39	PC	7	USART6_RX	U	USART6_RX_FROM_IO__RC_INPUT
40	PC	8	UART5_RTS	V	UART5_RTS_TELEM2
41	PC	9	UART5_CTS	V	UART5_CTS_TELEM2
42	PC	10	SPI3_SCK	S	SPI3_SCK_SENSOR3_BMI088
43	PC	11	SPI3_MISO	S	SPI3_MISO_SENSOR3_BMI088
44	PC	12	PC12	G	nARMED
45	PC	13	PC13	G	VDD_3V3_SD_CARD_EN
46	PC	14	OSC32_IN	X	32KHZ_IN
47	PC	15	OSC32_OUT	X	32KHZ_OUT
48	PD	0	CAN1_RX	C	CAN1_RX
49	PD	1	CAN1_TX	C	CAN1_TX
50	PD	2	UART5_RX	V	UART5_RX_TELEM2
51	PD	3	USART2_CTS	U	USART2_CTS_TELEM3
52	PD	4	USART2_RTS	U	USART2_RTS_TELEM3
53	PD	5	USART2_TX	U	USART2_TX_TELEM3
54	PD	6	SDMMC2_CLK	SD	SDMMC2_CLK
55	PD	7	SDMMC2_CMD	SD	SDMMC2_CMD
56	PD	8	USART3_TX	U	USART3_TX_DEBUG
57	PD	9	USART3_RX	U	USART3_RX_DEBUG
58	PD	10	PD10	G	FMU_nSAFETY_SWITCH_LED_OUT
59	PD	11	PD11	G	SPI6_DRDY1_EXTERNAL1
60	PD	12	PD12	G	SPI6_DRDY2_EXTERNAL1
61	PD	13	TIM4_CH2	T	FMU_CH5
62	PD	14	TIM4_CH3	T	FMU_CH6
63	PD	15	PD15	G	VDD_3V3_SENSORS2_EN
64	PE	0	UART8_RX	V	UART8_RX_GPS2
65	PE	1	UART8_TX	V	UART8_TX_GPS2
66	PE	2	PE2	D	TRACECLK
67	PE	3	PE3	G	nLED_RED
68	PE	4	PE4	G	nLED_GREEN
69	PE	5	PE5	G	nLED_BLUE
70	PE	6	SPI4_MOSI	S	SPI4_MOSI_SENSOR4_BMM150
71	PE	7	PE7	G	VDD_3V3_SENSORS3_EN
72	PE	8	UART7_TX	V	UART7_TX_TELEM1

73	PE	9	UART7_RTS	V	UART7_RTS_TELEM1
74	PE	10	UART7_CTS	V	UART7_CTS_TELEM1
75	PE	11	TIM1_CH2	T	FMU_CH3
76	PE	12	SPI4_SCK	S	SPI4_SCK_SENSOR4_BMM150
77	PE	13	SPI4_MISO	S	SPI4_MISO_SENSOR4_BMM150
78	PE	14	TIM1_CH4	T	FMU_CH1
79	PE	15	PE15	G	VDD_5V_PERIPH_nOC
80	PF	0	I2C2_SDA	I	I2C2_SDA_BASE_GPS2_MAG_LED_PM2
81	PF	1	I2C2_SCL	I	I2C2_SCL_BASE_GPS2_MAG_LED_PM2
82	PF	2	PF2	G	SPI1_DRDY1_ICM20602
83	PF	3	PF3	G	SPI4_DRDY1_BMM150_DRDY
84	PF	4	ADC3_IN14	A	HW_VER_SENSE
85	PF	5	ADC3_IN15	A	HW_REV_SENSE
86	PF	6	UART7_RX	V	UART7_RX_TELEM1
87	PF	7	SPI5_SCK	S	SPI5_SCK_FRAM
88	PF	8	SPI5_MISO	S	SPI5_MISO_FRAM
89	PF	9	TIM14_CH1	T	BUZZER_1
90	PF	10	PF10	G	SPI6_nRESET_EXTERNAL1
91	PF	11	SPI5_MOSI	S	SPI5_MOSI_FRAM
92	PF	12	PF12	G	VDD_5V_HIPOWER_nEN
93	PF	13	PF13	G	VDD_5V_HIPOWER_nOC
94	PF	14	I2C4_SCL	I	I2C4_SCL_FMU
95	PF	15	I2C4_SDA	I	I2C4_SDA_FMU
96	PG	0	PG0	G	HW_VER_REV_DRIVE
97	PG	1	PG1	G	nPOWER_IN_A
98	PG	2	PG2	G	nPOWER_IN_B
99	PG	3	PG3	G	nPOWER_IN_C
100	PG	4	PG4	G	VDD_5V_PERIPH_nEN
101	PG	5	PG5	G	I2C2_DRDY1_BMP388
102	PG	6	PG6	G	PG6
103	PG	7	PG7	G	SPI5_nCS1_FRAM
104	PG	8	PG8	G	VDD_3V3_SENSORS4_EN
105	PG	9	SDMMC2_D0	SD	SDMMC2_D0
106	PG	10	SDMMC2_D1	SD	SDMMC2_D1
107	PG	11	SDMMC2_D2	SD	SDMMC2_D2
108	PG	12	SDMMC2_D3	SD	SDMMC2_D3
109	PG	13	ETH_TXD0	E	ETH_TXD0
110	PG	14	SPI6_MOSI	S	SPI6_MOSI_EXTERNAL1
111	PG	15	PG15	G	ETH_POWER_EN
112	PH	0	OSC_IN	X	16_MHZ_IN
113	PH	1	OSC_OUT	X	16_MHZ_OUT
114	PH	2	PH2	G	VDD_3V3_SPEKTRUM_POWER_EN
115	PH	3	PH3	G	NFC_GPIO
116	PH	4	PH4	G	FMU_SAFETY_SWITCH_IN

117	PH	5	PH5	G	SPI2_nCS1_ISM330
118	PH	6	TIM12_CH1	T	FMU_CH7
119	PH	7	I2C3_SCL	I	I2C3_SCL_BASE_MS5611_BARBED_EXTERNAL1
120	PH	8	I2C3_SDA	I	I2C3_SDA_BASE_MS5611_BARBED_EXTERNAL1
121	PH	9	TIM12_CH2	T	FMU_CH8
122	PH	10	TIM5_CH1	T	SPIX_SYNC
123	PH	11	PH11	G	PH11
124	PH	12	TIM5_CH3	T	SPI2_DRDY2_ISM330_INT2
125	PH	13	UART4_TX	V	UART4_TX
126	PH	14	UART4_RX	V	UART4_RX
127	PH	15	PH15	G	SPI4_nCS1_BMM150
128	PI	0	TIM5_CH4	T	FMU_CAP1
129	PI	1	SPI2_SCK	S	SPI2_SCK_SENSOR2_ISM330
130	PI	2	SPI2_MISO	S	SPI2_MISO_SENSOR2_ISM330
131	PI	3	SPI2_MOSI	S	SPI2_MOSI_SENSOR2_ISM330
132	PI	4	PI4	G	SPI3_nCS1_BMI088_ACCEL
133	PI	5	TIM8_CH1_IN	T	FMU_PPM_INPUT
134	PI	6	PI6	G	SPI3_DRDY1_BMI088_INT1_ACCEL
135	PI	7	PI7	G	SPI3_DRDY2_BMI088_INT3_GYRO
136	PI	8	PI8	G	SPI3_nCS2_BMI088_GYRO
137	PI	9	PI9	G	SPI1_nCS1_ICM20602
138	PI	10	PI10	G	SPI6_nCS1_EXTERNAL1
139	PI	11	PI11	G	VDD_3V3_SENSORS1_EN