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D2.5

Form-factor board design & BoM

1. DOCUMENT INFORMATION

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4. ABSTRACT

The EoT Form-factor board (FfBoard) is the 2nd revision of board for EoT wearable devise. Unlike the 1st revision, the DevBoard, the board size and the power consumption are the matters of utmost importance in FfBoard. In fact, the board size should be as close as possible to 1.5x3 cm target size and the power consumption should be minimized as much as possible. Price has been considered as the 3rd priority in design. To achieve these goals, several component review and selection processes have been accomplished. On this basis, components that deliver the best compromise in terms of power/size/price factors, respectively, have been selected. The design mostly involves the components optimisation by substituting the DevBoard components with the lower power, smaller and cheaper ones from the exactly same brands to minimize the risk. Except the power management that has been redesigned and changed due to different requirements of FfBoard such as supplying the board using the battery, powering up the board using the USB connector, charging the battery and so on, which are different from DevBoard.

5. FORM-FACTOR BOARD

Introduction

According to EoT project's timeline, the EoT Form-factor board (FfBoard) comes after the EoT DevBoard. The plan for the DevBoard was to apply the minimum changes to Movidius Mv0182 evaluation reference board in terms of changing the size of the board as well as the components to minimize the risk in delay etc. However, the board was still based on MA2100 Myriad2, same as the MV0182 board (at the time of designing the DevBoard). Mainly, it was about applying the following changes:

- Removing the Ethernet and HDMI connectivity from MV0182 board (because of being out of scope of EoT) and freeing up the pins.
- Adding Wi-Fi connectivity as the main means of communication for EoT boards. The TI CC3100 was the Wi-Fi module targeted to be used in EoT DevBoard that has been accompanied by a level-shifter to provide the voltage consistency between the Wi-Fi module and the board. The SPI driver also was another component that has been developed to allow using the Wi-Fi functionalities on EoT DevBoard.
- Adding a new tiny low-power camera, called NanEye, interface and functionality to the board. Since, the NanEye sensor's data output is 10 bits digital LVDS, it is a different protocol to get connected to Myriad. Therefore, a Lattice FPGA component, MachX03-6900, has been used to interface the camera to Myriad2. The FPGA codes also was incorporated to the FPGA to support the camera functionality.
- Upon the scope of EoT proposal, we incorporated motor control header to the board to allow us developing the robotic applications using the board.

Fig. 5-1 shows the block diagram of the EoT DevBoard.

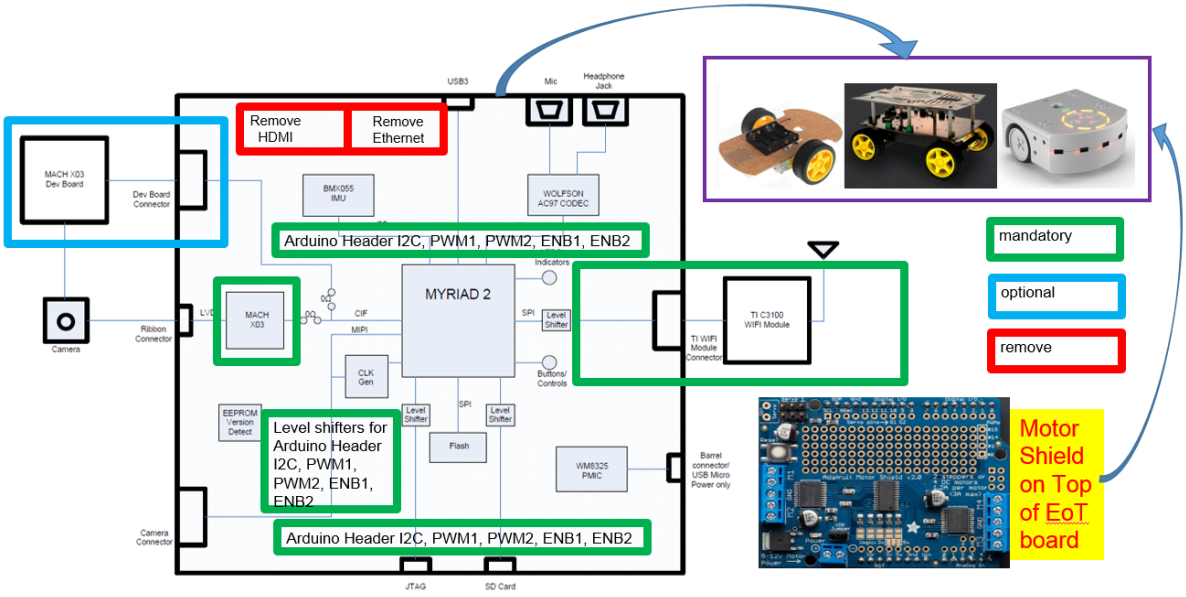

Figure 5-1: EoT DevBoard block diagram.

Fig. 5-2 shows the manufactured EoT DevBoard according to the changes listed above. As you can see, the DevBoard supports two NanEye camera connections as well as an 8-pin header for programming the Lattice Mach X03 FPGA. Also, all the CIF pins have been exposed on the Rear of the board for the sake of development and debugging. Different components and parts have been highlighted on this figure.

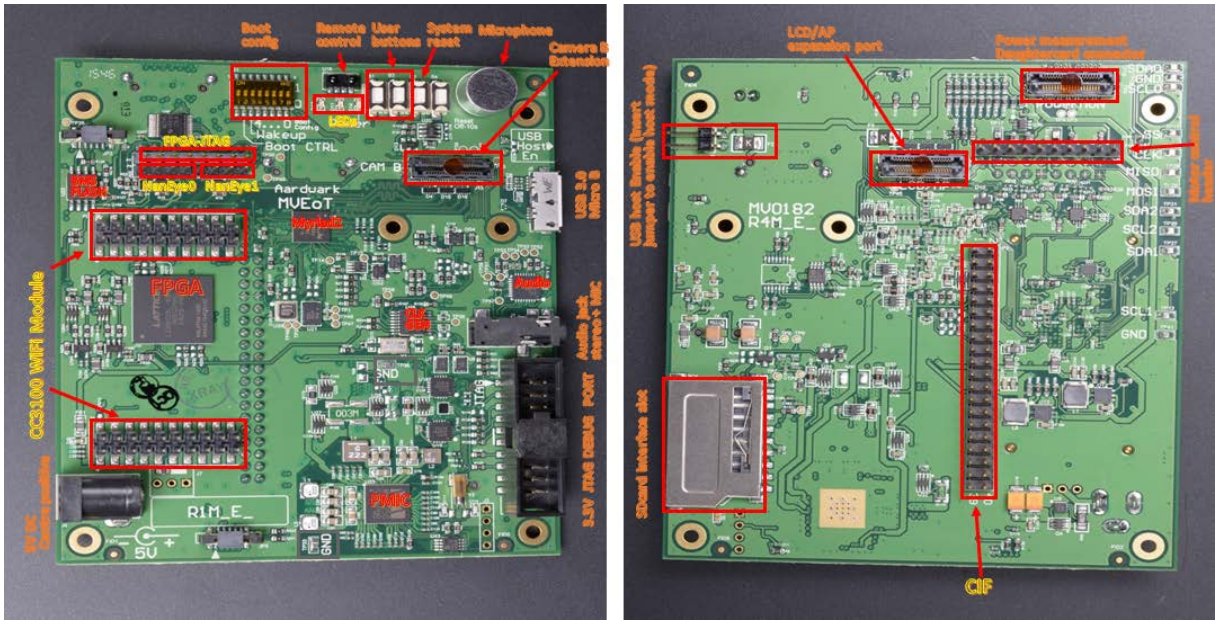

Figure 5-2: Manufactured EoT DevBoard; left: front view; right: rear view.

EoT FfBoard design strategy

After fulfilling the DevBoard process, which happened by manufacturing and testing the board, the EoT FfBoard job was started. The focus of this task was to minimize the board area as much as possible by removing more components (as long as it doesn't violate the scope and functionality of the EoT project) and substituting the components with the smaller and more efficient ones. Obviously, three factors of power/size/price are involved in designing a form-factor board. It is kind of impossible to fulfil all these parameters simultaneously. So, one of them should be sacrificed for the price of the others to achieve a compromise between them. Or at least a priority amongst them should be established.

In this project, we prioritized them as power/size/price, while we wouldn't push the one with the lowest priority too far. According to the EoT project's proposal, the target size for FfBoard is to achieve 1.5x3 cm (approx.), as close as possible, although it is really challenging objective. One of the main reasons for this challenge is the modules such as Wi-Fi where the designed packed module (no matter what is the brand) should be used in the FfBoard design. Otherwise, using the Wi-Fi chip appeals an exhausting process of getting the license and legal permissions. This process forces us to use the packed modules which are large enough to apply restrictions on making the board very small. On the other hand, it was possible to go for a stackable form-factor board, which makes it easier to achieve the target size. However, we decided to avoid this strategy and make a one stack board, as small as possible by cleverly selecting the components and by increasing the EoT FfBoard layers. Fig. 5-3 shows the EoT FfBoard block diagram according to the finalised spec.

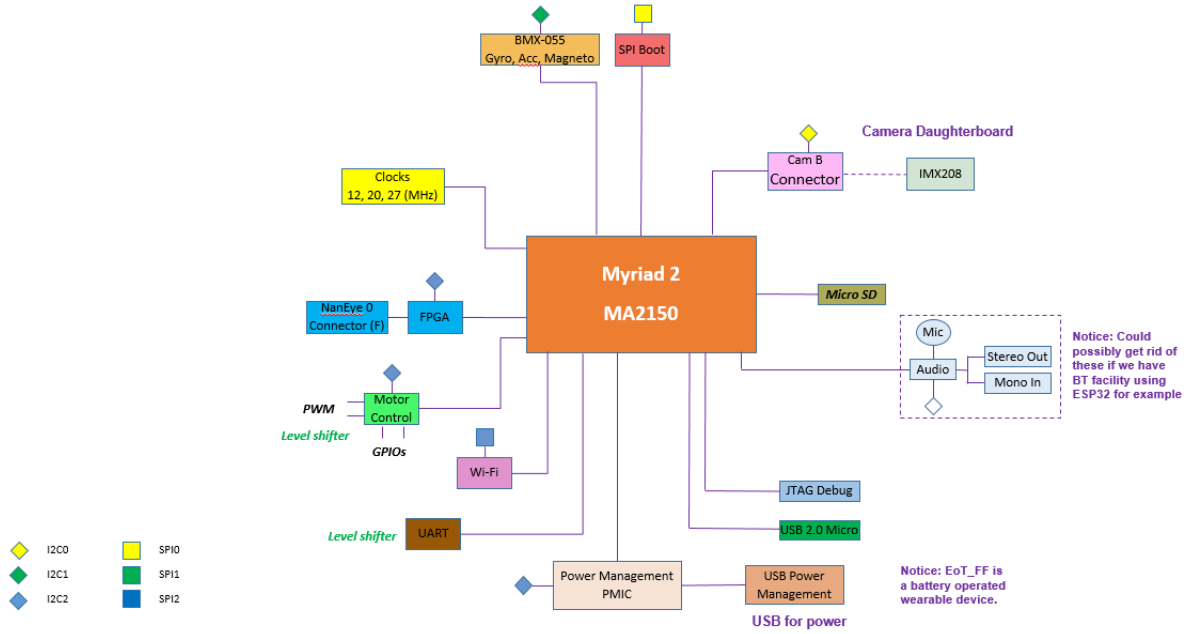

Figure 5-3: EoT FfBoard block diagram.

Accordingly, the components of DevBoard have been reviewed several times to see what components are the best choices for FfBoard. On this basis, the following changes, removals, additions, and optimisation have been considered in design of the EoT FfBoard:

- **Myriad2 - MA2150:** Since the MA2100 support by Movidius is going to be finished soon and also owing to the higher spec of MA2150, the EoT FfBoard has been designed based on this chip.
- **Wi-Fi**: FfBoard will use the same brand as the DevBoard, TI module, but the smaller canned version. We have been thinking to go for other modules such as ESP32 that supports Wi-Fi and Bluetooth simultaneously. However, the availability issue as well as the extra efforts that this change appeals for adoption of the Wi-Fi driver to the new part stopped us of going for this change.
- **FPGA**: Similar to DevBoard, the Lattice X03 module has been decided to use here but the smaller and lower power member of the family, i.e., the LCMXO3L-1300E.
- **Rev detector EEPROM**: To save the space, we decided to omit the Rev detector EEPROM and use the SD card instead for this purpose.
- **UART**: To provide the serial asynchronous communication with the Myriad2, we decided to incorporate the FfBoard with the UART header.
- **NanEye camera**: Although the DevBoard has been designed to support two NanEye sensor connectivity (two 4-pins headers), it was decided to get rid of one of them and have only one NanEye sensor on FfBoard. Also, two modes of FPGA to Myriad2 communication, Mode A: direct mode; and Mode B: through a signal translator and a comparator, have been designed for the DevBoard. Mode B has been the native option of Awaiba, while Mode A has been the EoT desirable option due to the less components it needs. We considered both modes on DevBoard, first of all

to be able to test Mode A and then to have access to Mode B in case Mode A doesn't work. Owing the result of DevBoard testing, Mode A satisfies EoT requirements and so we decided to design the EoT FfBoard only based on Mode A. Besides, a new version of sensor, called NanEye RS is going to be available in July 2016. So, we have been working to provide the support for the new sensor too.

- **Motor Control**: A level-shifter 5V compatible or selectable by powering from external source has been designed for the motor control part.
- **PMIC power management**: Owing to the more sophisticated power requisites of EoT FfBoard such as powering up the board from battery, selecting between the battery and USB power supply (if the power cord is connected to the board), battery charger (optional), and also using USB port as the power jack, we needed to go for a new and more advanced PMIC. Since it is a completely new design, it will be described in details in the Section 5.
- **JTAG debugging connector**: To save more space, we decided to go for a low profile JTAG such as MOLEX 87832-1220.
- **USB connector**: USB 2.0 is enough for FfBoard and can help to save more space.
- **SD Card**: The MicroSD card connector would be the preference of FfBoard due to its smaller size.
- **Optical audio jack**: This is an extra audio connection possibility (beside the standard 3.5mm audio jack) we have added to EoT FfBoard. All these 2 audio jacks as well as the battery socket are connected to the board using flex-cables for the sake of space saving.
- **GPIOs rearrangement**: Due to the changes in components, a new GPIO arrangement should be performed for FfBoard. The GPIO arrangement in section 4.4.
- **Unused GPIOs and FPGA pins**: to provide more opportunity for developers to extend their ideas, we decided to expose the unused GPIO and FPGA pins on the edge of the board using 0.1" headers. It will take two side of the board approximately (see Fig. 5-4).
- **Break-off sections**: Since the FfBoard is a wearable device that is supplied by battery, it is desirable to reduce the weight of the board as much as possible. We thought it would be nice to push the optional components to the edge of the board using a snap-off scenario. So, the user can break those parts and make the board smaller and even lighter in terms of the weight in this way. The test points, designed for testing the validation (Val) board are also located on the break-off area. Fig. 5-4 shows the EoT FfBoard modular block diagram along with the break-off sections.
- **Secondary cameras**: Similar to DevBoard, the EoT FfBoard is supported by a higher resolution secondary camera, which is on a daughter-card and is connected to the board through an LSHM connector. The camera is the Sony IMX208 sensor which communicates with Myriad2 using the MIPI protocol.

EoT FfBoard specs:

The EoT FfBoard design and manufacturing has been started according to the changes listed above and also based on the existing EoT DevBoard PCB in Altium. Briefly, the FfBoard should include the following features and specifications:

- **Shape**: desired 1.5x3 cm, to be confirmed after preliminary checks (min. 1.5 x 3 cm – max 2.0x4.5 cm).
- **Validation board:** with more layers and with test points for debugging.
- **Form-factor board**: based on the results of testing the validation boards and its layout may or may not be same as the validation board.
- **Principal active/passive components/subsystems**:
  - VPU: MA2150 SoC.
  - FPGA: Lattice Mach XO3.
  - Wi-Fi: SPI Wi-Fi I/F (canned CC3100, the CC3100MOD SimpleLink Certified Wi-Fi Network Processor Internet-of-Things Module Solution for MCU Applications.
  - Motor control.
  - BMX-055 IMU with I2C interface.
  - SPI Flash for boot.
  - Clock generation.
  - Power Management IC + USB VCC.
  - USB2.0 Micro port.
  - JTAG connector (low profile).
  - MicroSD socket.
  - TI TLV320AIC3204 CODEC I2S interface, connected to an on-board microphone and to a headphone jack.
  - Connectors:
    - LSHM MIPI camera.
    - NanEye camera (4 pins).
    - FPGA programmer (8 pins).
    - Motor control header.
    - Unused GPIOs and FPGA pins.
- **SMT mounting**: top and bottom layer.
- Presence of fine pitch BGA, 0.4mm minimum required.
- **Break-off sections**: sections specified in the modular block diagram of Fig. 5-4 could be on break-off section.

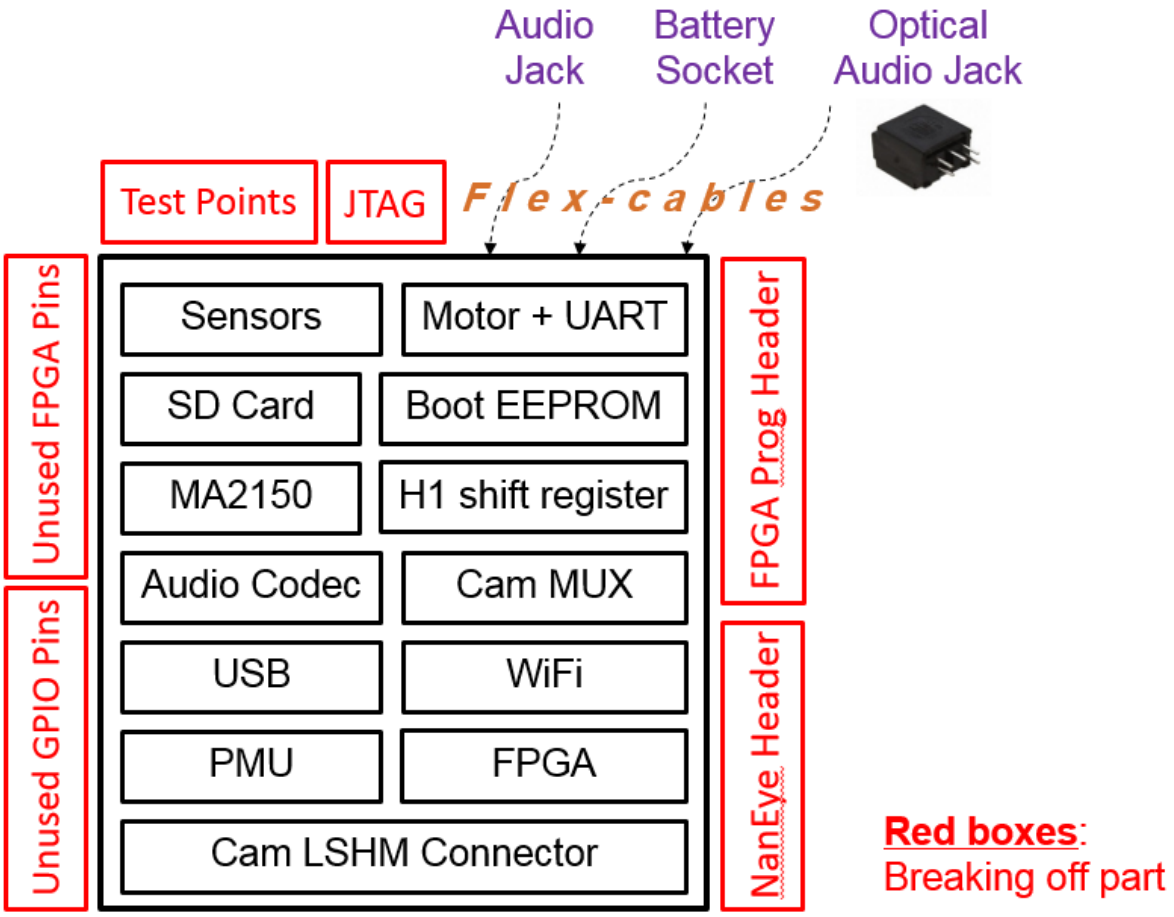

Figure 5-4: EoT FfBoard modular block diagram.

Fig. 5-5 shows the specification standard that the EoT FfBoard PCB layout has been developed based on.

Technology and stack-up	8 layers, Material TG 150
PCB shape	Min. 15 x 30 mm – max 20 x 45 mm
Thickness	1,55mm
Structures outside	>= 250um
Structures inside	>= 192um
Final drill diameter	>= 0,10 mm
Smallest rout tool	<= 1,0mm and >= 0,50mm
Copper thickness	35um outside, 35um inside
Surface finish	Electroless nickel gold (ENIG)
Additional surface	Top+Bottom, hard gold with plating ties
Solder resist	Top+Bottom, color to be defined
Silk screen	Top+Bottom, white
E-test	Yes
UL marking	Yes, standard compliant
Additional documentation	Certificate of Conformity

Figure 5-5: PCB layout specification standard.

EoT FfBoard, schematic and GPIO arrangement:

Since the EoT FfBoard job is in progress at the time of preparing this document, the preliminary schematic is presented here. The updated and finalised schematic as well as the PCB layout can be found in deliverable D2.6, “EoT device with form-factor board”. Fig. 5-6 visualises the whole FfBoard schematic design.

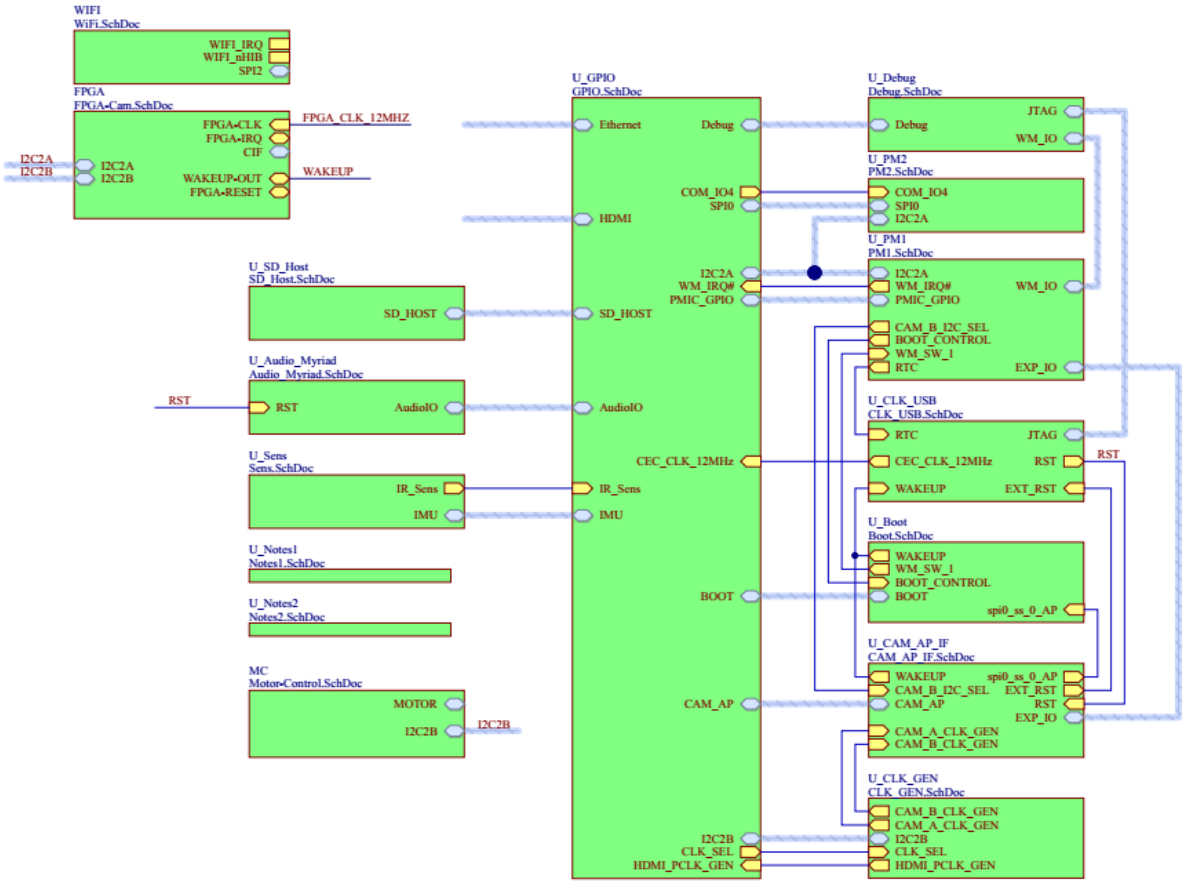

Figure 5-6: EoT FfBoard schematic.

Due to the HW changes in FfBoard, the GPIO rearrangement has been performed as mentioned earlier. Table 5-1 shows the GPIO arrangement for FfBoard. Correspondingly, Fig. 5-7 shows the GPIOs connection on Myriad2.

Table 5-1: EoT FfBoard GPIO arrangement.

Signal Name	MA2150	FF schematic GPIO function	FF schematic GPIO names	Mode
gpio_0	ETH_125CLK	cam_mclk	NanEye/Himax-MCLK	0
gpio_1	ETH_TX_CLK	cam_pclk	NanEye/Himax-PCLK	0
gpio_2	ETH_TX_EN	cam_vsync	NanEye/Himax-VSYNC	0
gpio_3	ETH_TX_ERR	cam_hsync	NanEye/Himax-HSYNC	0
gpio_4	ETH_RX_CLK	cam_data0	NanEye/Himax-DO	0

gpio_5	ETH_RX_DV	cam_data1	NanEye/Himax-D1	0
gpio_6	ETH_RX_ER	cam_data2	NanEye/Himax-D2	0
gpio_7	ETH_RX_COL	CPU direct control	BMX_055_INT3	7
gpio_8	ETH_RX_CRS	spi2_mosi	spi2_mosi	3
gpio_9	ETH_MDIO	spi2_miso	spi2_miso	3
gpio_10	ETH_MDC	spi2_sclk_out	spi2_sclk_out	3
gpio_11	ETH_TXD_0	spi2_ss_out_in_0	spi2_ss_out_in_0	3
gpio_12	I2C1_SCL	I2C1_SCL	I2C1_SCL	2
gpio_13	I2C1_SDA	I2C1_SDA	I2C1_SDA	2
gpio_14	IR_SENS	uart_apb_sin	MOTOR-UART-RX	1
gpio_15	CAM_B_GPIO0	uart_apb_sout	MOTOR-UART-TX	1
gpio_16	SD_HST1_DAT_3	SD_HST1_DAT_3	SD_HST1_DAT_3	3
gpio_17	SD_HST1_CLK	SD_HST1_CLK	SD_HST1_CLK	3
gpio_18	SD_HST1_CMD	SD_HST1_CMD	SD_HST1_CMD	3
gpio_19	SD_HST1_DAT_0	SD_HST1_DAT_0	SD_HST1_DAT_0	3
gpio_20	SD_HST1_DAT_1	SD_HST1_DAT_1	SD_HST1_DAT_1	3
gpio_21	SD_HST1_DAT_2	SD_HST1_DAT_2	SD_HST1_DAT_2	3
gpio_22	AP_IRQ	CPU direct control	MOTOR-DIR0	7
gpio_23	I2S0_SCK	CPU direct control	MOTOR-DIR1	7
gpio_24	I2S0_WS	CPU direct control		7
gpio_25	I2S0_IN_SD0	CPU direct control		7
gpio_26	I2S0_OUT_SD0	CPU direct control		7
gpio_27	CAM_A_PWM	CPU direct control		7
gpio_28	WM_IRQ#	I2S0_SCK	I2S0_SCK	3
gpio_29	HDMI_PCLK_GEN	I2S0_WS	I2S0_WS	3
gpio_30	VSYNC	I2S0_IN_SD0	I2S0_IN_SD0	3
gpio_31	HSYNC	CPU direct control	BMX_055_INT1	7
gpio_32	BMX_055_INT5	CPU direct control	BMX_055_INT5	7
gpio_33	CAM_B_PWM	pwm_out_0	CAM_B_PWM	3
gpio_34	BMX_055_INT1	I2S0_OUT_SD0	I2S0_OUT_SD0	3
gpio_35	ETH_GTX_CLK	cam_data3	NanEye/Himax-D3	2
gpio_36	Y0	cam_data4	NanEye/Himax-D4	2
gpio_37	Y1	cam_data5	NanEye/Himax-D5	2
gpio_38	Y2	cam_data6	NanEye/Himax-D6	2
gpio_39	Y3	cam_data7	NanEye/Himax-D7	2
gpio_40	Y4	cam_data8	NanEye/Himax-D8	2
gpio_41	Y5	cam_data9	NanEye/Himax-D9	2
gpio_42	Y6	cam_data10	Free for possible Himax use	2
gpio_43	Y7	cam_data11	Free for possible Himax use	2
gpio_44	CB/R0	CPU direct control	CAM_B_GPIO0	7
gpio_45	CB/R1	SPI0_MOSI	SPI0_MOSI	4
gpio_46	ETH_RXD_5	SPI0_MISO	SPI0_MISO	4
gpio_47	ETH_RXD_6	CPU direct control	I2C2_SCL	4

gpio_48	ETH_RXD_7	CPU direct control	H0_INT	7
gpio_49	CB/R5	pwm_out_3	MOTOR-PWM-0	3
gpio_50	CB/R6	pwm_out_4	MOTOR-PWM-1	3
gpio_51	CB/R7	CPU direct control	H0_TRIG	7
gpio_52	COM_IO1	CPU direct control	BOOT1	7
gpio_53	COM_IO2	CPU direct control	BOOT2	7
gpio_54	COM_IO3	CPU direct control	H1_INT	7
gpio_55	COM_IO4	CPU direct control	H1_TRIG	7
gpio_56	COM_IO5	CPU direct control	BOOT3	7
gpio_57	BMX_055_INT3	CPU direct control	sd_pwr_ctr	7
gpio_58	CLK_SEL	CPU direct control	SPI0_SCLK_OUT	4
gpio_59	CAM_A_GPIO0	CPU direct control	NanEye/Himax-MUX	7
gpio_60	I2C0_SCL	I2C0_SCL	I2C0_SCL	0
gpio_61	I2C0_SDA	I2C0_SDA	I2C0_SDA	0
gpio_62	ETH_TXD_1	CPU direct control	WIFI-IRQ	7
gpio_63	ETH_TXD_2	CPU direct control	WIFI-nHIB	7
gpio_64	ETH_TXD_3	CPU direct control	FPGA-on/off	7
gpio_65	ETH_TXD_4	cam_data12	Free for possible Himax use	4
gpio_66	ETH_TXD_5	cam_data13	Free for possible Himax use	4
gpio_67	ETH_TXD_6	cam_data14	Free for possible Himax use	4
gpio_68	ETH_TXD_7	cam_data15	Free for possible Himax use	4
gpio_69	ETH_RXD_0	cam_data16	Free for possible Himax use	4
gpio_70	ETH_RXD_1	cam_data17	Free for possible Himax use	4
gpio_71	ETH_RXD_2	cam_data18	Free for possible Himax use	4
gpio_72	ETH_RXD_3	cam_data19	Free for possible Himax use	4
gpio_73	ETH_RXD_4	cam_data20	Free for possible Himax use	4
gpio_74	SPI0_MOSI	cam_data21	Free for possible Himax use	4
gpio_75	SPI0_MISO	cam_data22	Free for possible Himax use	4
gpio_76	SPI0_SCLK_OUT	cam_data23	Free for possible Himax use	4
gpio_77	SPI0_SS_OUT_IN_0	SPI0_SS_OUT_IN_0	SPI0_SS_OUT_IN_0	0
gpio_78	SPI0_SS_1	SPI0_SS_OUT_IN_1	SPI0_SS_1	5
gpio_79	I2C2_SCL	SPI0_SS_OUT_IN_2	SPI0_SS_2	5
gpio_80	I2C2 _SDA	I2C2 _SDA	I2C2 _SDA	2
gpio_81	AUDIO_MCLK	cpr_io_out_clk_1	AUDIO_MCLK	2
gpio_82	CB/R2	CPU direct control	Motor_Brake0	7
gpio_83	CB/R3	CPU direct control	CLK_SEL	7
gpio_84	CB/R4	CPU direct control	Motor_Brake1	7

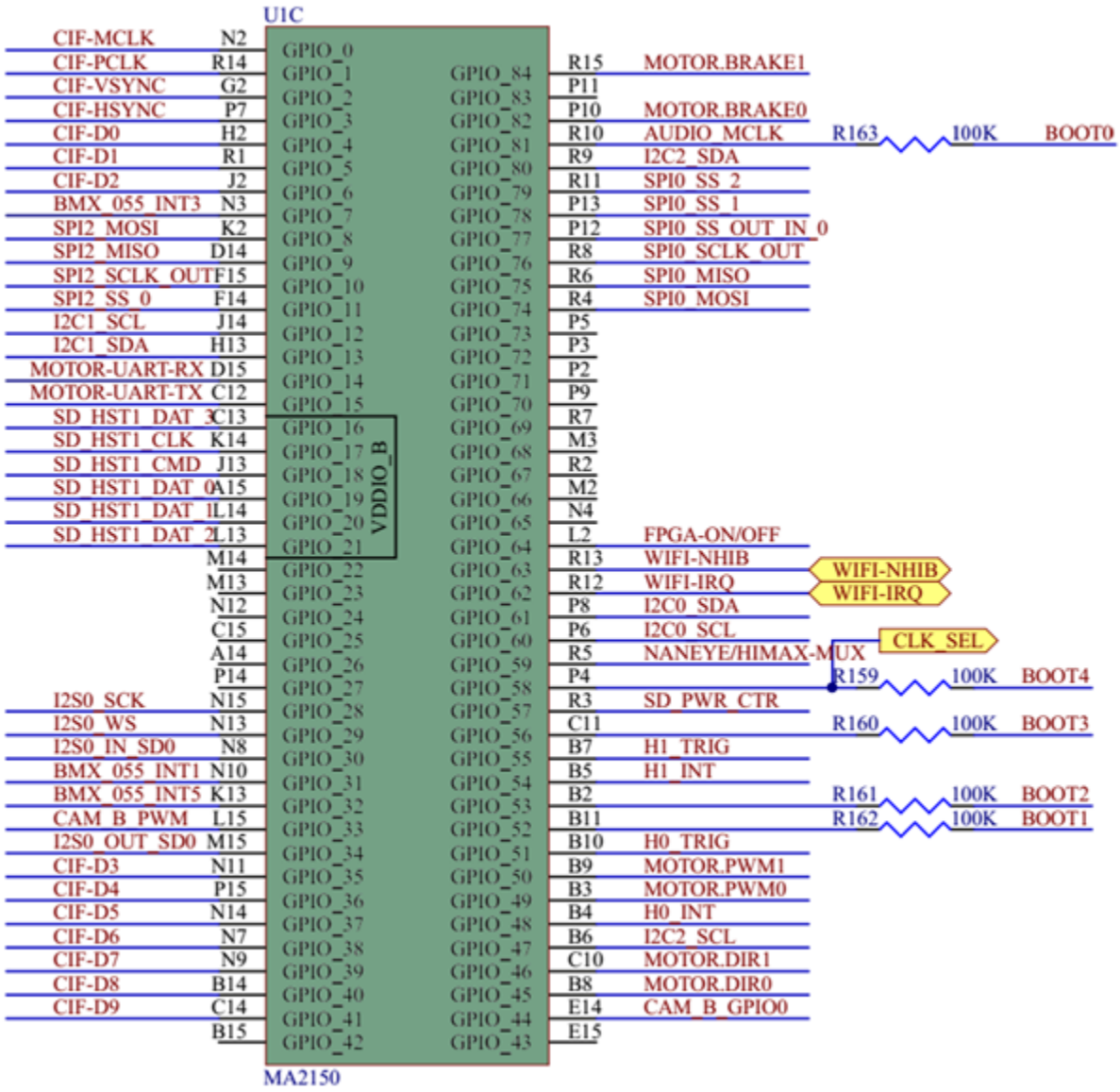

Figure 5-7: EoT FfBoard GPIO arrangement.

6. POWER MANAGEMENT

Power management concerns the supply and control of all electrical power to the board components. The power supply rails must meet the tight specifications of the Myriad2 and other sensitive components, supply switchable voltages for certain applications, and meet specified power-up and power-down timing thresholds. The wearable nature of the EoT form factor board makes the selection and design of the power management block a particularly crucial step in the board design, as power management must maximise the efficiency of power regulation in the minimum board area.

Functional Requirements

Power management functional requirements address the following questions:

- How many supply rails are required?
- What voltage and current specifications should each rail have?
- How should component supplies be grouped together onto rails?
- What are the sequencing requirements for the rails on power-up?
- How is the board powered (power input to the power management block)?

6.1.1. MA2150 Myriad2 Power

The MA2150 Myriad2 VPU is a low-power System-on-Chip (SoC) targeted at computer and machine vision applications. Due to its silicon structure it must be powered up in a predefined sequence. Within the SoC are two dies - the MA2150 silicon plus a stacked DRAM memory die. These dies have distinctive power requirements that must be met in order to ensure correct SoC operation. Overall the MA2150 has 18 independent power islands that allow fine-grained power management, and these require multiple supply voltages with separate current draw characteristics so that the islands can be independently powered up and down.

The list of individual power rails for the MA2150 are provided in Table 6-1. They are logically grouped into sequence stages from S0 to S4, where all the rails in each stage power up together. Requirements for the stage sequence timing are shown in Table 6-2. Although valid power-up can be achieved in less than 5 stages, depending on the required Myriad functionality and the connection of peripheral components, specifying power management requirements for the full 5 stage start-up provides maximum application flexibility. The mandatory power sequencing concerns the DRAM die supplies.

Table 6-1: Power rail requirements for MA2150.

Sequence Stage	Rails Powered	Purpose	Start Time
S0	USB_VDD330	USB Phy High Voltage Analog Supply	T0
	MIPI_VDD	MIPI Analog Supply	
	VDDIO	I/O Supply	
	PLL_AVDD	PLL Analog Supply	
	DRAM_MVDDA	Myriad DDR PLL Analog Supply	

	VDDCR, VDDCV	Core Retention Supply	
	USB_VP_VDD	USB Phy Low Voltage Analog Supply	
	VDDIO_B3.3	IO Supply B Voltage Range	
S1	DRAM_VDD1	DRAM Die Core Power 1	T1
S2	DRAM_VDD2	DRAM Die Core Power 2	T2
S3	DRAM_VDDQ	DRAM I/O Buffer Power	T3
S4	DRAM_MVDDQ	Myriad DDR I/O Supply	T4
Complete			T5

Table 6-2: Power supply timing requirements for MA2150.

Timing Requirements		Notes
1	T5-T0<=20ms	Not mandatory but considered good practice
2	T5-T4>=1ms	Suggested but not mandatory. However, voltages in the previous stage should have reached their nominal values before starting the next stage
	T4-T3>=1ms	
	T3-T2>=1ms	
	T2-T1>=1ms	
3	T5-T2<=20ms	Mandatory (DRAM_VDD1, DRAM_VDD2, DRAM_VDDQ rise times from 300mV to start of operating range < 20ms)
4	All rise times > 10us	Mandatory

The voltage and current specification for the MA2150 supply rails are presented in Table 6-3. Current draw is dependent on processing load, but should not exceed the specified values. Power rails should be individually switchable to enable power saving by powering down power islands. VDDIO_B3.3 should additionally be switchable between 1.8V and 3.3V to natively meet the two different speed standards for SD card IO.

Table 6-3: Power supply definition for MA2150.

Power Rail	Purpose	Nominal Voltage (V)	Maximum Current (mA)
USB_VDD330	USB Phy High Voltage Analog Supply	3.3	80
MIPI_VDD	MIPI Analog Supply	1.8	60
VDDIO	I/O Supply	1.8	250
PLL_AVDD	PLL Analog Supply	1.8	10
DRAM_MVDDA	Myriad DDR PLL Analog Supply	1.8	80
VDDCR, VDDCV	Core Retention Supply	0.9	2600
USB_VP_VDD	USB Phy Low Voltage Analog Supply	0.9	66
VDDIO_B3.3	IO Supply B Voltage Range	1.8/3.3 switchable	
DRAM_VDD1	DRAM Die Core Power 1	1.8	25
DRAM_VDD2	DRAM Die Core Power 2	1.2	220
DRAM_VDDQ	DRAM I/O Buffer Power	1.2	25
DRAM_MVDDQ	Myriad DDR I/O Supply	1.2	300

6.1.2. Peripherals and Passives Power

Apart from the MA2150, the WiFi module is the only functional block that has sensitive power requirements. The chosen CC3100 WiFi module from Texas Instruments can be supplied either by a 3.3V supply, which is then internally regulated, or by a 1.85V pre-regulated supply. The 1.85V pre-regulated option was chosen for the form factor board in order to minimise power loss. This option has the added benefit of requiring fewer external components and thus requiring a smaller footprint on the board. The cost of this choice is a more tightly regulated supply, as specified in Table 6-4.

Table 6-4: CC3100MOD Wi-Fi module power requirements.

Function	Nominal Voltage (V)	Min Voltage (V)	Max Voltage (V)	Max P-P Ripple (mV)	Max Current (mA)	Settling Time (us)
CC3100 Supply	1.85	1.76	1.9	35	1000	Line and load regulation with <2% ripple with 500 mA step current and settling time of <4 µs with the load step

None of the remaining board peripherals have start sequence requirements, and they all require either 1.8V or 3.3V supplies to their power rails. All 5V devices have been eliminated from the board so that step-up converters are not required as part of the power management (board supply is nominally 3.7V from a Li-Po battery, see 'Input Supply' section below). Outline power specifications for the remaining components are outlined in Table 6-5.

Table 6-5: Component IC power requirements.

Component	Purpose	Nominal Voltage (V)	Quiescent Current (mA)	Peak Current (mA)
PCA9306	I2C bus translator	1.8	<1	
SN74AVC8T245	Level shifter	1.8	<1	
NC7WZ16P6X	High speed buffer	1.8	<1	
ASDMB-12	Oscillator	1.8	5	15
ASDMB-27	Oscillator	1.8	5	15
ASDMB-20	Oscillator	1.8	5	15
TPS3808G01	0.9V voltage monitor	1.8	3	5
LTC2630	DAC	3.3	<1	
SN74AVC4T774	Bus transceiver	1.8, 3.3	<1	12
TLV320AIC3204	Audio Codec	1.8, 3.3		2
CDCEL925PW	Clock	1.8	2	5
N25Q064A11ESE40G	EEPROM	1.8	<1	20
SN74LVC1G3157DCKR	Switch	1.8	<1	<1
BMX_055	IMU sensor	1.8, 3.3	5.3	24
SN74AVC4T245R5VR	Bus transceiver	1.8, 3.3	12	<1
TXS0206A	SD card transceiver	1.8, 3.3	<1	<1

ADG781BCPZ	Switch	1.8, 3.3	<1	<1
LCMX03L-6900C	FPGA	1.8, 3.3	17	52

6.1.3. Input Supply

The EoT form factor board is a wearable/portable device and in normal operation will be battery powered. Lithium-ion Polymer (Li-Po) batteries have a high energy density, are rechargeable, and have a typical 3.7V output. They are commonly used for remote controlled devices due to their energy density and their ready market supply in various shapes and sizes. A single Li-Po 3.7V cell will provide power to the EoT form factor board when operating autonomously.

When tethered, such as during code development, testing and validation, the board should be powered from a non-battery source. This requirement improves economy, prevents undesirable browning-out during code development, and conserves the battery power for autonomous mode operation and thus lengthens its inter-charge operational duration. Two options are available for tethered powering: (1) a standard mains powered step-down transformer connected to a dedicated on-board power jack; (2) USB cable connected to a micro-USB on-board port.

The USB option was chosen for tethered supply to the EoT form factor board because (a) there is already a functional requirement for a micro-USB socket on the board (for PC communications), thus powering via USB does not require additional components or consume additional board area; and (b) both USB ports and micro-USB cables are ubiquitous, and will become even moreso with their adoption as the standard phone charging medium. USB power can be sourced either from a computer USB port or via a mains-powered step-down transformer that adheres to the USB 2.0 specification, thus USB provides maximum power supply flexibility.

Battery recharging via the mini-USB port is a ‘nice-to-have’ feature, but is not a requirement for the form factor board. The acceptable alternative to on-board charging is to disconnect the discharged battery from the board and connect it to a dedicated charger.

[redacted]Power Management IC Selection

A Wolfson (now Cirrus) WM8325 Power Management IC (PMIC) is used for all power management on the EoT DevBoard. When input power is applied to the PMIC, the power rail voltages and sequences are loaded from an external EEPROM over I2C. Alteration of the PMIC settings is achieved by altering the EEPROM contents. One Time Programming (OTP) of this PMIC is possible but is not used for the DevBoard.

Ricoh Electronic Devices Company are a significant player in the worldwide power management IC market. The RC5T619 Power Management Unit (PMU) is an alternative power management solution for the EoT form factor board. It has OTP functionality only and is factory programmed before shipment. In volume the RC5T619 is very competitively priced.

Table 6-6 provides a comparison of these two PMICs/PMUs across the parameters that are relevant to the EoT form factor board. The RC5T619 was

chosen as the PMU for the EoT form factor based on this comparison. The EoT requirement for powering via USB, the 'nice to have' on-board battery recharging feature, and the ability to switch between USB and battery were significant factor in changing from the WM8325. Given that the EoT DevBoard PMIC cannot provide any of these functions, a new PMIC is required. Although other Wolfson PMICs are available with feature closer to those of the RC5T619, the level of support provided by Ricoh is exceptional, as evidenced by multiple technical calls and support documentation provided by them to date. This is particularly important given the short design cycle for the form factor board.

Table 6-6: Power management comparison matrix, WM8325 versus RC5T619, superior parameters are highlighted in green.

Parameter	WM8325	RC5T619
# DC/DCs	4	5
# LDOs	11	12
RTC	yes	yes
GPIOs	12	5
Size	64mm^2	36mm^2
Documentation + support	average	excellent
USB power input?	no	yes
Seamless supply switching	no	yes
Fuel gauge	no	yes
Battery charging	no	yes
ADC	yes	yes
User programmable	yes	no

Ricoh RC5T619 Power Management Unit

The RC5T619 is the highest performance PMU in Ricoh's line-up. It is mass produced in a 36mm2 85 pin CSP format. Figure 6-1 shows the PMU functionality that is of primary relevance to the EoT form factor board. Also shown are the range of voltage and current outputs that each DCDC and LDO can provide. The DCDC and LDO outputs can be allocated across 15 sequence stages, with 0.5/2ms separation between stages. Output voltages are configurable in 12.5mV steps for the DCDCs, and in 25mV steps for the LDOs. With reference to Tables 6.3-6.5 it can be seen that these parameters are sufficient to cover the required voltages, currents, and sequencing for the MA2150, Wi-Fi module, and other peripherals on the form factor board.

The RC5T619 is targeted at wearable and IoT applications, and its low consumption current (0.5mA in typical operating mode) is ideally suited to the form factor board. All outputs can be turned on/off via I2C so that Myriad power islands can be powered down when not in use. Output voltages are also

switchable via I2C, as is required for the MA2150 VDDIO_B power rail to achieve high-speed SDIO.

Once the PMU has been programmed by OTP, changes can be made via I2C from the MA2150. The RTC, Interrupt and Watchdog features are not required for the form factor board, but they may be useful for certain applications (in particular the RTC).

A detailed minimal-boardspace layout and routing plan for the RC5T619 PMU and all peripherals (including those necessary for battery recharging and fuel gauge functionalities) is provided by Ricoh. The size of the bounding box for this layout is 18.6mm x 25mm. Some example drivers for the various RC5T619 functions have also been provided by Ricoh.

Input power supply to the PMU is via USB and/or battery and/or power adaptor, as shown in Fig. 6-2. The RC5T619 manages the distribution of this power automatically - use cases that apply to the form factor board are outlined in Table 6-7. When moving from case 2 to cases 3 or 4 by connecting a powered USB cable, the PMU automatically switches to sourcing power from the USB input. Likewise, the PMU automatically sources power from a connected battery (if battery voltage is sufficiently high) when a powered USB cable is disconnected. Case 3 is battery charging mode; case 4 is power assist mode. Trickle charge functionality is implemented in battery charging mode, and the maximum charge current is set to 500mA. A GPIO is configured to act as a charging-charged visual indicator. Note that the USB and ADP paths will be shorted internally in the PMU.

The PMU will power up from an off state when a power button is pressed for one second, and power down from an on state when the same button is pressed for one second. Connecting a powered USB to the form factor board will also trigger full PMU power-up.

The integrated fuel gauge on the PMU can monitor battery voltage, energy discharge and temperature, and feed these into a battery model in order to estimate instantaneous battery State of Charge (SOC) percentage.

Table 6-7: PMU management of input supply.

Case	USB connected?	Battery connected?	Power source	Power distribution
1	yes	no	USB	components
2	no	yes	battery	components
3	yes	yes	USB if [USB pwr] > [required pwr]	battery + components (charging mode)
4	yes	yes	battery+USB if [USB pwr] < [required pwr]	components

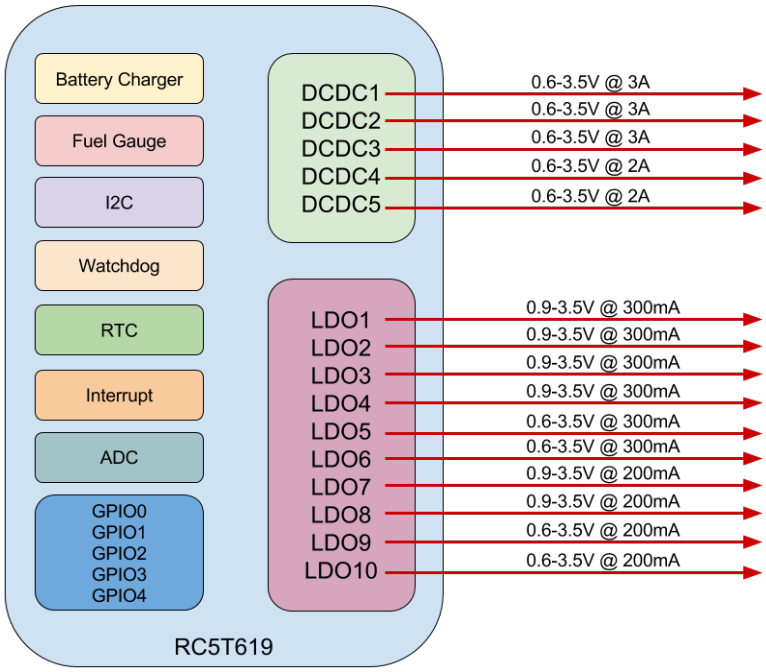

Figure 6-1: RC5T619 PMU functional outline.

Final Power Rail Allocations

In conjunction with engineers from Ricoh, the RC5T619 power outputs were optimally matched to the EoT form factor board power requirements. Table 6-8 shows the power rail mappings and start-up sequence. Power rails were grouped into the sequence stages shown based firstly on the Myriad power sequencing requirements (see Section MA2150 Myriad2 Power), and secondly on the following criteria (where possible):

1. Rails with higher current draw should be brought up before rails with lower current draw.
2. Rails with high current draw should be brought up in separate stages.
3. Rails bring-ups should be spread across stages.
4. Rails with low voltages should be supplied by internal rail voltages that closely match the output voltages in order to improve power dissipation.

Pursuant to criteria (4) the voltage of DCDC4 was adjusted from 1.8V to 1.85V to make it suitable for supplying LDO5, LDO7 and LDO8 (and thereby improve power dissipation).

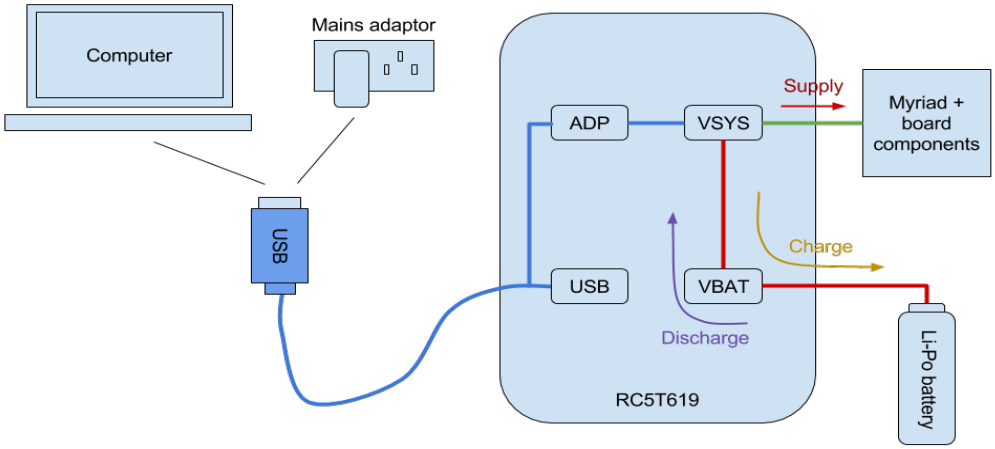

Figure 6-2: PMU power paths.

Table 6-8: Final power rail mapping and sequencing for EoT form factor board.

Board Power Rail	Sequence Stage	Voltage | Output Type	RC5T619 Power Block
3.3VLDO3_7	Slot_0	3.3V LDO	LDO1 eco
2.8VLDO11	Slot_0	2.8V LDO	LDO2 eco
1.8VDC4	Slot_2	1.85V DCDC	DCDC4
1.85VDC5	Slot_3	1.85V DCDC	DCDC3
3.3VLDO4	Slot_4	3.3V LDO	LDO4 eco
1.8VLDO6	Slot_5	1.8V LDO	LDO9
1.8VLDO9	Slot_5	1.8V LDO	LDO10
1.8VLDO8	Slot_5	1.8V LDO	LDO6 eco
0.9VDC2	Slot_6	0.9V DCDC	DCDC2
0.9VDC1	Slot_6	0.9V DCDC	DCDC1
LDO2	Slot_6	3.3V LDO	LDO3 eco
1.8VLDO5	Slot_7	1.8V LDO	LDO7
1.2VLDO1	Slot_8	1.2V LDO	LDO5 eco
1.2VLDO10	Slot_9	1.2V LDO	LDO8
1.2VDC3	Slot_10	1.2V DCDC	DCDC5

7. EOT FORM-FACTOR BOM

Table 7-1 shows the EoT FfBoard BoM generated from FfBoard schematic.

Table 7-1: EoT FfBoard BoM.

Item	Quantity	Comment	Description	Designator	DIST
1	1	Micro USB 3.0 Type Micro AB		J5	Farnell
2	1	TPS3803-01DCKR		U25	Farnell
3	1	MCP1726-1202E/MF	1.2V LDO	U14	Farnell
4	2	SN74AVC4T245RSVR	4-Bit Dual-Supply Bus Transceiver with Configurable Voltage Translation and 3-State Outputs	U7, U8	Farnell
5	2	10 pin FFC	10 pin FPC Header	JP3, JP5	Wurth
6	1	ASDMB-12.000MHZ-LC-T	12Mhz Osc Module	OS2	Digikey
7	1	ASDMB-20.000MHZ-LC-T	20MHz Osc Module	OS4	Mouser
8	1	25MHz 2520	25Mhz Osc Module	OS1	Farnell
9	1	ASDMB-27.000MHZ-LC-T	27Mhz Osc Module	OS3	Digikey
10	1	0R01 0.5%	1206 current shunt	R174	Farnell
11	1	0R003 1%	2412 current shunt	R169	Mouser
12	1	ADV7513	Analog Dev HDMI TX	U4	Farnell
13	1	TLV320AIC3204	Audio Converter	U2	Mouser
14	2	12p	Capacitor	C111, C112	
15	2	47uF	Capacitor	C8, C9	Mouser
16	2	47uF/10V	Capacitor	C118, C119	Farnell
17	2	100nF	Ceramic Capacitor SMD	C13, C16	
18	14	10nF	Ceramic Capacitor SMD	C17, C23, C24, C28, C29, C36, C37, C38, C39, C40, C51, C56, C57, C61	

19	92	100nF	Ceramic Capacitor SMD	C1, C3, C6, C11, C14, C15, C18, C19, C25, C27, C30, C31, C32, C33, C34, C42, C43, C46, C47, C48, C49, C52, C55, C58, C59, C60, C63, C66, C67, C68, C70, C73, C74, C77, C78, C113, C121, C122, C125, C126, C128, C131, C132, C133, C134, C135, C136, C137, C138, C139, C140, C141, C142, C143, C145, C146, C148, C149, C151, C152, C153, C154, C155, C156, C159, C160, C161, C162, C164, C165, C167, C168, C170, C171, C172, C173, C175, C176, C178, C179, C180, C181, C182, C190, C192, C194, C195, C196, C197, C198, C200, C202	Farnell
20	7	2.2uF	Ceramic Capacitor SMD	C93, C94, C97, C98, C101, C102, C115	Farnell
21	19	1uF	Ceramic Capacitor SMD	C7, C69, C91, C92, C95, C96, C99, C100, C103, C104, C105, C106, C107, C108, C109, C110, C114, C116, C117	Farnell
22	43	10uF/6V	Ceramic Capacitor SMD	C2, C4, C5, C10, C12, C20, C21, C22, C26, C35, C41, C44, C45, C50, C53, C54, C62, C64, C79, C120, C124, C127, C129, C130, C144, C147, C150, C157, C158, C163, C166, C169, C174, C177, C185, C186, C187, C188, C189, C191, C193, C199, C201	Farnell
23	9	22uF	Ceramic Capacitor SMD	C81, C82, C83, C84, C85, C87, C88, C89, C90	Farnell
24	2	4.7uF	Ceramic Capacitor SMD	C80, C86	Farnell
25	2	RClamp05	Clamp Diode	D5, D6	Farnell

		02B			
26	2	RClamp0524P	Clamping diode array	U10, U11	Farnell
27	1	SJ-43514-SMT-TR	CONN AUDIO JACK 3.5MM STEREO + MIC SMD	J1	DIGIKEY
28	1	32.768KHz	Crystal	Y2	Farnell
29	1	27.000MHZ	Crystal 27MHz	Y1	Farnell
30	1	NEB 21 R	DC Jack 1.95mm ID 6.0mm OD 3A	J6	Farnell
31	2	BAT54A	Diode dual common anode	D10, D13	Farnell
32	1	TPD2EUSB30	DIODE, ESD, DUAL, USB3.0, SOT-3	D7	FARNELL
33	3	1N4148	Diode, small signal, 0805	D9, D20, D21	Farnell
34	1	SW DIP-8	DIP Switch	S1	Wurth
35	2	24AA32A-I/MS	EEPROM SERIAL 32KB, SMD, MSOP8	U43, U45	Farnell
36	10	TPD4EUSB30	ESD PROTECTION ARRAY, 4CH, SON-10	D1, D2, D3, D4, D8, D15, D16, D17, D18, D19	FARNELL
37	1	KSZ9031MNX	GIGABIT ENET PHY, 1PORT, 48QFN	U3	Farnell
38	1	7499111221A	GigaBit Ethernet connector with mags.	J3	Wurth
39	1	Wurth HDMI	HDMI Connector	J4	Wurth
40	1	BMP180	I2C DIGITAL PRESSURE SENSOR	U26	Mouser
41	1	TPS3808G01	IC Voltage monitoring	U20	Farnell
42	2	MP2012DQ	IC, 1.5A synchronous step-down converter	U12, U13	Mouser
43	1	N25Q064A11ESE40G	IC FLASH 64MBIT 108MHZ	U22	Farnell
44	1	BMI160	IMUs - Inertial Measurement Units 6-Axis	U21	Mouser

			950uA		
45	10	600R/100 MHz	inductance	FB1, FB2, FB3, FB4, FB5, FB6, FB7, FB8, FB9, FB10	Farnell
46	2	2.2uH	inductance	L3, L5	Mouser
47	2	3.3uH	Inductance	L1, L6	Farnell
48	1	1uH	inductance	L2	Mouser
49	1	2.2uH	inductance	L4	Farnell
50	1	TSOP7533 8TT	IR sensor 38KHz	U18	Farnell
51	1	JUMPER	Jumper	J9	Wurth
52	15	TP	Keystone TEST POIN	TP9, TP10, TP11, TP12, TP13, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP36, TP41	DIGIKEY
53	1	LSHM-120-06.0-L-DV-A-S-K-TR	LCD/AP connector	J10	Samtec
54	1	TLV70033 DCKT	LDO, 200MA, 3.3V, 5SC70	U38	Farnell
55	4	LED	LED	D11, D12, D14, D22	Farnell
56	1	MA2150	MA2150	U1	
57	1	MIC	Microphone	MK1	Farnell
58	3	SI1416ED H-T1-GE3	MOSFET N-CH SINGLE 30V 4A SO-8 PowerPAK	Q1, Q2, Q4	Mouser
59	1	DDTC114 YCA-7-F	NPN prebiased transistor	Q3	Digikey
60	2	LTC4361C DC-1#TRMPB F	Over-Voltage protection	U5, U9	Farnell
61	1	CDCEL925 PW	PROGRAMMAB LE 2-PLL VCXO CLOCK SYNTHESIZER WITH 1.8-V, 2.5-V and 3.3-V LVCMOS OUTPUTS	U19	Farnell
62	3	0.75A	Resettable Fuse 750mA hold 1.5A Trip	F1, F2, F3	Farnell
63	2	0	RESISTOR	RZ7, RZ8	
64	1	27K	RESISTOR	R66	
65	1	37.4K	RESISTOR	R16	
66	7	40.2K	RESISTOR	R43, R44, R62, R63, R64, R67, R92	Farnell

67	1	100R	RESISTOR	R111	
68	1	200R 1%	RESISTOR	R108	
69	1	887R 1%	RESISTOR	R73	
70	33	0	RESISTOR	RZ1, RZ2, RZ3, RZ4, RZ5, RZ6, RZ11, RZ12, RZ13, RZ14, RZ17, RZ18, RZ19, RZ20, RZ21, RZ22, RZ25, RZ26, RZ29, RZ30, RZ33, RZ35, RZ36, RZ37, RZ38, RZ39, RZ40, RZ41, RZ42, RZ43, RZ44, RZ50, RZ52	
71	6	22	RESISTOR	R49, R110, R113, R115, R157, R158	
72	8	100K	RESISTOR	R85, R86, R129, R159, R160, R161, R162, R163	
73	1	187R	RESISTOR	R189	
74	2	22Rx4	Resistor Network 22R x4	RN1, RN2	Farnell
75	6	4.02K	Resistor SMD	R101, R102, R103, R104, R105, R106	
76	24	1K	Resistor SMD	R5, R7, R8, R11, R18, R21, R22, R38, R42, R84, R88, R126, R127, R128, R147, R177, R178, R179, R180, R181, R182, R192, R197, R198	
77	6	1.8K	Resistor SMD	R91, R93, R164, R165, R190, R191	
78	7	2K	Resistor SMD	R9, R10, R27, R72, R74, R75, R77	
79	1	2.7K	Resistor SMD	R6	
80	57	10K	Resistor SMD	R2, R3, R4, R12, R13, R14, R15, R17, R20, R23, R28, R29, R30, R31, R32, R37, R39, R40, R41, R46, R50, R51, R52, R53, R54, R55, R57, R59, R76, R79, R81, R82, R90, R107, R109, R112, R117, R118, R119, R120, R121, R122, R123, R124, R125, R130, R131, R148, R155, R183, R184, R185, R186, R187, R188, R193, R194	
81	1	12.1K	Resistor SMD	R26	

82	1	39K	Resistor SMD	R97	
83	1	121K	Resistor SMD	R58	
84	2	300K	Resistor SMD	R61, R65	
85	1	390K	Resistor SMD	R60	
86	6	680R	Resistor SMD	R33, R36, R83, R150, R151, R196	
87	10	0.1R	Resistor SMD	R19, R34, R35, R45, R48, R89, R166, R168, R171, R172	Farnell
88	2	0.05R	Resistor SMD	R167, R173	Farnell
89	1	0.025R	Resistor SMD	R56	Farnell
90	3	240R 1%	Resistor SMD, Resistor SMD, RESISTOR	R47, R87, R156	
91	1	HEADER 10X2	Standard header, SMD 20 way	JP4	Wurth
92	6	SN74LVC1G3157DCKR	STDP analog switch	U15, U16, U17, U36, U37, U44	Farnell
93	4	DTSM32N	Tact Switch	B1, B2, B3, B4	Farnell
94	1	NC7WZ16P6X	TinyLogic UHS Dual Buffer	U6	Farnell
95	1	WM8325	WM8325	U23	Farnell
96	1	SD connector	Wurth SD push pull connector half size	SD1	Wurth
97	13	INA210	Zero-Drift, Current-Shunt Monitor, 200 Gain	U27, U28, U29, U30, U31, U32, U33, U34, U35, U39, U40, U41, U42	DIGIKEY
98	3	LSHM-120-03.0-L-DV-A-S-K-TR	[NoValue], Camera connector, Camera connector	J8, J12, J13	Samtec
99	3	49.9R	[NoValue], Resistor SMD, Resistor SMD	R1, R24, R25	

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