

**Edge Device and FBG Interrogator**

**Architectural Requirements for Edge Device**

**Draft Rev 0.1**

| Document information | |
| --- | --- |
| HPRM ref | D/xx/xxxxxx |
| Date | 1 March 2021 |
| Security class | CONFIDENTIAL |

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# SCOPE AND GENERAL

# SCOPE

* + 1. This document covers the high-level architectural requirements for the FiBridge Edge Device Unit, which consists of an FBG Interrogator module integrated inside an IP54 enclosure with a Gateway module, a modem, and a power supply. The Gateway module includes computing and data storage resources that will be shared with FBGS interrogator module.

FiBridge is responsible for the design, implementation and qualification of the Non-optical portions of the Edge device (including but not limited to: connection method, computation elements, external I/O and cellular modem). FBGS is responsible for the design, implementation, and qualification of the FBG Interrogator module (optical) of the device and the equipment enclosure. This is to be considered a living document, and as such modification and changes will be tracked as decisions are finalized.

Issues involving power consumption and heat dissipation will be jointly addressed.

It is assumed that this document will capture technical discussions / decisions where necessary.

# GENERAL

* + 1. FiBridge Edge Device Unit consists of the following items, which are covered by their own function requirements specification:
* FBG Interrogator module; Gen3
* Modem
* Power Supply
* Compute Resource
* I/O (such as Ethernet and USB)
* Watchdog Environmental Monitoring
* Local Memory Storage

Overall architecture will be discussed below for each of these sections.

# Acronyms

|  |  |
| --- | --- |
| EDU | Edge Device Unit |
| FBGI | Fibre Braggs Grating Interrogator Module |
| PSM | Power Supply Module |
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# Definitions

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| Must | Means that the definition is an absolute requirement of the specification and is mandatory. |
| Should | Means that the definition is a recommended requirement of the specification and is highly desirable. |
| May | Means that the definition is an optional requirement of the specification and is truly discretionary. |
| EDU | Enclosure that contains FBGI, GWM, and PSM |
| PSM | Power supply inside of the EDU enclosure that creates all internally needed supply voltages from the one externally provided DC voltage |
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# References

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# Overview and Architecture

The overall aim of the system is to construct an embedded / deployable / in-field Fiber Optic Interrogator system which can process several Fiber Optic inputs and send the collected information to an external endpoint for further data processing. The general requirements for power and heat are covered in a different document (“FiBridge Edge Device and FBG Interrogator Functional Requirements Specification Rev 1.7”)

All I/O cables, connectors, and indicators will be connected to the front of the unit. It is desired to have all connections (all I/O including power connectors) on the front of the unit for easy install and replacement The optical module will connect to the compute resource via a USB 2.0 protocol and a +5VDC power connector.

The compute resource will be responsible for controlling and operation of the optical module. All programming of the interface and operation will be enabled through an API (TBD) which will include install requirements, Initialization requirements and normal operational requirements.

Data from the Optical module will be processed locally and then assembled into messages. These messages will then be transmitted via a cellular / or similar wireless modem to the web-based endpoint where additional processing and classification of the data will be completed)

In addition to the normal operational capabilities, the compute resource will require additional storage memory, a watchdog Environmental monitor, and power regulation circuity. A custom PCB will be developed for the purpose of addressing these needs / requirements.

# Compute Resources

Raspberry Pi Compute Module 4

The Raspberry Pi Compute Module 4 (CM4) is a System on Module (SoM) containing processor, memory, eMMC Flash and supporting power circuitry. These modules have extra IO interfaces over and above what is available on the Raspberry Pi boards, opening more connection options.

The design of the CM4 is loosely based on the Raspberry Pi 4, Model B.

The electrical interface of the CM4 is via two 100-pin high density connectors.

This addition allows new interfaces; an additional second HDMI, PCIe, and Ethernet. The addition of these new interfaces, especially PCIe, would not have been possible while preserving the previous form factor.

Key features of the CM4 are as follows:

* Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
* Small Footprint 55mm × 40mm × 4.7mm module
* 8GB LPDDR4-3200 SDRAM with ECC (see Appendix B)
* 32GB eMMC Flash memory (see Appendix B)
* Two Gigabit Ethernet PHY supporting IEEE 1588
* 1 × PCIe 1-lane Host, Gen 2 (5Gbps)
* 2 × USB 2.0 port (highspeed)
* 28 × GPIO supporting 3.3v signalling and peripheral options:
  + Up to 5 × UART
  + Up to 5 × I2C
  + Up to 5 × SPI
* A choice of either a 24VDC or 12VDC input.

While some of these protocols are used to connect existing devices (such as one USB will be required for the Optical Module) the remaining will be useful for future capabilities.

Please refer to the CM4 datasheet for additional electrical and thermal specifications. Basic operation of the system allows for the operation via a single 12VDC power supply and has an operating temperature range of -40C to +85C.

# Modem

Quectel EG25-G module which is certified in both the U.S. market and the Australian market. This will be configured (or purchased) as a plug-in card using either a combination of USB and UART interfaces or the PCIe connection. This needs to be a plug-in card so that it can be swapped for regulatory related issues worldwide (although this module is licensed currently worldwide, so this requirement maybe relaxed)

# Power Supply

The CM4 runs on a single +5VDC power supply of 3A max requirement. The carrier board will require additional power for other peripherals. The carrier board will provide the power to the CM4 module and all other connected devices (with the possible exception of the Optical Module). Currently the Carrier board as either a +12VDC input or a +24VDC input. This is internally jumper selectable. It is currently intended that all additional power conversion will be done on the carrier board.

# Watchdog Environmental Monitoring

The system is required to provide information for various environmental condition monitoring. Collection of environmental conditions is to be taken from the viewpoint of the external case (but internal cabinet) space. Local processing and collection of this information will be done on a continuing basis and transmitted to the server endpoint for processing and potential operator alerts. These environmental sensors will connect to the GPIO lines on the Raspberry Pi Hat interface (TBD). The sensors will include dual temperature sensors, dual humidity sensors, four magnetic door sensors, a sense loop and additional ‘mast’ sensors for the solar panel mast system.

# Local Memory Storage

Some amount of local storage will be necessary to hold both the operating system (program) and act as a data store. It is currently unclear just how much space is necessary and if this needs to be in non-volatile memory. This could either be place on the carrier board, PCIe, or connected to USB. Additional requirements are necessary here.

Current version of the CM4 module contain up to 32GB eMMC Flash memory which may be used for this local storage purpose.

# I/O (such as Ethernet and USB)

Dual HDMI 2.0 connectors

Optional. Would only be considered for debug purposes. Not in final product.

Gigabit Ethernet RJ45

The Raspberry Pi Compute Module 4 IO Board uses a standard 1:1 Ethernet. Additional ESD protection is provided on the Raspberry Pi Compute Module 4 IO Board. An additional Ethernet port is included, but as a USB 2.0 bridge device. It will require additional (manufacture supplied Linux Drivers).

USB 2.0 two standard ports, one internal ports

The Raspberry Pi Compute Module 4 IO Board has an onboard USB 2.0 hub. This connects to the CM4 USB 2.0 port. Two ports from the hub are connected to a connector. The one other port is connected to a header. There is an internal current limit switch to provide VBUS to the USB connectors. The current limit is set to approximately 1.2A

PCIe Gen2 x1 Socket

The PCIe socket is designed to take standard PC PCIe cards. You should ensure that there is a suitable OS driver for your card. The PCIe link on the Raspberry Pi 4, Model B is used for the USB 3.0 interface via the VLI805 XHCI controller. If the application requires USB 3.0 interface, then an external XHCI controller is required like the VLI805. The PCIe link has been successfully used with an NVMe drive via a passive PCIe adaptor. Currently the CM4 bootloader doesn’t support NVMe drives so you must boot via a different source. If the application uses a standard PCIe card, then it might be useful to have a small PCIe adapter to rotate the PCIe card 90degress to enable a more compact case. Raspberry Pi Compute Module 4 IO Board 2.4. Gigabit Ethernet RJ45 5 Note the PCIe Interface doesn’t support MSI-X. Typically PCIe devices will fall back to MSI.

Raspberry PI Hat Connector

The Raspberry Pi Compute Module 4 IO Board has a standard Raspberry Pi 40-way HAT connector. The mounting holes are also provided so that standard HATs may be used. Specific functions have been used (from the list of GPIO) for specific signals on the board. These are:

GPIO06 – COMM(Ring)

GPIO12 – Optical Power Enable

GPIO13 – COMM(DtR)

GPIO18 – WTCDG\_DIN

GPIO19 – COMM(W\_Disable)

GPIO22 – Comm(User Button)

GPIO26 – COMM(Hat\_Power\_Off)

GPIO27 – Comm(User Led)

# Electrical Requirements

# Mechanical Requirements

# Board Stackup

This is a four-layer board (FR-4 material). The stack up is as follows:

Top trace layer CU 0.035mm thick

Core layer of 0.09mm thick

Ground layer (pour) 0.035mm thick

PrePreg layer of 1.26 mm thick

3V power layer of 0.035mm thick

Core layer of 0.09mm thick

Bottom trace layer CU 0.035mm thick

A total thickness of the board is 1.6mm

This follows the suggested values from the RPi carrier board.

Nominal trace width 0.2mm was used (exceptions for differential pairs, and power / ground traces).

# Board Schematic Description

# Page 1: CM4 module

Contains connectors for CM4 module. Also contains jumpers for eMMIC write enable, Bluetooth Enable, RT wake-up, and run\_pg

Page one contains the Raspberry Pi Compute Module 4. Basically, on the layout you’ll see the full outline of the module, but really all that matters is the placement of the two Hirose high density connectors. Power is supplied to this module on the 5V Source from 5. Pins 77, 79, 81, 83, 85, 87 are the main power input pins (to the CM4). Grounds are connected to pins 1, 2, 7, 8, 13, 14, 22, 23, 32, 33, 42, 43, 52, 53, 59, 60, 65 66, 71, 74, 98, 107, 108, 113, 114, 119, 120, 125, 126, 131, 132, 144, 150, 155, 156, 161, 162, 167, 168, 173, 174, 179, 180,185, 186, 191, 192, 197, 198. Signals which are differential pairs have the suffix of “\_N” or “\_P”. Signals for the USB, Ethernet, HDMI, and PCIe have differential pairs (which are impedance matched) for the data lines.

Ethernet and HDMI both require an impedance of 100 ohms. For this board this works out to a 0.127mm trace width.

PCIe and USB both require an impedance of 90 ohms. For this board this works out to a value of 0.147mm trace width.

The module faces the back of the board (layout) which does not present any issues. There are no antenna connections for this module. Two zero-ohm resistors are also on this page. These disable both the eMMIC memory (used for OS initialization) and also Bluetooth (which shouldn’t be necessary for this application).

# Page 2: Ethernet connection #1

Contains circuity for primary Ethernet port. ESD protection is provided by TPD4EUSB30DQAR on all Ethernet data pins. Header for some additional options.

Board layout of this section is from the CM4 module to the topmost Ethernet connector. Both Ethernet connectors are from Bel Fuse Ince (L836-1J1T-43 1port 1000 Based-T capable). They are supported by two TVS Diodes which again was used in the RPi carrier board. These devices have been placed as close as possible to the connector to prevent spikes during connect/disconnect cycles. All differential pairs are tuned to length of 141.55mm (+/- 0.009mm) which is within tolerance of the required (better than) 0.15mm. While matching between pairs is not critical, it has been done for these first boards.

# Header Page 3: Temporary HDMI and Raspberry Pi

Contains circuity for HDMI (dual port) and shows Pi header. Sensors will be directly connected to the Pi Header pins TBD**.**

This page only contains the HDMI and HDMI power supply. On the board layout, the connectors are located on the top between the USB on the go (otg) connector and the RPi module. They are only used for initial debugging of the system and will not be included in the final product. (i.e. easily removed and board space reclaimed). This page also holds the RPi 40 pin connector, which on the layout is located at the middle back side of the board. Stitching all the required GPIO from the processor used both top and bottom traces. This bus is power by the 5V supply. The supply for the HDMI is a 5V supply via a MIC2025 regulator which is capable of supplying up to 1.25A (short circuit) and a max of .7A typical. Supply trace width was increased to deal with current draw.

# Page 4: PCIe connector

Connector for PCIe

Taken directly from the RPi carrier board. This connector sits under the CM4 module. Use of this expansion bus will require either a cable or a 90-degree card edge to take into consideration the enclosure height.

# Page 5: Power Regulation 1, 3V3, 5V, watchdog reset

Internal power regulation. From 12V to 3.3V, 5V, VBUS (usb power)

Also contains power watchdog

Two external power connectors face the front end of the board. Both are threaded barrel jacks (2.5x5.5mm). One connector is used to source the external 24V DC supply (lower connector) and the upper connector is used to supply 12V DC to the system. These both run to a jumper where a jumper selects between the two potential input sources. In production the dual inputs will be reduced to one and the jumper removed. Input source power traces use a larger “pour” polygon, thus increasing surface area for these high draw current sources. These two sources currently run to a single 12V output regulator and use a Ferrite Bead to filter any potential line noise before splitting off the power to both a 3VDC and a 5VDC regulator. Both take a 12V input and product either the 3V or 5V output (both at 3A max). There is sufficient filtering based on multiple 22uF cap’s on the output lines. It should not be necessary to use multiple capacitor values (using modern SMD devices).

Thermal planning for placement of these regulators was observed. The largest heat source in the Edge Device / Optical Module is the Optical light source. From discussions this heat source will be in the top half of the board, so care was taken to move all heat producing power regulation to the lower half of the system. All power regulators are also spread out so as not to create a localized hot spot. The more heat generation will come from the initial two regulators (12V and 24V to 12V\_unregulated). These have been moved to the lower section of the board (out of the way of all other circuity).

The reset watchdog also is on this page. Located at the bottom of the board (next to the battery holder). It’s next to J19 which is the 3x3 jumper block. The jumper block allows the modification of timing (how much time can elapse before the reset line is pulled active. I’ve also added a jumper to select between the CM4 module reset and an LED on the front panel (for debug). This will be removed for production. Ability to disable the watchdog will aid in debugging (without having the system reset).

Finally, the VBUS 5V power source is also located on this page. This is the USB connector power (USB 2.0 Type A connectors). It is controlled by the USB controller which can enable or disable external USB power. Power busses are not separated (no requirement). This power regulator is located near the center of the board.

# Page 6: Real Time clock and wake circuit

Real Time clock and wake up circuit. Also had indicator LED’s

As this is not a critical route, this component has been placed in the lower half near the back of the board, next to the 3V battery holder. It connects to the SDA/SCL lines and can generate an interrupt when the processor is put into a sleep or standby mode. Also, on this page at two LED’s one which shows power to this board (3V) and the other which shows that the Processor is active. Both use a 470-ohm resistor to limit current draw. There is also an LED for the Optical module power (5V). All three of these LEDS are located on the front panel between the USB connector and the Optical Module 5V output.

# Page 7: USB 2.0

Contains USB circuit. J12 (usb otg) can be used to bypass RPi to operate USB devices directly. The RPi module has a single USB 2.0 connection. This runs from the Module to the USB controller. There it generates four additional USB channels. There is also a USB Mux chip. This allows (if power is applied to the USB OTG port) to switch from normal USB control (from the RPi module) to the external USB connector. This is used to initialize the eMMIC (Linux OS) on the CM4 Module. Two channels of USB go to the front panel (via connector located in the middle of the front panel), one channel is spare, and the final channel is used for the second Ethernet port. Again, the external USB connector signals are electrically protected by two Diode chips placed as close to the connector as possible. These diodes cover the upstream USB signal and Channel 1, 2, and 3, where the fourth is connected to the USB / Ethernet bridge chip. The USB controller chip is located near the USB external connector. All differential signals are tuned to a length of 60.86mm with an accuracy of (+/-)0.007mm. Except for USB2 which is located on the RPi Module and the USBD signals which connect to the external USB OTG connector (top of the board)

# Page 8: Input Voltage, output voltage regulation

Allows external connection to either 12VDC or 24VDC (select via jumper). The generates internal regulated 12VDC. Also generates 5V 5A for optical module. The two potential input sources are then further regulated by a secondary regulator. This then generates at 12V regulated signal. This is then passed through a Ferrite Bead (currently undersized for current). Which then becomes the basis for all other voltage regulation. This circuity is contained in the lower portion of the board. Running from the lower left (from the front panel) to the middle of the board where the 3V and 5V signals are generated. The 3V power is then routed to the third copper plane which is the primary 3V plane. There are a few 12V power routed there as well (best to isolate to this plan for current draw). The power generated for the Optical module also copies the 5V regulator circuit but is dedicated to the 5VDC output for the external module. This will allow for a 5A current draw (max).

# Page 9 & 10: Ethernet Controller #2

Contains second Ethernet controller. This is using a USB to Ethernet bridge – so it uses USB4 to create another Ethernet port. Located on the layout next to the second Ethernet port (lower Ethernet connector) it takes the internal USB 4 channel and creates an Ethernet port. This is a complex part which has a driver set (for all platforms, written in C) which will need to be evaluated and tested for our needs. The part (LAN7800 from microchip) works with either USB 3.0 or 2.0 by disabling some of the USB input pins. The circuit was taken from the application notes. The connector is also protected by the same diode circuit. Finally, on page 10, a fan controller was added. This circuit contains a control loop for Tach and PWM and uses a 12VDC output voltage (on the connector). This is not an edge connector – and will need to change for production. This connector has been placed between the input DC voltage sources and the Optical module output 5V supply.

Please note that the current Eloque logo, copywrite and versioning information is also included in the upper back side of the board.