IoT Expansion Card

Design Specification

Limitation of Liability	The information in this manual is subject to change without notice and does not represent a commitment on the part of Sierra Wireless. SIERRA WIRELESS AND ITS AFFILIATES SPECIFICALLY DISCLAIM LIABILITY FOR ANY AND ALL DIRECT, INDIRECT, SPECIAL, GENERAL, INCIDENTAL, CONSEQUENTIAL, PUNITIVE OR EXEMPLARY DAMAGES INCLUDING, BUT NOT LIMITED TO, LOSS OF PROFITS OR REVENUE OR ANTICIPATED PROFITS OR REVENUE ARISING OUT OF THE USE OR INABILITY TO USE ANY SIERRA WIRELESS PRODUCT, EVEN IF SIERRA WIRELESS AND/OR ITS AFFILIATES HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES OR THEY ARE FORESEEABLE OR FOR CLAIMS BY ANY THIRD PARTY. Notwithstanding the foregoing, in no event shall Sierra Wireless and/or its affiliates aggregate liability arising under or in connection with the Sierra Wireless product, regardless of the number of events, occurrences, or claims giving rise to liability, be in excess of the price paid by the purchaser for the Sierra Wireless product.

Document details	Title: IoT Expansion Card Design Specification Author: Sierra Wireless Source: http://mangoh.io/

Disclaimer	Indicate any modifications made to the original document.

Trademarks	mangOH™ and the mangOH logo are trademarks of Sierra Wireless. Other trademarks are the property of their respective owners.

Contact Information

Sales information and technical support, including warranty and returns	Web: sierrawireless.com/company/contact-us/ Global toll-free number: 1-877-687-7795 6:00 am to 6:00 pm PST
Corporate and product information	Web: sierrawireless.com

Consult our website for up-to-date product descriptions, documentation, application notes, firmware upgrades, troubleshooting tips, and press releases:

www.sierrawireless.com

Revision History

Revision number	Release date	Changes
1	June 2015	Creation (limited release)
2	January 2016	Added power class and height class specifications Removed PWM Added 'Class C' temperature spec to Table 2-1 on page 13 Added Power Category on page 14 Added Connector Height Category on page 23 Updated Figure 4-2 on page 25 (pad dimension 2.10 replaces 1.60) Added Figure 4-4 on page 27 Updated Table 4-2 on page 28 (board name field size; added example header columns; added 'Additional fields') Updated Figure 5-3 on page 35 (added Detail A and Detail B) Updated Figure 5-4 on page 36 (added Detail A and Detail B) Added Self-enclosed IoT Expansion Card on page 40
3	February 2016	Changed terminology from 'IoT Modules' to 'IoT Connectors'
4	April 2016	Updated (modified bottom component placement area dimensions) Figure 4-2 on page 25, Figure 4-3 on page 24, Figure 6-7 on page 43. Updated (consolidated notes, no specification changes) Figure 4-4 on page 27, Figure 6-2 on page 38, Figure 5-3 on page 35, Figure 5-4 on page 36.
5	June 2016	Replaced 'IOT Connector' references with 'IOT Expansion Card'
6	Aug 2016	Corrected document # on page footers (cover # was okay)
7	Nov 2016	Updated EEPROM structure to version 1.0 Removed wide-module specifications Noted that hot-swapping is not supported
8	April 2017	Corrected required host application behavior in Reset Signal (n_RESET) on page 19

Contents

List of Figures

List of Tables

1: Introduction

1.1 Overview

The IoT Expansion Card form factor represents an open hardware standard for sensors, network adapters, and other IoT technologies that can be "plugged" into host applications (e.g. hardware development board) to provide new features and interfaces. As a family, IoT Expansion Cards share a standardized footprint and pinout, with several interfaces to support various IoT technologies.

1.2 Rationale for the IoT Expansion Card Form Factor

The IoT Expansion Card form factor is designed to be a cost-competitive solution for several current and emerging market demands for host applications, including:

- On-demand hardware applications—The same host application can be used for different market segments by including unique expansion card solutions for each segment. For example, a Wi-Fi/Bluetooth solution for one segment and an environmental sensor for another segment.

- Electrical and feature compatibility across IoT technologies—Availability of several data interfaces allows support for various IoT solutions. For example, digital audio over PCM, application control and data transfer over USB, etc.

- Enables Configure/Built to Order

- Accommodates various PAN technologies, sensors, and other IoT applications

Using the IoT Expansion Card's modular design, all actors of the M2M value chain can benefit.

- Host applications can, without requiring redesign, inherit new features and interfaces for their products

- Technology specialists such as PAN, LPRF, Industrial Fieldbuses or sensors can bring their expansion cards to market

- System integrators and end customers can easily combine host applications and expansion cards to fit their specialized needs
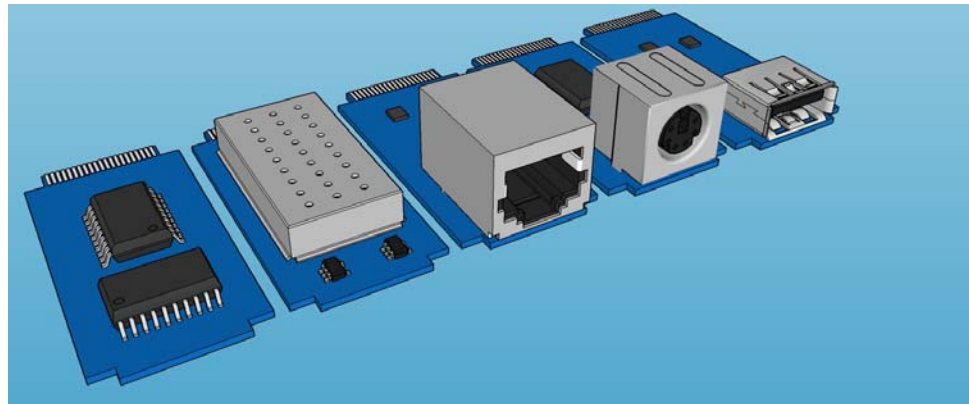
Figure 1-1: IoT Expansion Cards—Common footprint, variable designs

1.3 Specification Objective

This document defines a standard open-hardware pluggable module form factor specification. The specification describes supported interfaces and the mechanical design requirements (device-side and host-side) for building IoT Expansion Cards and integrating them into host applications.

1.4 Targeted Applications

The IoT Expansion Card form factor provides a common platform for OEMs to make a wide range of technologies available for use with expansion card-compatible host applications. Some examples of technologies that could be implemented on IoT Expansion Cards include:

- PAN (Personal Area Network): Wi-Fi, Bluetooth, Zigbee, etc.
- Common LAN/WAN: Ethernet, USB, Serial, etc.
- Low power and Low Power Long Range wireless technologies
- Industrial Fieldbuses: Modbus, Profibus, MPI, PPI
- Global Navigation Satellite Systems (GNSS)
- Specialized I/Os: Digital, Analog, Counting, PT1000, etc.
- Sensor networks
- Specialized sensors: Accelerometers, Temperature, Environment

1.5 IoT Expansion Card Classes and Categories

The IoT Expansion Card specification defines classes based on power consumption categories and height categories. See Power Category on page 14 and Height Category on page 24 for details.

1.6 IoT Expansion Card Characteristics

Key characteristics of the IoT Expansion Card specification include:

- Standard footprint
- Low-cost IoT Connectors
- Several available host interfaces:
  - ADC
  - GPIOs
  - I2C
  - I^2S
  - PCM
  - PPS Clock (Stratum 1)
  - SPI
  - UART
  - USB
  - SDIO

1.7 Document Organization

- Technical Specifications—Environmental, EMC/ESD, and power specifications
- Interfaces Specification—Host interface details for all supported interfaces
- Mechanical / Form Factor—Operational specifications, and hardware design (host and IoT Expansion Card) requirements
- IoT Expansion Card-side Details—EEPROM header structure and IoT Expansion Card boot process
- Mounting Methods—Mounting design details (host and IoT Expansion Cards)
- Pinout—IoT Expansion Card pin details

2: Technical Specifications

2

2.1 Overview

This chapter describes environmental, EMC/ESD, and power specifications for IoT Expansion Cards.

2.2 Environmental Specifications

IoT Expansion Cards must satisfy the operational and non-operational environmental specifications defined in Table 2-1.

The environmental class is identified in the EEPROM header (see EEPROM Header on page 28).

Table 2-1: Environmental Specifications

Parameter	Range	Operating Class
Ambient Operating Temperature	-30°C to +70°C	Class A—The host application and IoT Expansion Card remain fully functional across the specified temperature range, meeting the cellular performance requirements of ETSI or other appropriate wireless standards.
	-40°C to +85°C	Class B—The host application and IoT Expansion Card remain fully functional across the specified temperature range. Some cellular parameters may deviate from the performance requirements of ETSI or other appropriate wireless standards.
	0°C to +50°C	Class C—Commodity Class. The host application and IoT Expansion Card remain fully functional across the specified temperature range, meeting the cellular performance requirements of ETSI or other appropriate wireless standards.
Ambient Storage Temperature	-40°C to +85°C	

2.3 Power Requirement

IoT Expansion Cards are powered by DC power provided by the host application via the pins (voltage rails) described in Table 2-2 on page 14.

Note: Hot-swapping (hot-plugging) of IoT Expansion Cards is not supported.

Table 2-2: Power Supply Pins

Pin	Name	Function	Specification	Notes
1	VCC_5V0	USB power supply/ 5V power supply	5.0V ± 10%, 500 mA	
11	VCC_1V8	1.8V power supply	1.8V ± 10%, 500 mA	
28	VCC_3V3	3.3V power supply	3.3V ± 10%, 500 mA	Each pin must be capable of 500 mA. IoT Expansion Cards may require up to 1 A total.
29	VCC_3V3	3.3V power supply	3.3V ± 10%, 500 mA	
Maximum combined power across all voltage rails (pins 1, 11, 28, 29)			3.3W	

2.3.1 Required Power-up Procedure

To prevent the possibility of latchup during the power-up sequence:

1. Host application must provide power rails (5V and 3.3V) first.
2. After power rails are provided, host application can provide I/O voltage (1.8V).
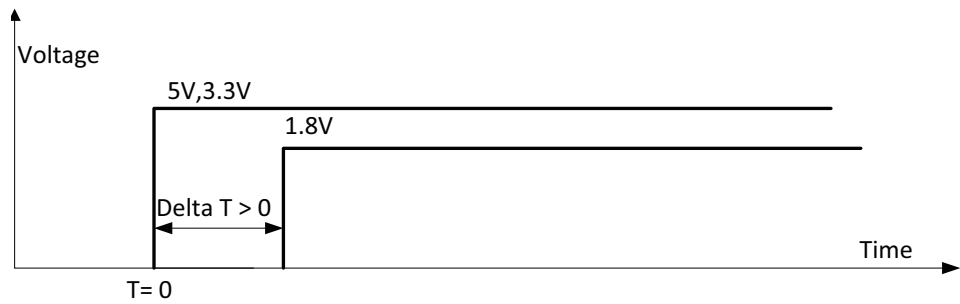
Figure 2-1: Power-up Sequence Timing

Note: Well-designed host applications will follow this procedure to make sure latchup will not occur. Developers may also include, if desired, latchup-resistant chips and/or a latchup protection technology (LPT) circuit to prevent latchup during the power-up sequence.

2.3.2 Power Category

IoT Expansion Cards are assigned a power category based on their power consumption:

• Category 1: <2.5W
• Category 2: ≥2.5W to <3.3W
• Category 3: ≥3.3W

The power category is identified in the EEPROM header (see EEPROM Header on page 28).

2.4 EMC and ESD Recommendations

When designing an IoT Expansion Card, make sure that potential EMC (Electromagnetic Compatibility) issues are considered, and appropriate ESD protection is incorporated in the design.

For example:

- Identify and mitigate possible spurious emissions radiated by the application to the host application's RF receiver in the receiver band.
- ESD protection is strongly recommended on the expansion card on all externally-accessible signals, such as:
  - Serial link
  - USB
  - Antenna port
  - Ethernet
- Perform EMC/ESD tests on the expansion card as soon as possible to detect potential issues
- Follow generic EMI mitigation philosophies
  - For high-speed buses, place decoupling capacitor close to the IoT Connector in case it is needed for signal speed reduction
  - Place bulk capacitors close to power rails. Ratings for these capacitors depend on the specific expansion card design.
- Provide ESD protection ground strips underneath the expansion card.
  Host applications should include ESD protection in the form of ground clips that engage with the expansion card's ground protection strips.
  For details, see Mounting Methods on page 37.
- If appropriate, place series resistors inline with high speed traces to drop speed and eliminate ringing effects. For example, place 33 Ω resistors inline on SDIO traces.

Table 2-3: ESD Specifications [a]

Category	Connection	Specification
Operational	Externally-accessible signals	IEC-61000-4-2 - Level (Electrostatic Discharge Immunity Test). Contact and Air limits are specific to the end product in which the IoT Expansion Card will be installed.

a. ESD protection is highly recommended at the point where the UIM contacts are exposed, and for any other signals that would be subjected to ESD by the user.

3: Interfaces Specification

3

3.1 Overview

This chapter describes the interfaces supported by IoT Expansion Card form-factor devices and provides specific voltage, timing, and circuit recommendations for each interface.

3.2 IoT Expansion Card Platform Features

The IoT Expansion Card platform provides several interfaces for device control and data transfer:

- USB on page 16
- SDIO Interface on page 17
- UART on page 17
- SPI Bus on page 18
- Reset Signal (n_RESET) on page 19
- ADC on page 19
- I2C Interface on page 19
- General Purpose Input/Output (GPIO) on page 20
- n_CARD_DETECT on page 20
- Digital Audio on page 22
- Stratum Clock (PPS) on page 22

3.3 USB

The IoT Expansion Card supports one high-speed USB2.0 Interface that conforms to *[3] Universal Serial Bus Specification, Revision 2.0*. The interface may be used for application control and data transfer between the expansion card and a host application.

Table 3-1: USB2.0 Interface Pins

Pin	Signal name	I/O[a]	Function	If unused	Voltage
1	VCC_5V0	I	USB power supply/5V power supply	No connect	5.0V
2	USB_D+	I/O	Differential data interface positive	No connect	
3	USB_D-	I/O	Differential data interface negative	No connect	
4	GND	-	Ground	No connect	

a. Direction with respect to IoT Expansion Card

3.4 SDIO Interface

The IoT Expansion Card supports an SDIO (Secure Digital Input/Output) interface that conforms to *[4] SD Specifications Part E1 SDIO Simplified Specification, Version 3.00*. The interface may be used for data communication between the expansion card and a host application.

The expansion card can incorporate an SDIO card or an embedded SDIO device, as identified in the EEPROM header (see EEPROM Header on page 28). The host application must identify the SDIO type and take appropriate steps to work with it (as described in the SDIO specification).

Table 3-2: SDIO Interface Pins

Pin	Signal name	I/O[a]	Function	If unused	Voltage
5	SDIO_CLK	I	SDIO clock	No connect	SDIO card: 2.7–3.6V
6	SDIO_CMD	I	Command/Response	No connect	
7	SDIO_DAT3/CD	I/O	Data 3/Card Detection	No connect	Embedded SDIO device:
8	SDIO_DAT2	I/O	Data 2	No connect	1.7–-1.95V or 2.7–3.6V
9	SDIO_DAT1	I/O	Data 1	No connect	
10	SDIO_DAT0	I/O	Data 0	No connect	See ([4] SD Specifications Part E1 SDIO Simplified Specification, Version 3.00 for details.

a. Direction with respect to IoT Expansion Card

3.5 UART

The IoT Expansion Card supports a 4-wire UART interface. The interface may be used for data communication between the expansion card and a host application.

Flow control is managed using the RTS/CTS signals, or using software XON/XOFF.

For additional information, see Digital I/O Characteristics on page 23.

Table 3-3: UART Interface Pins

Pin	Signal name	I/O[a]	Function	If unused	Voltage
12	UART_TXD	O	UART Transmit Data	No connect	1.8V ± 10%
13	UART_RXD	I	UART Receive Data	No connect	
14	UART_CTS	I	UART Clear to Send	No connect	
15	UART_RTS	O	UART Ready to Send	No connect	

a. Direction with respect to IoT Expansion Card

3.6 SPI Bus

The IoT Expansion Card supports a 3/4/5-wire serial peripheral interface (SPI) that may be used for data communication between the expansion card and a host application.

The following features are available on the SPI bus:

- Mode: Slave (Master mode is not supported)
- 3/4/5-wire interface

Note: Although the IoT Expansion Card supports 3, 4, and 5-wire implementations of the SPI bus, it will only work if the host application supports the same architecture (number of signals, bus speed, data length) as the expansion card.

Table 3-4: SPI Interface Pins

Pin	Signal name	I/O[a]	Function	If unused	Voltage
16	SPI_CLK	I	SPI serial clock	No connect	1.8V ± 10%
17	SPI_MISO	O	SPI2 Master Input/ Slave Output (Data transfer from IoT Expansion Card to host application)	No connect	
18	SPI_MOSI	I	SPI Master Output/ Slave Input (Data transfer from host application to IoT Expansion Card)	No connect	
19	SPI_SS/MRDY	I	SPI Slave Select	No connect	
26	SPI_SRDY (alternate function)	O	SPI Slave Ready	No connect	

    a.   Direction with respect to IoT Expansion Card

3.6.1 SPI Configuration

Table 3-5: SPI Configuration

Operation	Max Speed	SPI-Mode	Duplex	4-wire Type
Slave	Host application-dependent	0,1,2,3	Full	SCLK (SPI_CLK) MOSI (SPI_MOSI) MISO (SPI_MISO) SS (SPI1_SS/MRDY)

3.7 Reset Signal (n_RESET)

The IoT Expansion Card supports an interface that allows an external application to reset the expansion card.

To bring the expansion card out of reset, the host application must bring up the power rails for the expansion card and drive (pull) n_RESET high.

To reset the expansion card, the host must pulse n_RESET low.

Table 3-6: n_RESET Interface Pin

Pin	Signal name	I/O[a]	Function	If unused	Voltage
32	n_RESET	I	Active low reset from host application to IoT Expansion Card	No connect	1.8V ± 10%

    a.   Direction with respect to IoT Expansion Card

3.8 ADC

The IoT Expansion Card supports one general purpose Analog to Digital Converter (ADC) output.

The interface may be used for one-way (output) communication from the expansion card to the host application. For example, ADC0 could be used as an indicator to the host application to notify when a specific analog event occurs (such as a sensor being triggered).

Table 3-7: ADC0 Interface Pin

Pin	Signal name	I/O[a]	Function	If unused	Voltage
20	ADC0	O	Analog to Digital Converter	No connect	1.8V ± 10%

    a.   Direction with respect to IoT Expansion Card

3.9 I^{2}C Interface

The IoT Expansion Card supports one I^{2}C (Inter-Integrated Circuit) interface. The interface may be used for data communication between the expansion card and a host application.

The I^{2}C bus implemented on the expansion card should support 100 kbps (standard mode) to be compatible with the widest variety of host applications. Higher speeds may also be implemented (for example, 400 kbps, 1 Mbps, etc.) but will only be attainable if also supported by the host application.

The I^{2}C interface has the following hardware requirements:
- Host application—All required pull-up resistors, including a weak pull-up for the I^{2}C bus, should be located on the host application, not on the expansion card.

Resistor values are host-dependent. For pull-up details, see Pull-up Resistors on page 27.

- IoT Expansion Card—A configuration EEPROM is required. For details, see n_CARD_DETECT on page 20 and EEPROM on page 28.

Table 3-8: I²C Interface Pins

Pin	Signal name	I/O[a]	Function	If unused	Voltage
22	I2C_SDA	I/O	I²C Data (Tx/Rx)	No connect	1.8V ± 10%
23	I2C_SCL	I	I²C Clock	No connect	1.8V ± 10%

    a.   Direction with respect to IoT Expansion Card

3.10 General Purpose Input/Output (GPIO)

The IoT Expansion Card supports four GPIOs that may be used for data communication between the expansion card and a host application.

For additional information, see Digital I/O Characteristics on page 23.

Table 3-9: GPIO Pins

Pin	Signal name[a]	I/O[b]	Function	If unused	Voltage
24	GPIO_1[c]	I/O		No connect	1.8V ± 10%
25	GPIO_2	I/O	General purpose I/O	No connect	1.8V ± 10%
26	GPIO_3	I/O		No connect	1.8V ± 10%
27	GPIO_4	I/O		No connect	1.8V ± 10%

    a.   Alternate functions available: pin 26: SPI_SRDY
    b.   Direction with respect to IoT Expansion Card
    c.   May be used as an interrupt line if the IoT Expansion Card has an IRQ line

Note: GPIOs are logic I/O signals that should not be used to directly drive electric loads.

3.11 n_CARD_DETECT

The IoT Expansion Card provides a signal that is used by the host to detect whether an expansion card is present in a slot on the host application.

Table 3-10: n_CARD_DETECT Pin

Pin	Signal name	I/O	Function	Voltage
31	n_CARD_DETECT	I/O	Host checks the signal to determine if an IoT Expansion Card is inserted (active low) or not (high)	1.8V ± 10%

Figure 5-3 on page 36 describes the process the host application uses when booting to detect whether expansion cards are inserted in slots on the host application.

All expansion cards are assigned the same address (0x53) while they are inactive. When the host needs to work with a specific expansion card, it accesses the appropriate slot and activates the expansion card. When finished with an expansion card, it is deactivated, and the host can then access another expansion card if desired.

Expansion cards can be inserted before the host application boots. The host application checks the state of the n_CARD_DETECT pins on each slot to determine if an expansion card is present or not.

Note: n_CARD_DETECT must have a pull-up (≥ 47k) on the host. For details, see Schematic—Recommended EEPROM on page 35 and Pull-up Resistors on page 27.

Table 3-11: n_CARD_DETECT States

State[a]	Logic state	Address pin A0 (level)	EEPROM address	Comments
Input	High	High	0x53	No IoT Expansion Card detected
Input	Low	High	0x53	IoT Expansion Card is inactive
Output	High	Low	0x52	IoT Expansion Card is active

a. Direction with respect to IoT Expansion Card

3.12 Digital Audio

The IoT Expansion Card supports a 4-wire digital audio interface that can be configured for either PCM (Pulse Code Modulation) or I²S (Inter-IC Sound) audio.

Table 3-12: PCM/I²S interface signals [a]

Pin	Signal name	I/O[b]	Function	If Unused
33	PCM_DIN	Output	PCM Data In The frame "data in" relies on the selected configuration mode.	Leave open
	I2S_IN		I2S Data In The frame "data in" relies on the selected configuration mode.	
34	PCM_DOUT	Input	PCM Data Out The frame "data out" relies on the selected configuration mode.	Leave open
	I2S_OUT		I2S Data Out The frame "data out" relies on the selected configuration mode.	
35	PCM_SYNC	Input	PCM Sync The frame synchronization signal delivers an 8 kHz frequency pulse that synchronizes the frame data in and the frame data out.	Leave open
	I2S_WS		I2S Word Select The word select clock indicates which channel is currently being transmitted (low cycle indicates left audio channel, high cycle indicates right audio channel).	
36	PCM_CLK	Input	PCM Clock The frame bit clock signal controls data transfer with the audio peripheral.	Leave open
	I2S_CLK		I2S Clock The frame bit clock signal controls data transfer with the audio peripheral.	

a. All values are preliminary and subject to change.
b. Direction with respect to IoT Expansion Card

3.13 Stratum Clock (PPS)

The IoT Expansion Card accepts a Stratum 1 clock input (PPS signal) from the host application. The host application should operate as a stratum 1 time source, connected to GPS (a stratum 0 source).

This signal can then be used to manage timing for sensor nodes (or other devices) that are attached to the expansion card.

For additional information, see Digital I/O Characteristics on page 23.

Table 3-13: Clock interface pin descriptions

Pin	Signal name	I/O	I/O type	Description	If Unused
37	PPS	Input	1.8V	Stratum Clock 1 Pulse per second signal.	No connect

3.14 Digital I/O Characteristics

The I/O characteristics for supported 1.8V digital interfaces (GPIOs, UART, PPS) are described in the following table.

Table 3-14: Digital I/O Characteristics (V_{DD_PX} = 1.80 V (nominal)) [a]

Parameter		Comments	Min	Typ	Max	Units
V_{IH}	High level input voltage	CMOS/Schmitt	$0.65 * V_{DD\_PX}$	-	$V_{DD\_PX} + 0.3$	V
V_{IL}	Low level input voltage	CMOS/Schmitt	-0.3	-	$0.35 * V_{DD\_PX}$	V
V_{SHYS}	Schmitt hysteresis voltage		100	-	-	mV
I_{IH}	Input high leakage current[b]	No pull-down	-		1	μA
I_{IL}	Input low leakage current[c]	No pull-up	-1		-	μA
R_P	Pull up/down resistance		55		390	kΩ
V_{OH}	High level output voltage	CMOS, at pin-rated drive strength	V_{DD_PX} - 0.45	-	V_{DD_PX}	V
V_{OL}	Low level output voltage	CMOS, at pin-rated drive strength	0	-	0.45	V
I_{OZH}	Tri-state leakage current[b]	Logic high output, no pull-down	-		1	μA
I_{OZL}	Tri-state leakage current[c]	Logic low output, no pull-up	-1		-	μA
R_K	Keeper resistance		30		150	kΩ
I_{ISL}	Sleep crystal input leakage		-0.15	-	0.15	μA
I_{IHVKP}	High-V tolerant input leakage	With keeper	-1	-	-	μA
C_{IN}	Input capacitance[d]		-	-	5	pF
I_{PIN}	Current per pin		-	-	16	mA

a. All values are preliminary and subject to change.
b. Pin voltage = V_{DD_PX} max. For keeper pins, pin voltage = V_{DD_PX} max - 0.45 V.
c. Pin voltage = GND and supply = V_{DD_PX} max. For keeper pins, pin voltage = 0.45 V and supply = V_{DD_PX} max.
d. Input capacitance is guaranteed by design, but is not 100% tested.

4: Mechanical / Form Factor

4.1 Overview

This chapter describes mechanical specifications for the IoT Expansion Card and host devices.

4.2 Mechanical Dimensions

4.2.1 Height Category

IoT Expansion Cards are assigned a height category based on the top height (distance from the top face of the PCB to the top of the tallest component on the PCB):

• Category 1: ≤14.00 mm
• Category 2: >14.00 mm

The height category is identified in the EEPROM header (see EEPROM Header on page 28).

4.2.2 Required Top/Bottom Clearance

Figure 4-1 illustrates the space requirements between the IoT Expansion Card and a host application, and Figure 4-2 on page 25 provides detailed dimensions.

Thus, maximum component heights on the expansion card's top and bottom face are:

• Top:
  · Category 1: ≤14.00 mm
  · Category 2: >14.00 mm
• Bottom—2.5 mm (0.5 mm clearance required to host PCB)

Category 1: ≤14.00mm
Category 2: >14.00mm

0.5 mm minimum
(Module bottom to host)

3.0 mm
Module PCB bottom
to host
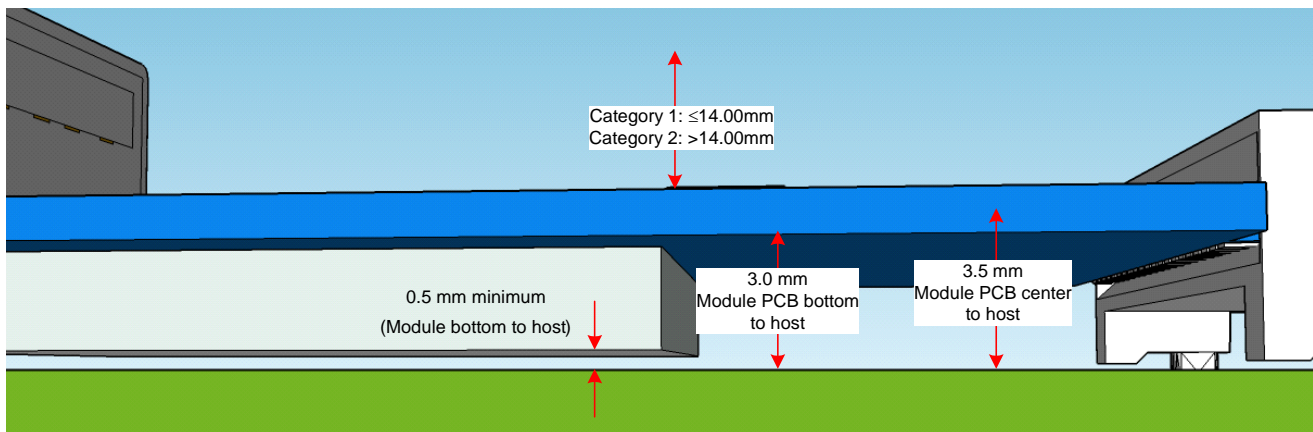
3.5 mm
Module PCB center
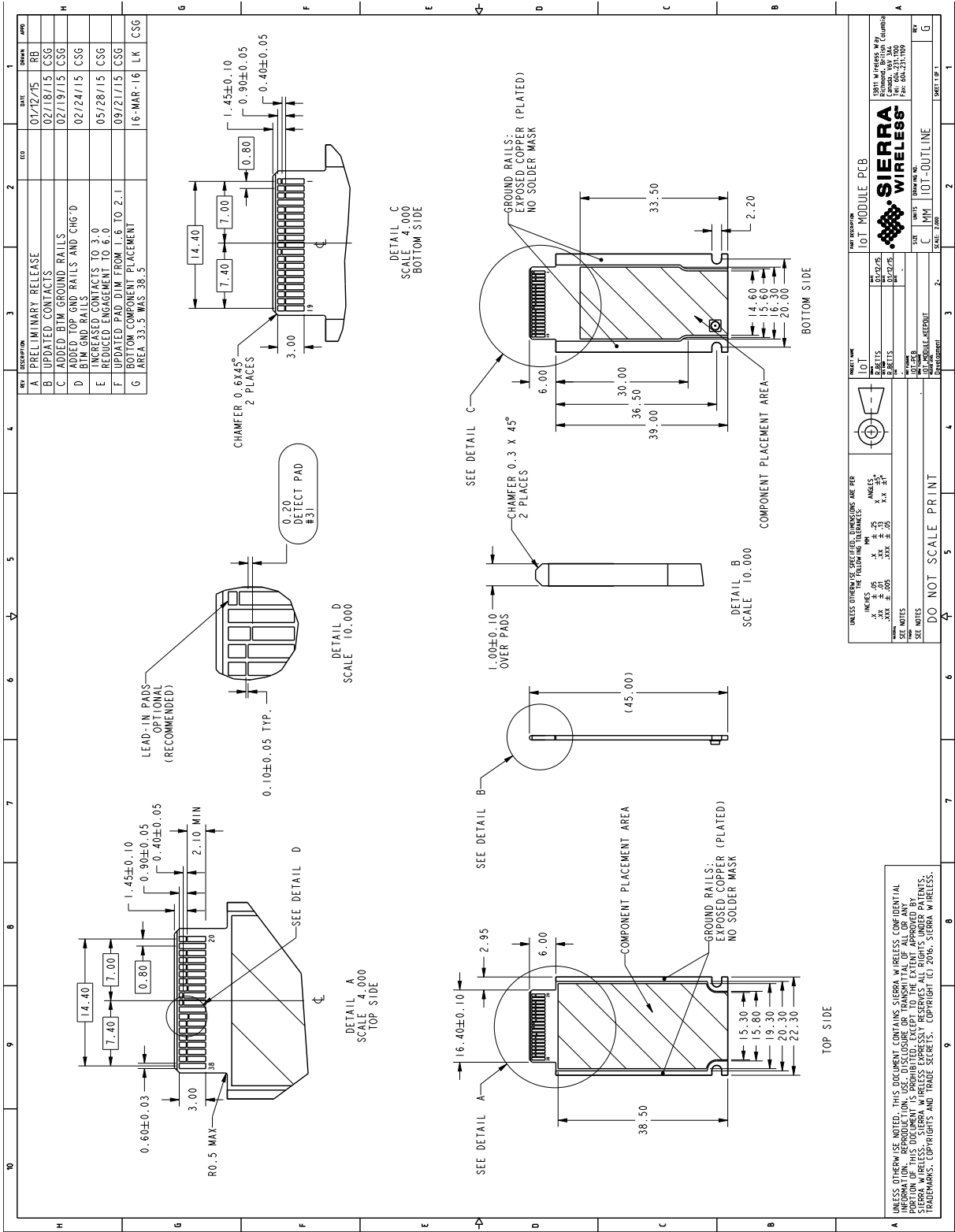to host

Figure 4-1: IoT Expansion Card Height Limits

Figure 4-2: IoT Expansion Card Details

4.3 Host-side Requirements and Considerations

4.3.1 IoT Connector

IoT Expansion Cards connect to host applications via an IoT Connector (QSFP+) mounted on the host application. This connector style was selected for ease of use, and wide commercial availability from multiple vendors.

The host application can be designed with as many connectors as desired—there is no prescribed limitation on the number of IoT Expansion Cards that a host application may support at one time.
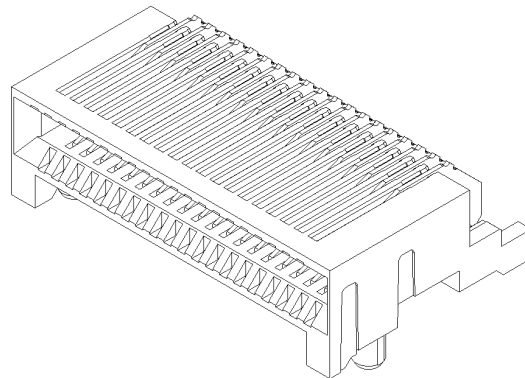
Figure 4-3: IoT Connector (QSFP+ connector)

The QSFP+ connector standard is described in SFF-8436 Specification for QSFP+ 10 Gbs 4X Pluggable Transceiver (Standardized as EIA-964 at Rev 4.8 dated October 31, 2013)
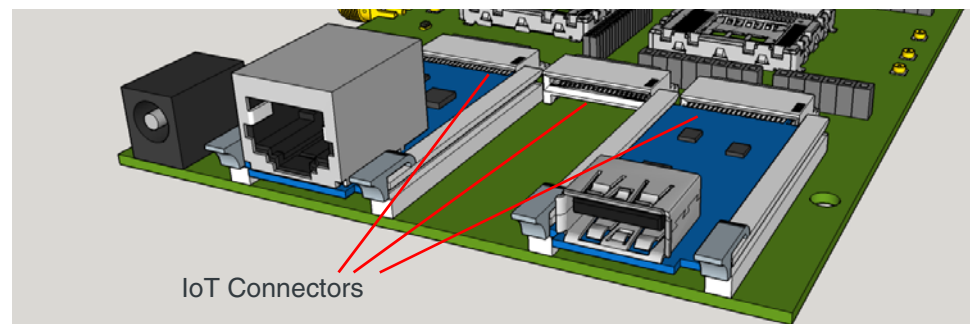
Figure 4-4: Installed IoT Connectors

4.3.2 IoT Expansion Card Mounts

IoT Expansion Cards are mounted on host applications using one of three methods:
- Screwed into spacers
- Screwed into soldered standoffs
- Plugged in via rails

For details, see .

4.4 Pull-up Resistors

All required pull-up resistors (for example, for the I2C interface and n_CARD_DETECT) should be located on the host application, not on the IoT Expansion Card.

Figure 4-5: Host-side Pull-up Resistor Requirements

5: IoT Expansion Card-side Details

5.1 Overview

This chapter describes the IoT Expansion Card's EEPROM structure and the boot process.

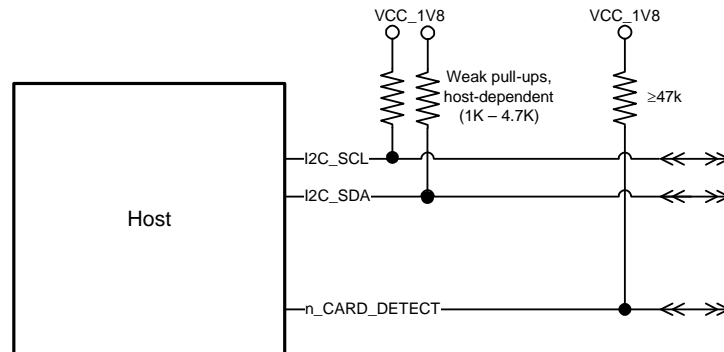## 5.2 EEPROM

5.2.1 EEPROM Requirements

Each IoT Expansion Card must use an I2C EEPROM that meet the specifications in Table 5-1.

Note: If a card does not have a functioning EEPROM, it will not be detected by the IoT framework.

Table 5-1: EEPROM Requirements

Attribute	Requirement	Options/Restrictions
Model	24Cxx type 1.8V I2C EEPROM	Other model types are not supported (for example, 3.3V or 5V)
Addressing	16-bit only	• 8-bit and 24-bit addressing are not supported • Address when device is inactive: 0x52 • Address when device is being scanned: 0x53
I2C mode support	100 kHz	OEM may also support higher speeds, which will only be usable if the host application also supports the higher speeds.
Memory paging	Not supported	Do not use paged type EEPROMs.
I2C clock stretching	Not supported	Do not use EEPROMs that perform I2C clock stretching
Write protect pin	Must be supported, and must protect the entire device memory	

EEPROMs that satisfy these requirements are available from several vendors. One example is ON Semiconductor part # CAT24C32.

5.2.2 EEPROM Header

All IoT Expansion Cards must include an EEPROM header that contains a 192-byte component describing card details (version, serial number, etc.) and one or more 64-byte interface specification components describing supported interfaces.

Refer to https://github.com/mangoh/mangoh to download a script that generates EEPROM binaries from human-readable input files (sample input files are also available for download).

Note: EEPROM data is stored in network byte order ("big-endian"—multi-byte fields are stored with the most-significant byte first).
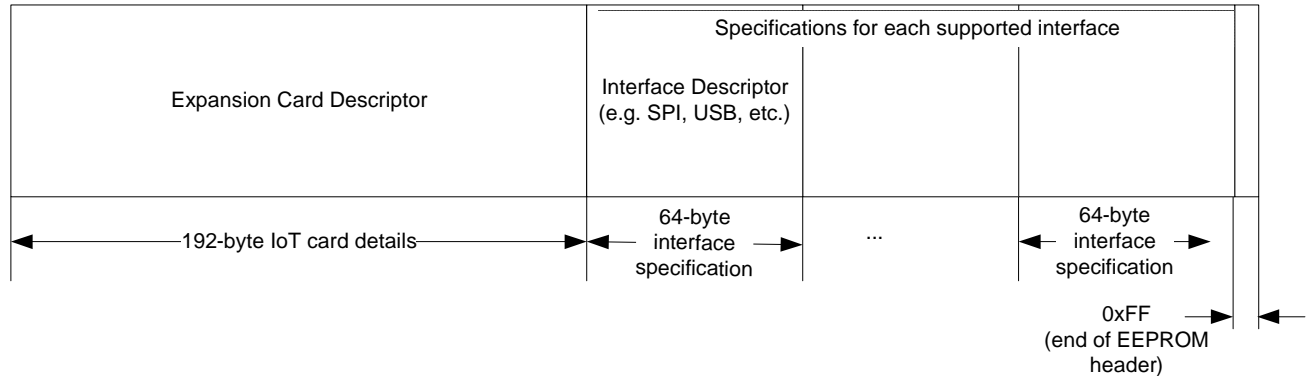

Figure 5-1: EEPROM Header Format

Table 5-2: Expansion Card Descriptor[a]

Field	Offset	Size (bytes)	Description	Example
Header Identifier	0	2	Fixed value • 0xAA55	0xAA55
Header Version (Major)	2	1	0x01	0x01 (major) 0x00 (minor) Header version is 1.0
Header Version (Minor)	3	1	0x00	
Board ID				
Vendor Name	4	32	IoT card vendor • Null-terminated utf-8 string—maximum 31 printable characters	"Vendor Name" + '\0'
Product Name	36	32	IoT card name • Null-terminated utf-8 string—maximum 31 printable characters	"Sensor module" + '\0'
Hardware Revision (Major)	68	1	Major revision number • 0x00–0xFF (0–255) • Each new version of the IoT card should have an updated major.minor value. (If the new version requires different software behavior, the value must be updated.)	0x08 (major) 0x01 (minor) Hardware revision is 8.1
Hardware Revision (Minor)	69	1	Minor revision number • 0x00–0xFF (0–255)	

Table 5-2: Expansion Card Descriptor[a] (Continued)

Field	Offset	Size (bytes)	Description	Example
Serial Number	70	32	IoT Expansion Card serial number • Null-terminated utf-8 string—maximum 31 printable characters • Format: Determined by card manufacturer. For example, the format could be YYMMDDnnnn: ‐ YY = 2 digit year of production ‐ MM = 2 digit month of production ‐ DD = 2 digit day of production ‐ nnnn = incrementing board number • Recommendation—IoT card serial numbers should be unique within the specified vendor/product pair.	"1504240001" Year = 2015 Month = April Day = 24 Board number = 0001
Environmental Class	102	1	Environmental class • ASCII format • 'A', 'B', 'C'	'A' Class A (-30°C to +70°C)
Power Category	103	1	Power class number • 1–3	2 Category 2 (≥2.5W to <3.3W)
Height Category	104	1	Height Class number • 1–2	2 Category 2 (>14.00mm)
Write Protected	105	1	EEPROM write-protect state • 0—Not write-protected • 1—Write-protected	1 The EEPROM is write-protected.
Reserved	106	86	Reserved for future use	n/a
Interface Descriptors	192	64 (each)	• See Table 5-3, Interface Descriptor, on page 31 for details. • 64-byte specification sections (type + u) for each interface supported by the IoT card. • Specification sections can be included in any order. • End of EEPROM structure (no more interface specifications) is indicated by the character 0xFF.	n/a

a. Structure details are preliminary and subject to change.

Table 5-3: Interface Descriptor[a]

Field	Offset[b]	Size (bytes)	Description	Example
Type	0	1	Interface specification type • 0x00—GPIO • 0x01—I2C • 0x02—SPI • 0x03—USB • 0x04—SDIO • 0x05—ADC • 0x06—PCM • 0x07—Clock • 0x08—UART • 0x09–0xFE—Reserved for future use. • 0xFF—End of EEPROM structure (No 'u' field (specification data) follows this value.)	0x00
Data	1	63	Specification data. • GPIO—See Table 5-4 on page 32. • I2C—See Table 5-5 on page 32. • SPI—See Table 5-6 on page 33. • USB—See Table 5-7 on page 33. • SDIO—See Table 5-8 on page 33. • ADC—See Table 5-9 on page 33. • PCM—See Table 5-10 on page 34. • Clock—See Table 5-11 on page 34. • UART—See Table 5-12 on page 34.	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Expansion Card Descriptor section (e.g. the first specification begins at offset 192).

Table 5-4: GPIO Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example
GPIO Settings	0	4	GPIO specifications • 4-byte array (Byte 0 (GPIO_1) to Byte 3 (GPIO_4) • For each GPIO (directions are from the host's perspective): · 0x01—Input to host, pull-up · 0x02—Input to host, pull-down · 0x03—Input to host, floating · 0x04—Output low from host · 0x05—Output high from host *Note: If a GPIO is used as an interrupt, it must be configured as an input to the host, with the appropriate pull configuration (pull-down or pull-up).* *Note: Unused GPIOs should be set as input high on the host.*	0x5243 GPIO_1=5 (Output high) GPIO_2=2 (Input, pull-down) GPIO_3=4 (Output low) GPIO_4 = 3 (Input, floating)
Reserved	4	59	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the GPIO Settings field begins at offset 1 of the interface specification.

Table 5-5: I^{2}C Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Examples
Address	0	1	I2C device address • Format—7 bits (10-bit addresses are not supported)	
Interrupt GPIO	1	1	GPIO used for interrupts • 0x00—GPIO_1 • 0x01—GPIO_2 • 0x02—GPIO_3 • 0x03—GPIO_4 • 0xFF—No interrupt required	0xFF (No interrupt) 0x03 (GPIO_4 used as interrupt)
Device Name	2	32	Linux device name for the device on the card • Null-terminated utf-8 string—maximum 31 printable characters • If no driver required, string is empty (null string)	"sx1509q" + '\0'
Reserved	34	29	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Address field begins at offset 1 of the interface specification.

Table 5-6: SPI Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example
Interrupt GPIO	0	1	GPIO used for interrupts • 0x00—GPIO_1 • 0x01—GPIO_2 • 0x02—GPIO_3 • 0x03—GPIO_4 • 0xFF—No interrupt required	0xFF (No interrupt) 0x03 (GPIO_4 used as interrupt)
Device Name	1	32	Linux device name for the device on the card • Null-terminated utf-8 string—maximum 31 printable characters • If no driver required, string is empty (null string)	"mcp2515" + '\0'
Reserved	33	30	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Interrupt GPIO field begins at offset 1 of the interface specification.

Table 5-7: USB Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example
Reserved	0	63	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Reserved field begins at offset 1 of the interface specification.

Table 5-8: SDIO Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example Value
Reserved	0	63	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Reserved field begins at offset 1 of the interface specification.

Table 5-9: ADC Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example Value
Reserved	0	63	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Reserved field begins at offset 1 of the interface specification.

Table 5-10: PCM Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example Value
Reserved	0	63	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Reserved field begins at offset 1 of the interface specification.

Table 5-11: Clock Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example Value
Reserved	0	63	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Reserved field begins at offset 1 of the interface specification.

Table 5-12: UART Interface Descriptor Specification Data[a]

Field	Offset[b]	Size (bytes)	Description	Example Value
Reserved	0	63	Reserved for future use	n/a

a. Structure details are preliminary and subject to change.
b. Offset from the end of the Interface Descriptor section (e.g. the Reserved field begins at offset 1 of the interface specification.
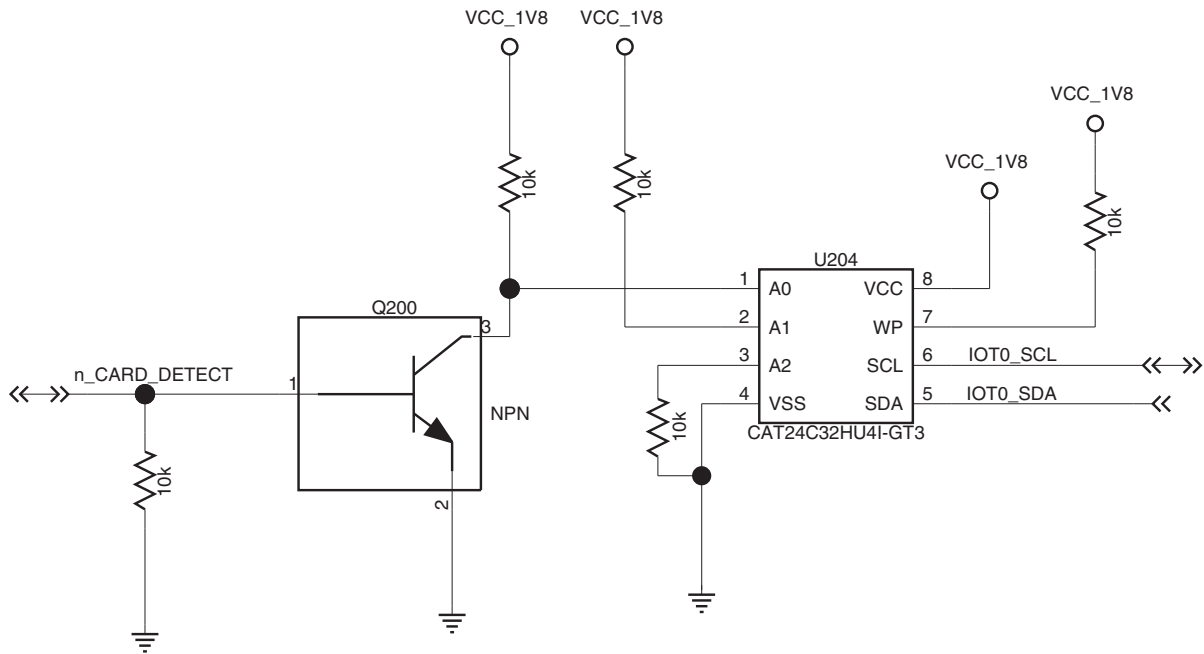
5.2.2.1 Recommended EEPROM Schematic

*Figure 5-2: Schematic—Recommended EEPROM*

Key EEPROM usage notes:

- Active device Address: 0x52
- Inactive Device Address: 0x53
- n_CARD_DETECT:
  · Tie to ground using a ≤10k pull-down resistor
  · Connect through the transistor to pin A0 on the EEPROM

5.3 IoT Expansion Card Boot Process

When an IoT Expansion Card is detected, the host application reads the expansion card's EEPROM header information (see EEPROM Header on page 28.)

Figure 5-3 on page 36 illustrates the expansion card boot process.
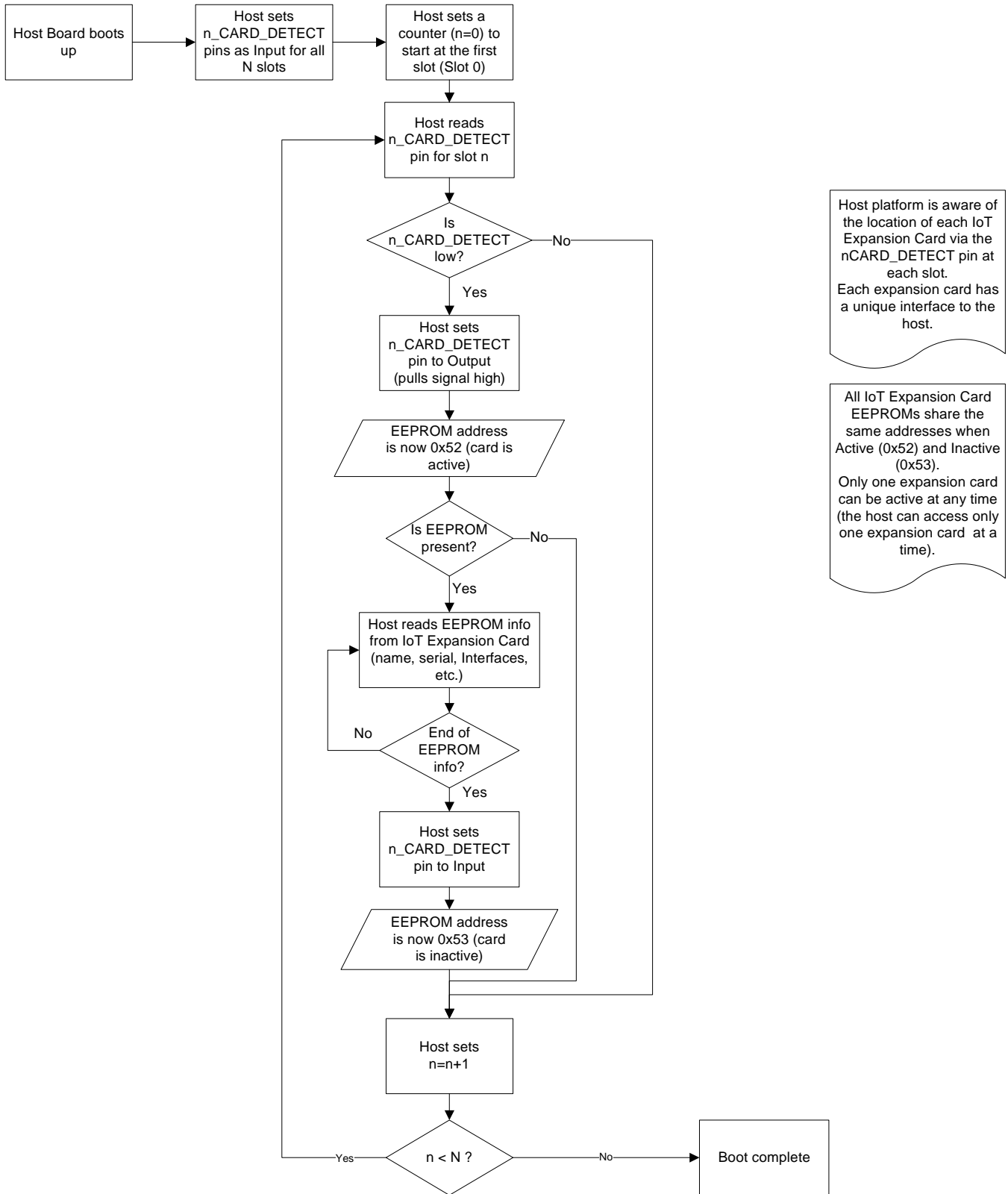
Figure 5-3: Host Process for IoT Expansion Card Detection

6: Mounting Methods

6.1 Overview

This chapter describes methods and hardware specifications for mounting IoT Expansion Cards in Host applications.

Expansion cards are designed to be mounted in host applications via three methods to meet customer requirements:

- Plug in via rails. 3D-printing files are available at mangoh.io, and molded versions will be made available in future.
- Screwed into platform via spacers
- Screwed into platform via soldered standoffs
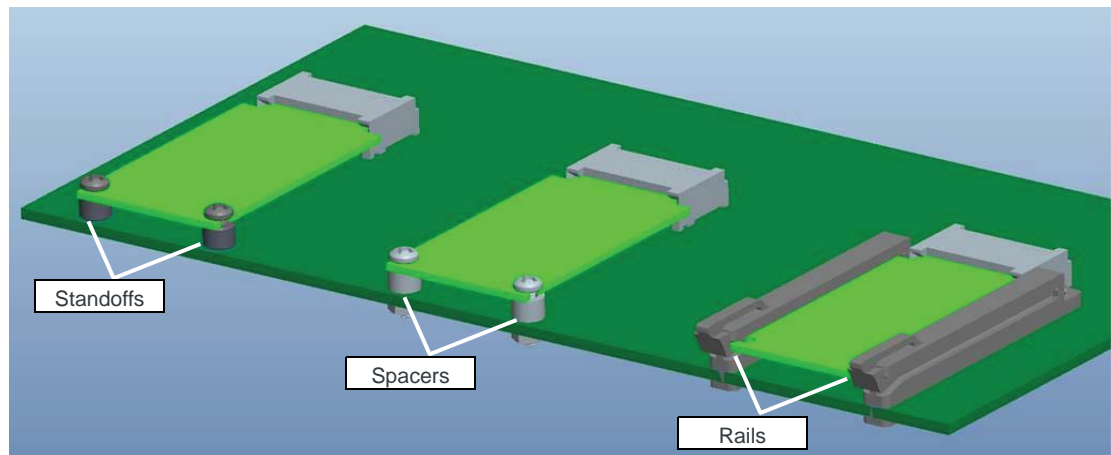
Figure 6-1: IoT Expansion Card Mounting Methods

Figure 6-1 and Figure 6-2 on page 38 provide detailed specifications for the various mounting types.
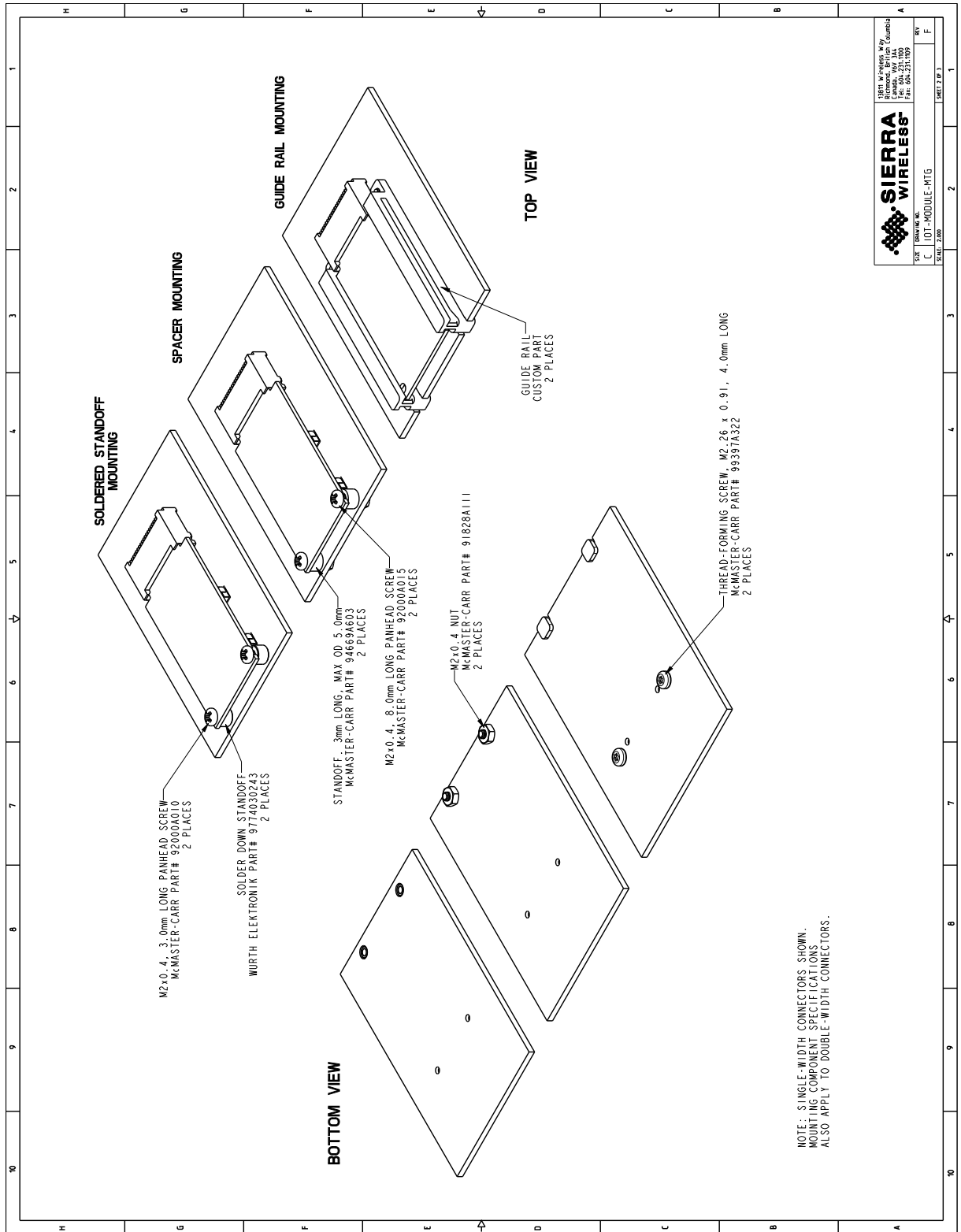
Figure 6-2: Host-side Mounting Types
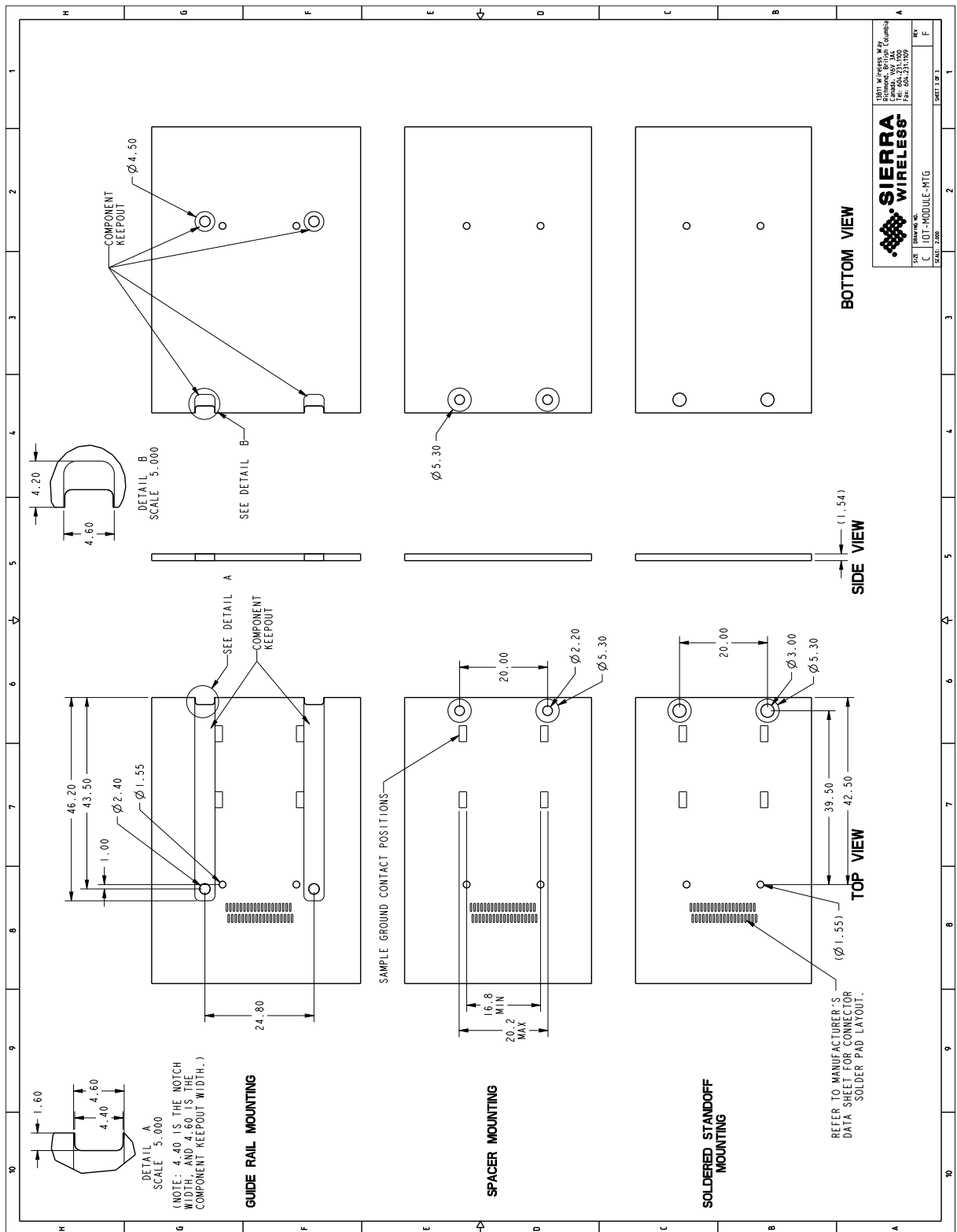
Figure 6-3: IoT Expansion Card-side Mounting Details

6.2 Self-enclosed IoT Expansion Card

When designing an IoT Expansion Card, you may want to consider enclosing the PCB in a 'box'. This would make the expansion card less susceptible to incidental damage while storing, handling, and installing.
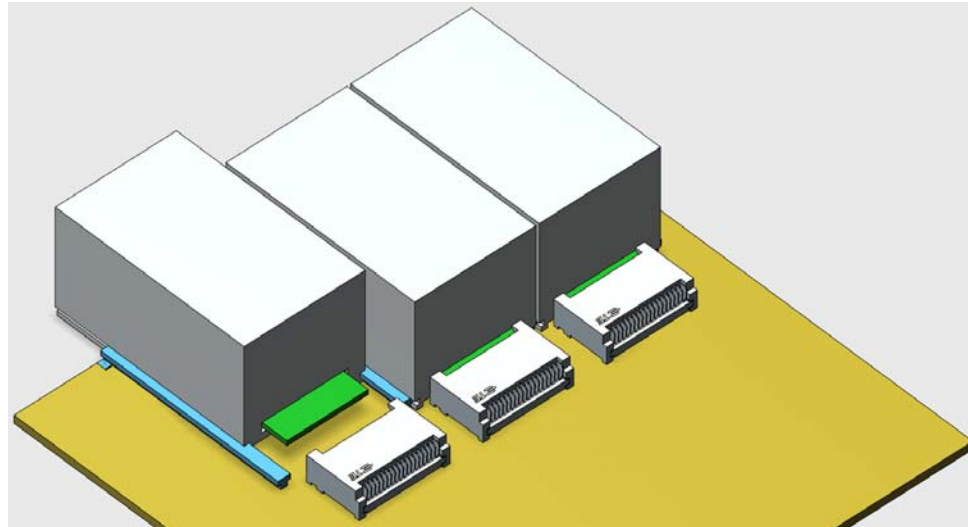
Figure 6-4: Enclosed ('Box') IoT Expansion Card Concept—Front View
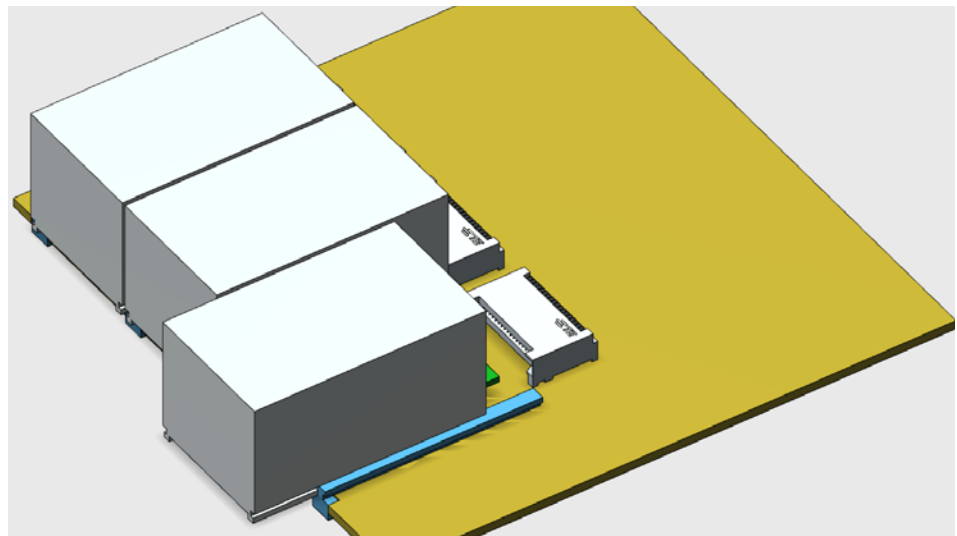
Figure 6-5: Enclosed ("Box") IoT Expansion Card Concept—Rear View

6.3 ESD Protection

IoT Expansion Card mounts on the host application require ground protection appropriate to the mounting method:

- Mounting screws—Either ground the mounting screws, or install grounding clips as described below.
- Rails—Install grounding clips as described below.

6.3.1 Grounding Clips

IoT Expansion Cards are designed with copper strips on their bottom side as shown in Figure 6-7 on page 43. A host application can use these strips for grounding by installing grounding clips as shown in Figure 6-6 on page 42. (ITT Cannon Universal Contact, 4mm, part #120220-0206, or equivalent)

When the expansion card is connected to the host, the grounding clips are in contact with the expansion card's copper strips, thus providing protection against ESD zap.

Ground clips for ESD protection must engage with ground rails on underside of IoT Expansion Card (shown in figure on next page). Quantity and positioning of clips is determined by the developer.

Clip types: ITT Cannon Universal Contact, 4mm, Part# 120220-0206, or equivalent
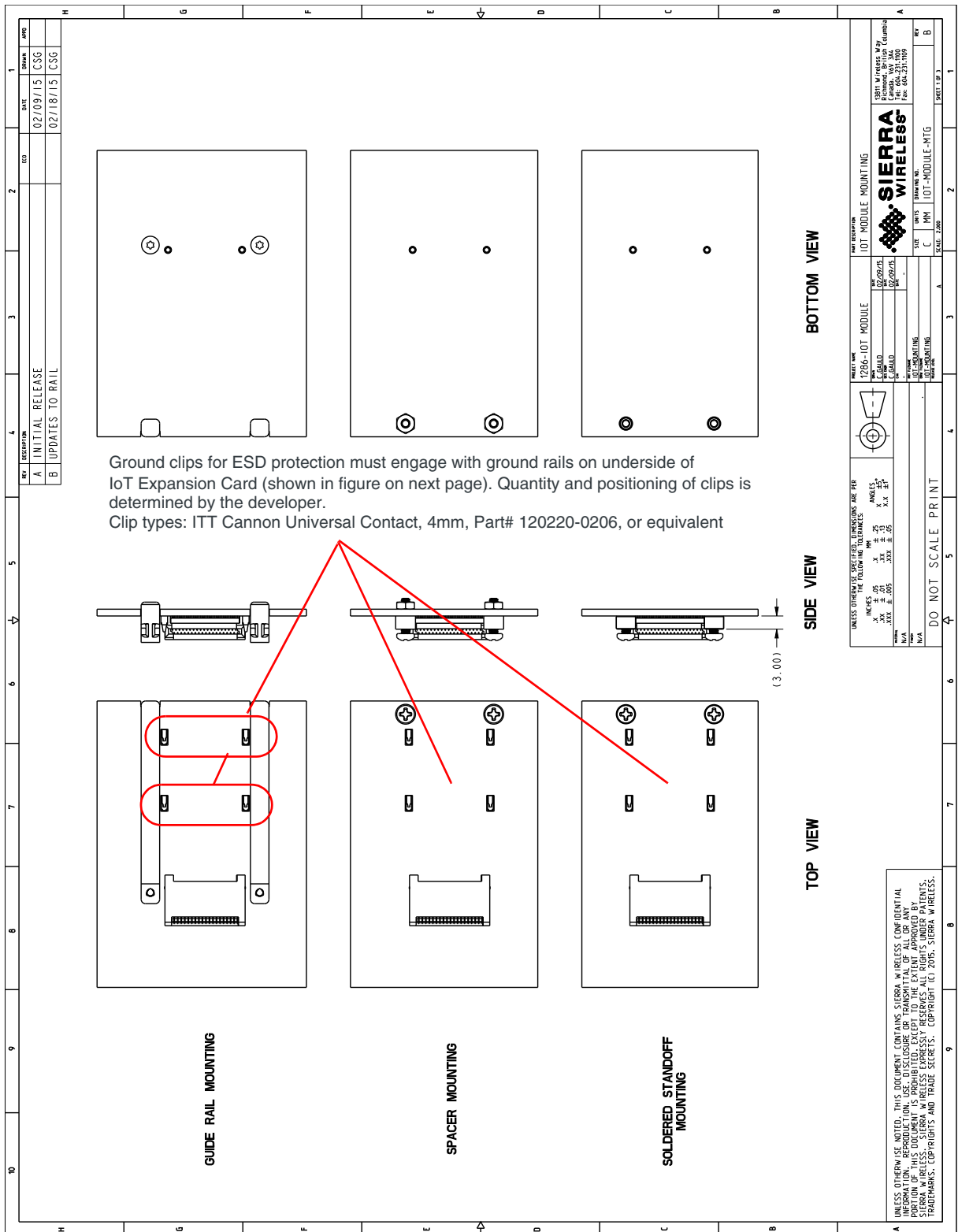
Figure 6-6: Host-side ESD Protection
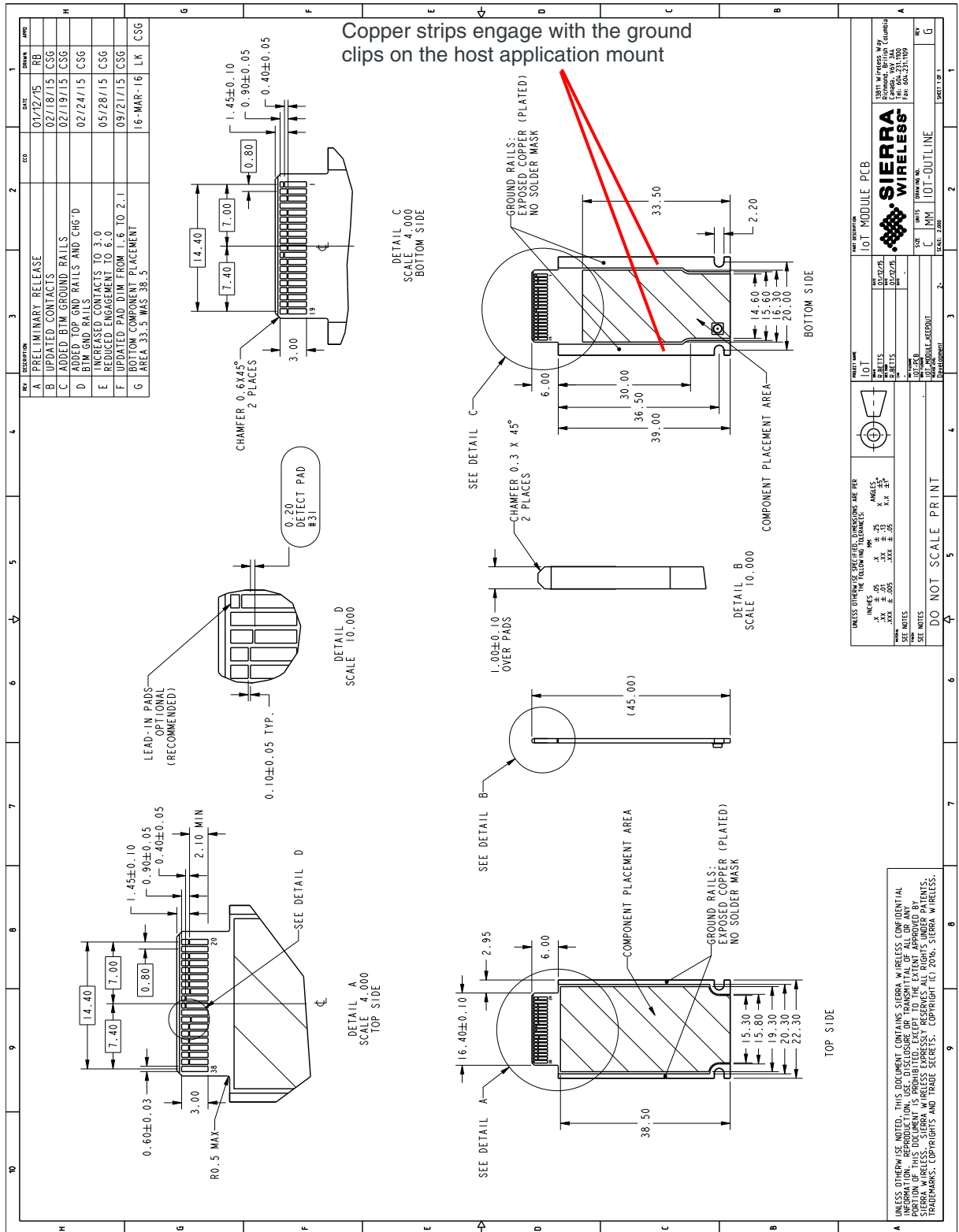
Figure 6-7: IoT Expansion Card ESD Protection

7: Pinout

7.1 Overview

The system interface of the IoT Expansion Card is through the gold-plated contacts on the end of the expansion card (19 on bottom, 19 on top).

7.2 Pin Configuration

Figure 7-1 illustrates the expansion card's edge connector pin locations.

Figure 7-1: IoT Expansion Card Edge Connector Pin Locations

Figure 7-2 illustrates the pin configuration.

Figure 7-2: Edge Connector (USB/SDIO) Schematic—IoT Expansion Card View

7.3 Pin Definitions

Table 7-1 lists detailed information for the expansion card's pin connector.

Table 7-1: Pin Definitions

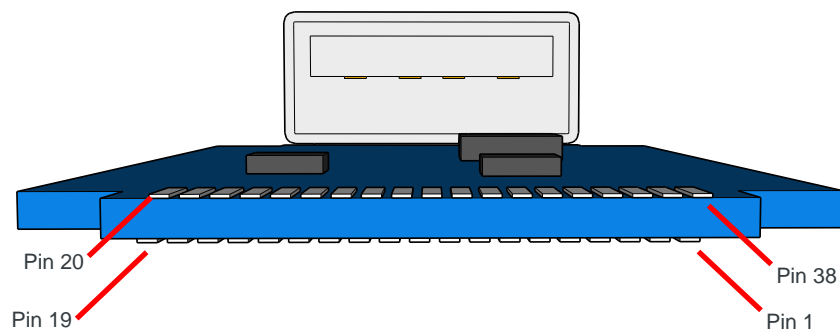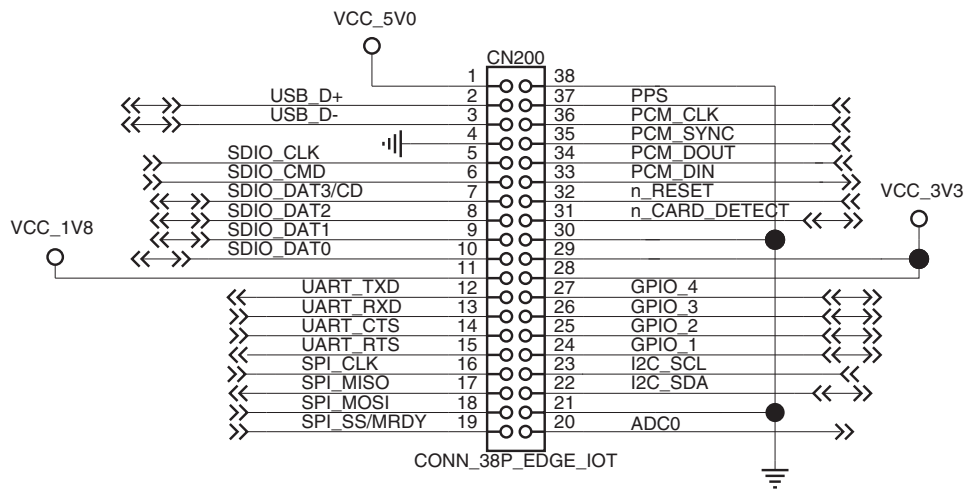| Pin	Group	Signal name	Function	Voltage/Current	I/O[a]
Connector bottom side					
1	Power	VCC_5V0	USB power supply/5V power supply	5.0V, 500mA	I
2	USB	USB_D+	USB Data positive	See ([3] Universal Serial Bus Specification, Revision 2.0)	I/O
3	USB	USB_D-	USB Data negative	See ([3] Universal Serial Bus Specification, Revision 2.0)	I/O
4	Power	GND	Ground		-
5	SDIO	SDIO_CLK	SDIO Clock	See footnote[b]	I
6	SDIO	SDIO_CMD	Command/Response	See footnote[b]	I
7	SDIO	SDIO_DAT3/CD	Data 3/Card Detection	See footnote[b]	I/O
8	SDIO	SDIO_DAT2	Data 2	See footnote[b]	I/O
9	SDIO	SDIO_DAT1	Data 1	See footnote[b]	I/O
10	SDIO	SDIO_DAT0	Data 0	See footnote[b]	I/O
11	Voltage reference	VCC_1V8	GPIO voltage output	1.8V ±10%	I
12	UART	UART_TXD	UART Transmit data	1.8V ±10%	O
13	UART	UART_RXD	UART Receive data	1.8V ±10%	I
14	UART	UART_CTS	UART Clear to Send	1.8V ±10%	I
15	UART	UART_RTS	UART Ready to Send	1.8V ±10%	O
16	SPI	SPI_CLK	SPI clock	1.8V ±10%	I
17	SPI	SPI_MISO	SPI master RX data	1.8V ±10%	O
18	SPI	SPI_MOSI	SPI master TX data	1.8V ±10%	I
19	SPI	SPI_SS/MRDY	SPI Slave Select/Master Ready	1.8V ±10%	I
Connector top side					
20	Analog	ADC0	Analog to Digital Converter	1.8V max	O
21	Power	GND	Ground		-
22	I2C	I2C_SDA	I2C Tx/Rx data	1.8V ±10%	I/O
23	I2C	I2C_SCL	I2C Clock	1.8V ±10%	I
24	GPIO	GPIO_1	General purpose I/O	1.8V ±10%	I/O
25	GPIO	GPIO_2	General purpose I/O	1.8V ±10%	I/O

Table 7-1: Pin Definitions (Continued)

Pin	Group	Signal name	Function	Voltage/Current	I/O[a]
26	GPIO	GPIO_3	General purpose I/O	1.8V ±10%	I/O
	SPI	SPI_SRDY	SPI Slave Ready		O
27	GPIO	GPIO_4	General purpose I/O	1.8V ±10%	I/O
28	Power	VCC_3V3	3.3V	3.3V ±10%, 500mA	I
29	Power	VCC_3V3	3.3V	3.3V ±10%, 500mA	I
30	Power	GND	Ground		-
31	DETECT	n_CARD_DETECT	Card detect: Active low detect	1.8V ±10%	I/O
32	Reset	n_RESET	Reset expansion card	1.8V ±10%	I
33	PCM	PCM_DIN	PCM Data IN (Input to Host)	1.8V ±10%	O
	I2S	I2S_IN	I2S Data In (Input to Host)		O
34	PCM	PCM_DOUT	PCM Data OUT (Output from Host)	1.8V ±10%	I
	I2S	I2S_OUT	I2S Data Out (Output from Host)		I
35	PCM	PCM_SYNC	PCM Synchronization	1.8V ±10%	I
	I2S	I2S_WS	I2S Word Select		I
36	PCM	PCM_CLK	PCM Clock	1.8V ±10%	I
	I2S	I2S_CLK	I2S Clock		I
37	Clock	PPS	Stratum Clock 1	1.8V ±10%	I
38	Power	GND	Ground		-

a. Direction with respect to IoT Expansion Card
b. SDIO card: 2.7–3.6V; Embedded SDIO device: 1.7–-1.95V or 2.7–3.6V. See ([4] SD Specifications Part E1 SDIO Simplified Specification, Version 3.00 for details.

8: References

For more details, see the references listed below.

8.1 Web Site Support

For the latest IoT Expansion Card documentation, see mangoh.io.

8.2 Reference Documents

[1] High-Speed Inter-Chip USB Electrical Specification, Version 1.0 (a supplement to the USB 2.0 specification)

[2] Legato.io for Legato API details

[3] Universal Serial Bus Specification, Revision 2.0

[4] SD Specifications Part E1 SDIO Simplified Specification, Version 3.00

[5] RS232 Interface Specification

[6] I^{2}C Specification

[7] SFF-8436 Specification for QSFP+ 10 Gbs 4X Pluggable Transceiver (EIA-964 Rev 4.8, October 31, 2013)

A: Abbreviations

Table A-1: Acronyms and definitions

Acronym or term	Definition
3GPP	3rd Generation Partnership Project
ADC	Analog to Digital Converter
Bluetooth	Wireless protocol for data exchange over short distances
CLK	Clock
CPU	Central Processing Unit
CTS	Clear To Send
DC	Direct Current
DCD	Data Carrier Detect
EEPROM	Electrically Erasable Programmable Read-Only Memory
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharges
ETSI	European Telecommunications Standards Institute
GND	Ground
GNSS	Global Navigation Satellite Systems (GPS, GLONASS, BeiDou, and Galileo)
GPIO	General Purpose Input Output
Host Host application	The device into which an IoT Expansion Card is inserted
Hz	Hertz = 1 cycle/second
I/O	Input/Output
I2C	Inter-Integrated Circuit
I^2S	Inter-IC Sound
IoT	Internet of Things
kHz	Kilohertz = 10e3 Hz
LAN	Local Area Network
LPRF	Low-Power RF
LPT	Latchup Protection Technology
M2M	Machine to Machine
MHz	Megahertz = 10e6 Hz

Table A-1: Acronyms and definitions (Continued)

Acronym or term	Definition
OEM	Original Equipment Manufacturer—a company that manufactures a product and sells it to a reseller.
PAN	Personal Area Network
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PPS	Pulse Per Second
RTS	Request To Send
RX	Receive
SDIO	Secure Digital Input/Output
SPI	Serial Peripheral Interface
TBC	To Be Confirmed
TBD	To Be Determined
TX	Transmit
UART	Universal Asynchronous Receiver-Transmitter
USB	Universal Serial Bus
VCC	Supply voltage
WAN	Wide Area Network