



Caprica 2L
**Play-Fi™ Wireless Module Design
Guide**

PHORUS-CAP-TSD- 0010 (2L)

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1 Document Scope

This document describes interface requirements for the second-generation Play-Fi Wireless Module, also known as Caprica2L. Caprica2L is a WiFi audio module designed for wireless, multi-room audio distribution. Caprica2L streams with 16 bit resolution and 44.1 KHz sampling rate. The module may be utilized in speakers, stand-alone receivers or incorporated into other products like AVRs. This document provides guidelines for the inclusion of this module into such products.

2 Definitions

2.1 Host

Host refers to the off board MCU that processes user interactions and controls audio processing.

2.2 Play-Fi Wireless Module

Play-Fi Wireless Module refers to the Caprica2L module with integrated Wi-Fi radio.

3 Applicable Documents

3.1 Reference Design Documents

The following documents form a part of this specification. Each utilized and referenced document shall be the most recent released issue.

Phorus Reference Documentation
PHORUS-CAP-TSD-0004-Caprica-Host-Communication-Protocol
BTB Connector datasheet (88079-0800A1_88079-xxxxAx-aces_rev-U.pdf)
BTB Connector Specification (88079_SPEC-88069-xxxx_rev-L.pdf)
Play-Fi Module Outline and Mounting Drawings (Caprica_2L_PCB_RevA.DWG, Caprica_2L_PCB_RevA.pdf)
3D design file, outline and mounting (Caprica_2L_PCB_RevA.stp)

4 Features BT Disable

The Caprica2L Play-Fi Wireless module is a programmable, high-performance, encapsulated design that enables manufacturers to wirelessly distribute audio to multiple devices. Sources can include Play-Fi Applications, Play-Fi Drivers, or other sources of a manufacturer's choice, such as Bluetooth, via a I2S input. The design supports a number of interfaces that enable easy integration of the module to traditional consumer electronic designs. Caprica2L features include:

4.1 800MHz ARM-based Processor

Marvell PXA166 ARM v6/v7-compatible core:

- Up to 1848 DMIPS
- 16K/16K L1 I/D Caches
- 64K L2 Cache
- 5-8 Stage Variable Pipeline
- Retire up to 2 Instructions per Cycle
- Out-of-Order Execution
- Three-level Branch Prediction

4.2 wMMX2 DSP Support

Up to 1600 MMACS per second. Supports complex Digital Signal Processing with little CPU overhead. Audio CODECs including MP3, WMA and AAC utilize the wMMX2 engine.

4.3 802.11a/b/g/n 1x1 Wi-Fi

Dual-band design with 2.4GHz and 5GHz support. Supports transmit modes up to 150mbps.

4.3.1 20MHz and 40MHz Channels

Supported in both 2.4 and 5 GHz bands

4.3.2 Diversity Antenna Support

Caprica2L supports two antenna connections in a diversity antenna configuration (using orthogonal mounting).

4.4 128MB DDR3 Memory

High-performance memory for maximum processor and network performance.

4.5 128MB SLC Flash Memory

4.6 I2C

The I2C Interface is the port which Caprica2L communicates with the external system. The communication protocol "Play-Fi Host Communication Protocol" is described in a separate document (PHORUS-CAP- TSD-0004-Caprica-Host-Communication-Protocol). The Caprica2L Module is configured as a I2C slave with address 0x52.

4.7 I2S Output

Caprica2L outputs digital audio via an I2S port. Caprica acts as the master device. The format is MSB Left Justified.

LRCLK- 44.1 KHz

BITCLK- 2.8224 MHz ($64 * F_s$)

Data – 16 bits of data followed by 16 bits forced 0 on each rising/falling edge of LRCLK

This format cannot be changed.

4.8 I2S Input

Caprica2L can accept auxiliary inputs via I2S. Caprica is the slave here. The format is MSB Left Justified.

LRCLK- 8KHz, 16KHz, 22.05KHz, 32KHz, 44.1KHz, 48KHz, 96KHz. (PIN 67)

BITCLK- 2.8224 MHz ($64 * F_s$) (PIN 65)

Data – 16 bits of data followed by 16 bits forced 0 on each rising/falling edge of LRCLK

This format cannot be changed. (PIN 69)

4.9 USB 2.0HS OTG

Configured as a Host in standard configurations. All Play-Fi devices require a USB Host is required for Factory USB updates.

4.10 Wi-Fi LED Control

Caprica2L controls a consumer-facing LED that gives indication as to Wi-Fi status.

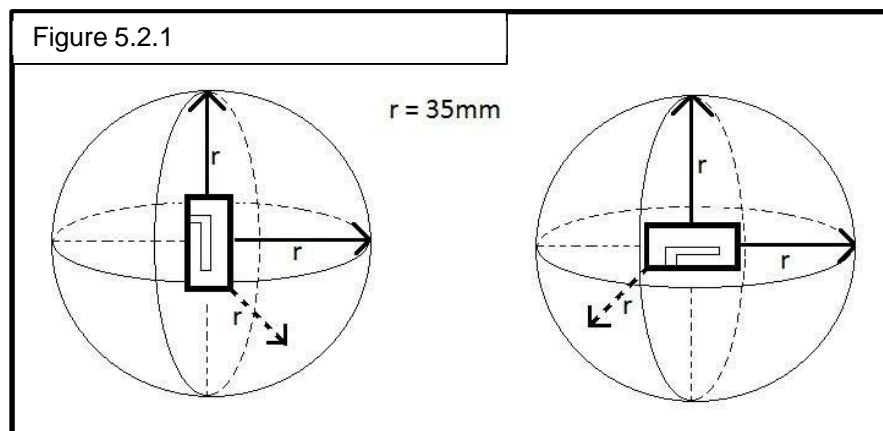
5 Radio Frequency Performance

5.1 RF Interface

Wi-Fi RF connectivity is provided by 2 dual-band antennas, connected via miniature RF cables. These antennas are tuned for both 2.4GHz and 5GHz operation.

5.2 Antenna Placement

For optimal RF coverage, antennas should be mounted orthogonally to each other. Each antenna should be at least 35mm away from any other metal object in 3D space. The antennas should be mounted as high on the vertical axis as possible while maintaining 35mm distance from other metal objects. The farther apart the antennas are mounted from each other the better, however, the feed line from antenna to Wi-Fi Module connection should not exceed 150mm to minimize RF losses through wire.



6 Caprica Module Electrical Interface Definition

6.1 Caprica Module Pin Definitions 80-pin Connector

BTB Conn.	Net	Function
	Name	CAPRICA 2L
1	V1_1	Power (3.3V)
2	V5_2	Power (1.8V)
3	V1_1	Power (3.3V)
4	V5_2	Power (1.8V)
5	V1_1	Power (3.3V)
6	V2_2	Power (1.8V)
7	V3_3	Power (1.1V)
8	V2_2	Power (1.8V)
9	V3_3	Power (1.1V)
10	3V3_RTC	RTC (3.3V)
11	V3_3	Power (1.1V)
12	GND	
13	DC_5V	Power (5V)
14	USB_OTG_ID	Reserved
15	GND	
16	GND	
17	TDI	JTAG
18	USB_OTG_DM	USB_OTG
19	TMS	JTAG
20	USB_OTG_DP	USB_OTG
21	TCK	JTAG
22	GND	
23	TDO	JTAG
24	USB_HOST_DM	Reserved
25	TRST	JTAG
26	USB_HOST_DP	Reserved
27	UART3_TXD	Reserved
28	GND	
29	UART3_RXD	Reserved
30	RJ_TX+	Reserved
31	UART3_CTS	Reserved
32	RJ_TX-	Reserved
33	UART3_RTS	Reserved
34	RJ_RX+	Reserved
35	SCL	I2C
36	RJ_RX-	Reserved
37	SDA	I2C

38	GND	
39	GND	
40	LED[0]	Reserved
41	MMC1_CLK	Reserved
42	LED[1]	Reserved
43	MMC1_CMD/XD_CLE	Reserved
44	GND	
45	MMC1_D0/XD_D3	Reserved
46	SCL1	I2C1
47	MMC1_D1/XD_D4	Reserved
48	SDA1	I2C1
49	MMC1_D2/XD_nRE	Reserved
50	GND	
51	MMC1_D3/XD_nCE	Reserved
52	SSP2_CLK	Reserved
53	GND	
54	SSP2_FRM	Reserved
55	I2S_MCLK	I2S
56	SSP2_TXD	Reserved
57	I2S_BCLK	I2S
58	SSP2_RXD	Reserved
59	I2S_LRCK	I2S
60	GND	
61	I2S_SDOUT	I2S
62	GND	
63	I2S_SDIN	I2S
64	GPIO0	Reserved
65	I2S1_BCLK/AC97_BCLK	I2S1
66	GPIO1	Apple Auth
67	I2S1_LRCK/AC97_DIN0	I2S1
68	GPIO2	Reserved
69	I2S1_SDOUT/AC97_DOUT	I2S1
70	GPIO3	Reserved
71	GND	
72	GPIO4	Reserved
73	RSR_IN#	Reserved
74	GPIO5	Reserved
75	WIFI_LED_G	WIFI_LED
76	GPIO6	Reserved
77	INT_TO_MCU	INT
78	GPIO7	Reserved
79	I2C_ADDR	ADDR
80	EXT_WAKEUP	Reserved



6.2 Pin Description, Electrical Characteristics

I/O Descriptions of CAPRICA			
Net/ Signal (s)	Type	Level (V)	Description
POWER			
DC_5	P	5	Power supply input: 5V; AVDD5_USB; USB VBUS, analog input for monitoring USB type A connector power.
V1_1	P	3.3	Power supply input: 3.3V
V5_2	P	1.8	Power supply input: 1.8V
V2_2	P	1.8	Power supply input: 1.8V_DDR
V3_3	P	1.1	Power supply input: 1.1V Power On Last
GND	P	0	Ground for power, signal and shielding.
RTC (Reserved function)			
3V3_RT	P	3.3	Real Time Clock (RTC) power supply input; 3.3V
SDIO (Reserved Function)			
MMC1_D3/XD_nCE	I/O	3.3	Reserved
MMC1_D2/XD_nRE	I/O	3.3	Reserved
MMC1_D1/XD_D4	I/O	3.3	Reserved
MMC1_D0/XD_D3	I/O	3.3	Reserved
MMC1_CLK	O	3.3	Reserved
MMC1_CMD/XD_CLE	I/O	3.3	Reserved
SPI (Reserved Function)			
SSP2_RXD	I	3.3	Reserved

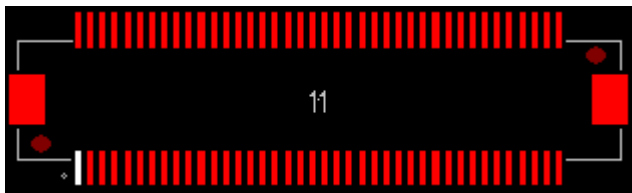
SSP2_TXD	O	3.3	Reserved
SSP2_CLK	O	3.3	Reserved
SSP2_FRM	O	3.3	Reserved
JTAG (Optional)			
TDI	I	3.3	JTAG data input Required
TMS	I	3.3	JTAG mode select Required
TCK	I	3.3	JTAG clock Required
TDO	O	3.3	JTAG data output Required
TRS	I	3.3	JTAG reset Required
UART			
UART3_RXD	I	3.3	Reserved
UART3_TXD	O	3.3	Reserved
UART3_RTS	O	3.3	Reserved
UART3_CTS	I	3.3	Reserved
I2C			
SC	I	3.3	I2C_SCL; Connect to MCU. Caprica is slave device.
SDA	I/O	3.3	I2C_SDA; Connect to MCU. Caprica is slave device.
SCL	I/O	3.3	I2C_SCL; Airplay Certification
SDA1	I/O	3.3	I2C_SDA; Airplay Certification
AUDIO			
I2S_MCLK	O	3.3	MCLK, audio master clock output from CAPRICA
I2S_LRCK	O	3.3	LRCK, audio word clock output from CAPRICA. 44.1KHz
I2S_BCLK	O	3.3	BCLK, audio bit clock output from CAPRICA. 2.82 MHz
I2S_SDI	I	3.3	DATA, audio data input to CAPRICA.
I2S_SDOUT	O	3.3	DATA, audio data output from CAPRICA.
I2S1_BCLK/AC97_BC	I	3.3	BCLK, BT audio bit clock input to CAPRICA. BT Disable
I2S1_LRCK/AC97_DI	I	3.3	LRCK, BT audio word clock input to CAPRICA. BT Disable
I2S1_SDOUT/AC97_D	I	3.3	DATA, BT audio data input to CAPRICA. BT Disable
ETHERNET (RESERVED - DO NOT USE)			
RJ_RX	I	--	Reserved
RJ_RX	I	--	Reserved
RJ_TX	O	--	Reserved
RJ_TX	O	--	Reserved
LED[0]	O	3.3	Reserved
LED[1]	O	3.3	Reserved
USB			
USB_OTG_DM	I/O	--	USB OTG data signal. As host mode only.
USB_OTG_DP	I/O	--	USB OTG data signal. As host mode only.

USB_OTG_ID	I	3.3	USB OTG ID signal. Leave open.
USB HOST (RESERVED - DO NOT USE)			
USB_HOST_DM	I/O	--	Reserved
USB_HOST_DP	I/O	--	Reserved
CONTROL			
INT_TO_MCU	O	3.3	Interrupt signal from CAPRICA (module) to MCU (system).
I2C_ADDR	I	3.3	I2C address pin. Leave open.
RST_IN	I	3.3	Reserved
WIFI_LED_G	O	3.3	WIFI indicate LED.
EXT_WAKEUP	I	3.3	External wakeup pin.
GPIO			
GPIO	I/O	3.3	Reserved
GPIO	I/O	3.3	Airplay Certification- Reset
GPIO	I/O	3.3	Reserved
GPIO	I/O	3.3	Reserved
GPIO	I/O	3.3	Reserved
GPIO	I/O	3.3	Reserved
GPIO	I/O	3.3	Reserved
GPIO	I/O	3.3	Reserved

6.3 Interface Connector Information, Mechanical

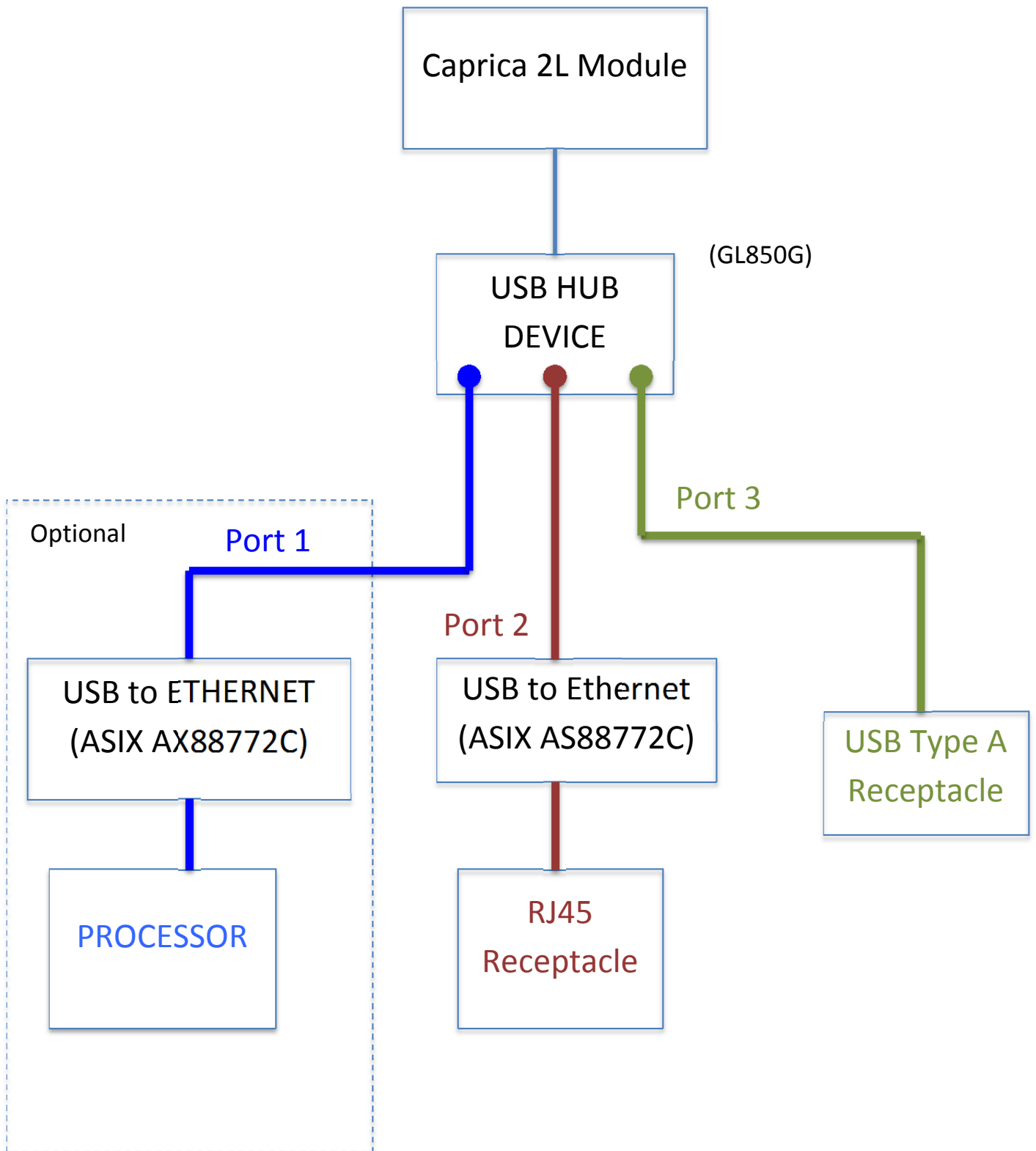
6.3.1 80-pin Board-to-Board Connector

The Caprica2L utilizes a 0.5mm BTB SMT Female type, P/N: 8396-8041 (See 88079-0800A1_88079-xxxxAx-aces_rev-U.pdf) for Board to Board (BTB) connection.



6.3.2 Wired Ethernet Connectivity

The Caprica2L has the capability to be connected to a network via Ethernet cable. To implement this functionality, USB to Ethernet part ASIX AX88772C and a USB HUB device are required. USB HUB Device should be a 4-port device. Use port configuration shown in image below.



6.3.3 Apple Authentication Coprocessor Integration

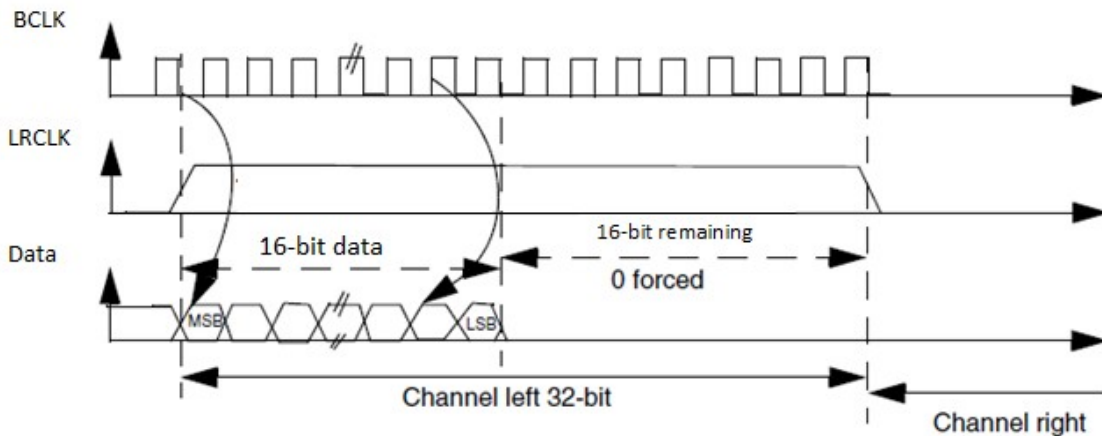
Caprica2L supports integration of Apple Authentication Coprocessor. This is required for builds which wish to certify Apple AirPlay. The interface between Caprica2L and Apple Coprocessor requires three connections, 2 connections for I2C and one for Reset. The Caprica2L pins designated for this are **pin 46 (SCL1)**, **pin 48 (SDA1)**, and **pin 66 (GPIO1)** for reset. The GPIO1 connection is a jumper while SCL1 and SDA1 require external pullup resistors. Apple MFi Accessory Interface Specification recommends using 2.2k Ohm resistors for pullup to Vcc used to power Coprocessor.

7 Electrical Characteristics

This section describes the electrical characteristics of the module including power consumption power sequencing, and timing diagrams

7.1 I2S Output Format Reference Diagram

This diagram displays the Left Justified (MSB) output format of Caprica2L I2S bus.



7.2 Operating Voltages

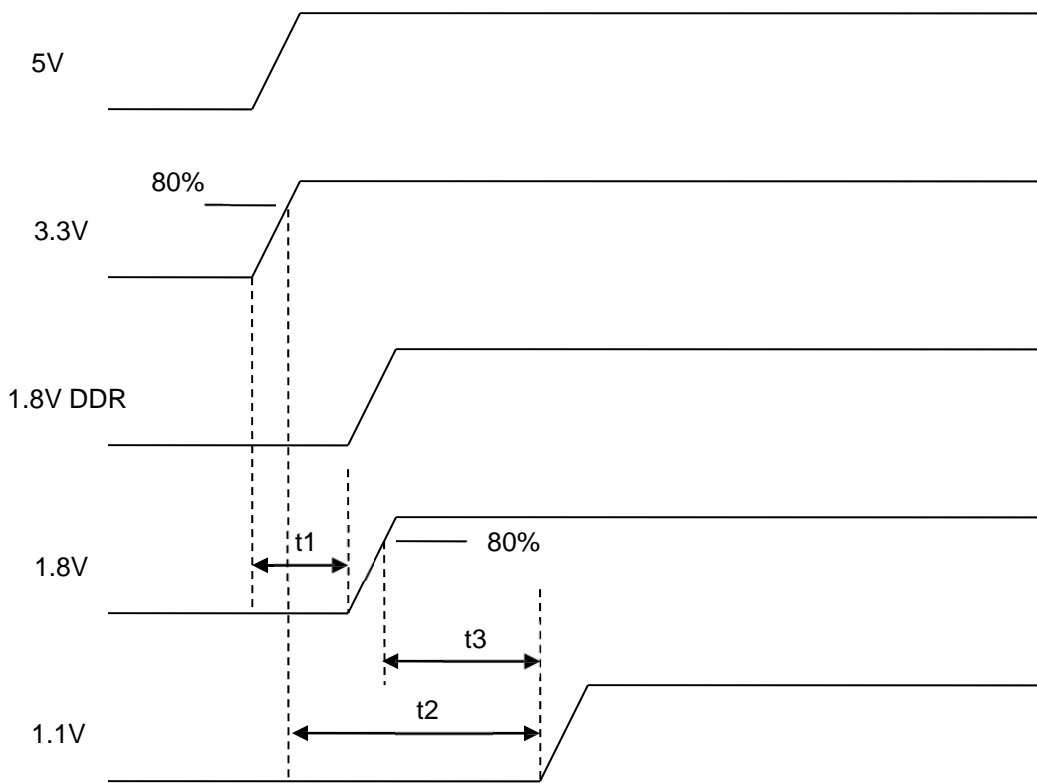
Symbol	Min	Typical	Max	Units
DC_5V (5V)	4.75	5.0	5.25	V
V1_1 (3.3V)	2.97	3.3	3.6	V
V2_2 (1.8V_DDR)	1.7	1.8	1.9	V
V5_2 (1.8V)	1.7	1.8	1.9	V
V3_3 (1.1V)	1.05	1.10	1.155	V

7.3 Power Consumption

Symbol	V3		V5		V2		V1		5V	
Voltages	1.1V		1.8V		1.8V		3.3V		5V	
Test Point	R219		R218		R217		R215		R216	
Test Mode	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
Normal (connect AP)	409.8	477.1	5.5	5.8	199.6	386.7	13.3	16.9	116.4	140.5
Play Music 1K Tone	412.8	439	5.6	5.8	201.2	254	15.1	14.9	117	131
Unit : mA										

Average Power	0.9698 W
Max Power	1.2675 W
In Rush	2.5350 W

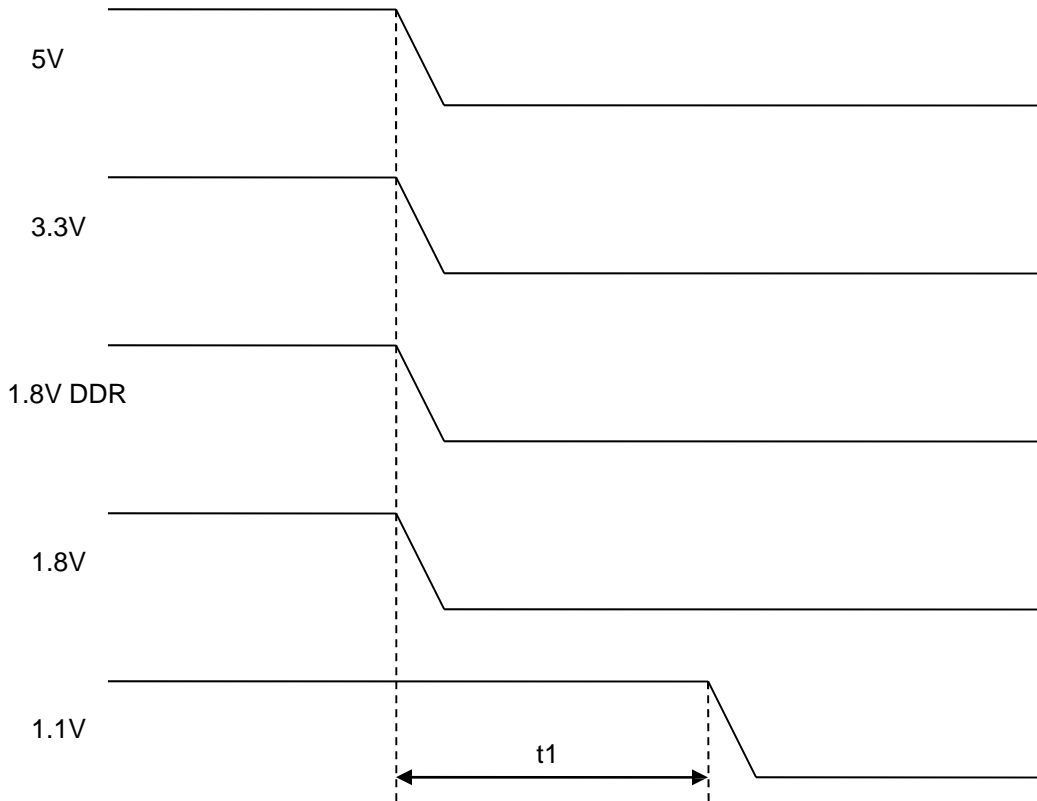
7.4 Power Up Sequencing



7.4.1 Power up timing specifications

Symbol	Min	Unit
t1	0	ms
t2	0	ms
t3	0	ms

7.5 Power Down Sequencing



7.5.1 Power down timing specifications

Symbol	Max	Unit
t1	10	ms

8 Caprica2L Software Architecture (for reference only)

The Caprica2L Software Architecture allows for Over the Air (OTA) reprogramming as well as factory updates using a built in USB port.

8.1 Base Linux OS

The Base Linux OS (“OS”) includes the following sub-components:

- Power management
- Network connectivity
- Dual-Band WiFi support

Notes:

- Supports the WiFi standards 802.11a/b/g/n protocol
- Supports all popular non-enterprise WiFi security scheme: WEP (64 and 128bit), WPA Pre-Shared Key (WPA-PSK, TKIP + AES), and WPA2-PSK TKIP + AES
- Supports WiFi Protected Setup (WPS) with Push Button Configuration (PBC) option

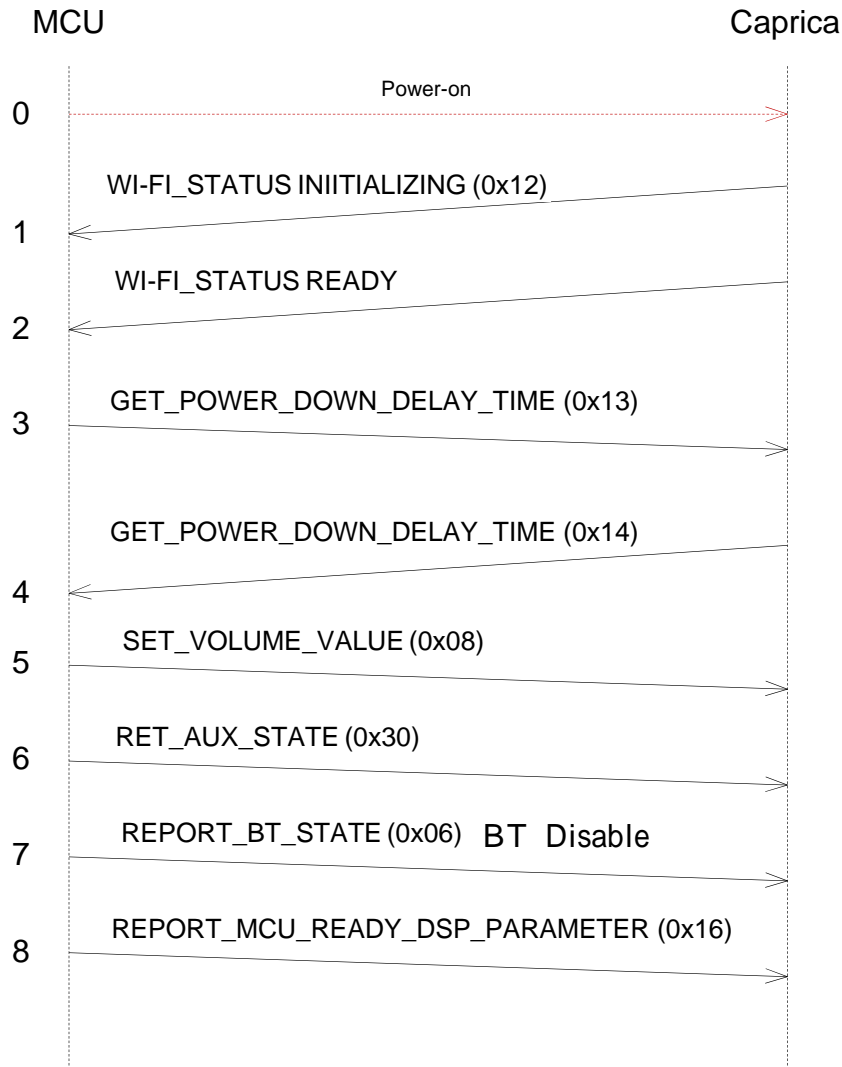
8.2 System Update

- System update monitor automatically checks for software update availability
- System update download and installation
- Update via Network (OTA)
- Factory Update via USB

9 Host Control Communication

The following describes initialization between Microprocessor (“Aspen”) inside Caprica2L Module and Microcontroller. Please refer to **PHORUS-CAP-TSD-0004-Caprica-Host-Communication-Protocol**.

System Initialization Sequence



10 Mechanical Interfaces

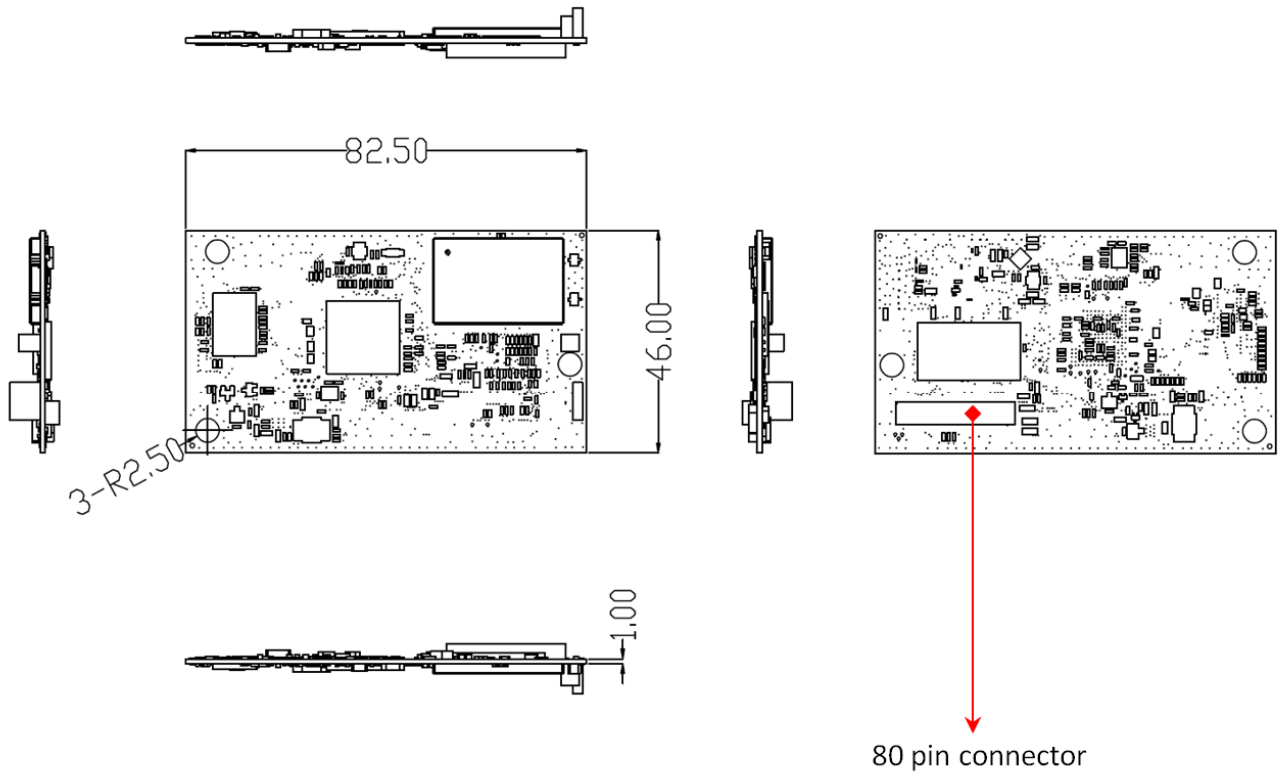
The Caprica2L is physically mounted to the host with the 80-pin connector and 3 mounting fasteners.

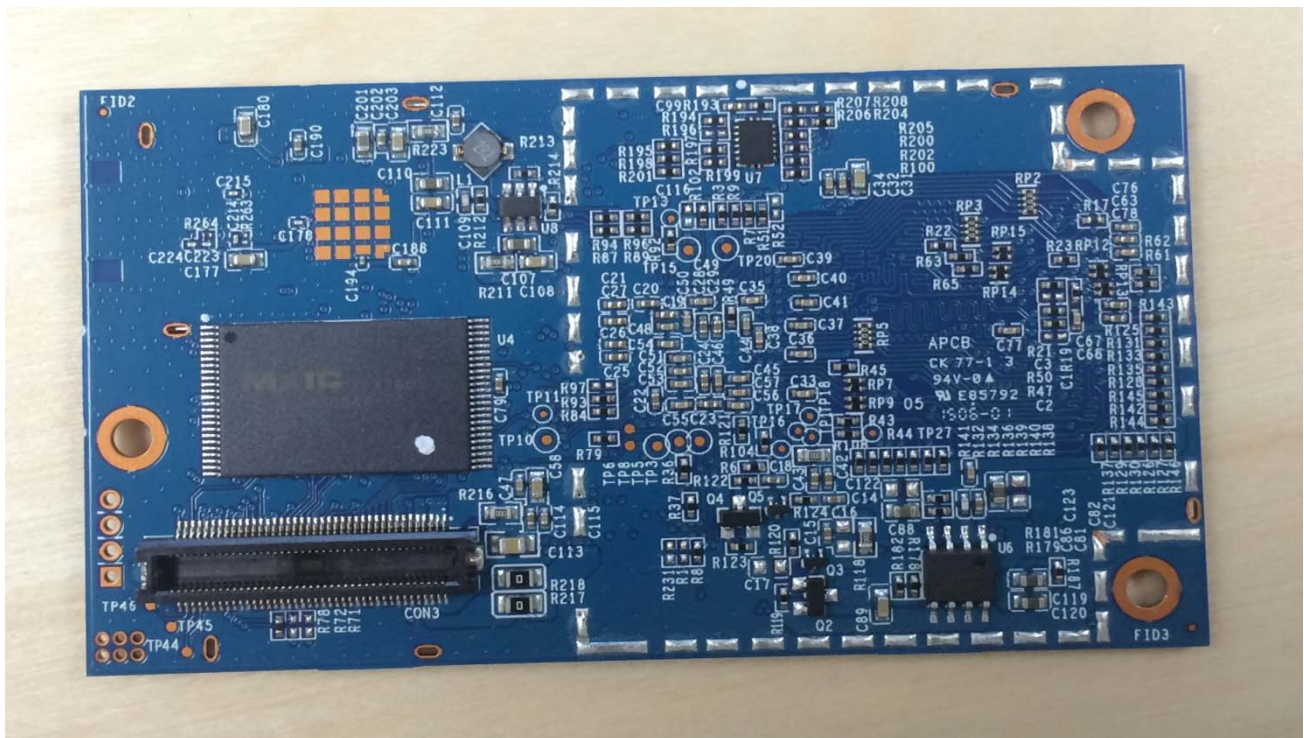
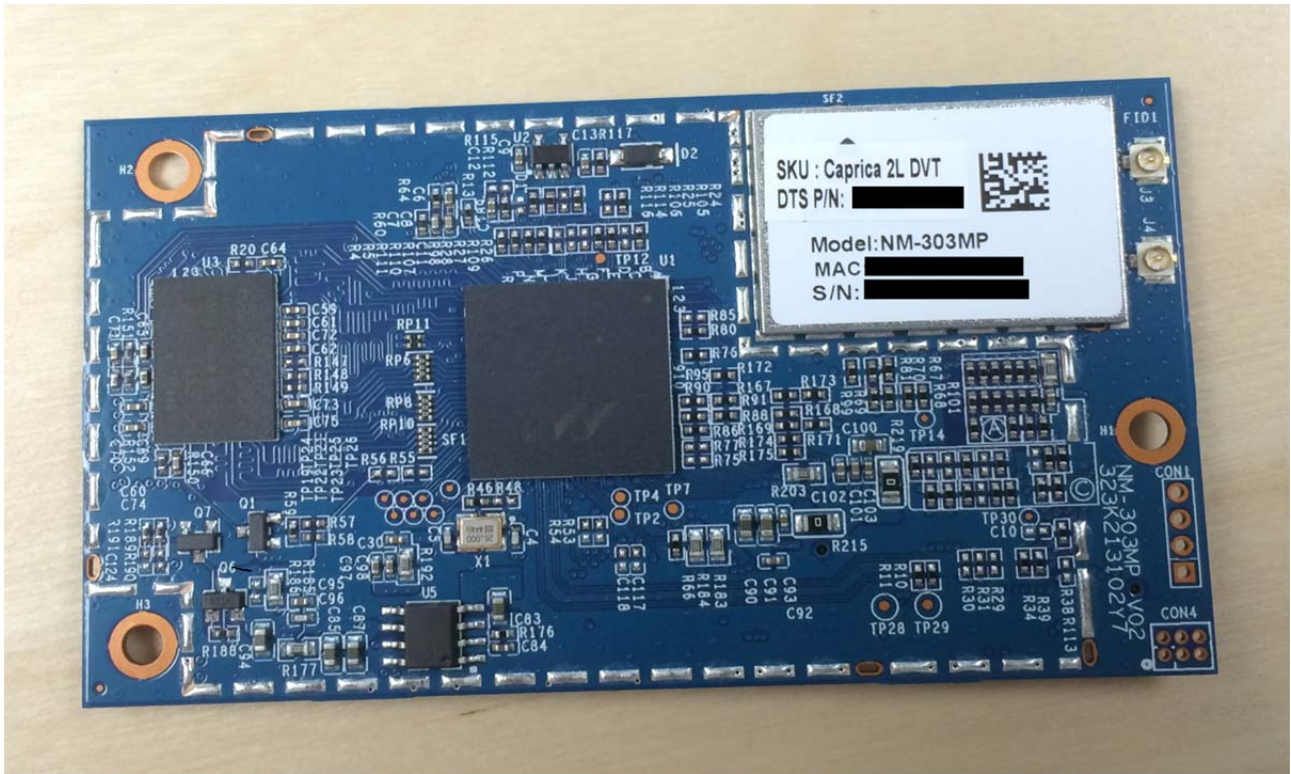
The dimensions for these mounting points, as well as general keep out areas are detailed in **Play-Fi Module Outline and Mounting Drawings (Caprica_2L_PCB_RevA.DWG, Caprica_2L_PCB_RevA.pdf)**.

3D model information is included in both STEP format in **Caprica_2L_PCB_RevA.stp**

11 Mechanical Outline

All measurements in millimeters





12 Certification Requirements

12.1 User Interface

12.1.1 User Input

The device shall have the following user inputs:

Required Feature	Implementation Requirement	Additional Notes
Volume Up	Confirm 30 volume states can be accessed via all user interface methods	These apply to hardware and application interfaces
Volume Down	Confirm 30 volume states can be accessed via all user interface methods.	
Mute ¹	Must return to the “FF” as a mute state.	
Wi-Fi Set-Up	If a separate WiFi set up button is used (as opposed to using Factory Reset) the button must support WiFi Setup and WPS modes (WPS mode requires the Wi-Fi setup button.	An indicator (LED) must be used to reflect WiFi state.
Factory Reset	A single user accessible button shall provide the factory reset feature. This shall return all other system functions to the factory new state, as well as cycling power.	Can provide WiFi reset functionality if required.
Power	Provides a user command to turn the unit from off state to on state and vice versa.	
USB Type A Plug	Type A plug is used for Caprica Firmware update, using a USB memory “stick” type device	

¹ A mute button is option on the industrial design. If it is not included the simultaneous press of volume up and volume down will operate the mute function.

12.1.2 Play-Fi to other System Controls

Play-Fi module to system controls:

Criteria	Implementation Requirement	Notes
Re-Start after USB update	Device restarts as expected after USB update of Caprica	
Reboot all	The unit cycles power in the same manner as a user commanded power cycle.	

12.1.3 Visual Feedback BT Disable

The device shall have visual indicators for Wi-Fi Set-Up, Bluetooth Set-Up (if included), and Mute.

A WiFi light shall indicate the following states:

Required Feature	Implementation Requirement	Notes
Wi-Fi Set-up mode	Pulsing Blink	Ramp from Off to On for 750 msec, Ramp On to Off for 750 msec
WPS Mode	Double Blink	On for 100 msec, Off for 100 msec, On for 100 msec, Off for 750, repeat
Connected, Searching	Blinking	250 msec on, 250 msec off
Connected	Solid (LED on)	
Powering Down	Blinking	

There shall be a visual way the user can recognize the device is in a Mute state:

Required Feature	Implementation Requirement	Notes	Result
Mute Visual Feedback	Provide a visual feedback to user indicating mute state		

12.1.4 Audible Feedback

The system shall provide the following audible feedback to the user as noted:

Required Feature	Implementation Requirement	Notes
Wi-Fi set-up mode is active	Each feature requires unique audible feedback which can be a combination of audio cues	
WPS mode is active		
WPS set-up mode is no longer active		
Reset initiated		
Factory reset initiated		

12.2 Wi-Fi Performance

The Play-Fi module requires a minimum level of Wi-Fi performance.

:

Functional Criteria	Implementation Requirement	Notes
WiFi Performance at -72 dBm RSSI	Validates UDP performance, transfer 90% of 1 second samples at 5.5 Mbps	

12.3 Branding Requirements

12.3.1 Product Industrial Design

The Play-Fi logo shall be visible to the end consumer. These requirements are documented in the Play-Fi Branding Guidelines

Criteria	Implementation Requirement	Notes
Play-Fi Logo meets requirements		

12.3.2 Product Packaging BT Disable

The Play-Fi logo shall be printed on the product's packaging in close proximity to other wireless certification logos (i.e. Bluetooth, Wi-Fi, etc.). If the packaging is full color then the full color version of the logo shall be used, otherwise the monochromatic version shall be used.

Packaging requirements:

Criteria	Inspection Results	Notes
Play-Fi is Logo properly placed		
Play-Fi is Logo properly sized		
Play-Fi is Logo colored properly		

12.3.3 Module Identification

The Wi-Fi MAC ID of Play-Fi Module shall be displayed somewhere on the product.

Criteria	Implementation Requirement	Notes
Wi-Fi Mac ID is displayed on product		
MAC ID displayed on product matches MAC ID of Play-Fi module inside product.		

13 MCU Controlled Audio Feedbacks

Caprica is not involved in producing audio feedbacks for any of below mentioned cases.

- Power ON
- Bluetooth connect/disconnect BT Disable
- Factory reset

MCU sends commands to the DSP to render stored sounds in these 3 cases.

When the device is put in WPS/Access point modes, MCU informs the Caprica of the event. Caprica then informs MCU to send commands to the DSP to render adequate sound for the event.

FCC Warning

Information to user

Any changes or modifications not expressly approved by the party responsible for compliance could void your authority to operate the equipment.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Labelling requirements

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

- (1) this device may not cause harmful interference and (2) this device must accept any interference received, including interference that may cause undesired operation.

RF Radiation Exposure Statement:

1. This Transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.
2. This equipment complies with FCC RF radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of 20 centimeters between the radiator and your body.

IC Warning

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

*The device for the band 5150-5250 MHz is only for indoor use.

OEM Statement:

Labelling Requirements for the Host device

The host device shall be properly labelled to identify the modules within the host device. The certification label of the module shall be clearly visible at all times when installed in the host device, otherwise the host device must be labelled to display the FCC ID and IC of the module, preceded by the words "Contains transmitter module", or the word "Contains", or similar wording expressing the same meaning, as follows:

Contains FCC ID: 2AAWQ-CAPRICA2L

Contains IC: 11138A-CAPRICA2L

This module is intended for OEM integrator. The OEM integrator is still responsible for the FCC compliance requirement of the end product which integrates this module.

20cm minimum distance has to be able to be maintained between the antenna and the users for the host this module is integrated into. Under such configuration, the FCC radiation exposure limits set forth for an population/uncontrolled environment can be satisfied.