LN930 M.2 Hardware User Guide

1VV0301078 Rev.10 – 2015-11-11

Making machines talk.

APPLICABILITY TABLE

PRODUCT
LN930
LN930-AP

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Contents

1 Introduction

This document is a technical specification for Telit's next generation form factor M.2 module family. The next generation form factor M.2 module family is a natural transition from the PCI Express Mini Card and Half Mini Card to a smaller form factor size.
The M.2 Card Type 3042 offers single sided component mounting, 75 pins (8 dedicated for key), in a compact size (30 mm x 42 mm). A range of 2G/3G/4G (LTE) M.2 modules supporting multiple operating systems and unique features in the WWAN Card Type 3042 form factor are available.

1.1 Scope

The document will cover the features of the M.2 modules presently available. It will also identify the M.2 module application interface along with hardware, software, reliability, and mechanical specifications.

1.2 Purpose

The intent of this document is to provide design guidelines and information for each M.2 module.
In addition to the M.2 module family features and performance metrics, this document describes the interface signals, operating conditions, physical and mechanical requirements of the M.2 cards.

1.3 Audience

This document is intended for editors who are about to write or edit documentation for Telit.

1.4 Contact Information, Support

For general contact, technical support, to report documentation errors and to order manuals, contact Telit Technical Support Center (TTSC) at:

TS-EMEA@telit.com
TS-NORTHAMERICA@telit.com
TS-LATINAMERICA@telit.com
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Alternatively, use:

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For detailed information about where you can buy the Telit modules or for recommendations on accessories and components visit:

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Our aim is to make this guide as helpful as possible. Keep us informed of your comments and suggestions for improvements.

Telit appreciates feedback from the users of our information.

1.5 Document Organization

This document contains the following chapters (sample):

"Chapter 1: "Introduction" provides a scope for this document, target audience, contact and support information, and text conventions.

"Chapter 2: "Chapter two" gives an overview of the features of the product.

"Chapter 3: "Chapter three" describes in details the characteristics of the product.

"Chapter 6: "Conformity Assessment Issues" provides some fundamental hints about the conformity assessment that the final application might need.

"Chapter 7: "Safety Recommendation" provides some safety recommendations that must be follow by the customer in the design of the application that makes use of the AA99-XXX.

1.6 Text Conventions

Danger – This information MUST be followed or catastrophic equipment failure or bodily injury may occur.

Caution or Warning – Alerts the user to important points about integrating the module, if these points are not followed, the module and end user equipment may fail or malfunction.

Tip or Information – Provides advice and suggestions that may be useful when integrating the module.

All dates are in ISO 8601 format, i.e. YYYY-MM-DD.

1.7 Related Documents

TBA

2 M.2 Overview

This section will provide an overview of the standard features of a M.2 Card, information on the various SKUs of 2G/3G/4G (LTE) M.2 modules along with a respective functional block diagram of each SKU.

2.1 SKUs - 2G/3G/LTE M.2 Modules

There are five different M.2 modules available in the M.2 Card Type 3042 form factor:

- HN930 - HSPA+
- LN930-AP - APAC LTE
- LN930 - LTE

A comparison of the features, RF band Support, and data rates for the various M.2 modules is shown in Table 1 through Table 3

Table 1 M.2 Module - General Feature

Feature	Description	Additional Information	M.2 module		
			HN930	LN930-AP	LN930
Mechanical	M.2 Card Type 3042 Slot B	30 mm x 42 mm Pin count: 75 (67 usable, 8 slot)	x	x	x
Operating Voltage	3.3 V +/- 5%	-	x	x	x
Operating Temperature	-10˚C to +55˚C – Normal +55˚C to +70˚C – Extended	Extreme - This is the surrounding air temperature of the module inside the platform when the card is fully operating at worst case condition	x	x	x
Application Interface (75 pin card)	Interprocessor Communications	USB 2.0 High-speed	x	x	x
	USIM w/ Card Detect	SIM_CLK, SIM_RESET, SIM_IO, SIM_PWR, SIM_DETECT	x	x	x
	M.2 Control	Full_Card_Power_On_Off	x	x	x
		Reset#	x	x	x
		W_DISABLE#	x	x	x
		LED #1	x	x	x
		DPR (Body SAR)	x	x	x
		Wake on WWAN	x	x	x
		GNSS Disable	x	x	x
	Global Positioning (GPS/ GLONASS)	I2C_SCL, I2C_SDA, I2_IRQ, CLKOUT, TX_BLANKING	x	x	x
	Antenna Tuning	(4) GPO (RF Transceiver)	-	x	x
	RF Coexistence	(3) GPIO	-	x	x
RF Antenna	Main & Diversity/ GNSS	Separate coax connectors	x	x	x
Debug	JTAG	-	x	x	x
	ETM11	-	-	x	x
	MIPI PTI	-	-	x	X

Table 2. M.2 Module - RF Band Support

RF Band	UE Transmit	UE Receive	M.2 Module								
			HN930			LN930-AP			LN930		
			GSM	UMTS	LTE	GSM	UMTS	LTE	GSM	UMTS	LTE
001 I	1920 MHz - 1980 MHz	2110 MHz - 2170 MHz		x			x	x		x	x
002 II	1850 MHz - 1910 MHz	1930 MHz - 1990 MHz	x	x					x	x	x
003 III	1710 MHz - 1785 MHz	1805 MHz - 1880 MHz	x					x	x		x
004 IV	1710 MHz - 1755 MHz	2110 MHz - 2155 MHz		x						x	x
005 V	824 MHz - 849 MHz	869 MHz - 894 MHz	x	x					x	x	x
006 VI	830 MHz - 840 MHz	875 MHz - 885 MHz					x				
007 VII	2500 MHz - 2570 MHz	2620 MHz - 2690 MHz									x
008 VIII	880 MHz - 915 MHz	925 MHz - 960 MHz	x	x			x	x	x	x	x
009 IX	1749.9 MHz - 1784.9 MHz	1844.9 MHz - 1879.9 MHz						x			
010 X	1710 MHz - 1770 MHz	2110 MHz - 2170 MHz									
011 XI	1427.9 MHz - 1447.9 MHz	1475.9 MHz - 1495.9 MHz					x	x			
012 XII	699 MHz - 716 MHz	729 MHz - 746 MHz									

013 XIII	777 MHz - 787 MHz	746 MHz - 756 MHz									x
014 XIV	788 MHz - 798 MHz	758 MHz - 768 MHz									
017 XVII	704 MHz - 716 MHz	7734 MHz - 746 MHz									x
018 XVIII	815 MHz -830 MHz	860 MHz -875 MHz						x			x
019 XIX	830 MHz - 845 MHz	875 MHz - 890 MHz					x	x			x
020 XX	832 MHz - 862 MHz	791 MHz - 821 MHz									x
021 XXI	1447.9 MHz - 1462.9 MHz	1495.9 MHz - 1510.9 MHz						x			
022 XXII	3410 MHz - 3490 MHz	3510 MHz - 3590 MHz									
023 XXIII	2000 MHz - 2020 MHz	2180 MHz - 2200 MHz									
024 XXIV	1626.5 MHz - 1660.5 MHz	1525 MHz - 1559 MHz									
025 XXV	1850 MHz - 1915 MHz	1930 MHz - 1995 MHz									
026 XXVI	814 MHz - 849 MHz	859 MHz - 894 MHz						x			
027 XXVII	806 MHz - 824 MHz	851 MHz - 869 MHz									
028 XXVIII	703 MHz - 748 MHz	758 MHz - 803 MHz									

029 XXIX	1850 MHz - 1910 MHz or 1710 MHz - 1755 MHz	716 MHz - 728 MHz									
001 I	1920 MHz - 1980 MHz	2110 MHz - 2170 MHz									

Table 3. M.2 Module - Data Services

Data Service	M.2 module		
	HN930	LN930-AP	LN930
GPRS Class 33: DL 85.6 kbps, UL 85.6 kbps	x	-	x
EDGE Class 33: DL 236.8 kbps, UL 236.8 kbps	x	-	x
WCDMA: DL 384 kbps, UL 384 kbps	x	x	x
HSPA+: DL 21 Mbps, UL 5.7 Mbps	x	x	x
HSPA+: DL 42 Mbps, UL 5.7 Mbps	-	x	x
LTE FDD: DL: 100 Mbps, UL 50 Mbps	-	x	x
LTE FDD: DL: 150 Mbps, UL 50 Mbps	-	x	x

Module supports DL 150 Mbps in LN930. This is only for generic SW and VZW SW, but not for AT&T SW.

2.2 M.2 Module – Block Diagrams

2.2.1 M.2 HN930 Module

The M.2 HSPA+ module is Intel's Next Generation Form Factor design based on Intel's XMM™6260 modem platform. The M.2 HSPA+ card is a dual-mode (UMTS/GSM) 3GPP release 7 HSPA+ modem.

The M.2 HSPA+ module includes support at the 75 pin application interface for M.2 Control, USB 2.0 HS, GNSS, and USIM. Antenna Tuning is not supported.

A block diagram of the M.2 HSPA+ module is shown in Figure 1.

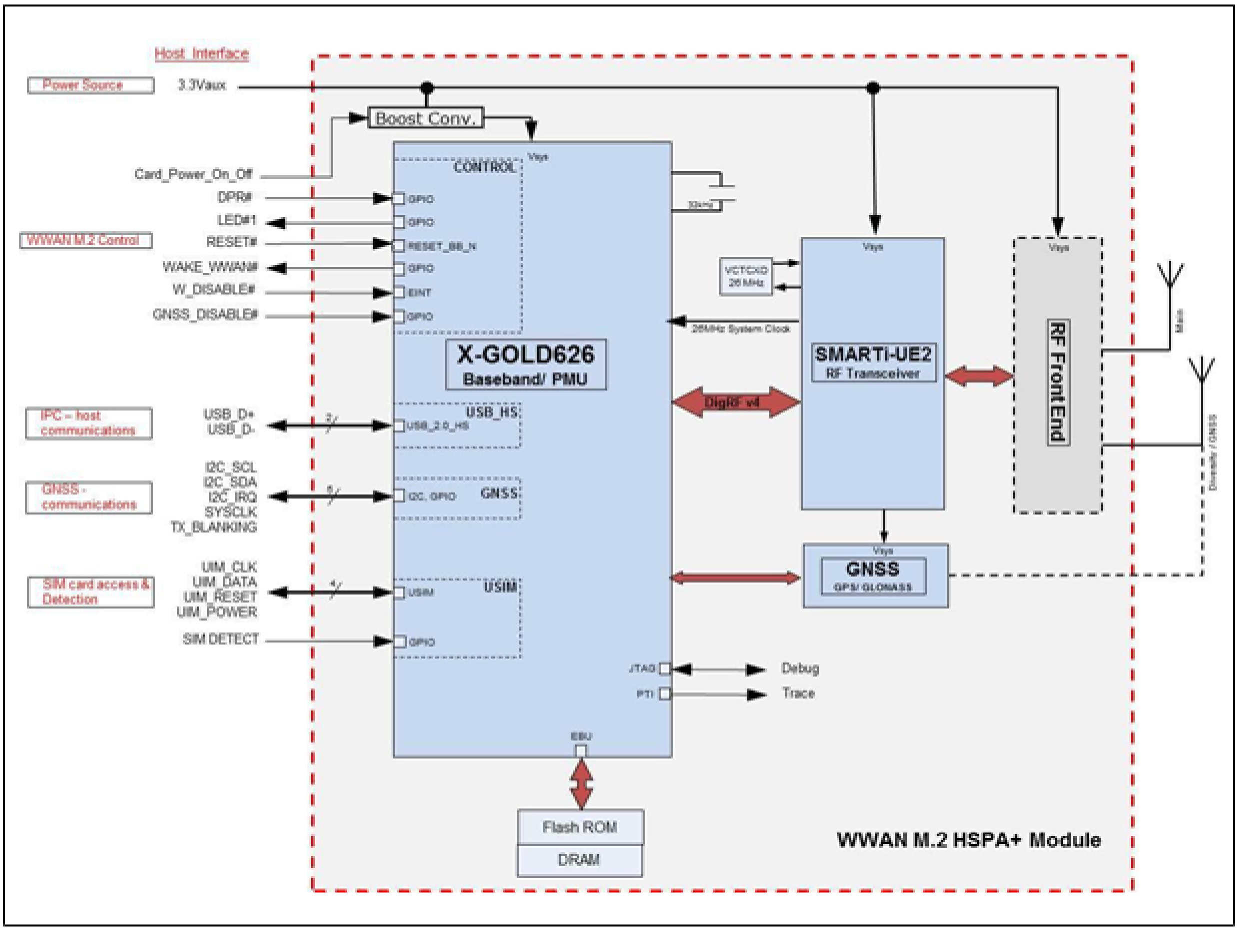

Figure 1 M.2 HSPA+ Block Diagram

2.2.2 M.2 LN930-AP Module

The M.2 APAC LTE module is another Intel design based on the XMM™7160 modem platform. The module has a targeted area of operation in the Asia Pacific rim and offers 3G and LTE datacard functionality, 2G Functionality is not supported.

The M.2 APC LTE module includes support at the 75 pin application interface for M.2 Control, USB 2.0 HS, GNSS, USIM and Antenna Tuning.

A block diagram of the M.2 APAC LTE module is shown in Figure 2.

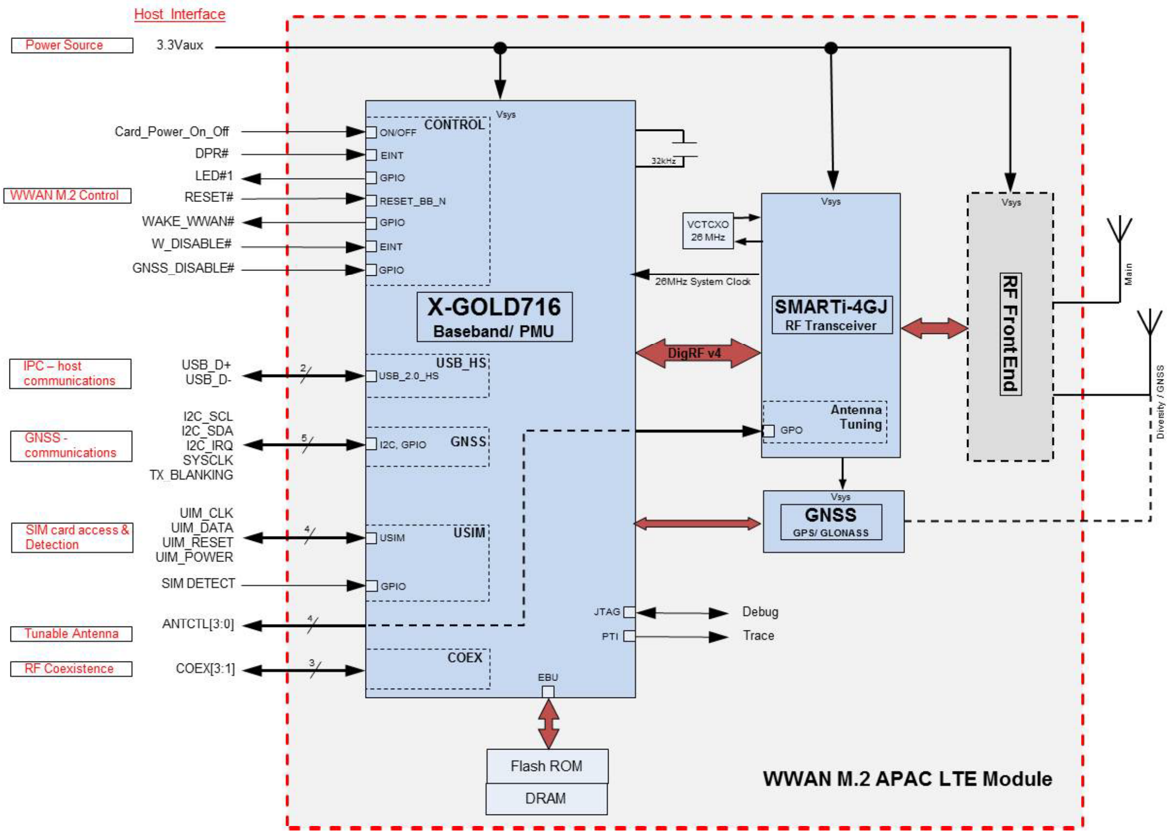

Figure 2 M.2 APAC LTE Module Block Diagram

2.2.3 M.2 LN930 Module

The M.2 LTE module is based on Intel's XMM™7160 modem platform. The M.2 LTE module is a triple-mode (2G, 3G, and 4G) 3GPP release 9 modem providing datacard functionality.

The M.2 LTE module includes support at the 75 pin application interface for M.2 Control, USB 2.0 HS, GNSS, USIM and Antenna Tuning.

A block diagram of the M.2 LTE module is shown in Figure 3.

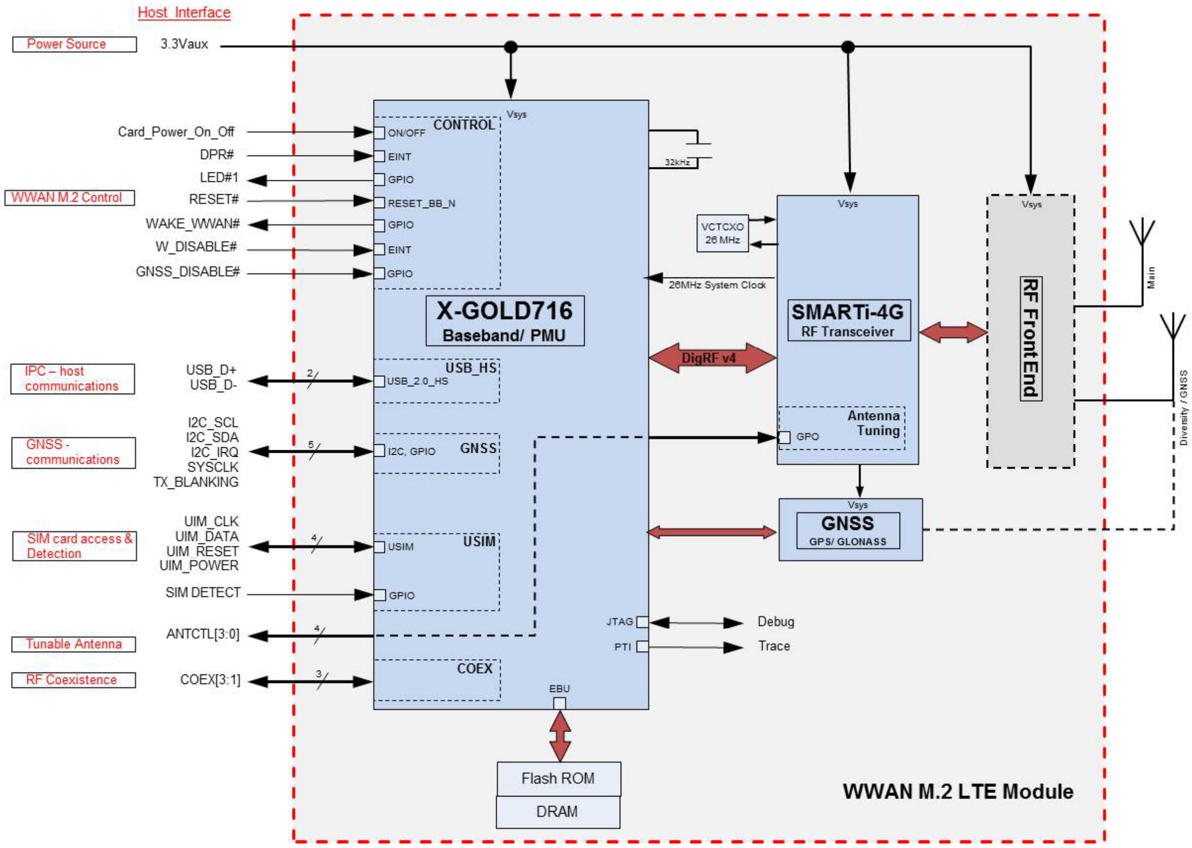

Figure 3 M.2 LTE Module Block Diagram

A more detailed interconnect diagram of the RF Engine utilized on the M.2 LTE Module is shown in Figure 4.

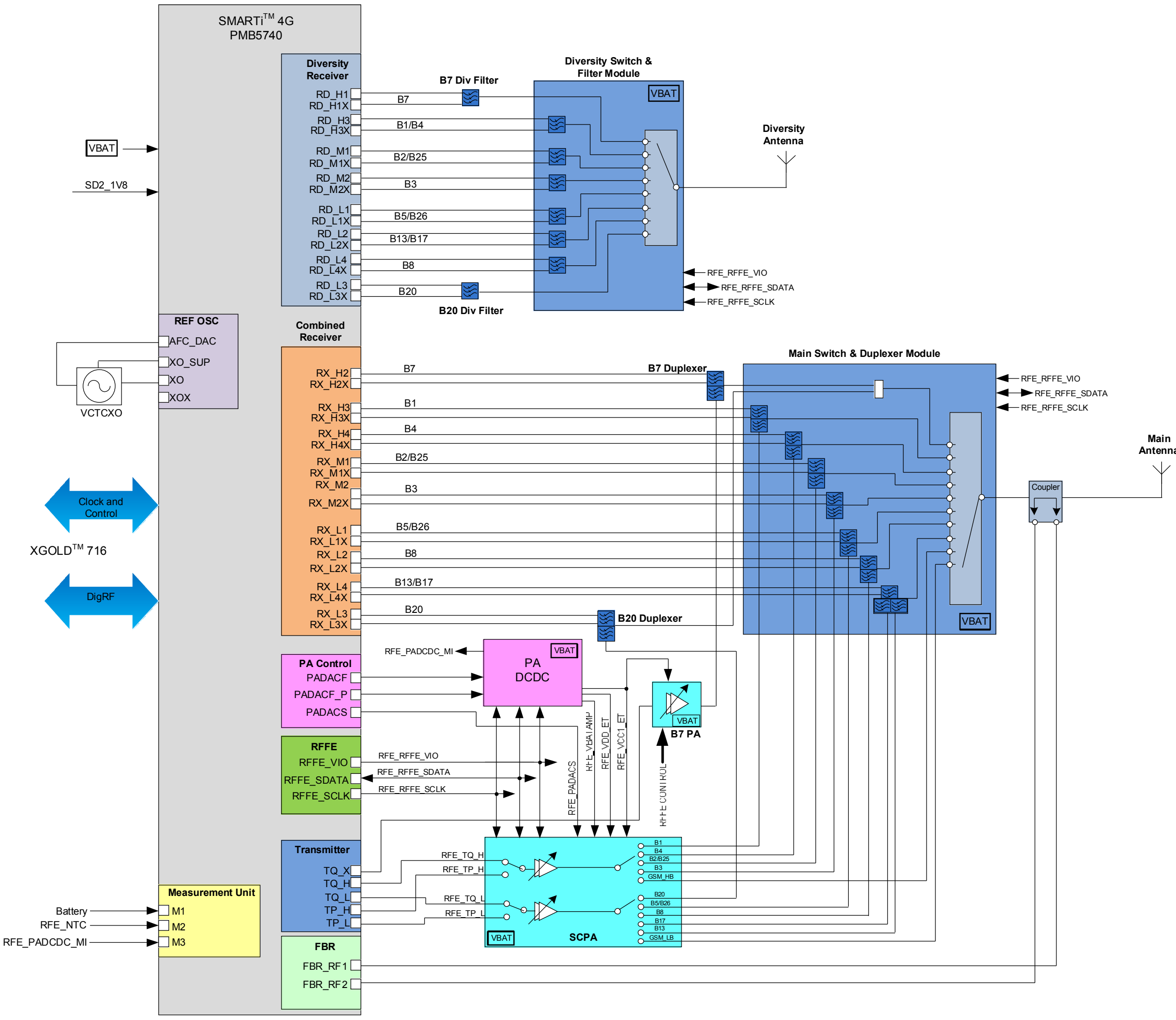

Figure 4 Detailed Interconnection of M.2 LTE Modem RF Engine

2.3 Host Interface Signals

This section describes the signals available to the host processor at the 75 pin application interface. Eight signals are eliminated by the notch on the host connector, leaving 67 usable signals. A diagram of the M.2 module identifying the 75 pin interface is shown in Figure 5.

Note that the M.2 module has all components mounted on the top side. Odd pin numbers are on the top side while even pins on the bottom side.

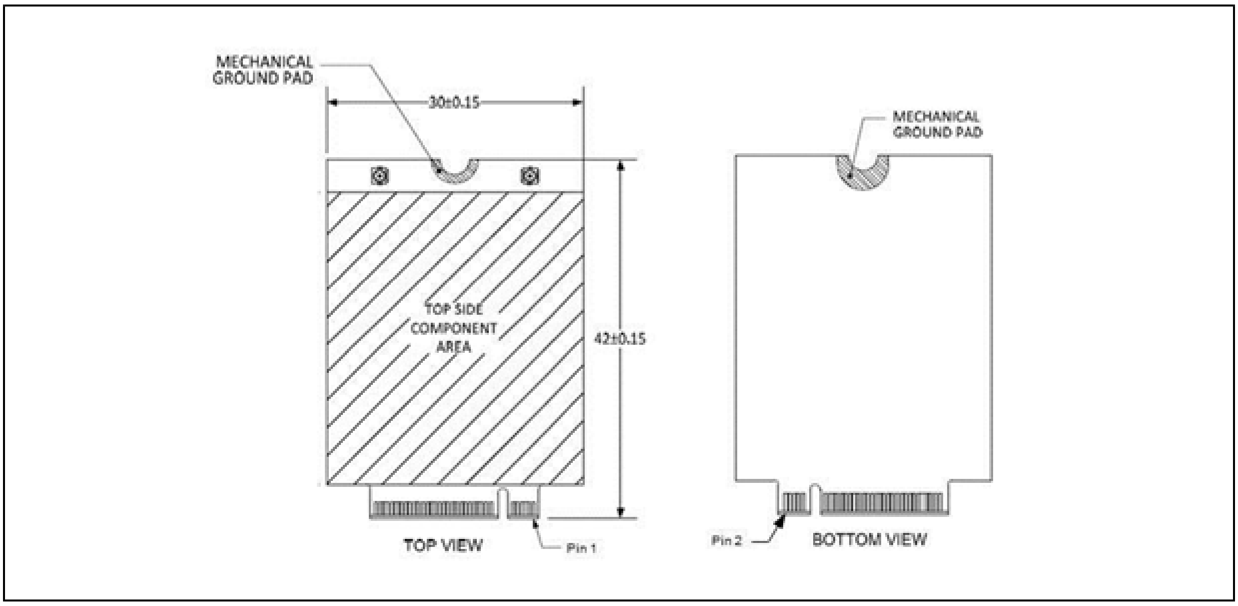

Figure 5 PCI Express M.2 Module Interface

A complete description of all interface signals available at the host interface is listed in Table 4. Some features, such as GNSS and Antenna Tuning, are not available on every M.2 module. On those modules, the signals at the application interface are not connected on the M.2 module.

Table 4 M.2 Host Interface Signals

Pin	Signal Name	I/O	Description	Supply
1	CONFIG_3	O	Presence Indication: WWAN M.2 Connects to GND internally	-
2	3.3V	P	M.2 Supply Pin 3.3 V	3.3 V
3	GND	P	Ground	-
4	3.3V	P	M.2 LTE Supply Pin 3.3 V	3.3 V
5	GND	P	Ground	-
6	FULL_CARD_POWER_OFF#	I	Control signal to power On/Off M.2.	1.8 V
7	USB D+	IO	USB 2.0 HS DPLUS Signal	
8	W_DISABLE#	I	Active low signal to Disable Radio Operation	3.3 V
9	USB D–	IO	USB 2.0 HS DMINUS Signal	

10	LED#1	O	Open Drain, active low signal used for add-in card to provide status	3.3 V
11	GND	P	Ground	-
12	SLOT KEY			
13	SLOT KEY			
14	SLOT KEY			
15	SLOT KEY			
16	SLOT KEY			
17	SLOT KEY			
18	SLOT KEY			
19	SLOT KEY			
20	AUDIO0	IO	PCM Clock (I2S_CLK)	1.8 V
21	CONFIG_0	O	Configuration Status. Presently not connected on WWAN M.2 module.	-
22	AUDIO1	I	PCM In (I2S_RX)	1.8 V
23	WAKE_WWAN#	O	Wake On WWAN Use by M.2 to wake up host.	1.8 V
24	AUDIO2	O	PCM Out (I2S_TX)	1.8 V
25	DPR	I	Dynamic Power Reduction - Body SAR control signal	1.8 V
26	GNSS_DISABLE#	I	Disable GNSS function	1.8 V
27	GND	P	Ground	-
28	AUDIO3	IO	PCM Sync (I2S_WA0)	1.8 V
29	SSIC_RxN	I	SSIC Receive N (Not Supported)	-
30	UIM-RESET	O	SIM Reset (I)	1.8 V/3.0 V
31	SSIC_RxP	I	SSIC Receive P (Not Supported)	-
32	UIM-CLK	O	SIM Clock (I)	1.8 V/3.0 V
33	GND	-	Ground	-
34	UIM-DATA	IO	SIM Data (I/O)	1.8 V/3.0 V
35	SSIC_TxN	O	SSIC Transmit N (Not Supported)	-
36	UIM-PWR	O	SIM power	1.8 V/3.0 V
37	SSIC_TxP	O	SSIC Transmit P (Not Supported)	-
38	N/C	-	Not connected internally on M.2	-
39	GND	P	Ground	-
40	I2C_SCL	IO	I2C Clock – GNSS Support	1.8 V

41	N/C	-	Not connected internally on M.2	-
42	I2C_SDA	IO	I2C Data – GNSS Support	1.8 V
43	N/C	-	Not connected internally on M.2	
44	I2C_IRQ	I	GNSS Interrupt Request – GNSS Support	1.8 V
45	GND	P	Ground	-
46	SYSCLK	O	26 MHz reference Clock output for external GNSS module	1.8 V
47	N/C	-	Not connected internally on M.2	-
48	TX_BLANKING	O	GNSS Blanking Signal used to indicate 2G Tx burst and LTE band 13 Tx burst.	1.8 V
49	N/C	-	Not connected internally on M.2	-
50	N/C	-	Not connected internally on M.2	-
51	GND	P	Ground	-
52	N/C	-	Not connected internally on M.2	-
53	N/C	-	Not connected internally on M.2	-
54	N/C	-	Not connected internally on M.2	-
55	N/C	-	Not connected internally on M.2	-
56	N/C	-	Not connected internally on M.2	-
57	GND	P	Ground	-
58	N/C	-	Not connected internally on M.2	-
59	ANTCTL0	O	RF Antenna Tuning Control Signal 0	1.8 V
60	COEX3	O	Wireless Coexistence between WWAN and WiFi/BT modules. IDC_LteDtxEnv	1.8 V
61	ANTCTL1	O	RF Antenna Tuning Control Signal 1	1.8 V
62	COEX2	I	Wireless Coexistence between WWAN and WiFi/BT modules. IDC_CwsPriority	1.8 V
63	ANTCTL2	O	RF Antenna Tuning Control Signal 2	1.8 V
64	COEX1	O	Wireless Coexistence between WWAN and WiFi/BT modules. IDC_LteFrameSync	1.8 V
65	ANTCTL3	O	RF Antenna Tuning Control Signal 3	1.8 V
66	SIM DETECT	I	SIM Card Detection (I) (low active). • Pull-up resistor on WWAN M.2 module	1.8 V
67	RESET#	I	Single control to reset WWAN	1.8 V
68	N/C	-	Not connected internally on M.2	-

69	CONFIG_1	O	Configuration Status WWAN M.2 Connects to GND internally	-
70	3.3V	P	WWAN Supply Pin 3.3 V	-
71	GND	P	Ground	-
72	3.3V	P	WWAN Supply Pin 3.3 V	-
73	GND	P	Ground	-
74	3.3V	P	WWAN Supply Pin 3.3 V	-
75	CONFIG_2	O	Configuration Status WWAN M.2 Connects to GND internally	-

3 M.2 Module Interface Details

This section provides details on the various interfaces available M.2 modules.

3.1 Interprocessor Interface (IPC)

There are two interfaces on the M.2 host interface that support interprocessor communications (ICP); however, for the WWAN M.2 modules covered by the Product Description only the USB 2.0 High-speed port will be supported.

The other ICP interface, USB Super-speed Inter-Chip (USB_SSIC), is not supported and the signals should not be connected at the host.

The host processor, connected via an ICP interface, has access to the functions of the WWAN card.

3.1.1 USB 2.0 High-Speed – IPC Interface

The USB 2.0 High-speed interface supports the following device classes: CDC-MBIM, CDC-ACM, and CDC-NCM.

The USB Controller is compliant to the USB 2.0 Specification and with the Link Power Management (LPM) Addendum. LPM introduces a new sleep state (L1) which significantly reduces the transitional latencies between the defined power states; hence, improving the responsiveness of the WWAN platform regarding connecting to the internet (Quick Connect).

- USB2.0 LPM L1 Support
- Support for OS assisted fast dormancy
- Selective Suspend support
    - Very low power when in Selective Suspend:
        - <4mw when connected to network (wake)
        - <1 mW no wake

It supports High-speed (HS, 480 MBit/s); Full-speed (FS, 12 MBit/s) transfers. Low- speed mode is **not** supported. Because there is not a separate USB-controlled voltage bus, USB functions implemented on the M.2 module are expected to report as self-powered devices

General Features

- In device mode : High-speed (480 MBit/s) and Full-speed (12 MBit/s)
- In host mode: High-speed (480 MBit/s), Full-speed (12 MBit/s). Low-speed mode (1.5 Mbit/s) is **not** supported.
- Support for 16 bidirectional end points and channels including the end point 0.

Table 5 USB HS Interprocessor Communications Interface

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
USB_D+	USB Data Plus	7	I, O	Per USB 2.0 specification
USB_D–	USB Data Minus	9	I, O	

3.1.2 USB Super-speed IC (Reserved)

The USB Super-speed IC (USB SSIC) solution is not supported by the WWAN M.2 modules presented in this Product Description. It is set aside for future development. These signals should be left un-connected on the host.

Table 6 USB SSIC – ICP Interface

Signal Name	Description	Pin	Direction (WWAN)	Operating Voltage Range
SSIC_RXN	USB SSIC Receiver Signal N	29	O	Per SSIC specification
SSIC_RXP	USB SSIC Receiver Signal P	31	O	
SSIC_TXN	USB SSIC Transmitter Signal N	35	I	
SSIC_TXP	USB SSIC Transmitter Signal P	37	I	

3.2 (U)SIM Interface

The USIM interface is compatible with the ISO 7816-3 IC Card standard on the issues required by the GSM 11.12 and GSM 11.18 standard.

Both 1.8 V and 3 V SIM Cards are supported.

A few comments on the SIM_DETECT signal

1. An external pull-up resistor is connected to SIM_DETECT on the WWAN M.2 module.
2. When a SIM is inserted, SIM_DETECT will be high.
3. When a SIM is removed or not present, SIM_DETECT will be low.
4. The host does not need to drive this signal. It can be tri-stated.

Table 7 (U)SIM Interface Signals

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
UIM_CLK	Clock SIM Card	32	O	1.8 V/3.0 V
UIM_DATA	Input/ Output SIM Card	34	I, O	1.8 V/3.0 V
UIM_RESET	Reset signal for SIM card	30	O	1.8 V/3.0 V
USIM_PWR	1.8 V/3 V Supply for SIM Card	36	O	1.8 V/3.0 V
SIM Detect	SIM Card Detection	66	I	1.8 V

3.2.1 SIM Design Recommendations

The following design guidelines are recommended for the SIM card socket mounted on the host system:

- Length of the traces UIM_CLK, UIM_DATA, and UIM_RESET should not exceed 10 cm.
- UIM_DATA is a sensitive open-drain bi-directional signal. It should not be mounted beside the UIM_CLK signal for long distances. It is recommended to place the UIM_RST trace between UIM_DATA and UIM_CLK to provide isolation. If the traces are run a long distance, surround the UIM_DATA with ground to shield from system noise and UIM_CLK.
- The rise time for UIM_DATA should not exceed 1 µs per the 3GPP specification. High input capacitance may increase rise time and lead to certification failure.
  - Keep UIM traces with low capacitance between each other and to GND
  - An ESD component with high capacitance may increase rise time.

   - The pull-up current cannot be increased to speed up rise time, because the pull-up current must not exceed 1 mA including any crosstalk.
   - Pull-up current is defined by the 4.7 kΩ pull-up resistor (to USIM_PWR) on the WWAN M.2 module, plus 200 µA from the baseband chip is approximately 0.8 mA.
- Place a decoupling capacitor close to the SIM card socket.

3.3 GNSS Interface

Some M.2 modules incorporate GPS and GLONASS receivers with aGPS to support Global Positioning.

For M.2 modules that feature GNSS support, see Table 1, the M.2 module incorporates the CG1960 Single-Chip GNSS Device, which is a complete receiver for simultaneous reception and processing of both GPS and GLONASS signals. It includes LNA, mixer, bandpass filter, VCO, ALC, fractional-N frequency synthesizer, digital tunable filters, PGA stage, and multi-bit ADCs. A UART interface is used by the X-GOLD™ Communications Processor on the M.2 module to control the GNSS device. The solution offers best-in-class acquisition and tracking sensitivity, TFF and accuracy.

The GNSS device supports several different power management modes which gives the lowest possible energy usage per fix. The pre-calculated location data will be sent over the USB host interface. In addition, the M.2 will produce GPS data when the system is in sleep mode via an I2C interface to allow for applications to be available in low power modes.

GNSS General Features

- Autonomous GPS / GLONASS
- Assisted GPS Using SUPL 1.0/2.0
  - MS Assisted positioning (SET / NET Initiated)
  - MS Based positioning (SET / NET Initiated)
- SUPL 2.0 Feature Sets
  - Version Negotiation
  - Periodic Triggers
  - Emergency Positioning
  - Area Event Triggers (SET Init & NET Init)
  - Application ID
  - Enhanced Cell Id
  - Multiple Location IDs
  - Session Info Query
  - Location Transfer to 3rd Party
  - Notification Verification Based on Current Location
  - Location Request to another SET

A diagram of the GNSS connections on the M.2 module is shown in Figure 6. This diagram identifies the signals between the X-GOLD™ baseband and GNSS devices along with the USB and GNSS signals available to the host at the card interface.

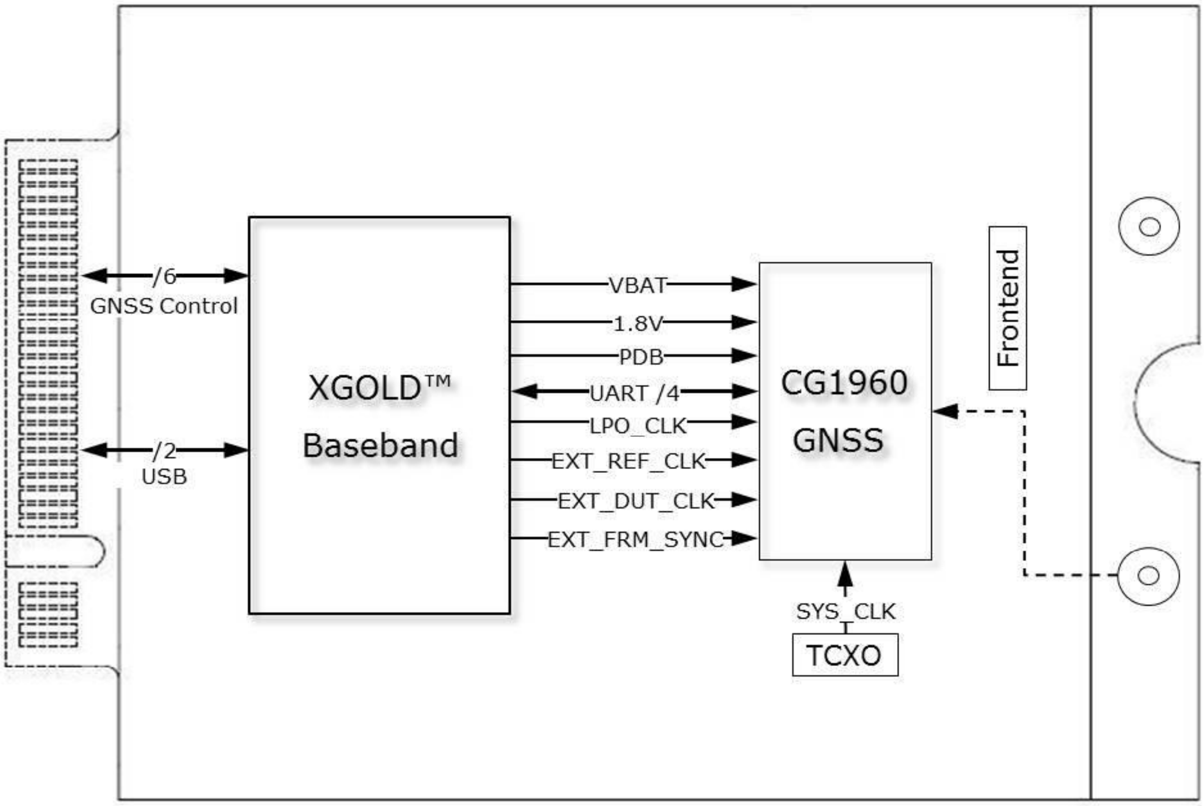

Figure 6 GNSS Connections and Interface

A description of the signals between the X-GOLD™ baseband and the CG1960 interface are defined in Table 8.

Table 8 X-GOLD™ Baseband to GNSS Interface Signals

Signal	Description
VBAT	Battery Supply
1.8V	1.8 V Supply provided from X-GOLD™ Baseband
UART	The data and control I/F between the X-GOLD™ baseband and the GNSS device is over a 4 wire UART interface which include CTS/RTS handshaking.
PDB	X-GOLD™ baseband uses this signal to control Power-on/reset of the GNSS device
LPO_CLK	X-GOLD™ baseband provides a permanently active 32 kHz clock to the GNSS device
EXT_REF_CLK	X-GOLD™ baseband provides a 26 MHz clock to the GNSS device for frequency aiding.
EXT_DUT_CLK	X-GOLD™ baseband provides this signal to notify the GNSS device of that GSM Tx activity (PA Blanking)
EXT_FRM_SYNC	X-GOLD™ baseband provides a strobe signal to the GNSS device to allow fine time assistance based on 3GPP cell timing.

The GNSS signals available to the host at the WWAN module interface to support GNSS operation are shown in Table 9.

Table 9 GNSS Module Interface Signals

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
I2C_SCL	I2C Clock	40	I, O	1.8 V
I2C_SDA	I2C Data	42	I, O	1.8 V
I2C_IRQ	I2C IRQ - Interrupt signal	44	I	1.8 V
SYSCLK	Synchronization Clock	46	I	1.8 V
TX_BLANKING	TX Blanking – Active High when M.2 is transmitting.	48	O	1.8 V
GNSS_DISABLE#	GNSS Disable • High: GNSS function is determine by AT command. • Low: GNSS function is disabled. • GNSS_DISABLE# pin has a pull-up resistor on the WWAN M.2 module	26	I	1.8 V

3.4 System Control Interface

The system control interface is used to control the power-up and reset of the WWAN module. There are additional control signals to disable the radio, drive an LED as a status indicator, an output to wake the host processor, and an input for body SAR.

3.4.1 Power On & Reset

The host processor has two signals that can be used to power on and reset the modem. Powering off the modem is accomplished through an AT command.

Table 10 Power-on & Reset Signals

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
FULL_CARD_POWER_ON_OFF	**Modem power on:** For Tablet based designs only; this signal is used for power on-off control of X-GOLD™ Baseband IC.WWAN M.2 module • Logic Low: M.2 Off • Logic High: WWAN M.2 Power On This pin has an internal pull-down resistor. **Ultrabook designs:** Ultrabook host should deliver a 1.8V signal to turn on the module. If 1.8V is not feasible, recommend using a 47kΩ series resistor connected to 3.3V.	6	I	1.8 V
RESET#	Reset the WWAN system. This signal is used to reset the module. This signal is part of the **modem rigorous power-off** procedure. The host will first assert this signal, followed by assertion of: • FULL_CARD_POWER_OFF# signal (for **Tablet**) • Switch off 3.3V regulator (for **Ultrabook**) Asserting RESET first is to trigger PMU internal state machine to run shutdown sequences e.g. for SIM and external memory controller (EMIC), before switching off power supplies. • Asynchronous, active low signal. When active, the WWAN M.2 module will be placed in a power–on reset condition. RESET# pin has a pull-up resistor on the WWAN M.2 module	67	I	1.8 V

3.4.2 Host Radio Disable Operation

An additional control signal is used to disable the radio on the module.

Signal W_DISABLE# is provided to allow users to disable, via a system-provided switch, the add-in card's radio operation in order to meet public safety regulations or when otherwise desired. Implementation of this signal is required for systems and all add—in cards that implement radio frequency capabilities.

The W_DISABLE1 signal is an active low signal that when driven low by the system shall disable radio operation. The assertion and de-assertion of the W_DISABLE# signal is asynchronous to any system clock. All transients resulting from mechanical switches need to be de-bounced by the host system and no further signal conditioning will be required. When the W_DISABLE# signal is asserted, all radios attached to the add-in card shall be disabled. When the W_DISABLE# is not asserted or in a high impedance state, the radio may transmit if not disabled by other means such as software.

The operation of the W_DISABLE# Signal is:

Enable, ON (3.3V): The radio transmitter is to be made capable of transmitting.

Disable, OFF (low): The radio transmitter(s) is to be made incapable of transmitting.

Standard TTL signaling levels shall be used making it compatible with 1.8 V and 3.3 V signaling.

W_DISABLE# pin has a pull-up resistor on the M.2 module.

Table 11 Radio Disable Signal

Signal Name	Detailed Description	Pin	Direction (WWAN)	Voltage Level
W_DISABLE#	**Disable Radio.** This active low signal allows the host to disable the M.2 radio operation in order to meet public safety regulations or when otherwise desired. • Logic Low: M.2 Off • Logic High: function is determined by Software (AT Command). If this pin is left un-connected, functionality is controlled by software. Care should be taken not to activate this pin unless there is a critical failure and all other methods of regaining control and/or communication with the M.2 module have failed.	8	I	Compatible with 1.8 V/3.3 V

Standard TTL signaling levels shall be used.

Table 12 Host Radio Disable Interface (W_DISABLE#)

Requirement	Detailed Description
Radio disable duration	On reception of a HW or SW disable signal, the WWAN module will initiate within one **second** the mandatory cellular procedures (which are dependent on current state) for disconnecting from the cellular network. The time taken to complete the procedures will be dependent on external factors including but not limited to: 3G/4GPP specifications, network implementation, radio conditions, etc. Once those procedures are complete, the WWAN module will switch off the RF.
Radio enable duration	On reception of a hardware or software enable signal the WWAN module will initiate within **one second** the mandatory cellular procedures for connecting to the cellular network.
Radio enable during selective suspend	If radio is disabled due to W_DISABLE# assertion and WWAN module is in selective suspend, then W_DISABLE# de-assertion shall be detected by WWAN module and the module shall initiate exit from selective suspend.

3.4.3 LED Interface – Status Indicator

An LED will be used to provide status indications to users via system provided indicators.

LED#1 (pin 10) is an active low output signal intended to drive system-mounted LED indicators. These signals shall be capable of sinking to ground a minimum of 9.0 mA at up to a maximum VOL of 400 mV.

Table 13 LED#1 Signal

Signal Name	Detailed Description	Pin	Direction (WWAN)	Voltage Level
LED#1	LED Status Indicator	10	O (OD)	3.3 V

Figure 7 is an example of how an LED indicator is typically connected in a platform/system using 3.3 V. The series resistor can be adjusted to obtain the desired brightness.

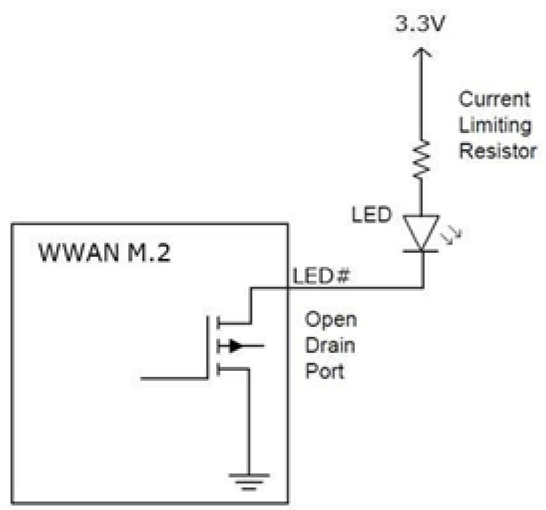

Figure 7 Typical LED Connection

The indication protocol for the LED is shown in Table 14.

Table 14 LED State Indicator

State	Definition	Characteristics	WWAN
OFF	The LED is emitting no	-	Not
ON	The LED is emitting light in a stable non-flashing state	-	Powered registered but not transmitting or receiving

3.4.4 Wake on WWAN Signal

An output signal is available to wake the host system, WAKE_WWAN#. This is an active low, open-drain output.

This output requires a pull-up resistor on the host system.

Table 15 Wake on WWAN Signal

Signal Name	Detailed Description	Pin	Direction (WWAN)	Voltage Level
WAKE_WWAN#	Used by M.2 module to wake the host. Active Low, Open Drain output	23	O (OD)	3.0 V

3.4.5 Dynamic Power Reduction

With the arrival of Tablets and Ultrabook™ platforms where the antenna is in the base of the unit, there is a significant issue passing Specific Absorption rate (SAR) requirements for certification.

The WWAN M.2 module has the ability to configure RF TX power levels based on proximity sensor input from the host.
A WWAN M.2 power control API is available to the host to dynamically reduce RF transmit power levels of the WWAN module based on proximity sensor input from the host.
The DPR# (Dynamic Power Reduction) signal is available on the host interface to assist in meeting regulatory SAR (Specific Absorption Rate) requirements for RF exposure. The signal is provided by a host system proximity sensor to the WWAN module to provide an input trigger causing a reduction in the radio transmit output power.
In conjunction with the DPR signal, a full power control API is available to the host to adjust the RF transmit power level of the WWAN module.
DPR pin has a pull-up resistor on the WWAN M.2 module.

Table 16 DPR#/ SAR Support Signal

Signal Name	Detailed Description	Pin	Direction (WWAN)	Voltage Level
DPR#	Dynamic Power reduction.	25	I	1.8 V

3.5 Tunable Antenna Control Interface

In notebook platforms, since the WWAN antennas are usually located on the top of the lid, there is a long RF mini-coax cable that can be up to 60 cm long between the antenna and WWAN module, it is preferred to use switches/tunable components directly on the antenna for antenna band switching/tuning to improve efficiency.
On select WWAN M.2 modules, four (4) GPOs are available on the host interface that can be connected to an external antenna switch, to load the antenna with different impedances, configuring the different frequency responses for the main antenna. A sample block diagram depicting the antenna control signal connections to the antenna switch is shown in Figure 8.

Intel's current antenna control solution offers an open loop control solution. The WWAN M.2 modem expects the AP to provide the antenna profile detection and through a pre-defined API, notify the WWAN M.2 modem with the correct antenna profile. The WWAN M.2 modem then applies the proper antenna profile data accordingly.

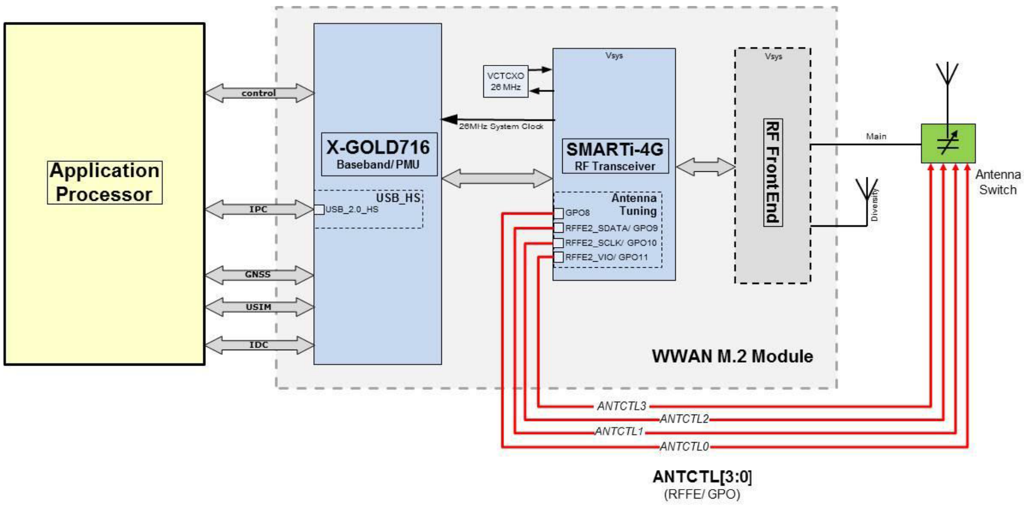

Figure 8 Antenna Control – Connections Detail

The electrical specification for the antenna control GPIOs are shown in Table 17.

Table 17 Tunable Antenna Control Signals

Signal Name	Description	Smarti™ 4G Signal	Pin	Direction (WWAN)	Voltage Level
ANTCTL0	Antenna Control 0	GPO8	59	O	1.8V
ANTCTL1	Antenna Control 1	RFFE2_SDATA/ GPO9	61	O	1.8V
ANTCTL2	Antenna Control 2	RFFE2_SCLK/ GPO10	63	O	1.8V
ANTCTL3	Antenna Control 3	RFFE2_VIO/ GPO11	65	O	1.8V

3.6 In-Device Coexistence Interface

As more and more radios are added to PC Ultrabook™ and tablet platforms, the sources RF interference increases significantly as multiple radios will have overlapping transmissions and receptions. This problem will increase further as overlapping bands continue to be rolled out; WIFI, BT, WWAN will all use overlapping band from 2300 MHz to 2600 MHz.

In-Device Coexistence is a feature which improves the user experience and maximizes throughput and Quality of Service of connectivity systems (WLAN, BT and GNSS) when these radios are simultaneously running with the WWAN M.2 LTE modem.

A diagram of the In-Device Coexistence architecture is shown in Figure 6.

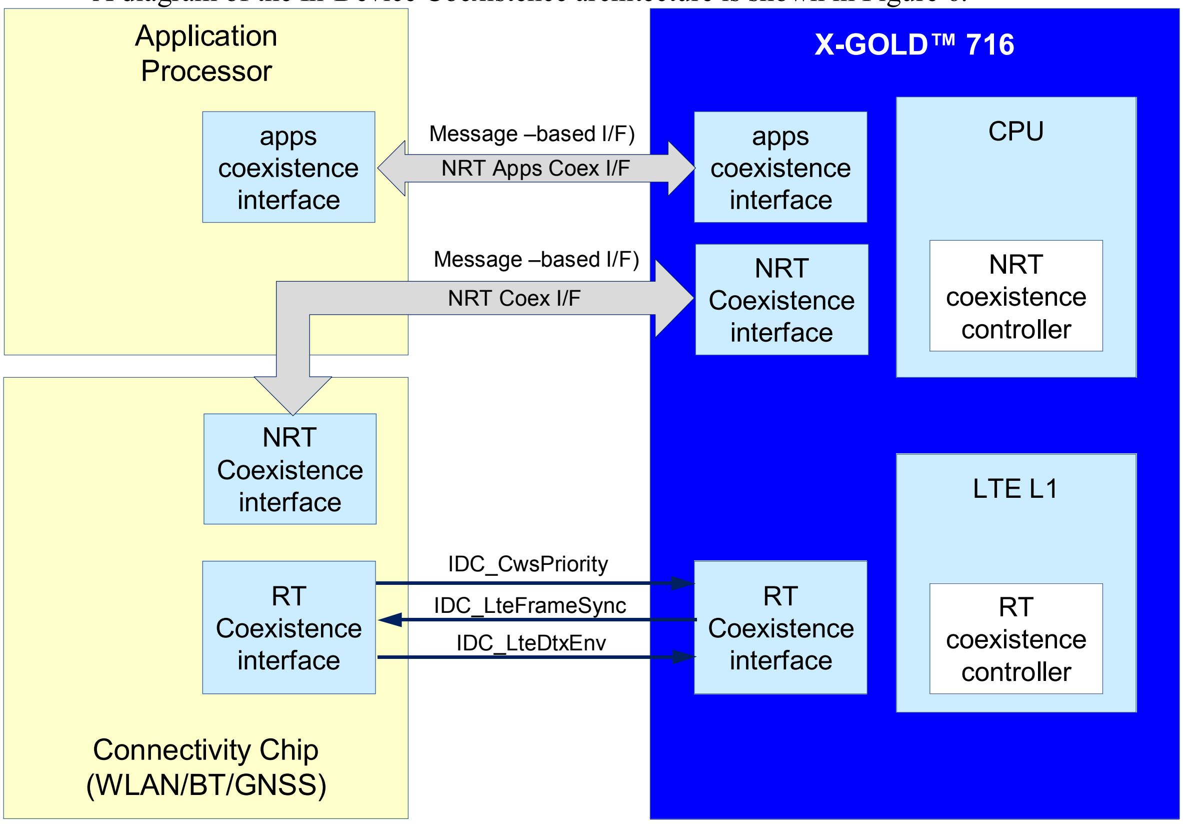

Figure 9 In-Device Coexistence Architecture

Seamless Co-running

In-Device-Coexistence primarily aims at avoiding interference between radio systems to allow seamless co-running where LTE and WLAN/BT/GNSS ensuring their maximum throughput and performance. To do so, a Non Real Time (NRT) coexistence controller is implemented on the ARM™ CPU. The NRT coexistence controller centralizes LTE, WLAN, BT and GNSS information and performs interference avoidance mechanisms, selecting interference-safe frequency configurations whenever possible. The NRT coexistence controller is also in charge of enabling some Real Time (RT) coexistence mechanisms when

NRT mechanisms are not sufficient to guarantee seamless co-running of LTE and connectivity systems (WLAN, BT, and GNSS).

Inter-system Synchronization

For the cases where co-running of LTE and connectivity systems cannot be achieved, a Real Time (RT) coexistence controller is implemented in the LTE Layer-1 subsystem. The RT coexistence controller is in control of the RT coexistence interface, which is exposed to the connectivity chip. The RT coexistence controller exploits real time information received from the LTE Layer-1 subsystem and from the connectivity chip to coordinate LTE and connectivity "in the air" activities. The coordination function protects LTE traffic while optimizing the throughput and availability of WLAN/BT/GNSS. When operating in this mode, the connectivity systems have reduced capability since they access the medium when LTE is inactive, or when their respective operations do not impact each other significantly.

The Non Real-Time mechanism implements a messaging based interface, formatted as AT commands that are passed to the AP host over the IPC interface (USB). A simple piece of SW residing on the AP host will tunnel the Non Real-Time messages between the BT/WLAN device and M.2 module, translate AT commands to/from the BT/WLAN driver commands, and maintain the states of the BT/ WLAN and M.2 LTE modem. The host software will also be responsible for initializing the Real-Time mechanism.

The Real-Time mechanism consists of 3 GPIO signals which allow the synchronization of multiple TX and RX events. The signals to support real Time coexistence are listed in Table 18.

If the coexistence signals are not used by the host system, they should not be connected.

Table 18 Coexistence – Hardware Synchronization Signals

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
COEX3	**IDC_LteDtxEnv** - Synchronous signal indicating LTE UL gap. Envelop signal with edges occurring 1ms before in-the-air gap (raising and falling edges) RT arbiter indicates to connectivity cores when there is no LTE Tx (Envelope)	60	O	1.8 V
COEX2	**IDC _CwsPriority** - 0 : Low priority / 1 : high priority CWS Indicates if the coming activity is high priority	62	I	1.8 V

COEX1	**IDC_LteFrameSync** - Synchronous signal indicating LTE frame start. Indicates LTE frame start to BT/WLAN device. Can be used by BT to synch up periodic activity with LTE timing	64	O	1.8 V

3.7 Power Supply Interface

The M.2 modules require the host to provide the 3.3 V power source. The voltage source is expected to be available during the system's stand-by/suspend state to support wake event processing on the communications card.

The 3.3 V power and ground pins are listed in Table 19.

Section 8, Power Delivery Requirements, provides electrical requirements for the power supply and I/O signals.

Table 19 Power & Ground Signals

Power Pins	Description
2, 4, 70, 72, 74	3.3 V Supply
3, 5, 11, 27, 33, 39, 45, 51, 57, 71, 73	Ground

3.8 Trace & Debug Interface

The USB port on the M.2 module will be used to support system tracing of the Protocol stack. The USB HS and USB_SSIC ports can be used for software download, tracing, and manufacturing testing

The JTAG & MIPI PTI1 ports are accessible on the module to support system debug. A temporary cable assembly over flat flex should be assembled on bottom of the module and lead out of the final product. The cable would not be mounted on the final product.

3.9 Configuration Pins

There are 4 configuration pins on the M.2 module to assist the host identifying the presence of an Add-In card in the socket.
On the M.2 module, pins CONFIG_0..3 are configured as shown in Table 20.
All configuration pins can be read and decoded by the host platform to recognize the indicated module configuration and host interface supported. On the host side, each of the CONFIG_0..3 signals needs to be fitted with a pull-up resistor.

Table 20 M.2 Configuration Pins

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
CONFIG_0	This signal is not connected to the WWAN M.2 module.	21	O	-
CONFIG_1	Tied to Ground internally on the WWAN M.2 module.	69	O	0 V
CONFIG_2	Tied to Ground internally on the WWAN M.2 module.	75	O	0 V
CONFIG_3	Tied to Ground internally on the WWAN M.2 module.	1	O	0 V

3.10 Audio Pins (Reserved)

There are 4 signals on the host interface that are reserved to support a digital audio interface. This is for future development, all existing WWAN M.2 modules do not support audio; **therefore, these signals should be left unconnected at the host to avoid any contention**.

Table 21 Audio Signals (Future development)

Signal Name	Description	Pin	Direction (WWAN)	Voltage Level
AUDIO0	PCM Clock (I2S_CLK)	20	IO	1.8 V
AUDIO1	PCM In (I2S_RX)	22	I	1.8 V

AUDIO2	PCM Out (I2S_ TX)	24	O	1.8 V
AUDIO3	PCM Sync (I2S_WA0)	28	IO	1.8 V

3.11 No Connect Pins

The M.2 has several No Connect pins. The pins are not connected on the M.2 module.

Table 22 No Connect Pins

Pins	Description
38, 41, 43, 47, 49, 50, 52, 53, 54, 55, 56, 58, 68	No Connect Pins
12, 13, 14, 15, 16, 17, 18, 19	Slot key

3.12 Antenna Interface

The M.2 module has space for six antenna connectors; yet, as a minimum, only two will be populated to support a main Rx/Tx antenna and a secondary antenna that will be multiplexed between the Diversity receiver and GPS receiver (if applicable). Further details on the antenna connector assignment can be found in Section 11.3.

The antenna signals are not available at the host interface but have their own connectors. A diagram on the M.2 module with the location of the RF connectors appears in Figure 10.

Table 23 Antenna Requirements

Requirement	Detailed Description
Connection to module	The connector of WWAN antenna cable is I-PEX MHF4 or equivalent
Multi-band single antenna	Single antenna has to support all bands of WWAN module specified in the Product Features.
Rx Diversity antenna	Diversity antenna has to support all bands WWAN module specified in the Product Features in addition GPS/GLONAAS frequencies.
GPS Antenna	The GPS antenna will share the Diversity antenna connector.

Figure 10 RF Antenna – Coaxial Connector Location

4 Development Tools

Intel Mobile Communications provides a carrier development board to facilitate system test and verification of the M.2 module. In addition, a set of comprehensive tools to enable rapid integration and customization of the M.2 software is provided.

The hardware and software tools for M.2 development are summarized below.

4.1 Carrier Board

The M.2 Carrier Board, shown in Figure 11, is Intel Mobile Communications hardware platform to facilitate the test and verification on the M.2 module. Once the M.2 module is mounted on the Carrier board, the user has access to all necessary interfaces on the module (host interface signals, debug and trace, and antenna) allowing full system test, debugging, and diagnostics. The carrier board with a mounted WWAN M.2 module is shown in Figure 11. Carrier Board.
Note: The Main and Diversity antenna locations have been swapped on the FIH7160 PR3.2 and earlier modules.

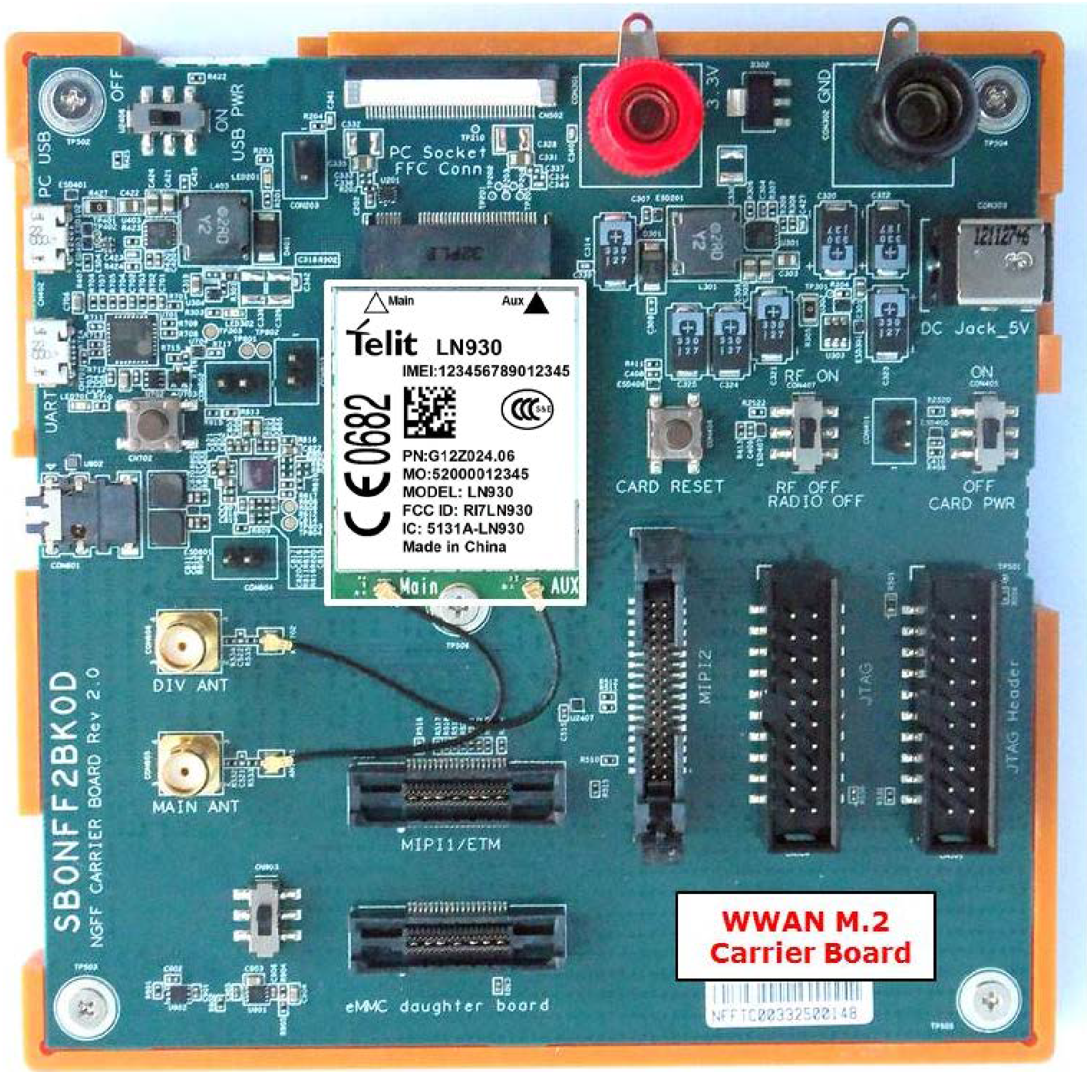

Figure 11 M.2 Carrier Board

4.1.1 FlashTool

Intel Mobile Communications provides a utility program called FlashTool for downloading a binary image into the Flash memory of the M.2 module. The USB-HS port or USIF on the platform is used for connection to a PC via a USB cable for flashing.

FlashTool is a Win32/64 application built on top of the dynamic link library, Download.DLL.

4.1.2 PhoneTool

PhoneTool is a development tool built on top of the so-called “production test dll, DWDIO.dll”. PhoneTool can be used to fine tune the parameters of:

- Audio configuration and settings (if enabled on M.2 module)
- NV (Non-Volatile) memory
- RF power ramp
- Security data IMEI
- SIM
- Real Time Clock

It also includes interfaces for:

- AT Terminal for sending and receiving AT commands.
- DWDIO interface for manual access to the production test dll DWDIO.dll.
- Generic Test Interface (GTI) for RF calibration.

4.1.3 System Trace Tool

System Trace Tool (STT) allows capturing trace sub-streams from different sources on the platform in one combined stream.

Depending on the trace interface bandwidth, the combined data stream can be sent either over one of the standard communication interfaces (e.g. USB) or over a dedicated high-speed MIPI trace interface.

Captured trace data includes standard 3GPP IPC messages, print statements inserted by developers in the code, error messages, and core dump (crash) information. The actual decoding of the trace data is done by pluggable decoder libraries, DLL’s and scripts, which are specific to the version of the mobile station software from which the trace is captured.

The STT application has a GUI (Graphical User Interface) which provides an easy to use graphical interface to view, search and analyze trace data. It supports advanced message filtering runs on all Microsoft Windows® platforms.

STT will become the only tool for trace analysis in the future, the legacy trace tools, Mobile Analyser and Artemis, will be continue to be supported for the 2G/3G WWAN M.2 HSPA+ module.

4.1.4 RF Calibration

XMMCalTool is a utility program that can be used for RF calibration. XMMCalTool supports the following features:

- Optimized calibration
- 3G TX closed loop power control
- Parallel calibration 2G low/high band
- Non-signaling verification
- Industry leading fast sequenced test concept
- Supports parallel RX and TX verification

- Proven Single-Ended BER for faster BER
- < 4 sec/per channel for 3G fast verification (BER, RSSI, TX, ILPC)

Tester supported: R&S CMU200, CMW500, and Agilent 8960

4.1.5 Noise Profiling Scan Tool

M.2 modules are marketed for use on Tablet, Ultrabook, and Laptop devices. OEM vendors routinely offer multiple hardware configurations for the same base model, with different processor speed, drive type, or display type, etc. Each configuration has a different Radio Frequency emission profile with the possibility of introducing new interference sources to a modem module.

The Noise Profiling Tool will measure, record down & plot graph of the RF noise level present on each RX channel. This SW tool will switch on receiver port and sweep all applicable RX channels on each band and each technology (WiFi, Bluetooth, GPS, and GLONASS). This will allow OEM vendors to quickly know the noise jamming profile to the modem module plugged in their devices.