PCI Express MiniCard

Hardware Integration Guide

213xxxx
Rev 0.1

SIERRA WIRELESS

HEART OF THE WIRELESS MACHINE®
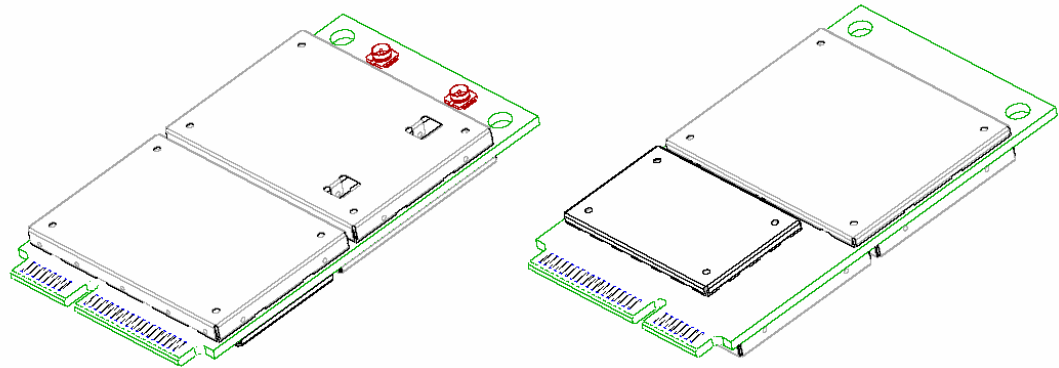
Preface

Important notice

Due to the nature of wireless communications, transmission and reception of data can never be guaranteed. Data may be delayed, corrupted (i.e., have errors) or be totally lost. Although significant delays or losses of data are rare when wireless devices such as the Sierra Wireless modem are used in a normal manner with a well-constructed network, the Sierra Wireless modem should not be used in situations where failure to transmit or receive data could result in damage of any kind to the user or any other party, including but not limited to personal injury, death, or loss of property. Sierra Wireless accepts no responsibility for damages of any kind resulting from delays or errors in data transmitted or received using the Sierra Wireless modem, or for failure of the Sierra Wireless modem to transmit or receive such data.

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Do not operate the Sierra Wireless modem in areas where blasting is in progress, where explosive atmospheres may be present, near medical equipment, near life support equipment, or any equipment which may be susceptible to any form of radio interference. In such areas, the Sierra Wireless modem **MUST BE POWERED OFF**. The Sierra Wireless modem can transmit signals that could interfere with this equipment.

Do not operate the Sierra Wireless modem in any aircraft, whether the aircraft is on the ground or in flight. In aircraft, the Sierra Wireless modem **MUST BE POWERED OFF**. When operating, the Sierra Wireless modem can transmit signals that could interfere with various onboard systems.

> Some airlines may permit the use of cellular phones while the aircraft is on the ground and the door is open. Sierra Wireless modems may be used at this time.

The driver or operator of any vehicle should not operate the Sierra Wireless modem while in control of a vehicle. Doing so will detract from the driver or operator's control and operation of that vehicle. In some states and provinces, operating such communications devices while in control of a vehicle is an offence.

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Patents

Portions of this product are covered by some or all of the following US patents:

5,515,013	5,617,106	5,629,960	5,682,602	5,748,449
5,845,216	5,847,553	5,878,234	5,890,057	5,929,815
6,169,884	6,191,741	6,199,168	6,327,154	6,339,405
6,359,591	6,400,336	6,643,501	6,516,204	6,561,851
6,653,979	D367,062	D372,248	D372,701	D416,857
D442,170	D452,495	D452,496	D453,733	D459,303

and other patents pending.

**QUALCOMM®
3G CDMA**

This product includes technology licensed from

QUALCOMM Incorporated under one or more of the following United States patents and/or their counterparts in other nations:

4,901,307	5,056,109	5,101,501	5,109,390	5,228,054
5,267,261	5,267,262	5,337,338	5,414,796	5,416,797
5,490,165	5,504,773	5,506,865	5,511,073	5,535,239
5,544,196	5,568,483	5,600,754	5,657,420	5,659,569
5,710,784	5,778,338			

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Comments

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Your comments and suggestions on improving this documentation are welcome and appreciated. Please e-mail your feedback, noting document 2130367 Rev 1.1, to documentation@sierrawireless.com. Thank you.

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

www.sierrawireless.com

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Introduction

Sierra Wireless manufactures several modules that are designed to be embedded in other products, such as mobile phones and PDAs (Personal Digital Assistants). The Sierra Wireless modules form the radio component of these products, providing the ability to establish wireless phone calls and/or data connections. There are several models of these embedded modules, including:

- The **MC5720** which operates on CDMA networks using the IS-95A and CDMA 1x, and EvDO (IS-866) network standards

- The **MC8755** which operates on GSM networks using the GSM/GPRS/EDGE/W-CMDA/HSDPA network standards

- Other modules under development that will operate using other network standards.

Typically, integrating an embedded module into another product has these phases:

1. **Embedded module evaluation**—The capabilities of the EM are evaluated, and an interface strategy is developed.

2. **Interface development**—The host software is designed using the appropriate communications protocols and control signal sequencing.

3. **Embedded module integration**—A probe-ready connection is created between the embedded module and the host product.

This guide is concerned with the third phase of integration and provides the information necessary to create a connection between the embedded module and the host product. Recommendations related to the host design are also provided. An understanding of network technology and experience in integrating hardware components into electronic equipment is assumed.

The Universal Development Kit

Sierra Wireless manufactures a Universal Development Kit (UDK) that facilitates all phases of the integration process. The UDK is based on a development platform that is designed to support multiple members of the Wireless Embedded Module (EM) product family. For more information, see the *Universal Development Kit Hardware User Guide*.

Document organization

This document is organized into the following sections:

1. **Introduction** (this section)

2. **RF Integration** (page 11)—Discusses antenna connection methods and grounding issues, and describes how to design the host in order to minimize RF interference and desense issues as well as noise from other components. This section also discusses regulatory approvals and regulatory information requirements.

    Note: The RF integration section is placed at the front of this guide to emphasize the importance of designing the shielding to minimize isolation issues. Having RF design issues an afterthought of product design often results in compromised performance and failure to meet release schedules.

3. **Power Interface** (page 20)—Describes the power control signals used by the embedded module and discusses design issues related to battery use.

4. **Host Interface** (page 29)—Details the control signals available to the host.

    Note: In this document, the terms "modem", "module", "PCI Express MiniCard", and "MiniCard" all refer to the embedded module (EM) and are used interchangeably. The term "host" always refers to the host device.

5. **XIM Interface** (page 34)—Describes how to implement a SIM/RUIM card interface on the host.

6.   (page 36)—Explains how to measure talk and standby currents in the product, and how these relate to advertised talk and standby times.

    Note: Throughout this document, signal directions in each table are taken from the module's perspective.

RF Integration

This chapter provides information related to the RF (Radio Frequency) integration of the EM. The frequencies of operation and performance specifications vary depending on the EM model used. RF performance parameters for a typical EM are listed below.

Table 1: Typical RF parameters for a CDMA Embedded Module

Parameter	Band	Value
Transmit Band	PCS	1851 to 1910 MHz
	Cellular	824 to 849 MHz
	IMT	1920 to 1980 MHz
Maximum Transmit Power	PCS	+24.0 dBm (251 mW)
	Cellular	+24.0 dBm (251 mW)
	IMT	+23.0 dBm (200 mW)
Receiver Band	PCS	1930 to 1990 MHz
	Cellular	869 to 894 MHz
	IMT	2110 to 2170 MHz
Receiver Sensitivity	PCS	>-106 dBm
	Cellular	>-106 dBm
	IMT	>-105 dBm
GPS Band		1575.42 MHz

RF connection

You can attach an antenna to the antenna connection point on the embedded module using the Hirose UFL connector.

Any coaxial connection between the EM and the antenna requires the antenna to be correctly matched to 50 Ω. Note that additional RF cabling losses affect the performance values listed in the EM specification.

Ground connection

There needs to be a very god ground connection to the modem through the host connector. It is recommended that the two mounting holes at the top of the MiniCard be connected to system ground. The integrator needs to be careful about noise on the ground getting into the RF. Noise could potentially be coupled to the module from the host board, depending on the design. This is mainly an issue for host designs that have signals traveling along the length of the module, or circuitry operating at both ends of the module interconnects. In some cases if

the noise cannot be reduced, isolating the mounting holes from the ground may actually help.

Shielding

The module is fully shielded to protect against EMI and to ensure FCC Part 15 (or equivalent) compliance. To maintain the shield effectiveness, the modem shields must not be removed.

Ground plane isolation

The coaxial cable connecting the module to the antenna carries the ground connection. To avoid a ground loop, the ground plane for the antenna and the ground plane used by the modem must be electrically isolated from each other.

If your integration uses the device's case as part of the ground connection, then, to avoid creating a ground loop, the external antenna connection must be isolated from the case.

Antenna and cabling

In selecting the antenna and cable, it is critical to RF performance to match antenna gain and cable loss.

For proper matching, the antenna along with any associated circuitry should have a nominal impedance of 50 Ω with a return loss ≤ -10 dB across each frequency band of operation. Overall system antenna gain, with cable loss, should be ≥ 0 dBi and ≤ +6 dBi. Keep in mind that the system gain value impacts radiated power and the FCC MPE/SAR (or equivalent) test results.

Many antenna vendors produce dual-band antennas that would work with the EM. You may instead choose to develop a custom-designed antenna. This requires a skilled RF engineer to ensure that the RF performance is maintained.

Antenna location may also impact RF performance. The modem itself is shielded to prevent interference in most applications, but this does not mean that antenna placement can be ignored.

Any connecting cables between the modem and the antenna (if required) must have 50 Ω impedance. Mismatching the impedance of the EM will result in a significant reduction in RF performance.

Interference and sensitivity

Several sources of interference could impact the RF performance of the EM. Common sources are discussed below.

Most carriers require a certain level of receiver performance to ensure proper functioning of the device on the their networks. Although the EM has been designed to meet these carrier requirements, it is still susceptible to various performance inhibitors. As part of the Engineering Services package, Sierra Wireless offers modem OTA (Over-The-Air) sensitivity testing and desensitization (desense) investigation. For more information, contact your account manager or the Sales Desk (see page 4).

Power supply noise

Noise in the power supply can lead to noise in the RF signal. The EM specification contains limits for power supply ripple, which should be no more than 200 mVp-p 1 Hz to 100 kHz. This includes voltage ripple due to transmitter burst activity.

Device-generated RF

All electronic computing devices generate RF interference. You should pay particular attention to RF noise—it can impact the receive sensitivity of the EM wireless modem.

The proximity of host electronics to the antenna can have an adverse effect on the radio's sensitivity. There are many high-speed devices (in particular the processor itself) running at frequencies of 10s of MHz. These signals generate higher order harmonics due to the rapid rise and fall of the clock signal. These harmonics often fall within the operating frequency band of the EM, causing a decrease in receiver sensitivity.

For example, on a sub-system running at 40 MHz, the 22nd harmonic falls at 880 MHz, which is within the cellular receive frequency band. In practice, there are usually numerous interfering frequencies and harmonics. The net effect can be a series of desensitized receive channels. Most device designers are familiar with having to pay attention to radiated emissions in order to meet the FCC Part 15 (or equivalent) rules. The components most likely to cause RF desense are: the microprocessor and memory, display panel and display drivers, and switching-mode power supplies.

RF desense mitigation

To mitigate RF desense, some or all of these techniques can be used:

- Locate the antenna as far as possible from sources of interference. The drawback is that the modem may be less convenient to use.

- Shield the host device. The EM itself is well shielded to avoid interference. However the antenna cannot be shielded for obvious reasons. In most instances, it is necessary to employ shielding on the components of the host

device (such as the main processor and parallel bus) that have the highest RF emissions.

- To filter out unwanted high-order harmonic energy, use discrete filtering on low frequency lines.

- To form shielding layers around high-speed clock traces, use multi-layer PCBs.

It is important to investigate sources of localized interference early in the design cycle.

Hearing aid considerations

Just as outside frequencies can interfere with the modem's sensitivity, the modem can cause noise in hearing aids due to the keying of the transmitter.

Most digital wireless technologies do not transmit radio frequencies continuously. They transmit in bursts, usually of specific durations, referred to as RF burst frequencies.

Unfortunately, most hearing aids are not immuned to RF; they convert the burst frequencies into audible frequencies. This causes unpleasant noise for hearing aid users in close proximity to transmitters, as is the case with digital wireless phones.

Radiated sensitivity measurement

A wireless device contains many sources of noise, such as the LCD, the digital processor and memory, and any high-speed digital bus (due to the fast rise and fall times of the digital signals). These sources can generate noise over a wide range of frequencies, with significant energy in the receive band. If noise generated in the receive band is allowed to radiate from the device and the antenna detects it, the noise may mask low-level desired signals, thereby decreasing the sensitivity of the device. To determine the extent of any desensitization of receiver performance due to self-generated noise in the host device, Over the Air (OTA) or radiated testing is required.

Physical configuration

To make OTA measurements, a test chamber is required. A full-size anechoic chamber is not necessarily required. Figure 1 shows a small anechoic chamber manufactured by Lindgren. This does not provide power to the same accuracy as a full-size anechoic chamber, but is sufficient for this application. A base station simulator, in this case an Agilent 8960, is used to provide FER (Frame Error Rate) measurements.

Figure 1: Anechoic chamber

Approx . 1 m
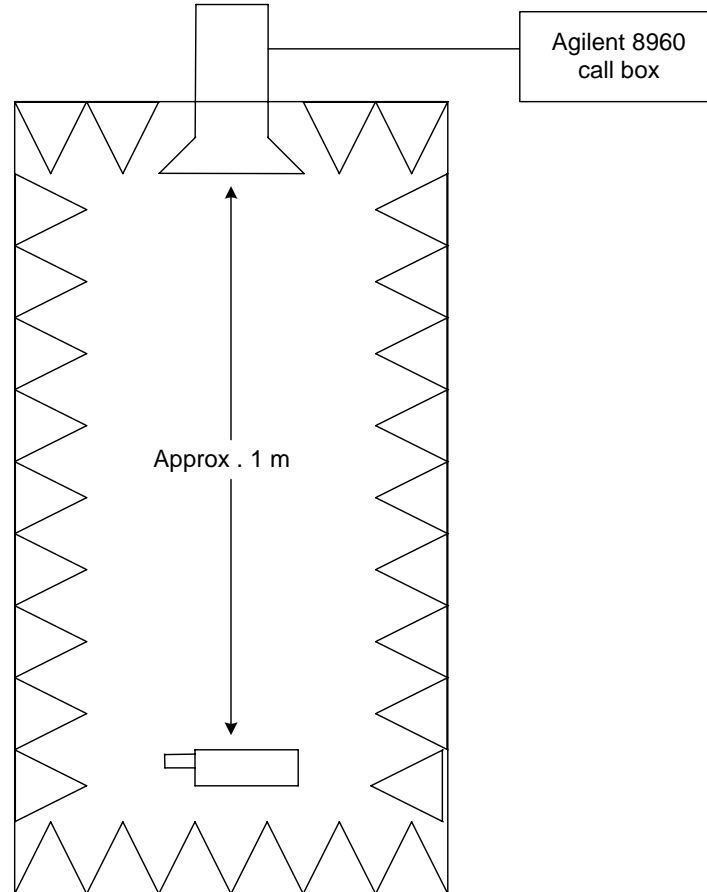
Path loss calculation

The chamber is calibrated for path loss using a reference antenna with known gain that is feeding a spectrum analyzer or power meter. This makes it possible to determine the radiated power available to the receiving antenna, which is equal to the measured received power, plus any cable losses, minus the gain of the reference receive antenna. Path loss is then determined by subtracting the input power. It is not necessary to know the gain of the transmitting antenna; it is included in the path loss.

Positioning the DUT (Device Under Test)

To achieve meaningful results, the device must be positioned such that the peak of the receive antenna pattern is pointed toward the source antenna. Theoretically, the best way to accomplish this is to modify the DUT so that antenna output is through coaxial cable. The device is then rotated until the receive power is maximized.

Path loss can also be calculated without modifying the DUT by using the transmit capabilities of the unit. This method of calculation is possible because the position that maximizes transmitter power provides a sufficiently accurate

location for receiver desense measurements. The unit is placed in a call and set to generate peak output power, either through a test mode, or by configuring the base station simulator to issue the appropriate command. The unit is then positioned for maximum power as determined by the call box.

Sensitivity vs. frequency

Sensitivity is defined as the input power level in dBm that produces a FER of .5%. Sensitivity should be measured at all CDMA frequencies across the band. In the US PCS band for example, there are 25 physical channels with a spacing of 50 KHz. The first CDMA channel is CH25.

Figure 2: US PCS sensitivity measurements
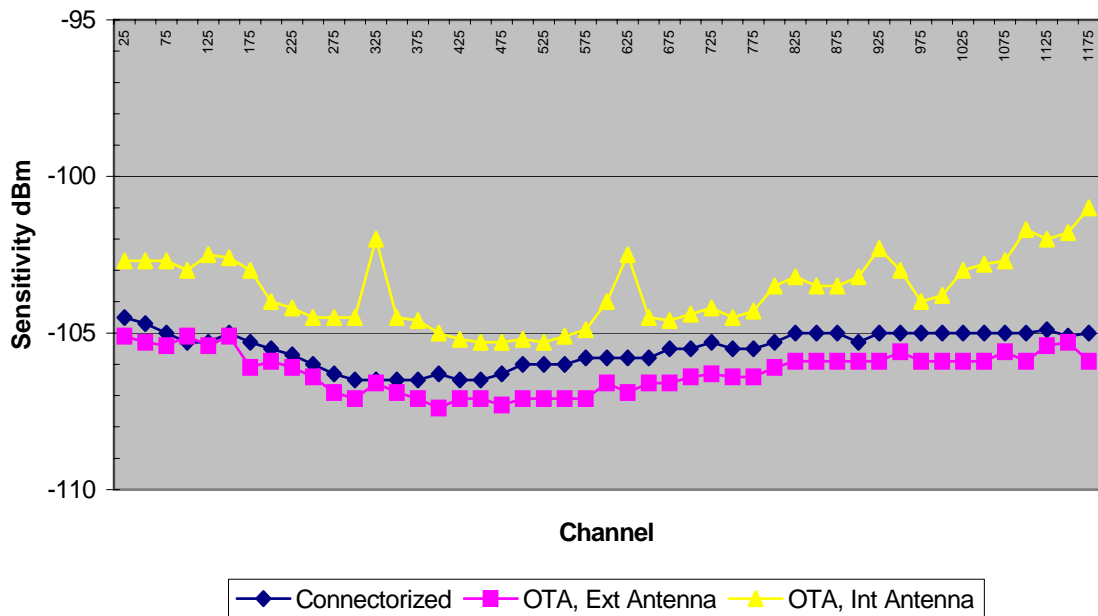
Figure 2 shows typical test results for the US PCS band for both conducted and over-the-air connections. The conducted (or "connectorized") measurements were made using an RF coaxial cable connection. The over-the-air measurements were made using both an external antenna and a typical device antenna.

In this test, the external antenna performed best—the expected result if a high efficiency antenna with some gain is used. The internal antenna has less gain than the external antenna, so the internal antenna's performance is offset above the external antenna. The antenna gain must be known to determine whether the offset is strictly the result of antenna gain or if broadband desense is present. Narrowband desense can be seen at channels 325, 625, and 925.

Regulatory information

Refer to the EM Reference Guides for Regulatory Information. Regulatory compliance information is dependent upon both the individual module certification as well as the intended market.

FCC module acceptance criteria

FCC classification of mobile vs. portable devices

For operation in the United States, your module integration is required to meet certain regulatory requirements for stand-alone operation, including 47 CFR Parts 2, 15, 22, and 24.

Part 15 testing must be performed on the "complete device" that has incorporated the EM and is therefore your responsibility.

The Office of Engineering and Technology has published a document entitled "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", OET Bulletin 65. This provides a detailed description of the difference between mobile and portable devices.

The FCC Guidelines differentiate between these devices according to the antenna's proximity to people, either the user or others nearby.

Mobile: The FCC defines a mobile device as being designed for use "in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is maintained between radiating structures and the body of the user or nearby persons".

Mobile devices including vehicle-mounted systems are designed to be used by people that are typically well separated from the antenna. This also includes wireless devices associated with a personal computer, provided the antenna is kept 20 centimeters away from the body.

These devices are normally evaluated for exposure potential with relation to MPE (Maximum Permissible Exposure) limits. The FCC rules for evaluating mobile devices for RF compliance are found in 47 CFR Part 2.1091 (b).

Portable: A portable device has a transmitter "designed to be used with any part of its radiating structure in direct contact with the user's body or within 20 centimeters of the user or bystander under normal operating conditions."

This category includes hand held cellular telephones with antennas built into the device.

Portable devices are evaluated with respect to SAR (Specific Absorption Rate) rules. These can be found in 47 CFR Part 2.1093 (b).

RF exposure requirements for mobile approval

Certain Sierra Wireless embedded modules have been approved for mobile operations only in accordance to 47 CFR Part 2.1091 (b). The Reference Guide for your EM model contains the FCC ID Number if approved.

Warning: If this module will be used as a portable device, you are responsible for separate approval to satisfy the SAR requirements of 47 CFR Part 2.1093 (b).

To ensure the module meets the current FCC exposure guidelines, a separation distance of at least 20 cm must be maintained between the module's antenna and the body of the user and any nearby person at all times and in all applications and uses. Additionally, in mobile applications, maximum antenna gain must not exceed 6.0 dBi (or less, depending on actual FCC grant verbiage) in order to comply with FCC regulations limiting both maximum RF output power and human exposure to RF radiation.

Product labeling requirements

For mobile devices, using the FCC approval obtained by Sierra Wireless, a label must be attached to the outside of your product- into which the authorized module is incorporated- with a statement similar to the following:

"This device contains TX FCC ID: N7N-XXXXX"

Note: Sierra Wireless can provide specific FCC ID numbers for each particular EM that has completed module level certification testing.

You will also need to provide a manual with your end product that clearly states the operating requirements and conditions that must be observed to ensure compliance with current FCC RF exposure guidelines (as detailed above).

The warnings must appear in a prominent location in the User Guide for your product and may include the following text:

Caution: Unauthorized modifications or changes not expressly permitted by the manufacturer could void compliance with regulatory rules, and thereby your authority to use this device.

Warning (EMI): This equipment has been tested and found to comply with the limits pursuant to Part 15 of the FCC rules. These limits were designed to provide reasonable protection against harmful interference in an appropriate 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 and 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 suggestions:

- 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

Power Interface

Overview of operation

The EM is designed to run off the same power supply as the host system (typically 3.3V). There is neither an independent power supply within the EM nor any protection circuits to guard against electrical issues. It is the responsibility of the host system to provide safe and continuous power to the EM at all times.

The EM powers on when W_Disable# is floated or driven high, and valid power is applied to the VCC rail. Once turned on by the host system, the EM remains on until the host commands the module to power down. Once the unit is powered off, the host can turn the unit on again. The EM unit monitors its voltage and informs the host if the power rail gets too low by requesting shutdown.

EM power signals

shows the signals comprising the host-EM power interface. A sample schematic of the interface and BOM (Bill of Materials) are shown on the following page. See the Product Specification document for your module for detailed specifications on the power signals.

Electrostatic discharge

You are responsible for any ESD protection on digital circuits. Specific recommendations are provided as needed for each of the interfaces described in this guide; however, the level of protection required depends on your application. For ESD protection level of the EM pins during your product assembly and test, refer to the EM Product Specification.

Extra precaution should be taken on the U-SIM/R-UIM signals as these signals are usually brought out externally and are susceptible to ESD events. ESD protection is recommended at the point where the contacts are exposed.

EM power state transitions

Figure 3 shows how the EM transitions between power states. Each power state is described in the sections that follow.

Figure 3: Power state transition diagram

DISCONNECTED state

This power state occurs when the host power supply is disconnected from the EM. In this state, all voltages associated with the EM are at 0 V and the host may or may not be powered off. If the host and the EM share the same battery power rail, then both the host and EM unit are powered off in this state. If the host controls the connection between the EM and the battery power, the host can put the EM into the disconnected state by cutting power to it.

OFF state

In this power state, the host is powered up and the EM is powered down. The EM unit defaults to the OFF state when VBATT is first applied in the absence of ON/OFF control. The host keeps the EM powered off by de-asserting the ON/OFF signal.

> **Note:** In this state, the VCC_RADIO signal is 0 V out of the EM. To minimize current leakage and prevent unintentional partial power-up of the EM, the host should not drive any outputs to the module at a voltage exceeding VCC_RADIO.

Current draw in this mode is an absolute minimum (not more than 50 µA).

NORMAL state

This is the active state of the EM. The EM is fully powered and capable of placing and receiving phone calls on the CDMA network. All functional interfaces to the module are enabled (audio, MIO, serial, and, when used, USB). VCC_RADIO is driven high by the module at 2. 5~3.0 V, indicating full power status.

LOW BATTERY state

The EM has detected a low battery condition (VBATT $<= 3.4$ V) and requests shutdown from the host via UART messaging. The EM carries on its regular tasks.

SHUTDOWN ROUTINE state

In this state, the EM has received a request from the host to power down and is completing its active tasks and initiating the shutdown routine. At the completion of the shutdown routine, the EM drives its OFF signal high and completely powers down. To keep the EM powered down, the host should keep ON/OFF de-asserted.

> **Note:** For the duration of the shutdown routine, the EM asserts the VCC_RADIO signal. Only upon actual power-down does the EM de-assert its VCC_RADIO signal.

EMERGENCY SHUTDOWN state

In this state, the EM has detected a critically high or critically low battery supply and sets an internal timer of 15 sec. If the host sends a shutdown request prior to the expiration of the timer, the EM enters the shutdown routine state. If the timer expires prior to the host shutdown command, the module automatically enters the shutdown routine. If the host fails to assert ON/OFF throughout the EM automatic shutdown routine, an unintentional power-down/power-up cycle may occur.
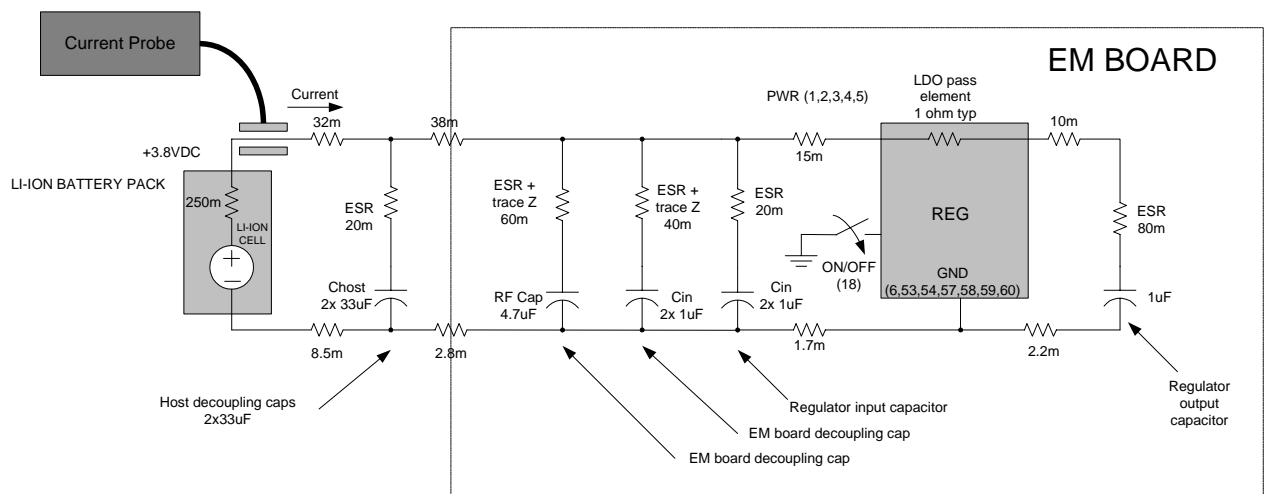
Inrush currents

There are two power events that cause large inrush currents from the host supply to the EM on the power pins.

One event is the application of the supply to the host. This occurs when the supply is enabled. This event charges the input decoupling capacitors on the EM power rail.

Figure 4 shows a model of this event.

Figure 4: Inrush model

The second event is more important to module integration, and occurs when the host asserts the ON/OFF signal to power up the EM. This event enables the power management system of the EM, charging several internal regulator output capacitors. Sufficient capacitance must be added to the host power rail to limit the inrush current and stabilize the supply of power to the EM.

Figure 5 (page 22) and Figure 6 (page 24) show typical inrush current measurements at room temperature when the host deasserts the W_Disable# signal to power up the EM. Note that the current spikes are staggered because the EM internal regulators switch on at slightly different times. In some circumstances, depending on temperature and the components in use, two or more regulators may switch on at the same instant. The host power system must be designed to handle this scenario. Note that the peak current is dictated by the equation: IPEAK = VBATTERY / RSERIES.

RSERIES is the sum of:

- The path from the positive terminal of the battery to the PWR pins of the EM to the ground point thru the regulator pass element and output capacitor, and

- The path from the negative terminal of the battery to the GND pins of the EM regulator

Figure 5 shows a 700 mA inrush from the host battery without the use of large decoupling caps. A minor dip in VBATT results.

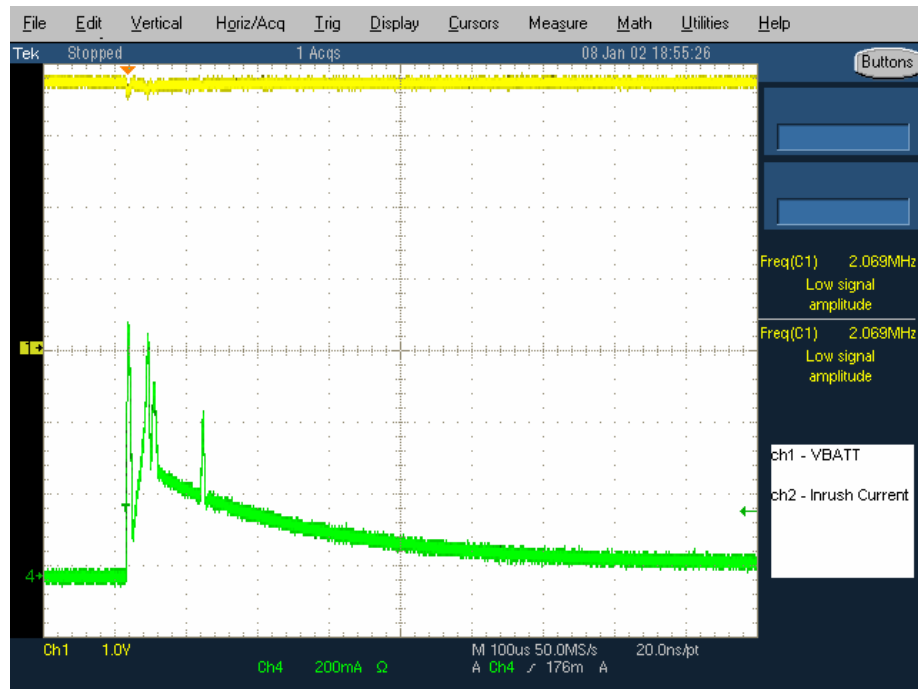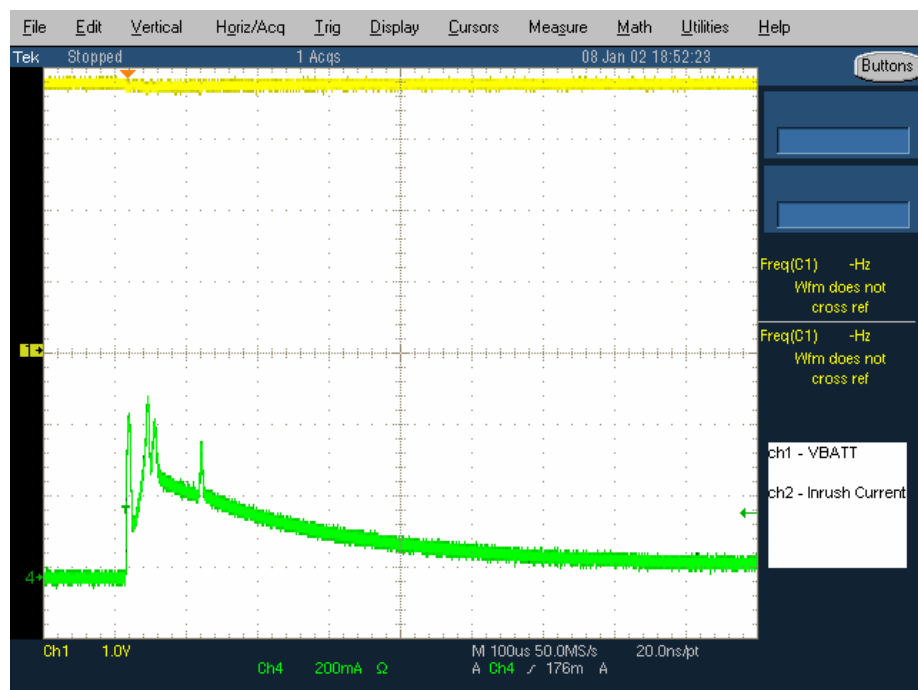Figure 5: Inrush without large decoupling capacitors

Figure 6 shows the effect of increasing decoupling capacitors on the inrush current (inrush of about 400 mA from the host battery using 66 uF decoupling caps).

Figure 6: Inrush with 66μF decoupling capacitors

Current consumption

Electrical requirements and current specifications are listed in Table 2. Conditions related to the various modes of operation are described in subsections following the table. These specifications identify the maximum current drain; typical use should result in less drain, depending on the application.

For sleep modes, the figures are given for the actual sleep state. The modem wakes at intervals to control timing and check for traffic. At those moments the current consumption is higher.

Table 2: Current specifications

Condition	Minimum	Typical	Maximum	Units
CDMA Transmitting[1]	250	300	950	mA
CDMA Receiving	90	100	120	mA
CDMA Sleep[2] (slot cycle 2)	1.4	1.7	1.75	mA
GSM Transmitting[3]	-	140	2750	mA
GSM Receiving	-	75	-	mA
Deep Sleep average	0.5	0.7	1.5	mA
Shutdown	0.03	0.05	0.1	mA

Note 1— CDMA Transmitting

The transmit current is dependent on the radio band in use and the network's control of the modem output power. The "typical" value is based on 40% full rate and 60% 1/8th rate over -35 – +23.5 dBm.

Note 2—CDMA Sleep

The EM supports slotted mode operation and Quick Paging Channel. Both of these features enable reduced sleep current. The figures quoted are the lowest power consumption (/DTR1 must be deasserted) during the sleep cycle.

The default Slot Cycle Index (SCI) for slotted mode operation is determined by the PRI setting (usually set to 1). To achieve the lowest current consumption, the DTR signal must be deasserted. Figures given are during the sleep state as outlined in the mode details.

Note 1— GSM Transmitting

The transmit current is dependent on the radio band in use and the network's control of the modem output power. The "typical" value is based on 1Tx slot @ +5 dBm. The "maximum" value is the highest pulse current during a +33 dBm Tx burst.

Modes

The EM operates in several different modes; the mode can have a significant impact on current consumption.

Shutdown

Shutdown mode is the state of the modem when /ShutDown (the shutdown request) is asserted, or /DTR1 is deasserted—based on AT command configuration—and the modem is shut down. The modem gracefully disconnects any call and is ready to power down. This is the state entered via Windows power management (ACPI suspend state).

Slotted mode sleep and dormant mode

The CDMA 1X specification describes a reduced power mode in which the modem cycles between wake and sleep on a defined interval—the Slot Cycle Index (SCI). Slotted mode sleep is the normal state of the modem between calls.

Dormant mode behaves in the same way as slotted mode sleep, but it keeps an active PPP session open at both ends—even when there is no physical link (channel resource) in place. The modem keeps the connection open but is permitted to sleep for short periods when there is no active traffic.

For more information on slotted mode sleep and dormant mode, see the EM Software Integration Guide.

Current consumption in sleep/dormant mode follows a pattern as illustrated in Figure 7.

Figure 7: Current measurement in slotted mode sleep (SCI = 1)
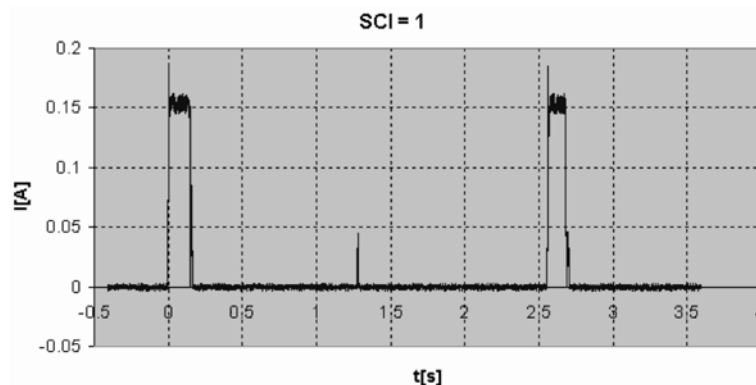
The current consumption has a small spike at each slot cycle interval (1.28 s). When the index value is reached, the modem comes on to check the quick paging channel. The receiver's on-time is approximately 150 ms. If there is a call request, the modem stays active to handle it.

The average current consumption of the EM during slotted mode sleep depends on the SCI. Higher value SCI settings mean longer intervals between the receiver being switched, therefore lower current consumption. The default slot cycle index is 2, yielding the figures in Table 2 on page 25.

Table 3 shows the typical average slotted mode current consumption for each SCI.

Table 3: Average current consumption in slotted mode sleep

Slot cycle index	Cycle duration (seconds)	Average current consumption (mA)
0	1.28	10.4
1	2.56	5.8
2	**5.12**	**3.4**
3	10.24	2.2
4	20.48	1.6
5	40.96	1.3
6	81.92	1.1
7	163.84	1.0

Deep sleep

The modem enters deep sleep mode after failing within 15 minutes to acquire service on a CDMA channel. The modem exits deep sleep every three minutes to attempt to acquire a CDMA channel. The figures for typical consumption in Table 3 (page 27) are based on a complete absence of radio signal (no attempts to register). If a viable channel is detected, the modem attempts to register. This increases the power consumption for the duration of the attempt, bringing up the average consumption.

Current consumption in deep sleep mode follows a pattern as shown in Figure 8.

Figure 8: Current measurement for a wakeup event from deep sleep
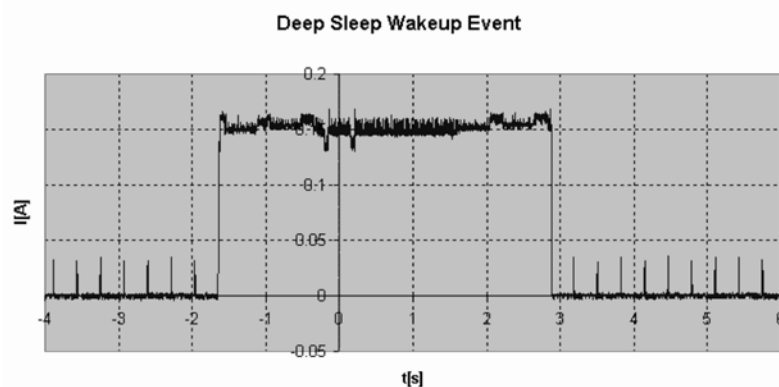
There are small spikes at the SCI unit interval for the modem timing tasks. A wakeup to check for coverage takes about 4.5 seconds, and requires about 150 mA.

Usage models

To calculate actual current consumption (and anticipated battery life), a usage model is needed. As applications of the EM can vary widely, we can provide only samples here.

Slotted mode sleep is assumed when not actively receiving or transmitting (SCI = 2).

Transmit power is assumed to be +3 dBm.

Table 4: Power consumption of a sample application

	PDA with voice	Field worker (data only)	Remote data logging
Upload (modem Tx)	20 e-mails / day avg 5 kB each	1000 kB / day	40 kB / hr
Download (modem Rx)	40 e-mails / day avg 5 kB each 500 kB web use	500 kB / day	100 kB / day
Coverage / data rate	1x / 80 kbps	1x / 80 kbps	IS-95 / 14.4 kbps
Hours of operation	16 / day (off 8 hrs / day)	8 / day (off 16 hrs / day)	24 / day
Total power consumed over 24 hours	**250 mAh**	**60 mAh**	**200 mAh**

Back-power issues

Preventing back-power when the modem is off

Note: Without proper input protection, the modem may draw sufficient current to remain powered, even when the normal supply power is removed.

Active low signals may be deasserted (driven high) by the host when the modem is not needed. This applies 3.0 V to the modem on these pins and presents the risk of back-powering.

All connector inputs must be either high impedance (>20 kohm), or driven low, when the modem is powered off. This is required to prevent back-powering the modem.

USB signals can be driven while the modem is disabled.

Host Interface

This chapter provides detailed information about the Host-EM interface, describing the signals required for serial data transfer, handshaking and digital module I/O (MIO).

Operation modes

The embedded module supports the following logical communication interfaces:

- **Data channel**—Supports AT command and PPP packet exchange during data calls

- **Control channel**—Supports modem control and call processing commands

- **Diagnostic channel** – Supports modem status and diagnostic logging

USB interface

The USB physical interface is the only path for communication between the host and modem.

General USB background information can be found in the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification*.

The USB interface is designed to comply with the Universal Serial Bus Specification, Revision 1.1. The EM USB interface supports the full-speed (12 Mbps) data rate, and can be used to transfer general data, phone diagnostic data, over-the-air data, or voice PCM samples between the module and a USB host. The USB interface provides 10 endpoints:

- One bi-directional control endpoint

- Isochronous IN and OUT endpoints for voice

- Four IN endpoints

- Three OUT endpoints

For more background information on USB, see the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification*.

Physical layer

Differential 1 and 0

The USB uses differential signaling (called D+ and D-) with NRZI (Non-Return to Zero, Inverted) encoding. A NRZI encoder toggles the output for input source data bit 0 and maintains current output state for source data bit 1. A differential 1 exists at the driver when the D+ output is at least 2.8 V and the D- output is no greater than 0.3 V. A differential 0 exists at the driver when D- is at least 2.8 V and D+ is no greater than 0.3 V. At the receiver, a differential 1 exists when D+ is at least 2 V, and the difference between D+ and D- is greater than 200 mV. A differential 0 exists when D- is at least 2 V, and the difference between D- and D+ is at least 200 mV.

Suspend and resume

The USB master signals "suspend" by not sending the periodic 1 ms SOF for a minimum of 3 ms.

The USB exits from the suspend state in either of these ways:

- Resume is initiated by the USB master, or
- The USB slave devices initiate remote-wakeup.

Both resume and remote-wakeup generate the resume signaling on the bus.

For more information on USB signal definitions, see the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification*.

Suspend and resume

If the USB is not completely powered off and interrupts are still enabled, resume and suspend interrupts can control the USB's sleep/wakeup model provided that the host USB driver supports suspend mode and remote wakeup. USB_SUSPEND and USB_RESUME interrupts are provided in the USB_INT_STATUS register (for more detail, see the USB XCVR data sheets.)

Full-speed devices send SOF, which is a timing reference the host sends at 1 ms intervals. The SOF keeps devices from entering the low-power suspend state when there is no other USB traffic. Low-speed devices do not see the SOF packet. Instead, the device's hub translates the SOF to a simpler End-of-Packet signal called the *low-speed keep-alive signal*. As the SOF does for full-speed devices, the low-speed keep-alive keeps low-speed devices from entering the suspend state. Note that the EM is a full-speed device.

The USB controller automatically enters suspend mode when the USB bus has been idle for 3 ms. No more than 500 μA current can be drawn from the bus when in the suspend state. This is indicated by the USB_SUSPEND interrupt. The current suspend status of the USB is checked through the USB_RUNNING bit of USB_CORE_STATUS. When the USB controller enters the suspend state, the modem is able to shut down the 48 MHz oscillator to save power.

USB activity is resumed either by the USB host or by the modem. The USB controller automatically detects the USB host resuming bus activity, even if the 48 MHz oscillator is disabled. This is indicated by the resume interrupt. When the resume interrupt is detected, the modem must re-enable the 48 MHz oscillator for the USB controller. If the modem is initiating the resume via remote wakeup, the 48 MHz oscillator must first be re-enabled. Then the modem directs the USB controller to resume USB activity by writing the RESUME command (0x02) to USB_CONTROL_CMD.

POWER and RESET handshaking protocols

This section describes the power-up and power-down on the embedded module.

Power on

The power-on sequence is shown in on page 31. The letters in the figure correspond to these events:

A. VCC_3V3 is asserted,.

B. The host deasserts the W_Disable# signal to power up the module.

Power off

The power off sequence is shown in on page 31. The letters in the figure correspond to these events:

A. The host sends the module the AT command to prepare for power down. (See the *EM AT Command Reference*).

B. The module performs any necessary housekeeping functions and then responds to the message.

C. W_Disable# should be asserted by the host.

USB handshaking

The module behaves as a non-host device supporting full-speed USB. Consequently, the host that interfaces to the module must act as a USB host device. The module does not use discrete hardware signals for handshaking; instead the USB standard Resume and Suspend functions are used to control the sleep and wakeup states. Detailed specifications for the Resume and Suspend functions can be found in the USB specification in the *Compaq, Intel, Microsoft, and NEC, Universal Bus Specification*.

EM modules are either equipped with an on-board USB transceiver, or provide the interface to a USB transceiver. This section covers both types of EM modules.

> **NOTE:** The host USB driver must not send start-of-frames when the modem or host have no data to send. This causes modem wake-ups and adversely impacts current consumption of the module.

Suspending

A USB controller automatically enters suspend mode when the USB bus has been idle for 3 ms. The USB controller triggers the USB_SUSPEND interrupt to the module's processor and the module shuts down the 48 MHz clock to save power.

While in the suspend state, the module provides power to the D+/- interface to signal to the host device of its current state. During the Suspend state, the host must maintain the VCC_3V3 voltage. The SOFTCON interface signal is also maintained during suspend.

Critical timing parameters for the suspend state can be found in the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification*.

Resume

USB activity may be resumed by either the USB host or by the module. If the host initiates USB activity the USB transceiver detects the change in bus activity and triggers the USB_RESUME interrupt to the module's processor. The module then enables its USB clock and responds to the host.

If the module initiates USB communication, it must first enable its USB clock, enable the USB transceiver, and then send the resume signal for at least 20 ms. (See the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification.)*

Critical timing parameters for the resume state can be found in the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification*.

Host USB driver requirements

The following are critical requirements that must be met by the USB driver on the host device:

- The host USB driver must support remote wakeup, resume, and suspend operations as specified by the USB specification. (See the *Compaq, Intel, Microsoft, and NEC Universal Serial Bus Specification.*)

- If the control port is communicated over the USB interface, the host USB driver must be able to receive both HI and DM messages and route DM messages out to diagnostic tools via another port (another host UART or USB port running at 115.2 kbps minimum). (See the *Host Modem Interface Control Port ICD.*)

- The host USB driver must support serial port emulation.

- The host USB driver must not send any SOF tokens (start-of-frames) to the modem when it doesn't have any valid data to send. This messaging will keep the module awake and cause unnecessary power consumption.

LED output

The MiniCard Drives the LED output according to the PCI-Express MiniCard specification.

Figure 9: Example LED
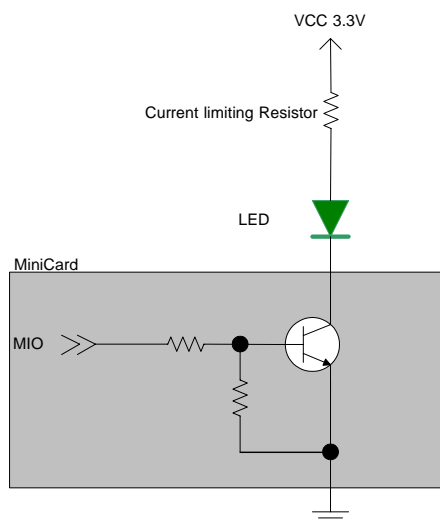
XIM Interface

The EM is designed to support one SIM (Subscriber Identity Module) or RUIM (Removable User Identity Module). SIM is a smart card developed for GSM networks while RUIM is for CDMA cellular systems. Each provides personal user information that allows a mobile to attach to the wireless network. The XIM feature provides the user with handset independence.

There are four required and one optional signals in the XIM interface. These are defined in Table 5 with an example circuit (EM3420) shown in Figure 10.

Some EM models contain the voltage regulator for the XIM interface, while others provide an enable signal. See the EM Reference Guide for your EM model for details.

Table 5: XIM pins

Pin name	RUIM pin number	Function
XIM_VCC	1	XIM VCC
/XIM_RESET	2	Active low XIM reset
XIM_CLK	3	Serial clock for XIM data.
XIM_DATA	4	Bi-directional XIM data line

Figure 10: RUIM application interface
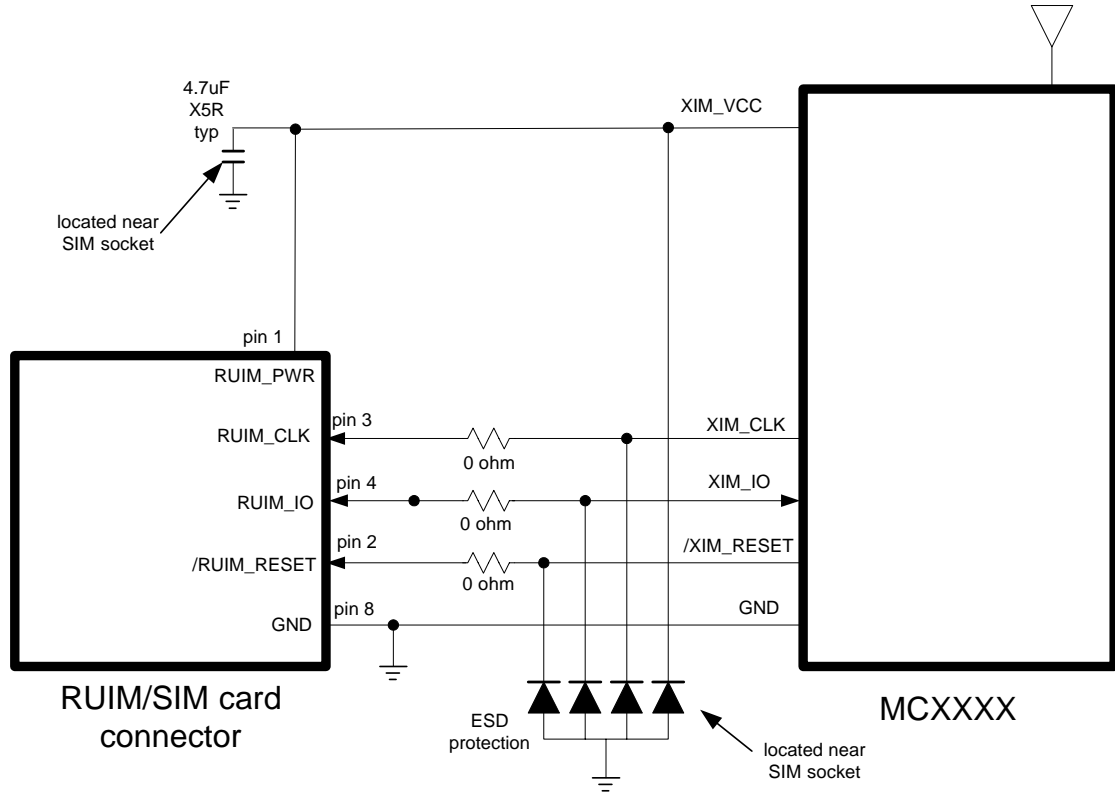
XIM notes of operation

- To save power, the XIM interface should be powered down when not in use.

- XIM is specified to run up to 5 MHz (XIM clock rate). Take note of this speed in the placement and routing of the XIM signals and connectors.

- To protect the modem CPU, ESD protection is required for XIM_CLK, XIM_IO, /XIM_DETECT (if used), and /XIM_RESET lines. Additionally spaces for possible series resistors should be added to the layout. Possible values of up to 470 ohm may be used depending on ESD testing requirements.

- It is recommended to put a placeholder capacitor near the SIM socket. The longer the trace length (impedance) from the socket to the MiniCard, the greater the capacitance requirement will be to meet compliance tests.

Acronyms and definitions

Table 6: Acronyms and definitions

Acronym or term	Definition
ADC	Analog to Digital Converter
AGC	Automatic Gain Control
Bi-directional	Microphone with lower sensitivity along the circumference of the housing, higher sensitivity towards the front and rear sections of the housing.
Call Box	Base Station Simulator - Agilent E8285A or 8960, Rohde & Schwarz CMU200
Cellular	800MHz radio spectrum air interface
dB	Decibel = 10 x $\log_{10}$ (P1/P2) (Power dB) Decibel = 20 x $\log_{10}$ (V1/V2) (Voltage dB)
dBm	Decibels, relative to 1 mW - Decibel(mW) = 10 x $\log_{10}$ (Pwr (mW)/1mW)
dBSPL	Decibel unit of acoustic sound pressure - 20 x log (sound pressure in Pa / 20E-6 Pa)
dBV	Decibels, relative to 1 Volt - Decibel(V) = 20 x $\log_{10}$ (V1/1.0V)
Directivity	Sensitivity as a function of sound wave inflection angle
DUT	Device Under Test
Electret	Device that translates air pressure changes into electrical signals
EM	Embedded Module
ESD	ElectroStatic Discharge
EVRC	Enhanced Variable Rate Coder – an 8kbs codec compression technique
FER	Frame Error Rate – a measure of receive sensitivity
FIR	Finite Impulse Response – a form of digital filter
GPIB	General Purpose Interface Bus – IEEE std protocol for test equip communication
GPS	Global Positioning System
IS-95	2G radio standards targeted for voice (cdmaONE)
IS-2000	3G radio standards for voice and data-centric use
LDO	Low Drop Out – refers to linear regulator
LSB	Least Significant Bit
MHz	MegaHertz = 1e6 Hertz (Hertz = 1/second)
MIDI	Musical Instrument Digital Interface – musical note standard interface
MIO	Module Input/Output
Modem	Modulator – demodulator (the EM)

Acronym or term	Definition
MP	Mass Production – the finished product.
Newton	Unit of force: 1 N = force required to accelerate 1 kg object 1 meter per second per second. F = m x a. Force = mass x acceleration
Noise-canceling	Active microphone with built in filtering. Better noise cancellation performance than Uni-directional.
Omni-directional	Microphone designed to receive audio input from every direction
OTA	Over the Air or Radiated through the antenna.
OVP	Over Voltage Protection
Pascal	Unit of pressure: 1 Pa = 1 Newton of force applied over an area of 1 meter squared
PCS	Personal Communication System - PCS spans the 1.9GHz radio spectrum
PSD	Product Specification Document
QCELP	Qualcomm Code Excited Linear Predicator – a 13kbs codec compression technique
QPCH	Quick Paging Channel – IS2000 feature which increases standby time when enabled
Reverse Pilot Gating	IS2000 technique of reducing transmitter on time during conversation to improve battery life.
RF	Radio Frequency
RUIM	Removable User Identity Module
Sensitivity (RF)	Measure of lowest power signal that the receiver can measure
Sensitivity (Audio)	Microphone performance specification – output voltage measured when the microphone detects a given sound wave (1kHz) for fixed load conditions. Measured in dBV/Pa.
Sidetone	Feeding a fraction of transmit audio level into the receive path. This gives the user some feedback that an audio link is established.
SIM	Subscriber Identity Module
SOF	Start of Frame - a USB function
UART	Universal Asynchronous Receiver Transmitter
UDK	Universal Development Kit
Uni-directional	Microphone designed to receive audio input from a single direction. Effective in passive reduction of background noise.
USB	Universal Serial Bus
UVP	Under Voltage Protection
VAF	Voice Activity Factor - % time voice is active in a conversation (40% is typical).
VR	Voice recognition
xIM	Either RUIM or SIM, as the cards themselves are interchangeable