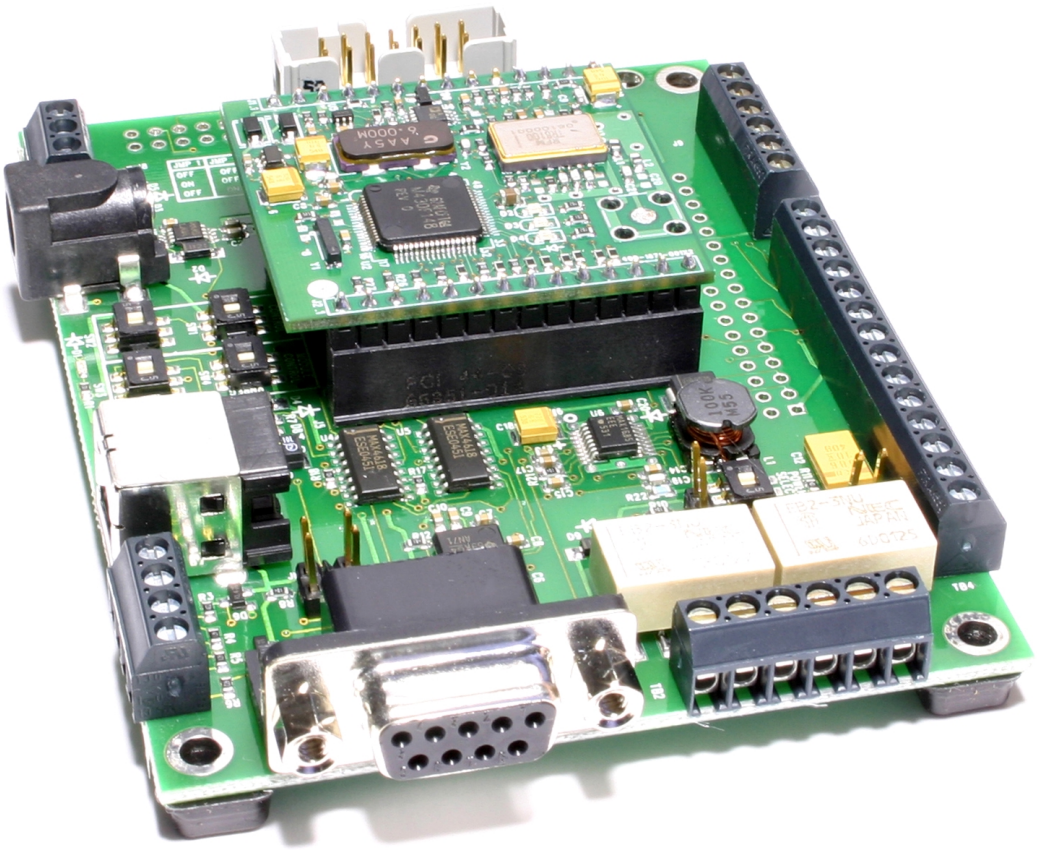
DM2200-916VM
System User's Guide



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DM2200-916VM and IM2200 Warranty

Limited Hardware Warranty. Cirronet, Inc. ("CIRRONET") warrants solely to the purchaser that the hardware DM2200-916VM and IM2200 modules will be free from defects in materials and workmanship under normal use for a period of 360 days from the date of shipment by CIRRONET. This limited warranty does not extend to any components which have been subjected to misuse, neglect, accident, or improper installation or application. CIRRONET's entire liability and the purchaser's sole and exclusive remedy for the breach of this Limited Hardware Warranty shall be, at CIRRONET's option, when accompanied by a valid receipt, either (i) repair or replacement of the defective components or (ii) upon return of the defective components, refund of the purchase price paid. **EXCEPT FOR THE LIMITED HARDWARE WARRANTY SET FORTH ABOVE, CIRRONET AND ITS LICENSORS PROVIDE THE HARDWARE ON AN "AS IS" BASIS, AND WITHOUT WARRANTY OF ANY KIND EITHER EXPRESS, IMPLIED OR STATUTORY, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF NONINFRINGEMENT, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.** Some states do not allow the exclusion of implied warranties, so the above exclusion may not apply to you. This warranty gives you specific legal rights and you may also have other rights which vary from state to state.

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Notice on the Restricted use of the DM2200-916VM and IM2200

The DM2200-916VM and IM2200, and any products employing them, operate on a shared radio band. Radio interference can occur in any place at any time, and thus communications may not be absolutely reliable. Products using the DM2200-916VM and IM2200 must be designed so that a loss of communications due to radio interference or otherwise will not endanger either people or property, and will not cause the loss of valuable data. CIRRONET assumes no liability for the performance of products which are designed or created using the DM2200-916VM and IM2200. **CIRRONET products are not suitable for use in life-support applications, biological hazard applications, nuclear control applications, or radioactive areas.**

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1 DM2200-916VM Introduction

1.1 Use and Applications

DM2200-916VM radio modules are used to build wireless sensor mesh networks. These networks are used to monitor a wide range of physical parameters, conditions and events, in applications such as utility metering and building sub-metering, public works, agriculture, food processing, waste management, manufacturing and industrial processes, security, building automation, and transportation.

There are hundreds of potential applications for short-range wireless sensor mesh networks. Some of the most common applications are presented below to illustrate how a DM2200-916VM wireless sensor networks can be used:

- Mesh networks are growing in popularity for automatic utility meter reading (AMR). Mesh networks allow meters to be read in near real time, facilitating service provider transfers and allowing electrical outages, water leaks, etc., to be quickly located. Sub-metering refers to individually metering the utilities for each tenant in a building, so the overall utility bill for a building can be fairly allocated to each tenant. Sub-metering is often done as a building retrofit installation, and is well suited to wireless mesh networking.

- Public Works - water and sewage treatment systems have requirements for numerous temperature and humidity measurements. In addition, parameters such as PH, dissolved oxygen, turbidity, chlorine concentration, flow rates, tank and pond levels, compost temperatures, etc., must be monitored, controlled and logged to meet regulatory requirements. Related plant measurements include contact status monitoring for valve position, electrical switch position, motor and pump bearing temperatures, etc.

- Agriculture - temperature and humidity measurements are valuable in many areas of agriculture, including vineyards, citrus groves, curing barns, aging cellars, hatcheries, poultry production, feedlots, commercial fish tanks, grain and hay storage, sugar beet storage, smokehouses, etc.

- Food Processing - baking and other forms of food processing are sensitive to ambient temperature and humidity conditions, along with temperature profile variations within ovens, etc. Quality control often includes requirements for cold-chain monitoring of raw ingredients and finished products. Other parameters and events related to food processing include ingredient and finished product volume and/or weight, flow rates, viscosity, PH, turbidity, incoming and outgoing water quality measurements, plus machine operational and maintenance parameters such as motor and pump temperature, etc.

- Manufacturing - this application class covers a broad range of applications including building material manufacturing, refining and petrochemical, electronic components manufacturing, electronic equipment manufacturing, pharmaceutical and chemical manufacturing, automotive, marine and aircraft assembly, white

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goods manufacturing, and so on. Despite the wide diversity of manufacturing processes, there are many similar monitoring requirements and process improvement goals, including increasing yields, reducing energy costs, reducing equipment maintenance time and unscheduled equipment down time, etc. Manufacturing processes from wood products production to semiconductor manufacturing are sensitive to ambient temperature and humidity. Motors, pumps, ovens, kilns, crackers and motorized material handing systems are found in a wide variety of manufacturing systems. Many manufacturing processes require water, so incoming and outgoing water quality must be monitored.

- Security - this application class includes military security, homeland security and commercial security. Security sensor outputs frequently take the form of contact closures. Ambient temperature and humidity sensors can provide an early warning of a fire, water leak, or broken door or window. Military security requires state-of-the-art sensors including geophones and high sensitivity vibration sensors, PID sensors, infrared laser beams, acoustic sensors, and chemical and biological sensors.

- Building Automation - this application class includes office buildings, hotels, convention centers and similar facilities. Building automation often takes the form of a distributed control and monitoring system, where a tenant, guest or visitor manually controls light switches, thermostats, etc., within a room during occupancy, with control reverting to a central control point when the room is unoccupied. Ambient temperature and lighting are the two main parameters to control. Other parameters under automatic control include water treatment, hot water, water pressure, fire control systems, etc. In addition to automation, in-building systems will be used to monitor large motors, pumps, etc., to facilitate preventive maintenance and minimize peak and average energy usage.

- Transportation - this application class includes two broad application categories; monitoring the condition of transported items, and monitoring the condition of transportation infrastructures. During the transport of many items, and especially for cold-chain monitoring, ambient temperature and humidity must be periodically logged and stored for reading at the destination. In some cases peak shock and vibration levels must also be recorded. Infrastructure monitoring includes items such as wind speed, strain, tilt, displacement and water level in and around structures such as docks, bridges, dams, rails and runways to detect the need for maintenance and/or to detect the onset of a dangerous condition.

1.2 Product Features

The DM2200-916VM radio module is based on RFM's TR8100 3rd generation *amplifier-sequenced hybrid* (ASH) radio. The DM2200-916VM also includes Cirronet's VersaMESH mesh network protocol and application firmware. These hardware and software technologies provide important benefits in industrial sensor networks, including:

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Very low operating power requirements compatible with battery operation

- Robust master-slave *and/or* symmetrical mesh network connectivity
- Self-optimizing, self healing, rules-based mesh routing technology
- Straightforward command/response application programming interface
- Flexible application I/O capability including pulse-count metering support
- Integrated firmware power management
- FCC 15.247 module certification
- RoHS compliant construction, DM2200-916VM-1 and IM2200-1

1.3 Design-In Support

Cirronet offers comprehensive support to customers designing DM2200-916VM modules into their products and systems:

- *DM2200-916VM System User's Guide* - this manual, which covers incorporating DM2200-916VM modules into products and systems, including how to install, configure, operate and maintain a DM2200 mesh network.
- *DM2200-916VM, DM2200-916VM-1, IM2200 and IM2200-1 Data Sheets* - these documents cover the specifications of the DM2200-916VM and DM2200-916VM-1 (RoHS) Transceiver Modules and the optional IM2200 and IM2200-1 (RoHS) Application Interface Modules.
- *DM2200-916VM Software User's Guide* - this document covers the use and format of all application programming interface (API) commands, responses, event and data messages supported by VersMESH, and how to use them to configure and operate a DM2200 network with your application program.
- *DM2200-916VM Development Kits* - each kit includes four DM2200-916VM nodes (a master and three field nodes), four IM2200 interface boards, four sets of power supplies, and software utilities and documentation.
- *Factory and Field Application Support* - Cirronet's application engineering staff provides customer support by e-mail, phone, FAX, field seminars and on-site visits. See Section 7 below for further details.
- *DM2200 Customization* - Cirronet offers hardware and software customization services for specific applications. See Section 7 below for further details.

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1.4 System Specifications

DM2200-916VM system specifications are provided in the following table, and are further discussed in Sections 4 and 5 below.

DM2200-916VM System Characteristic	Specification
Network Size	up to 1500 nodes
Network Creation	by node binding
Air Data Rate	9600 b/s
Transmission Latency	260 ms/hop typical
Open Field Range	600 meters/hop typical
Routing	possible through any node
Routing Methodology	rules-based, self-optimizing mesh
Network Modes	point-to-point, point-to-multipoint master-slave mesh, symmetrical mesh
Node Mobility Support	yes
Messaging Modes	command/response/event messages
Encryption	optional, 3 available modes
Node Power Management	duty cycle individually configurable for each node
ACK Mechanism	end-to-end ACK implied by response to command or by explicit ACK request
Integrated Application Support	default configuration includes two 12-bit ADC channels, 3 digital input channels with a 24-bit pulse-count option on 1 input, 2 digital output channels, all reconfigurable

1.5 DM2200-916VM Hardware Specifications

DM2200-916VM hardware specifications are summarized in the following table. Please refer to Section 2 below and the *DM2200-916VM* Data Sheet for additional information.

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DM2200-916VM Module Characteristic	Specification
FCC Certification	15.247 Module Certification
Operating Frequency	916.5 MHz
Modulation	OOK on BPSK Spreading Code
Receiver Sensitivity	10-3 BER @ -102 dBm typical
Receive Mode Current	5.5 mA typical
Peak Transmitter Output Power	10 dBm typical
Peak Transmitter Output Current	32 mA typical
Sleep Mode Current	68 uA typical (RTC & interrupts active)
Analog Input Measurement	12-bit, 3 selectable reference voltages
Regulated Power Supply Input Range	3.3 to 14 Vdc
Operating Ambient Temperature	-40 to 85 C

2 DM2200-916VM Hardware

2.1 Theory of Operation

As shown in Figure 2.1.1, the major components of the DM2200-916VM include the RFM TR8100 3rd generation ASH transceiver and the Texas Instruments MSP430F148 microcontroller. The TR8100 operates at 916.5 MHz using a BPSK “digital modulation” spreading code with OOK modulation applied to transmit data. The TR8100 utilizes *amplifier-sequenced hybrid* technology for data reception and a *SAW-stabilized 916.5 MHz oscillator* with modulated buffer amplifier for data transmission. Peak transmitter output power is nominally 10 mW.

The MSP430F148 is a low current 16-bit microcontroller. The MSP430F148 has two reference crystals, a 6 MHz crystal and a 32.768 kHz crystal. The firmware runs on the 32.768 kHz crystal when possible to minimize current consumption. The microcontroller UART is used to provide a serial interface to the module. Seven of the microcontroller’s general purpose I/O pins plus three auxiliary digital I/O pins are available for external application monitoring and control. The three LEDs on the transceiver module display communication activity. The DM2200-916VM includes an on-board 3.0 voltage regulator with an input voltage range of 3.7 to 14 V. The DM2200-916VM also includes an under voltage reset circuit for the MSP430F148 to protect against FLASH memory write errors during a module power down or brown out.

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DM2200 Block Diagram

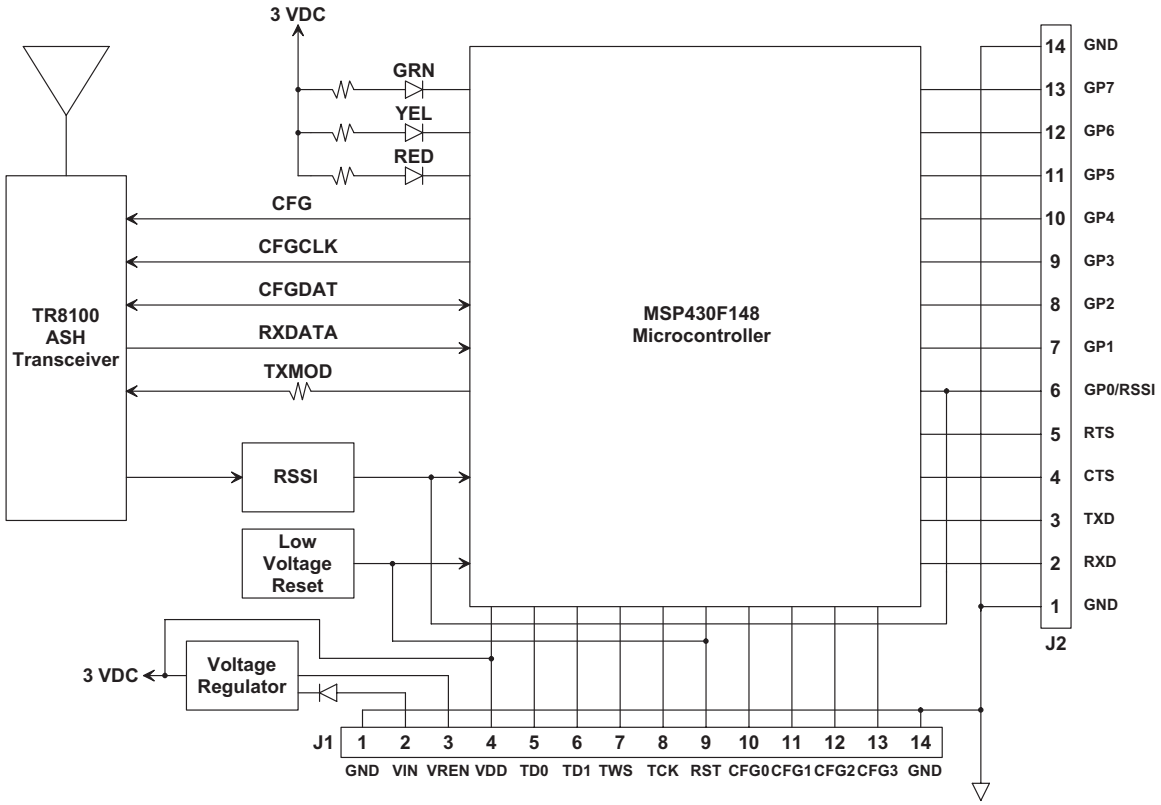


Figure 2.1.1

2.2 Application Hardware Interfaces

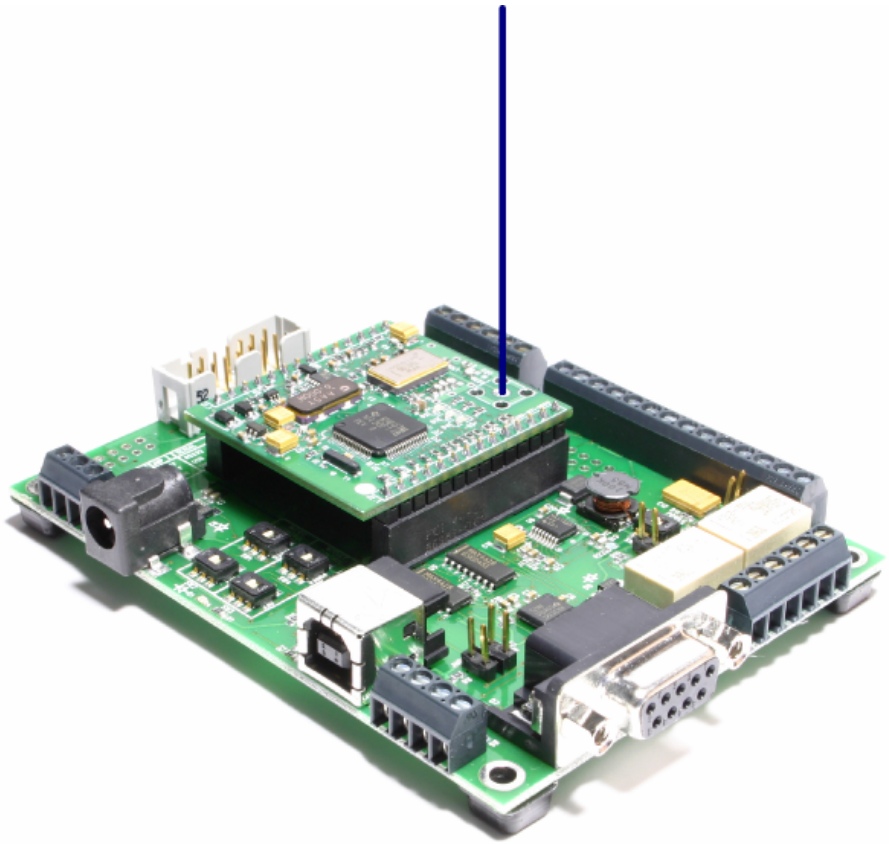
The DM2200-916VM provides the follow application hardware interfaces:

- Serial port for data communications
- 12-bit ADC for analog signal measurements
- Digital inputs
- Digital outputs

Referring to Figure 2.1.1, there are seven general purpose I/O ports available for application interfacing, GP1 - GP7, and three auxiliary digital ports, CFG0 - CFG2. Port GP0 is dedicated to RSSI readings, and should always be defined as an analog input. Ports GP1 through GP7 can be individually configured as analog inputs, digital inputs or digital outputs. However, GP1 and GP2 have special capabilities when configured as digital inputs, and GP4 and GP5 have special capabilities when configured as digital outputs. These capabilities are discussed in Section 6 below.

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Port CFG3 is always defined as a logic input and is used to initiate software resets. CFG3 should be held at a logic high state for normal operation. If this input is brought low for one second, the three LEDs on the DM2200-916VM will blink once. If CFG3 is brought high immediately after the LEDs blink, the DM2200-916VM will initiate a “power on” software reset sequence. If this input is held low for four seconds following the blink, the LEDs will go on solid and the DM2200-916VM will erase all data store in its non-volatile memory, restoring factory defaults. The LEDs will then blink seven more times, and a “power on” reset will then be initiated. Auxiliary digital ports CFG0 - CFG2 have no dedicated functionality in VersaMESH and can be individually configured as digital inputs or digital outputs.



DM2200-916VM Mounted on IM2200
Figure 2.3.1

2.3 Mounting Options

There are two ways to mount and use the DM2200-916VM in an application. The DM2200-916VM transceiver module can be used with companion application interface boards, the IM2200 and IM2200-1, as shown in Figure 2.3.1. The IM2200 and IM2200-1 have provisions for powering the transceiver module from a USB cable, an external unregulated DC supply such as a 5 Vdc “wall” transformer, an external regulated 3 Vdc

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power supply, or an external battery. The IM2200 also provides the choice of UART, RS232 or USB for the host computer serial interface. In addition, the IM2200 includes captured-screw terminal strips for connecting analog inputs, digital inputs, digital outputs and form-C relay outputs. Refer to the IM2200 Data Sheet for additional details.

The DM2200-916VM can also be integrated into the user's own application board. The DM2200-916VM pin descriptions are given in the *DM2200-916VM Data Sheet* on Pages 4 and 5. The transceiver module pin-out locations are shown in Figure 2.3.2, and the PCB layout for the mating connectors is shown in Figure 2.3.3. The use of connectors is strongly recommended rather than soldering the DM2200-916VM pins to the user's application board.

DM2200 Pin Out

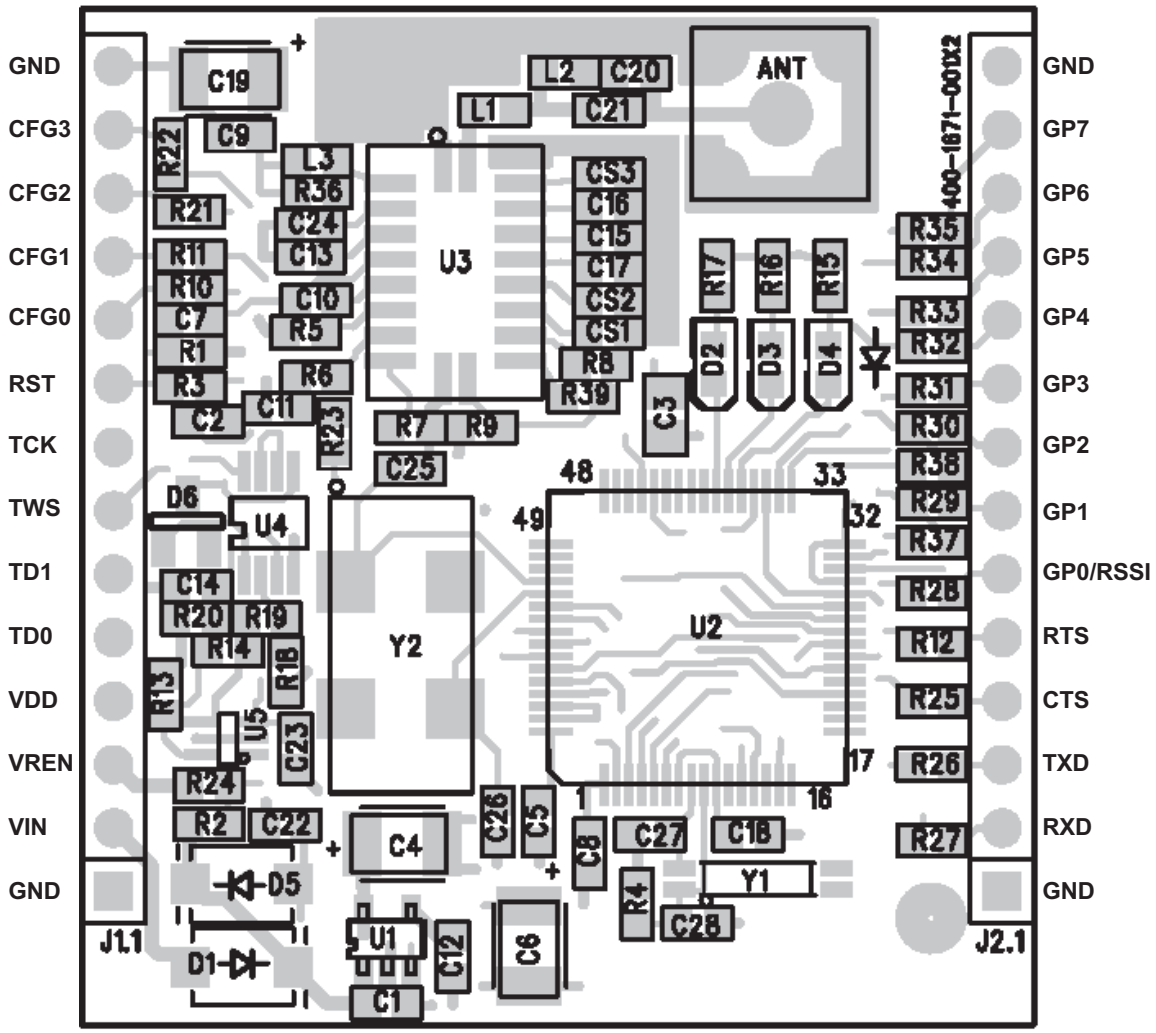
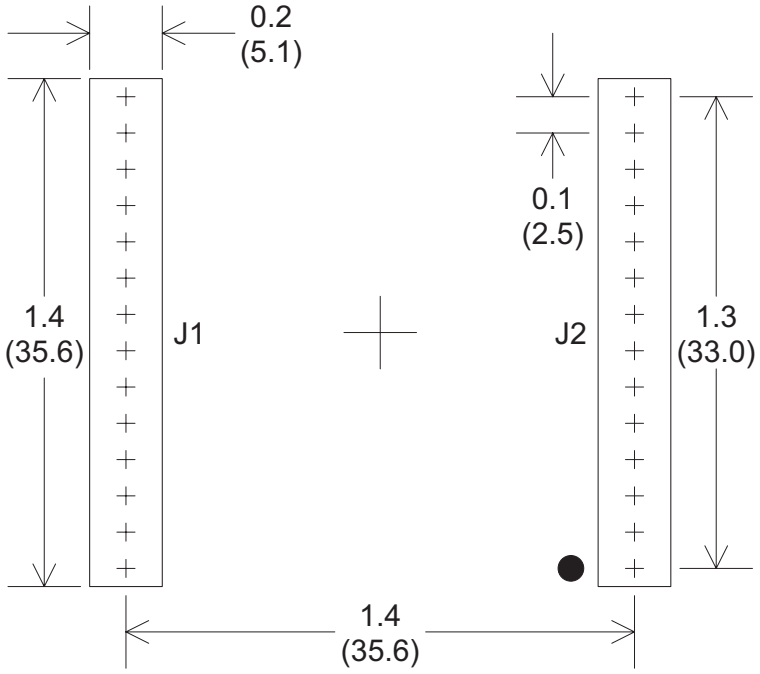


Figure 2.3.2

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DM2200 Interface Connector
PCB Layout Detail



Connectors are FCI Electronics 66951-014 or equivalent
Dimensions in inches and (mm)

Figure 2.3.3

2.4 Power Supply Considerations

Referring to Figure 2.3.2, the DM2200-916VM has an on-board 3 Vdc regulator input on Pin J1-2. To use the on-board regulator, connect J1-3 to J1-2 and apply a voltage to this connection of at least 3.3 Vdc, but not greater than 14 Vdc, including ripple variations. When running from the on-board regulator, up to 5 mA is available on J1-4 to operate external circuitry. Any external circuitry connected to J1-4 must not induce more than 10 mV_{P-P} ripple on the regulated 3 Vdc at this pin.

The DM2200-916VM can also be run from an off-board regulated supply or a battery. In this case, connect J1-3 to ground, leave J1-2 unconnected, and apply the regulated supply or battery input to J1-4. Note the input voltage range for J1-4 must be in the range of 2.9 to 3.7 Vdc, with no more than 10 mV_{P-P} ripple. Only pins J1-2 and J1-3 are rated to operate from a supply voltage higher than 3.7 Vdc. *Further, care must be taken so that analog or logic inputs applied to the transceiver module stay within the voltage range of 0 to VDD (voltage at J1-4). Applying a voltage outside of the 0 to VDD voltage range to an analog or logic input can damage the module.*

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2.5 ESD and Transient Protection

DM2200-916VM and IM2200 circuit boards are electrostatic discharge (ESD) sensitive. ESD precautions must be observed when handling and installing these components. DM2200-916VM and IM2200 installations must be protected from electrical transients on the power supply and I/O lines. This is especially important in outdoor installations, and/or where connections are made to sensors with long leads. *Inadequate transient protection can result in damage and/or create a fire and safety hazard.*

2.6 Enclosures and Antennas

Enclosures must be made of plastics or other materials with low RF attenuation to avoid compromising antenna performance. Metal enclosures are not suitable as they will block antenna radiation and reception. Outdoor enclosures must be water tight, such as a NEMA 12 fiberglass enclosure.

The operating range of the DM2200-916VM critically depends on the antenna being located properly. The standard DM2200-916VM antenna (part number 400-1687-001) should be straight and perpendicular to the DM2200 PCB, and the DM2200 should be mounted so that the antenna is vertical. Care should be taken to keep the antenna at least 0.5 inch away from the sides of its enclosure. *Note: many other antennas can be used with the DM2200-916VM, but each new antenna must be added to the DM2200-916VM FCC module certification before deployment.* Contact Cirronet for details.

2.7 FCC Compliance, Labeling and Notices

The DM2200-916VM is certified as a module for operation under FCC Part 15 Rules, Section 15.247. In order to take advantage of this module certification, the user must provide proper enclosure labeling, include specific disclaimer language in the user's manual, and use the antenna supplied by Cirronet with the module.

A clearly visible label is required on the outside of the user's (OEM) enclosure stating that: *This product contains a DM2200-916VM radio module, FCC ID: TE6-DM2200A.*

Further, the manual for the user's product or system must include the follow advisory: *This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.*

WARNING: This device operates under Part 15 of the FCC rules. Any modification to this device, not expressly authorized by Cirronet, Inc., may void the user's authority to operate this device.

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3 DM2200 VersaMESH™ Firmware

3.1 VersaMESH Capabilities

The DM2200 VersaMESH firmware includes a robust mesh network protocol, plus application support for analog inputs, digital inputs, metering pulse inputs, digital outputs and serial communications. VersaMESH also includes provisions for network monitoring, field node power management to support battery operation, and encryption options to provide payload data security.

The mesh protocol used in VersaMESH optimizes and heals network traffic flow using distributed rules-based routing. The default set of rules and parameters provides robust network performance for a broad range of DM2200 applications, and can be adjusted as needed to support unusual network topologies or traffic flow requirements.

3.2 Command, Response, Event and Data Messages

The default serial port mode for a DM2200 is called the *command* mode. This mode handles four types of messages:

- *Command* messages are used to control the operation and configuration of a DM2200 node. Commands can control a node directly through its serial port, or they can control a node remotely through the RF network.
- *Response* messages are returned for most commands. For example, an IO_ADC command (read ADC input) will be answered with a message containing the ADC reading.
- *Event* messages are generated by field nodes in response to certain conditions, and are always directed to the master node.
- *Data* messages are used to input and output a string of bytes through a node's serial port.

Most, but not all commands automatically invoke a response. The reception of a command that does not automatically cause a response message can be verified by setting an acknowledgement (ACK) request flag in the command. This causes the destination node to send a message back to the source of the command.

3.3 TARP Protocol

The mesh network routing protocol integrated into VersaMESH is a highly customized version of TARP (*tiny ad-hoc routing protocol*). The default settings for the TARP rules and parameters provide robust network performance in most applications. Commands are included in VersaMESH to set TARP configuration data. Except for the TARP forwarding rule, it is strongly recommended that the default settings not be changed without consulting with Cirronet, as inappropriate changes can disable a DM2200

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network. As an engineering service, Cirronet maintains a network simulator for tuning TARP rules and parameters for special network topologies and performance requirements.

3.4 Reliable Reporting Support for Event and Data Messages

Field nodes can automatically generate messages related to events such as receiving a string of bytes when in the *data* mode, a change of state on a digital input, or reaching a count threshold on a pulse input. The maximum number of times a data or event message is sent by a the field node, and the timeout interval between transmissions can be configured for each node. Data and event messages are repeated until the maximum is reached or an acknowledgement is received from the master node.

3.5 Application Interface Support

VersaMESH provides firmware support for all DM2200 hardware interfaces. An integrated operating system in the firmware coordinates protocol and applications tasks to achieve responsive, seamless operation.

The DM2200 serial port can operate in two modes. The default mode is the *command* mode. An optional *data* mode is also provided for passively routing strings of data without interaction.

VersaMESH includes a rich set of commands to read, write and configure the general purpose (GP) ports and auxiliary digital ports. These commands provide the following functionality:

- Configure a GP port as an analog input and make a 12 bit ADC measurement.
- Configure a GP port or auxiliary digital port as a digital input and read its state. The firmware also supports pulse counting on GP1, and event messaging on both GP1 and GP2.
- Configure a GP or auxiliary digital port as a digital output and set or read its state.

3.6 Encryption Modes

VersaMESH offers two encryption modes, and three selectable 128-bit encryption keys that are preloaded in firmware. Mode 0 decrypts a message using the key index referenced in the header of the packet. Mode 1 decrypts a message using the key specified by an earlier configuration command. TEA encryption methodology is used to provide a good balance between computational efficiency and security.

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3.7 Power Management

Network power management cycles are controlled by the master node, which is always *awake* or active. When power management is enabled, the master node alternates between two states, *synchronization* and *rest*. The period for each of these states is programmable. During the synchronization period, the master node adds “seconds until sleep” data to its master beacons. At the start of the sleep period, the master node switches to its rest state. During the rest period, the master node continues to send out beacons, but without sleep synchronization data. At the end of its rest period, the master node switches back to its synchronization state, beginning a new power management cycle.

The field node counterpart to synchronization is *preparation*. A field node only has to hear one master beacon with synchronization data to prepare for its sleep period. During a field node’s preparation period, it continues normal operation but runs its own “*seconds to sleep*” timer that has been synchronized with the master beacon data.

The sleep *mode* and the sleep *period* are both programmable for each field node. There are four possible sleep modes:

- *Deep sleep*, with the radio turned off and the microprocessor running at minimum power consumption for a specified time period.
- *Light sleep*, with the radio turned off and the microprocessor configured to service interrupts for pulse counting, etc., for a specified time period.
- *Awake*, for those nodes in the network running from mains power. Awake nodes operate continuously.
- *Transmit only*, for “leaf” nodes at the edge of a network that transmit only event messages. Transmit only nodes must be supported by routing paths consisting of awake nodes.

By default, a field node is configured with sleep enabled, the sleep mode set to deep sleep, and with a 90 second sleep period. Note that enabling sleep in a field node does not itself cause the node to sleep. Each sleep cycle is initiated by receiving a master beacon with synchronization data, which switches the field node into sleep preparation and then into its sleep period.

When a node becomes the master node, sleep is disabled, the synchronization period defaults to 60 seconds, and rest period defaults to 120 seconds. Any changes to the default sleep mode parameters in either a master node or a field node are stored in nonvolatile memory, and are retrieved when the node is powered up.

The sleep period for a field node is usually set shorter than the master node rest period, allowing an interval for active operation during each master node power management cycle. However, it is also possible to set the sleep period on a field node to span a

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number of master node cycles, where operation of the field node can be infrequent and very low power usage is important.

3.8 VersaMESH Message Summary

There are more than 80 command, response, event and data messages supported by VersaMESH. The primary message are organized into seven different categories, as summarized below:

Node Configuration

Get Local Node Network Configuration
Get Equipment Serial Number
Set Network ID
Get Network ID
Designate Master Node
Get Master ID
Enable/Disable Master Automatic ACK
Get Master RSSI
Set Event Message Retries and Timeout
Get Event Message Retries and Timeout
Set Radio Mode
Get Radio Mode
Reset Node
Get Firmware Version

Routing

Bind Request Event Message
Bind Node to Network
Set Master Beacon Interval
Set Routing Mode
Get Routing Mode
Set Route Recovery
Get Route Recovery
Set Connectivity Data
Get Connectivity Data
Connectivity Event Message

Encryption

Set Encryption Mode and Key
Get Encryption Configuration

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Power Management

Set Node Sleep Mode Configuration
Get Node Sleep Mode Configuration
Set Sleep Period
Get Sleep Period
Set Rest Period
Get Rest Period

Serial Port

Set Serial Port Configuration
Get Serial Port Configuration
Set Serial Port Command/Data Mode
Get Serial Port Command/Data Mode
Serial Port Data Input Message

Application I/O

Set I/O Pin Configuration
Get I/O Pin Configuration
Get Digital I/O State
Write Digital Output State
Get Analog Input Measurement
Start Pulse Counter (GP1)
Get Pulse Counter
Stop Pulse Counter
Set Comparator Value
Get Comparator Value
Comparator Event Message
Set Offset Value
Get Offset Value
Set Offset Mode
Get Offset Mode
Get Pulse Counting State
Enable GP2 Event Messages
GP2 Event Message

Diagnostics

Send Trace
Trace Acknowledgement

3.9 Using the DM2200-916VM Software User's Guide

The *DM2200-916VM Software User's Guide* covers the use and format of all application programming interface (API) commands, responses, event and data

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messages supported by VersMESH, and how to use them to configure and operate a DM2200 network with your application program. The *DM2200-916VM Software User's Guide* is the main guide for developing DM2200-916VM application programs that take advantage of the extensive feature set of VersaMESH. This *System User's Guide* covers what you can do with the DM2200-916VM and VersaMESH, and the *Software User's Guide* covers how to do it with your application program.

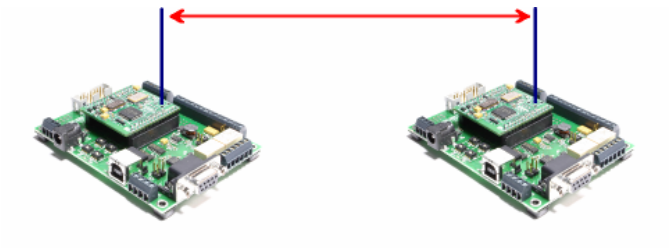
4 Creating a Network

4.1 Choosing a Network Topology

The DM2200-916VM radio module is suitable for building four network topologies.

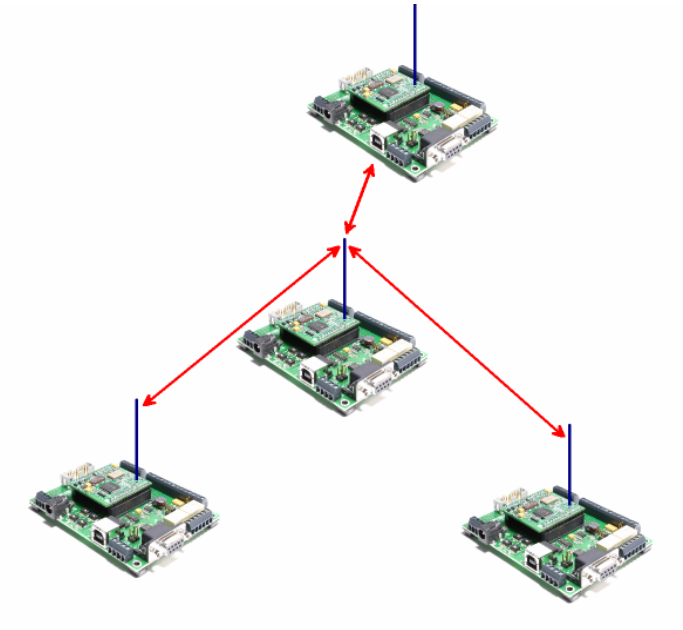
- A point-to-point network topology, as shown in Figure 4.1.1. This topology supports single-hop transmissions between a master node and one field node.
- A point-to-multipoint network topology as shown in Figure 4.1.2. This topology supports single-hop transmissions between one master mode and several field nodes.
- A master-slave, multi-hop mesh network topology, as shown in Figure 4.1.3. This topology supports communications between one master node and a number of field nodes, where the field nodes cooperate to forward traffic to and from the master node to their neighbors. In this topology, a message from one field node to another field node is always routed through the master node.
- A symmetrical, multi-hop mesh network topology, as shown in Figure 4.1.4. This topology supports communications between any two nodes in the network. Traffic between two field nodes will not be routed through the master node unless the path through the master node is the most efficient path. A master node is still required in a symmetrical network topology as it performs several special functions, as explained in Section 4.3 below.

The default VersaMESH network routing rules support all these topologies. Note that unless the network routing rules are deliberately constrained, a point-to-multipoint network topology will evolve into a master-slave, multi-hop topology automatically under marginal single-hop connectivity conditions.

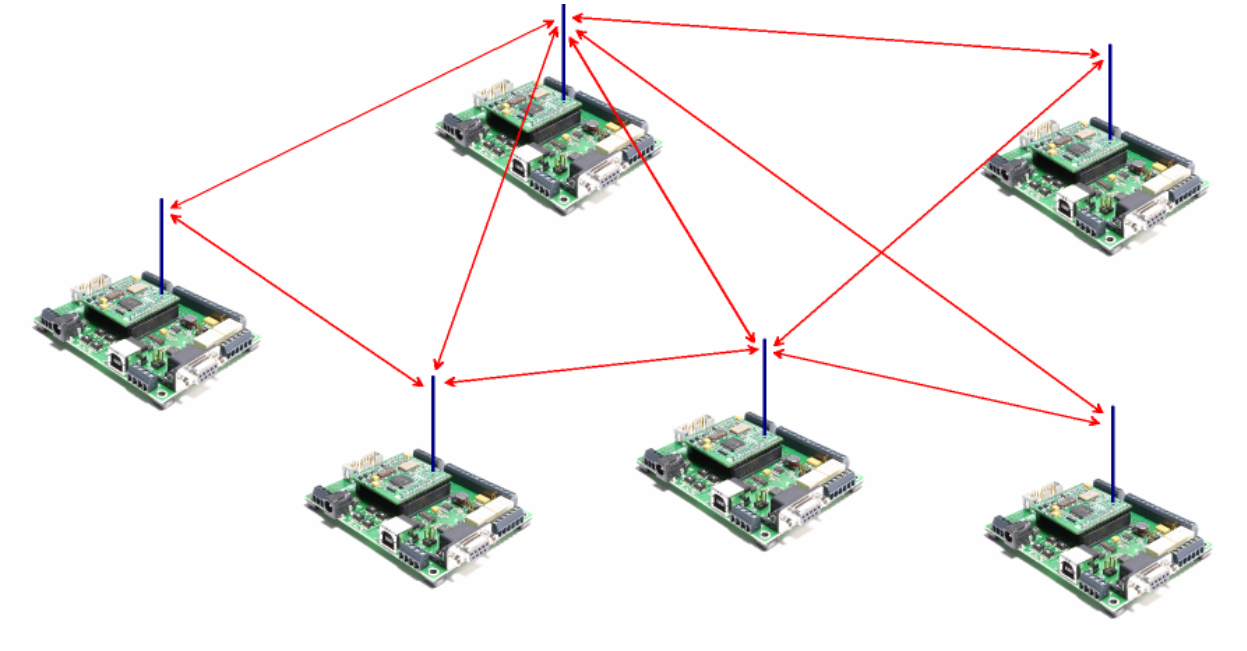


Point-to-Point Topology
Figure 4.1.1

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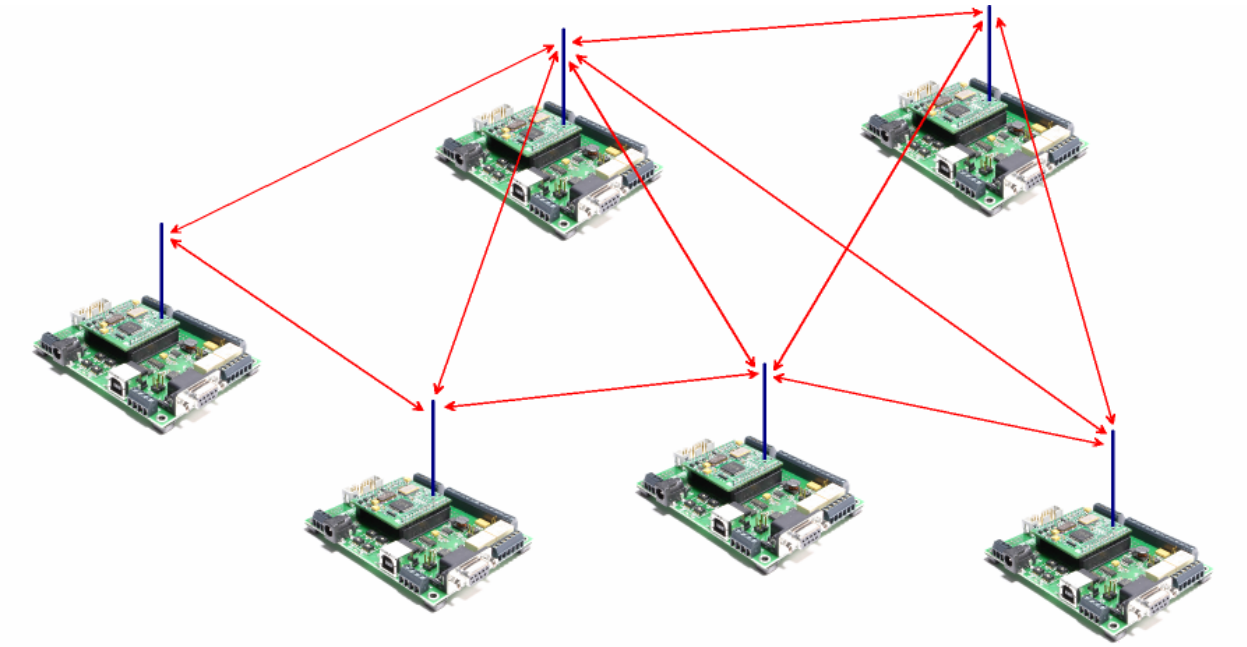


Point-to-Multipoint Topology
Figure 4.1.2



Master-Slave Mesh Topology
Figure 4.1.3

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Symmetrical Mesh Topology
Figure 4.1.4

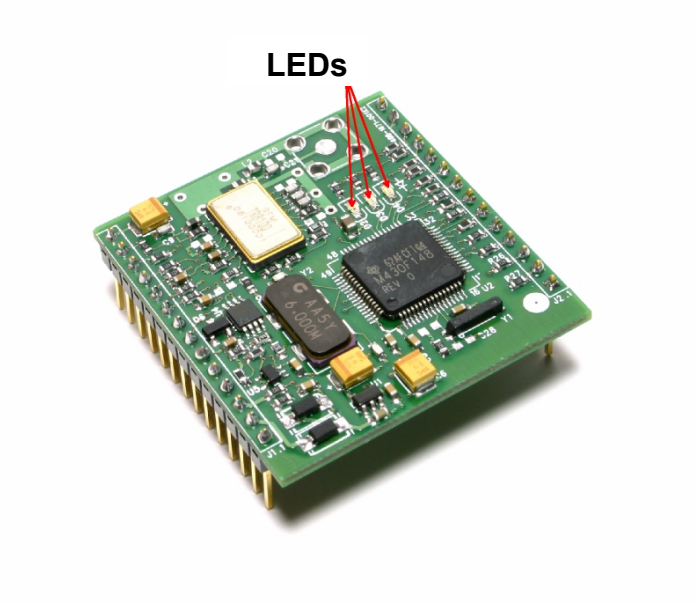
4.2 Locating and Installing Nodes

DM2200-916VM field nodes are normally located close to the sensors being connected to them. The exceptions to this rule is where the sensors are located in a very harsh environment (high temperature, caustic atmosphere, etc.), or the sensors are in a location where RF propagation would likely be very poor, such as point near ground level with a heavy concentration of metal walls, pipes, etc. In these cases, DM2200 field nodes should be located as near as practical to the sensors but in a relatively benign environment with reasonably good RF propagation potential. DM2200 enclosures should be mounted so the antenna is at least 3 feet above the ground or floor, and where practical 6 to 12 feet above the ground or floor. Ideally, DM2200 enclosures should be mounted in open areas with the antennas spaced away from metal objects, wires or cables.

The “open field” operating range between two DM2200-916VM nodes placed 4 feet above the ground is about 600 meters. The operating range will be less if the DM2200-916VM nodes are near the ground and/or in a difficult RF propagation environment. Except in very poor RF environments, the operating range between two DM2200-916VM nodes should be at least 200 meters. A simple installation sketch is useful in estimating the distances between the nodes in a DM2200-916VM network, and assessing if redundant routing paths appear to exist. In some installations, supplemental router nodes will be required, as discussed in Section 4.5. It is recommended that 10% additional DM2200-916VM field nodes be on hand for an

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installation, so that supplemental router nodes can be installed during network commissioning if the need arises.



Location of LEDs
Figure 4.3.1

4.3. LED Interpretation

There is a green, yellow and red LED located on top of the DM2200-916VM, as shown in Figure 4.3.1. The green LED blinks when the node receives a packet. The yellow LED blinks when the node transmits a packet. The red LED provides connectivity status as follows:

- Fast blinking indicates the node is not bound to a network
- Solid ON indicates the node is bound and hearing most of beacon traffic from the master node
- Slow blinking indicates the node is bound, but has not heard a packet from the master node since waking from sleep, powering up, or for a length of time longer than a specified number of beacon periods.
- Solid OFF indicates the node is powered down, in a sleep cycle, or is on and bound, but has not heard a packet from the master node in a length of time longer than a specified number of beacon packets.

The red LED connectivity indication is useful in maintaining a DM2200 network, as discussed in Section 5 below.

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4.4 Designating a Master Node

The first configuration step in creating a DM2200 network is to designate a *master node,* also referred to as a coordinator or base station. The master node is unique in four ways. First, only the master node that can initiate RF commands to *bind* (add) other nodes into the network. Second, the master node is always the destination for *status* and *event messages* generated by other nodes in the network. Third, the master node periodically sends *beacons* that are used by the other nodes in the network to optimize their routing to the master node. Fourth, master beacon orchestrates the network's power management sleep cycles.

A node is designated as a master by sending it a sequence of configuration commands. Here is an overview of the command sequence:

- A command is sent to the node to retrieve its current node ID, electronic serial number (ESN), and master ID.
- A command is then sent updating the node ID. This ID must be unique within the network.
- Next, a command is sent, using the new node ID, to set the value of several connectivity beacon parameters. These will be passed on to any node being bound to the master node's network.
- A command is then sent to set the network ID. Only messages carrying this node ID will be handled by the network. This allows overlapping networks to operate independently.
- Next, a command is sent to set the master node beacon interval, typically in the range of 10 to 60 seconds.
- Finally, a command is sent to set the operating mode of the node as a *master node*.

A newly configured master node immediately sends out its first beacon to announce its designation as the network master. The master node configuration is preserved when a node is powered off.

4.5 Binding Nodes into a Network

Once a master node has been designated, the rest of the nodes can be bound to the network. When an unbound node is turned on, it periodically transmits a bind request. If the unbound node can communicate directly with the master node, the master acts on the request directly. Otherwise, the bind request is routed to the master node starting with a bound node(s) that can directly hear the bind request and is configured to forward it. Once a bind request is received by the master node, it is passed to the master node's host computer.

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The role of the host computer in the binding process is to determine if the node generating the bind request is authorized to become part of the network. If so, the host computer issues a bind command through the master node. If the unbound node can communicate directly with the master node, the command is sent directly to the unbound node. Otherwise, the command is sent to a bound node that is in direct communication with the unbound node.

It is good practice to power up and bind nodes one at a time before field installation. This avoid the possibility of overloading a new network with bind requests and bind command packets.

When a node is bound, it receives its unique node ID, the network ID, the master node ID, connectivity parameters and encryption data. As soon as the newly bound node receives a master beacon, its connectivity LED will switch from rapid blinking to solid on. Shortly after being bound, the newly bound node will send a status message to the master node. The node is then ready to accept I/O configuration commands, and to participate in network activities.

4.6 Adding Supplemental Router Nodes

The RF path loss between two points can be very difficult to judge, and can change dramatically with time, especially in a location with a lot of metal infrastructure, as is the case at many industrial sites. In commissioning and maintaining a DM2200 network, it may be necessary to install supplemental router nodes to improve connectivity to certain locations. If a node or a group of nodes in a new network exhibit poor connectivity, the path to the master node can be enhanced by adding one or more additional nodes to supplement routing. These supplemental nodes should be placed generally between the master node and the node or group of nodes exhibiting a poor RF link.

Field node red “connectivity” LEDs and status messages can be evaluated to identify marginal paths in a new network and deteriorating paths in an existing network.

5 Network Operation and Maintenance

5.1 Beacon Operation

Beacons sent by the master node are key to network operation. Beacons are monitored by each field node (1) to optimize and/or recover routing to the master node, (2) to assess path robustness, and (3) to synchronize power management cycles. The beacon period is a configurable parameter, with a default value of 29 seconds. Setting the beacon period longer helps improve power management and extend battery life, with the trade-off of slower overall network dynamics. Setting the beacon period shorter improves the dynamics of a network, but lessens the effectiveness of power management.

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The beacon interval must be coordinated with the maximum number of hops required by the network. As a general rule, 250 ms should be allocated for each hop in a DM2200 network. The beacon period should be no less than 10 times the propagation time through the maximum number of hops in the network. For example, if a network uses a maximum for four hops, the maximum route propagation time is one second. The beacon period should then be at least 10 seconds.

5.2 Network Maintenance

Field nodes periodically send status messages to the master node. This allows the host computer at the master node to track connectivity to each field node without explicitly sending a command to it.

VersaMESH also includes three *trace* diagnostics - bidirectional trace, trace forward and trace backward, for pinpointing network problems in real time.

The red connectivity LED on each field node provides a local indication of the path robustness to the master node. Solid ON indicates good connectivity, slow blinking indicates marginal connectivity, and OFF indicates very poor or no connectivity.

5.3 Node Mobility

Master node beacons allow VersaMESH to maintain a node's connectivity as it physically moves through the network, provided the motion is not too fast compared to the beacon period. Also, a single network can consist of a number of isolated "cluster" locations, such as warehouses in different cities. Provided the same network ID and encryption key is used at each cluster location, a node can leave one cluster and join another cluster without needing to rebind. Joining a new cluster if facilitated by receiving the master beacon, which allows the joining node to recognize the address of the local master.

6 Using DM2200-916VM Application I/O

6.1 Serial Port Data Mode Operation

VersaMESH includes an RF command to select a serial port's input mode of operation, either *command* or *data*. When a field node is in the data mode, it will send a string of bytes input to its serial port to the master node. The string is encapsulated in a packet and sent when (1) terminated by an ASCII carriage return, (2) the string reaches 64 bytes in length, or (3) after a one second pause in the byte reception. After the data message is acknowledged by the master node, the serial port will accept a new string. Note that when a node is placed in the data input mode, it can only be switched back to the command mode through the RF link. VersaMESH also includes a command to output payload (only) data.

The data mode is useful in routing traffic through a DM2200 network to/from a data logger, printer, or other peripheral with fixed programming functionality.

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6.2 Analog-to-Digital Converter (ADC) Operation

VersaMESH includes a command to make an ADC measurement on GP1 through GP7. In addition to specifying the port number, the command includes several options. First, the ADC full-scale reading can be referenced to the 1.5 V or 2.5 V internal reference voltages, or to the 3 Vdc power supply. Second, the sample-and-hold settling time for the ADC can be set from 1 to 64 ms.

6.3 Digital Input Operation

VersaMESH includes a rich set of commands related to digital inputs. Ports GP1 through GP7 and auxiliary digital ports CFG0 through CFG2 can be configured and read as digital inputs.

When GP1 is configured as a digital input, it can optionally count pulses used in applications such as utility sub-metering. GP1 is able to count up to 10 pulses/second, with the option to count low pulses (high-to-low edges) or high pulses (low-to-high edges). Pulse counts are stored in a 24-bit register that can be preset, read and reset. Note that GP1 can count pulses during a power management sleep cycle when in the “light sleep” mode. The pulse count can be stored in nonvolatile memory periodically to protect against loss due to a power outage. This period is a configurable parameter, with 15 minutes a typical value.

The pulse counter is supported by two 24-bit companion registers. The first companion register provides a *comparator* function. When the comparator register is loaded with a value and enabled, an event message can be triggered when the pulse count matches the value in the comparator. At this point the value of the comparator can be optionally subtracted from the pulse counter to reset it.

The second companion register is an *offset* register that can be used with either the pulse counter or the comparator register. The offset register supports two modes of operation. In the *comparator offset* mode, when the pulse-count register value reaches the comparator value, an event message is triggered, and the value in the comparator is *increased* by the value in the offset register. For example, if the value in the comparator register is initially 1000 and the value in the offset register is 100, an event message will be sent when the value in the pulse-count register reaches 1000, 1100, 1200, etc.

In the *counter offset* mode, when the pulse count reaches the comparator value, an event message is triggered, and the value in the pulse counter is *decreased* by the value in the offset register. For example, if the value in the comparator register is initially 1000 and the value in the offset register is 100, an event message will be sent when the value in the pulse counter reaches 1000. At this point, the value in the pulse counter is “backed down” 100 counts to a value of 900. When the value in the pulse counter again reaches 1000, the next event message with be sent and the value in the pulse counter will again be reset to 900. The pulse-count register and comparator

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register exhibit 24-bit modulo behavior and will gracefully “wrap around” on an overflow or underflow.

When GP2 is configured as a digital input it can generate event messages as a configuration option.

6.4 Digital Output Operation

VersaMESH also includes a set commands related to digital outputs. Ports GP1 through GP7 and auxiliary digital ports CFG0 through CFG2 can be configured as digital outputs. Digital outputs can be set to a high or low logic state, and the state can be read.

If GP4 and GP5 are configured as digital outputs, these signals can be used to drive the two Form-C relays on the IM2200 interface board.

7. About Cirronet, Inc.

7.1 Company Overview

Cirronet, Inc. was founded in 1987 and became a wholly owned subsidiary of RF Monolithics, Inc. in 2006. Since its founding, Cirronet has delivered a wide range of high performance RF products for industrial, commercial and medical applications. Cirronet’s RF product line includes high performance FHSS radios, industrial WiFi and Bluetooth radios, 802.15.4 and Zigbee modules, and the DM series wireless mesh network sensor modules.

RF Monolithics, Inc. (RFM) was founded in 1979, and became a publicly traded company in 1994 (NASDAQ, RFMI). Since its founding, RFM has shipped more than 750,000,000 products for low power radio applications. Applications for these products include automotive keyless entry and tire pressure monitoring systems, wireless utility meter reading systems, garage door and gate controls, residential and commercial alarm systems, medical telemetry, and active RFID tags. Applications for other RFM products include satellite broadcast radios, cellular phone systems, commercial and military avionics, and fiber optic communications.

7.2 Web Site Support

Cirronet’s web site address is www.cirronet.com. The latest information on the DM2200-916VM and other radio modules and products are maintained here. Check Cirronet’s web site for the latest information on the DM2200-916VM and other Cirronet products.

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7.3 E-mail Support

Cirronet's general E-mail information and support address is info@cirronet.com. It is often useful to follow-up an E-mail inquiry with a support phone call, so please include your phone number and time zone in your inquiry.

7.4 Phone and FAX Support

Cirronet's main phone number is US 678.684.2000. Operator assistance is available from 08:00 to 17:00 (US Eastern Time Zone) Monday through Friday. Cirronet's main FAX number is 678.684.2001.

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