Powerhouse Dynamics
WiTemp+
FCC Compliance Operational Description

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Overview

This document describes the operation of Powerhouse Dynamics' WiTemp+ sensor and how it complies with the applicable FCC rules regarding its runtime performance.

Hardware

The WiTemp+ is a battery powered temperature and dry contact sensor that periodically transmits sensor readings to a central receiver device called a Gateway within the 915MHz ISM band. It has one internal 1-Wire temperature sensor, and optionally supports one external 1-Wire temperature sensor and one dry contact input. In addition, the battery voltage is also monitored and reported to the Gateway. The radio, a transmitter only, is integrated with a small microprocessor. The supplied battery voltage is conditioned by a power supply that supplies a constant voltage of 3.3V to the digital logic and RF transmitter. Two 1.5V AA lithium or alkaline cells in series provide a nominal 3V source to the onboard power supply. A single red LED is the only integrated hardware user interface and is used to show RF transmission activity.

Firmware

The WiTemp+ firmware runs on the microprocessor that is integrated with the RF transmitter. More than 99% of the time the microprocessor is in a deep sleep state and the RF transmitter is off. Periodically, it will wake from sleep mode, take temperature, dry contact, and battery voltage readings and then transmit those readings to the Gateway. Additionally, the WiTemp+ will report, as necessary, its firmware version or other diagnostic values as part of the transmitted readings.

There are two periodic modes. Install mode occurs when the device is initially powered (batteries inserted.) It will transmit readings no faster than once every 10 seconds and no slower than once every 12 seconds from the end of the last transmission for about the first eight minutes of operation. After Install mode expires the device will enter Normal mode until the next time the batteries are removed and replaced. During Normal mode it will transmit readings at a random interval no faster than once every 57 seconds and no slower than once every 63 seconds, and generally averaging about one reading every 60 seconds.

RF Transmitter

The radio is a transmitter only in the 915MHz ISM band. The modulation is OOK (On-Off Keying) where a logical bit value of 1 is represented by a signal being transmitted and a logical bit value of 0 is represented by the absence of a signal being transmitted. The bit rate of the transmissions is 10000bps. Since the radio is a transmitter only it is not possible to detect if the transmission channel is in use, therefore the firmware randomizes transmission times to prevent permanent cyclic RF collisions due to multiple synchronized transmitters.

The RF transmitter outputs a signal at 0dBm power utilizing a precision length wire antenna with a peak gain of +0.9dBi and an average gain of -3.2dBi. While not strictly required at this power output level the transmissions uses spread spectrum frequency hopping to distribute the utilized bandwidth across a wider swath of the 915MHz band. The frequency hopping uses 51 channels starting at 902.5MHz and ending at 905.3MHz equally spaced with 56kHz between channels. Three of the 51 channels are used to synchronize the channel hopping sequence with the gateway. These three synchronization channels are at 903.34MHz, 904.068MHz, and 904.796MHz. The other 48 data channels are used to transmit the sensor readings.

Each transmission on a specific channel starts with a 4 byte preamble of alternating 1's and 0's. The preamble is followed by a 4 byte sync word, that allows the Gateway to synchronize its receiver with the data stream. The sync word is followed by a 1 byte length byte that indicates the number of data bytes that will be transmitted as part of the message. Following the length byte exactly length bytes of data are transmitted.

The three synchronization channels only transmit 2 bytes of data that encodes the channel on which the WiTemp+ will transmit its actual sensor data. Each of the forty-eight data channels can transmit an absolute maximum payload of 176 bytes of encoded sensor data, but typically less than that depending on installation of an external 1-Wire temperature sensor and if diagnostic data is also transmitted.

After the WiTemp+ takes its sensor readings it will transmit a channel synchronization message on each of the three synchronization channels. For each sensor reading cycle the transmission sequence of the three synchronization channels is randomized. The reason for transmitting synchronization data on three different channels is to provide frequency diversity for the Gateway receiver to listen to a different synchronization channel in the case a specific synchronization channel is unreliable in a particular customer environment.

After sending the third synchronization message, the WiTemp+ will wait approximately 50ms before it transmits the sensor readings on the data channel just specified in each of the synchronization messages. This permits the Gateway time to process the synchronization message and change receive channels in preparation to receive the sensor data message. For each sensor reading cycle the data channel is pseudo-randomly sequenced through all 48 data channels such that all data channels are used equally and not simply used in a predictable pattern, such as ascending or descending RF frequencies.

There are no retransmissions or other acknowledgement or support transmissions except those previously described.

Bandwidth Calculations

Based on the description of the RF transmitter in the previous sections the absolute maximum transmission time on any given channel for each sensor reading data transmission is:

Maximum Packet Framing Bytes: 9

Maximum Packet Sensor Data Bytes: 176

(9 + 176)bytes * 8bits/bytes * (1/10000bps) = 148ms

And the maximum transmission time for each synchronization channel transmission is:

Maximum Packet Framing Bytes: 9

Maximum Packet Synchronization Bytes: 2

(9 + 2)bytes * 8bits/bytes * (1/10000bps) = 8.8ms

Over the course if a 20s sliding transmission window the same data channel will not be reused, therefore the maximum utilization for any data channel is 148ms. However, over the course of a 20s sliding transmission window each synchronization channel will be used twice for a maximum utilization of 17.6ms.

Description of Circuitry and Devices

L1-L6 inductors and C1-C3 capacitors on the RF output of the transmitter provide the filtering and matching for the transmitted signal. These components are tuned for the 915MHz ISM band. A precision cut wire antenna is soldered at the end of this filtering and matching circuit.

U1 is the combined RF transmitter and microprocessor. The microprocessor's firmware controls the operation of the RF transmitter. Resistor R2 ensures the radio is powered to a known off state. Capacitors C5, C6 provide power supply decoupling for both the microprocessor and RF transmitter. X1 is a 26MHz crystal that provides a stable source frequency for generating the 915MHz band transmissions.

U2 is the DC to DC power supply, which converts the battery voltage into a stable 3.3V for use by the digital logic and RF transmitter. The input side of U2 includes; R3 a 0ohm jumper, R12 a current limiting resistor for battery voltage sensing by the microprocessor, C7 a filtering capacitor, and L7 a feedback inductor. The output side of U2 includes; R5/R6 voltage setting resistors, C6, C8, C9 filtering and bulk capacitors, and R4 a 0ohm jumper.

U3 is a 1-Wire integrated temperature sensor connected the same bus exposed on Pin 1 of external connector TB1, which permits a single external 1-Wire temperature sensor to be connected. Resistor R8 and Diode clamp D2 are present to reduce the potential of hardware damage from high voltage/high current external sources. Resistor R7 is a pull-up resistor for the 1-Wire bus.

Pin 3 of external connector TB1 is the external dry contact input. Resistor R9 and Diode clamp D3 are present to reduce the potential of hardware damage from high voltage/high current external sources. R10 is a current limiting resistor on the signal generated by the microprocessor to detect if the dry contact is open or closed. R10 is a current limiting resistor for the red LED D4.

Section 15.203 Compliance

The WiTemp+ has a factory installed precision length wire antenna permanently soldered to the circuit board. Therefore the WiTemp+ complies with this section.

Section 15.247 (a)(1)/RSS-247 Section 5.1(a) Compliance

a. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies.

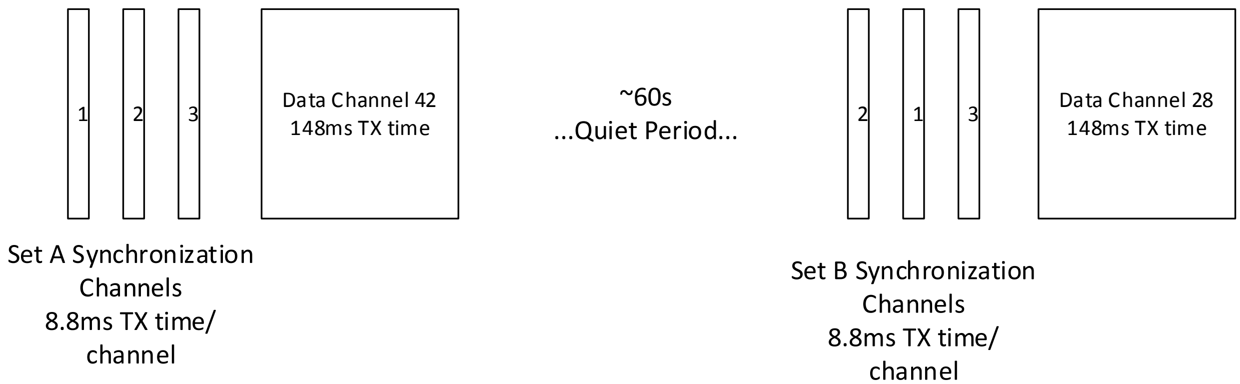
The WiTemp+ sequentially iterates through the pseudo-random list of data channel frequencies as listed below:

Data Channel #	Data Channel Frequency (Hz)
42	904964000
28	904124000
33	904404000
24	903844000
36	904572000
45	905132000
16	903396000
10	903004000
4	902668000
23	903788000
13	903172000
35	904516000
48	905300000
5	902724000
47	905244000
32	904348000
8	902892000
21	903676000
39	904740000
30	904236000
14	903228000
1	902500000

44	905076000
27	904012000
7	902836000
3	902612000
26	903956000
11	903060000
20	903620000
46	905188000
2	902556000
6	902780000
31	904292000
38	904684000
43	905020000
12	903116000
25	903900000
41	904908000
29	904180000
22	903732000
34	904460000
18	903508000
15	903284000
9	902948000
19	903564000
40	904852000
17	903452000
37	904628000

The WiTemp+ sequentially iterates through the pseudo-random list of synchronization channel frequencies as listed below:

Set	Synchronization Channel #	Synchronization Channel Frequency (Hz)
A	1	903340000
	2	904068000
	3	904796000
B	2	904068000
	1	903340000
	3	904796000
C	2	904068000
	3	904796000
	1	903340000



The above diagram shows how three synchronization channel transmissions occur before each data channel transmission, followed by a ~60s quiet period before the next set of transmissions occur, which is followed by another ~60s quiet period, etc.

b. Each frequency must be used equally on the average by each transmitter.

The WiTemp+ has been designed to reasonably and equitably utilize all 51 hopping channels within the limitations of implementing a channel hopping scheme having only a RF transmit capability that prevents it from receiving any external synchronization signals, and that is robust enough to be used for its intended location and use as described in a later section where multiple WiTemp+ devices may be deployed within RF range of each other and communicating to a single Gateway receiver.

In Normal mode the WiTemp+ will transmit a reading on average once per minute. Since there are 48 data channels it will take the system approximately 48 minutes to iterate once through the entire pseudorandom list of data channel frequencies. As described in the bandwidth calculation section, each data channel will transmit once for a maximum of 148ms for each complete iteration of all data channels. Each of the three synchronization channels will transmit once for each of the 48 data channel transmissions at 8.8ms/transmission for a total of 422.4ms for each complete iteration of all data channels. On average, the bandwidth utilization over time for each data channel frequency is 148ms/48 minutes = 0.0051% and the average bandwidth utilization over time for each synchronization channel frequency is 422.4ms/48 minutes = 0.015%.

All data channels use an equal amount of bandwidth on average. All synchronization channels also use an equal amount of bandwidth on average. Additionally, the synchronization channels are used on average within the same order of magnitude as the data channels. While it was considered to pad the transmission time on the data channels to more closely match the average time used on the synchronization channels, doing so would only cause more overall RF bandwidth utilization across the spectrum used by the WiTemp+, and it would consume additional system power, reducing battery life.

c. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters.

The WiTemp+ is not a receiver. The Gateway receiver has been configured to match the hopping channel bandwidths of the WiTemp+ transmitter.

d. The system receivers shall shift frequencies in synchronization with the transmitted signals.

The Gateway receiver listens on one of the 3 synchronization channel frequencies waiting to receive a synchronization message. Once it receives the synchronization message it immediately switches to the data channel frequency specified in the synchronization message. After receiving the data message, or on a timeout, the Gateway will change back to the original synchronization channel frequency to listen for the next message.

Location and Intended Use

The WiTemp+ is marketed as a Class A device for use in a commercial, industrial, or business environment as an optional component that is one part of a portfolio of hardware and software solutions for monitoring energy utilization and food safety compliance. A typical use case would be for a restaurant to use several WiTemp+ to monitor the temperature of a food cart, and the temperature of multiple refrigeration units.