Low Power Module

915 MHz ISM Band RF Transceiver Module

KEY FEATURES

- Receiver sensitivity: -140 dBm
- Transmit power: 100 mW
- TX Peak Current: 125 mA
- RX Peak Current: 10 mA
- Sleep current: 10 **µ**A
- Adjustable I/O voltage:
  1.65 V to 5.5 V
- Selectable digital interface:
  UART or SPI

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SYSTEM OVERVIEW

Specifications

Frequency band	915 MHz ISM (902 MHz – 928 MHz)
On-air data rate	90 bps to 37.5 kbps
Output power	Programmable: +20 to -4 dBm in .6 dB steps
Supply Voltage	3.5 V to 5.5 V
I/O Voltage	1.65 V to 5.5 V
Tx Current	125 mA
Rx Current	10 mA
Sleep Current	10 µA
Dimensions	21 mm x 25.5 mm
Operating Temperature	-40 to 85° C (industrial)
UART baud rate	600 to 230400 (non standard rates also supported)
SPI data rate	3.5 MHz max

Pin Descriptions

Pin #	Name	Type	Description
1	GND	Ground	
2	BUS_SEL	I (VCC voltage level)	When low, UART interface is used. When high, SPI interface is used.
3	{reserved}	NC	Not connected
4	{reserved}	NC	Not connected
5	{reserved}	NC	Not connected
6	nRESET	I	External reset pin, active low
7	VCC	Output voltage	Power digital. Used to drive BUS_SEL
8	VCCIO	Input voltage	Power digital. Configures logic voltage for external IO interfaces.
9	IO2	IO	General purpose IO
10	WAKEUP	I	Wakeup control signal
11	IO0	IO	General purpose IO
12	IO1	IO	General purpose IO
13	nCS	I	SPI interface: chip select, active low
14	CLK	I	SPI interface: Serial clock. Maximum 3.5 MHz
15	MISO/TX	O	SPI interface: Serial out UART interface: module Tx
16	MOSI/RX	I	SPI interface: Serial in UART interface: module Rx
17	Vsupply	Input voltage	Module supply voltage
18	GND	Ground	
19	GND	Ground	
20	GND	Ground	
21	GND	Ground	
22	GND	Ground	
23	Antenna	RF IO	RF Antenna path

PCB LAYOUT REQUIREMENTS

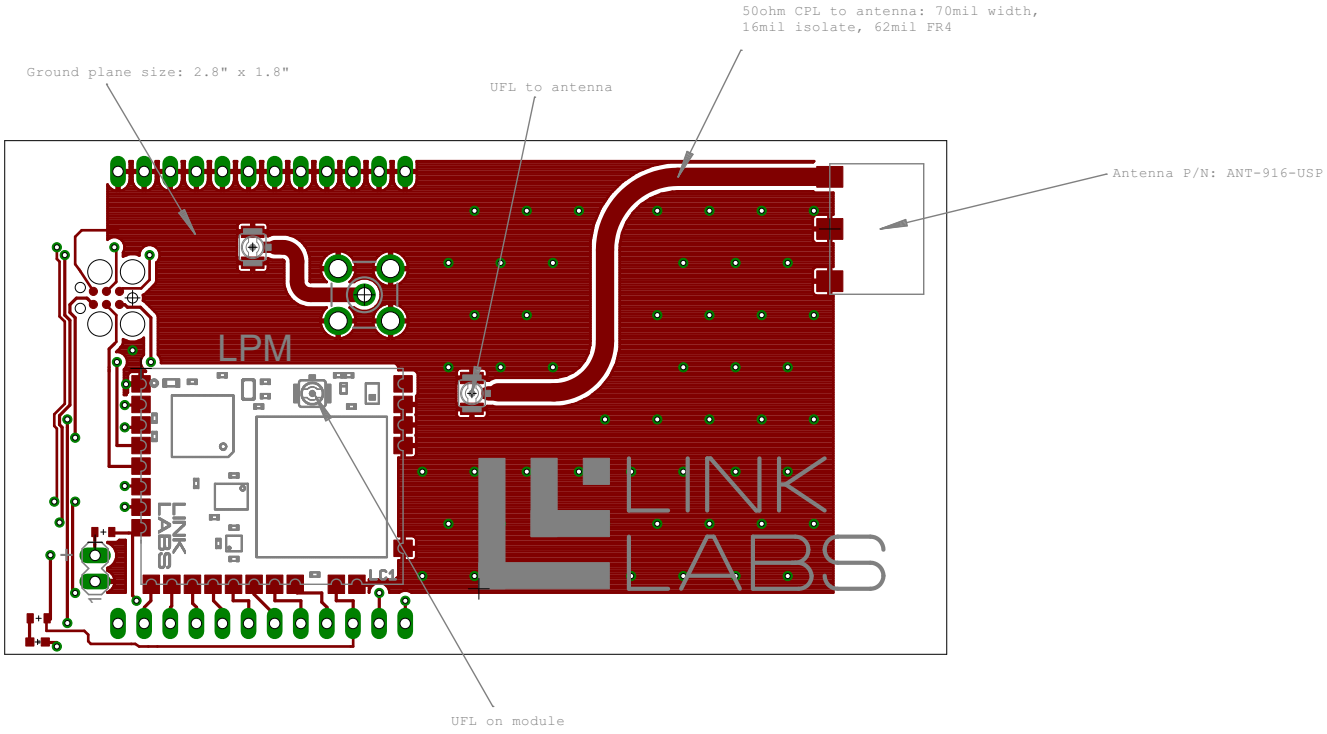
Since this module and its associated set of approved antennas has been certified by the FCC and Industry Canada (IC) as a Modular Radio, the end user is authorized to integrate this module into an end-product, and is solely responsible for the Unintentional Emissions levels produced by the end-product.

In order to preserve the Modular Radio certifications, the integrator of the module must abide by the PCB layout recommendations outlined in the following paragraphs. Any divergence from these recommendations will invalidate the modular radio certifications and require the integrator to re-certify the module and/or end product.

The module must be used with one of the approved antennas:

- ½-wave center-fed dipole antennas tuned for 915 MHz with a maximum gain of 1.9 dBi or less, such as ANT-916-CW-HWR-SMA
- Chip Antennas with maximum gain of 0.3 dBi or less, such as ANT-916-USP

CHIP ANTENNA REFERENCE DESIGN



A reference layout design can be found in the Gerber file, *LL_LP_ChipAnt Reference.zip*.

Design Guidelines

When using a chip antenna, this module can only be used with a host antenna circuit trace layout design in strict compliance with the diagram above and the following design parameters:

1. Trace layout and dimensions
   a) 50 Ohm CPL to antenna
      i) 70 mil width
      ii) 16 mil isolate
      iii) 62 mil FR4
   b) Chip antenna gain must 0.3 dBi or less

Design Verification

1. Output Power Measurement
   a) Place module in test transmit mode (continuous transmit)
   b) Connect UFL on module to spectrum analyzer
   c) Set center frequency of spectrum analyzer to DUT frequency
   d) Place spectrum analyzer in zero-span mode, with RBW set to 1MHz
   e) Measure power level
   f) **Pass criteria**: Measured power level must be between +18dBm and +20dBm

2. Antenna Impedance Matching
   a) Calibrate Vector Network Analyzer (VNA) and test cables with at 915MHz
   b) Connect to antenna UFL and measure S11 of antenna (P/N: ANT-916-USP)
   c) If SWR is greater than 2, add passive match elements as needed to improve match
   d) **Pass criteria**: SWR < 2

3. EIRP Test
   a) In an environment suitably free of reflectors (e.g. anechoic chamber), position a transmit antenna and receive antenna (of known gain) at a fixed distance
   b) Connect a signal generator tuned to 915MHz to the transmit antenna and set output power to 0dBm
   c) Connect a spectrum analyzer to the receive antenna with the following settings: CF = 915MHz, SPAN = 0Hz, RBW = 500kHz
   d) Measure received power
   e) Determine path loss with the following equation:

$$PL = P_{tx} - P_{rx} = (0 - L_{cable} + G_{tx\ antenna}) - (P_{rx_{meas}} - L_{cable} + G_{rx\ antenna})$$

   f) Replace TX antenna/source with DUT in continuous TX mode
   g) Measure received power
   h) Determine EIRP with the following equation:

$$EIRP = PL + P_{rx} = PL + (P_{rx_{meas}} - L_{cable} + G_{rx\ antenna})$$

i) **Pass criteria**: EIRP between +19.2dBm and +20.3dBm

Production Verification

1. Output Power Measurement
   a) Place module in test transmit mode (continuous transmit)
   b) Connect UFL on module to spectrum analyzer
   c) Set center frequency of spectrum analyzer to DUT frequency
   d) Place spectrum analyzer in zero-span mode, with RBW set to 1MHz
   e) Measure power level
   f) **Pass criteria**: Measured power level must be between +17dBm and +18dBm

HOST INTERFACE

The communication between the Link Labs module and an external host controller is a point-to-point Master/Slave communications protocol using a UART connection. The following chapters describe the message flow and message format.

Message Flow

The host interface defines two different message types that are exchanged between the host controller and the radio module:

1. Command packet
2. Response packet

The host initiates communication (protocol master) by sending 1 command packet, and waiting for a response before sending another command packet. The slave responds immediately to 1 command packet with 1 response packet.

Any data that flows from the slave to the master must be done in the form of a polled request from the master to the slave. To allow devices to be put into low power sleep modes, an interrupt should be provisioned from the slave device to the host device, after which the master should poll the slave device.

Message Format

Command Packet

Byte Number	Description	Comments
0	Start of Frame	Always equal to 0xC4
1	Command Byte	Specifies which master command is contained in this message.
2	Message number	An 8-bit number incremented by the master device. Expected to rollover: 253, 254, 255, 0, 1, 2, …
3	Payload Length	Total number of bytes in the payload. Valid range is 0-255.
	Payload Byte 0	
	Payload Byte 1	
	Payload Byte 2	
…	…	
Payload Length +5	Checksum Byte	An 8-bit checksum. See the next section for details on computing the checksum.

Response Packet

Byte Number	Description	Comments
0	Start of Frame	Always equal to 0xC4
1	Command Byte	Specifies which master command is being replied to.
2	Message number	Specifies the message number that is being replied to.
3	ACK Byte	00 = ACK: Command Acknowledged 01 = NACK: Command not supported 02 = NACK: Incorrect Checksum 03 = NACK: Payload length out of range 04 = NACK: Payload value out of range 05: …
4	Payload Length	Total number of bytes in the response payload. Valid range is 0-255.
	Payload Byte 0	
	Payload Byte 1	
	Payload Byte 2	
…	…	
Payload Length +6	Checksum Byte	An 8-bit checksum byte. See the next section for details on computing the checksum.

Checksum

The checksum byte will be computed on all bytes that precede the checksum byte. The checksum will be computed as follows:

```
/**
 * @brief
 *   compute_checksum
 *
 * @param[in] buf
 *   byte array to compute checksum on
 *
 * @param[in] len
 *   size of the byte array in bytes
 *
 * @return
 *   The 8-bit checksum
 */
static uint8_t compute_checksum(uint8_t* buf, uint16_t len)
{
    uint16_t i;
    uint32_t checksum=0;

    if (buf == NULL)
    {
        return(0);
    }

    for(i=0; i<len; i++)
    {
        checksum += buf[i];
    }

    return((uint8_t)(checksum&0xFF));
}
```

HOST APPLICATION INTERFACE

Reset

The module reset is controlled via pin 6. To apply an external reset source to this pin, it is required to only drive this pin low during reset, and let the internal pull-up en- sure that reset is released.

Wakeup

The wakeup procedure is required when the module is in sleep mode. The wakeup signal is issued with a logic high pulse of at least 60 µs in duration.

Sleep

Command Byte: 0x14 (20)

Command Payload:

None

Response Payload:

None

Issuing the sleep command disables the radio and puts the device into its lowest power state. The host interface is disabled during sleep mode and communication will only resume by following the wakeup procedure.

Firmware Version

Command Byte: 0x00 (0)

Command Payload:

None

Response Payload:

Payload Length	4 bytes
Payload Byte 0	Major version
Payload Byte 1	Minor version
Payload Byte 2	Tag most significant byte
Payload Byte 3	Tag least significant byte

Radio Channel

Command Byte: 0x01 (1)

Command Payload:

Payload Length	1 byte
Payload Byte 0	RF channel for the ISM band between 902 and 928 MHz. Channels are 500 kHz wide in 500 kHz steps between channel 0 (902.65 MHz) and 49 (927.15 MHz).

Response Payload:

None

Packet Send

Command Byte: 0x30 (48)

Command Payload:

Payload Length	n bytes
Payload Byte 0	User specified payload
Payload Byte …	“
Payload Byte …	“
Payload Byte n-1	“

Response Payload:

None

Packet Receive

Command Byte: 0x40 (64)

Command Payload:

None

Response Payload:

Payload Length	n bytes
Payload Byte 0	Received payload
Payload Byte …	“
Payload Byte …	“
Payload Byte n-1	“

Packet Receive with RSSI

Command Byte: 0x41 (65)

Command Payload:

None

Response Payload:

Payload Length	n + 1 bytes
Payload Byte 0	RSSI
Payload Byte 1	Received payload
Payload Byte …	“
Payload Byte …	“
Payload Byte n-1	“

Rssi[dBm] = –137 + rssi

SYSTEM OPERATION MODES

The module can operate in one of four modes: End-node, Coordinator, Gateway, and Peer-to-peer. When choosing a high-level role, the module will manage the MAC layer to optimize transmit power, data rate, and current consumption.

End-node

An end-node is the most basic operating mode in the network. This mode is optimized for low-power long-range two-way communication. In this mode, the module stays in a deep sleep mode the majority of the time. The module only wakes up for the minimum amount of time required to maintain connectivity.

Coordinator

The coordinator operating-mode is an extended mode where an end-node can also act as relay between other nodes and the gateway. This allows for a star of stars or clustered-tree topology to extend the overall wireless range of the network.

Gateway

The gateway operating-mode serves as the center node in the star network. It sends periodic beacons and aggregates messages from the nodes in the network. This mode is typically used for a concentrator or gateway in the system.

Peer-to-Peer

The peer-to-peer operating-mode is used when there are only 2 nodes in the network.

REGULATORY COMPLIANCE INFORMATION

To satisfy FCC RF Exposure requirements for mobile and base station transmission devices, a separation distance of 20cm or more should be maintained between the antenna of this device and persons during operation. To ensure compliance, operation at closer than this distance is not recommended.

The antenna(s) used for this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

OEM Labeling Requirements for End-Product

The module is labeled with its own FCC ID and IC Certification Number. The FCC ID and IC certification numbers are not visible when the module is installed inside another device, as such the end device into which the module is installed must display a label referring to the enclosed module. The final end product must be labeled in a visible area with the following:

"Contains Transmitter Module FCC ID:
"Contains Transmitter Module IC:

or

"Contains FCC ID:
"Contains IC:

The OEM of the module must only use the approved antenna(s) listed above, which have been certified with this module.

OEM End Product User Manual Statements

The OEM integrator should not provide information to the end user regarding how to install or remove this RF module or change RF Related parameters in the user manual of the end product.

Other use manual statements may apply.

Federal Communication Commission Interference Statement

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

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

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.

FCC CAUTION: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

Conformité aux normes FCC Cet équipement a été testé et trouvé conforme aux limites pour un dispositif numérique de classe B, conformément à la Partie 15 des règlements de la FCC. Ces limites sont conçues pour fournir une protection raisonnable contre les interférences nuisibles dans une installation résidentielle.

Cet équipement génère, utilise et peut émettre des fréquences radio et, s'il n'est pas installé et utilisé conformément ment aux instructions du fabricant, peut causer des interferences nuisibles aux communications radio.

Rien ne garantit cependant que l'interférence ne se produira pas dans une installation particulière. Si cet équipement provoque des interférences nuisibles à la réception radio ou de télévision, qui peut être déterminé en comparant et en l'éteignant, l'utilisateur est encouragé à essayer de corriger les interférence par une ou plusieurs des mesures suivantes:

- Réorienter ou déplacer l'antenne de réception.
- Augmenter la distance entre l'équipement et le récepteur.
- Branchez l'appareil dans une prise sur un circuit différent de celui auquel le récepteur est connecté.
- Consultez votre revendeur ou un technicien radio / TV pour assistance.Avertissement

Les changements ou modifications à cet appareil sans expressément approuvée par la partie responsable de conformité pourraient annuler l'autorité de l'utilisateur de faire fonctionner cet équipement.

Industry Canada Statements

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

This device complies with RSS-210 of the Industry Canada Rules. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

This device has been designed to operate with the antennas listed in the filing, and having a maximum gain of 1.9 dBi. Antennas not included in this list or having a gain greater than 1.9 dBi are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

Cet appareil est conforme avec Industrie Canada exempt de licence Rss standard(s). Son fonctionnement est soumis aux deux conditions suivantes : (1) cet appareil ne peut causer d'interférences, et (2) cet appareil doit accepter toute interférence, y compris des interférences qui peuvent provoquer un fonctionnement indésirable du périphérique.

Ce dispositif est conforme à la norme CNR-210 d'Industrie Canada applicable aux appareils radio exempts de licence. Son fonctionnement est sujet aux deux conditions suivantes: (1) le dispositif ne doit pas produire de brouillage préjudiciable, et (2) ce dispositif doit accepter tout brouillage reçu, y compris un brouillage susceptible de provoquer un fonctionnement indésirable.

Pour réduire le risque d'interférence aux autres utilisateurs, le type d'antenne et son gain doivent être choisies de façon que la puissance isotrope rayonnée équivalente (e.i.r.p) ne dépasse pas celle admise pour une communication réussie.

Cet appareil a été conçu pour fonctionner avec les antennes énumérées ci-dessous, et ayant un gain maximum de 6,0 dB. Antennes pas inclus dans cette liste ou ayant un gain supérieur à 6,0 dB sont strictement interdites pour une utilisation avec cet appareil. L'impédance d'antenne requise est de 50 ohms.

IMPORTANT NOTICE

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