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Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



Anaren Integrated Radio (AIR)

Low-power RF modules, firmware & development tools that make it easy to 'go wireless'



Anaren Integrated Radio

A2500R24x User's Manual

Release Date: 11/15/16

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USER'S MANUAL

Models A2500R24A and A2500R24C

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1. Overview

The A2500R24C and A2500R24A are surface mount modules with an integrated crystal, internal voltage regulator, matching circuitry and filtering. The A2500R24A has an integral antenna, whereas the A2500R24C utilizes an external antenna through a U.FL connector (see Table 1). The modules operate in the global non-licensed 2.4GHz ISM/SRD frequency band and are ideal for achieving low power wireless connectivity without having to deal with extensive RF, antenna design and regulatory compliance, and provide quick time to market. The modules are 100% tested to provide consistent performance.

The A2500R24C and A2500R24A have received regulatory approvals for modular devices in the United States (FCC), Canada (IC) and Europe (ETSI). The modular approval allows the OEM or end user to place either an A2500R24A or an A2500R24C with an approved antenna inside a finished product without having to perform costly regulatory testing for an intentional radiator. Section 2.3 has information on the requirements the end user/integrator must fulfill to use the modules without intentional radiator regulatory testing.

The A2500R24C and A2500R24A are based on the CC2500 transceiver IC from Texas Instruments. All control lines for the transceiver are provided at module level for full control of its operation. Please see the CC2500 data sheet (www.ti.com) for how to control the modules.

The A2500R24C and A2500R24A modules both measure 9x12x2.5mm and are footprint compatible with each other.

1.1. A2500R24A

The A2500R24A has an integral antenna, providing high efficiency and near omni-directional radiation pattern. This approach offers the lowest system cost when the application allows collocation of radio and antenna.

1.2. A2500R24C

The A2500R24C has a compact antenna connector that allows for locating the antenna away from the module due to form/function or in order to exit a metal enclosure, see Figure 8 – Figure 9 for more information on antenna location and enclosure considerations.

Table 1 Approved Antennas

| Item | Part Number | Manufacturer | Type | Gain |
|------|----------------------------|--------------|--------------------------|------|
| 1 | Integral part of A2500R24A | Anaren | Integral Antenna | 2 |
| 2 | 66089-2406 | Anaren | Monopole whip, 6mm lead | 3 |
| 3 | 66089-2430 | Anaren | Monopole whip, 30mm lead | 3 |
| 4 | 66129-2480 | Anaren | Patch. 80mm lead | 5 |

1.3. Features

Features:

- Frequency range: 2400 – 2483.5 MHz
- Ultra small package size 9mm x 12mm x 2.5mm
- Shielded Package
- 1.8 to 3.6 V operation
- SPI Interface
- RoHS Compliant
- Approximate weight 0.4 grams
- LGA Footprint
- Low Power Consumption
- Digital RSSI output
- Programmable channel filter bandwidth
- Programmable output power up to +1 dBm
- High sensitivity (–104 dBm at 2.4 kBaud, 1% packet error rate)
- Low current consumption (13.3 mA in RX, 250 kBaud, input well above sensitivity limit)
- Separate 64-byte RX and TX data FIFOs
- Fast startup time: 250µs from SLEEP to Rx or Tx mode
- Data Rate: 1.2 – 500 Kbit/Sec
- Programmable data rate from 1.2 to 500 kBaud
- Sleep state: 0.4µA
- Idle State: 1.5mA

Benefits Summary:

- Operating temperature -40 to +85C
- 100% RF Tested in production
- Common footprint for all family members
- No RF engineering experience necessary
- Only requires a 2 layer PCB implementation
- Excellent receiver selectivity and blocking Performance
- Suitable for frequency hopping and multichannel systems due to a fast settling frequency synthesizer with 90 µs settling time
- FCC 15.247, IC RSS-210 and IC RSS-Gen certified.
- Compliant with ETSI EN 300 328
- No regulatory “Intentional radiator” testing required for integrating module into end product. Simple certification labeling replaces testing.

1.4. Theory of Operation

The A2500R24C and A2500R24A are for low power wireless applications in the 2400MHz to 2483.5MHz global ISM/SRD band. The devices can be used to implement a variety of networks, including; point to point, point to multipoint, peer to peer and mesh networks.

Figure 1 and Figure 2 show the functionality of A2500R24A and A2500R24C, respectively. Both modules operate in a similar manner except with respect to the antenna, in that the A2500R24A module communicates through a built-in antenna, whereas the A2500R24C communicates through an external antenna attached to a U.FL connector.

The modules interface to an application microcontroller via an SPI bus. Physical and MAC layer functionality are accessed via the SPI bus and through addressable registers as well as execution commands. Data received or to be transmitted are also accessed through the SPI bus and are implemented as FIFO registers (64 bytes each for Tx and Rx).

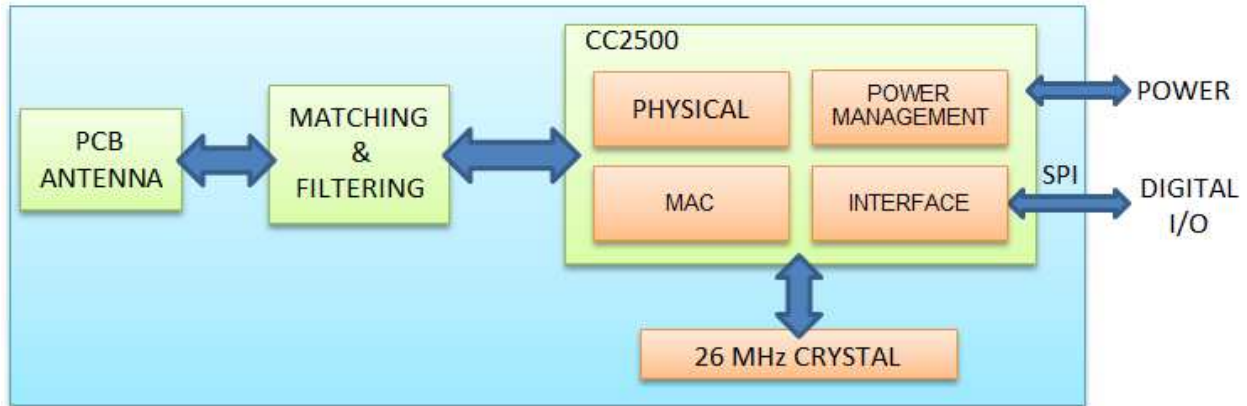


Figure 1 The functionality of the A2500R24A, using an integral antenna

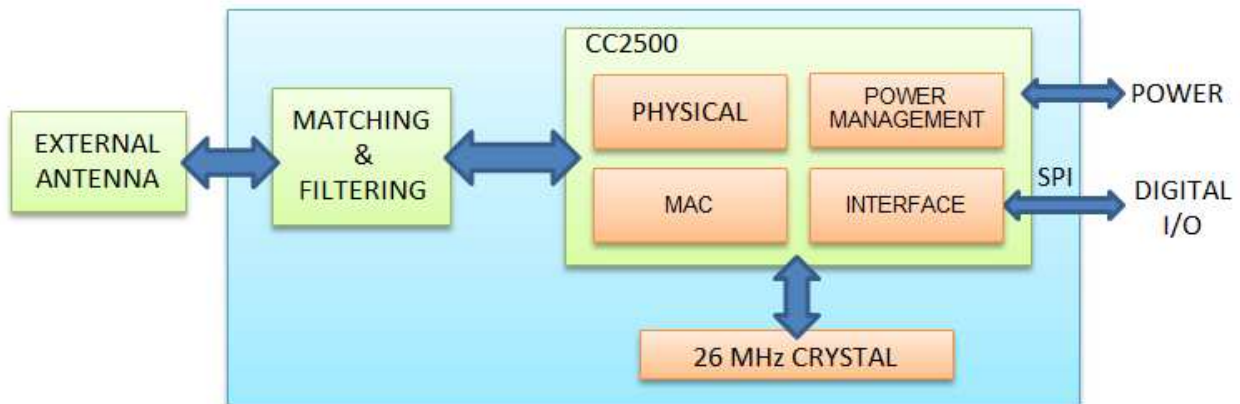


Figure 2 The functionality of the A2500R24C, using an external antenna

The description of the functional blocks shown in Figure 1 and Figure 2 is given as follows:

- **Antenna**
 - The antenna couples energy between the air and the module. For applications where installations are done by an end user (non-professional), an omni-directional antenna pattern is desired such that the application will work equally well in any direction. Similarly for peer to peer or point to multipoint applications an omni-directional pattern is desired such that all nodes have a fair chance of communicating. The A2500R24A module has an integral antenna that is near omni-directional, whereas the A2500R24C has approved antenna options ranging from near omni-directional to shaped front/back patterns (useful for inline, professional installations). Note that the end radiation pattern depends not only on the antenna, but also on the ground plane, enclosure and installation environment.
- **Matching & Filtering**
 - Matching provides the correct loading of the transmit amplifier to achieve the highest output power as well as the correct loading for the receive LNA to achieve the best sensitivity.

- Filtering removes spurious signals to comply with regulatory requirements, provides reduced susceptibility to power supply and digital noise, and filters out RF and high frequency noise from the communication data and control link.
- **Physical**
 - The physical layer provides conversions between data, symbol and RF signal.
- **MAC**
 - The MAC layer is part of the Logical Link Layer and provides frame handling, addressing and medium access services.
- **Microcontroller Interface**
 - The microcontroller interface exposes registers and commands for the physical and MAC layers to a microcontroller.
- **Power Management**
 - Power management ensures a stable supply for the internal functions as well as providing means for a low power sleep mode (in which case, most of the transceiver is powered off).

The block diagram for the CC2500 transceiver chip is provided in Figure 3 for reference.

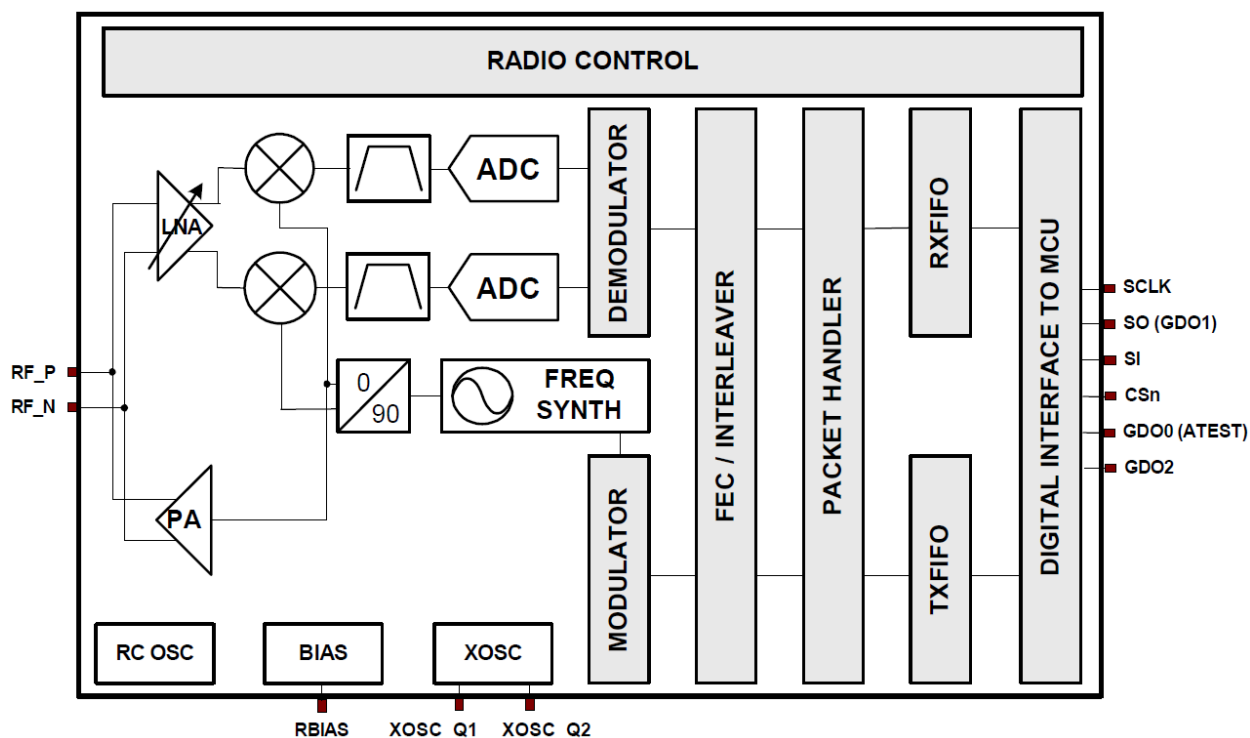


Figure 3 Transceiver IC block diagram.

To transmit, a frame of data is placed in the FIFO; this may include a destination address. A transmit command is given, which will transmit the data according to the initial setup of the registers. To receive data, a receive command is given, which enables the unit to “listen” for a

transmission and when one occurs put the received frame in the FIFO. When neither transmit nor receive is required, the device can enter either an Idle mode, from which it can quickly re-enter receive/transmit mode, or a low power sleep mode, from which a crystal startup is also required prior to a receive/transmit operation.

1.4.1. Typical Flow

Figure 4 shows the normal operation flow diagram after initial setup of the registers for desired operation. In applications of infrequent data transmissions the transceiver would be in “sleep” mode to save power. From there, it would awaken and then enter “idle” mode. As part of the wake up process, the crystal oscillator is started (~250µs) and the digital microcontroller interface is powered up. Before transmit or receive, the frequency synthesizer needs to be started (“FS_Wakeup”) and, having been powered off (or idle for a while), the control loop of the VCO/PLL needs to be calibrated (“calibrate”).

A data frame is loaded into the transmit FIFO and the “TX” mode is entered. The transceiver will transmit the data and enter “idle” mode after completion. When transmit is complete “RX” mode is entered to wait for the acknowledge frame. Once a frame is received the transceiver will again enter “idle” mode. If no acknowledge frame is received within a given timeout the data frame would be re-transmitted. If the acknowledge frame indicates that the data was received, the next data frame will be transmitted. After the last data frame has been transmitted successfully, the transceiver will again be put in “sleep” mode.

1.5. Applications

- Wireless alarm and security systems
- Industrial monitoring and control
- Wireless sensor networks
- AMR – Automatic Meter Reading
- Home and building automation
- Wireless game controllers
- Wireless audio
- Wireless keyboard and mouse
- RF enabled remote controls
- Existing applications where simple upgrade to wireless is desired

1.6. Configuration

Table 2 lists the radio module configuration parameters, and the level of configurability by the user.

Legend:

| |
|--|
| Certification is valid for any value chosen |
| Use the provided certified settings as other may degrade performance |
| Any modification of this value is a violation of the certification and the customer is responsible for obtaining their own certification |
| Unused/undocumented function. The provided default value must be written. No assumption should be made on the value read from this field |
| Read only register (burst mode read only, command strobcs otherwise). |

Medium Access

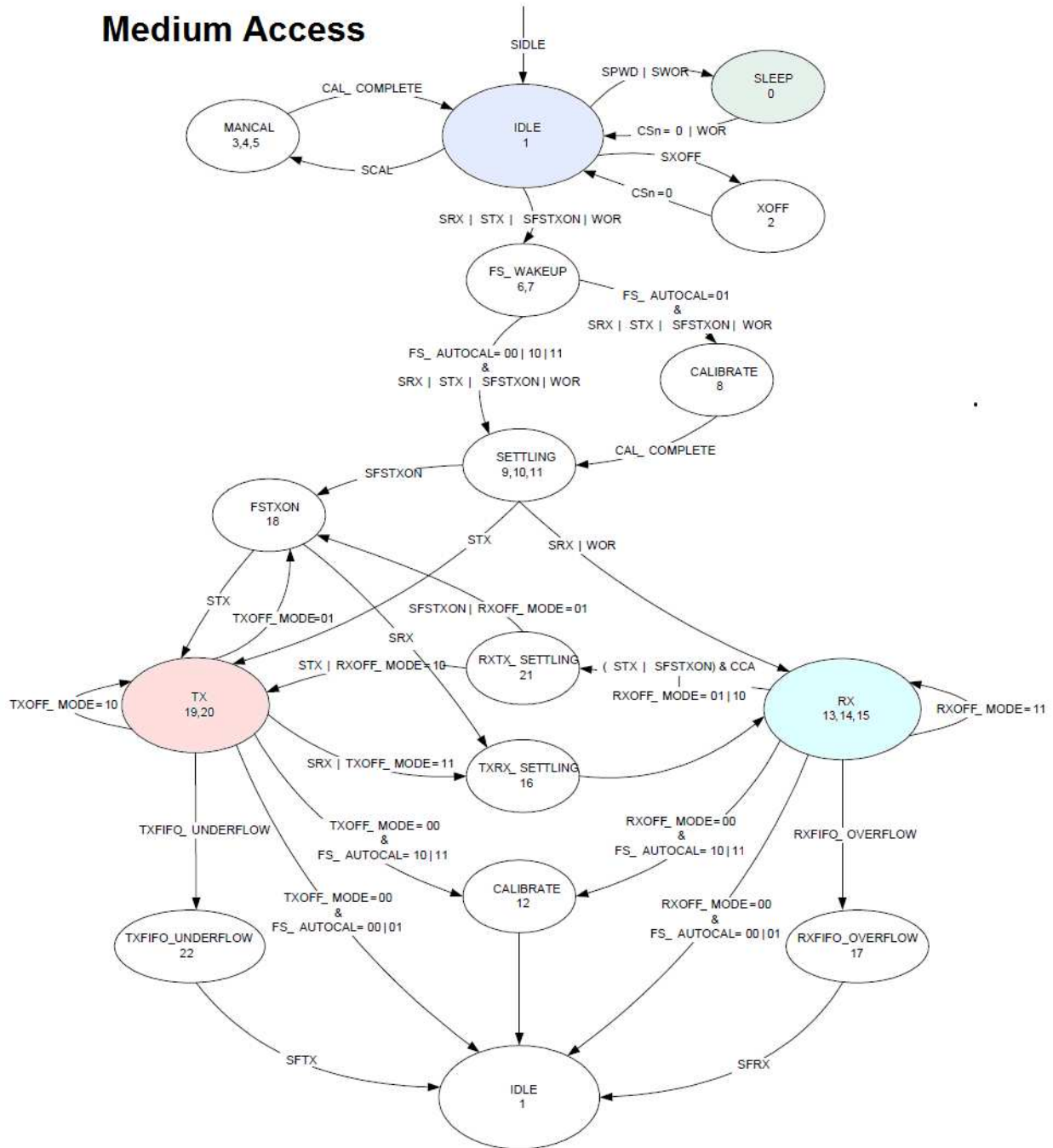


Figure 4 Transceiver state diagram

Table 2 Configuration Parameters

| Register Name | Register Address (Hex) | Retained during sleep | Bit Fields Within Register | | | | | | | | |
|----------------|------------------------|-----------------------|----------------------------|----------------------|-----------------------|-----------------|-------------------|-----------------------|----------------|---------------|--|
| | | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| IOCFG2 | 00 | 1 | 0 | GDO2_INV | GDO2_CFG | | | | | | |
| IOCFG1 | 01 | 1 | GDO_DS | GDO1_INV | GDO1_CFG | | | | | | |
| IOCFG0 | 02 | 1 | GDO0_TEMP_SENSOR_ENABLE | GDO0_INV | GDO0_CFG | | | | | | |
| FIFOTHR | 03 | 1 | Reserved | ADC_RETENTION | CLOSE_IN_RX | | | FIFO_THR | | | |
| SYNC1 | 04 | 1 | SYNC_MSB | | | | | | | | |
| SYNC0 | 05 | 1 | SYNC_LSB | | | | | | | | |
| PKTLEN | 06 | 1 | PACKET_LENGTH | | | | | | | | |
| PKTCTRL1 | 07 | 1 | PQT | | | | 0 | CRC_AUTOFLUSH | APPEND_STATUS | ADR_CHK | |
| PKTCTRL0 | 08 | 1 | 0 | WHITE_DATA | PKT_FORMAT | | 0 | CRC_EN | LENGTH_CONFIG | | |
| ADDR | 09 | 1 | DEVICE_ADDR | | | | | | | | |
| CHANNR | 0A | 1 | CHAN | | | | | | | | |
| FSCTRL1 | 0B | 1 | 0 | 0 | FREQ_IF | | | | | | |
| FSCTRL0 | 0C | 1 | FREQOFF | | | | | | | | |
| FREQ2 | 0D | 1 | FREQ[23:22]=0 | | | | FREQ[21:16] | | | | |
| FREQ1 | 0E | 1 | FREQ[15:8] | | | | FREQ[7:0] | | | | |
| FREQ0 | 0F | 1 | FREQ[7:0] | | | | | | | | |
| MDMCFG4 | 10 | 1 | CHANBW_E | | CHANBW_M | | DRATE_E | | | | |
| MDMCFG3 | 11 | 1 | DRATE_M | | | | | | | | |
| MDMCFG2 | 12 | 1 | DEM_DCFILT_OFF | MOD_FORMAT | | | MANCHESTER_EN | SYNC_MODE | | | |
| MDMCFG1 | 13 | 1 | FEC_EN | NUM_PREAMBLE | | | 0 | CHANSPC_E | | | |
| MDMCFG0 | 14 | 1 | CHANSPC_M | | | | | | | | |
| DEVIATN | 15 | 1 | 0 | DEVIATION_E | | | 0 | DEVIATION_M | | | |
| MCSM2 | 16 | 1 | 0 | RX_TIME_RSSI | | RX_TIME_QUAL | RX_TIME | | | | |
| MCSM1 | 17 | 1 | 0 | CCA_MODE | | RXOFF_MODE | | TXOFF_MODE | | | |
| MCSM0 | 18 | 1 | 0 | FS_AUTOCAL | | | PO_TIMEOUT | | PIN_CTRL_EN | XOSC_FORCE_ON | |
| FOCFG | 19 | 1 | 0 | FOC_BS_CS_GATE | | FOC_PRE_K | | FOC_POST_K | | FOC_LIMIT | |
| BSCFG | 1A | 1 | BS_PRE_K | | BS_PRE_KP | | BS_POST_K | | BS_POST_KP | | |
| AGCCTRL2 | 1B | 1 | MAX_DVGA_GAIN | | | MAX_LNA_GAIN | | | MAGN_TARGET | | |
| AGCCTRL1 | 1C | 1 | 0 | AGC_LNA_PRIORITY | CARRIER_SENSE_REL_THR | | | CARRIER_SENSE_ABS_THR | | | |
| AGCCTRL0 | 1D | 1 | HYST_LEVEL | | WAIT_TIME | | AGC_FREEZE | | FILTER_LENGTH | | |
| WOREVT1 | 1E | 1 | EVENT0[15:8] | | | | | | | | |
| WOREVT0 | 1F | 1 | EVENT0[7:0] | | | | | | | | |
| WORCTRL | 20 | 1 | RC_PD | EVENT1 | | | RC_CAL | 0 | WOR_RES | | |
| FREND1 | 21 | 1 | LNA_CURRENT | | LNA2MIX_CURRENT | | LODIV_BUF_CURRENT | | MIX_CURRENT | | |
| FREND0 | 22 | 1 | 0 | LODIV_BUF_CURRENT_TX | | | 0 | PA_POWER | | | |
| FSCAL3 | 23 | 1 | FSCAL3[7:6] | | | CHP_CURR_CAL_EN | | FSCAL3[3:0] | | | |
| FSCAL2 | 24 | 1 | 0 | VCO_CORE_H_EN | | | FSCAL2 | | | | |
| FSCAL1 | 25 | 1 | 0 | FSCAL1 | | | | | | | |
| FSCAL0 | 26 | 1 | 0 | FSCAL0 | | | | | | | |
| RCCTRL1 | 27 | 1 | 0 | RCCTRL1 | | | | | | | |
| RCCTRL0 | 28 | 1 | 0 | RCCTRL0 | | | | | | | |
| FSTEST | 29 | 0 | FSTEST | | | | | | | | |
| PTEST | 2A | 0 | PTEST | | | | | | | | |
| AGCTEST | 2B | 0 | AGCTEST | | | | | | | | |
| TEST2 | 2C | 0 | TEST2 | | | | | | | | |
| TEST1 | 2D | 0 | TEST1 | | | | | | | | |
| TEST0 | 2E | 0 | TEST0[7:2] | | | | | | VCO_SEL_CAL_EN | TEST0[0] | |
| PARTNUM | 30 | 1 | PARTNUM | | | | | | | | |
| VERSION | 31 | 1 | VERSION | | | | | | | | |
| FREQOFF_EST | 32 | 0 | FREQOFF_EST | | | | | | | | |
| LQI | 33 | 0 | CRC_OK | LQI_EST | | | | | | | |
| RSSI | 34 | 0 | RSSI | | | | | | | | |
| MARC_STATE | 35 | 0 | MARC_STATE | | | | | | | | |
| WORTIME1 | 36 | 0 | TIME[15:8] | | | | | | | | |
| WORTIME0 | 37 | 0 | TIME[7:0] | | | | | | | | |
| PKTSTATUS | 38 | 0 | CRC_OK | CS | PQT_REACHED | CCA | SFD | GDO2 | GDO0 | | |
| VCO_VC_DAC | 39 | 0 | VCO_VC_DAC | | | | | | | | |
| TXBYTES | 3A | 0 | TXFIFO_UNDERFLOW | NUM_TXBYTES | | | | | | | |
| RXBYTES | 3B | 0 | RXFIFO_OVERFLOW | NUM_RXBYTES | | | | | | | |
| RCCTRL1_STATUS | 3C | 0 | RCCTRL1_STATUS | | | | | | | | |
| RCCTRL0_STATUS | 3D | 0 | RCCTRL0_STATUS | | | | | | | | |
| PATABLE | 3E | 1 | PATABLE | | | | | | | | |
| FIFO | 3F | 0 | TXFIFO/RXFIFO | | | | | | | | |

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2. Approvals and Usage

The A2500R24x modules meet many national regulations for world-wide Industrial Scientific and Medical (ISM) radio bands use. In particular, the radio modules have been certified to the following standards.

2.1. Product Approvals

2.1.1. USA (Federal Communications Commission, FCC)

The A2500R24x modules have been tested to comply with FCC CFR47 Part 15 sub-part C “Intentional Radiators” standard. The modules meet the requirements for modular transmitter approval as detailed in FCC public notice DA 00-1407 Released: June 26, 2000. The modular transmitter approval eliminates the need to re-perform costly and time-consuming ‘intentional radiator’ testing when submitting an end product for certification.

(15.19a3) The A2500R24x modules comply 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.

Any changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

2.1.1.1. FCC Labeling Requirements

The A2500R24x modules have been labeled with their own FCC ID number and if the FCC ID is not visible when the module is installed inside another device, then the outside of the finished product into which the module is installed must also display a label referring to the enclosed module. This exterior label can use wording such as the following:

Contains Transmitter Module FCC ID: X7J-A10030501

-or-

Contains FCC ID: X7J-A10030501

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.

2.1.1.2. End User Manual

The end user manual should include the following 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 or more 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.*

2.1.1.3. RF Exposure

All transmitters regulated by the FCC must comply with RF exposure requirements. OET Bulletin 65 "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields" provides assistance in determining whether proposed or existing transmitting facilities, operations or devices comply with limits for human exposure to Radio Frequency (RF) fields adopted by the Federal Communications Commission (FCC). The bulletin offers guidelines and suggestions for evaluating compliance.

If appropriate, compliance with exposure guidelines for mobile and unlicensed devices can be accomplished by the use of warning labels and by providing end users with information concerning minimum separation distances from transmitting structures and proper installation of antennas.

The following statement must be included as a CAUTION statement in manuals and OEM products to alert end users of FCC RF Exposure compliance:

To satisfy FCC RF Exposure requirements for mobile and base station transmission devices, a separation distance of 20 cm 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.

If the A2500R24x modules are used in a portable device (antenna is less than 20 cm from persons during operation), the end user is responsible for performing Specific Absorption Rate (SAR) testing in accordance with FCC rules 2.1093.

2.1.2. Canada (Industry Canada, IC)

The A2500R24x modules have been certified for use in Canada under Industry Canada (IC) Radio Standards Specifications (RSS) RSS-210 and RSS-Gen.

From section 3.2 RSS-Gen, Issue 3, December 2010, Modular Approval for Category I Equipment or Category II Equipment:

“Modular approval permits the installation of the same module in a host device or multiple host devices without the need to recertify the device. Equipment certification for a modular device may be sought for either Category I equipment or Category II equipment.”

Transmitters designed as modules for the installation in a host device may obtain equipment certification as a modular device provided that the applicable RSS is met and the following conditions in this section are met.”

In RSS-Gen section 7.1.2 Transmitter Antenna, it has been mentioned that the user manuals for transmitters shall display the following notice in a conspicuous location:

Notice: *Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. 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 necessary for successful communication.*

Avis: *Sous la réglementation d'Industrie Canada, ce transmetteur radio ne peut fonctionner qu'en utilisant seulement une antenne d'un type et d'un maximum (ou moins) de gain approuvé pour l'émetteur par Industrie Canada. Pour réduire des potentielles interférences radio pour les autres utilisateurs, le type d'antenne et son gain doivent être choisis de sorte que la puissance isotrope rayonnée équivalente (PIRE) ne dépasse pas ce qui est nécessaire pour une communication réussie.*

In RSS-Gen section 7.1.2 Transmitter Antenna, it has been mentioned that the user manuals for transmitters equipped with detachable antennas shall also contain the following notice in a conspicuous location:

Notice: *This radio transmitter (IC: 8975A-A10030501) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.*

Avis: *Cet émetteur radio (IC: 8975A-A10030501) a été approuvé par Industrie Canada pour fonctionner avec les types d'antennes énumérés ci-dessous avec le gain maximal admissible et l'impédance d'antenne requise pour chaque type d'antenne indiqué. Les types d'antennes ne figurant pas dans cette liste, ayant un gain supérieur au gain maximal indiqué pour ce type, sont strictement interdits pour l'utilisation avec cet appareil.*

2.1.2.1. IC Labeling Requirements

From section 3.2.1 RSS-Gen, Issue 3, December 2010, Labeling Requirements for the Host Device:

“The host device shall be properly labeled to identify the modules within the host device. The Industry Canada certification label of a module shall be clearly visible at all times when installed in the host device, otherwise the host device must be labeled to display the Industry Canada certification number of the module, preceded by the words “Contains transmitter module”, or the word “Contains”, or similar wording expressing the same meaning.”

From section 5.2, RSS-Gen, Issue 3, December 2010, Equipment Certification Numbers and Labels:

“Every unit of Category I radio apparatus certified for marketing and use in Canada shall bear a permanent label on which is indelibly displayed the model number and Industry Canada certification number of the equipment model (transmitter, receiver, or inseparable combination thereof). Each model shall be identified by a unique combination of a model number and a certification number, which are assigned as described below in this section.

The label shall be securely affixed to a permanently attached part of the device, in a location where it is visible or easily accessible to the user, and shall not be readily detachable. The label shall be sufficiently durable to remain fully legible and intact on the device in all normal conditions of use throughout the device's expected lifetime. These requirements may be met either by a separate label or nameplate permanently attached to the device or by permanently imprinting or impressing the label directly onto the device.

The label text shall be legible without the aid of magnification, but is not required to be larger than 8-point font size. If the device is too small to meet this condition, the label information may be included in the user manual upon agreement with Industry Canada.”

Section 5.2 continues:

“The model number is assigned by the applicant and shall be unique to each model of radio apparatus under that applicant's responsibility. The model number shall be displayed on the label preceded by the text: “Model:”, so it appears as follows:

Model: model number assigned by applicant”

Label:

Contains IC: 8975A-A10030501

Notice: This device complies with Industry Canada licence-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.

Avis: Cet appareil est conforme avec Industrie Canada RSS standard exempts de licence (s). Son fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositif.

From section 7.1.4, RSS-Gen, Issue 3, December 2010, Radio Apparatus Containing Digital Circuits (ICES-003):

“Radio apparatus containing digital circuitry which can function separately from the operation of a transmitter or an associated transmitter, shall comply with ICES-003. In such cases, the labeling requirements of the applicable RSS apply, rather than the labelling requirements in ICES-003.”

For more information, see: Industry Canada <http://www.ic.gc.ca/>.

2.1.2.2. RF Exposure

All transmitters regulated by IC must comply with RF exposure limits as set forth in RSS-102, Issue 4, section 4, “Exposure Limits”. Furthermore RSS-102, Issue 4, Section 2 “Certification Requirements”, provides assistance in determining the specific requirements for compliance. If appropriate, compliance with exposure guidelines for mobile and unlicensed devices can be accomplished by the use of warning labels and by providing users with information concerning minimum separation distances from transmitting structures and proper installation of antennas.

The following statement must be included as a CAUTION statement in manuals and OEM products to alert users of IC RF Exposure compliance:

Notice: To satisfy IC RF Exposure requirements for mobile and base station transmission devices, a separation distance of 20 cm 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.

Avis: Pour répondre à la IC d'exposition pour les besoins de base et mobiles dispositifs de transmission de la station, sur une distance de séparation de 20 cm ou plus doit être maintenue entre l'antenne de cet appareil et les personnes en cours de fonctionnement. Pour assurer le respect, l'exploitation de plus près à cette distance n'est pas recommandée. L'antenne (s) utilisé pour cet émetteur ne doit pas être co-localisés ou fonctionner conjointement avec une autre antenne ou transmetteur.

If the A2500R24A and A2500R24C modules are used in a portable application (antenna is less than 20 cm from persons during operation), the integrator/OEM is responsible for performing Specific Absorption Rate (SAR) testing in accordance with IC rules and methods of RSS-102.

2.1.3. Europe (Conformité Européenne, CE)

The A2500R24x modules have been certified for use in European countries covered by ETSI regulations. The following tests have been performed and the module found to be compliant to the requirements:

- Test standard ETSI EN 300 328 V1.9.1 (2015-02)
 - ✓ RF Output Power
 - ✓ Duty Cycle
 - ✓ Occupied Bandwidth

- ✓ RF Output Power
 - ✓ Spectral Power Density
 - ✓ Transmitter Spurious Emissions
 - ✓ Receiver Spurious Emissions
- Electro-Static Discharge and RF Immunity (ETSI EN 301 489-17)
 - RF Exposure (ETSI EN 62311:2008)
 - Safety (IEC 60950-1:2005 and EN 60950-1:2006)

A helpful document that can be a starting point in understanding the use of short range devices (SRD) in Europe is the European Radio Communications Committee (ERC) Recommendation 70-03 E, downloadable from the European Radio Communications Office (ERO) <http://www.erodocdb.dk/Docs/doc98/official/pdf/REC7003E.PDF>.

The end user is responsible for ensuring compliance with harmonized frequencies and labeling requirements for each country the end device is marketed and sold.

For more information see:

- Radio And Telecommunications Terminal Equipment (R&TTE) http://ec.europa.eu/enterprise/sectors/rtte/index_en.htm
- European Conference of Postal and Telecommunications Administrations (CEPT) <http://www.cept.org/>
- European Telecommunications Standards Institute (ETSI) <http://www.etsi.org/>
- European Communications Office (ECO) <http://www.cept.org/eco>

2.2. Potential Interference Sources

The radio modules operate in the unlicensed ISM band, in which there are many other applications e.g. WLAN, Bluetooth® and microwave ovens. This can cause interference that may, in certain conditions, prohibit radio communication. The user is encouraged to implement a number of channels and to alternate between those channels based on one of the below methods.

- Sense if a particular channel is clear prior to transmitting (clear channel assessment)
- Pseudo Random channel change
- Select channels with the least interference (site survey)

Some of the most common interferences are listed below.

2.2.1. WLAN

Wireless Local Area Networks (WLANs) are divided into a number of overlapping channels. Figure 5 below shows the channels used by WLAN; for the US and Canada, only channels 1-13 may be used. Predominantly, channels 1, 6 and 11 are used to achieve non-overlapping channels. The user is therefore encouraged to select a channel scheme that also has channels

falling in between, or entirely outside, WLAN channels. Using a detection scheme (clear channel assessment) will enable the user to find channels with minimal interference from WLAN devices.

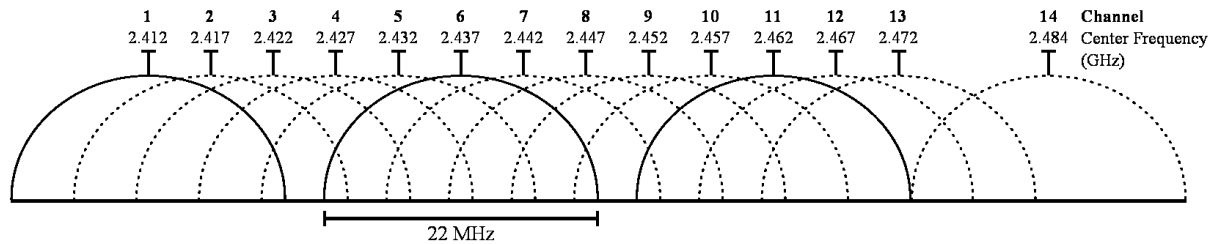


Figure 5 WLAN channels

2.2.2. Bluetooth®

Bluetooth® divides the 2.402-2.480 GHz band into 79 channels, each of which is 1MHz wide. However, since Bluetooth® changes channels rapidly (up to 1600 times a second), it is unlikely to cause continuous interference in a specific channel and can be overcome by implementing a simple acknowledge/retransmit functionality.

2.2.3. Microwave ovens

A typical microwave oven uses a self-oscillating magnetron with a duty cycle below 50%, because the tube is completely off for half of every AC mains cycle (8.33 ms in 60 Hz countries and 10 ms in 50 Hz countries). The frequency of the microwave oven changes cyclically within each AC mains synchronized on period, and is generally not predictable.

The user is encouraged to have packet transmission durations less than half the AC mains period and implement an acknowledge/retransmit method.

2.2.4. Other Interference

Systems similar to the user’s system may also exist within range and may also be a source of interference; some typical applications to consider are:

- Alarm systems
 - These typically use low duty cycles and are therefore easy to avoid using acknowledge/retransmit methods
- Car alarms (internal motion sensors)
- Video surveillance
 - These are typically operated on a fixed channel, determined at installation time and can be avoided by using clear channel assessment. It may be useful to change the channel used by the video surveillance equipment also, if possible.

2.2.5. Time critical data

If the user requires specific time critical data throughput that cannot tolerate the delays of potentially many re-transmissions, the user is encouraged to implement an environment-aware algorithm that periodically monitors/scans the frequency band and maintain a list of “best available” channels.

2.3. Approved Usage

The A2500R24A and A2500R24C modules have been approved for use in the US, Canada and Europe. The user is encouraged to use minimum power required to establish a link, thus minimizing interference.

Changes or modifications to the module and/or operation outside the limits are prohibited and could void the user's authority to operate the modules.

Table 3 shows the certified modulation types and data rates along with recommended channel spacing values. These configurations are common for FCC, IC and Europe.

Table 3 Certified configurations for FCC, IC and ETSI

| Modulation Type | Datarate (kbps) | Deviation (kHz) | Phase Transition | Channel Spacing (kHz) | RX Filter BW (kHz) |
|-----------------|-----------------|-----------------|------------------|-----------------------|--------------------|
| 2-FSK | 1.2 | 140 | NA | 310.242 | 650 |
| | 2.4 | 140 | NA | 310.242 | 650 |
| | 4.8 | 140 | NA | 310.242 | 650 |
| | 10 | 140 | NA | 310.242 | 650 |
| | 20 | 140 | NA | 310.242 | 650 |
| | 38 | 140 | NA | 310.242 | 650 |
| | 100 | 140 | NA | 310.242 | 650 |
| | 250 | 140 | NA | 310.242 | 650 |
| MSK | 500 | NA | 0 | 307.861 | 812.5 |

Table 4 shows certified frequencies of operations for each modulation type. Center frequencies outside the specified band, $[F_{cmin}, F_{cmax}]$, are prohibited, and therefore should not be used for communication.

Table 4 Certified frequencies of operations and power levels for FCC, IC and ETSI

| Modulation Type | F_{cmin} (MHz) | F_{cmax} (MHz) | Max. Output Power (dBm) | PA_Table (Hex) |
|-----------------|------------------|------------------|-------------------------|----------------|
| 2-FSK | 2401.3 | 2480.4 | 1 | 0xFF |
| MSK | 2401.8 | 2480.3 | 1 | 0xFF |

Table 5 shows available power levels from the device along with the corresponding PA_Table register settings. Users are encouraged to use minimum power required to establish a link, thus minimizing interference and current consumption.

Table 5 Output Power vs. PA Table Value

| Power (dBm) | PA_Table (Hex) | Power (dBm) | PA_Table (Hex) |
|-------------|----------------|-------------|----------------|
| 1 | 0xFF | -16 | 0x55 |
| 0 | 0xFE | -18 | 0x93 |
| -2 | 0xBB | -20 | 0x46 |
| -4 | 0xA9 | -22 | 0x81 |
| -6 | 0x7F | -24 | 0x84 |
| -8 | 0x6E | -26 | 0xC0 |
| -10 | 0x97 | -28 | 0x44 |
| -12 | 0xC6 | -30 | 0x50 |
| -14 | 0x8D | -55 | 0x00 |

2.3.1. US and Canada

Within the US and Canada, the A2500R24A and A2500R24C modules have been approved for use as digitally modulated transmitters, for which they conform to the BW (a minimum of 500 kHz 6-dB BW for US, a maximum BW of 0.5% of the carrier frequency for Canada), power spectral density (max of 8 dBm / 3 kHz), total output power (max 1W including the antenna gain) and spurious radiation (harmonics and others including the restricted bands) requirements.

In a frequency-agile implementation or an implementation with multiple systems sharing the same location, the user is encouraged to use only even channel numbers for 2-FSK, and every 3rd or 4th channels for MSK modulations to avoid overlapping channels (127 channels for 2-FSK, and 85 or 64 channels for MSK would thus be available).

It is encouraged to use a medium access technique which should include individual transceiver nodes addressing; and should include a combination of a clear channel assessment, transmit and detect, or a frequency hopping method. This ensures that the un-licensed band can be shared with other systems/applications.

2.3.2. Europe

For Europe, the maximum allowed power is 100mW (20 dBm) with a maximum spectral power density of 10mW/MHz (10 dBm/MHz); but there is no minimum occupied bandwidth requirement.

For Europe a medium access protocol is required. The transceiver module provides the following medium access services:

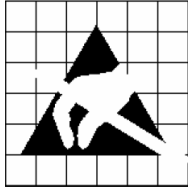
- Clear channel assessment
- 8 bit address
- Receive packet qualification (Address, CRC)
- Packetized/Frame handling.

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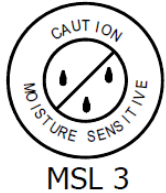
3. Electrical Characteristics

3.1. Absolute Maximum Ratings

Under no circumstances shall the absolute maximum ratings given in Table 6 be violated. Stress exceeding one or more of the limiting values may cause permanent damage to the device.



Caution!
 ESD sensitive device. Precaution should be used when handling the device in order to prevent permanent damage.



Caution!
 This assembly contains moisture sensitive devices and requires proper handling per IPC/JEDEC J-STD-033

Table 6 Absolute Maximum Ratings

| Parameter | Min | Max | Unit | Condition/Note |
|----------------------------|------|---------------------|------|--|
| Supply Voltage (Vdd) | -0.3 | 3.9 | V | |
| Voltage on any digital pin | -0.3 | Vdd+0.3, max 3.9 | V | |
| RF input power | | +10 | dBm | |
| Storage Temperature | -50 | 150 | °C | |
| Solder reflow temperature | | 260 | °C | According to IPC/JEDEC J-STD-020D |
| ESD | | <500 | V | According to JEDEC STD 22, method A114, Human body model |
| ESD | | 400 | V | According to JEDEC STD 22, C101C, Charged Device Model (CDM) |

3.2. Operating Conditions

Table 7 Operating Conditions

| Parameter | Min | Max | Unit | Condition/Note |
|----------------------|-----|-----|------|----------------|
| Supply Voltage (Vdd) | 1.8 | 3.6 | V | |
| Temperature Range | -40 | +85 | °C | |

3.3. Pin Out

The A2500R24C and A2500R24A radio modules share a common pin-out and foot print, that is also shared by Anaren modules using other frequencies -- thus enabling easy changeover from one to another, e.g. if changing the frequency, antenna scheme, or adaptive antenna tuning is desired. Below the common footprint are shown.

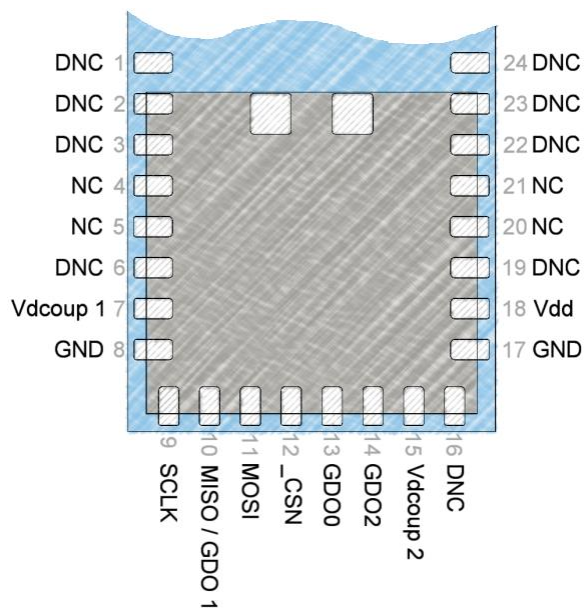


Figure 6 Pin Out.

NC = “No Connection”. Pin is NOT connected internally.

DNC = “Do Not Connect”. Pin reserved for internal use, ensure mating footprint pads are **isolated**.

GND = “Ground”. Connect the maximum number possible (minimum **one** for proper operation).

Table 8 Pin Descriptions

| Pin # | Pin Name | Pin Type | Description |
|-------|-----------|-----------------------------|--|
| 1 | DNC | NC | Internal GND connection used during testing, not recommended to connect to main GND. |
| 2 | DNC | NC | Internal RF output connection used during test. Connecting this pin to anything will require recertification for intentional radiators. |
| 3 | DNC | NC | Internal GND connection used during testing, not recommended to connect to main GND. |
| 4 | NC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 5 | NC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 6 | NC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 7 | Vdcoup1 | Analog | Optional decoupling of the modules internal Vdd supply. It is recommended to not connect anything to this pin. In particular noisy environment this pin can be used to further reduce the noise on the modules internal Vdd, please see section 3.5 for further information. |
| 8 | GND | Ground | One of two primary ground pins |
| 9 | SCLK | Digital Input | SPI bus clock signal |
| 10 | MISO/GDO1 | Digital Output | SPI bus data out from radio when CSN is low, and general purpose I/O pin when CSN is high |
| 11 | MOSI | Digital Input | SPI bus data into radio |
| 12 | CSN | Digital Input | SPI bus select (active low) |
| 13 | GDO0 | Digital I/O (Analog output) | General purpose port |
| 14 | GDO2 | Digital I/O | General purpose port |
| 15 | Vdcoup2 | Analog | Optional decoupling of the modules internal Vdd supply. It is recommended to not connect anything to this pin. In particular noisy environment this pin can be used to further reduce the noise on the modules internal Vdd, please see section 3.5 for further information. |
| 16 | NC | NC | No Connect, the pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 17 | GND | Ground | One of two primary ground pins |
| 18 | Vdd | Power Supply | Power supply pin |
| 19 | NC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 20 | NC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 21 | NC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 22 | DNC | NC | Internal GND connection used during testing, not recommended to connect to main GND. |
| 23 | DNC | NC | Pin is not connected internally, but is reserved for future expansion. It is recommended not to connect this pin to anything. |
| 24 | DNC | NC | Internal GND connection used during testing, not recommended to connect to main GND. |