PTR6100M -- nRF24L01+
2.4GHz 2Mbps Super MiNi Embedded Tranceiver Module

Operational Description:

The nRF24L01+ is a single chip 2.4GHz transceiver with an embedded baseband protocol engine (Enhanced ShockBurst™), suitable for ultra low power wireless applications. The nRF24L01+ is designed for operation in the world wide ISM frequency band at 2.400 - 2.525GHz.

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For U.S. and Canada the allowed frequency range is 2400-2483 GHz.
More technical informations are available in the section "Limitation of the single-modular transmitter (for U.S. and Canada)".

The embedded baseband protocol engine (Enhanced ShockBurst™) is based on packet communication and supports various modes from manual operation to advanced autonomous protocol operation. Internal FIFOs ensure a smooth data flow between the radio front end and the system's MCU. Enhanced Shock-Burst™ reduces system cost by handling all the high speed link layer operations.
The radio front end uses GFSK modulation. It has user configurable parameters like frequency channel, output power and air data rate. nRF24L01+ supports an air data rate of 250 kbps, 1 Mbps and 2Mbps.
In order to comunicate with the internal chip nRF24L01+ the external circuitry must implement a fast SPI over the following six 5Volts tollerant digital signal:

- **IRQ** (this signal is active low and controlled by three maskable interrupt sources)
- **CE** (this signal is active high and used to activate the chip in RX or TX mode)
- **CSN** (SPI signal)
- **SCK** (SPI signal)
- **MOSI** (SPI signal)
- **MISO** (SPI signal)

The SPI is a standard SPI with a maximum data rate of 10Mbps.
Thru the SPI interface the external logic can have access to any of the internal register, permitting to control the status (TX, Rx, stand by, etc) , to set the transmission power, read the received data and take control of others features.
A power antenna is printed directly into PCB avoiding external antenna connection.

Features:

Radio Features of the nRF24L01+ include:

- Worldwide 2.4GHz ISM band operation
- 126 RF channels
- GFSK modulation
- 250kbps, 1 and 2Mbps air data rate
- 1MHz non-overlapping channel spacing at 1Mbps
- 2MHz non-overlapping channel spacing at 2Mbps

Radio Transmitter:

- Programmable output power: 0, -6, -12 or -18dBm
- 11.3mA at 0dBm output power

Radio Receiver:

- Fast AGC for improved dynamic range
- Integrated channel filters
- 13.5mA at 2Mbps
- -82dBm sensitivity at 2Mbps
- -85dBm sensitivity at 1Mbps
- -94dBm sensitivity at 250kbps

RF Synthesizer:

- Fully integrated synthesizer
- No external loop filer, VCO varactor diode or resonator
- ±60ppm 16MHz crystal

Enhanced ShockBurst™:

- 1 to 32 bytes dynamic payload length
- Automatic packet handling

- Auto packet transaction handling
- 6 data pipe MultiCeiver™ for 1:6 star networks

Power Management

- Integrated voltage regulator
- 1.9 to 3.6V supply range
- Idle modes with fast start-up times for advanced power management
- 26µA Standby-I mode, 900nA power down mode
- Max 1.5ms start-up from power down mode
- Max 130us start-up from standby-I mode

Host Interface:

- 4-pin hardware SPI
- Max 10Mbps
- 3 separate 32 bytes TX and RX FIFOs
- 5V tolerant inputs
- Compact 20-pin 4x4mm QFN package

Transmitter and Receiver Ratings:

General RF conditions

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
f_{OP}	Operating frequency	a	2400		2525	MHz
PLL_{res}	PLL Programming resolution			1		MHz
f_{XTAL}	Crystal frequency			16		MHz
Δf_{250}	Frequency deviation @ 250kbps			±160		kHz
Δf_{1M}	Frequency deviation @ 1Mbps			±160		kHz
Δf_{2M}	Frequency deviation @ 2Mbps			±320		kHz
R_{GFSK}	Air Data rate	b	250		2000	kbps
$F_{CHANNEL\ 1M}$	Non-overlapping channel spacing @ 250kbps/ 1Mbps	c		1		MHz
$F_{CHANNEL\ 2M}$	Non-overlapping channel spacing @ 2Mbps	c		2		MHz

a. Regulatory standards determine the band range you can use.
b. Data rate in each burst on-air
c. The minimum channel spacing is 1MHz

Transmitter operation

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
P_{RF}	Maximum Output Power	a		0	+4	dBm
P_{RFC}	RF Power Control Range		16	18	20	dB
P_{RFCR}	RF Power Accuracy				±4	dB
P_{BW2}	20dB Bandwidth for Modulated Carrier (2Mbps)			1800	2000	kHz
P_{BW1}	20dB Bandwidth for Modulated Carrier (1Mbps)			900	1000	kHz
P_{BW250}	20dB Bandwidth for Modulated Carrier (250kbps)			700	800	kHz
$P_{RF1.2}$	1st Adjacent Channel Transmit Power 2MHz (2Mbps)				-20	dBc
$P_{RF2.2}$	2nd Adjacent Channel Transmit Power 4MHz (2Mbps)				-50	dBc
$P_{RF1.1}$	1st Adjacent Channel Transmit Power 1MHz (1Mbps)				-20	dBc
$P_{RF2.1}$	2nd Adjacent Channel Transmit Power 2MHz (1Mbps)				-45	dBc
$P_{RF1.250}$	1st Adjacent Channel Transmit Power 1MHz (250kbps)				-30	dBc
$P_{RF2.250}$	2nd Adjacent Channel Transmit Power 2MHz (250kbps)				-45	dBc

a. Antenna load impedance = 15Ω+j88Ω

Receiver operation

Datarate	Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
	RX_{max}	Maximum received signal at <0.1% BER			0		dBm
2Mbps	RX_{SENS}	Sensitivity (0.1%BER) @2Mbps			-82		dBm
1Mbps	RX_{SENS}	Sensitivity (0.1%BER) @1Mbps			-85		dBm
250kbps	RX_{SENS}	Sensitivity (0.1%BER) @250kbps			-94		dBm

Radio Control Description:

The nRF24L01+ has a built-in state machine that controls the transitions between the chip's operating modes. The state machine takes input from user defined register values and internal signals.
The nRF24L01+ can be configured in power down, standby, RX or TX mode.

Power Down mode

In power down mode nRF24L01+ is disabled using minimal current consumption. All register values available are maintained and the SPI is kept active, enabling change of configuration and the uploading/downloading of data registers.

Standby Modes

Standby-I mode is used to minimize average current consumption while maintaining short start up times. In this mode only part of the crystal oscillator is active.

Standby-II mode

In standby-II mode extra clock buffers are active and more current is used compared to standby-I mode. Register values are maintained and the SPI can be activated during both standby modes.

Rx Mode

The RX mode is an active mode where the nRF24L01+ radio is used as a receiver.
In RX mode the receiver demodulates the signals from the RF channel, constantly presenting the demodulated data to the baseband protocol engine. The baseband protocol engine constantly searches for a valid packet. If a valid packet is found (by a matching address and a valid CRC) the payload of the packet is presented in a vacant slot in the RX FIFOs. If the RX FIFOs are full, the received packet is discarded.
The nRF24L01+ remains in RX mode until the MCU configures it to standby-I mode or power down mode.

However, if the automatic protocol features (Enhanced ShockBurst™) in the baseband protocol engine are enabled, the nRF24L01+ can enter other modes in order to execute the protocol.

Tx Mode

The TX mode is an ctive mode for transmitting packets.
The nRF24L01+ stays in TX mode until it finishes transmitting a packet. The status of the TX FIFO determines the next action. If the TX FIFO is not empty the nRF24L01+ remains in TX mode and transmits the next packet.
If the TX FIFO is empty the nRF24L01+ goes into standby-II mode. The nRF24L01+ transmitter PLL operates in open loop when in TX mode. It is important never to keep the nRF24L01+ in TX mode for more than 4ms at a time. If the Enhanced ShockBurst™ features are enabled, nRF24L01+ is never in TX mode longer than 4ms.

Air data rate:

The air data rate is the modulated signaling rate the nRF24L01+ uses when transmitting and receiving data. It can be 250kbps, 1Mbps or 2Mbps. Using lower air data rate gives better receiver sensitivity than higher air data rate. But, high air data rate gives lower average current consumption and reduced probability of on-air collisions.
The air data rate is set by the RF_DR bit in the RF_SETUP register. A transmitter and a receiver must be programmed with the same air data rate to communicate with each other.
nRF24L01+ is fully compatible with nRF24L01. For compatibility with nRF2401A, nRF2402, nRF24E1, and nRF24E2 the air data rate must be set to 250kbps or 1Mbps.

RF channel frequency:

The RF channel frequency determines the center of the channel used by the nRF24L01+.
The channel occupies a bandwidth of less than 1MHz at 250kbps and 1Mbps and a bandwidth of less than 2MHz at 2Mbps. nRF24L01+ can operate on frequencies from 2.400GHz to 2.525GHz.

For U.S. and Canada the allowed frequency range is 2400-2483 GHz.
More technical informations are available in the section "Limitation of the single-modular transmitter (for U.S. and Canada)".

The programming resolution of the RF channel frequency setting is 1MHz.
At 2Mbps the channel occupies a bandwidth wider than the resolution of the RF channel frequency setting. To ensure non-overlapping channels in 2Mbps mode, the channel spacing must be 2MHz or more. At 1Mbps and 250kbps the channel bandwidth is the same or lower than the resolution of the RF frequency. Transmitter and a receiver must be brogrammed with the same RF channel frequency to communicate with each other.

Device circuitry description:

The PTR6100M module embeds the nRF24L01+ all in one RF chip (from Nordic Semiconductor) with few components around it like crystal resonator, bias resistor and decoupling capacitors.
SMD Pads connections to the I/O SPI of RF chip are directly available externally.

11 Electrical Schema

nRF24L01+ with single ended matching network crystal, bias resistor, and decoupling capacitors.

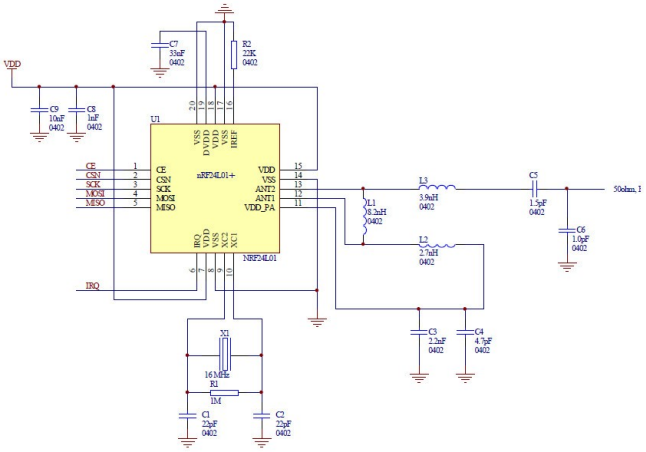
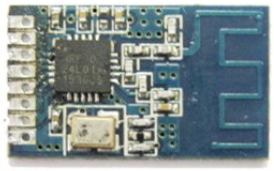


Figure 32. nRF24L01+ schematic for RF layouts with single ended 50Ω RF output

Device PCB and antenna description:

This PCB has a ground plane on the bottom layer.
Additionally, there are ground areas on the component side of the board to ensure sufficient grounding of critical components. A large number of via holes connect the top layer ground areas to the bottom layer ground plane.
The PCB antenna is printed on a side of the module, it's a single ended antenna accorded as a 50 Ohm impedence RF output.



Limitation of the single-modular transmitter (for U.S. and Canada)

The modular transmitter embeds the nRF24L01+ Single Chip 2.4GHz Transceiver manifactured by Nordic Semiconductor.

Frequency limitations for U.S. and Canada:
The modular transmitter is subject to § 15.212 rules, and has to be limited U.S. and Canada.
To assure that the module can transmit ONLY inside the permitted frequency band specified by FCC rules (§15 chapter), the manufacturer (only MOTION S.P.A.) must program the RF-single chip with the admitted values, limited to the following registers.

In reference to the original datasheet from Nordic Semiconductor titled "nRF24L01+ Single Chip 2.4GHz Transceiver Product Specification v1.0" Revision 1.0, Chapter "9 Register Map", Table 28. "Register map of nRF24L01+" page 58:

Register "RF_CH - RF Channel"

Address (Hex)	***Mnemonic***	***Bit***	***Reset Value***	***Type***	***Description***
0x05	*RF_CH*	*6:0*	*0000010*	*R/W*	*Sets the frequency channel nRF24L01+ operates on*

MUST BE PROGRAMMED WITH VALUES BETWEEN 0x00 and 0x52 (hexadecimal *v*alue)

This register specify the radio channel used during transmission/receiving data. If the user doesn't program this register at all, his values at the power on of the equipment will be equals to 0x02 and the frequency of transmission will be 2400MHz + 2Mhz = 2402MHz that is inside the allowed RF band. The minimum Channel correspond to 2400MHz and the maximum correspond to 2482MHz (both inside the allowed RF band).

For U.S. and Canada the allowed frequency range is 2400-2483 GHz and MOTION S.P.A. limits always the frequencies to this range.

No other register or software adjustment practice are required to submit the FCC requirements.