

USERS MANUAL FOR NRF24 TRANSCEIVER



RF Module NRF24WDS Rev A
Front View

OVERVIEW:

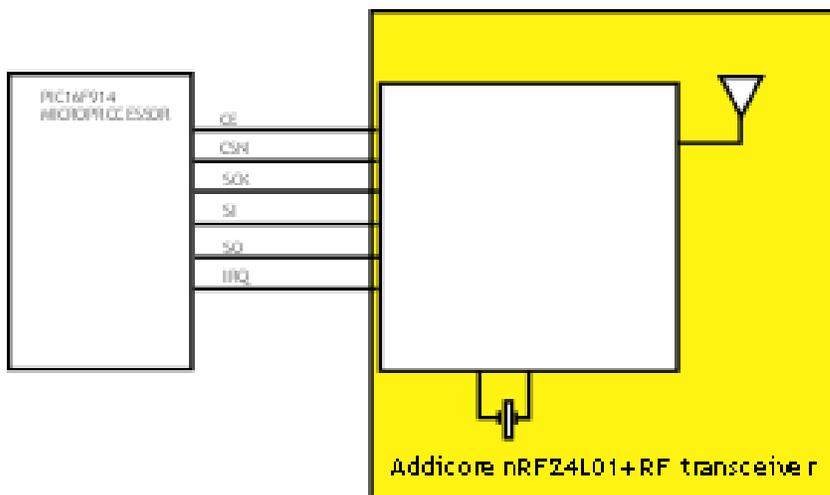
The NRF24L01 RF Module is configured on a printed circuit board to include the Nordic NRF24L01+ QFM 20 Integrated circuit, antenna matching network, antenna and interface to a microprocessor.

Antenna: The antenna is configured as a simple dipole operating in the range of 2400 MHz to 2480MHz with a measured gain of -7.7dBi across the range. The antenna is arranged on the printed circuit board

The NRF24L01+ Nordic single chip transceiver is interfaced to a microprocessor by the use of a connector at one end of the pc board. The interface lines to the microprocessor consist of:

1. Input power 3.3V filtered
2. Chip Enable (CE) brought low while loading data or copying received packet.
Brought high to set active receive or transmit mode.
3. Chip Select N (CSN). SPI slave select pin; brought low to initiate SPI transaction, and brought high to complete the transaction.

4. SPI Clock (SCK) The clock signal generated by external control.
5. Master Out, (MOSI) Master out, slave in. Data transferred serially over this pin from external control.
6. Master In (MISO) Master in, slave out. Data transferred serially over this pin from NRF24L01 to control.
7. Interrupt Request (IRQ) the NRF24 drives this pin low to trigger an interrupt.
8. GND



Block Diagram of NRF24 module attached to external control (microprocessor)

Power Requirements:

The NRF24 Module requires a filtered input voltage between 2.7VDC to 3.6VDC and draws a maximum of 12.5 mA.

Output Power: The following table shows the NRF24 configurable output power settings:

<u>Power</u>	<i>Signal Output</i>	<i>Total Current</i>
0 dBm	1mW	11.5 mA
-6 dBm	250 μ W	9 mA
-12 dBm	63 μ W	7.5 mA
-18 dBm	16 μ W	7.0 mA

RF Antenna:

The RF antenna is configured by the copper traces on the pc board. Measured antenna gain is -7.7 dBi

RF Channels (MHz):

2405
2408
2411
2414
2417
2420
2423
2426
2429
2432
2436
2438
2441
2444
2447
2450
2464

The Serial peripheral Interface:

A common method of communicating between microprocessor devices is use of the SPI (serial peripheral interface). The SPI uses four pins, CSN, SCK, MISO, MISI for data transmission and reception.

The CSN (chip select not) pin is active-low and is normally kept high.

When this pin goes low, the NRF24L01 begins listening on its SPI port for data and processes it accordingly.

C_n – SPI Instruction Bit
 S_n – Status Register Bit
 D_n – Data Bit (note: LSByte to MSByte, MSBit in each byte first)

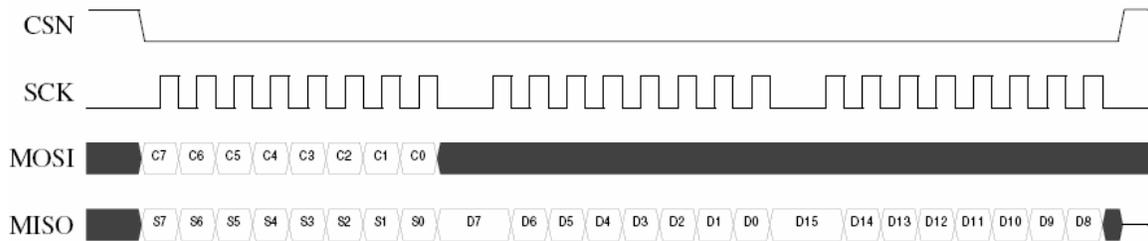


Figure 8 SPI read operation.

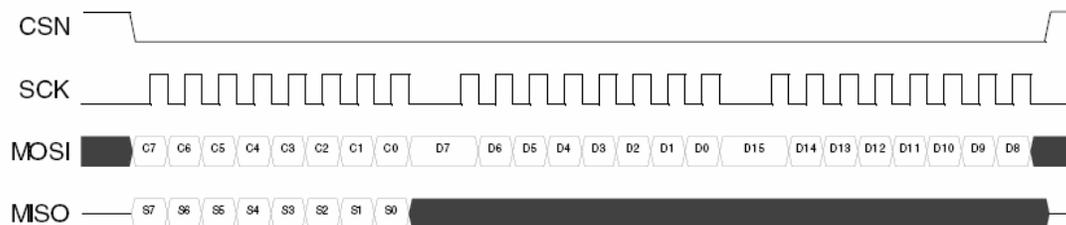
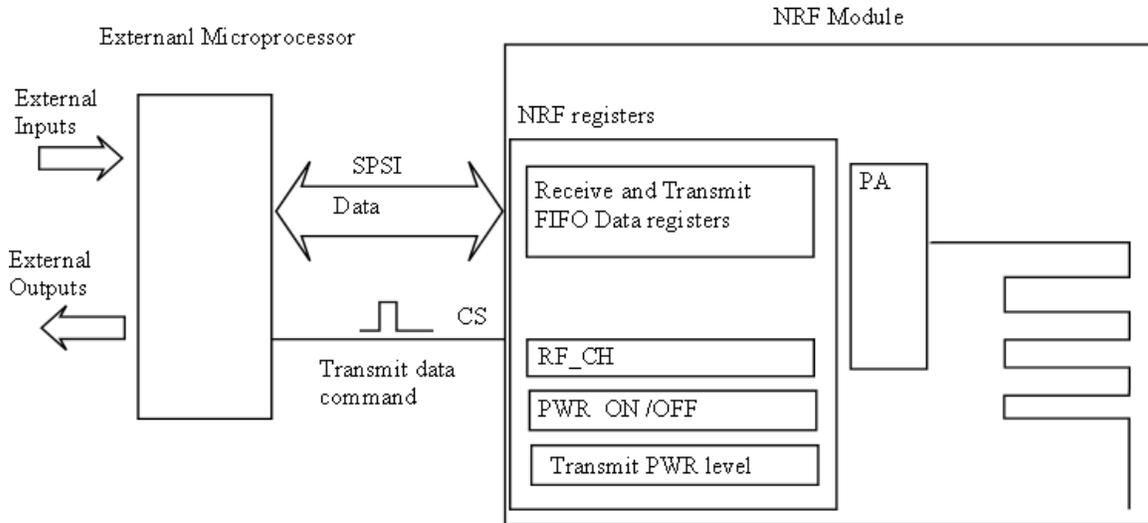


Figure 9 SPI write operation.

In order to send data to or receive data from the SPI port on the 24L01, several steps are required. The CSN pin on the 24L01 must be high to start out with. Then, the CSN pin is set low to alert the 24L01 that it is about to receive SPI data. (Note: this pin will stay low throughout the entire transaction.) Then, you will transmit the command byte of the instruction you wish to send. If you are receiving data bytes for this instruction, you must then send one byte to the 24L01 for every one byte that you wish to get out of the 24L01. If you are just sending the 24L01 data, you simply send your data bytes and generally don't worry about what it sends back to you. When receiving data from the 24L01, it makes absolutely no difference what is contained in the data bytes you send after the command byte, just so long as you send the correct number of them. Once you have transmitted and/or read all of the bytes that you need, you bring CSN back high.



Instructions:

The NRF24 is controlled using twelve instructions that can be sent over the SPI bus. An instruction must be sent using this process:

1. Set CSN low
2. Send instruction byte
3. If the instruction has arguments send the argument bytes.
4. set CSN high

Data shifted into the registers are also shifted back.

Registers:

The Registers are used to configure the different settings. Each register has a five bit address that is marked by the read and write instructions.

CONFIG:	Configure Interrupts, CRC, power and TX/RX status
RF_CH	Sets the RF channel
EN_AA:	Enable and disable Enhanced shockburst
EN_RXADDR	Enable and disable RX pipes
RF_SETUP	Set the output power level
SETUP_AW	Set the address width
SETUP_RETR	Configure the retry delay and number of times of retries.
STATUS	Get the interrupt bits, TX FIFO full bit
OBSERVE	TX, get count of lost or re-transmitted packets
CD	Get the carrier detect bit
RX_ADDR_Pn	Set the address for the RX pipe
TX_ADDR_	Set the destination address for the transmitted packets
RX_PW_Pn	Set the static payload width
FIFO STATUS	Get the auto-retransmit status.
ACK_PLD	Send payload with ACK

TX_PLD TX FIFO
RX_PLD RX FIFO

Instruction Registers:

R_Register	Read the value from the register that has the five bit address AAAAA
W_Register	Write the argument bytes to the register that has the Five bit address AAAAA
R_RX_Payload	Read the data payload that is at the head of the RX FIFO
W_TX_Payload	Write the data payload to the transmit into the TX FIFO
Flush_TX	Delete all packets from the TX FIFO
Flush_RX	Delete all packets from the RX FIFO

Registers used in this application:

CONFIG
RF_CH
RF_SETUP
R_Register
W_Register
R_RX payload
W_TX payload
Flush_TX
Flush_RX

All other registers are left in their default state. There may be times when other registers will be required to be altered but each register is dependent on the application.

Default:

Upon the application of power to the NRF24 module, the module automatically sets the above registers to a default condition:

RF_CH set to 2402 MHz
CONFIG: set as a receiver
CONFIG: power to the NRF24L01 IC is turned off
NOTE: All other registers are set for standard packet widths of 2 bytes and a data rate of 127 Kbps.

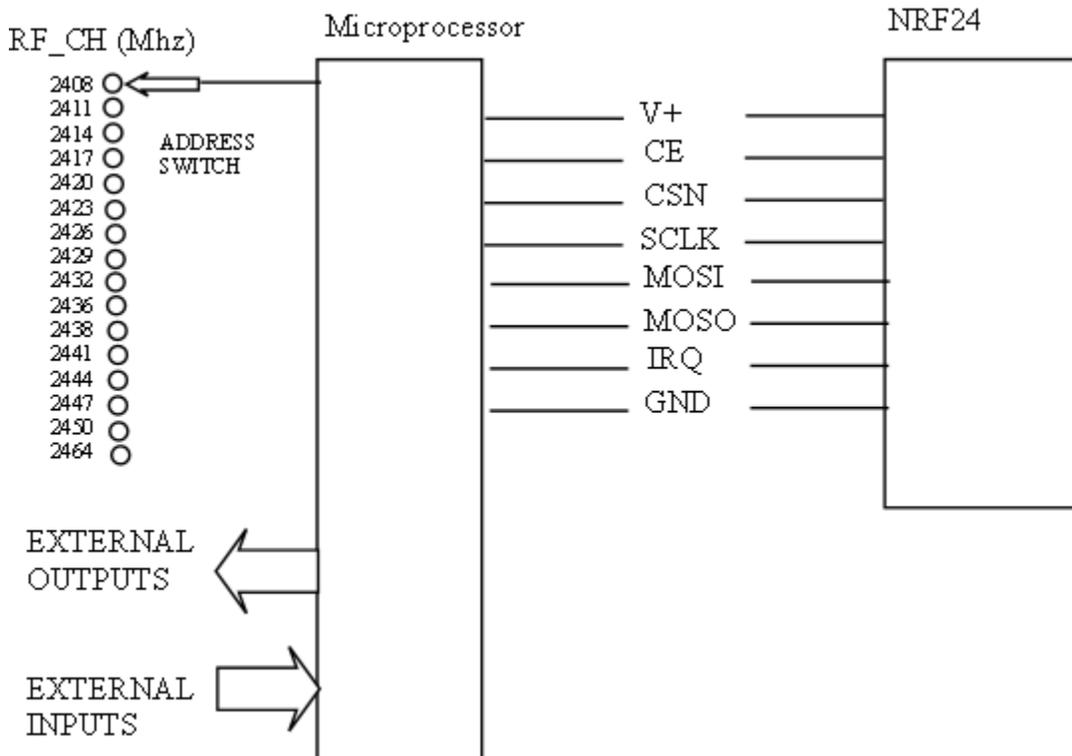
The attached controller will initialize the NRF24 Module by reading all the registers and comparing them to its internal mask for defaults and, if registers are correct, set its RF_CH to 2405 MHz, receiver mode and power turned on.

Configuring the NRF24:

The NRF24 module can be configured as one of the following:

1. Transmitter only
2. Receiver only
3. Transceiver

In order to configure the NRF24 Module, a control interface using approved firmware is required. The control interface consists of a microprocessor with its own on board clock, an address switch and connections to inputs or outputs.



Configuring the NRF24 as a Transmitter:

The attached controller contains the firmware to read and write to the registers located in the NRF25L01 chip on the NRF24 Module.

To setup as a transmitter:

1. Initialize the NRF24 by reading all the registers and comparing them to the default mask located within the controller non-volatile memory. Turn the NRF module power on.
2. Read the address switch setting and program the NRF24 RF_CH register with the RF channel selected by the Address switch.
3. Set the **RF_SETUP REGISTER FOR 0 dBM output power**.
4. Set the **CONFIG_REG as a Transmitter**.
5. Read the NRF24 Registers to ensure that they have been changed.
6. The transmitter is now ready to transmit information over the RF All other registers remain in their default settings.

To Transmit Data:

1. The Controller initiates the action of determining the type of information it is to send. Once determined, the controller configures and loads the data into the NRF24 Transmit FIFO.
2. Once loaded, the controller toggles the CSN pin low for approx 10 mSecs instructing the NRF24 to transmit the data loaded in its FIFO.
3. Once toggled by the CSN pin, the controller monitors the NRF24 IRQ pin and waits for the NRF24 to toggle the IRQ indicating that the data has been transmitted.

Remote Assignment of RF Channel:

In order for the system to operate correctly, it is imperative that all devices operate on the same RF channel. Remote devices may not always have an address switch that selects the operating RF channel. In this situation, the controller attached to the device will follow the initialization routine and set the **RF Ch to 2405 MHz identified as the SYNC Channel**.

The SYNC channel is the default RF channel for this system and will default to 2405 MHz. For other devices wishing to communicate with each other, a special routine is embedded in the control that will transmit a JUMP_TO command to the remote device over 2405 MHz. Included in the JUMP_TO command is the operating RF channel. For example: IF the Transmitter Address switch is set to RF_CH 2411 and wishes to communicate with a remote device; the Transmitter sends a JUMP_TO 2411 Command over 2405 MHz. The remote device set as a default receiver on RF channel 2405 MHz will receive the data. Its control device upon reading the data will set the RF_CH of the remote device to 2411 MHz.

NOTE: All RF approved channels are embedded in nor-volatile memory and prevent the NRF24 from moving to an un-authorized RF channel.

If the Remote device is configured as a Transmitter:

All remote devices are setup using the same initialization routine. Upon initialization, the **NRF24 is setup to operate on 2405 MHz (SYNC) as a receiver.**

Once configured, the controller can alter the NRF24 to operate as a Transmitter by changing its **CONFIG REG** from RX to TX. The **RF_SETUP** is pre-configured for a power setting of 0 dBm (default state)

Configuring the NRF24 as a Receiver:

The attached controller contains the firmware to read and write to the registers located in the NRF25L01 chip on the NRF24 Module.

To setup as a Receiver:

1. **Initialize the NRF24** by reading all the registers and comparing them to the default mask located within the controller non-volatile memory.
Turn the NRF module power on.
2. **Set the CONFIG_REG to RX, POWER ON**
3. **Set the RF_CH to 2405 MHz.**
4. The device is now configured as a receiver. All other registers remain in their default state.

The Receiver is now ready to accept commands sent over 2405 MHz.

Configuring the NRF24 as a Transceiver:

The attached controller contains the firmware to read and write to the registers located in the NRF25L01 chip on the NRF24 Module.

To setup as a Transceiver:

1. **Initialize the NRF24** by reading all the registers and comparing them to the default mask located within the controller non-volatile memory.
Turn the NRF module power on.
2. **Set the CONFIG_REG to RX, POWER ON**
3. **Set the RF_CH to 2405 MHz.**
4. The device is now configured as a receiver. All other registers remain in their default state.

To setup the device as a transceiver the attached controller must have an RF_Channel address switch. In the absence of an address switch, the Transceiver will need to be programmed remotely from a Transmitter device that contains an address switch.

1. From the Transmitter device, transmit the **JUMP_TO** command with **RF_CH** data over 2405 MHz to the receiver.
2. Upon reception of the **JUMP_TO** command, the control unit reads the RF channel tied to the **JUMP_TO** command and loads the receiver **RF_CH** register. The control unit also stores the RF channel in its non-volatile memory and will set the NRF24 to the RF channel stored in its non-volatile memory rather than 2405 MHz.

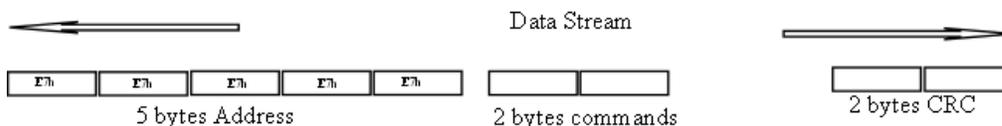
3. The control unit then changes the CONFIG_REG from RX to TX and will embed this data as a part of its start up routine whenever power is applied.

Operation of the NRF Module:

NOTE: The NRF Module is not a “stand alone” configuration and requires the interface to a pre-programmed microprocessor able to receive, process and send data to the NRF Module.

The data sent or received from the NRF Module consists of a data stream. Contained in the data stream are:

1. Five byte address E7h is used in all units as a default.
2. two byte commands
3. two bytes for CRC



UPPER 4 BITS				LOWER 4 BITS (0x0B = OUTPUTS 5-8)				
7	6	5	4	3	2	1	0	
0	0	0	0	0	0	0	0	;
0	0	0	1	0	0	0	0	;
0	0	1	0	0	0	0	0	;
0	0	1	1					;
0	1	0	0					;0x30 JUMP TO
0	1	0	1					;0x40 ENABLE
0	1	1	0					;0x50 FOOT ON
0	1	1	0					;0x60 DCMINITIALIZE
0	1	1	1					;0x70 FOOT OFF
1	0	0	0					;0x80 ALL OFF

Command bytes:

Jump_to_command: the NRF24L01 RF data received in its FIFO and is sent to the attached microprocessor which determines which RF channel the NRF module is to be set. Pre-programmed into the microprocessor are the RF_channels identified above. The command byte determines which of the sixteen RF_channels are to be used. Once determined, the microprocessor loads the NRF module registers with the appropriate data and the FIFO with data to be transmitted out. The microprocessor toggles the CS pin to instruct the NRF module to transmit the data.

Enable command: The data received by the NRF module is sent to the microprocessor instructing the microprocessor to enable or disable one of its pre-programmed outputs.

Data set to the NRF module from the microprocessor is loaded into the RF module FIFO “as data to be sent”. The data is transmitted to other RF devices by the microprocessor toggling the CS pin.

FOOT_ON: The FOOT ON command sent to the NRF Module from the microprocessor loads the data in the NRF module FIFO and then sends it out over the NRF module RF channel to other rf devices once the CS pin is toggled by the microprocessor.

The FOOT ON command received by the NRF Module FIFO is sent to the microprocessor to determine using its pre-programmed routines if any of the specified outputs are to be turned ON.

DCM Initialize Command: Data set to the NRF module from the microprocessor is loaded into the RF module FIFO “as data to be sent”. The data is transmitted to other RF devices by the microprocessor toggling the CS pin. Embedded in the Initialize command are instructions for which RF channel is to be used and if the device is to enable or disable one of the microprocessor pre-programmed outputs.

Data received from the NRF module FIFO is sent to the microprocessor which determines through its pre-programmed routines which RF channel it is to use and if any of its outputs are to be enabled or disabled.

Once determined by the pre-programmed routines, the microprocessor will send commands to the NRF module to RF_Ch register as to which channel it is to be tuned.

FOOT_OFF: The FOOT OFF command sent to the NRF Module from the microprocessor loads the data in the NRF module FIFO and then sends it out over the NRF module RF channel to other rf devices once the CS pin is toggled by the microprocessor.

The FOOT OFF command received by the NRF Module FIFO is sent to the microprocessor to determine, using its pre-programmed routines, if any of the specified outputs are to be turned OFF.

ALL OFF: RF data by the NRF Module FIFO is processed to the microprocessor which in turn determines through its pre-programmed routines to turn all outputs off. The NRF module registers are not altered with this command. Data sent from the microprocessor to the NRF Module FIFO instructs the module to transmit the data out over its pre-defined RF channel once the microprocessor toggles the CS pin.

WDCS System protocol:

The WDCS system uses two or more NRF24L01 RF modules to perform operational tasks. One of the units will use an address switch to select and determine the operating frequency for the system. Built into the controller is a microprocessor that has pre-programmed RF channels identified by the position of the address switch setting. All units upon power up set their RF channels to 2405 MHz (defined as the SYNC RF channel) set to receive mode. The control module with the address switch is the only unit that is capable of setting the RF channels for the other units within its environment and, upon power up, is set to transmit mode which is defined as the transmitter.

To SYNC:

Each receive unit must be selected to SYNC to the transmitter. In order to SYNC the receive unit to the transmitter, the receive unit controller waits for a SYNC button to be pressed, enabling the NRF24L01 RF module to listen and accept data over the 2405 MHz RF Channel. The receive controller will time out within fifteen seconds in the absence of an RF signal. The receive unit identifies it is in a SYNC mode by turning on a light.

To SYNC the receive unit to the transmitter, the transmitter controller waits for a device push button to be pressed. Upon being pressed, the controller loads the NRF24L01 module with the following information:

< 5 byte wide address > + < JUMP TO COMMAND +RF CHANNEL #> + < DEVICE # > + < 2 byte CRC >

NOTE: All units within the WDCS system are identified by a specific 5 byte wide address: E7, E7, E7, E7, E7 hex.

The transmitter controller loads the RF CHANNEL # into the NRF24L01 RF module thereby moving to the RF channel specified by the address switch.

The DEVICE # refers to a specific output on the receive unit that the transmitter is to control.

The data is sent three times by the transmitter.

Upon receiving the data, the receive unit checks to see if the 5 byte wide address matches its internal settings and, if so, performs an internal CRC check to verify that the data is valid.

Once verified, the receive unit controller reads the data from the NRF24L01 RF module and determines if the first byte is the "JUMP TO" command byte. If the data is not the "JUMP TO" command byte the controller ignores the data

and disables the NRF24L01 module off. The SYNC button on the receive controller will need to be pressed again in order to enable the NRF24L01.

If the receive unit controller verifies that the data, the controller executes the “JUMP TO” command by looking at the next byte (RF CHANNEL #) and determining if it falls within the parameters of its RF channel look up table located in its non-volatile memory. Once retrieved from its non-volatile memory, the controller sets the RF Channel of the NRF24L01 RF module to the RF channel specified by the received data. The receive unit is now operating on the new RF channel and also enables the device identified by the “DEVICE #” indicating the receive unit is ready to accept data from the transmitter unit over the new RF channel.

Acceptable types of Data:

The WDCS system will only accept specific commands and data as identified by the **Command bytes** above.

FCC Statements:

This module is approved for installation into mobile or/and portable host platforms and must not be co-located or operating in conjunction with any other antenna or transmitter except in accordance with FCC multi-transmitter guidelines.

The grant for this device is valid only when the device is sold to OEM integrators and the OEM integrators are instructed to ensure that the end user has no manual instructions to remove or install the device.

End users and installers must be provided with transmitter operating conditions for satisfying RF Exposure compliance.

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

NOTE: 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.