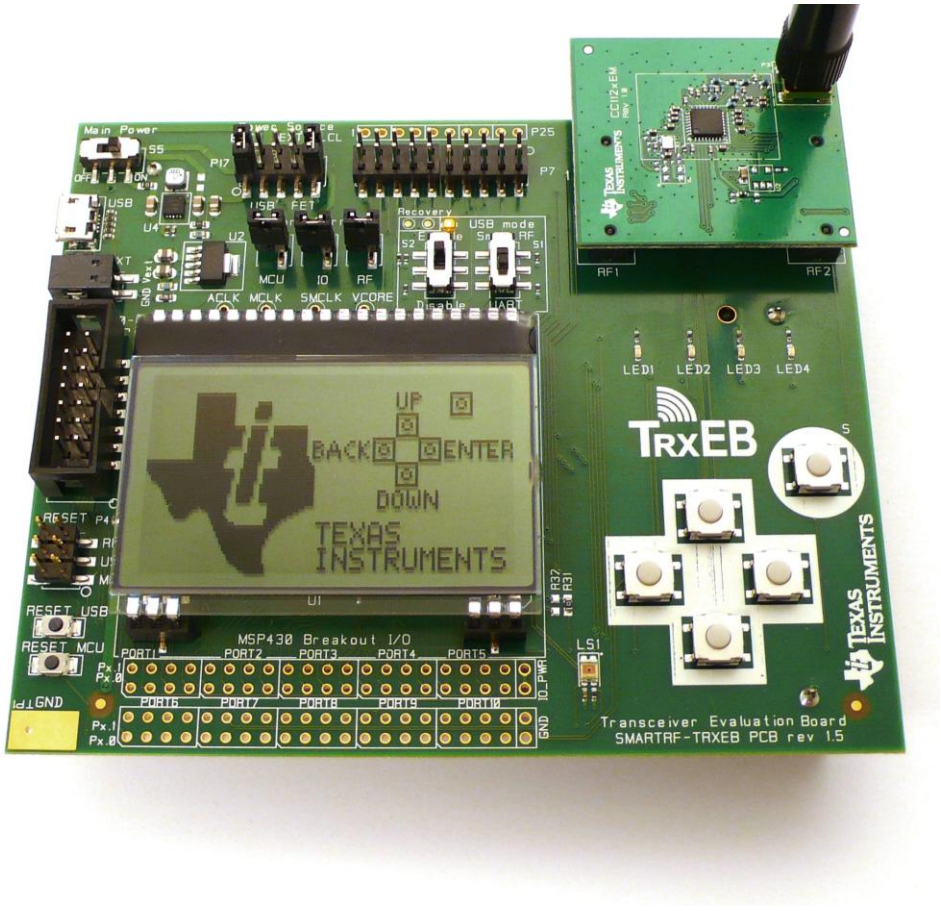
TrxEB RF PER Test Software Example

User's Guide



SWRU296

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1 Introduction

This guide will give a brief description of how to use the RF software examples that is pre-programmed on the MSP430 on the SmartRF Transceiver Evaluation Board (TrxEB).The SmartRF Transceiver Evaluation Board is the development platform for Texas Instruments Low Power RF transceivers.

The software consists of a generic Packet Error Rate Test (PER Test) which supports Texas Instruments sub-gigahertz transceivers, a simple link application that shows the basic functions needed for a one way RF link and a simple demonstration of the CC112x's RX Sniff Mode.

Note: This software is intended for demonstration purposes only. It is not recommended to use this software as a basis for production tests and/or other critical applications.

2 About this manual

This manual contains information on how to use the RF Software Examples that is pre-programmed on the SmartRF Transceiver Evaluation Board. Chapter 4 will give a short description to how to download and program the TrxEB with the software. Chapter 5 describes how to set up the TrxEB to run software from the MSP430 and Chapter 6 will give details on how to run the different applications.

3 Acronyms and Abbreviations

CRC	Cyclic Redundancy Check
EB	Evaluation Board
EM	Evaluation Module
LCD	Liquid Crystal Display
LPRF	Low Power RF
PER	Packet Error Rate
RF	Radio Frequency
RSSI	Received Signal Strength Indication
RX	Receive
TI	Texas Instruments
TrxEB	Transceiver Evaluation Board
TX	Transmit

4 Getting Started

The following section describes hardware and software setup, how to program the board and how to run example code from the debugger. A description of how to operate each software example is found in section 6 of this guide.

4.1 Set up hardware and software

Follow these steps to configure the hardware and software needed:

1. Install IAR Embedded Workbench for MSP430.
2. Download and unzip the TrxEB RF PER Test Software Example zip file [1] from the TI web site.
3. Attach the antenna to a supported evaluation module and insert this into the TrxEB.
4. Connect the MSP430 FET to the MSP430 debug connector on the TrxEB.
5. Power up the SmartRF TrxEB. See details in the SmartRF TrxEB Users guide [8] .

4.2 Program the MSP430 with IAR

6. Open IAR Embedded Workbench
7. Open the workspace file per_test.eww with IAR. This file is found in the sub-folder IDE\IAR in the unzipped project folder.
8. Select **Project -> Rebuild All**. This will perform a full rebuild of the selected project.
9. Select Project -> Debug. IAR will now establish a connection with the MSP430 and download the application. The debugger will be started, halting at the beginning of main().
10. Start the application by selecting **Debug -> Go**.
11. The board can be reset by selecting **Debug -> Reset**.
12. The debugger can be stopped by selecting **Debug -> Stop Debugging**.

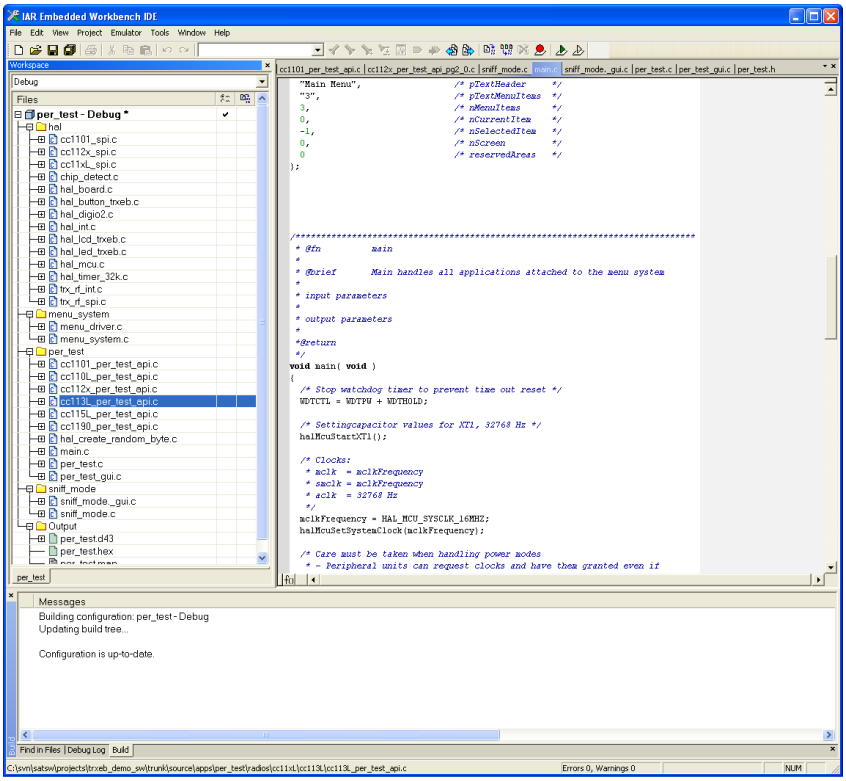


Figure 1 IAR Embedded Workbench

4.3 Program the MSP430 with SmartRF Flash Programmer

13. Open SmartRF Flash Programmer.

14. Choose the “Program CCxxxx SOC or MSP430” option in the scrolling window and select the MSP430 tab.
15. Load the per_test.hex file in the Flash image window. The per_test.hex file can be found in the sub-folder IDE\IAR in the unzipped project folder.
16. Choose “Erase, program and verify” under actions.
17. Press the “Perform Actions” button to flash the MSP430.

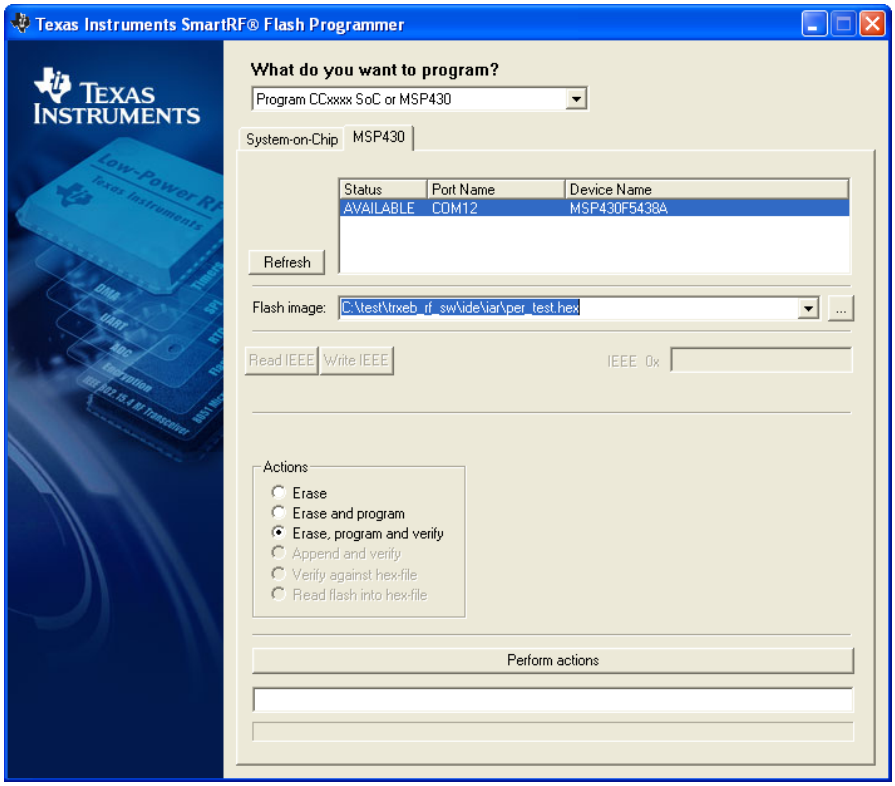


Figure 2 SmartRF Flash Programmer

5 Running the software

To run the software application from the MSP430 be sure that the MCU is enabled by setting the correct operating mode of the TrxEB. This can be done by setting switches S1 and S2 to “UART” and “Enable”. This enables the UART mode for the evaluation board which enables the MSP430 with the application software.

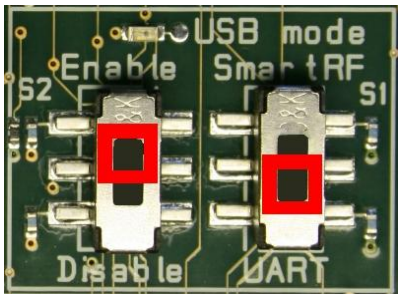


Figure 3 TrxEB UART mode

The first screen the user will see when the board is powered up is the TI welcome screen. Any button push on this screen will lead the user to the main menu.

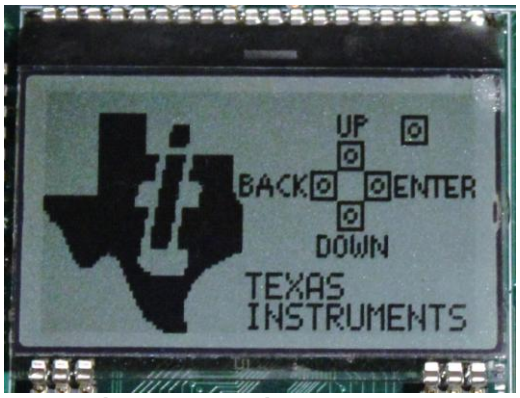


Figure 4 TI welcome screen



Figure 5 Main menu

In addition to a generic PER test the software example consists of two small applications, a simple link test that shows the minimum basic functions needed to set up an RF link, and simple demonstration of the CC112x RX Sniff mode. There is also a small application that displays information such as device name, version number and crystal frequency of the connected evaluation module. Use the up and down buttons to choose the correct application and press enter (right button) to select application.

6 Software applications

6.1 Packet Error Rate Test – PER Test

The Packet Error Rate Test or PER Test is an easy way to do range testing of TI's low power RF transceivers. The PER test currently supports the following RF Evaluation Modules:

- ***CC1120EM***
- ***CC1121EM***
- ***CC1125EM***
- ***CC1120-CC1190 869MHz EM***
- ***CC1120-CC1190 915MHz EM***
- ***CC1101EM***
- ***CC1101-CC1190 869MHz EM***
- ***CC1101-CC1190 915MHz EM***
- ***CC110L EM***
- ***CC113L EM***
- ***CC115L EM***
- ***CC1200 EM***
- ***CC1201 EM***

The PER Test application will detect if a supported EM is connected to the TrxEB and set up the appropriate radio functions depending on the radio type connected.

Figure 6 shows an overview of the menu structure of the PER test.

For the supported transceivers two modes of operation are available, Easy Mode and Expert Mode. Easy Mode sets up a one-way test and uses a set of default settings with few configuration options. In Expert Mode the user has more configuration options and can select between one-way or two-way topology. See section 6.1.3 for details on link topology.

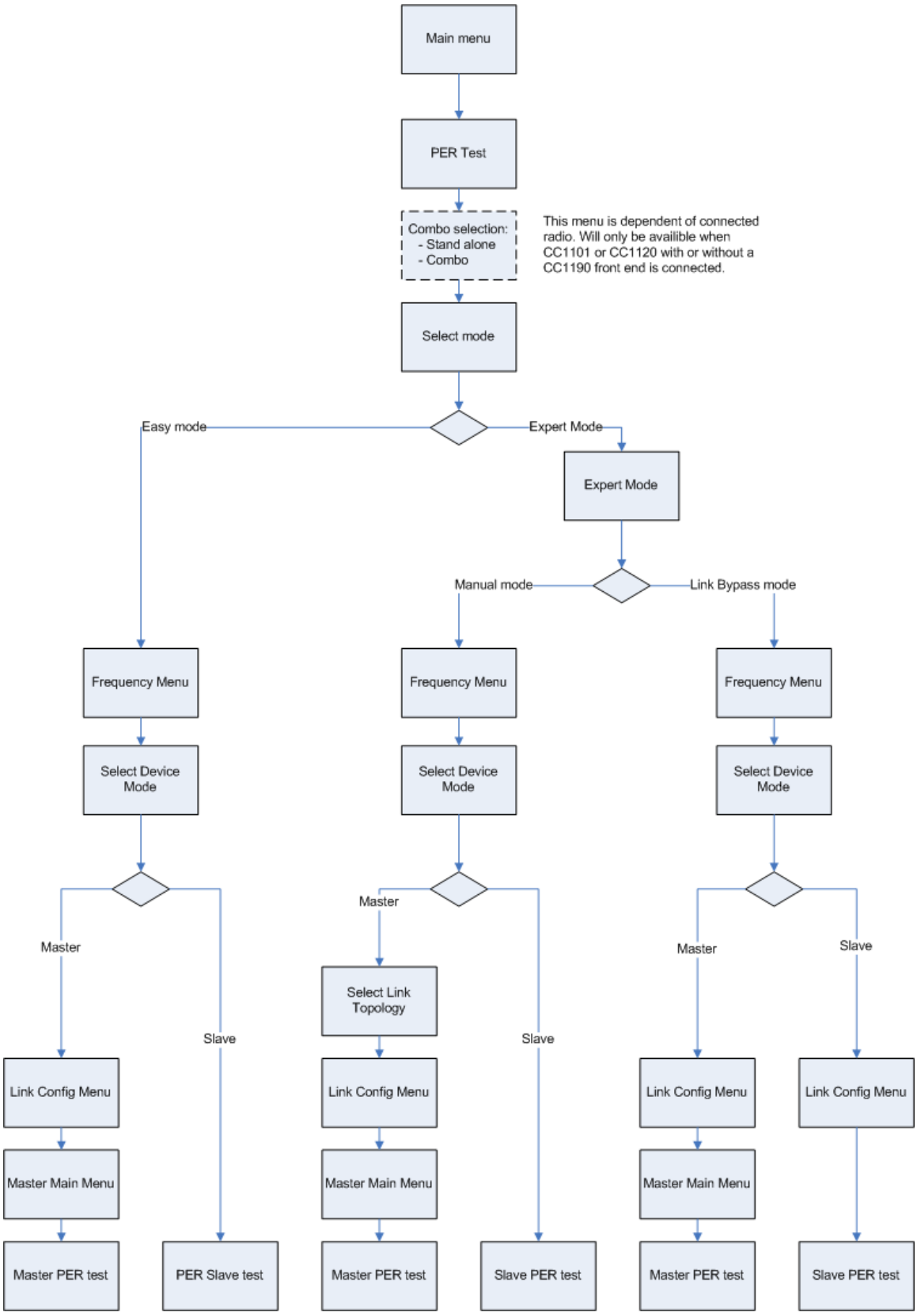


Figure 6 PER test Menu Tree

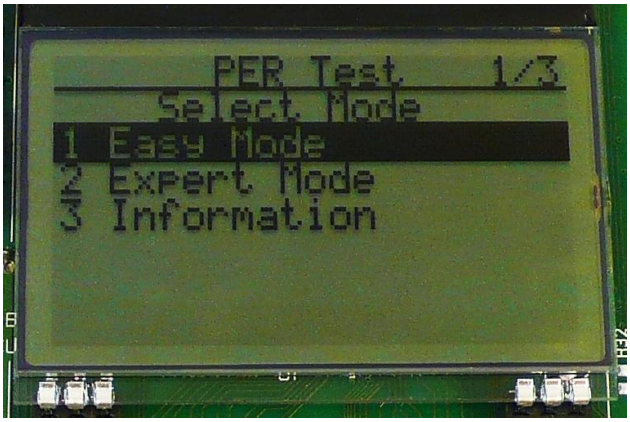


Figure 7 Test Mode Menu

6.1.1 Easy Mode

In easy mode the one-way link topology is used. The Slave will continuously transmit pre-defined packets until aborted by the user. The Master is set up to receive a certain number of packets and count the number of successful receptions. A timer is used to calculate a time window for receiving a packet. If no packet is received inside this window, the packet is considered lost.

In Easy Mode the user can select between different pre programmed frequency bands, data rate and output power.

When Easy Mode is selected the next menu the user will come to is the frequency selection.

6.1.1.1 Frequency Selection

In the frequency menu, the user can choose between a set of pre-programmed frequency bands. Use the up/down buttons to select between the options and press enter (right button) to set the desired frequency.

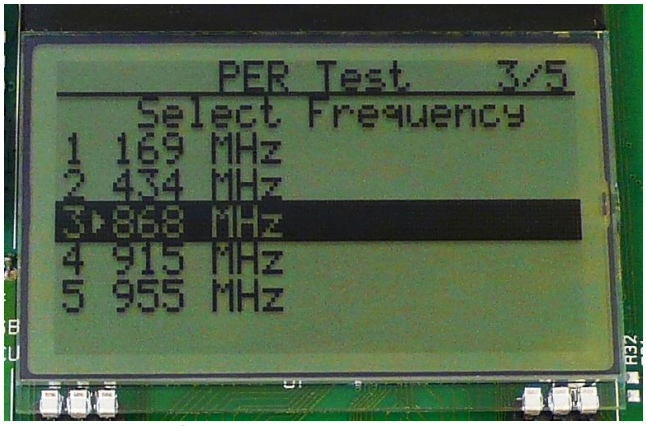


Figure 8 Frequency Menu

The frequency selection is depended on the connected radio type. The following frequency choices are available:

CC120x	CC112x	CC1101	CC110L	CC113L	CC115L	CC1101-CC1190	CC1120-CC1190
169 MHz	169 MHz	-	-	-	-	-	-
-	-	315 MHz	315 MHz	315 MHz	315 MHz	-	-
434 MHz	434 MHz	434 MHz	434 MHz	434 MHz	434 MHz	-	-
868 MHz	868 MHz	868 MHz	868 MHz	868 MHz	868 MHz	869 MHz	869 MHz
915 MHz	915 MHz	915 MHz	915 MHz	915 MHz	915 MHz	915 MHz	915 MHz
955 MHz	955 MHz	-	-	-	-	-	-

Table 1 Pre-programmed frequencies

After the frequency is selected, the user will be presented with the Device Mode Menu.

6.1.1.2 Select Device Mode

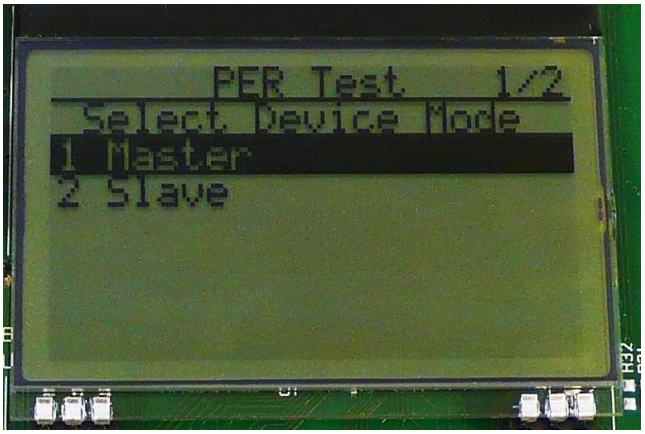


Figure 9 Device Mode Menu

The PER test has two different device modes, Master or Slave. When Slave is selected the radio will enter RX and wait for a configuration packet from the Master node. If Master is selected the user will be presented with the link configuration menu.

One exception from this is when CC113L and CC115L are used. Since the CC113L is a receiver and the CC115L is a transmitter, the test will not be able to do a two-way communication which is necessary for the link configuration procedure. For these radios the configuration must be manually set up on both nodes.

6.1.1.2.1 Slave Node

When Slave is selected by user, the radio will go in RX and wait for the configuration packet. This is indicated by the slave mode status displaying “Connecting…” on the LCD.

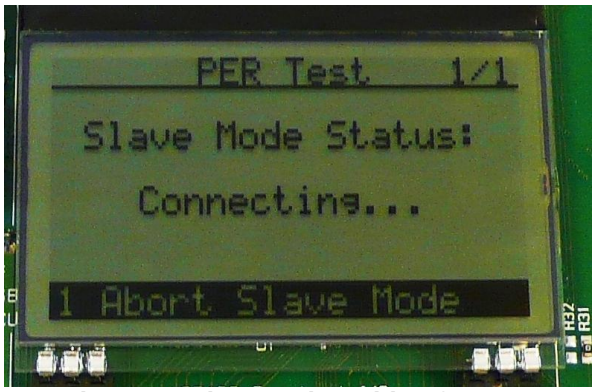


Figure 10 Slave node waiting for configuration packet

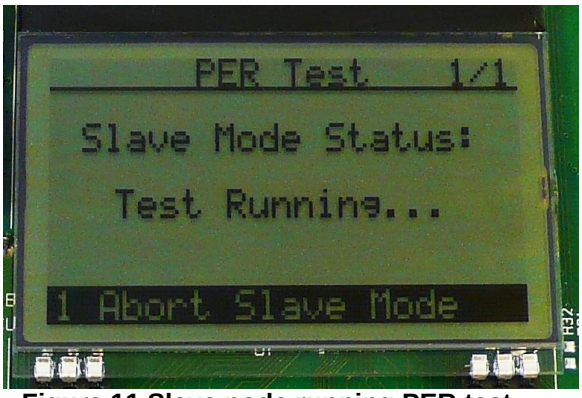


Figure 11 Slave node running PER test

As soon as the configuration packet is received, the Slave will start to transmit packets continuously at the configured data rate and output power. The slave mode status will be set to test running.

6.1.1.3 Easy Mode Link Configuration

If Master is selected in the device mode menu the PER test will present the configuration possibilities in the link configuration menu. For Easy Mode the available configuration possibilities are data rate and output power. The Master node will also generate a random address that will be used for address filtering of packets during the PER test. This makes it possible to do multiple tests with different boards at the same time without them interfering.

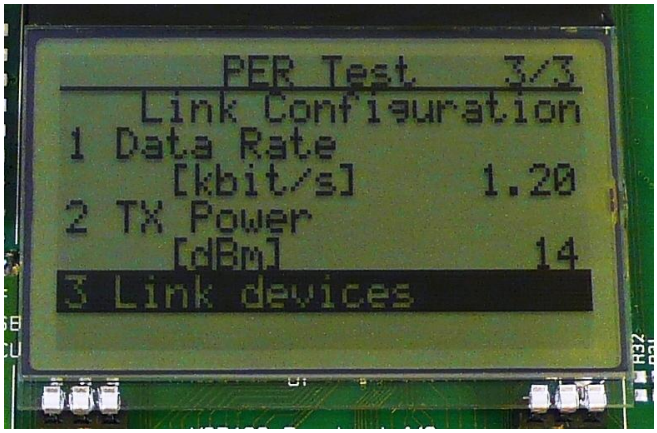


Figure 12 Link Configuration Menu

To send the configuration packet select “Link Devices”. The configuration packet will be sent from the Master node to the Slave which will start to continuously transmit packets to the Master node. The Master will enter the Master start menu.

Be sure that the Slave node is set up and is ready to receive the configuration packet before trying to link the devices.

6.1.1.3.1 Data rate

The PER test is programmed with three different data rates, low, medium and high data rate. The data rates depend on which radio connected to the evaluation board.

For the supported radios, the following data rates are available:

Radio	Low data rate	Medium data rate	High data rate
CC1200	1.2 kbps	50.00 kbps	200.00 kbps
CC1120	1.2 kbps	50.00 kbps	150.00 kbps
CC1101	1.2 kbps	38.38 kbps	249.49 kbps
CC110L	1.2 kbps	38.38 kbps	249.49 kbps
CC113L	1.2 kbps	38.38 kbps	249.49 kbps
CC115L	1.2 kbps	38.38 kbps	249.49 kbps
CC1101-CC1190	1.2 kbps	4.89 kbps	38.38 kbps
CC1120-CC1190	1.2 kbps	50.00 kbps	-

Table 2 PER Test Data rates

6.1.1.3.2 TX Output power

The TX output power available depends on the radio connected to the EB. The following table shows the available choices, depending on radio used:

CC1200	CC1120	CC1121	CC1101	CC110L	CC113L	CC115L	CC1101 - CC1190 (869 MHz)	CC1101 - CC1190 (915 MHz)	CC1120 - CC1190 (869 MHz)	CC1120 - CC1190 (915 MHz)
14 dBm	14 dBm	14 dBm	10 dBm	10 dBm	n/a	10 dBm	20 dBm	26 dBm	26 dBm	26 dBm
10 dBm	10 dBm	10 dBm	7 dBm	7 dBm	n/a	7 dBm	-	-	-	-
5 dBm	5 dBm	5 dBm	5 dBm	5 dBm	n/a	5 dBm	-	-	-	-
0 dBm	0 dBm	0 dBm	0	0	n/a	0	-	-	-	-
-5 dBm	-5 dBm	-5 dBm	-10 dBm	-10 dBm	n/a	-10 dBm	-	-	-	-
-10 dBm	-10 dBm	-10 dBm	-15 dBm	-15 dBm	n/a	-15 dBm	-	-	-	-
-16 dBm	-16 dBm	-16 dBm	-20 dBm	-20 dBm	n/a	-20 dBm	-	-	-	-
-	-	-	-30 dBm	-30 dBm	n/a	-30 dBm	-	-	-	-

Table 3 PER Test output power selection

6.1.1.4 Master start menu

When the link is configured successfully the user will come to the Master Start Menu.

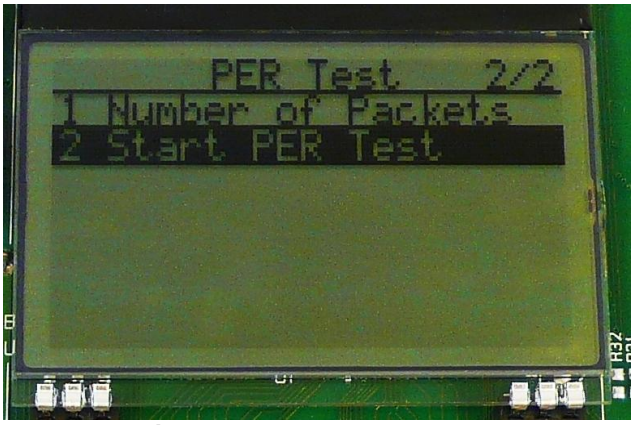


Figure 13 Master Start Menu

In the Master start menu the user can select the number of packets the Master will receive from the Slave. This number is used to calculate the packet error rate percentage. The following choices are available:

	Number of packets
1	100
2	1000
3	10.000
4	65.000

By default the number is set to 65.000 packets. When selecting “Start PER Test”, the Master will start counting packets and display the PER statistics.

6.1.1.5 PER Statistics

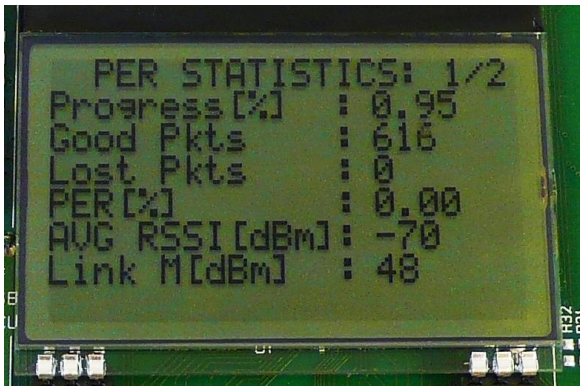


Figure 14 PER statistics 1/2

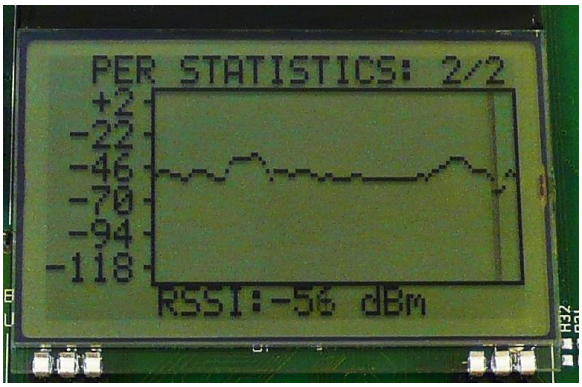


Figure 15 PER statistics 2/2

The Master will display the following PER statistics divided over two screens:

Screen	Name	Value	Topology	Description
½	Progress	Percent	One/Two-way	$\frac{LostPackets + GoodPackets}{NumberOfPackets}$
½	Good Packets	N	One/Two-way	Number of received packets with correct length and CRC ok.
½	Lost Packets	N	One/Two-way	Number of packets missed within the time window.
½	Packet Error Rate	Percent	One/Two-way	$PER = \frac{LostPackets}{LostPackets + GoodPackets} \times 100$
½	Average RSSI	dBm	One/Two-way	The average RSSI value from the last 16 valid RSSI values.
½	Link Margin	dBm	One/Two-way	$AverageRSSI - Sensitivity$
½	Number of retransmits	N	Two-way	Number of times a packet has been retransmitted due to lack of ACK
2/2	RSSI graph	-	One/Two-way	

Table 4 PER Statistics

The test will by default start to show the RSSI graph on screen two. To get access to the detailed statistics, press the Up button.

To reset the PER statistics simply return to the Master start menu by pressing the left (back) button and start PER test again.

6.1.2 Expert Mode

In expert mode the user can choose between Manual Mode and Link Bypass Mode. Manual mode offers more configuration settings than Easy Mode, where the user can now also chose between one-way or two-way link topology, packet length and number of retransmits.

Link Bypass Mode sets up a default link with pre-programmed data rate and output power without the need of a link configuration

6.1.2.1 Manual Mode

In this mode the user can choose between the two link topologies, one-way or two-way with retransmit. In addition to the data rate and output power, manual mode offers some extra configurable settings. User can set the packet length for one-way topology, and packet length and number of retransmits for the two-way link topology. For the two-way topology the PER statistics will in addition to the usual statistics also display how many times a packet has been retransmitted because of no acknowledgment from the Slave node.

6.1.2.2 Link Bypass Mode

In this mode the link configuration packet is skipped and the test runs at the low data rate pre defined setting of 1.2 kbps and maximum output power. The output power depends on the radio connected to the board. See Table 3 for details.

Address filtering is turned off and the packet format is defined for all compatible radios.

In this mode the packet configuration is identical for CC112x, CC1101, CC110L, CC113L and CC115L. This gives the ability to send packets between the different radio types.

6.1.3 Link Topologies

The PER Test uses two different link topologies, one-way link and two-way link with retransmit.
The link topology to be used is defined by the Master. In Easy Mode only the one-way link is available. For Expert Mode both link topologies can be selected.

6.1.3.1 One way link topology

In the one way link topology the Slave node continuously transmits pre-defined packets at a chosen data rate and output power to the Master node. The Master Node is set up to receive a certain number of packets and count the number of successful receptions. A timer is used to calculate when the Master expects to receive a packet. If no packets have been received within the expected time frame the packet is considered lost.

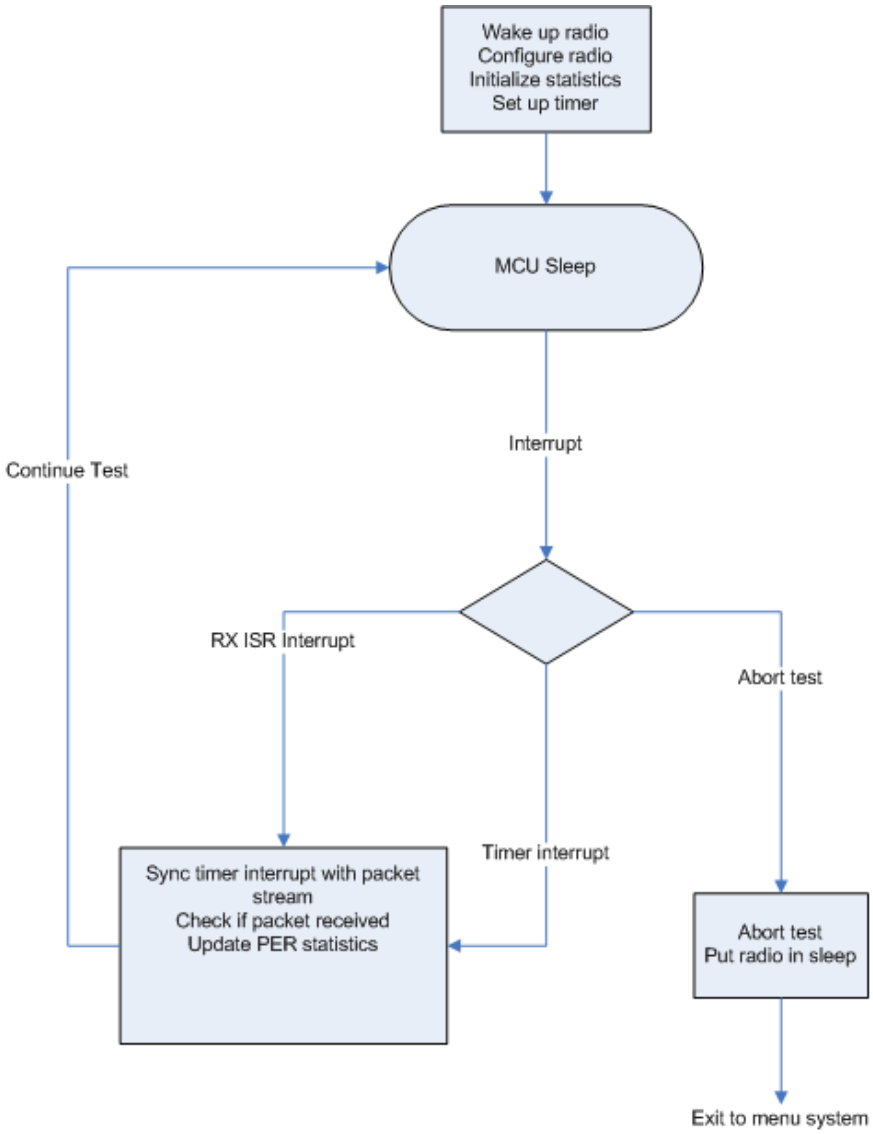


Figure 16 One-way PER test at Master

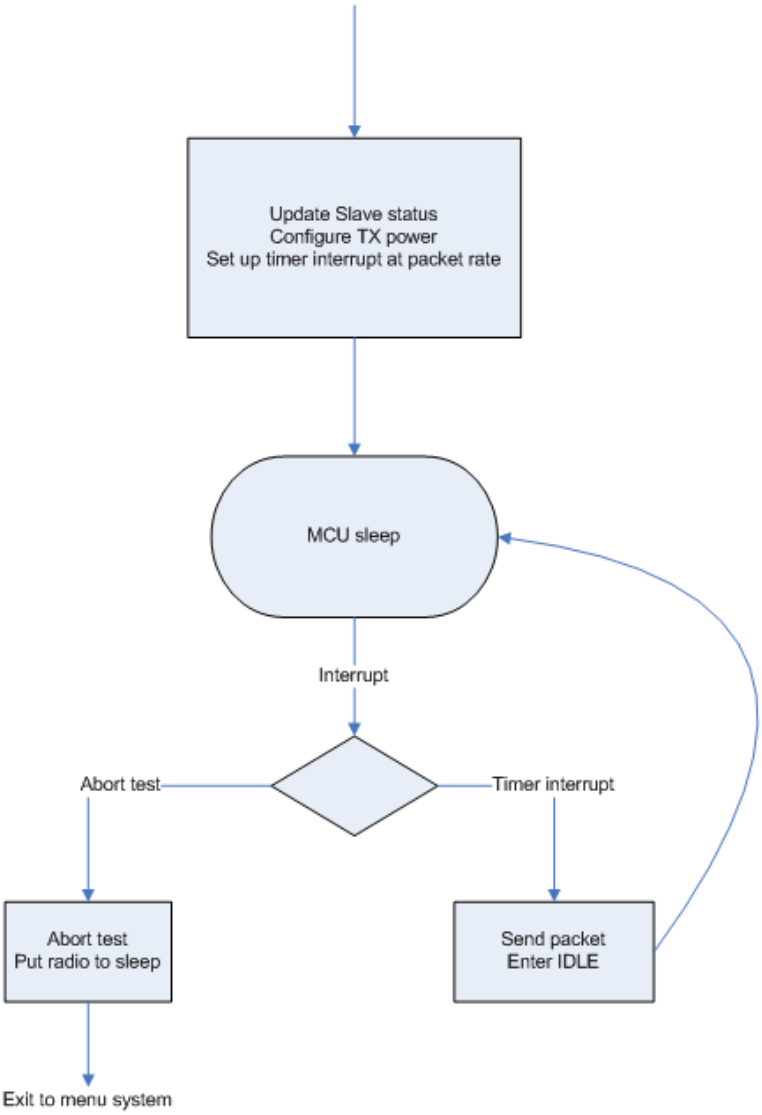


Figure 17 One-way PER test at Slave

6.1.3.2 Two way link topology

In the two way link topology the Master node transmits packets at a chosen data rate and output power to the slave node. The slave node will indicate that the package is received by sending an acknowledgment packet (ACK) of two bytes back to the Master node. The next time the Master is about to send a packet, it checks if it has received an ACK. Depending on configured number of retransmits, the Master node will either try to retransmit the last packet or consider the packet lost.

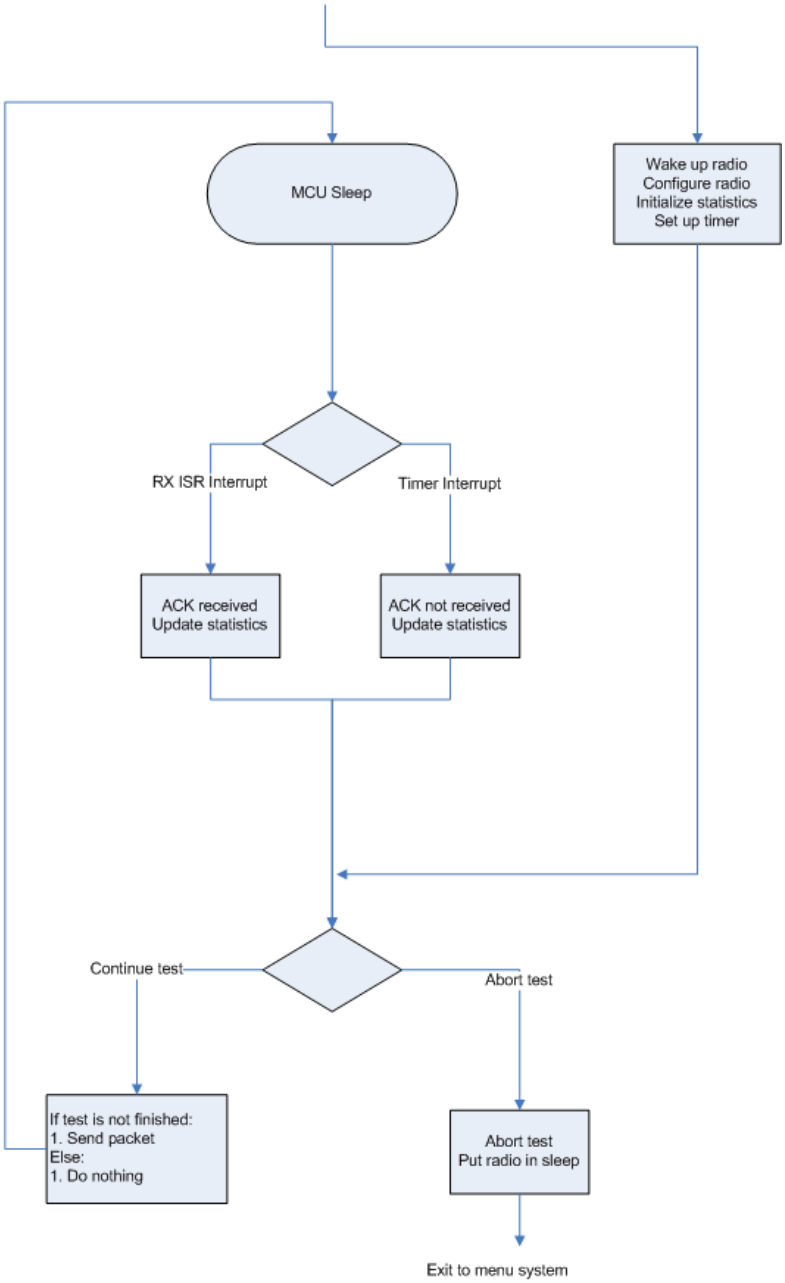


Figure 18 Two-way PER test at Master

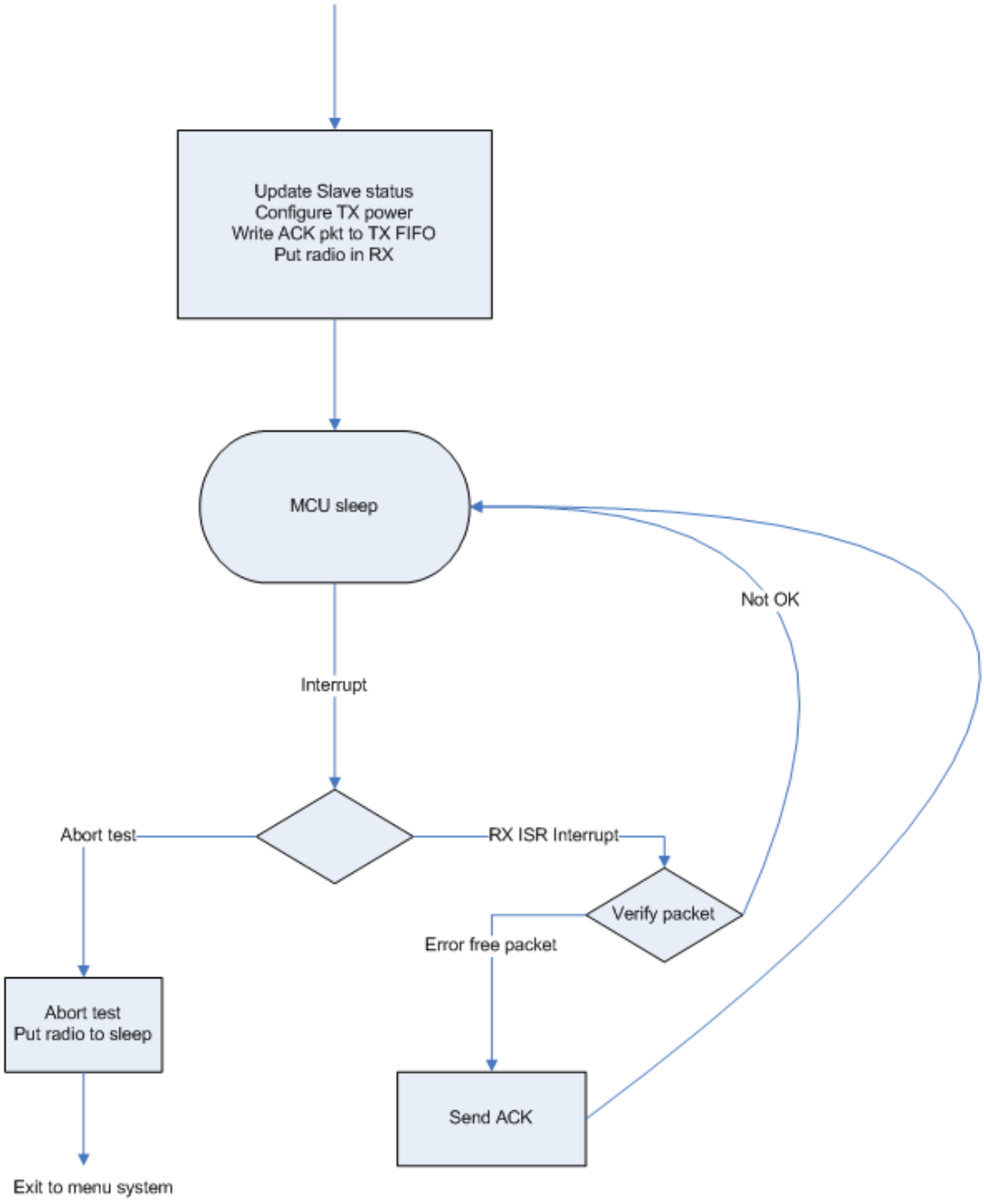


Figure 19 Two-way PER test at Slave

6.1.3.3 Link configuration flowchart

This section shows the program flow of the link configuration between the Master and the Slave node.

Configuration of the RF link is done for every link mode except for the Link Bypass Mode. When the configuration of the Slave has succeeded, Slave Mode must be aborted before a new configuration can be successfully achieved.

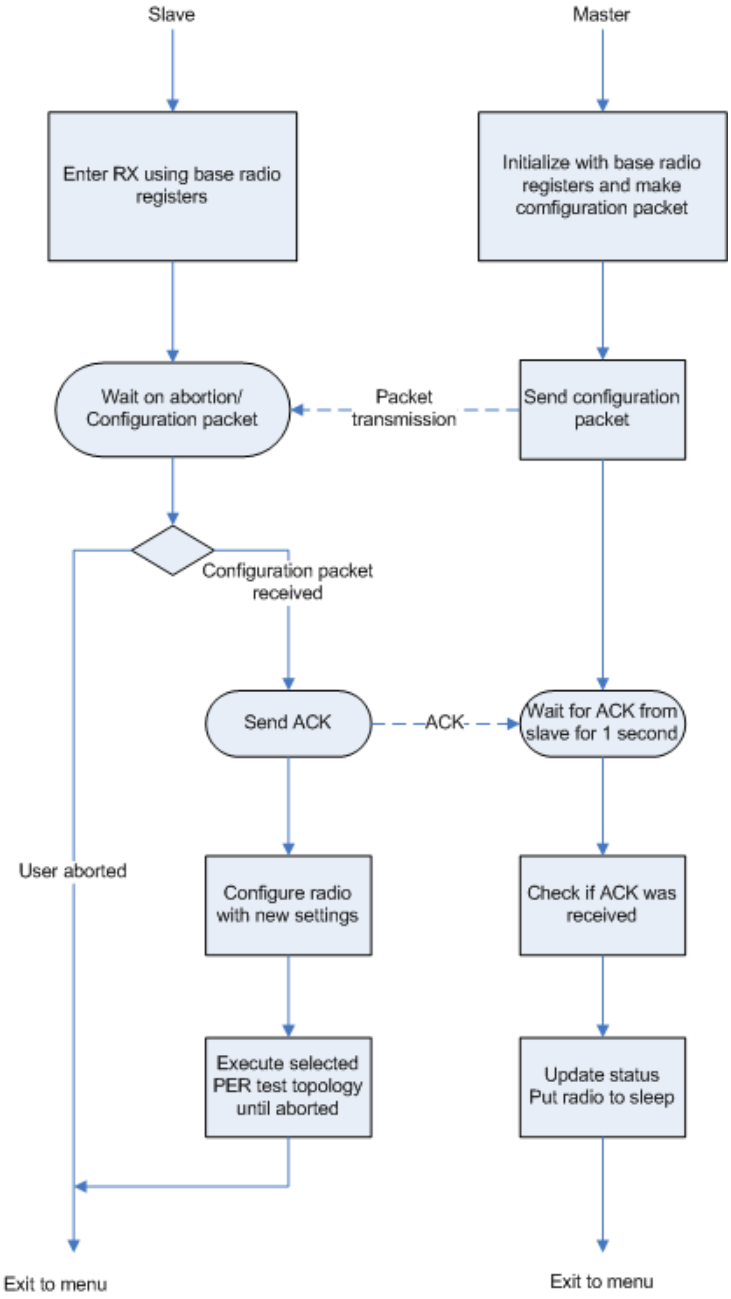


Figure 20 Link initialization

6.2 EasyLink Test

The Easy Link test is an easy one way link between two nodes where the Master continuously transmits packets to the Slave. The test currently supports link between a pair of the following devices:

- **CC1120EM**
- **CC1121EM**
- **CC1125EM**
- **CC1101EM**
- **CC110L EM**
- **CC113L EM**
- **CC115L EM**
- **CC1200 EM**
- **CC1201 EM**

The code is set up so it is easy for users to export register settings from SmartRF Studio [9] and substitute the pre- programmed register settings in the code. All register settings can be found in the cc1xxx_easy_link_reg_config.h files.

The pre-programmed register settings are the SmartRF Studio recommended register settings for 1.2 kbps 2-FSK transmission at 868 MHz, except for the CC1125 which is set to 869.225 MHz due to SAW filter restrictions on the EM:

6.2.1 Replacing register settings

1. Open SmartRF Studio
2. Open the device control panel for the desired radio
3. In expert mode change RF parameters as desired.(GDO has to be set to 0x06 for packet interrupt)
4. Press the register export button.
5. In the Register Export window be sure that the export format match the format used in the easy link test.

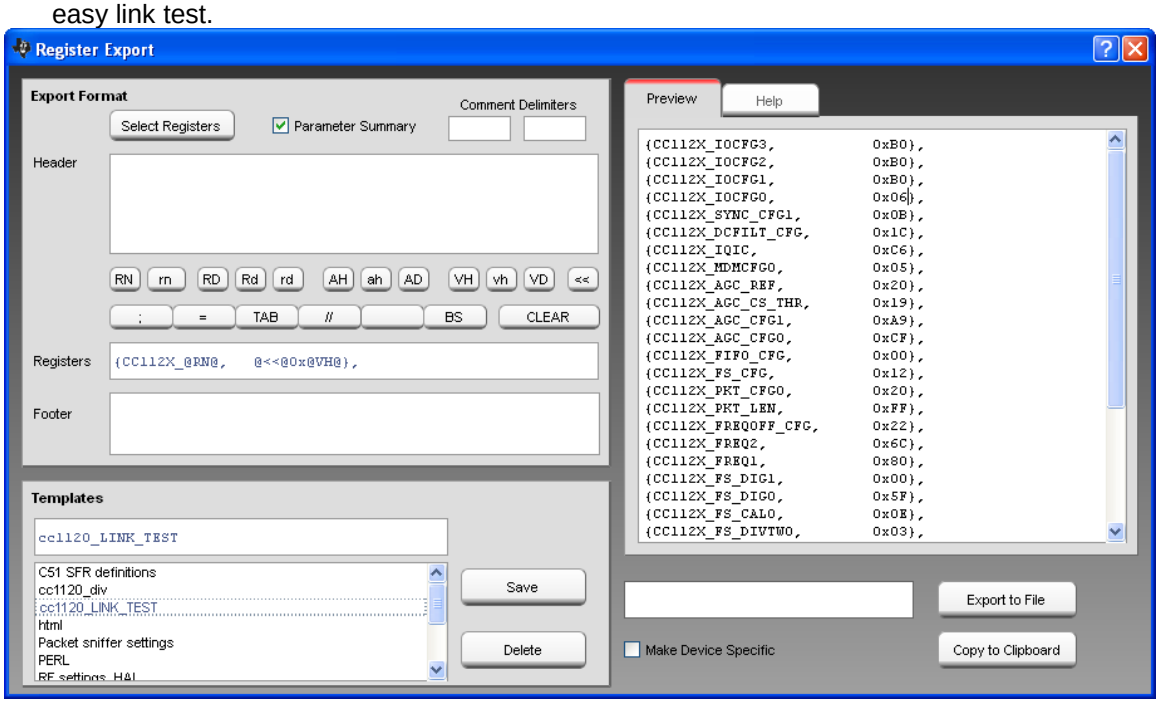


Figure 21 SmartRF Studio Register Export

6. Copy the new register settings to clipboard or save them to file.
7. Paste the exported register settings into the code.

6.2.2 EasyLink flowchart

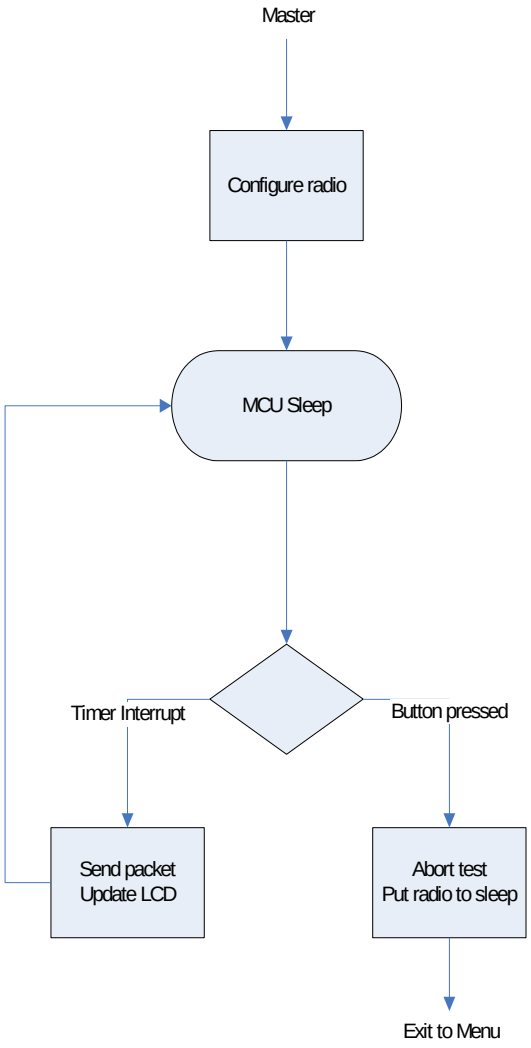


Figure 22 EasyLink Master

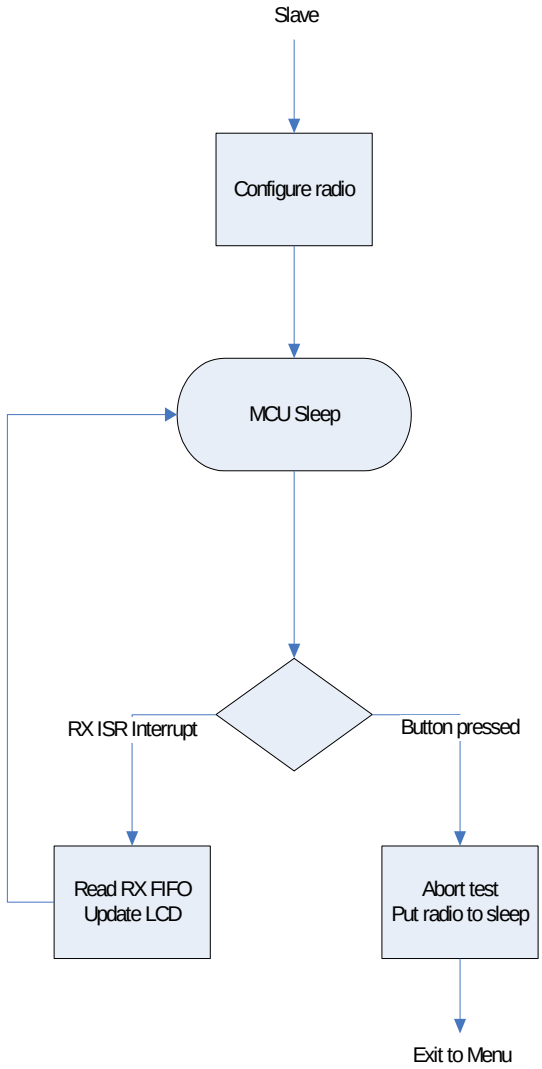


Figure 23 EasyLink Slave

6.3 RX Sniff Test

Note: This application will only work with a CC112x connected to the TrxEB.

The RX Sniff Test is a simple demonstration of the RX Sniff Mode feature of the CC112x Performance Line family. It sets up a simple link between a Master and a Slave node where the Master node sends a packet to the Slave each time the user presses the right (enter) button.

The Slave node uses the CC112x Wake On Radio (WOR) functionality to periodically sniff for RF activity. The CC112x is designed for quick settling time and the short settling time can be used for lower power operation by being able to quickly turn on and off the receiver.

RX Sniff mode is a duty cycled RX mode that significantly reduces the RX power consumption by using longer preamble than required for the demodulator. The receiver can quickly enter RX and check for activity and enter sleep if no activity is detected. By setting the wake up time to be shorter than the preamble length, the duty cycling will be transparent to the user.

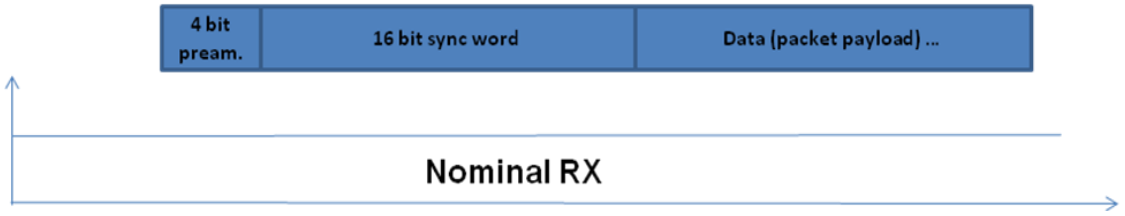


Figure 24 Normal RX

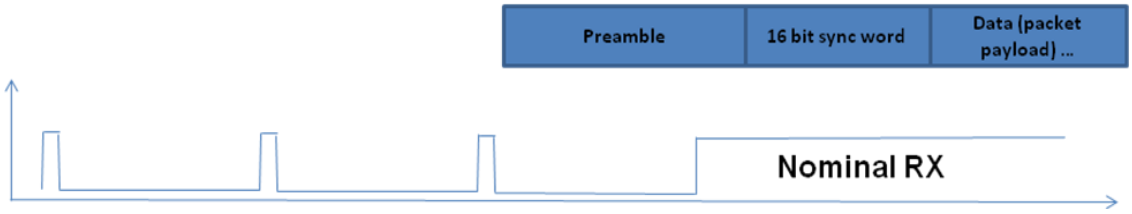


Figure 25 RX Sniff Mode

The configuration uses 1.2 kbps data rate with 4 byte preamble. In this example the average current consumption when the radio is duty cycling is measured to 1.9 mA opposed to 25.1 mA which is the current consumption when the receiver is set in continuous RX.

For details about the CC112x RX Sniff Mode and please refer to the CC112x User's guide [2] or the CC112x RX Sniff mode design note [14] .

6.3.1 Running the application

To run the RX Sniff Test, be sure to have a CC112x device connected to the evaluation board.

6.3.1.1 RX Sniff Test

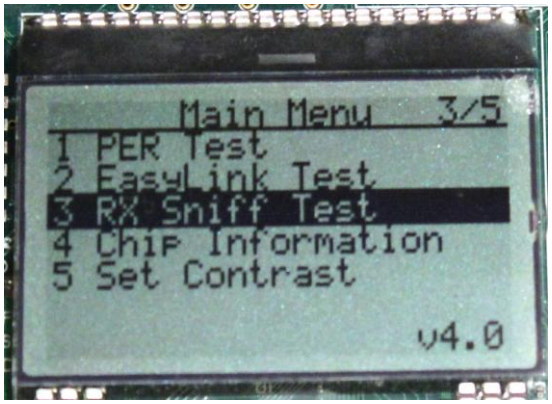


Figure 26 RX Sniff Test Menu

Select the RX Sniff Test by highlighting the selection (use up/down buttons), then press right (enter) button.

6.3.1.2 Select Frequency

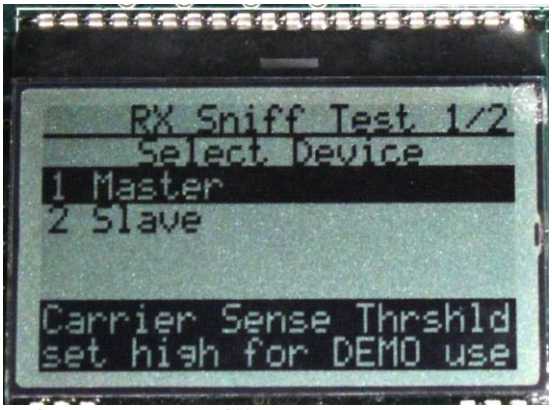


Figure 27 RX Sniff Test Frequency Menu

Select which frequency to use for the test. Be sure that the evaluation modules you have match the selected frequency.

6.3.1.3 Select Device Mode

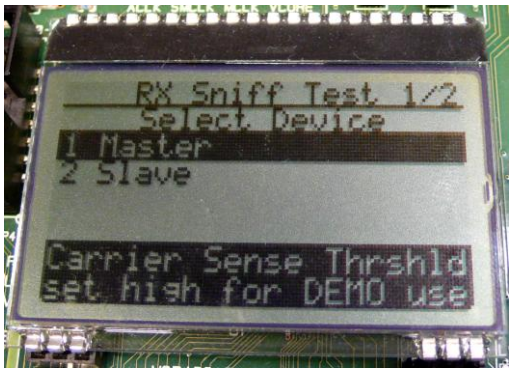


Figure 28 RX Sniff Test Device Mode Menu

One of the boards must operate as a Slave (receiver) and one as a Master (transmitter).

6.3.1.4 Waiting for first packet

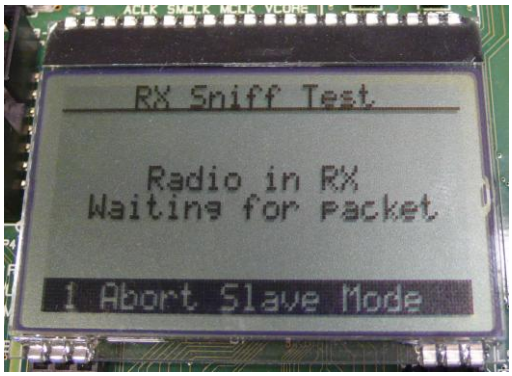


Figure 29 RX Sniff Test Slave Statistics 1

The Slave node will now wait for the first packet from the Master.

6.3.1.5 Slave test statistics

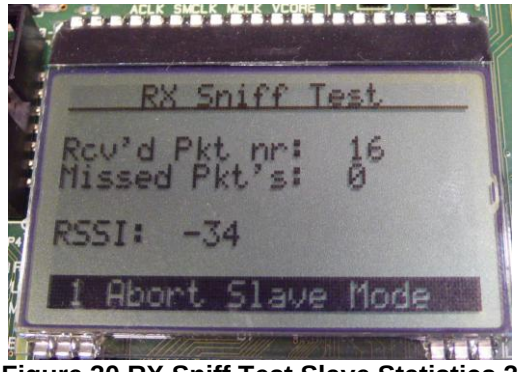


Figure 30 RX Sniff Test Slave Statistics 2

After first packet is received the Slave will show test statistics. Push left (back) button to abort test.

6.3.1.6 Master test statistics

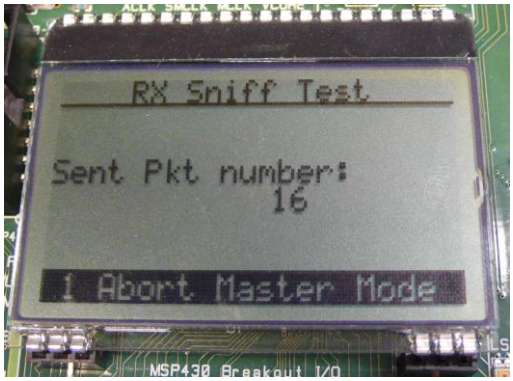
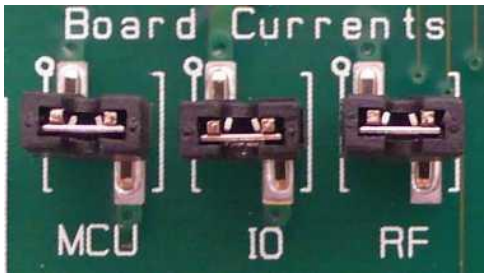


Figure 31 RX Sniff Test Master Statistics

The Master will show number of packets sent. Each time the right (enter) button is pushed a packet is sent. Push left (back) button to abort test.

6.3.2 Measuring the RF current

The TrxEB has three current measurement jumpers, MCU_PWR, IO_PWR and RF_PWR. By removing the jumper and connecting a multi meter on the RF_PWR pins, the RF current consumption can be measured.



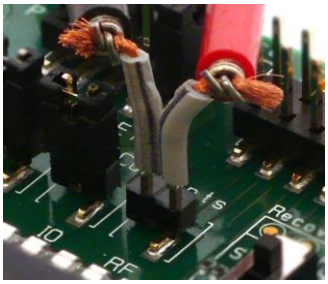


Figure 32 Current measurement

6.4 Chip Information

This small application reads the PARTNUMBER and PARTVERSION registers from the connected radio and displays radio type and version on the LCD. The application also estimates the frequency of the crystal connected to the radio by sampling a divided clock signal from one of the radios GDO pins.

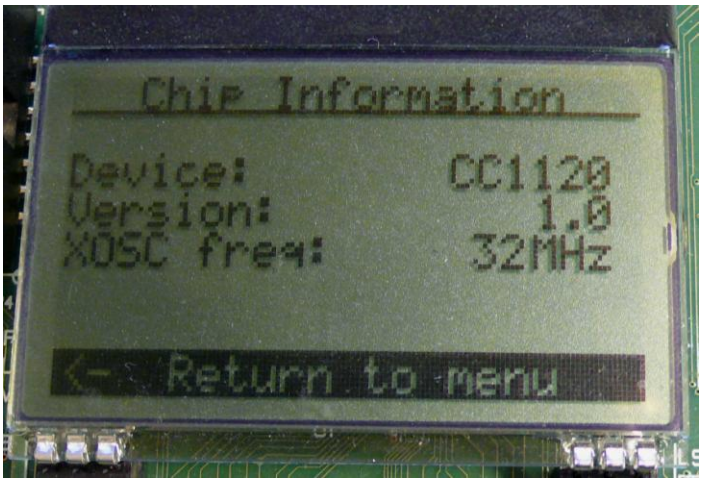


Figure 33 Chip Information

7 References

[1] TrxEB RF PER TEST Software Example (SWRC219)

[2] CC112X Low-Power High Performance Sub-1 GHz RF Transceivers User's guide (SWRU295)

[3] CC120X Sub-1 GHz RF Transceivers User's guide (SWRU346)

[4] CC1101 Low-Power Sub-1 GHz RF Transceiver (SWRS061F)

[5] CC110L Value Line Transceiver Datasheet (SWRS109)

[6] CC113L Value Line Receiver Datasheet (SWRS108)

[7] CC115L Value Line Transmitter Datasheet (SWRS105)

[8] SmartRF transceiver Evaluation Board User's Guide (SWRU294)

[9] SmartRF™ Studio Product Page
http://www.ti.com/smartrfstudio

[10] CC1120 Performance Line Development Kit
http://focus.ti.com/docs/toolsw/folders/print/cc1120dk.html

[11] CC1125 Performance Line Development Kit
http://focus.ti.com/docs/toolsw/folders/print/cc1125dk.html

[12] CC11xL Value Line Development Kit
http://focus.ti.com/docs/toolsw/folders/print/cc11xldk-868-915.html

[13] CC1200 Development Kit
http://focus.ti.com/docs/toolsw/folders/print/cc1200dk.html

[14] DNxxx CC112x RX Sniff Mode (TBD)

8 Document History

Revision	Date	Description/Changes
SWRU296b	2013.02.25	Added CC120x as supported device to the PER test Updated tables with CC1200 settings. Changed the name of the SimpleLink application to EasyLink and added support of more devices. (CC1200 and ValueLine devices) Replaced flow diagrams for the EasyLink application Added reference to CC120x user's guide and CC1200DK
SWRU296a	2012.03.27	Changed title name. Updated reference links. Added CC1125 as radio supported by the software. Changed all references to CC1120 to CC112x where the software supports all the Performance line transceivers. Added 915 MHz band and 50 kbps data rate to CC1120-CC1190 Combo PER test setup. Added reference to CC1125DK
SWRU296	2011.07.21	Initial release.

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