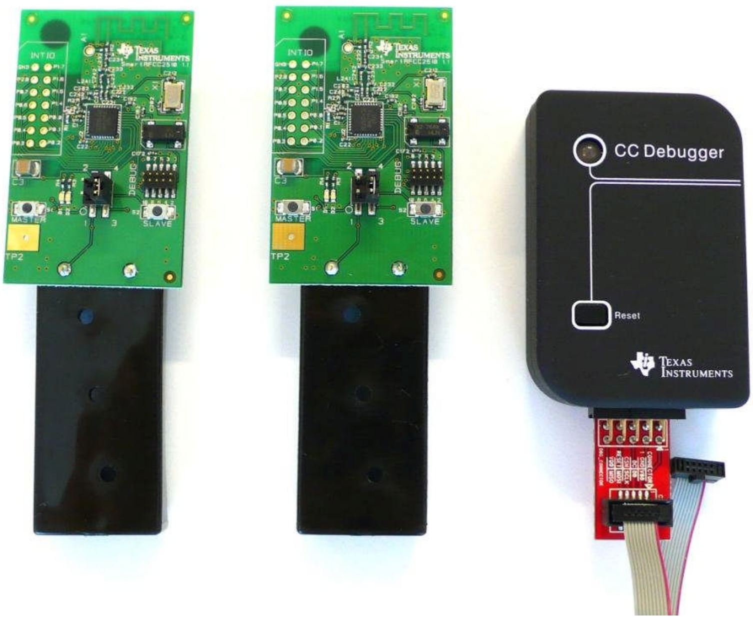
CC1110 & CC2510

Mini DK Software Example

User's Guide



SWRU237

Table of content

1 Introduction 3

2 About this manual 3

3 Acronyms 3

4 Flow chart for the application 4

5 Application example 5

5.1 Introduction 5

5.2 Running the application 6

5.3 Software 6

5.3.1 Master node 6
5.3.2 Slave node 7
5.3.3 Software features 7
5.3.3.1 Adaptive power adjustment 7
5.3.3.2 Random Address 8
5.3.3.3 Packet format 9
5.3.3.4 Frame time 9
5.3.3.5 Power Mode 10
5.3.3.6 Reset Device 10
5.3.4 Software structure 11

6 Power profiles 12

6.1 Master node at -20 dBm output power 12

6.2 Master node at 0 dBm output power 13

6.3 Master node at 10 dBm output power 13

6.4 Master node with 3 cycles of TX/RX 14

6.5 Master node retransmits 3 times without ACK 14

6.6 Slave node under typical conditions 15

7 References 16

1 Introduction

This document describes how to run the Simple Link application that is pre-programmed on the CC1110 and CC2510 Mini Development Kits.

The application is a robust link test. It consists of two end devices, a MASTER and a SLAVE, which establish a direct peer-to-peer connection using SimpliciTI.

The Simple Link application is written for the IAR Embedded Workbench for 8051 and is based on SimpliciTI 1.1.0 [1].

The application operates at 868.3 MHz for the CC1110 and 2.42575 GHz for the CC2510. It uses GFSK modulation and a bit rate of 2.4 kbps for both chips.

2 About this manual

This manual covers the Simple Link application for the CC1110 and CC2510 Mini Development Kit. It describes how the application works, shows power profiles and explains features implemented in the application.

3 Acronyms

ACK	Acknowledgment
CCA	Clear Channel Assessment
DK	Development Kit
GFSK	Gaussian Frequency Shift Keying
I/O	Input/ Output
IC	Integrated Circuit
ISM	Industrial, Scientific and Medical
LED	Light Emitting Diode
LPM	Low Power Mode
LPRF	Low Power RF
MCU	Micro Controller Unit
PCB	Printed Circuit Board
PCB	Printed Circuit Board
PM {0-3}	Power Mode 0-3
RAM	Random Access Memory
RF	Radio Frequency
RSSI	Received Signal Strength Indication
RX	Receive
SoC	System on Chip
SRD	Short Range Device
TI	Texas Instruments
TX	Transmit
UART	Universal Asynchronous Receive Transmit

4 Flow chart for the application

The flow chart shows an overview of the application.

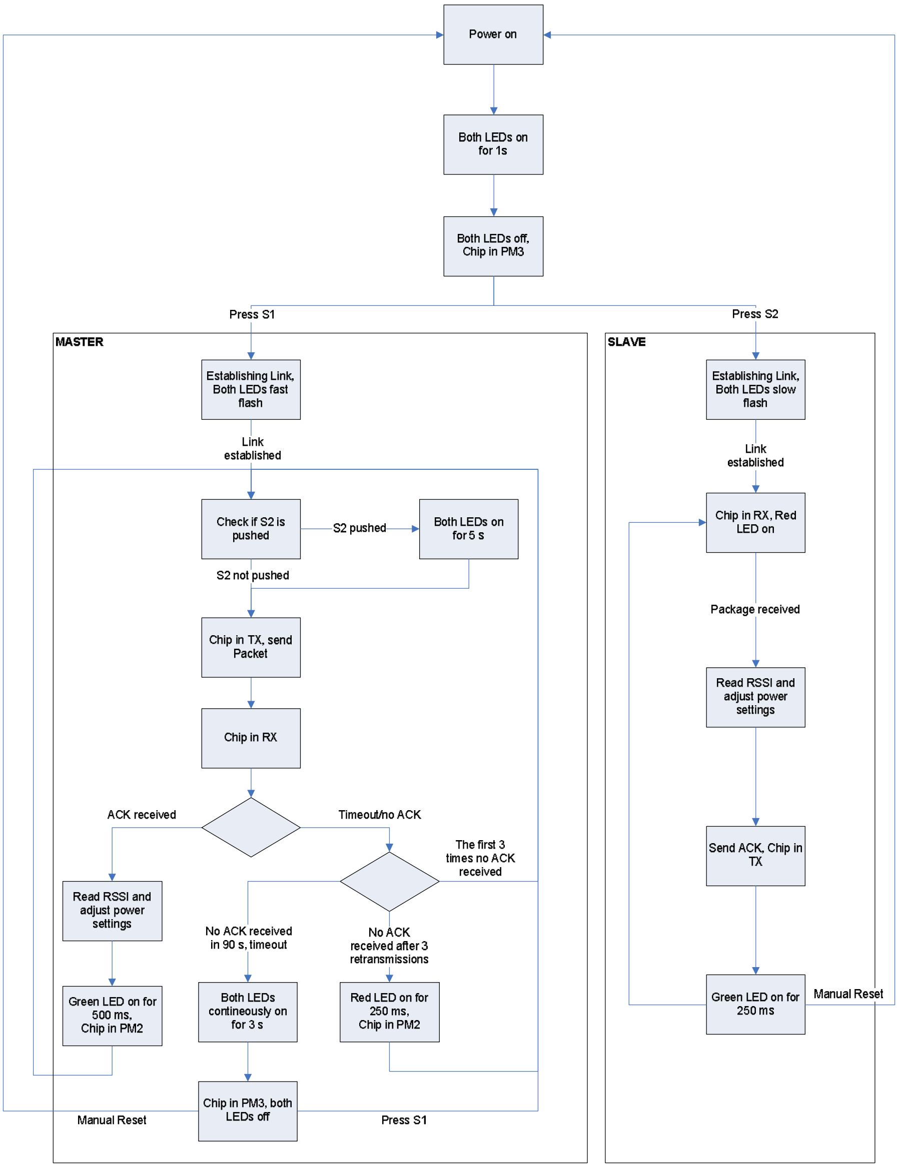


Figure 1 Flow chart for the Simple Link Application

5 Application example

5.1 Introduction

The SmartRFCC1110 and SmartRFCC2510 target boards are preprogrammed with the Simple Link Application. The application is an easy to use and robust link tester. It consists of a master node and a slave node that continuously send packets between each other.

When the power supply is attached, both LED's on the board will light for approximately 1 sec, indicating power on. After power up, the board will go to sleep in power mode 3 (PM3) and stay there until a button is pressed. Depending on button push, the node will enter either a master or a slave mode.

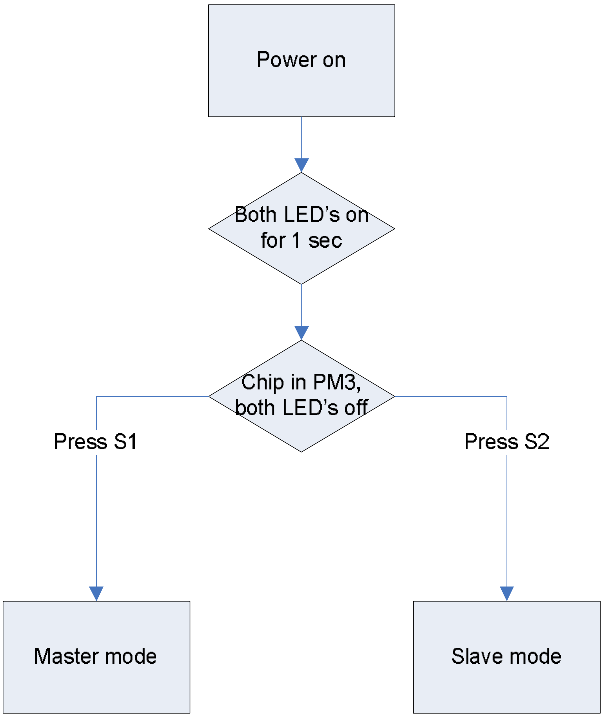


Figure 2 Application start up

Master
If the MASTER button (S1) is pressed, the node will try to establish link with a slave node. Both LED's will blink at a high rate (1.4 Hz) until this link is established. When the link is established, the master node will send packets approximately every 630 ms and wait for an acknowledgment (ACK) from the slave node. The green LED will blink each time an ACK is received.

Slave
If the SLAVE button (S2) is pressed, the node will try to establish link with a master node. Both LED's will blink at a low rate (0.11 Hz) until link is established. The red LED will light continuously when the link is valid. The green LED will blink each time a packed is received and an acknowledgment (ACK) is sent to the master node. To make the application more robust and less exposed to timing difficulties, the slave node is continuously in RX except when transmitting ACK.

This application uses power modes and an adaptive power adjustment to reduce power consumption, increase battery lifetime and avoid saturation. See 5.3.3.1 and 5.3.3.5 for details.

5.2 Running the application

To start the application, follow these steps:

1. Insert 2x AAA batteries in each board
2. Set the jumper in position 1-2 on the power supply selection connector P1 to power up the board. Both LED's will be on for 1 s before the board goes to sleep in PM3.
3. Set one board in master mode by pressing the MASTER (S1) button. Both LED's will flash rapidly while this master node tries to establish link with the slave node.
4. Set the other board in slave mode by pressing the SLAVE (S2) button. Both LED's will flash very slowly while the slave tries to establish link with the master node.
5. When the two nodes are successfully linked, they will periodically send packets between them until the link is broken.

For more details, please see the CC1110 Mini Development Kit 868-915 MHz Quick Start Guide and the CC2510 Mini Development Kit Quick Start Guide ([2] and [3]).

5.3 Software

This section describes the software for the Simple Link Application. Full source code for the application is available on the CC1110 Mini DK and the CC2510 Mini DK websites ([6] and [7]). It is written for the IAR Embedded Workbench for 8051 and is based on the SimpliciTI 1.1.0 protocol stack [1].

The software includes both MASTER and SLAVE function. The function used is dependent on which button was pressed after power up.

5.3.1 Master node

When a node is in master mode, it will continuously send data packets to the slave node. After each packet is sent, the master node goes in RX and waits for an acknowledgment (ACK) from the slave node. After 250 ms the master nodes checks if ACK is received. If ACK is received, the node turns on the green LED for 500 ms before it sends a new data packet.

If the master node does not receive any ACK after the first package is sent, it retransmits the package up to two more times. After tree attempts without receiving ACK, the node turns on the red LED for 500 ms.

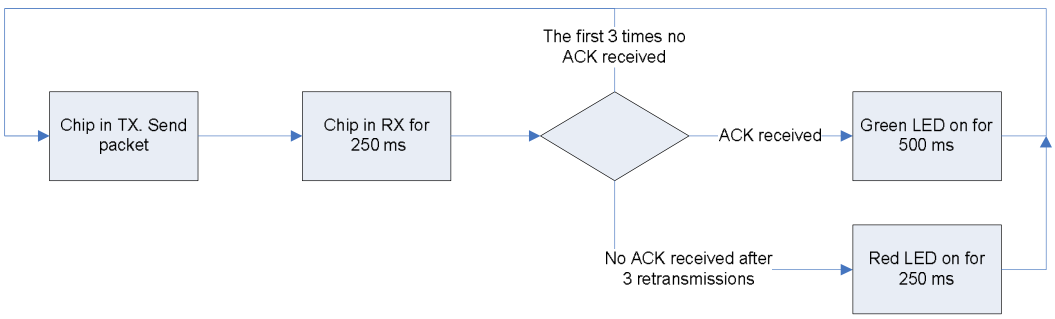


Figure 3 Cycle for master node

To reduce power consumption, the master node goes to sleep in PM3 after 90 sec without any ACK. Both the LEDs on the master node board will be on for 3 s to indicate this state. The node can be woken up by pressing the MASTER button (S1).

Both the data packet the master node sends and the ACK it receives from the slave node are 24 bytes long with 2 byte payload. See section 5.3.3.3 for more details. With a RX time of 250 ms, the master node can receive data packets up to 37 bytes before it checks for ACK.

As a test function, if the SLAVE button on the master node is pressed during operation, both LED's on this board will be on for 5 sec.

5.3.2 Slave node

If a node is in slave mode, the radio will be in RX waiting for data packages from the master node. Each time the slave node receives a data packet it responds by sending an ACK back to the master node. When the ACK is sent the node turns on the green LED for 250 ms before returning to RX ready for the next data packet.

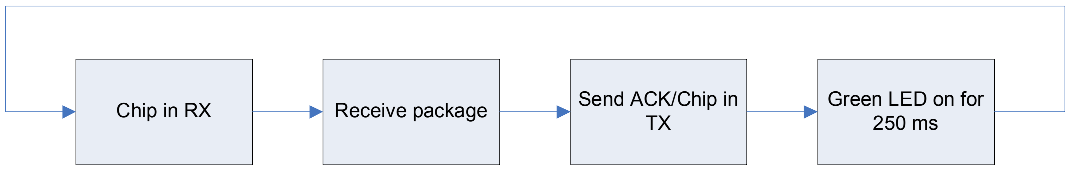


Figure 4 Cycle for slave node

The slave node does not use PM3 to go to sleep after a period without receiving packets like the master node has. This is because it is intended to be on a fixed power source. However, with the introduction of a timer-control to the protocol, this can be implemented.

5.3.3 Software features

5.3.3.1 Adaptive power adjustment

To reduce power consumption and avoid saturation, the application uses a simple adaptive output power method to regulate the output power for both nodes. There are three output power steps as seen in *Table 1.* These steps are chosen to give the application a large range of power settings and at the same time keep the application simple.

Output power:	CC1110	PA value	CC2510	PA value
MAXIMUM_OUTPUT_POWER	10 dBm	0xC0	0 dBm	0xC1
MEDIUM_OUTPUT_POWER	0 dBm	0x50	-10 dBm	0xCB
MINIMUM_OUTPUT_POWER	-20 dBm	0x0E	-20 dBm	0xFF

Table 1 Output power table with PA value for register setting

Algorithm

When a node receives a package, it reads the RSSI (received signal strength indicator) and checks if it is within an interval set by an upper and lower threshold of -40 and – 70 dBm. This interval is set to be well below the saturation point for the radio, but still have good margin to the sensitivity limit. This interval is chosen to make the application robust and is not optimized to reduce power consumption. If the signal strength is not within this interval, the node requests the output power from the other node to be reduced or increased, depended on the RSSI reading.

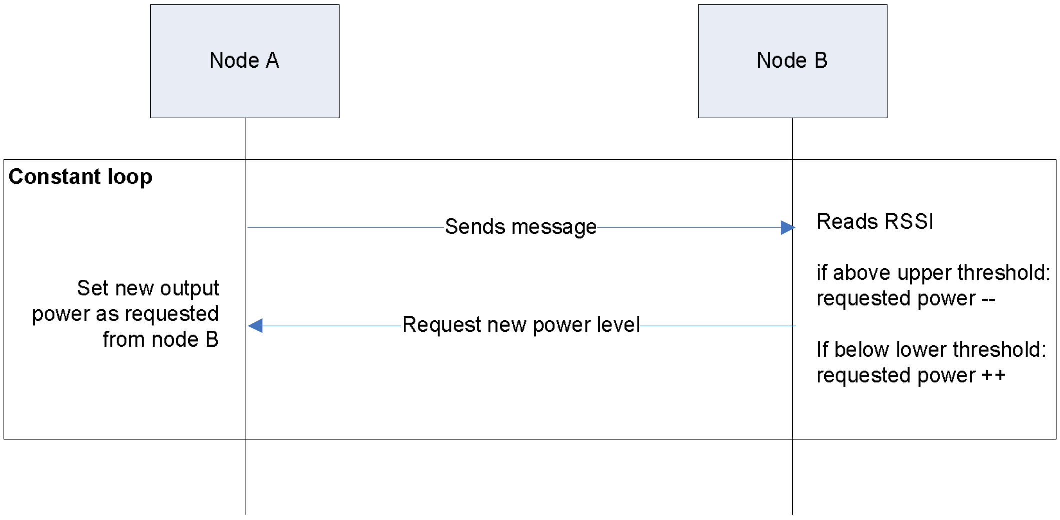


Figure 5 Sequence diagram of the adaptive power adjustment

Since the above method uses the data from the transmissions between the nodes to regulate its output power, the method will not work before there is a valid link between the two nodes. For the initial link procedure the output power is set to maximum. Using maximum output power increases the chance for the nodes to establish link even if the nodes are far apart.

There is no RSSI reading before the first packet is sent from a node, therefore the first packet is also sent at maximum power. All other packets are being sent at the power setting requested from the other node.

If the distance between the two nodes is changed faster than the method regulates the power output, packets may be lost due to received signal being either to high (above saturation point) or to low (below sensitivity limit). High interference close in frequency will affect the RSSI reading and may also result in packets being lost.

For the CC1110 Mini Development Kit
When establishing link between the nodes, the output power is set at maximum value of 10 dBm. If the nodes are to close together, the receivers may be saturated and the nodes will not be able to establish link. During the link procedure, be sure to have the nodes at least 1meter apart to avoid saturation. After link is established the adaptive power adjustment works, and the nodes can be moved closer together.

5.3.3.2 Random Address

The link establishing sequence consists of setting up a network with two end devices. In order to establish this network, each node must have a unique address. The address is 4-bytes long and is generated when the application starts.

The Random Number Generator on the SoC is used to generate the address. To get true random values, the function samples the temperature from the temperature sensor and uses the lower bits containing noise to seed the number generator. See the CC1110/C2510 datasheet for reference ([4] and [5]).

If the two nodes produce the same address, they will not be able to establish link. To generate a new address the node must be reset. See section 5.3.3.6 for details on resetting the nodes.

5.3.3.3 Packet format

The format of the data packet follows the SimpliciTI standard, and for this application consists of the following items:

Preamble	Sync Word	Length	MISC	DSTADDR	SRCADDR	PORT	DEVICE INFO	TRACKID	APP PAYLOAD	FCS
4	4	1	0	4	4	1	1	1	2	2

Table 2 Data packet format

For details about each item, please see chapter 6 in the SimpliciTI Specification [8]

The payload consists of two bytes, indicating current power level and requested power level. It has the following format:

1st Byte	2nd Byte
Requested power level	Current power level

Table 3 Application payload format

Requested power level is the power level the node wants the other node to send its next data package with. This is used for the adaptive power adjustment. **Current power level** is the power level the node has used to send the current data package.

Both the packets sent by the master node and the ACK's sent from the slave follows this format.

5.3.3.4 Frame time

For this application, the frame time is defined as the time the master node uses from sending a packet, to it has toggled one of the LED's and is ready to send a new packet.

In this application the frame time is not constant. This is because all the delays are set to a constant length. This will give a varying frame time depending on how many times the master node re-transmits a packet, see more in *Figure 6*. For the user this may be experienced by an uneven interval between the green flash on the master and slave node.

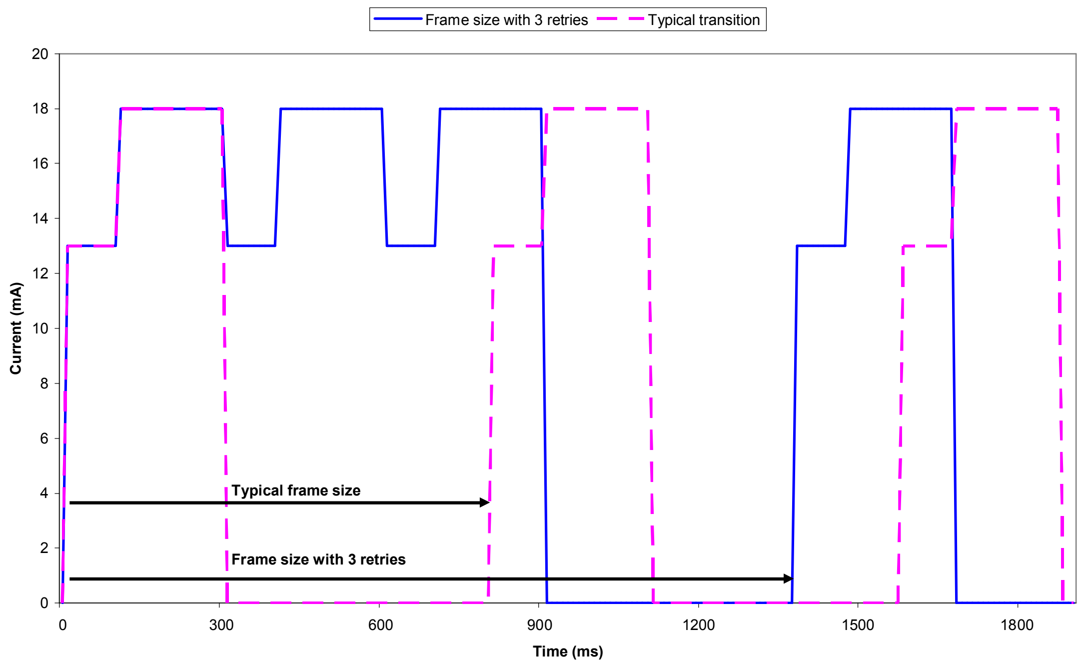


Figure 6 Different frame time dependent of retries

5.3.3.5 Power Mode

The application uses two different power modes, PM2 and PM3. In PM3 all internal circuits, oscillators and voltage regulators are turned off. The system will go in active mode on reset or external interrupt (e.g. button push). In PM2 the low speed RC oscillator is still on and the system will go in active mode on either timer or external interrupt.

The power modes are used to reduce power consumption. Note however that the application is not optimized for power consumption. When PM2 is used with the sleep timer, the I/O ports are not guarantied to be in optimum states. To minimize current consumption in sleep mode, be sure to set all the I/O pins according to load as described in section 12.4 in the CC1110/CC2510 data sheet [4], [5].

For more information about power modes, see design note DN106 [9].

5.3.3.6 Reset Device

In order to exit MASTER or SLAVE mode on a node, the board must be reset. This is done by removing the jumper on P1 and pushing one of the buttons to discharge the large capacitor on the power line. Re-mount the jumper on P1 to power the board again.

5.3.4 Software structure

The source code for the application is available on the CC1110 Mini DK and CC2510 Mini DK website [6], [7].

The IAR project (smpl_link) is organized into 2 different configurations:

- *smpl_link – srfccxx10_cc1110:* This configuration is used for the SmartRFCC1110 Target Board with the CC1110 SoC.
- *smpl_link – srfccxx10_cc2510:* This configuration is used for the SmartRFCC2510 Target Board with the CC2510 SoC.

The source code for the Simple Link application is structured into the following files:

- *smpl_link.c*: Contains implementation of the Simple Link application for the SmartRFCC1110 and SmartRFCC2510 Target Board.
- *bsp_extended.c*: Contains extended board specific functions such as random address, sleep functions and interrupt routines.
- *smartrf_CC1110_srfcc1110.h:* Radio register settings for the CC1110 SoC.
- *smartrf_CC2510_srfcc2510.h:* Radio register settings for the CC2510 SoC.

Radio register settings can be changed in the *smartrf_cc1110_srfcc1110.h* or *smartrfcc2510_srfcc2510.h* file.

The following changes where done to the standard distribution of SimpliciTI 1.1.0:

- Added header file *bsp_extended.h* and source file *bsp_extended.c,* which includes board specific functions. This includes random address generation, interrupt routines and sleep functions for the application.

- Changed the power settings in RF power tables for CC1110 and CC2510 in *mrfi_f1f2.c*:

CC1110 old value	CC1110 new value	CC2510 old value	CC2510 new value
0x0E	0x0E	0xC1	0xC1
0x27	0x50	0xCB	0xCB
0x50	0xC0	0xFE	0xFF

- Changed *mrfi_f1f2.h* to include the register files *smartrf_CC1110_srfcc1110.h* and *smartrf_CC2510_srfcc2510.h* instead of *smartrf_CC1110.h* and *smartrf_CC2510.h*.

- In *nwk_globals.c* edited the function `nwk_globalsInit` so it doesn't overwrite the address that the random address function in *bsp_extended.c* generates.

- Changed `MRFI_MIN_SMPL_FRAME_SIZE` in *mrfi_radio.c* so the radio will accept packets with 0 bytes payload. This is however not used by this application since we have a payload.

6 Power profiles

This section includes plots describing current consumption for the master and slave node for the CC1110 Mini Development Kit under typical conditions. All plots and measurements are done with 3 V power supply at room temperature.

Output power	TX	RX	Idle	PM2 with 1 LED on	PM2*	PM3
-20 dBm	17 mA	23 mA	3.5 mA	4 mA	0.6 µA	0.3 µA
0 dBm	22 mA	23 mA	3.5 mA	4 mA	0.6 µA	0.3 µA
10 dBm	45 mA	23 mA	3.5 mA	4 mA	0.6 µA	0.3 µA

Table 4 Current consumption under typical conditions for CC1110 Mini DK

* I/O pins optimized for current consumption. Not used in this application.

6.1 Master node at -20 dBm output power

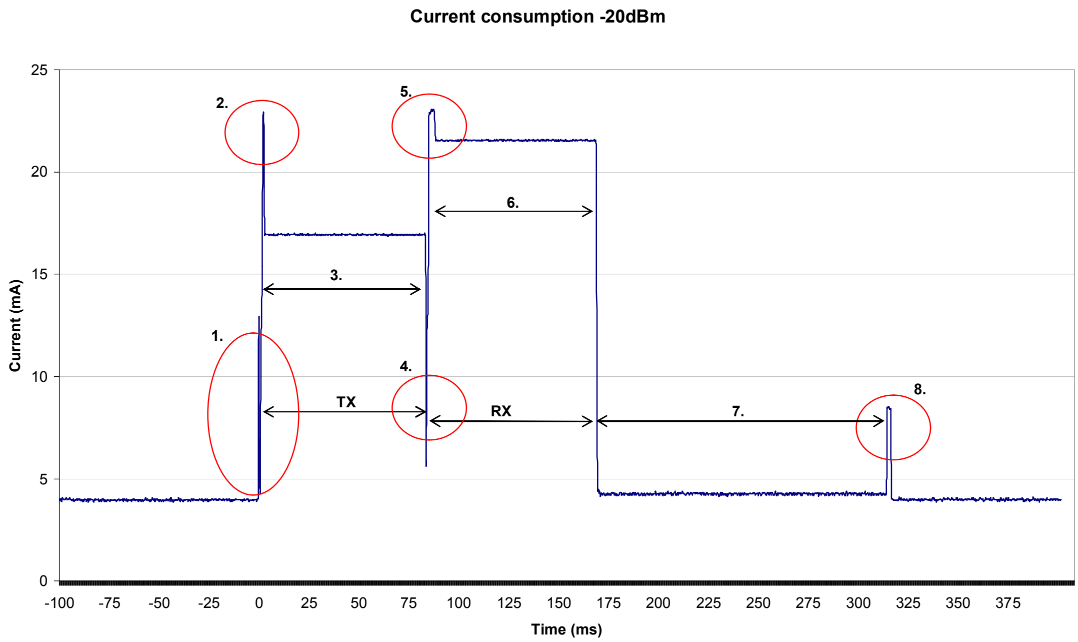


Figure 7 Current consumption for CC1110 Mini DK at -20dBm output power

Details

1. Wakes up from PM2, turns off green LED. System goes from RC oscillator to crystal oscillator.
2. Radio goes in RX and does a Clear Channel Assessment (CCA) before it goes in TX.
3. Radio in TX. Sends data packet
4. Radio goes from TX to idle before it enters RX.
5. Radio in RX at full gain.
6. Receives ACK, gain reduced.
7. When package is received, the radio goes in idle to reduce power consumption.
8. The application checks if it has received an ACK. Then it turns on green LED and goes to sleep in PM2. The radio goes from crystal to RC oscillator.

6.2 Master node at 0 dBm output power

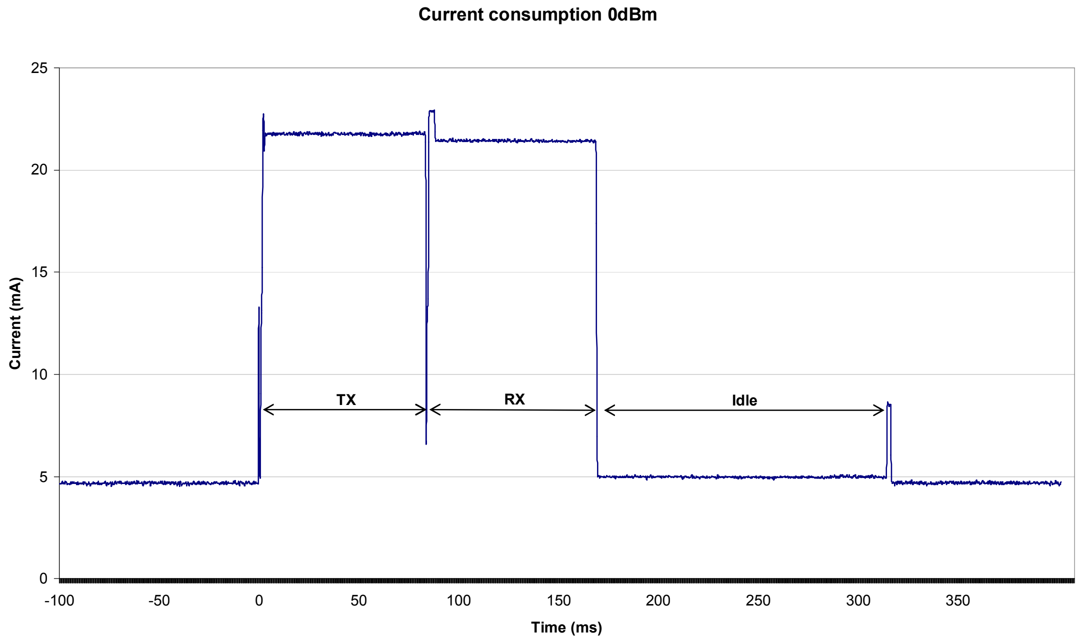


Figure 8 Current consumption for CC1110 Mini DK at 0dBm output power

6.3 Master node at 10 dBm output power

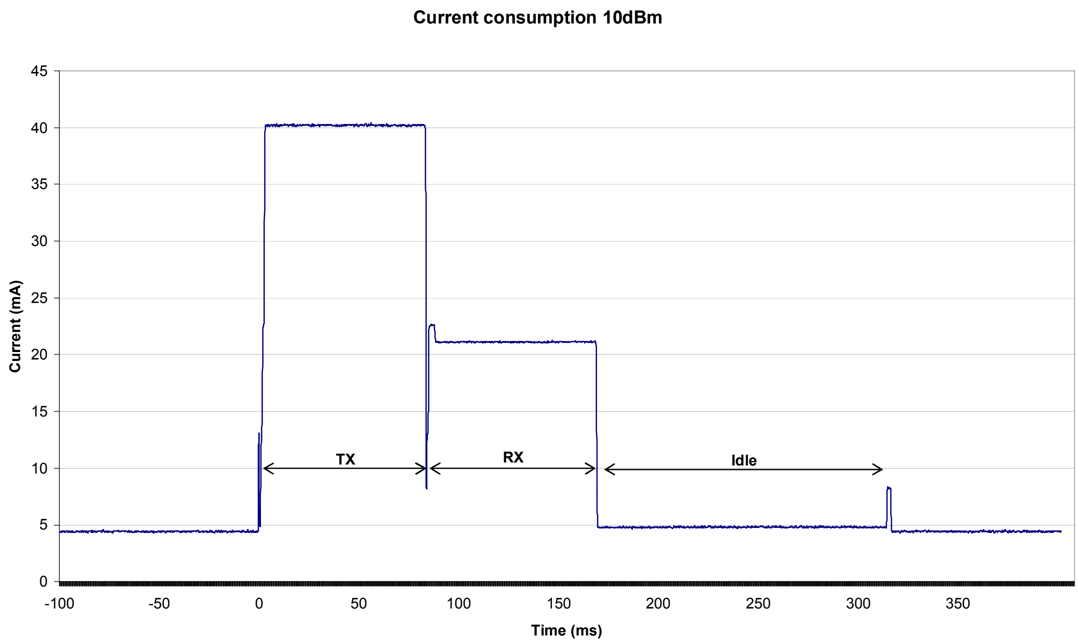


Figure 9 Current consumption for CC1110 Mini DK at 10dBm output power

6.4 Master node with 3 cycles of TX/RX

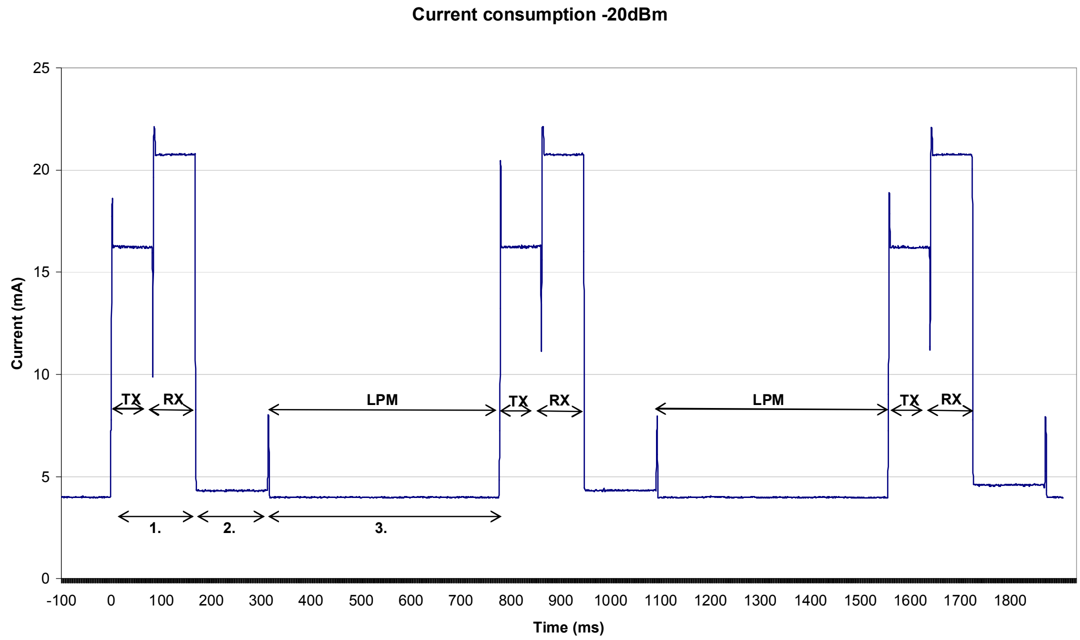


Figure 10 Time plot of tree TX/RX cycles

Details

1. Application sends one package, goes in RX and receives ACK.
2. When package is received, the radio goes in idle to reduce power consumption.
3. Low power mode (LPM). Green LED is on and radio in PM2.

6.5 Master node retransmits 3 times without ACK

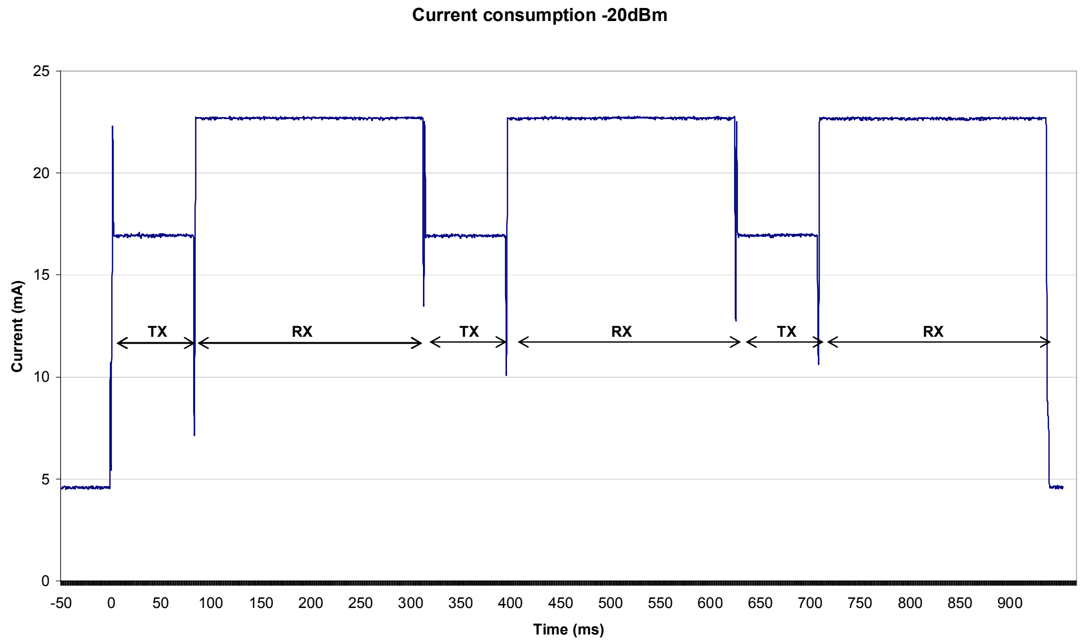


Figure 11 Current consumption for CC1110 Mini DK at -20dBm output power and 3 retransmits

6.6 Slave node under typical conditions

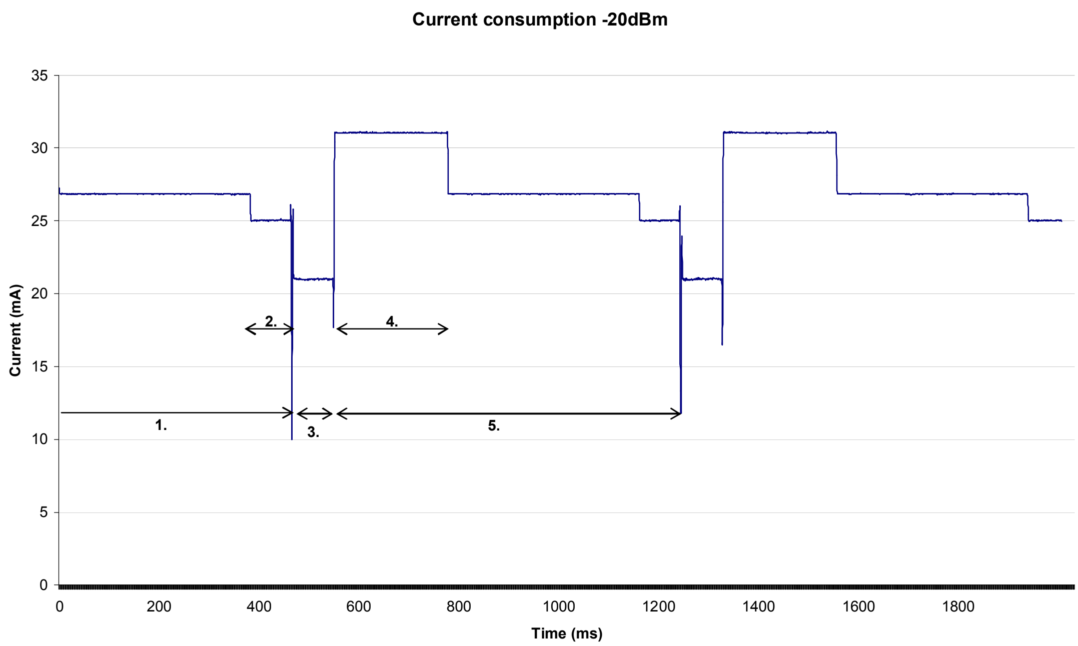


Figure 12 Slave node sending 2 ACK's

Details

1. Radio in RX waiting for package.
2. Receiving package. Gain reduced.
3. Sending ACK back to master node. Radio in TX.
4. Green LED on for 250 ms.
5. Radio in RX.

7 References

[1] SimpliciTI Compliant Protocol Stack
http://focus.ti.com/docs/toolsw/folders/print/simpliciti.html

[2] CC1110 Mini Development Kit 868-915 MHz Quick Start Guide
http://www.ti.com/lit/swru234

[3] CC2510 Mini Development Kit Quick Start Guide
http://www.ti.com/lit/swru235

[4] C1110 Data Sheet
http://focus.ti.com/lit/ds/symlink/cc1110f32.pdf

[5] C2510 Data Sheet
http://focus.ti.com/lit/ds/symlink/cc2510f32.pdf

[6] CC1110 Mini Development Kit website
http://focus.ti.com/docs/toolsw/folders/print/cc1110dk-mini-868.html

[7] CC2510 Mini Development Kit website
http://focus.ti.com/docs/toolsw/folders/print/cc2510dk-mini.html

[8] SimpliciTI Specification
Found under documents in the SimpliciTI installation folder under [1]

[9] Design note DN106: Power Modes in CC111xFx, CC243x, and CC251xFx
http://www.ti.com/lit/swra162

8 Document History

Revision	Date	Description/Changes
swru237	2009-09-02	First official revision.