



EZRadio-DK Range Test Demo

EZRADIO® Si4455 Two-Way AND Si4012/Si4355 ONE-WAY LINK DEVELOPMENT KIT USER'S GUIDE

1. Overview

Thank you for your interest in Silicon Labs' EZRadio® product family. The Silicon Labs EZRadio Si4455 Two-Way Link and Si4012/Si4355 EZRadio One-Way Link Development Kit (P/N EZR-LCDK2W-XXX and P/N 4012-LCDK1W-XXX) contains everything you need to familiarize yourself with and evaluate the Silicon Labs EZRadio family. The two-way kit has three versions: one for the 434 MHz band, one for the 868 MHz band, and one for the 915 MHz band. The one-way kit has two versions: one for the 434 MHz band, and one for the 915 MHz band. The key features of the development kit are as follows:

- The baseboards have an LCD display and four LEDs to display information and four push-buttons to receive user commands. Additionally, the Silicon Labs Toolstick Base Adapter is integrated on the board to be easily connected to the PC.
- The RF pico board provides connection to the radio device (either Si4455 transceiver, Si4355 receiver, or Si4012 transmitter). All supported types of RF pico boards can be applied to the baseboard.
- The provided software pack contains all the documentation and files needed to develop a user application.
- The kit supports the use of the Silicon Laboratories Integrated Development Environment (IDE) for software debugging and the use of the Keil & SDCC C compiler, assembler, and linker toolchain.
- The kit supports use of the Wireless Development Suite (WDS) for setting radio parameters and managing application firmware.
- The baseboards come with the EZRadio range test demo application. The range test demo implements Packet Error Rate (PER) measurement. PER is generally used in wireless systems to measure the quality of the RF link in given circumstances.

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1.1. Kit Contents

Table 1. Kit Contents

Qty	Part Number	Description
	EZR-LCDK2W-434	Si4455 EZRadio Two-Way Link Development Kit 434 MHz
2	MSC-LCDBB930-PER	LCD baseboard with range test demo code
2	4455-PCE10D434B	Si4455 pico board with PCB antenna and SMA connector—434 MHz
2	MSC-AT50-434	434 MHz antenna
2	USB-XTEN-MINI	USB cable (USBA-USB mini)
6	AA	AA alkaline battery
	EZR-LCDK2W-868	Si4455 EZRadio Two-Way Link Development Kit 868 MHz
2	MSC-LCDBB930-PER	LCD baseboard with range test demo code
2	4455-PCE10D868B	Si4455 pico board with PCB antenna and SMA connector—868 MHz
2	MSC-AT50-868	868 MHz antenna
2	USB-XTEN-MINI	USB cable (USBA-USB mini)
6	AA	AA alkaline battery
	EZR-LCDK2W-915	Si4455 EZRadio Two-Way Link Development Kit 915 MHz
2	MSC-LCDBB930-PER	LCD baseboard with range test demo code
2	4455-PCE10D915B	Si4455 pico board with PCB antenna and SMA connector—915 MHz
2	MSC-AT50-915	915 MHz antenna
2	USB-XTEN-MINI	USB cable (USBA-USB mini)
6	AA	AA alkaline battery
	4012-LCDK1W-434	Si4012/Si4355 EZRadio One-Way Link Development Kit 434 MHz
2	MSC-LCDBB930-PER	LCD baseboard with range test demo code
1	4355-PRXBD434B	Si4355 pico board with PCB antenna and SMA connector—434 MHz
1	4012-PSC10B434B	Si4012 pico board with PCB antenna and SMA connector—434 MHz
2	MSC-AT50-434	434 MHz antenna
2	USB-XTEN-MINI	USB cable (USBA-USB mini)
6	AA	AA alkaline battery

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Table 1. Kit Contents (Continued)

	4012-LCDK1W-915	Si4012/Si4355 EZRadio One-Way Link Development Kit 915 MHz
2	MSC-LCDBB930-PER	LCD baseboard with range test demo code
1	4355-PRXBD915B	Si4355 pico board with PCB antenna and SMA connector—915 MHz
1	4012-PSC10B915B	Si4012 pico board with PCB antenna and SMA connector—915 MHz
2	MSC-AT50-434	915 MHz antenna
2	USB-XTEN-MINI	USB cable (USBA-USB mini)
6	AA	AA alkaline battery



Figure 1. LCD Baseboard (P/N MSC-LCDBB930-PER)



Figure 2. Si4455 RF Pico Board—868 MHz (P/N 4455-PCE10D868B)

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Figure 3. LCD Baseboard with Connected RF Pico Board

The LCD baseboard is a development board that can be used with a connected RF pico board. The development board has LEDs, push-buttons, an LCD screen, and a buzzer for human interface usage. Silicon Labs Toolstick Debug Adapter is also integrated on the board to allow easy connection to the PC.

The EZRadio chip is mounted on the RF pico board. Device (board and RF) information of the RFstick is stored in the on-board EEPROM. The RF pico board can be connected to the LCD baseboard with RFP1 and RFP2 connectors.

For more information on using the LCD baseboard and RF pico boards to develop your own radio application, refer to the application note, “AN692: Si4x55 Programming Guide and Sample Codes” and “AN746: Si4012 Programming Guide”. The baseboards come with the EZRadio range test demo application; however, be sure to use the latest version of the application. The user can update the firmware on the boards using the firmware update functionality of the WDS. For more information on updating the firmware, refer to the “WDS User's Guide for EZRadio Next Generation”.

2. Range Test Demo

2.1. Basics

As earlier described, the range test demo is used to provide measured results on the quality of the RF link.

The demo uses two RF nodes: the LCD baseboard + RF picoboard. One node is used as the 'transmitter' (TX) and the other as the 'receiver' (RX). The Si4455 node can be either a transmitter or receiver. The Si4355 node can be only a receiver and the Si4012 node can be only a transmitter.

The transmitter sends packets to the receiver repeatedly with half second intervals. The packet includes the address of the transmitter and number of the sent packet. The packet number increments from packet to packet.

The receiver receives the packet and checks its address. If their addresses match, the packet number is stored. In two-way development kits, the receiver can send back an acknowledge packet (ACK) to the transmitter. The ACK packet also includes the address and packet number of the received packet.

PER can be calculated with the following equation:

$$PER = \frac{P_{TX} - P_{RX}}{P_{TX}} \times 100$$

where:

- PER: packet error rate (%).
- P_{TX} : number of sent packets.
- P_{RX} : number of received packets.

In two-way development kits the transmitter can calculate PER using the following data:

- P_{TX} : packet counter to be included in the packet.
- P_{RX} : number of all the received acknowledge packets.

Receiver can calculate PER using the following data:

- P_{TX} : packet number included in the last received packet.
- P_{RX} : number of all received data packets.

2.2. RF and Packet Parameters

This section provides information on user parameters of the range test demo. All the parameters (excluding frequency band and self node address) can be changed in the demo through its menu system (see section "2.4. Menu System of the Range Test Demo"). The following parameters are available:

- RF parameters
 - Frequency band (defined by the HW)
 - Communication frequency
 - Modulation
 - Data rate
 - Output power
- Packet parameters
 - Packet length
 - Maximum number of sent/received packets
 - Self node address (defined by the HW)
 - Destination node address

Demo parameters are stored in the MCU's flash memory and restored after power-on reset. Default values are loaded if no parameters were previously stored in the flash.

It is also possible to define custom RF parameters for communication. Custom parameters can be stored with the Wireless Development Suite (WDS). For more information on creating and storing custom RF parameters, refer to the "WDS User's Guide for EZRadio Next Generation".

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2.2.1. Frequency and Frequency Bands

The RF pico board has an on-board antenna and RF matching to provide solutions for supported frequency bands. A stand-alone antenna can also be used with the SMA connector.

Different RF matchings are required for each frequency band. The range test demo automatically reads frequency band information out of the on-board EEPROM and selects the appropriate frequency range.

Si4x55 devices support the following three frequency bands:

- Low band: 285–350 MHz
- Middle band: 425–525 MHz
- High band: 850–960 MHz

The EZRadio Development Kits are provided for the middle and the high bands; however, the range test demo supports all the three bands. The demo can be used with low band RF pico boards as well.

The range test demo provides four different selectable frequencies in all the supported bands. Table 2. lists the available frequencies.

Table 2. Frequency Options for the EZRadio Two-Way Development Kit

Low	Middle	High
289.28 MHz	433.92 MHz	867.84 MHz
289.43 MHz	434.15 MHz	868.30 MHz
305.67 MHz	458.50 MHz	917.00 MHz
316.67 MHz	475.00 MHz	950.00 MHz

2.2.2. Modulation

User can select from three types of modulation:

- 2GFSK with high precision TX crystal (TX: 30 ppm, RX: 30 ppm)*
- 2FSK/2GFSK (TX: 150 ppm, RX: 30 ppm) *
- OOK

***Note:** 2GFSK is supported by Si4x55 devices. 2FSK is supported by Si4012 devices.

2.2.3. Data Rate

The user can select from three different data rates. Table 3 lists the available data rates.

Table 3. Available Data Rates

Modulation	
2FSK/2GFSK (both types)	OOK
9.6 kbps	2.4 kbps
38.4 kbps	9.6 kbps
128.0 kbps*	20.0 kbps
*Note: Only supported by Si4x55 devices.	

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2.2.4. Output Power

The current version of the range test demo does not support changing the output power. The output power is defined for +11 dB for all the frequency bands.

2.2.5. Packet Length

The user can define the length of the communication packets. The packet length contains 4 bytes of preamble, 2 bytes of synch word, at least 7 bytes long payload, and 2 bytes of CRC. Increasing the packet length increases the length of the used payload. The length of the whole packet can be selected from 15 bytes to 72 bytes.

2.2.6. Maximum Number of Sent/received Packets

The user can define the maximum number of sent and received packets. The demo stops after the defined number of packets received or sent. The following packet counts can be selected: 200, 500, 1000, 2000, 5000, 10000.

2.2.7. Node Addresses

Each node of the range test demo reads the serial number of the connected RF pico board. The least significant byte of its serial number (0 - 255) is used as node address. The user has to define the address of the destination node in the menu system to pair the appropriate nodes.

2.2.8. Custom Parameters

As described earlier, the user can store custom RF parameters into the devices with WDS. One custom field is available in each of the nodes. If custom parameter mode is selected, the RF parameters (frequency, modulation, data rate) are defined by the stored custom parameters and they cannot be changed.

Note: Since custom parameters belong to a defined frequency band, the firmware goes to error state if the frequency band of the custom parameters mismatches with the frequency band of the connected RF pico board.

2.3. Error states

In case of critical error, the demo goes to error state. Power-on-reset can force the demo out of error state. In error state, LED4 is continuously ON and an error message is shown on the LCD screen.

Critical errors:

- Error message:** No RF pico board found! Connect an EZRadio RF pico then Reset!
Cause: There is no supported RF pico connected to the LCD baseboard.
Solution: Connect a supported EZRadio RF pico board (Si4x55 or Si4012) and reset the application.
- Error message:** Not supported radio! Connect a Si4x55 type RF pico then Reset!
Cause: The connected RF pico board holds unsupported radio.
Solution: Connect a supported EZRadio RF pico board (Si4x55 or Si4012) and reset the application.
- Error message:** Not supported custom frequency band! Custom freq band mismatches with RF pico.
Cause: Frequency band of the connected RF pico board mismatches with frequency band of the stored custom parameters.
Solution 1: Change custom parameters with WDS to match with the connected RF pico board.
Solution 2: Change the connected RF pico board to match with the stored custom parameters.
Solution 3: Use selected parameters instead of the custom parameters.

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2.4. Menu System of the Range Test Demo

After running the demo, the first screen is the Welcome Screen. The Welcome Screen is shown for up to 1.5 seconds or for as long as any of the push buttons are pressed. The second screen provides information on the firmware, covered device name, firmware name, and version number of the firmware is displayed.



Figure 4. Welcome Screen

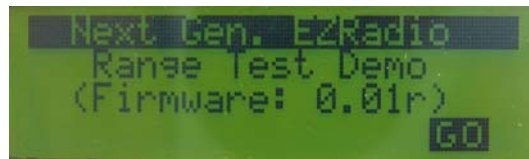


Figure 5. Firmware Information

The on-screen menu system is designed for easy configuration. The RF and packet parameters of the communication can be configured as described in the previous sections.

Four push buttons are used to navigate the menu system: soft labels on the LCD screen display the current function of the related buttons. In general, push button 1 (PB1) is used to go to the previous menu page; push button 2 (PB2) is used to select between menu items, push button 3 (PB3) is used to change value of the menu item, and push button 4 (PB4) is used to access the next menu page. Some of the menu items have more than ten possible values. In such cases, not only PB3 can be used to increase the value of the menu item, but PB2 and PB3 can be used together to decrease its value. To decrease such values, push and hold PB2 and then push PB3 several times to reach the required value.

A small arrow (→) points to the actual menu item. The demo can be configured through six menu pages.

The first page is used to select the functionality of the demo. The range test can be performed in single way (TX—transmit or RX—receive mode)* or bidirectional (TRx—transceiver mode)** radio communication. If custom RF parameters are stored, the user can choose between “Custom” or “Select” RF parameters. If “Custom” RF parameters is selected, the user can only check but not change the RF parameters on the following menu pages.

Notes:

1. Si4455 devices can be both transmitters or receivers; Si4355 devices can be only receivers, and Si4012 devices can be only transmitters.
2. Bidirectional mode is only supported by Si4455 devices.

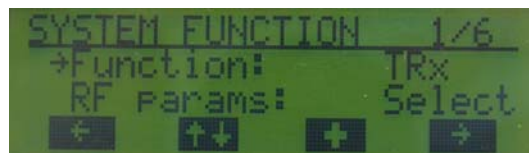


Figure 6. Menu Page: System Function 1/6

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The frequency and the modulation can be selected on the second menu page. Selectable frequency values belong to the frequency band of the RF pico board. Modulation can be “2GFSK_l”, which refers to 2GFSK with high-precision TX crystal, “2GFSK_h”, which refers to 2GFSK with low cost TX clock, and “OOK”.



Figure 7. Menu Page: RF Parameters 2/6

On the third menu page, only the data rate can be selected by the user. The second menu item only informs the user about deviation or bandwidth RF parameter, which depends on the selected modulation and data rate. “Deviation” is shown if the selected modulation is 2GFSK and “Bandwidth” if the modulation is OOK.



Figure 8. Menu Page: RF Parameters 3/6 (Modulation is 2GFSK)



Figure 9. Menu Page: RF Parameters 3/6 (Modulation is OOK)



Figure 10. Menu Page: RF Parameters 4/6 (Output power is not shown in one-way receiver mode)

The fifth and sixth menu page is used to configure the packet configuration of the range test demo. PB2 + PB3 button combo can be used on both pages to decrease the value of the selected menu item.

Packet length and maximum number of packets can be selected according to section “2.2.5. Packet Length” and section “2.2.6. Maximum Number of Sent/received Packets”. Packet length cannot be set if RX mode operation is selected previously, since the received packet contains the length information.

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Figure 11. Menu Page: Node Parameters 5/6 (Tx/TRx mode)



Figure 12. Menu Page: Node Parameters 5/6 (Rx mode)

The Self ID field is filled up automatically based on the serial number of the used RF pico board. It is important to setup the destination ID accurately, otherwise the link will not work. The destination ID has to be the self ID of the other device.



Figure 13. Menu Page: Node Parameters 6/6

As described earlier, demo parameters are stored in the MCU's flash memory and restored after power-on-reset. Default values are loaded if no parameters were previously stored in the flash. The default packet configuration of the demo is the following:

- Destination ID is the same as the Self ID
- Packet length is 15 bytes
- Max. packets is 1000 packets

2.5. Test Modes

2.5.1. Bidirectional (TRx) Range Test

After the demo is fully configured, it proceeds to the demo screen, where the range test can be started. The screen is divided into three sections. At the top of the screen, soft labels show the functions of the LEDs. LED1 blinks when a packet is transmitted; LED2 blinks if a packet is successfully received (with valid CRC and packet content that matches the expected value). The bar graph under LED3 shows the actual Receive Signal Strength Level (RSSI) of the received packet (shown and refreshed after a packet is received).

The middle section of the screen shows the part number of the radio and the source / destination addresses with arrows showing direction of the communication. RF parameters can be checked in the middle section before transmission / reception is started.

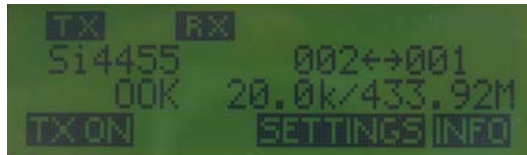


Figure 14. Demo Screen (TRx Mode)

On the bottom of the screen, the soft labels show the actual functionality of the push buttons. PB3 are used to return to the configuration menu. After entering demo mode, both ends of the link are in receive mode. The test starts if any of the link nodes starts to transmit ping packets. Transmission can be initiated by pressing PB1. After that, the originator transmits a ping packet for the other node. If it receives the packet correctly, it transmits back an acknowledgment packet. Each ping packet has a serial number (increased by the originator after every packet transmission), which is transmitted back by the acknowledgment packet. If the originator receives the acknowledgment within a predefined timeout, then it considers the link working, otherwise it increases the number of missed packets by one. The originator also stores the number of transmitted PING packets so the demo can calculate the Packet Error Rate based on this information. The Packet Error Rate is updated on the third line of the LCD after each packet transmission according to PER equation in section “2.1. Basics”.



Figure 15. Running PER Test (TRx Mode)

The demo runs as long as the number of transmitted packets reaches the predefined number or until it is interrupted by PB1.

The user can check predefined RF parameters of the measurement any time during a running test by using PB4. PB4 also is used in the info screen to show the actual results of the running measurement. Info screen is also available after all the packets are transmitted and the test is finished.

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2.5.2. Single Way (Tx-Rx) Range Test

The range test also can be performed with single way radio communication. In this case, one end of the link needs to be setup as a transmitter (this will be the originator as described in the bidirectional link) and the other end of the link needs to be a receiver. The test needs to be started at the transmit side by pressing PB1. The demo runs as long as the number of transmitted or received packets reaches the predefined number or until the demo is interrupted by PB1. The user can follow the number of transmitted packets on the LCD screen.



Figure 16. Running PER Test (Tx Mode)

The single way range test demo works the same as the bidirectional range test; however, the number of lost packets and the packet error rate is defined only at the receive side and is based on the first and last received packet ID.

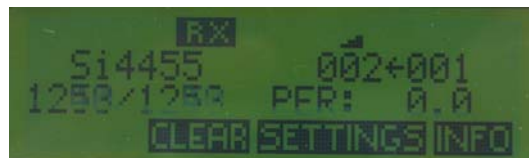


Figure 17. Running PER Test (Rx Mode)

2.6. How to Carry the Range Test Out

Connect RF pico boards to the two LCD baseboards. Put batteries into the devices and switch the devices on. Select both devices to be in TRX mode or one of them to be RX and the other to be in TX mode (note that Si4355 base devices can only be receivers and Si4012 devices can only be transmitters). Select the required demo parameters or start the measurements with the automatically reloaded configuration.

Check if transmitter sends packets and receiver answers as well.

The range test can be performed inside a building if indoor propagation is tested. However, it is advised to perform the test outside the building, line-of-sight to get the best possible range result. If PER>1%, reset the PER on the transmitter and try to walk further in the area. Propagation conditions usually improve if the user is further distanced from a possibly shadowed area.

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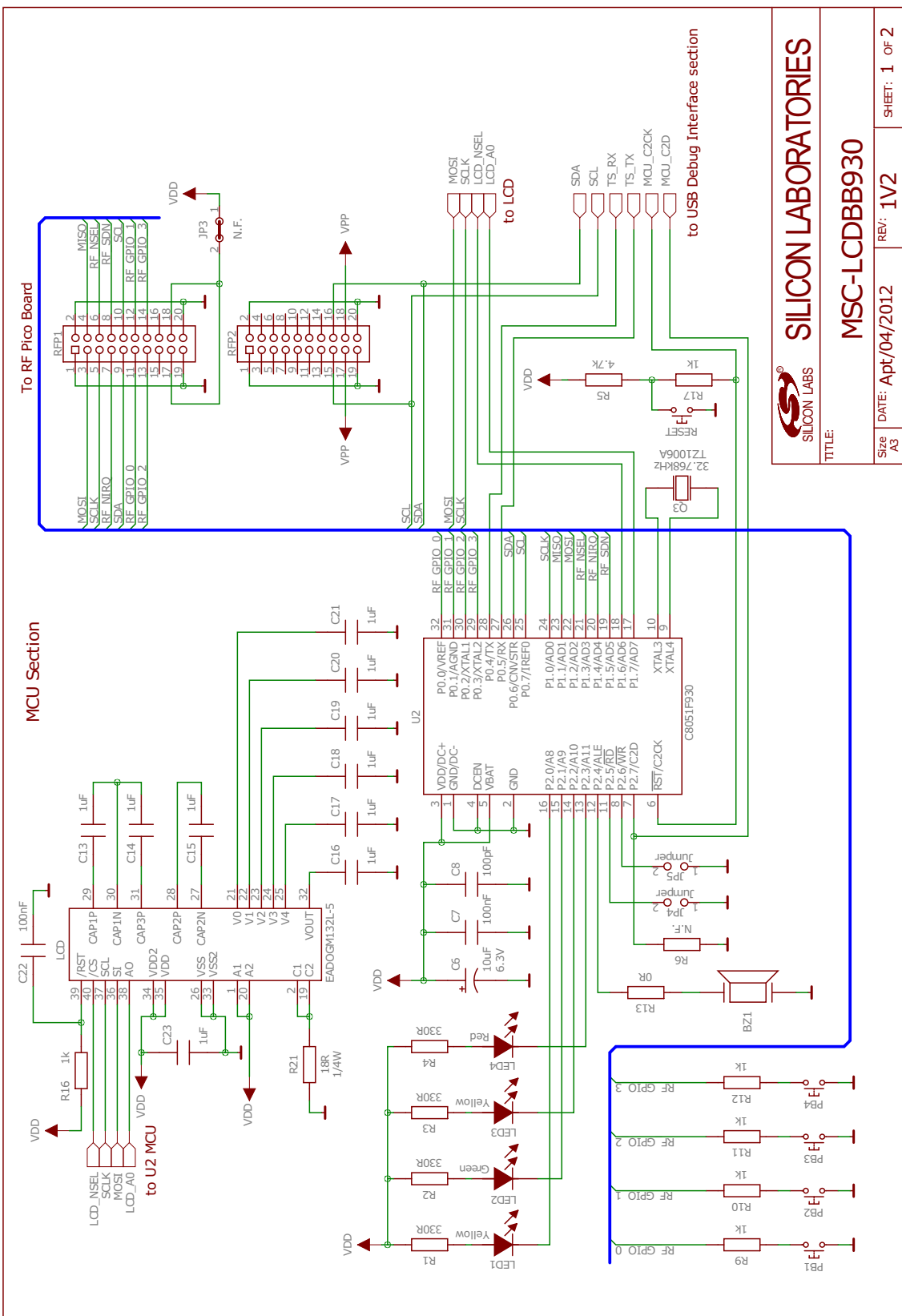


Figure 19. LCD Baseboard Schematic 1

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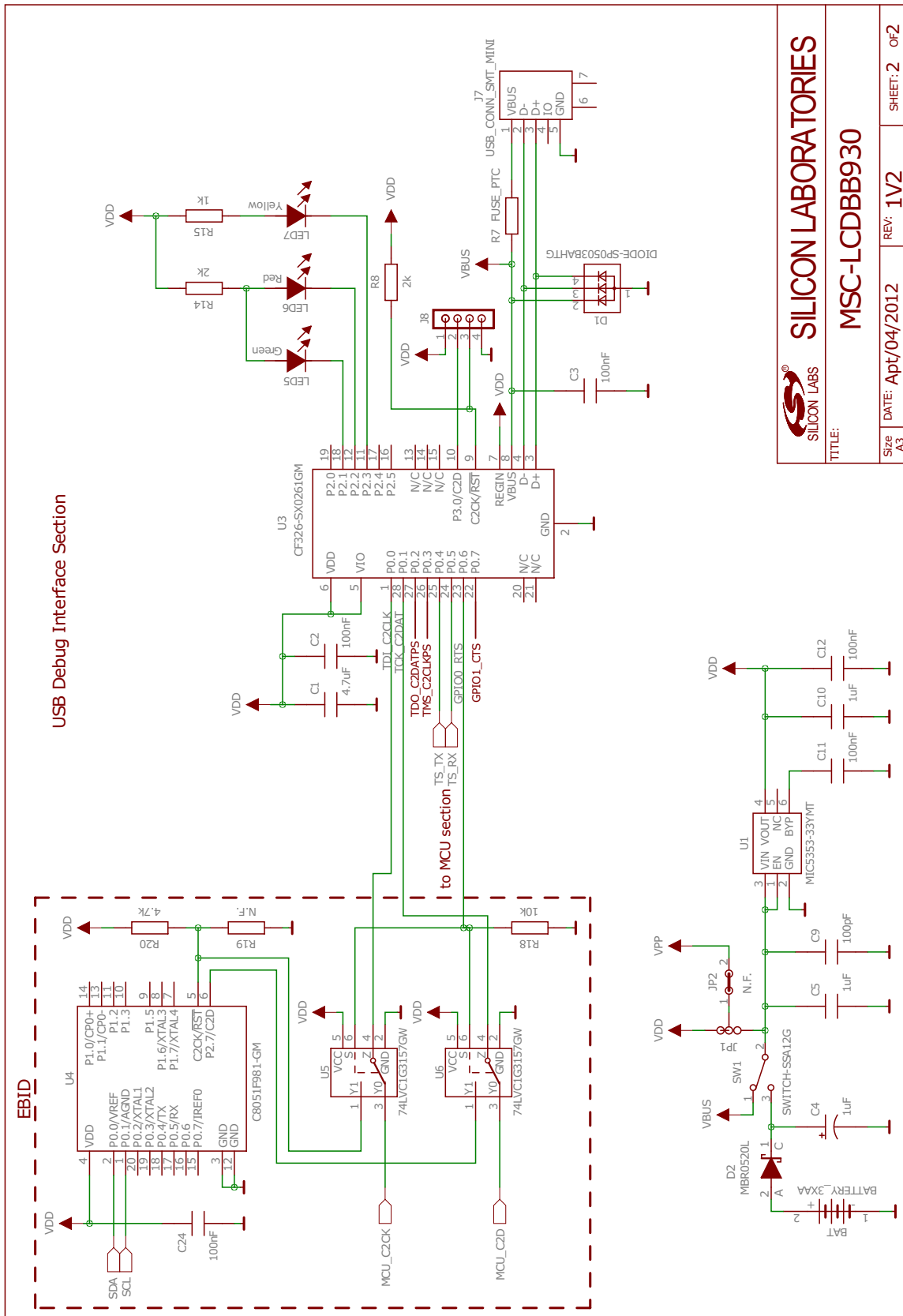


Figure 20. LCD Baseboard Schematic 2

DOCUMENT CHANGE LIST

Revision 0.1 to Revision 0.2

- Added Si4012 one-way range test demo support.

NOTES:

EZRadio-DK Range Test Demo

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