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SDBC-DK3 UG

C8051F930 Wireless Software Development Kit User's Guide

1. Introduction

The Silicon Labs Wireless Product Software Development Board, MSC-DBSB8, is designed to help engineers develop code for the Silicon Lab's EZRadio® and EZRadioPRO™ wireless products using the Silicon Labs C8051F9xx microcontroller platform.

The C8051F9xx Wireless Software Development Board (MSC-DBSB8) is designed for code development. A second platform, the WDS Loadboard, may also be purchased allowing for exhaustive RF lab based testing. The Loadboard can be bought under the part number MSC-DKLB2 but also within the ISM-DK3 kit.

Figure 1. MSC-DBSB8 Software Development Board (SDB)

Figure 2. MSC-DBLB2 (Not Included) Testing Platform for controlled Lab Tests (Loadboard)

Both boards come with the Silicon Labs standard 40-pin socket for connecting standard EZRadio® and EZRadioPRO™ evaluation testcards such as the Si4432-DKDB1. The onboard C8051F930 comes preloaded with sample firmware to demonstrate a packet-based wireless link between two systems.

The MSC-DBSB8 C8051F9xx software development board includes:

- One 40-pin socket for EZRadio and EZRadioPRO testcards
- C8051F930 microcontroller preloaded with demonstration software
- Standard debug connector for Silicon Labs C8051 programming and debugging
- 4 buttons and 4 LEDs for custom purposes
- LCD display for setup parameters and information display
- RS232 interface via a 9-pin DSUB male connector
- USB type B connector with Silicon Labs CP2102 USB > Serial Converter onboard
- On board 3.3 V PSU
- 5 x 19 through hole breadboard area for customer's application

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2. Power Supply

The board has three power options. The user can select between these options by the supply source selector switch (SW1).

2.1. On Board PSU

The on board PSU supplies 3.3 VDC. In this mode, the board should be powered by a standard 9 V ac or 9–12 V dc adapter.

2.2. External PSU

In this mode, the board can be powered via the direct dc supply connector by an external PSU. Any supply voltage can be used in the 3.3–4 V range. Polarity is marked on the PCB.

2.3. Powered by USB Port

In this mode, the board can be powered via the USB connector.

Note: When using the white LED Flash option, it is recommend to use an alternative power supply.

3. System Introduction: MSC-DBSB8 ICD Connector

Table 1. Debug Connector

Pin #	Description
1	VDD (3.3 V)
2	GND
3	GND
4	P2.7
5	RESET
6	P2.7
7	RST/C2CK
8	—
9	GND
10	—

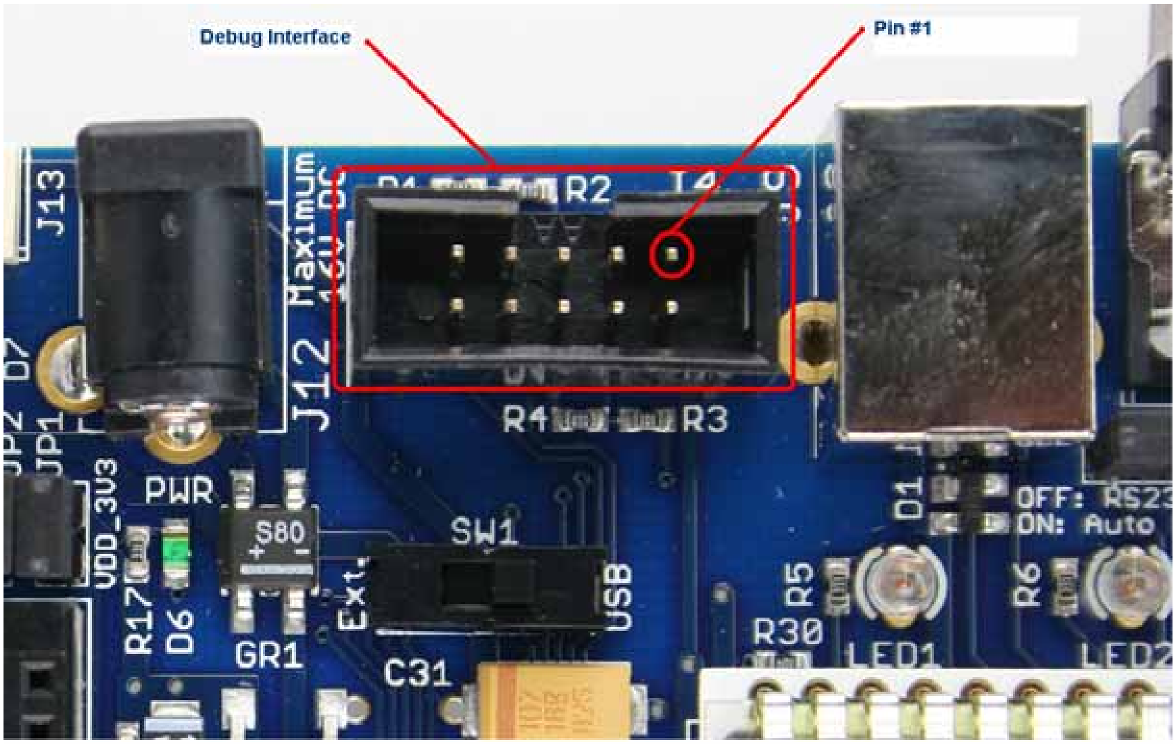


Figure 3. Debug Connector (Emulator and Programmer Interface)

Table 2. 40-Pin Testcard Connector (J5)

Pin #	Description	Pin #	Description
1	J6/1 (SPI_MOSI)	21	GND
2	J7/1	22	J15/1
3	J6/2 (SPI_SCK)	23	GND
4	J7/2	24	J15/2
5	J6/3 (RF_NSEL)	25	J8/1
6	J7/3	26	EBID port (SPI_MOSI)
7	J6/4	27	GND
8	J7/4	28	EBID port (SPI_MISO)
9	J6/5	29	J8/2
10	J7/5	30	EBID port (SPI_SCK)
11	J6/6	31	GND
12	J7/6 (RF_NIRQ)	32	EBID port (EE_NSEL)
13	J6/7 (PWRDN)	33	J8/3
14	J7/7(RF_NIRQ)	34	J15/3
15	J6/8 (GPIO)	35	GND
16	J7/8(SPI_MISO	36	J15/4
17	VDD (3.3 V)	37	J8/4
18	VDD (3.3 V)	38	J15/5
19	VDD (3.3 V)	39	GND
20	VDD (3.3 V)	40	J15/6

4. System Introduction: Schematic (MSC-DBSB8)

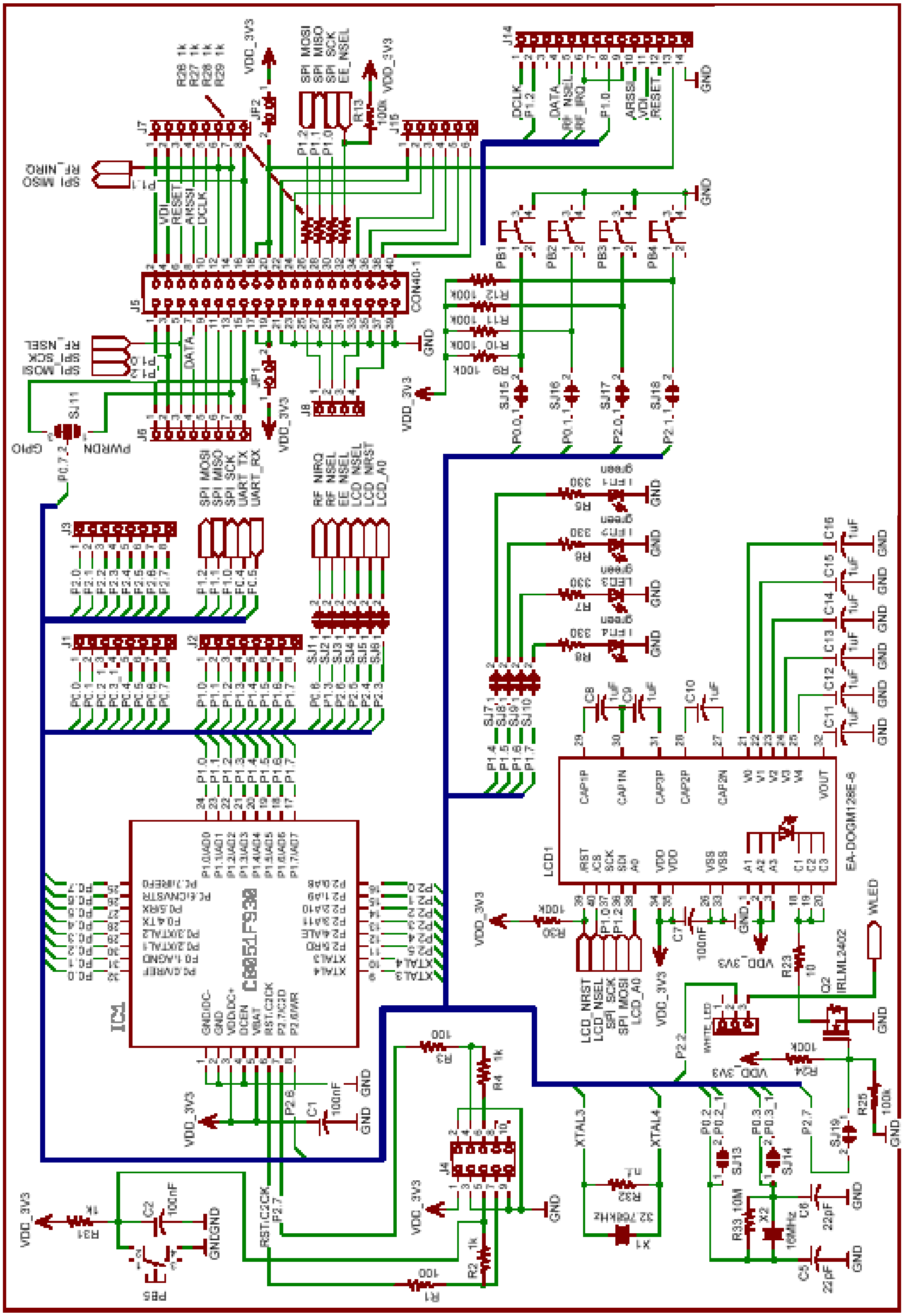


Figure 4. MSC-DBSB8 Schematic (1 of 2)

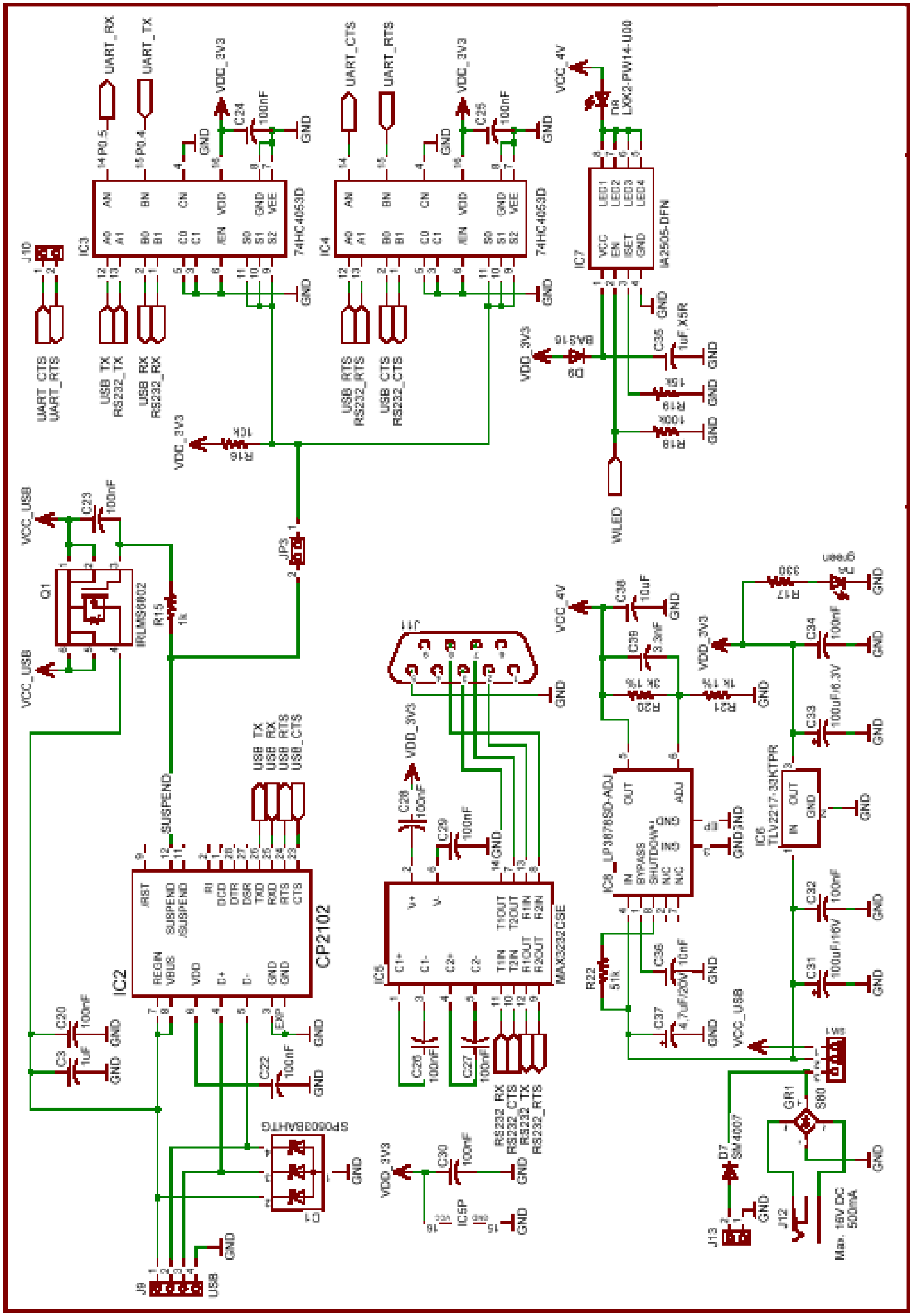


Figure 5. MSC-DBSB8 Schematic (2 of 2)

5. Typical Testboard Schematic (Si443x Testcard)

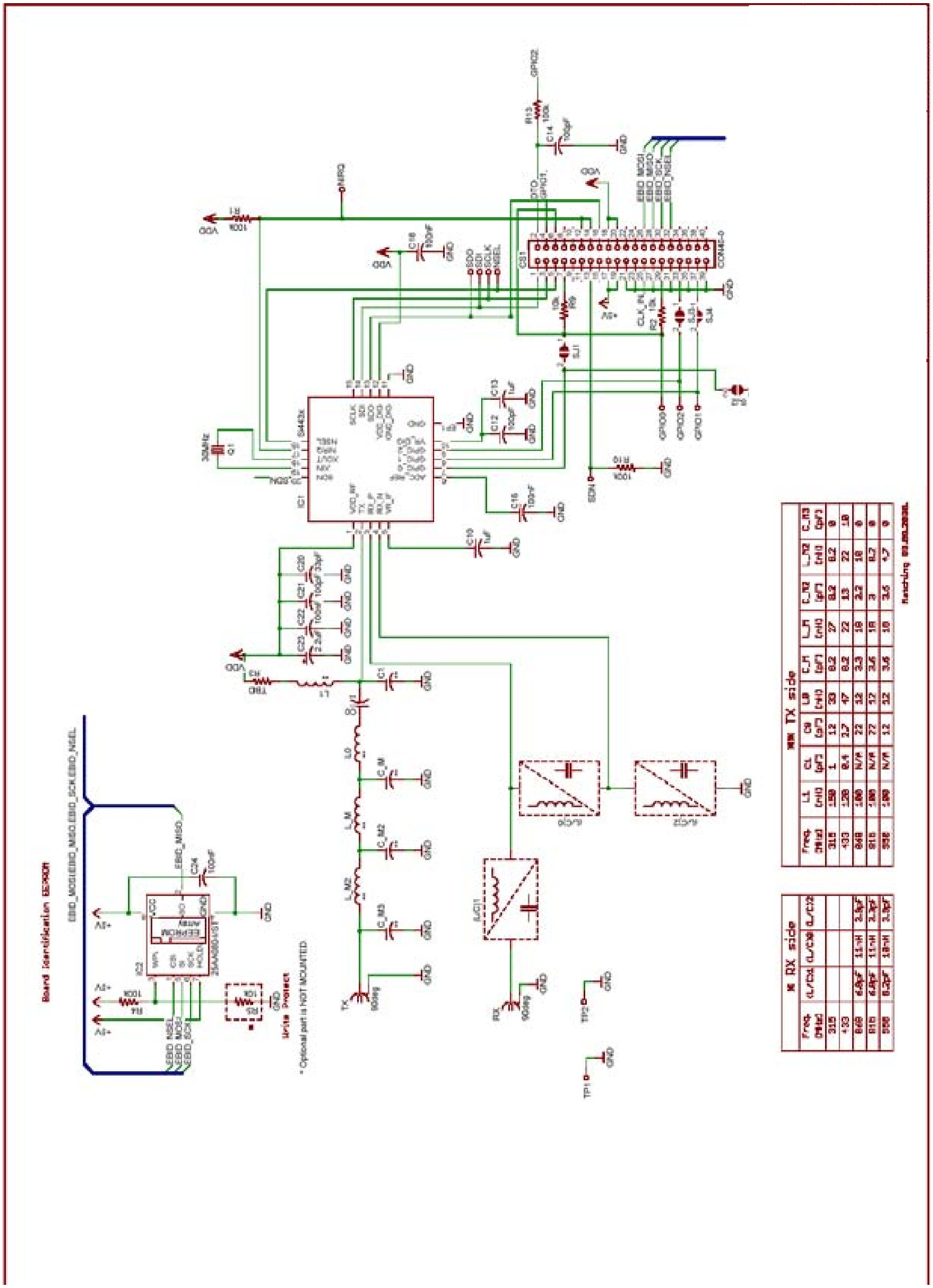


Figure 6. Si443x Testcard Schematic

6. Using the SDB with a Standard Testcard

The standard EZRadio or EZRadioPRO testcards that are typically plugged into the MSC-DBLB2 Loadboard when engineers are performing RF tests on the radio ICs can also be plugged into the 40pin socket on the Software Development Board (SDB), as demonstrated below.

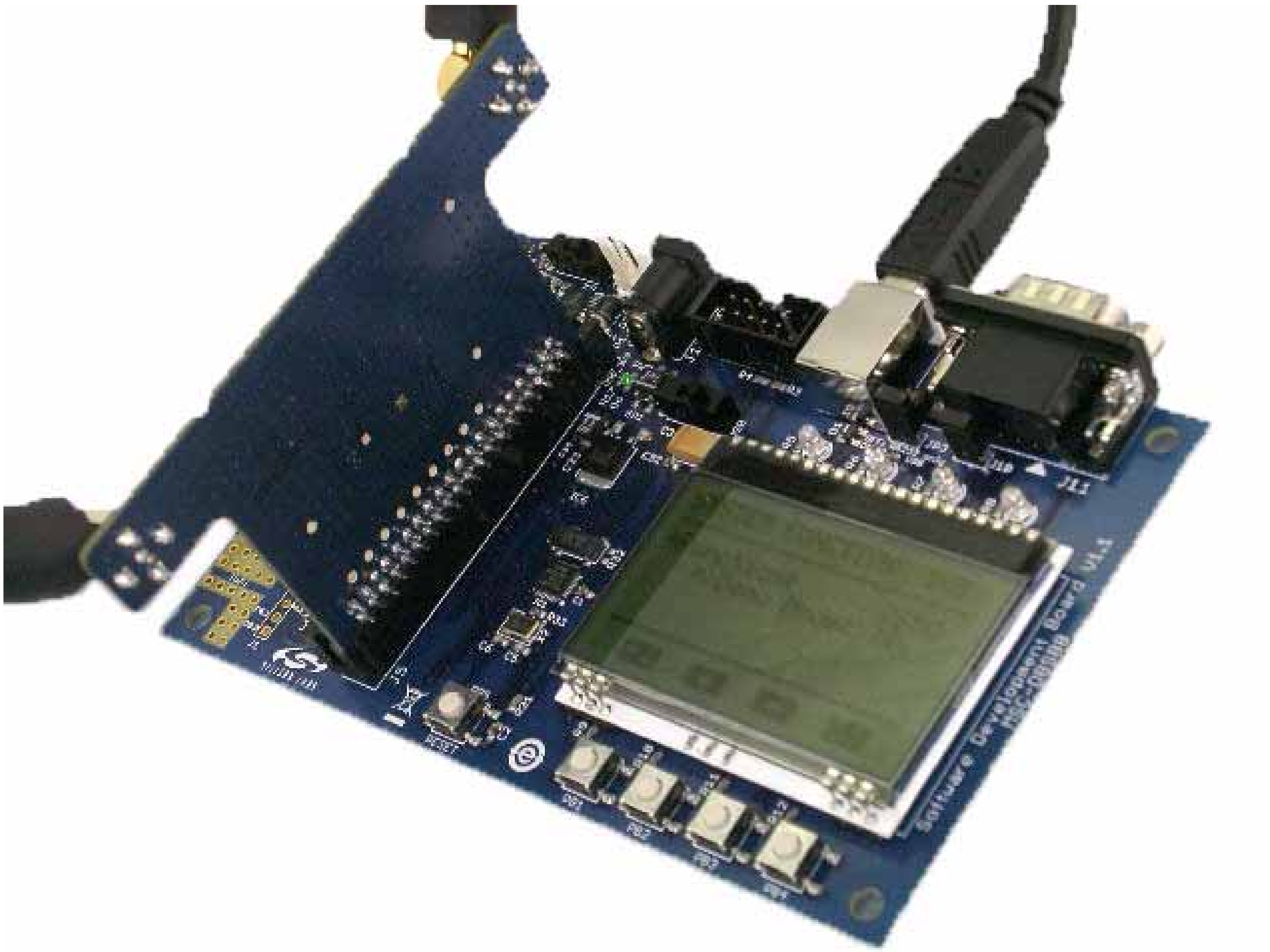


Figure 7. Software Development Board (MSC-DBSB8) with a Standard Silicon Labs Testcard Installed

7. Radio Evaluation

7.1. Demonstration Mode

When shipped, the MSC-DBSB8 comes with example firmware, which is used to demonstrate the basic RF capabilities of Silicon Labs' RFIC. In the current public release of this firmware only the EZRadioPRO Si4432 transceiver is supported, later releases are intended to demonstrate the ever increasing number of products from Silicon Labs.

Newer firmware versions of the factory firmware may be available on the Silicon Labs website or via the WDS CDROM.

Introducing the PER demonstration (Version 3.xr Firmware)

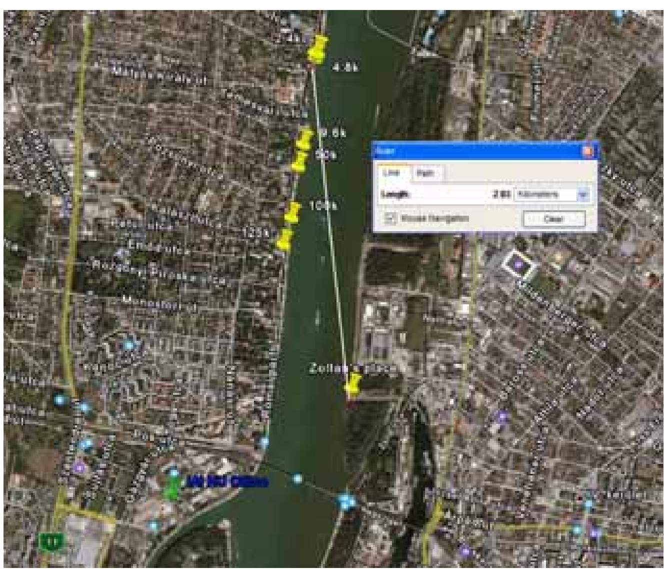
Reference firmware v3.xr is designed to show the Si443x in a packet error rate test demonstration. This firmware is preloaded on to the c8051F930 microcontroller, but it is also available on the WDS CD-ROMs in the SDB section. Source code to the Silicon Lab's firmware is also available in the same location, and is provided AS-IS for reference purposes.

7.1.1. Packet Error Rates (PER)

Packet Errors are common place in wireless communications. In real life applications, these errors are handled through the use of acknowledgements and retries. In the demonstration software such techniques are NOT implemented such that system designers can understand range limitations in various environments, allowing them to design robust protocols into their designs.

In order to use this demonstration, users should start the demo then move the two boards apart until packet errors can be seen to start appearing and the average PER is in the order of 5%. At this point, the PER demonstration should be cleared, and the test should be left alone to be re-run without being disturbed. It is expected that the PER % will be reduce since the environmental factors will be more constant. Re-run the previous steps until a 2–3% PER is found regularly at a given range. At this point, and with the current environmental conditions, you are at a range where a higher level protocol is required. Silicon Labs has found that at a low datarate and sending approximately 5000 packets, a 2–3 km range is attainable.

The demonstration shown below was performed along the Danube River in Budapest, Hungary using the Si4432.



Data rate	Range
2.4 kbps	2.05 km
4.8 kbps	2.03 km
9.6 kbps	1.5 km
50 kbps	1.37 km
100 kbps	1.1 km
125 kbps	0.96 km

Figure 8. Example Range-vs.-Data Rate
Location: Danube River in Budapest, Hungary

Note: The following screen shots reference firmware version 3.5r, screen shots may differ slightly from the version you have received.

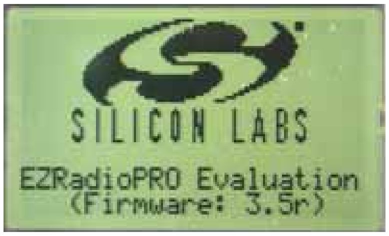


Figure 9. Welcome Screen

Users may by pass the introduction screen by pressing any of the pushbutton 1-4, alternatively wait until the screen times out and moves on itself.

The following screen allows users to select the mode of operation:

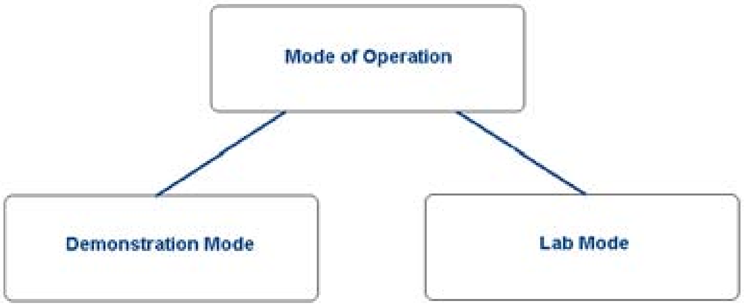


Figure 10. Operating Modes

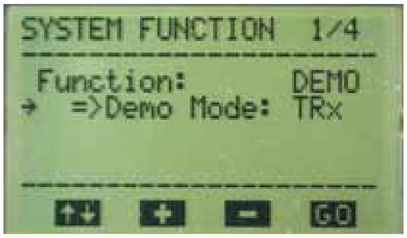


Figure 11. Screen 1: Demonstration Mode

Since the SDB's firmware recognized the Si4432 test card inserted into the 40 pin socket the appropriate modes of operation are presented on the menu system—in this case TRx (Transceiver). It is possible however to operate a transceiver in a RX (Receive) or TX (Transmit) mode also so menu features allow users to override the functionality. Menu's are driven through the push button's 1–4 under the LCD—the function of each button is shown on the screen.

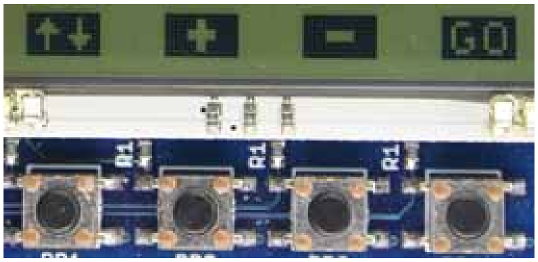


Figure 12. Push Buttons and LCD Labeling

The Up/Down button (PB1) moves the arrow up and down the LCD screen.

Figure 13. Active Menu Item Pointer

The arrow is used to highlight the function that will change when the user presses the '+' and '-' buttons. In the screen shown above, 'Function:' is highlighted, pressing the '+' and '-' buttons will switch the mode of operation between demonstration mode and lab mode.

Moving the arrow down to the ' =>Demo Mode: TRx' will allow the user to change between TRx, RX and TX functionality via the '+' and '–' buttons.

For the purpose of this introduction to the system we shall operate in 'Demonstration Mode'. Please ensure Demo mode is selected and TRx is enabled. The same selections should be made on both of the software development boards.

<Press the GO button>

7.1.2. Screen 2: Setting Up the RF Parameters

Figure 14. Screen 2: RF Parameters Menu

The 2nd screen sets up the RF parameters for the link. Adjustments are made by scrolling up and down the LCD using PB1, highlighting the relevant item to be changed and using the '+' and '-' buttons accordingly.

This introduction assumes the following settings:

Data Rate: 2.4 kbps

Modulation: GFSK

Frequency: 868.00 MHz

The same selections should be made on both of the software development boards.

<Press the GO button>

7.1.3. Screen 3: Setting up Further RF Parameters

On this screen, there may be a difference with respect to the screen shot available which is dependent on the testcard installed in to the 40 pin connector. Several testcard options are available for the SDBC-DK3 (see website for details). Typically, testcard variants include antenna diversity cards for use with antennas, single-ended Tx/Rx testcards (also intended for use with antennas), and split Tx/Rx testcards designed for use with coaxial cable to lab equipment (see "7.2. Lab Mode" on page 22 for more details).

Figure 15. Antenna Diversity Testcard (May be Ordered Separately)

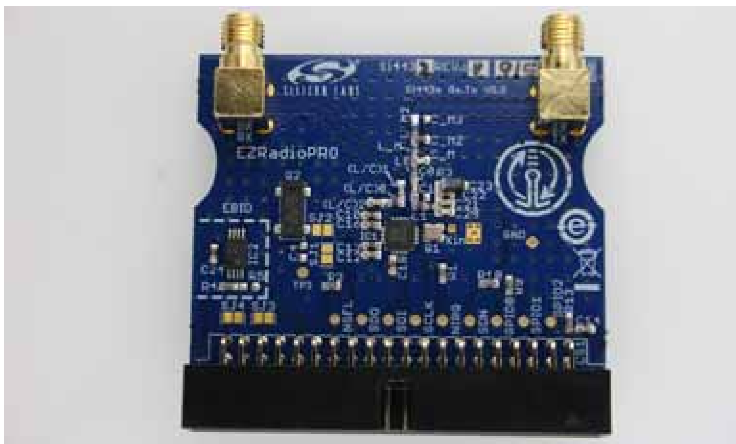


Figure 16. Split TX and RX Testcard (Rx: Left SMA, Tx: Right SMA) for Use with Coaxial Cable and RF Test Equipment for Scientific RF Evaluation (May be Ordered Separately)

Figure 17. Single-Ended TX and RX Testcard

If an Antenna Diversity card is fitted then the 'Antenna Mode' option on the 3rd screen will be available, this line is automatically removed when non-antenna diversity cards such as the 4432-DKDB1 are inserted. With this options users have the ability to select antenna 1, antenna 2 or both (antenna diversity enabled). For typical operation select “1&2”.

This screen also allows users to setup the PA output levels of the of the radio. Figure 18 demonstrates an output power of +20 dBm selected.

Figure 18. Screen 3: RF Parameters (Antenna Diversity Card Fitted)

7.1.4. Understanding Antenna Diversity and Where to Use It

Antenna Diversity is a technique that is use to improve the quality and reliability of a wireless link. The technique is particularly useful in city-like urban and indoor environments where clear lines of sight between the transmitter and the receiver cannot be achieved.

In environments where clear lines-of-sight (LOS) are not possible, signals reflect along multiple pathways (multipath) before being received, each reflection can introduce phase shifts, time delays, attenuations and distortions that can disrupt the quality of the signal which can cause problems for the receiver. Antenna diversity assists the receiver by allowing it to see the signal from two slightly different positions through the use of multiple antennas. Studies have shown that antenna diversity in both indoor and urban environments can recover 8–10 dB of the link budget that is usually lost to the environment when receivers use only single antenna implementations.

The technique however does not provide any major benefits in open environments and often this mis-understanding can cause confusion during range test exercises. In fact, due to the extra components used in the antenna switch it is possible that there maybe a small addition loss in the link budget thus reducing range. See Table 3 and Table 4.

Table 3. Illustrative Effects of Antenna Diversity in Indoor/Urban—Multipath Environments

	Single Antenna Implementation	Multiple Antenna Implementation
Transmit Power	+20 dBm	+20 dBm
Receive Sensitivity	–118 dBm	–118 dBm
Multipath Losses	–10 dBm	–2 dBm
Loss in Matching/Switch	–2 dBm	–3 dBm
Link Budget	126 dBm	133 dBm

Table 4. Effects of Antenna Diversity in Line of Sight (LOS)—Open Air Environments

	Single Antenna Implementation	Multiple Antenna Implementation
Transmit Power	+20 dBm	+20 dBm
Receive Sensitivity	–118 dBm	–118 dBm
Multipath Losses	0 dBm	0 dBm
Loss in Matching/Switch	–2 dBm	–3 dBm
Link Budget	136 dBm	135 dBm

It can be seen from Table 3 and Table 4 that while the effects of antenna diversity on LOS environments are negligible, the benefits in indoor/urban environments can significantly help create robust, higher quality robust links.

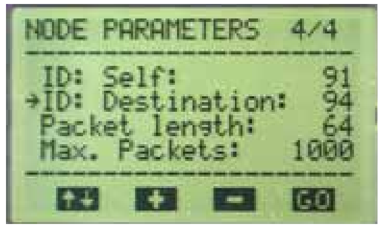


Figure 19. Screen 4: Setting Up the Node Parameters

The Self ID on each card should already be selected and is contained in the EBID eeprom on the testcard. The EBID is placed on the testcard so that our firmware and support GUI's (such as WDS) can recognize the characteristics of the board. The EBID is NOT required as part of the bill-of-materials in an end customers design. The EBID contains information such as the local ID, destination ID, matching network configuration and antenna/ test card configuration type.

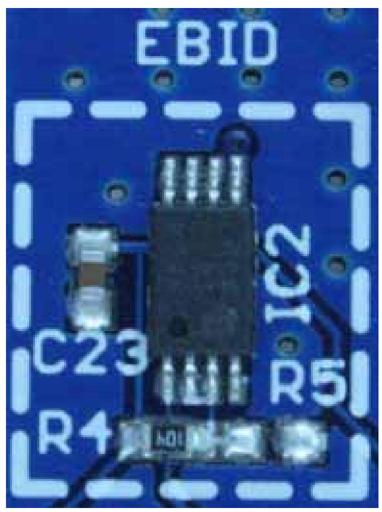


Figure 20. Test Card Characteristics EEPROM (EBID)

The SDBC-DK3 is initially configured with the same value for the destination ID and the self ID. In order to run the demo, you will need to configure the destination ID of the first board to that of the second and vice versa. This will allow the two SDB boards to communicate with each other. The ID is considered the address.

7.1.5. Packet Length

The node parameters screen also allows users to adjust the packet length so that they may:

1. Perform head-to-head comparisons with competitive radios
2. Learn the effects of packet length with respect to data-rate and robustness

Many things affect the robustness of a radio link and often the lack of understanding of some of these variables can skew test results quite substantially.

A good example of when this misunderstanding takes place is during head to head comparisons of different radio IC suppliers. By using the 'packet length' option in the menu, users may adjust the length of the packet to match such that they are looking at the same packet structure during their tests. (See section 7.7 for further details on the packet structure)

Once designers are satisfied with their head-to head comparisons of the radio IC's having based their tests on similar structures then designers can use the packet length option to experiment with their protocol. Packet length can have many tradeoffs with respect to power savings, robustness, data rates, processing overheads, etc.

Consider the following:

- During the transmission of long packets, there is an increased chance that a disturbance may occur somewhere along that packet—thus the need to implement good CRC checks.
- During the transmission of short packets, there is an increased chance that the entire packet may be lost during a disturbance—thus the need to implement more retries.
- Transmission of long/short packets with a slow data rates have good easily recognizable 1's and 0's but by comparison to fast data rates have a greater 'on time' and may use more power but retries may be less (in turn saving power).
- Transmission of long/short packets with a fast data rate may have a less 'on time' but retires may be greater, antenna diversity may help reduce the multipath effects.

The trade offs in radio applications are many and the list above is by no means the only possible scenarios, every application has its own list of acceptable trade offs and through the use of menu options such as data-rate, packet length and antenna diversity engineers can learn to best understand what options work for them and their environments.

7.1.6. Max Packets

So that designers can scientifically qualify the aforementioned trade offs, careful experimentation in applicable application-like environments is recommended, the 'Max. Packets' menu option allows designers to select the number of packets used to generate a Packet Error Rate (PER) result.

- A large number of packets (1000–9999) allows for a good averaged result but can take time particularly at low data rates.
- A small number of packets (100) allows for a quick environmental assessment to be made prior to an exhaustive test.

7.1.6.1. Example—Typical Usage

The designer will arrive at their test site and run a 100 packet test experiment prior to exhaustive testing. If the results are in accordance with previous tests then the environment is similar to those of the previous occasion. If there is a substantial difference in the results of a 100 packet test with any previous occasions results then new environmental factors are playing into tests and these should be recorded as comments so that results from exhaustive testing is better understood.

<Press the GO button>.

7.1.7. Screen 5: The Ready Screen

The ready screen on the LCD is the final step before starting your experimentation. The ready screen labels the LEDs 1–4 according to the function they will perform. In this demonstration they are TX, RX, Antenna 1 and Antenna 2. Note if you have disabled any of the antenna's or are using a none antenna diversity card then the associated antenna is not represented by the LEDs.

Figure 21. Non-Antenna Diversity Testcard

Note: Only one antenna highlighted on the top row and NO-ANTDIV shown in the second line of text.

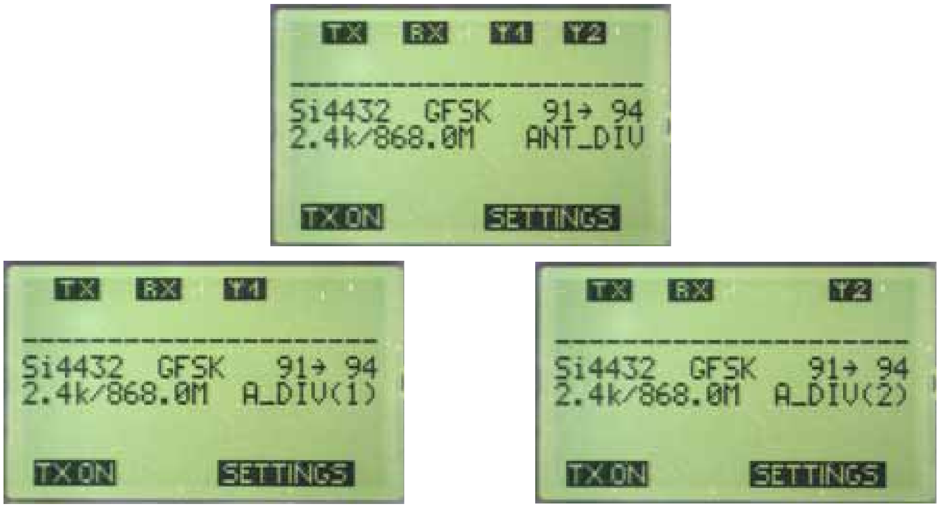


Figure 22. Antenna Diversity Testcard

Note: Depending on antenna selection the relevant antennas are shown on the top row and either ANTDIV, A_DIV(1), or A_DIV(2) is shown in the second line of text.

The ready screen is designed to allow you to review the settings on both boards. In the example shown above, we illustrate the following configuration:

- Our first board with ID 091 is sending its message to board with the ID 094
- At 2.4 kbps
- With frequency 868.00 MHz

Using the ready screen, we can see that there is an error on the split TX/RX board in that it is configured with a selfID of 054, this does not match the DestinationID on the antenna diversity board. From the 'ready screen' we can update the antenna diversity board accordingly. To do this, we can press PB3 or PB4, which are highlighted as 'SETTINGS' where we can re-run the setting accordingly.

Once the settings are correct we can run the demonstration accordingly.

If the user has the ability to see both ends of the link then a white LED driver is made available on the SDB with which you can enable a high brightness LED to make visual confirmation easier of the remote board.

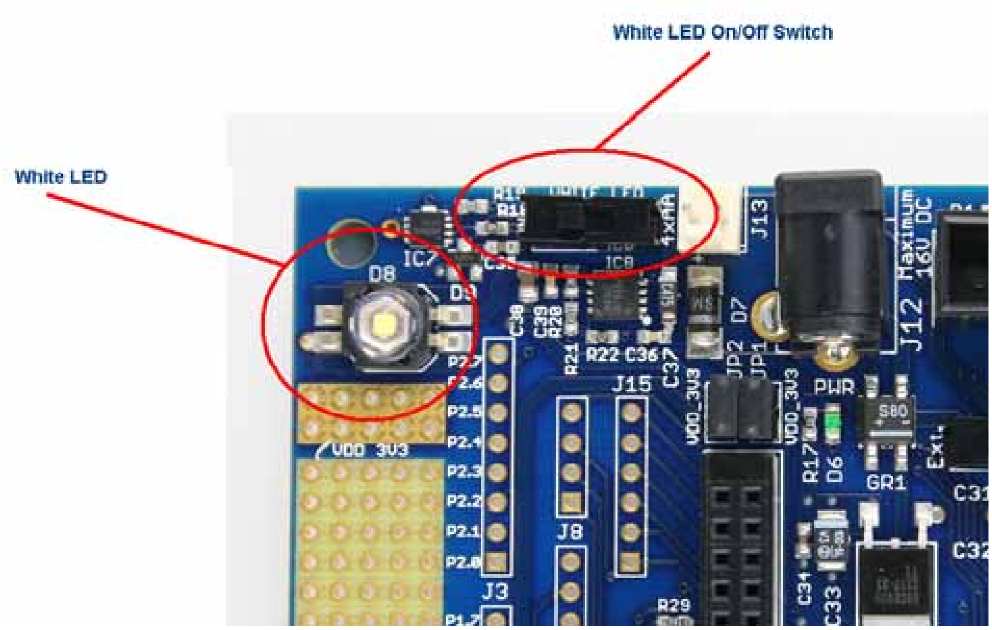


Figure 23. White LED Control

This feature is only manually enabled since the brightness of the LED may be distracting when on desk operation is being implemented.

7.1.8. Running the Demonstration

Longer tests provide better averages, but in the interest of time, this demonstration sends only 1000 packets. Users that modify the code can send as many or as few packets as they wish. The fact only 1000 packets are sent can cause higher PER percentages since most of the dropped packets will occur while the user is setting up the demonstration because he himself will absorb much of the radiation and add to multipath and fading effects. As users become more familiar with radio it is highly recommended a greater number of packets be sent such that a better average can be generated.

To run the demonstration, place one SDB in a fixed location. (If testing an antenna diversity system, place the antenna diversity unit in the fixed location while using a single-ended testcard as the roaming testcard). The SDB kept in the fixed location should be considered the “base unit”. This unit will act as the base unit. On the mobile unit, the unit with the split TX and RX, press 'TX ON' and walk away from the base unit until the PER settles around 5-7%. When the PER has settled and all 1000 packets are sent press the CLEAR button and run the test again but avoid being to close to the demo during the second test. If the test completes with 0-2% PER then the test should be run again with a greater range, if 4–6% then run again but with a lower range. Once you reliably get 2-3% at the end of the series of tests then, in that environment this can be considered the typical range in an application with limited error handling - as is the purpose of this experiment.

Good protocols and handling of dropped packets enable users to get much greater ranges.

During early experimentation, users may notice that the LCD and LEDs show information that represents antenna strength.

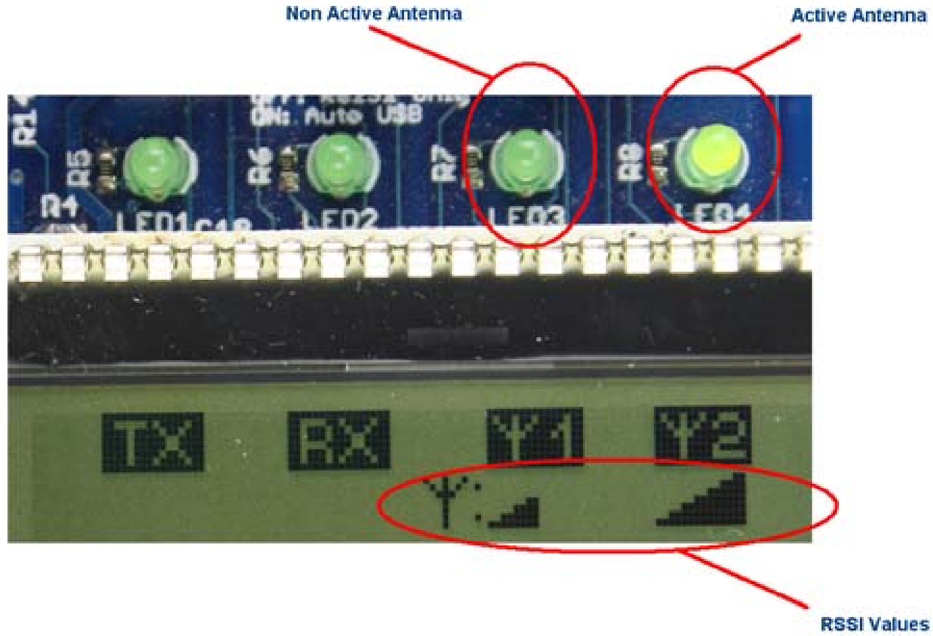


Figure 24. Active Antenna and RSSI Indications

7.2. Lab Mode

The lab mode is intended for users who want to evaluate the performance of the Silicon Labs RFICs, supported through the shipping factory firmware on the SDB platform.

Lab mode is intended so users can perform simple evaluations, such as:

- Transmitter Evaluation
  - Output power
  - Spectrum analysis
- Receiver Evaluation
  - BER Sensitivity
  - PER Sensitivity
  - Receiver parameters:
    - Automatic Frequency Control
    - Blocking
    - Selectivity

Using lab mode, users can independently evaluate transmit and receive performance. Table 5 lists the test cards available for ordering.

Table 5. Test Cards Available for Ordering

Type	Matching Network Configuration	Part Number
Transceivers	High band	4432 – DKDB1
		4431 – DKDB1
	Low band	4432 – DKDB5
		4431 – DKDB5
Receivers	High band	4330 – DKDB1
	Low band	4330 – DKDB5
Transmitters	High band	4032 – DKDB1
		4031 – DKDB1
	Low band	4032 – DKDB5
		4031 – DKDB5

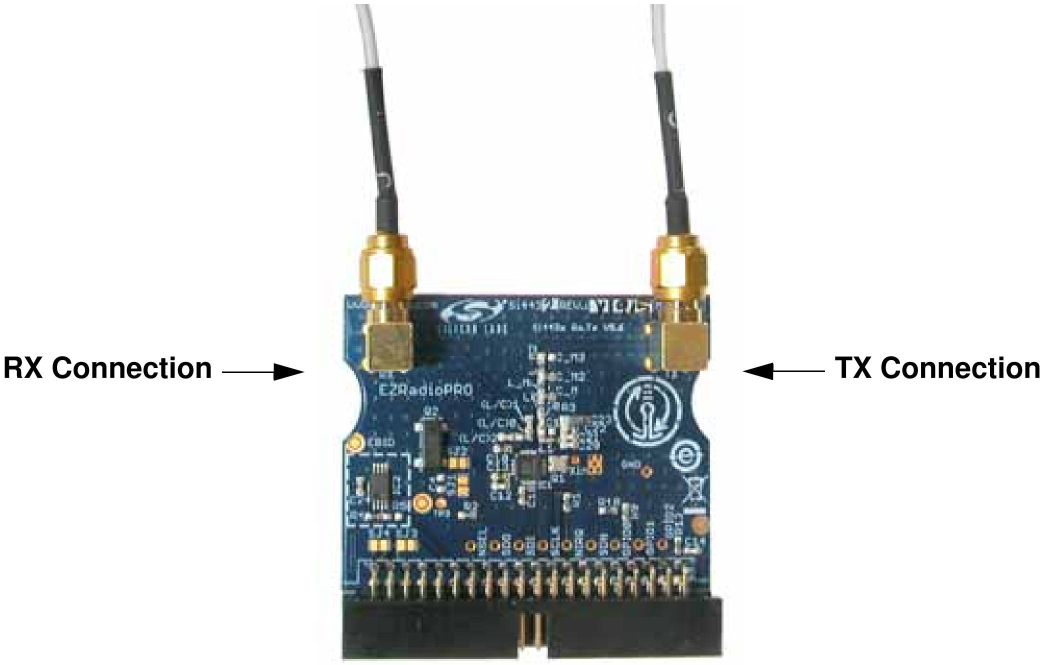


Figure 25. 4432-DKDB1 - Split TX/RX Antenna Card Using Coaxial Cable

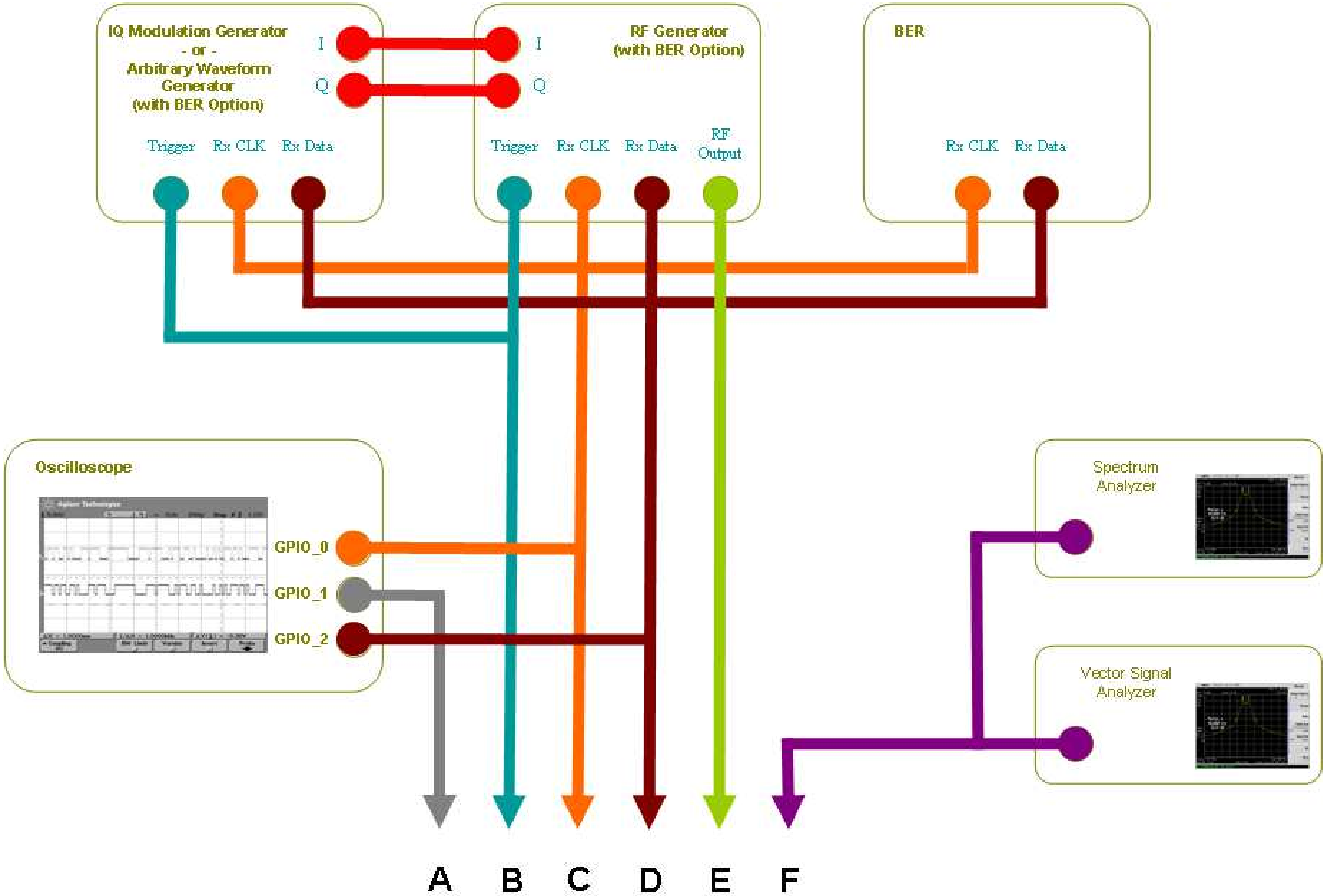


Figure 26. Lab Equipment Connection Diagram

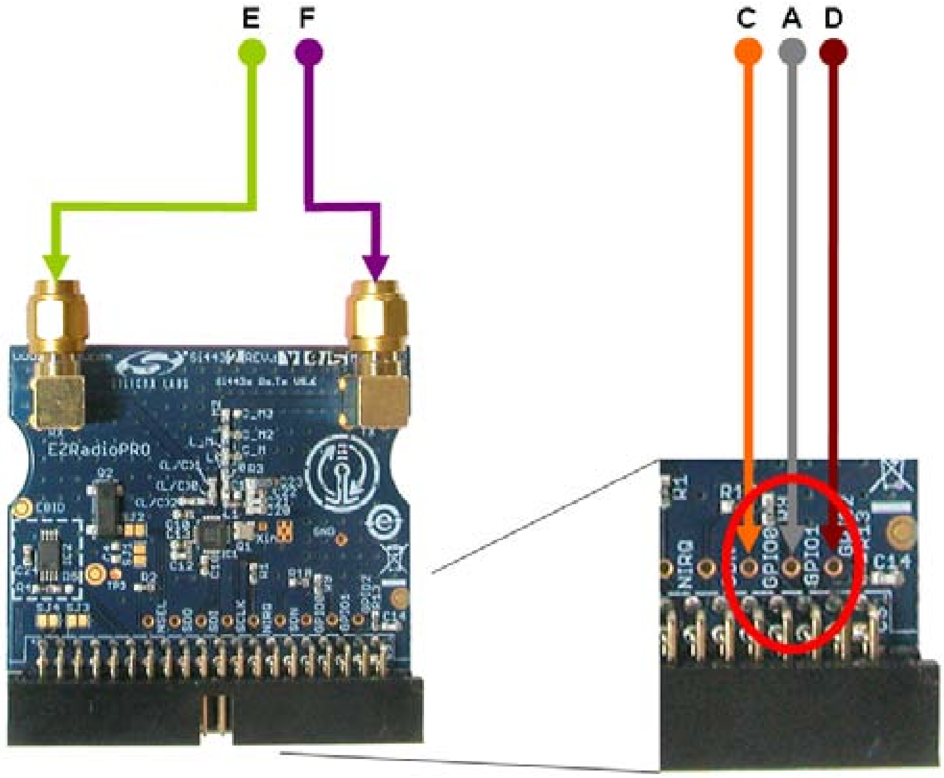


Figure 27. Test Card Connection Diagram

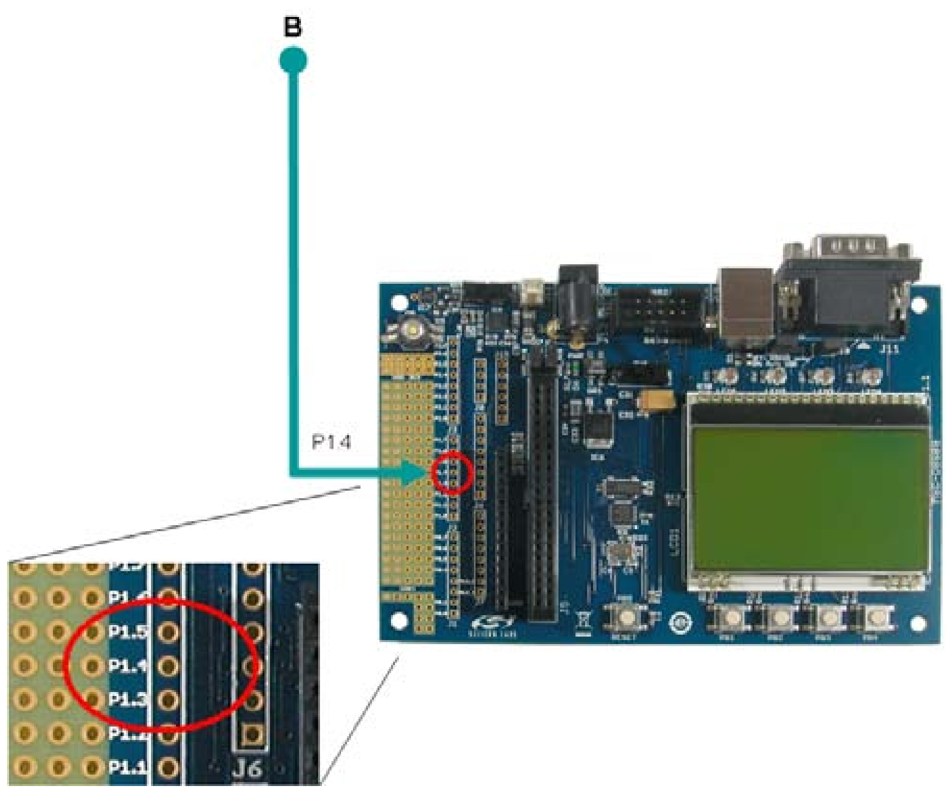


Figure 28. SDB Connection Diagram