Application note

DA1458x Bluetooth Direct Test Mode

AN-B-007

Abstract

This document is a guideline for testing the DA1458x SoC device in Bluetooth Direct Test Mode.

Contents

Figures

1 Terms and definitions

BLE	Bluetooth Low Energy (now: Bluetooth Smart)
DTM	Direct Test Mode (for Bluetooth Smart devices)
EUT	Equipment Under Test
GPIO	General Purpose Input Output
GUI	Graphical User Interface
PCB	Printed Circuit Board
PER	Packet Error Rate
SoC	System on Chip
UART	Universal Asynchronous Receiver/Transmitter

2 References

[1] UM-B-008, DA1458X Production Line Tool reference CLI, User manual, Dialog Semiconductor.

[2] Connection Manager Manual v1.0.4, *HelpConnectionManager.pdf*, Dialog Semiconductor.

3 Introduction

DA1458x are Bluetooth® Smart SoC devices, working with extremely low power while providing world-class RF performance, a small footprint and flexible peripheral configurations for a wide range of applications.

The DA1458x supports Direct Test Mode (DTM) for RF PHY testing as specified by the Bluetooth SIG. The Device Under Test (DUT) communicates with the Bluetooth tester over a 2-wire HCI UART. See Figure 1 for a description of the test setup.

The DA1458x supports Direct Test Mode when used with the split embedded configuration of the firmware. The *prod_test_58x.hex* files can be found in the latest SDK and can be downloaded from the Dialog Customer Support site. Please read sections 4.1 to 4.3.4 for setting up DTM for Bluetooth RF testing.

Additionally, using the latest Connection Manager tool and loading the same *prod_test_58x.hex* file, some production tests can be executed, for example: continuous modulated Tx output, Tx CW output and Rx testing with statistics. This test-mode is started when choosing ‘Boot Test Mode’ in the Connection Manager after downloading the *prod_test_58x.hex* file. This tool provides a GUI showing the available commands.

Furthermore, a command line interface based executable is available (*prodtest.exe),* offering similar functionality. Please read sections 4.6 and 4.7 for setting up these production test tools.

4 Setting up Direct Test Mode

4.1 Introduction

The measurements on the RF PHY can be performed using for instance the R&S CBT in local mode by controlling the buttons of the CBT equipment, or in remote mode under control of a PC tool running a test script such as CBTgo. The installation guide for the required hardware and software is provided in sections 4.3, 4.3.2, 4.5 and 4.3.3.

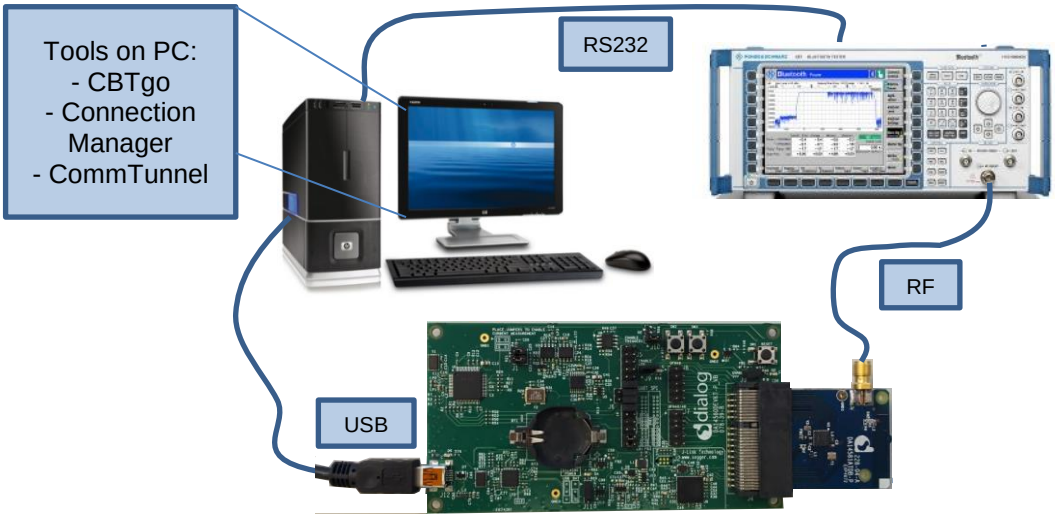


Figure 1: Setup for Bluetooth Direct Test Mode

4.2 UART baud rate considerations

The DA1458x UART baud rate is derived from the internal 1 MHz clock signal. This 1 MHz is the 16 MHz crystal oscillator clock divided by 16. The UART baud rates are defined in Figure 2 below.

Target baud rate (kBd)	Divisor value	Actual baud rate (kBd)	Error (%)
115.2	9	111.1	3.54
57.6	17	58.82	2.12
38.4	26	38.46	0.16
28.8	35	28.57	0.79
19.2	52	19.23	0.16
9.6	104	9.61	0.16

Figure 2: DA1458x actual UART baud rates

The target baud rate of 115.2 kBd actually is 111.1 kBd, having an error of 3.54 %. Since the UART specification allows for a total error of 5 %, this DA1458X baud rate error leaves only 1.46 % for the other side, e.g. the R&S CBT or the Anritsu MT8852B.

When the BLE test equipment is having communication problems with the actual UART baud rate of 111.1 kBd, which is the default value defined in the *cust_prod_test.hex* file, a lower baud rate must be selected. It is advised to use the target baud rate of 38.4 kBd by applying a divider value of 26, resulting in a very low error of 0.16 %. This lower baud rate will not affect the measurement time.

It was found that the Anritsu MT8852B BT tester definitely requires the lower baud rate of 38.4 kBd, while the R&S CBT normally works fine at a baud rate of 111.1 kBd (divider value 9), but some specific devices might require the lower 38.4 kBd baud rate.

The most flexible method for DTM signalling to the DA1458X is to use a Comm Tunnel tool running on the PC. This tool acts as a baud rate converter and also avoids the use of the level shifter, since the communication runs via the FTDI chip on the motherboard. The PC must have a physical or virtual COM port.

In the example of Figure 3, COM1 is the PC's COM port to which the serial port of the Bluetooth tester is connected and COM4 is the virtual UART COM port provided by the SDK evaluation mother board. For both endpoints a baud rate of 115.2 kBd is selected, at which the Anritsu MT8852 now also communicates well with the DA1458X. Before downloading the *prod_test_58x.hex* test software over UART, the Comm Tunnel tool must be stopped by using the 'Stop' button.

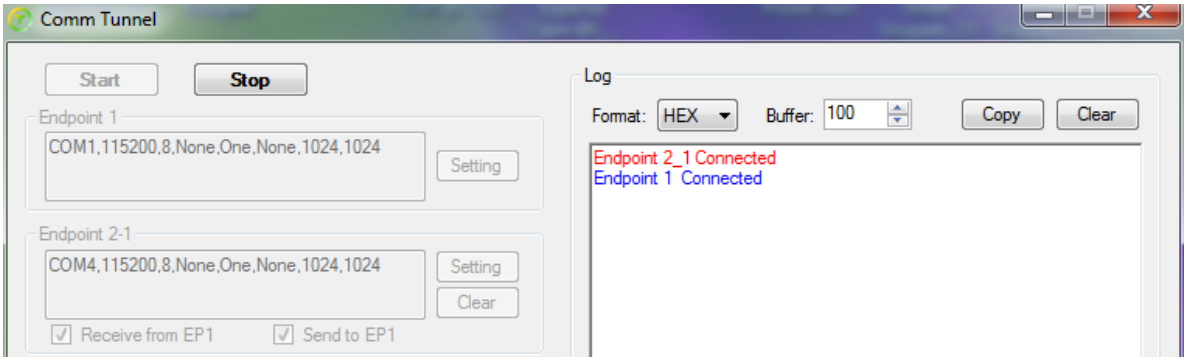
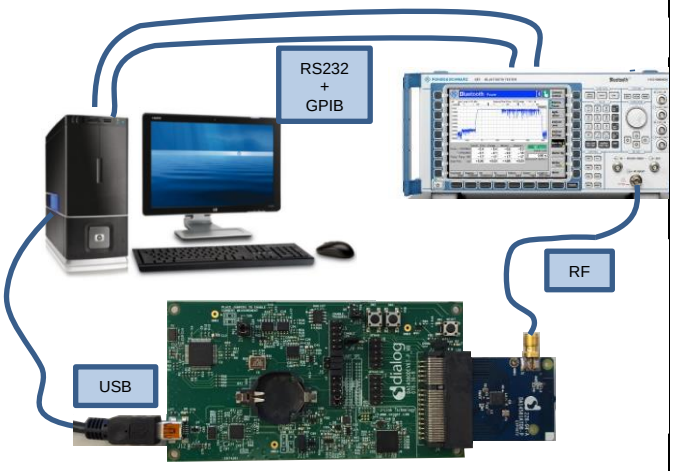


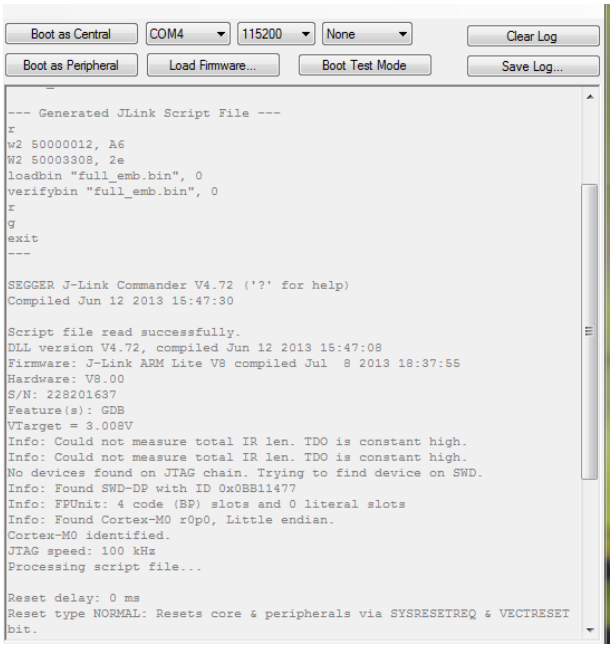
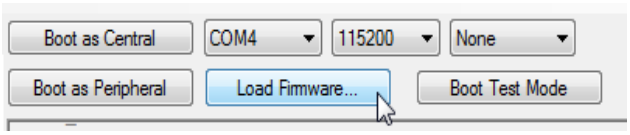
Figure 3: Example of a Comm Tunnel tool

4.3 Setting up R&S CBT BT/BLE tester

4.3.1 Setting up CBT hardware

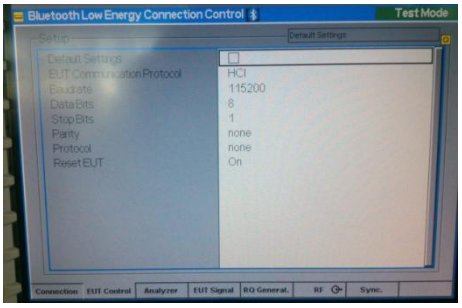
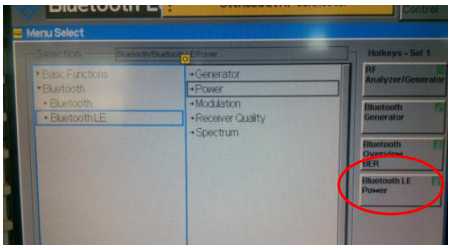
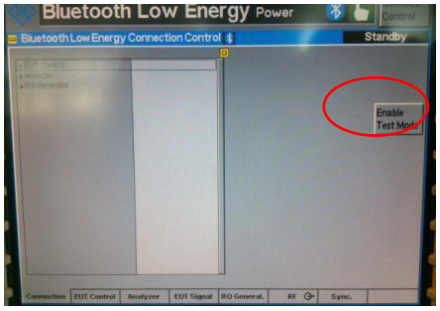
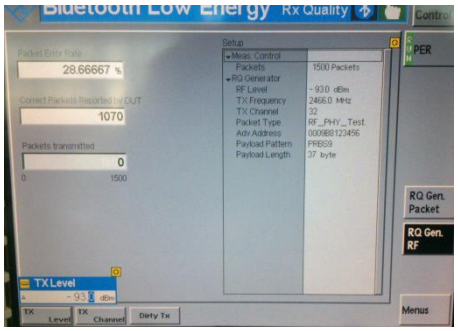
4.3.1.1	From the back of the CBT connect the GPIB to the PC and configure the interface. Also see the CBTgo user manual for details. From the back of the CBT connect an RS232 cable to the PC Supply and UART is provided by a USB cable between the PC and the development board. Connect a RF cable between the SMA connector and the CBT.	

4.3.2 Installing the software

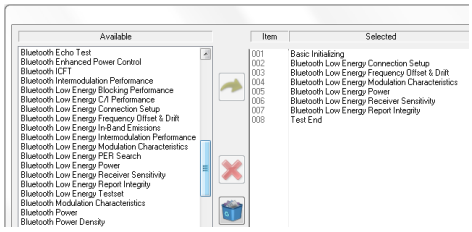
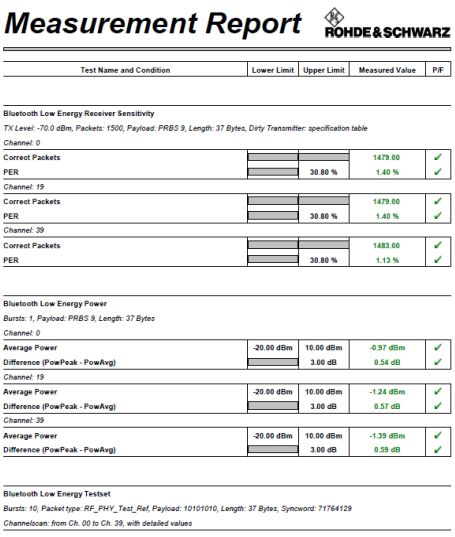
4.3.2.1	Download the CBTgo program from the Rohde&Schwarz website and install: http://www.rohde-schwarz.com/en/software/cbt_cbt32 Current CBTgo version is v3.0.0.	
4.3.2.2	Set the UART baud rate in the CBT to 115.2 kBd.	
4.3.2.3	Install and run the latest Connection Manager: *ConnectionManager.exe.* "Cortex-M0 identified" should be listed. Download this tool from the Dialog Semiconductor support website: under the tab "Guide / Software".	
4.3.2.4	In the Connection Manager, select the UART COM port. Locate the provided hex file. Download the SDK from the Dialog support website.	This is the port having the lowest COM-port number of the relevant COM-port pair. This is in the latest SDK. Filename: *prod_test_58x.hex.*
4.3.2.5	Power the DA1458x board and in the Connection Manager choose "Load Firmware". Point to the provided file *prod_test_58x.hex*.	

4.3.2.6	The result should look like the output on the right and should show “Verify successful”.	Feature(s): GDB VTarget = 3.008V Info: Could not measure total IR len. TDO is constant high. Info: Could not measure total IR len. TDO is constant high. No devices found on JTAG chain. Trying to find device on SWD. Info: Found SWD-DP with ID 0x0BB11477 Info: FPUnit: 4 code (BP) slots and 0 literal slots Info: Found Cortex-M0 r0p0, Little endian. Cortex-M0 identified. JTAG speed: 100 kHz Processing script file... Reset delay: 0 ms Reset type NORMAL: Resets core & peripherals via SYSRESETREQ & VECTRESET bit. Writing 00A6 -> 50000012 Writing 002E -> 50003308 Loading binary file... [cust_prod_test_ES5_v3060_original.bin] Writing bin data into target memory @ 0x00000000. Loading binary file cust_prod_test_ES5_v3060_original.bin Reading 21900 bytes data from target memory @ 0x00000000. Verify successful. Reset delay: 0 ms Reset type NORMAL: Resets core & peripherals via SYSRESETREQ & VECTRESET bit. Script processing completed.

4.3.3 Setting up Bluetooth LE Direct Test Mode

4.3.3.1	Set the UART baud rate in the CBT to 115.2 kBd.	
4.3.3.2	In Manual mode enable Bluetooth LE.	
4.3.3.3	Enable the device in test mode and the device will connect. Tx/Rx test cases can be selected using the software menu.	
4.3.3.4	Running an Rx test.	

4.3.4 Setting up Direct Test Mode with CBTgo

4.3.4.1	Run the CBTgo v.3.0.0 program from Rohde&Schwarz. For download link and installation, please refer to section 4.3.2.1.	
4.3.4.2	In CBTgo configure for a BT Low Energy device.	
4.3.4.3	In CBTgo configure the tests to be executed. These tests can be saved in a sequence file.	
4.3.4.4	Press the Start button in CBTgo to execute the sequence.	
4.3.4.5	The result file can be saved and exported to other formats.	

4.4 Setting up Anritsu MT8852B BT/BLE Tester

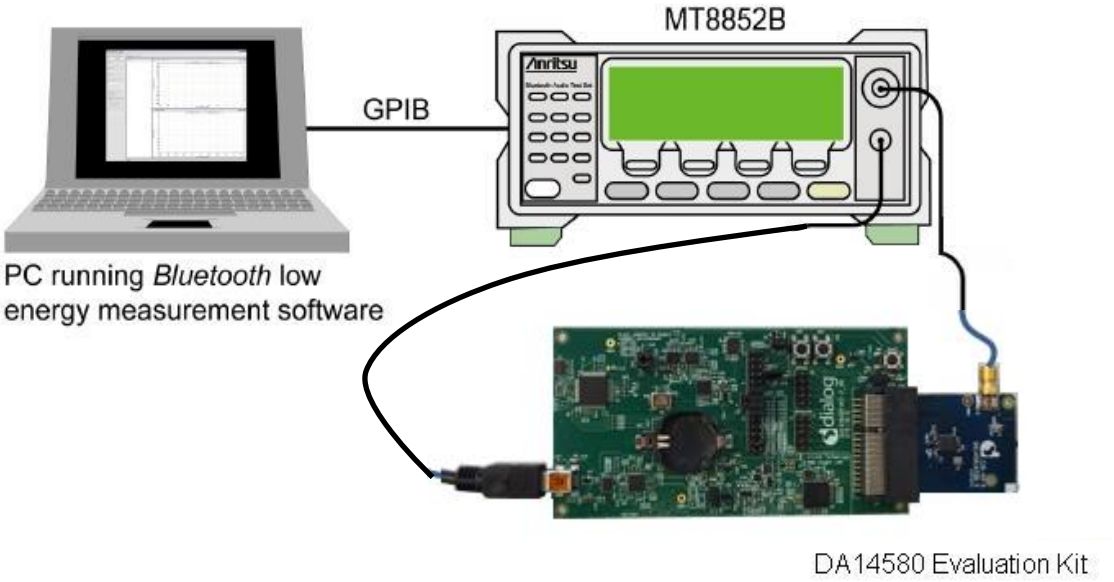


Figure 4: Anritsu MT8852B connections

Make sure the MT8852B has the latest firmware version: 4.18.000 (August 2014). This firmware version offers communication directly to the DA1458X evaluation kit's dual FTDI chip via the USB connector. In the tester's *EUT BT address* menu, select the following communication method: USB->RS232 (Source), A (Port). Port A is the UART communication port.

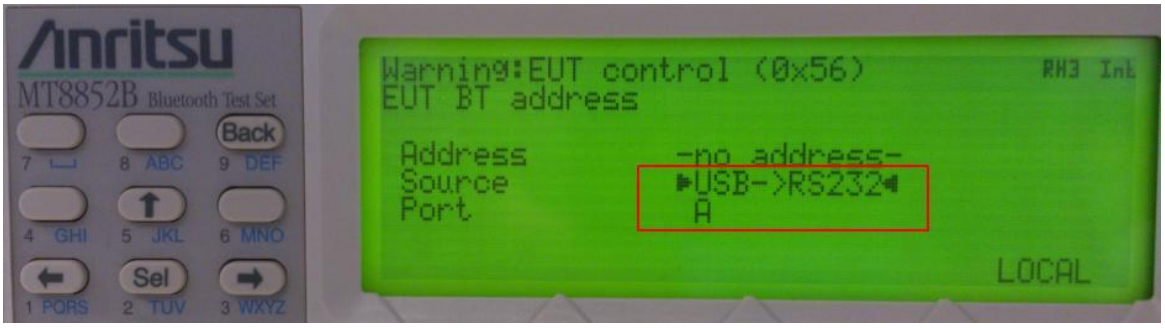


Figure 5: MT8852B EUT control

The Anritsu MT8852B appeared not to be able to communicate to the DA1458X device at a baud-rate of 115.2 kBd. The baud rate should be set to 38.4 kBd in order to function correctly.
In the MT8852B go to the *EUT RS232 setup* menu and set the Baud rate to 38400 Bd.

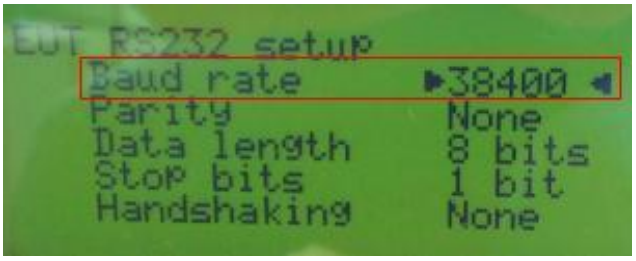


Figure 6: Change the baud rate from 115200 Bd to 38400 Bd

The EUT (DA1458x) must also be set to a baud rate of 38.4 kBd. The file *cust_prod_test.hex* must be prepared for this. In the Keil project *cust_prod_test*, the following must be defined in order to communicate at a baud rate of 38.4 kBd:

Define the divider value for UART_BAUD RATE_38K4 to 26:

```
/// Divider for 38400 bits/s
#define UART_BAUD RATE_38K4       26
```

In the following code, replace `UART_BAUD RATE_115K2` by `UART_BAUD RATE_38K4`:

```
132  void periph_init(void)
133  {
134    // Power up peripherals' power domain
135      SetBits16(PMU_CTRL_REG, PERIPH_SLEEP, 0);
136      while (!(GetWord16(SYS_STAT_REG) & PER_IS_UP)
137
138      SetBits16(CLK_16M_REG, XTAL16_BIAS_SH_DISABLE
139
140      // Initialize UART component
141  #ifdef PROGRAM_ENABLE_UART
142      SetBits16(CLK_PER_REG, UART1_ENABLE, 1);    /
143
144      // baudr=9-> 115k2
145      // mode=3-> no parity, 1 stop bit 8 data leng
146  #ifdef UART_MEGABIT
147      uart_init(UART_BAUDRATE_1M, 3);
148  #else
149      uart_init(UART_BAUDRATE_115K2, 3);
150  #endif // UART_MEGABIT
151  #endif // PROGRAM_ENABLE_UART
152
```

Compile and build the *cust_prod_test.hex* file. It is best to first rename this file to *cust_prod_test_38k4.hex* to differentiate it from the default version using 115 kBd.

Procedure:

1. Load the created hex file in the DA1458X.
2. Connect the USB->RS232 cable
3. Connect the RF-port of the MT8852B to the RF SMA connector on the DA1458x daughterboard.
4. For PC program based testing and test-report generation, connect the PC to the MT8852B by a GPIB cable.

   Available PC software: CombiTest v3.2 or BLE Measurement Software v1.15.

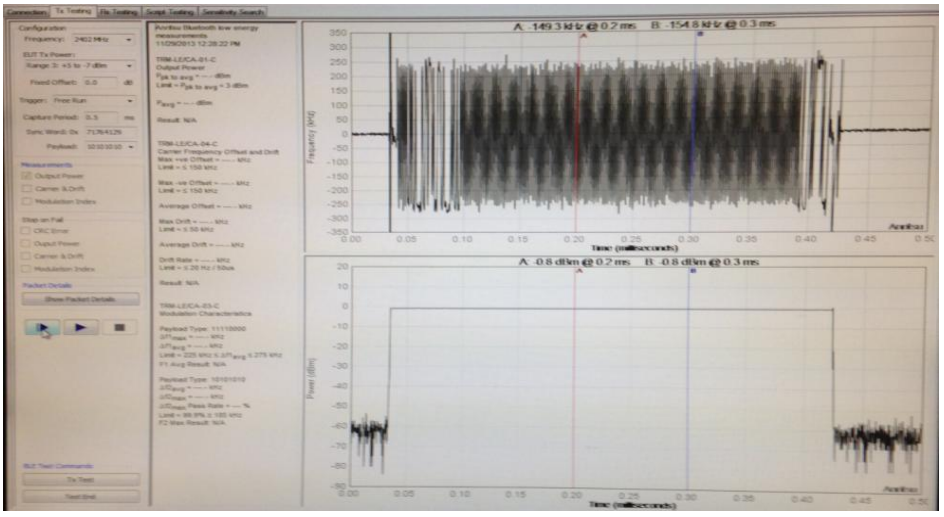


Figure 7: MT8852B BLE Measurement Software output example

4.5 Setting up LitePoint IQ2010/2015 BT/BLE Tester

The Litepoint IQ201x series of universal testers is targeted for fast production line testing.

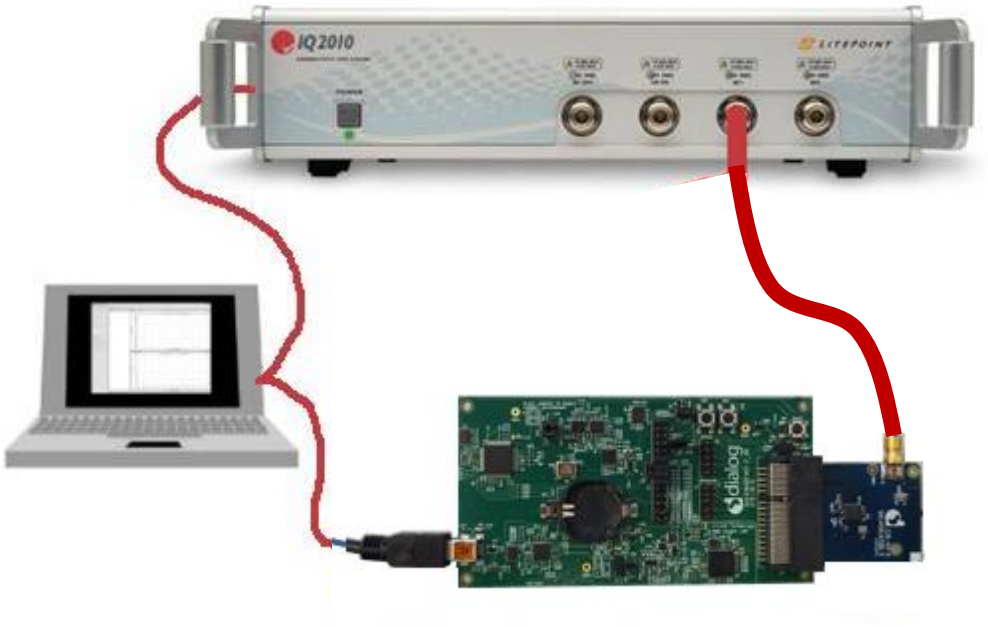


Figure 8: PC, Litepoint IQ2010 tester and DA1458X evaluation board

The setup is simple: the RF1 output of the Litepoint tester is connected to the DA1458X RFIO port, the SMA connector on the BLE device daughterboard. Please use a high quality coaxial cable for this. The PC controls the Litepoint tester and the EUT, the DA1458X device.

The DA1458x BLE device must be running the production test software, the BLE device will be in Direct Test Mode (DTM), also called non-link test mode. For this DTM mode, the following hex file must be loaded into the device: *cust_prod_test.hex*. It is the same file as used in section 4.3.

The procedure is as follows: for DA1458x Rx testing the IQ201x tester sends out a known number of packets, the Dialog Semiconductor production test software *prodtest.exe* or the *Connection Manager*

GUI tool reports the number of packets received by the DA1458X and then a packet error rate (PER) calculation can be executed. Unlike the R&S CBT or the Anritsu MT8852B tester, there is no EUT signalling by the IQ201x tester. The EUT must be controlled by the PC using CLI *prodtest.exe* or *Connection Manager* GUI. See section 4.9, showing the latter option.

4.5.1 Vector Signal Generator

The IQ201x tester is controlled by the Litepoint PC control software: *IQsignal*. For RF1 to be used as BLE RF output, as shown in Figure 8, it must be configured as follows in the *Bluetooth Settings* menu of the *IQsignal* program: RF2=>VSA / RF1=>VSG. See Figure 9.

In the Vector Signal Generator (VSG) tab, the required generator file can be selected and loaded. Then the generator can be run continuously or for a certain number of waveforms or packets. Also, the wanted frequency/channel and the RF output level of the tester can be set here. See Figure 10.

In Figure 10 the Dirty packets waveform *BT_LE_DirtyPacket.mod* has been loaded. This waveform contains 40 packets, so when transmitting the waveform 100 times by pressing the *RF On/Off* button, in total 4000 packets will be sent. This is the so-called BLE PER Report Integrity test.

A similar test using packets containing CRC errors can be executed by loading the waveform *BT_LE_CRC_ERROR.mod*. This waveform contains two packets, one good and one having the CRC error. The result at the receiver side could be as follows: 2000 packets received, 1000 packets having a CRC error, PER = 50 %. The resulting PER should be between 50 % and 65.4 %.

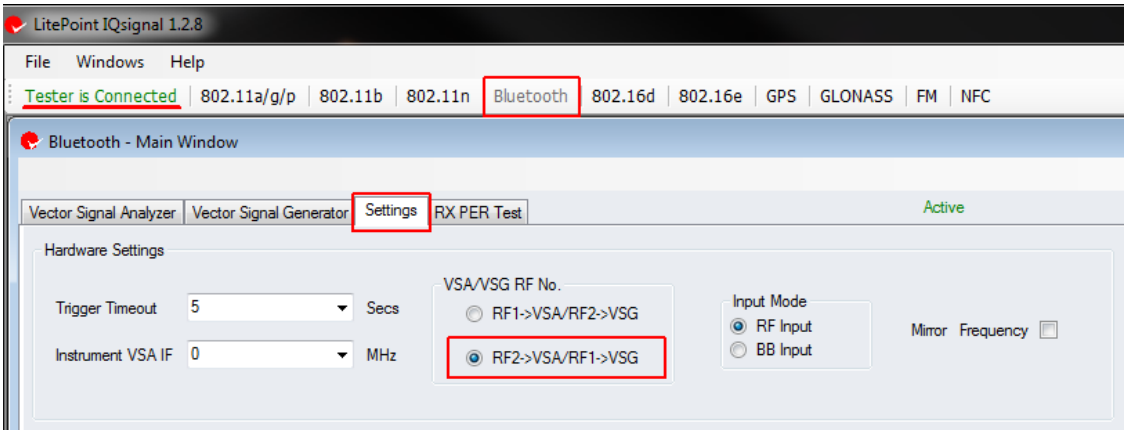


Figure 9: IQsignal Settings menu – using RF1 for VSG

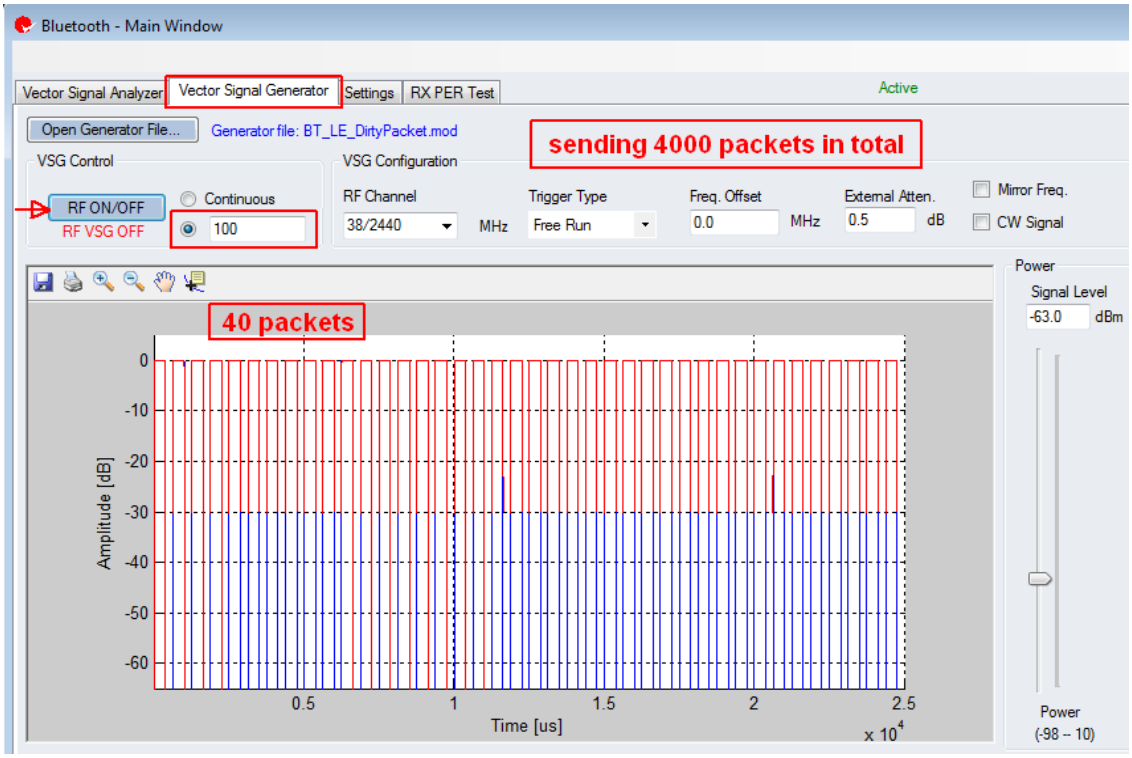


Figure 10: Vector Signal Generator tab - dirty-packets waveform loaded

Transmitting starts when the *RF ON/OFF* button is pressed, and when a number is selected, it stops transmitting when this number of waveforms has been sent.

Procedure:

1. Give the *Start Receiving* command to the EUT.
2. Press the RF ON/OFF button In the *IQSignal* program.
3. After finishing, give the *Stop Receiving* command to the EUT.

The transmitted number of packets is known. The received number of good packets can be read, either in the *prodtest.exe* output or in the *Connection Manager* GUI. In the latter, the test *Rx with Readback values* must be selected. See sections 4.6 and 4.7.

4.5.2 Vector Signal Analyzer

The Vector Signal Analyzer (VSA) can be used to analyse the Tx output of the EUT. For RF1 to be used as RF input, as shown in Figure 8, it must be configured as follows in the *Bluetooth Settings* menu of the *IQsignal* program: RF1=>VSA / RF2=>VSG. See Figure 11.

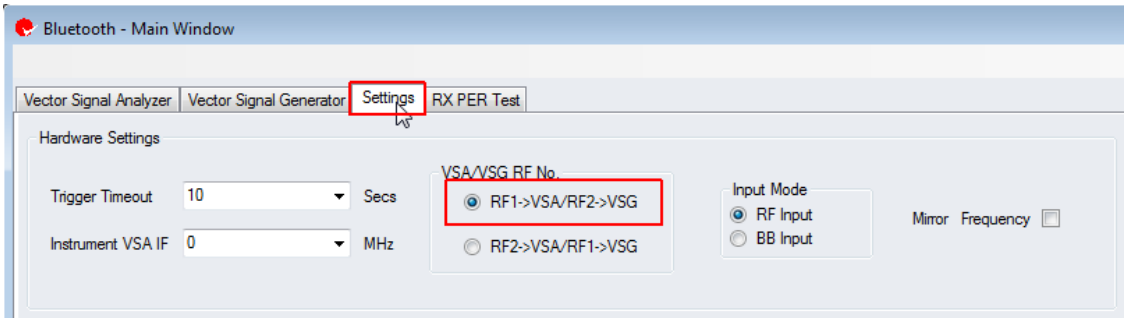


Figure 11: IQsignal Settings menu – using RF1 for VSA

The EUT (DA1458x) again is in Direct Test Mode, but now as Tx, transmitting either continuously or a certain number of packets. This can be set in the *Connection Manager* GUI or the CLI *prodtest.exe*. Use the LE Transmitter Test Command (see section 4.6.2) to set the desired frequency and payload.

The VSA screen displays the Peak Power, Frequency Offset, Delta F1, Delta F2 etc. Via the button *Plot Window* also a 'Spectrum Mask' or a 'Delta F2 Max versus Time' can be displayed. For Delta F1 the payload must be set to 11110000, for Delta F2 use a value of 10101010 (Figure 12). The capture length can be set to capture just one packet or multiple packets.

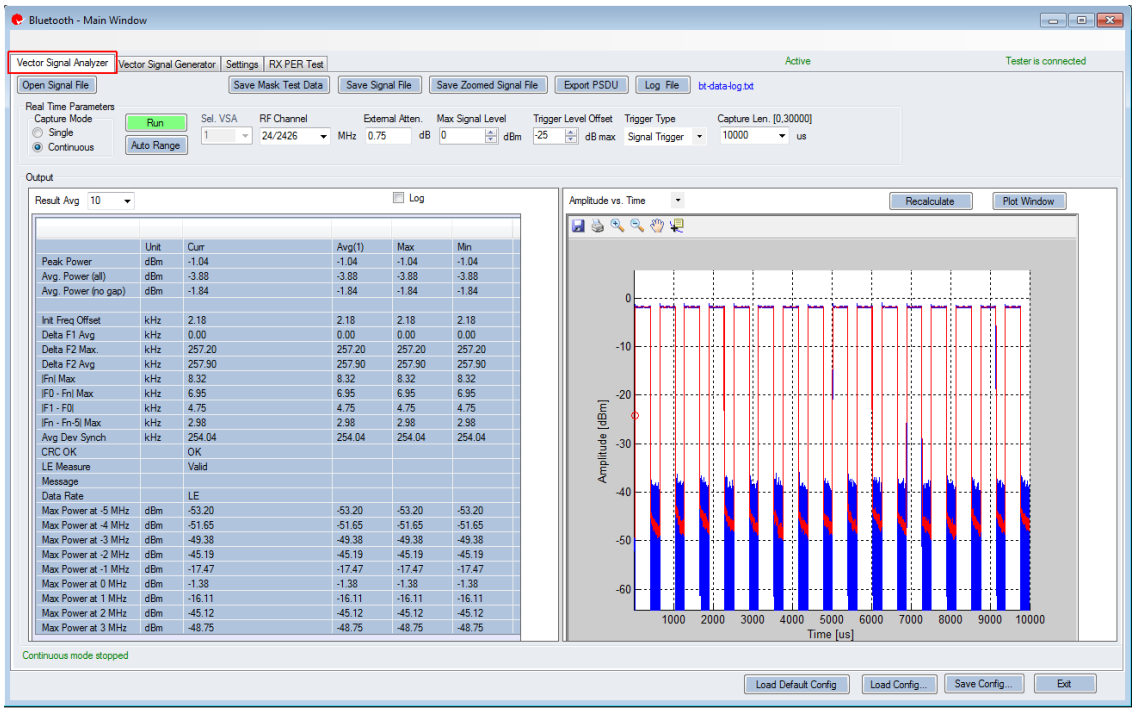
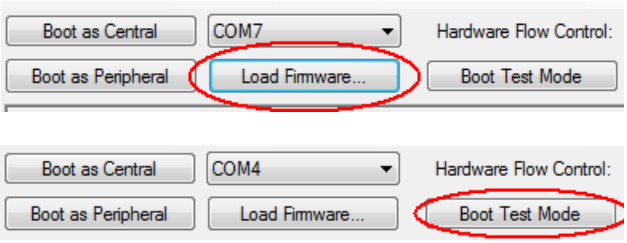
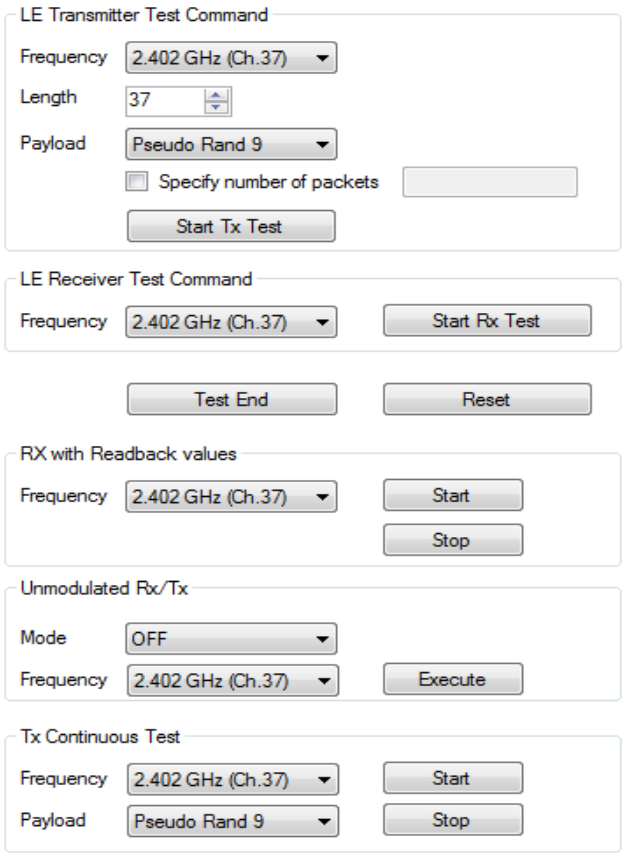
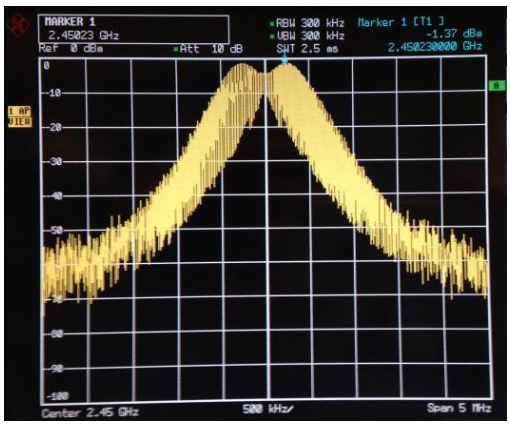


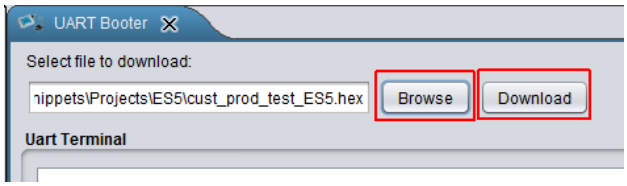
Figure 12: Vector Signal Analyzer - analysing DA1458X's Tx output

The received packets as shown in the right-hand window can be saved as a *waveform.mod* file, which again can be used as input waveform for the Vector Signal Generator.

4.6 Setting up test modes with Connection Manager

4.6.1	Run Connection Manager tool. Load the file *cust_prod_test.hex* and select Boot Test Mode.	
4.6.2	In the left-hand window of the Connection Manager, all available test cases are provided.	
4.6.3	Example: Tx Continuous Test at 2450 MHz will result in a modulated continuous Tx signal at the RFIOp pin. The centre frequency will be 2450 MHz in this example. Using a spectrum analyser, the modulation and the output power can be checked. See picture in next window. In case the Unmodulated Tx option is selected, an unmodulated CW signal is available at the RF output. The frequency accuracy could be checked by reading its frequency.	

4.7 Setting up test modes with Prodtest.exe (CLI)

4.7.1	Load the file *cust_prod_test.hex*, either using the Connection Manager (section 4.6.1) or SmartSnippets' UART Booter. The latter option is shown in the next window.	
4.7.2	`Prodtest.exe –h` lists all available options.	See output window in section 4.7.6. This CLI tool provides some more options than using the Connection Manager in Boot Test Mode: • Sleep modes: Deep- and Extended Sleep • 16 MHz Xtal trimming possibility Please refer to user manual UM-B-008 ([1]) for details on how to use this *Prodtest.exe* tool.
4.7.3	Example: `Prodtest –p 4 unmodulated Tx 2440`	This command will result in an un-modulated Tx at 2440 MHz. The switch '*–p '4* indicates that COM-port 4 is being used for communication.
4.7.4	Example: `Prodtest –p 4 Xtrim en`	This command enables the 16 MHz Xtal trimming. The 16 MHz oscillator signal will be switched to port P0_5 and can be measured by using e.g. a frequency counter.
4.7.5		

4.7.6	`prodtest –h`
	`prodtest –p <COM port number> cont_pkt_tx <FREQUENCY> <DATA_LENGTH> <PAYLOAD_TYPE>`
	`prodtest –p <COM port number> pkt_tx <FREQUENCY> <DATA_LENGTH> <PAYLOAD_TYPE> <NUMBER_OF_PACKETS>`
	`prodtest –p <COM port number> start_pkt_rx <FREQUENCY>`
	`prodtest –p <COM port number> start_pkt_rx_stats <FREQUENCY>`
	`prodtest –p <COM port number> stop_pkt_rx_stats`
	`prodtest –p <COM port number> stoptest`
	`prodtest –p <COM port number> unmodulated OFF`
	`prodtest –p <COM port number> unmodulated TX <FREQUENCY>`
	`prodtest –p <COM port number> unmodulated RX <FREQUENCY>`
	`prodtest –p <COM port number> start_cont_tx <FREQUENCY> <PAYLOAD_TYPE>`
	`prodtest –p <COM port number> stop_cont_tx`
	`prodtest –p <COM port number> reset`
	`prodtest –p <COM port number> sleep none <minutes> <seconds>`
	`prodtest –p <COM port number> sleep extended <minutes> <seconds>`
	`prodtest –p <COM port number> sleep deep <minutes> <seconds>`
	`prodtest –p <COM port number> xtrim rd`
	`prodtest –p <COM port number> xtrim wr <trim_value>`
	`prodtest –p <COM port number> xtrim en`
	`prodtest –p <COM port number> xtrim inc <delta>`
	`prodtest –p <COM port number> xtrim dec <delta>`	

Revision history

Revision	Date	Description
0.1	30-May-2013	Initial version.
0.2	05-Jun-2013	Corrections.
0.3	07-Nov-2013	Updated for ES3.
0.4	06-Jan-2014	Updated for ES4.
0.5	31-Mar-2014	Updated for DA14580_01, adding Anritsu MT8852B BT tester and adding production testing.
0.6	13-May-2014	Added Litepoint Tester setup.
0.7	22-Aug-2014	Updated section 4.6 for Anritsu tester.
1.0	06-May-2015	Added section 4.2 (UART baud rate considerations). Section 4.3 reorganised to include all CBT related information. Section 4.3.1 updated.
1.1	14-June-2016	Changed pictures and text for DEVKIT pro
1.2	01-Mar-2017	Generalized for DA1458x

Status definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

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