Application Note

Configuring Bluetooth LE devices for Direct Test Mode

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ABSTRACT

This application note describes the hardware setup and software configuration to perform Direct Test Mode (DTM) using Bluetooth® test equipment with TI's SimpleLink™ Bluetooth Low Energy MCUs. DTM is used to perform Bluetooth RF certification testing on a development board or a product and is described in the Bluetooth Core Specification 5.3 Vol 6 Part F.

A setup guide is provided for the CC26x2R1 family of Bluetooth Low Energy wireless MCUs using the CC26x2R Launchpad™ (LAUNCHXL-CC26X2R1). The procedure described in this document also applies to the CC1352 dual-band wireless MCU when running Bluetooth Low Energy software, as well as other Bluetooth LE enabled MCUs such as CC2640R2, CC2651R3, CC2651P3, CC2652R7 and CC2652P7.

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1 Requirements

Requirements for programming the DUT:

- One of the utilities below:
  - Uniflash
  - SmartRF Flash Programmer 2
  - Code Composer Studio (CCS)
  - IAR Embedded Workbench for ARM
- A Simplelink™ Launchpad™ or standalone JTAG Debug Probe
- The Simplelink™ Software Development Kit (SDK):
  - CC13x2 and CC26x2
  - CC2640R2

Requirements for testing:

- A Computer running Windows® 7 or 10.
- CBT and CBT32 Tester
  - The analyzer is CBT and the attenuator is CBT32.
- R&S® CBTGo software
- The DUT (Device Under Test) furnished with a coaxial connector to be plugged to the test system.
- A GPIB card or USB accessory and the appropriate GPIB cable to connect to the CBT tester. This procedure used a National Instruments® GPIB-USB-HS interface.
- A RS232 voltage translator accessory. This is very important. The voltages on the RS232 port in the back of the CBT tester are high and will damage your DUT.
- A Straight RS232 cable (not null modem) - typically female connector (to connect on the back port of the CBT tester) and a male connector (to connect on the RS232 voltage translator).

2 Testing overview

The overall setup to perform Bluetooth Low Energy using the CBT Bluetooth tester is shown in the diagram below.

Note

Although the procedure shows the CBT tester, the principles of operation and connections can be easily leveraged to other testers such as the CMW270, for example.

The CBT Bluetooth tester (Figure 2-1 shows two views: rear and front panels) connects to both a PC and the Device Under Test (DUT), which is a custom board or a development kit such as the Launchpad.

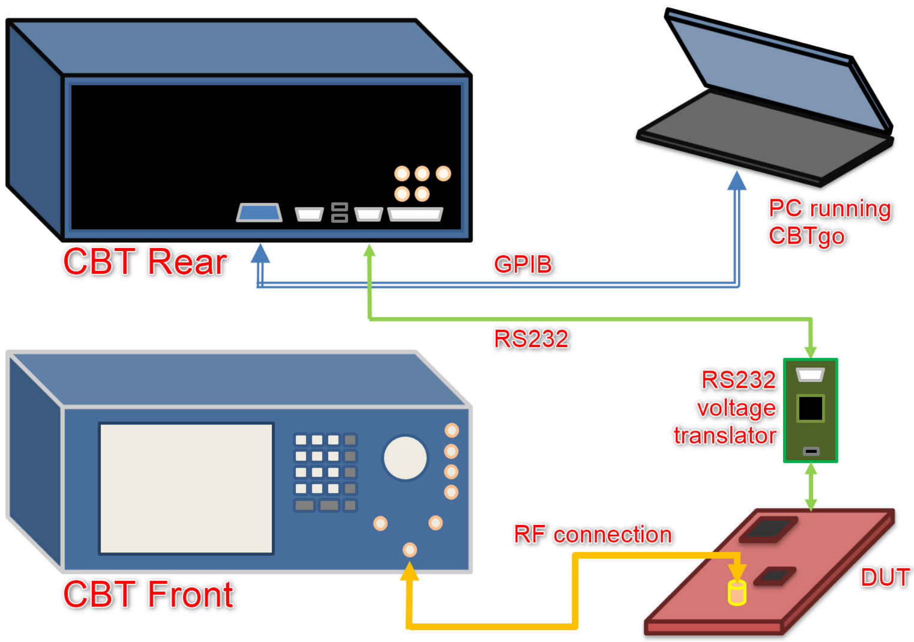

Figure 2-1. The test setup

The PC runs the CBTGo software and connects to the CBT via a General Purpose Interface Bus (GPIB) interface to control and configure it to perform the tests. It also gathers the test results for printing and sharing.

Note

The CBT can also be remotely controlled via GPIB. However, to test Bluetooth Low Energy devices, the RS232 port must be used to control the DUT, therefore only leaving the GPIB available to be connected.

The CBT connects to the DUT in two ways: a RF connection to transmit the Bluetooth data to the DUT and a RS232 connection to communicate with the DUT and perform control and gather packet data and statistics.

The DUT must have a software that exposes a communications interface to interact with the CBT. This can be accomplished by adding the Direct Test Mode (DTM) functionality to the application or use an application specifically designed for DTM.

The out-of-the-box host_test project, provided with the Simplelink SDK, is a complete HCI-enabled software that allows DTM to operate in a transparent manner through a UART port. For a Simplelink Launchpad, the UART port is the XDS110 secondary channel port (the one not used by the XDS110 JTAG functionality).

A discussion about enabling DTM on an end application is outside of the scope of this application note, but additional details about the DTM and HCI test modes can be found at the BLE5 Stack User's Guide chapter **BLE5-Stack → Host Controller Interface (HCI)**

To perform the testing, two setup procedures will be described in the next steps: program the DUT with the out-of-the-box host_test, install the control software and perform the hardware connections.

3 Programming the DUT

1. Download and install the Simplelink SDK. It typically installs under the directories below: (M_mm_mm_mm is the version being used).
   - CC13xx/26xx: C:\ti\simplelink_cc13xx_26xx_sdk_M_mm_mm_mm
   - CC2640R2: C:\ti\simplelink_cc2640r2_sdk_M_mm_mm_mm
2. Download and install one of the utilities referenced above to program the DUT on the development kit or the board.
3. The host_test has both a precompiled hexadecimal executable (.hex extension) or a complete project to be built with Code Composer Studio or IAR. This procedure will cover the use of the precompiled hexadecimal executable, which is typically located at the directory below:
   - CC13xx/26xx: C:\ti\simplelink_cc13xx_26xx_sdk_M_mm_mm_mm\examples\rtos\<BOARD>\ble5stack\hexfiles
   - CC2640R2: C:\ti\simplelink_cc2640r2_sdk_M_mm_mm_mm\examples\rtos\CC2640R2_LAUNCHXL\ble5stack\hexfiles

   Details about building and loading code using CCS or IAR can be found at the **BLE Quick Start Guide** chapter of the **BLE5 Stack User's Guide** or the **Bluetooth LE Fundamentals** module of the **SimpleLink Academy**.
4. Connect the board to the computer and open Uniflash. By default it will recognize the board and device as shown below (this will not work if you are using a standalone XDS110)

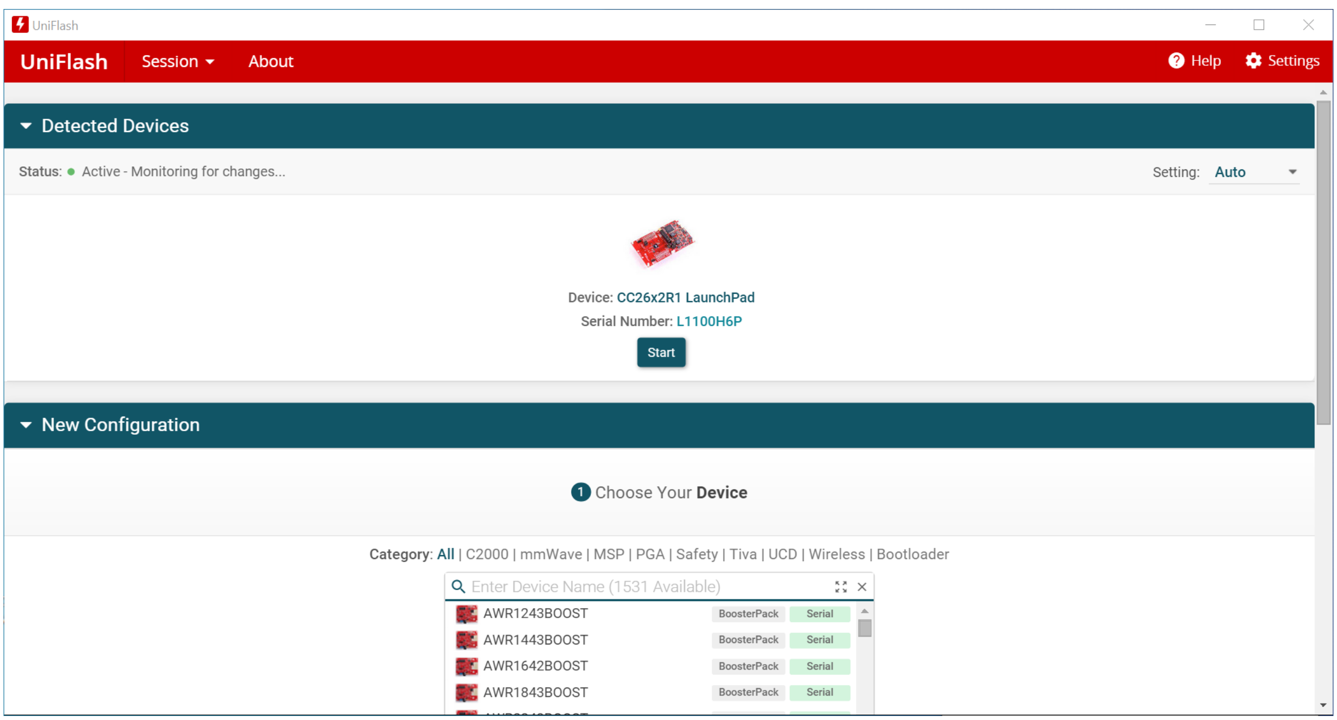

Figure 3-1. Uniflash main screen

5. Click the **Start** button.
6. In the screen that opens, click on the **Browse** button and browse to the directory where the <host_test_app.hex> file is located. Click on **Open**.

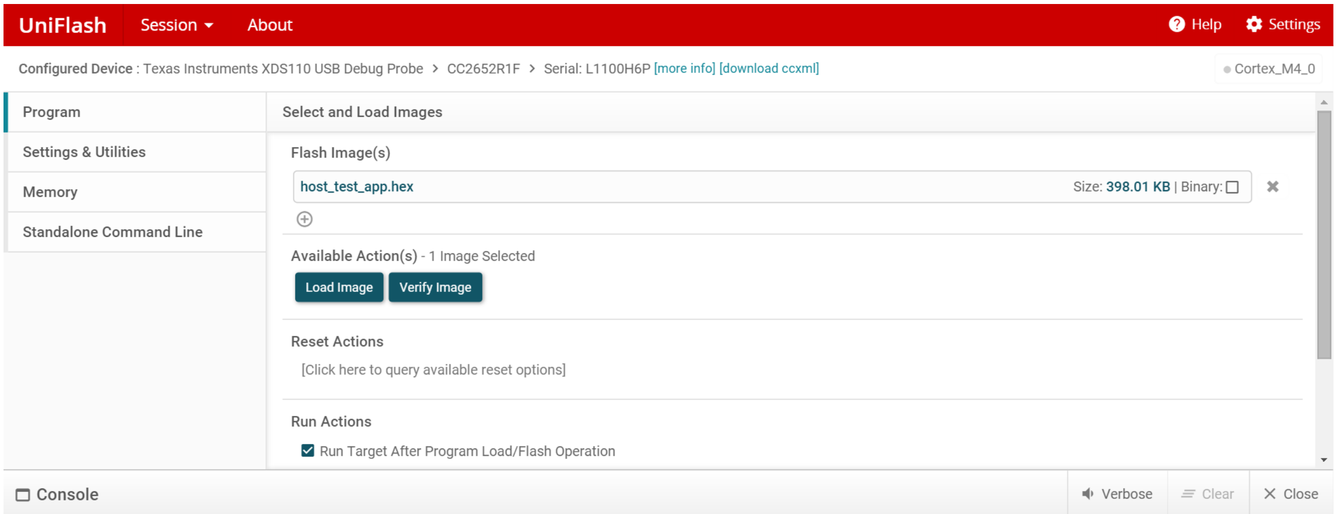

Figure 3-2. File loaded in Uniflash

7. Click on the **Load Image** button to connect and program the device. Several steps will be executed and it will end with the software flashed to the device.

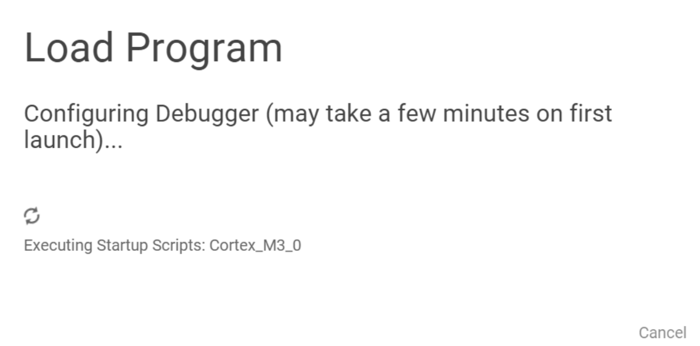

Figure 3-3. The program being flashed to the device

Note

Depending on the firmware loaded to the XDS110 programmer, the message below about the firmware update will be shown. This is normal. Simply click on **Update** to proceed.

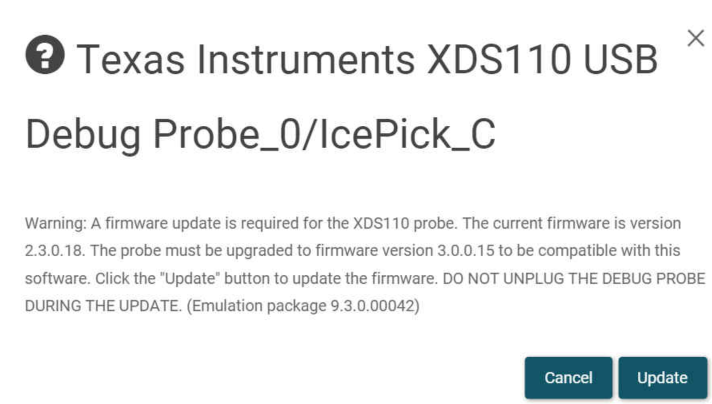

Figure 3-4. Firmware update message

8. Once the operation completes successfully, the device is programmed and Uniflash can be closed.

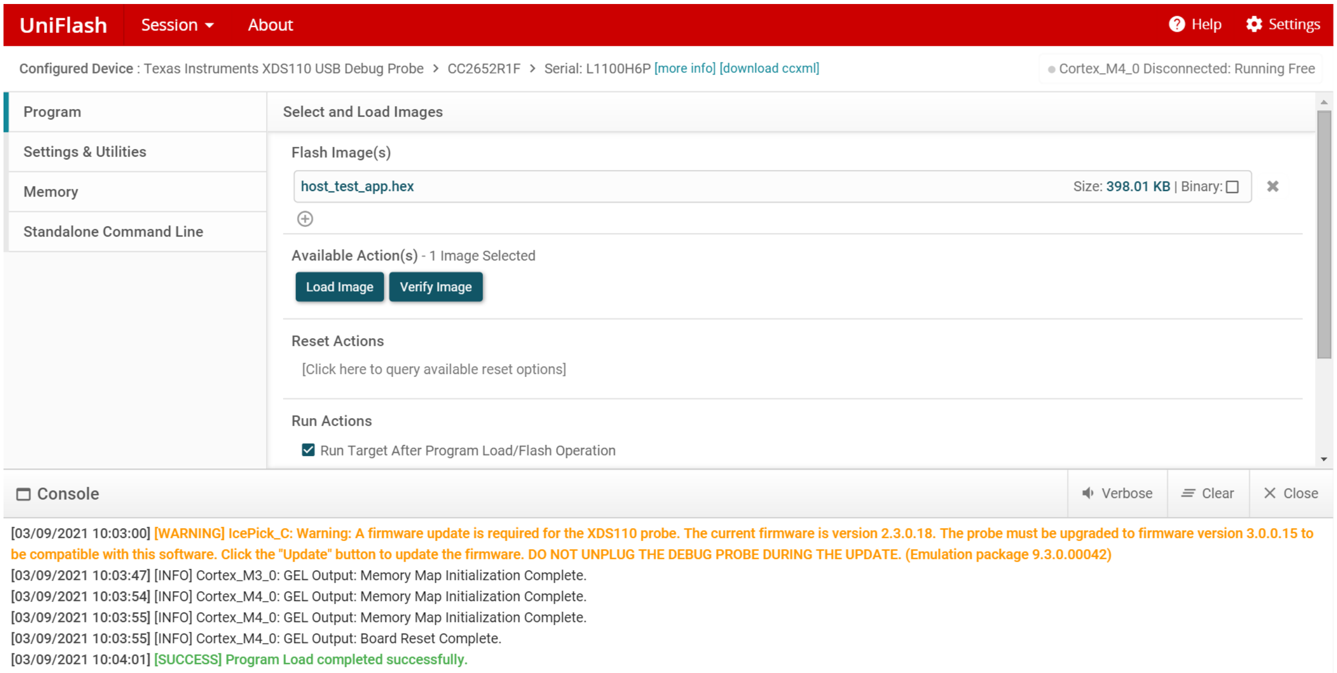

Figure 3-5. Operation completed successfully

4 Setting up the hardware

The overall setup to perform Bluetooth Low Energy using the CBT Bluetooth tester is shown in Figure 4-1

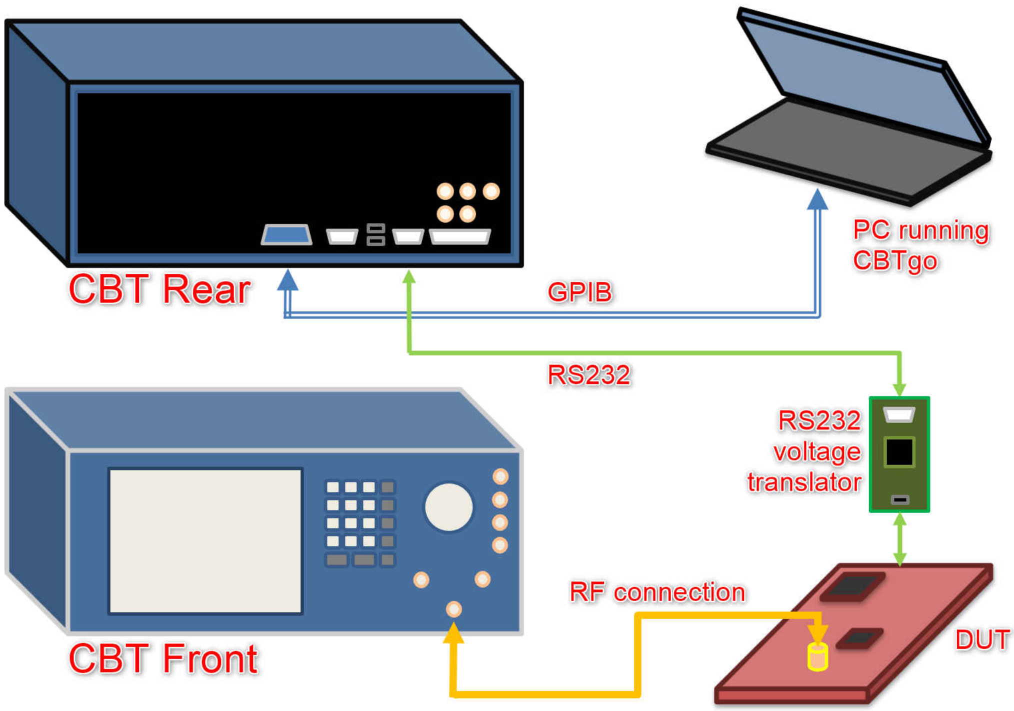

Figure 4-1. The test setup

1. First step is to install the CBTgo software in your host PC. Check the Requirements section for download locations.
    - The CBTgo Help (F1 key) is very helpful to understand the setup and connections required. Check the topics **Quick Start** → **Connecting the PD to the R&S CBT** and **Quick Start** → **Connecting Bluetooth Low Energy Device**
2. Connect the GPIB interface of the CBT unit to the GPIB interface of the host PC. This procedure will not get into the details about how to configure the GPIB interface in your host PC.
3. Connect the RS232 voltage translator to the port on the back of the CBT unit.
    - The CBT RS232 port pinout corresponds to a DTE (Data Terminal Equipment) - i.e., pin 2 is Rx, pin 3 is Tx and pin 5 is GND.
    - Most RS232 voltage translators expect to be connected to a DTE, so use a straight serial cable (not null modem) - check the documentation of your RS232 voltage translator unit.
4. Connect the output of the RS232 voltage translator to the DUT.
    - Be sure to connect the Tx output of the voltage translator to the Rx input of the DUT. Similarly, connect the Rx input of the voltage translator to the Tx output of the DUT.
    - Connect the GND pin of the voltage translator to the GND pin of the DUT.

> **CAUTION**
> Be extremely careful with ground voltage differences that can damage the tester, the host PC or the DUT (for additional details, check this video)

5. Perform the RF connection between the CBT and the DUT. On the Launchpad, a circuit modification is required to divert the RF path from the stripline antenna to the JSC connector mounted on the board.

The Launchpad design files (available for download as a .ZIP package on the product page at) has complete schematics and contains instructions to divert the RF path, as shown in Figure 4-2 for the LAUNCHXL-CC26X2R1:

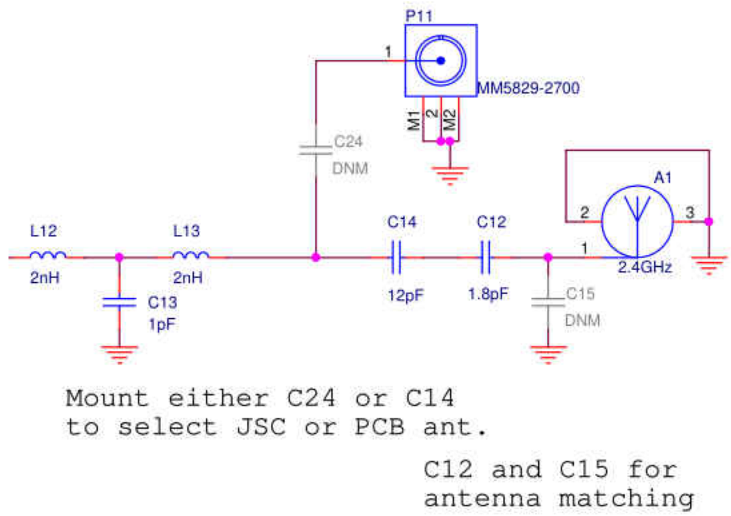

Figure 4-2. The schematic example

- Any RF connections must be thoroughly characterized using a VNA or a calibrated Spectrum Analyzer, as differences in attenuation across the spectrum range may cause tests to fail or show inaccurate results.
- An external attenuator will likely be needed.

6. Power on the system in this order: host PC, CBT, DUT and RS232 voltage translator.
   - It was observed that powering the RS232 voltage translator before the DUT can cause it to be in an unstable state.
7. The DUT must have a DTM software loaded and running on it, so it can properly receive the HCI commands from the CBT unit.
   - If the DUT maps the pins of the UART port the same way as our Launchpads, the host_test project from our SDKs can be used.
   - Attention must be taken also if there are no variations with regards to the crystal and other hardware aspects that influence the RF configuration.

5 Configuring the CBTGo tests

The setup of the CBTgo software is only necessary if the intention is to remotely control the tester. This is highly recommended to generate test reports.

A very comprehensive reference is the Help menu of the CBTgo software (F1 key). It contains very thorough explanations about the process and each menu option.

1. First step is to set up the GPIB connection on the menu *Configuration → Remote Port*. In this setup, the National Instruments Controller USB to GPIB adapter was used.
    - The Searching button is useful to find out the address of the CBT device. If there is a cable problem, this procedure might cause CBTgo to run for a very long time or lockup (useful troubleshooting).

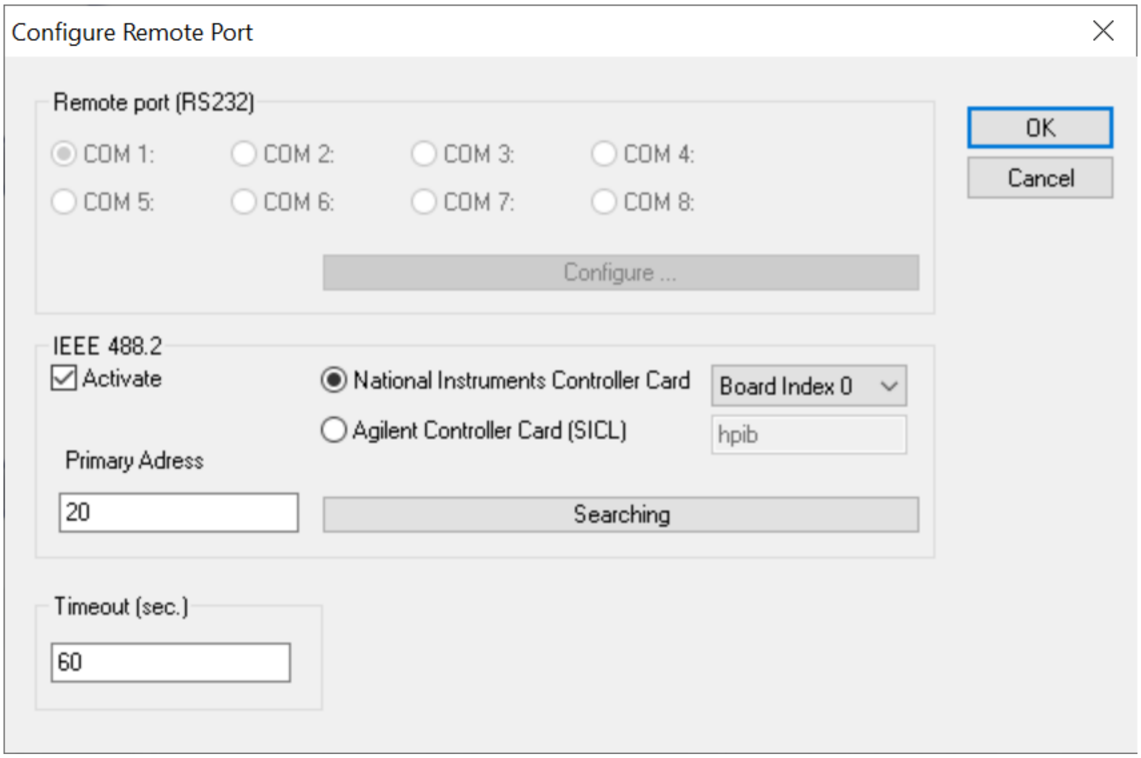

Figure 5-1. The remote GPIB port configuration

2. Go to menu *Configuration → BT Low Energy device*. This will setup the RS232 port to the DUT.
    - Select the CBT (COM1) and click on Configure to setup the UART settings (baud rate, flow control, start, stop and parity bits). The host_test uses 115200, 8N1 and no flow control.
    - Also, make sure the field EUT Protocol is set to HCI.

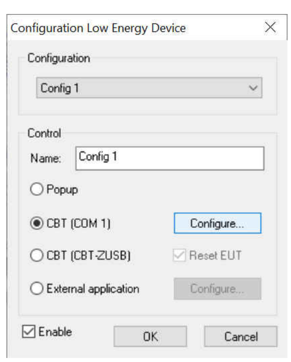

Figure 5-2. The remote RS232 port setup dialog box

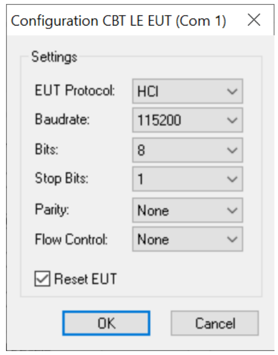

Figure 5-3. The control protocol setup dialog box

3. Go to menu *Configuration* → *Measurement Report*. This allows configuring the various formats to present the test results.
   - Several fields are self explainable (Operator, Comments, etc) and, in case of questions, the help reference (at **User Interface** → **Configuration menu** → **Measurement Report**) is very useful.
   - The Autosave Print Options controls the amount of information that will be present in the report. It is useful to select the option completely to get the full set of results. Also, if you have a printer driver that "Prints to PDF" (Adobe, Foxit, etc.) it is very useful to share a PDF file directly with customers.
   - The Autosave File Options controls the file type to save. The HTML format is the nicer one, although the Text or XML might be easier to feed into a script of parser to populate a spreadsheet.

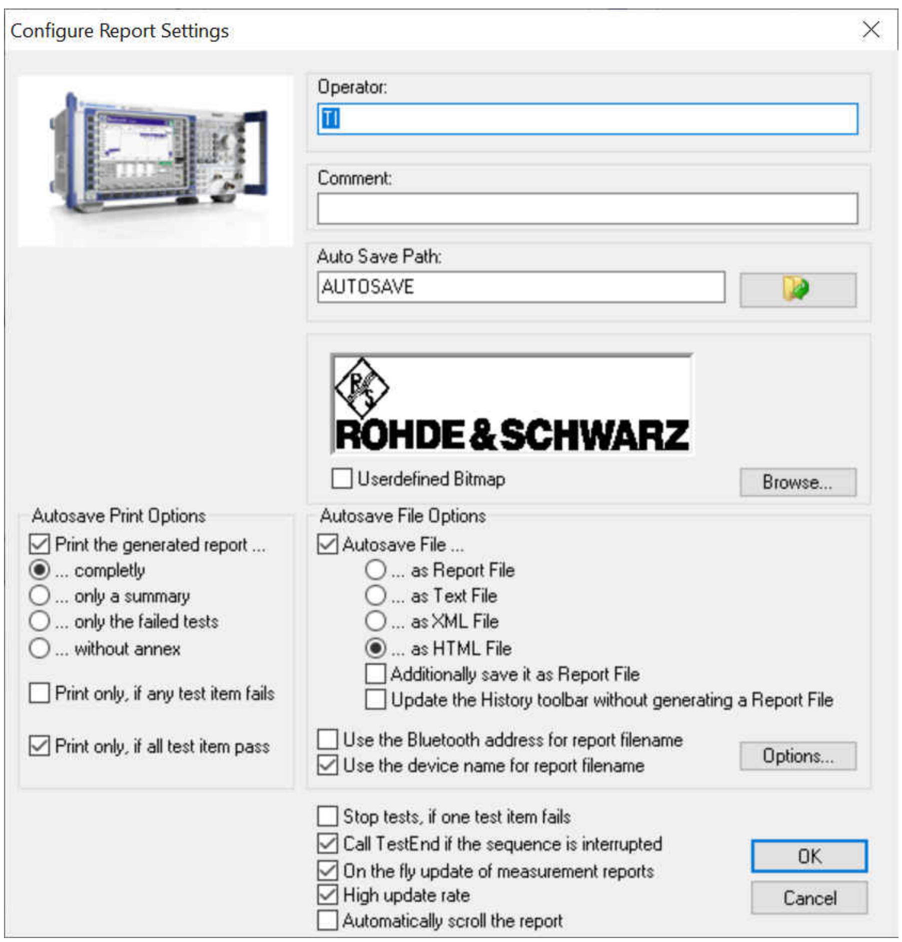

Figure 5-4. The measurement report setup screen

4. Go to menu *Configuration* → *Configure Tests*. That is where all the test steps will take place, including the initialization and termination of the sequence.

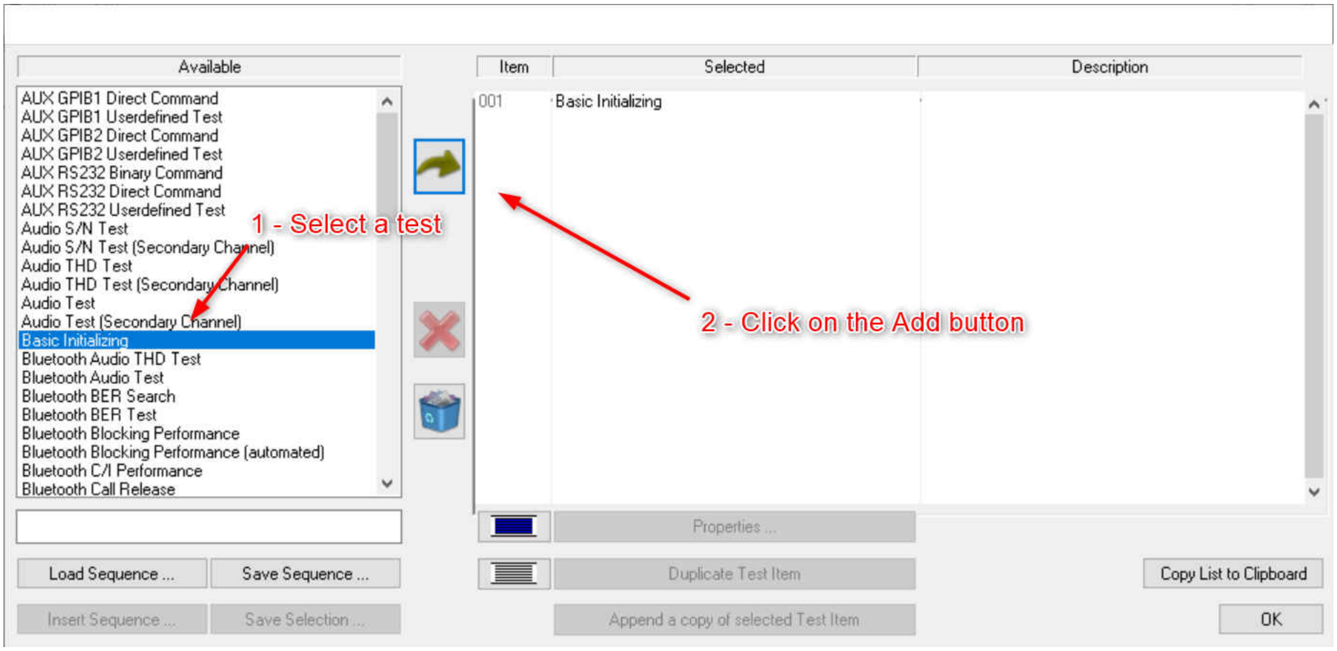

Figure 5-5. The Bluetooth test setup screen

- The test sequence always starts with the Basic Initializing (which sets up the function groups to be tested)
- For Bluetooth Low Energy, the second step is the Bluetooth Low Energy Connection Setup, which sets the RF connection parameters between the DUT and the CBT, including the external attenuator (mentioned in the prior section).

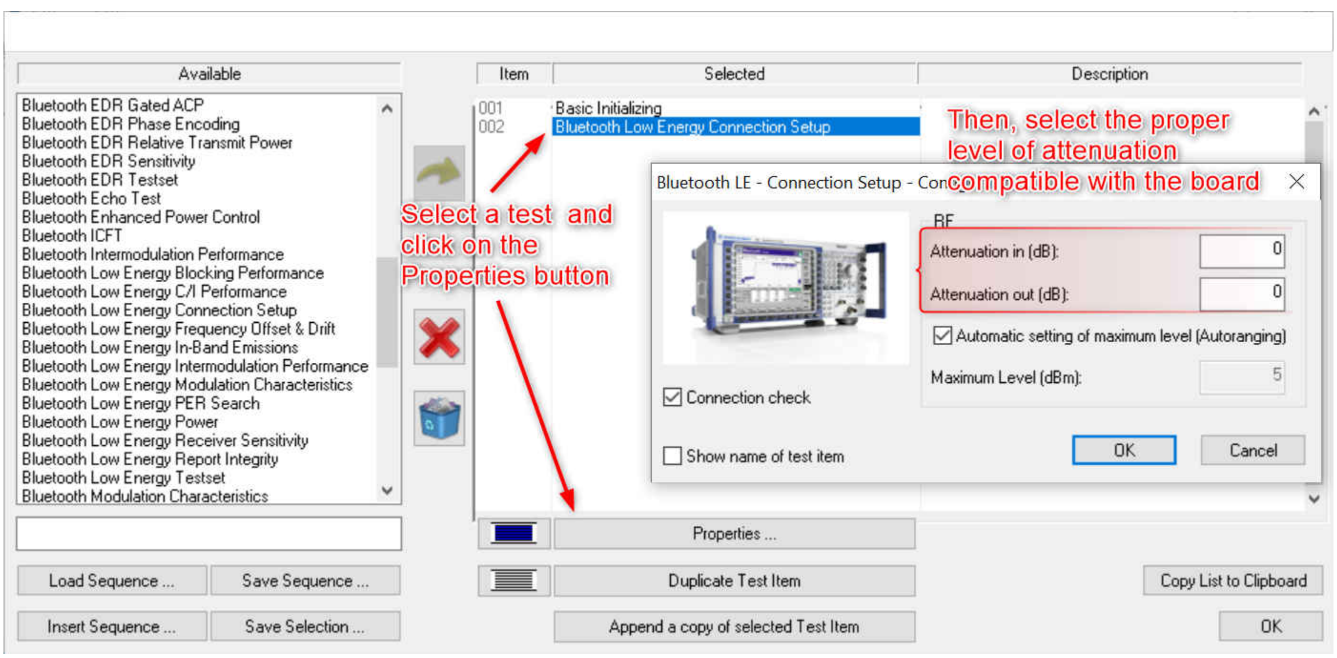

Figure 5-6. The Bluetooth test options dialog box

- Keep adding test steps to the sequence and configuring their properties. Comprehensive description of each test is shown in the help reference (at **Test Reference** → **Test Items**)

- Optionally, use one of the existing pre-defined Test Sequences by clicking on the button Load Sequence. It will contain a complete set of tests. Comprehensive description of each Test Sequence is shown in the help reference (at **Test Reference → Test Sequences**).

5. Once all is ready, simply click on the Play button at the top toolbar to initiate the tests.

Figure 5-7. Starting the Bluetooth test

6 The test sequence results

Once the tests finish running successfully, CBTgo will prompt to save the report or print it (if the option is chosen).

Output examples:

Measurement Report

Date & Time: Monday, June 7, 2021 14:11:03 PM
Operator: TI
CBTgo Version: 3.0.0
CBT Ident: Rohde&Schwarz,CBT-1153.9000.35,100788,CBT V6.01
Options: CBT-B41,CBT-B55,K52,K54,K55,K57,K53,FMR7,Intel Celeron M,480 MB,DIG FPGA
RF FPGA
Sequence: - - -

Test Name and Condition	Lower Limit	Upper Limit	Measured Value	Unit	P/F

Attenuation (In/Out): 0.0/0.0 dB, Max. Level: Auto

Connection to LE-Device: *duration of connection check: 375 ms*	---	---	---	---	Passed

TX Start Level: -70.0 dBm, Packets: 1000, Payload: PRBS 9, Length: 37 Bytes, Dirty Transmitter: off
Channelscan: from Ch. 00 to Ch. 39, with detailed values

RX Level @ *Ch: 00, PER: 29.80%, Count: 15*	---	---	-66.40	dBm	Passed
RX Level @ *Ch: 01, PER: 32.10%, Count: 11*	---	---	-66.60	dBm	Passed
RX Level @ *Ch: 02, PER: 32.20%, Count: 09*	---	---	-66.50	dBm	Passed
RX Level @ *Ch: 03, PER: 29.00%, Count: 10*	---	---	-65.80	dBm	Passed
RX Level @ *Ch: 04, PER: 32.50%, Count: 17*	---	---	-66.00	dBm	Passed
RX Level @ *Ch: 05, PER: 31.20%, Count: 18*	---	---	-65.90	dBm	Passed
RX Level @ *Ch: 06, PER: 29.80%, Count: 12*	---	---	-66.10	dBm	Passed
RX Level @ *Ch: 07, PER: 32.00%, Count: 12*	---	---	-66.30	dBm	Passed
RX Level @ *Ch: 08, PER: 30.80%, Count: 09*	---	---	-66.40	dBm	Passed
RX Level @ *Ch: 09, PER: 28.80%, Count: 12*	---	---	-66.40	dBm	Passed
RX Level @ *Ch: 10, PER: 30.20%, Count: 11*	---	---	-66.60	dBm	Passed
RX Level @ *Ch: 11, PER: 30.50%, Count: 09*	---	---	-66.50	dBm	Passed
RX Level @ *Ch: 12, PER: 32.60%, Count: 09*	---	---	-66.50	dBm	Passed
RX Level @ *Ch: 13, PER: 29.60%, Count: 09*	---	---	-66.40	dBm	Passed
RX Level @ *Ch: 14, PER: 30.00%, Count: 07*	---	---	-66.40	dBm	Passed
RX Level @ *Ch: 15, PER: 30.50%, Count: 09*	---	---	-66.50	dBm	Passed
RX Level @ *Ch: 16, PER: 31.40%, Count: 12*	---	---	-66.40	dBm	Passed

Figure 6-1. Example report in HTML format

Measurement Report

ROHDE&SCHWARZ

Operator:	TI	Monday, June 7, 2021 14:11:03 PM
CBT Ident:	Rohde&Schwarz,CBT-1153.9000.35,100788,CBT V6.01	CBTgo Version: 3.0.0
Options:	CBT-B41,CBT-B55,K52,K54,K55,K57,K53,FMR7,Intel Celeron M,480 MB,DIG FPGA RF FPGA	
Sequence:	- - -	

Test Name and Condition	Lower Limit	Upper Limit	Measured Value	P/F
Attenuation (In/Out): 0.0/0.0 dB, Max. Level: Auto				
Connection to LE-Device: duration of connection check: 375 ms			passed	

TX Start Level: -70.0 dBm, Packets: 1000, Payload: PRBS 9, Length: 37 Bytes, Dirty Transmitter: off

Channelscan: from Ch. 00 to Ch. 39, with detailed values

Measurement Report

ROHDE&SCHWARZ

Test Name and Condition	Lower Limit	Upper Limit	Measured Value	P/F
RX Level @ Ch: 00, PER: 29.80%, Count: 15			-66.40 dBm	
RX Level @ Ch: 01, PER: 32.10%, Count: 11			-66.60 dBm	
RX Level @ Ch: 02, PER: 32.20%, Count: 09			-66.50 dBm	
RX Level @ Ch: 03, PER: 29.00%, Count: 10			-65.80 dBm	
RX Level @ Ch: 04, PER: 32.50%, Count: 17			-66.00 dBm	
RX Level @ Ch: 05, PER: 31.20%, Count: 18			-65.90 dBm	
RX Level @ Ch: 06, PER: 29.80%, Count: 12			-66.10 dBm	
RX Level @ Ch: 07, PER: 32.00%, Count: 12			-66.30 dBm	
RX Level @ Ch: 08, PER: 30.80%, Count: 09			-66.40 dBm	
RX Level @ Ch: 09, PER: 28.80%, Count: 12			-66.40 dBm	
RX Level @ Ch: 10, PER: 30.20%, Count: 11			-66.60 dBm	
RX Level @ Ch: 11, PER: 30.50%, Count: 09			-66.50 dBm	
RX Level @ Ch: 12, PER: 32.60%, Count: 09			-66.50 dBm	
RX Level @ Ch: 13, PER: 29.60%, Count: 09			-66.40 dBm	
RX Level @ Ch: 14, PER: 30.00%, Count: 07			-66.40 dBm	
RX Level @ Ch: 15, PER: 30.50%, Count: 09			-66.50 dBm	
RX Level @ Ch: 16, PER: 31.40%, Count: 12			-66.40 dBm	
RX Level @ Ch: 17, PER: 30.40%, Count: 09			-66.50 dBm	
RX Level @ Ch: 18, PER: 31.30%, Count: 09			-66.40 dBm	
RX Level @ Ch: 19, PER: 32.00%, Count: 14			-66.30 dBm	
RX Level @ Ch: 20, PER: 30.00%, Count: 10			-66.50 dBm	
RX Level @ Ch: 21, PER: 30.50%, Count: 10			-66.50 dBm	
RX Level @ Ch: 22, PER: 31.40%, Count: 12			-66.50 dBm	
RX Level @ Ch: 23, PER: 30.00%, Count: 09			-66.30 dBm	
RX Level @ Ch: 24, PER: 32.00%, Count: 07			-66.40 dBm	
RX Level @ Ch: 25, PER: 30.00%, Count: 14			-66.50 dBm	
RX Level @ Ch: 26, PER: 28.80%, Count: 07			-66.40 dBm	
RX Level @ Ch: 27, PER: 30.60%, Count: 09			-66.50 dBm	
RX Level @ Ch: 28, PER: 29.30%, Count: 10			-66.40 dBm	
RX Level @ Ch: 29, PER: 29.20%, Count: 07			-66.40 dBm	
RX Level @ Ch: 30, PER: 30.90%, Count: 08			-66.60 dBm	
RX Level @ Ch: 31, PER: 32.50%, Count: 09			-66.50 dBm	
RX Level @ Ch: 32, PER: 29.90%, Count: 14			-66.50 dBm	
RX Level @ Ch: 33, PER: 31.00%, Count: 10			-66.40 dBm	
RX Level @ Ch: 34, PER: 29.80%, Count: 10			-66.40 dBm	
RX Level @ Ch: 35, PER: 31.30%, Count: 12			-66.20 dBm	
RX Level @ Ch: 36, PER: 31.10%, Count: 07			-66.40 dBm	
RX Level @ Ch: 37, PER: 29.00%, Count: 10			-66.40 dBm	
RX Level @ Ch: 38, PER: 29.40%, Count: 13			-66.50 dBm	
RX Level @ Ch: 39, PER: 31.20%, Count: 11			-66.40 dBm	
Avg. Step Count @ 40 tests with totally 422 steps			10.55	

Figure 6-2. Example report in PDF format

7 References

1. CBT/CBT32 page at Rhode & Schwarz website
2. Bluetooth Core Specification
3. App note about testing Bluetooth devices with CBTgo
4. Configuring the CC2640 for Bluetooth Direct Test Mode
5. BLE5 Stack User's Guide
6. SimpleLink Academy