Application Note

DA1453x Bluetooth® Direct Test Mode

AN-B-077

Abstract

This application note explains how to set up RF testing modes for DA14531 and DA14535 Bluetooth® LE SoC.

Contents

Figures

Tables

1 Terms and Definitions

LE	Low Energy
DTM	Direct Test Mode
DUT	Device Under Test, the Bluetooth® Low Energy application
EUT	Equipment Under Test
GPIB	General Purpose Interface Bus
GPIO	General Purpose Input Output
HCI	Host Controller Interface
OGF	Opcode Group Field
PC	Pesonal Computer
PLT	Production Line Testing
Pro-DK	Professional Development Kit
RF	Radio Frequency
SoC	System on Chip
SWD	Serial Wire Debug
UART	Universal Asynchronous Receiver Transmitter

2 References

[1] DA14531, Datasheet, Renesas Electronics.
[2] AN-B-043, DA1468x Bluetooth® Direct Test Mode, Application Note, Renesas Electronics.
[3] UM-B-117, DA14531 Getting Started Guide User Manual, Renesas Electronics.
[4] UM-B-165, DA14531 Getting Started Guide User Manual, Renesas Electronics.
[5] Bluetooth® Core specification v 5.1, Bluetooth® SIG.
[6] DA14535, Datasheet, Renesas Electronics.
[7] UM-B-083, SmartSnippets™ Toolbox, User Manual, Renesas Electronics.
[8] Configuration of the R&S CMW for Bluetooth Low Energy Direct Test Mode.
[9] USB RS232 Cable Series.
[10] Comm Tunnel.
[11] Bluetooth SIG Listings.

3 Introduction

The DA1453x ultra-low power SoC family features a 2.4 GHz transceiver and an Arm® Cortex®-M0+TM. In this family the DA14531 offers 48 kB RAM and 32 kB OTP memory, while the DA14535 provides 64 kB RAM and 12 kB OTP memory.

Both SoCs are versatile, serving as standalone application processors or data pumps in hosted systems. Achieving ultra-low power is facilitated by the integrated Low IQ Buck/Boost DCDC, operational during sleep in Buck mode. These SoCs are designed for efficiency, making them suitable for various applications demanding low-power consumption and reliable performance.

This document describes how to measure the RF performance of the DA1453x with a Bluetooth® tester like the Rohde & Schwarz (R&S) CBT, the R&S CMW270 and the Anritsu MT8852B using the Bluetooth® Low Energy Direct Test Mode (DTM).

Additionally, DTM can be used to set the Bluetooth LE device into different RX and TX modes. To provide easy access to the DTM commands Renesas provides RF Master, a tool that can be found in the Smart Snippets Toolbox.

The Direct Test Mode is described in the Bluetooth specification. The Bluetooth LE RF PHY test specification uses DTM for all TX and RX test cases. Frequency hopping and whitening are disabled.

DTM uses a direct communication channel between the Bluetooth LE DUT and the Bluetooth tester to control the DUT. The DA1453x SoC supports Direct Test Mode (DTM) for the RF PHY as specified by the Bluetooth SIG. The DUT, the DA1453x SoC, communicates with the Bluetooth tester over a 2-wire UART.

For the details on the software setup and the hardware setup, see Section 4.1 and Section 4.2.

Many items discussed in Ref. [2] (*DA1468x Bluetooth® Direct Test Mode*) are also applicable for the DA1453x, for example: alternative connection possibilities and a larger variety of Bluetooth testers, amongst others the LitePoint IQxel-M.

4 Set Up Direct Test Mode

4.1 Software setup

For standard Bluetooth LE DTM testing (Bluetooth LE core commands) it is advised to use the latest SDK `prod_test` project, which can be found in the following path:

```
\...\projects\target_apps\prod_test\
```

If you want to use pre-compiled binaries for the DTM you can find a few here:

DA14531 Target: `\..\binaries\da14531\prod_test`
DA14535 Target: `\...\binaries\da14535\prod_test`

For information on compilation and programming, see Ref. [3] or Ref [4]. Before compiling the software, `user_periph_setup.h` must be changed to assign the correct UART port.

Here is an example how to set the 1-wire UART mode on port P05:

```
#undef CONFIG_UART_GPIOS


/*************************************************************/
/* UART pin configuration                                    */
/* Supported Port/Pin Combinations:                          */
/* Tx: P00, Rx: P01                                          */
/* Tx: P02, Rx: P03                                          */
/* Tx/Rx: P03 (1-Wire UART)                                  */
/* Tx: P04, Rx: P05                                          */
/* Tx/Rx: P05 (1-Wire UART)                                  */
/* Tx: P06, Rx: P07                                          */
/*************************************************************/


#if defined(__DA14531__)
    #define UART1_TX_GPIO_PORT  GPIO_PORT_0
    #define UART1_TX_GPIO_PIN   GPIO_PIN_5      /*1-wire UART P05*/
    #define UART1_RX_GPIO_PORT  GPIO_PORT_0
    #define UART1_RX_GPIO_PIN   GPIO_PIN_5      /*1-wire UART P05*/
```

For 2-wire UART mode on P00 and P01, the file must be changed like this:

```
#undef CONFIG_UART_GPIOS


/*************************************************************/
/* UART pin configuration                                    */
/* Supported Port/Pin Combinations:                          */
/* Tx: P00, Rx: P01                                          */
/* Tx: P02, Rx: P03                                          */
/* Tx/Rx: P03 (1-Wire UART)                                  */
/* Tx: P04, Rx: P05                                          */
/* Tx/Rx: P05 (1-Wire UART)                                  */
/* Tx: P06, Rx: P07                                          */
/*************************************************************/


#if defined(__DA14531__)
    #define UART1_TX_GPIO_PORT  GPIO_PORT_0
    #define UART1_TX_GPIO_PIN   GPIO_PIN_0      /*2-wire UART P00*/
    #define UART1_RX_GPIO_PORT  GPIO_PORT_0
    #define UART1_RX_GPIO_PIN   GPIO_PIN_1      /*2-wire UART P01*/
```

To set up:

1. Compile the project.
2. Load the binary into RAM using the SmartSnippets™Toolbox Booter Ref. [7] or the Toolbox RF Master Firmware Download tool.

   The SmartSnippets™Toolbox RF Master tool is used as an example how to download the `prod_test_531.bin` or `prod_test_535.bin` firmware into RAM.
3. Connect the SmartSnippets™Toolbox through JTAG or COM port, choose RF Master, in the built binary, and click the **Download** button as in Figure 1.

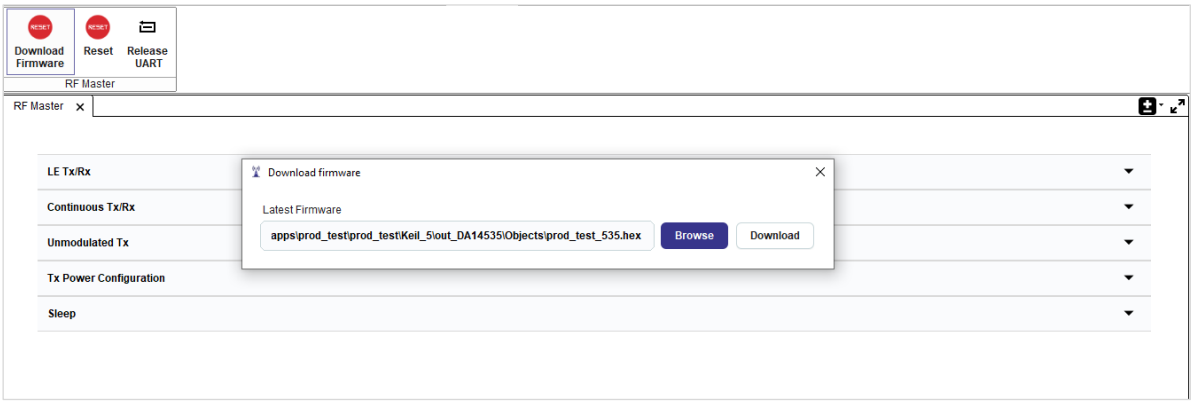

Figure 1. Firmware download in RF Master

After downloading the firmware, the RF Master tool can be used to set the DA1453x chip in different receive or transmit modes (for example, LE Transmitter Continuous Packet).

The UART COM port is selected by RF Master automatically or a pop-up box appears, asking for the right COM port.

By default, the UART baud rate is set to 115200 bit/sec and the UART GPIOs used for control and signaling between the Bluetooth tester and the DUT are set in SmartSnippets™'s Board Setup.

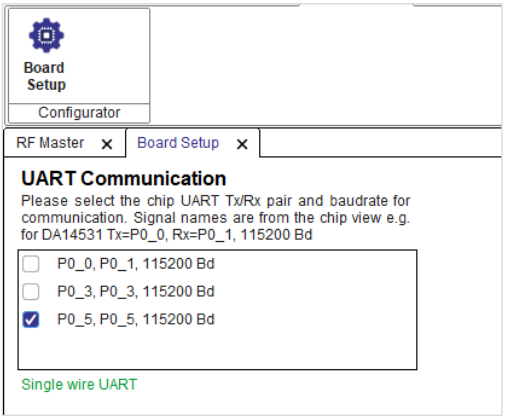

Figure 2. Board setup in SmartSnippets™Toolbox

Summarizing the UART configuration:

- UART Baud Rate: 115200 bit/sec
- Hardware Flow Control: None
- Byte Size: 8
- Stop Bits: 1
- Parity: None.

4.1.1 Set up RX/TX Test modes with RF Master

SmartSnippets™Toolbox's RF Master can be used to set up different RX and TX modes to check the performance of the DA1453x. See Figure 3.

1. In the Board Setup, select the correct UART configuration.
2. In the Smart Snippets menu, select RF Master, and then click **Download** to download the correct production firmware.
3. Select the desired RF mode, and then click **Start**.

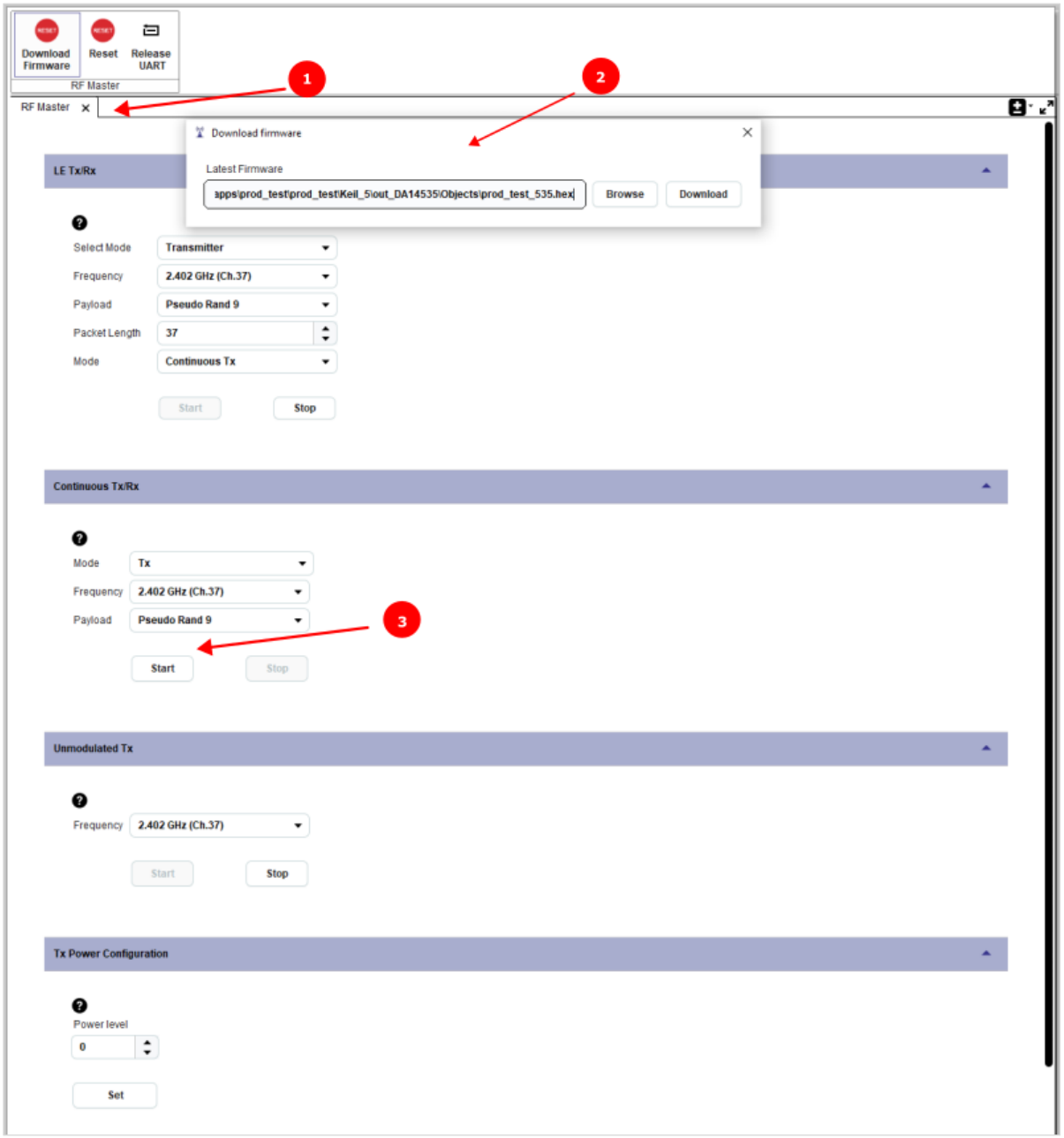

Figure 3. Setting up RF Master

4.1.2 Temperature-triggered RF recalibrations

Some notes about the temperature triggered RF recalibrations used in the SDK:

- In the SDK projects temperature triggered RF recalibrations are provided to make sure the radio is in optimal condition at any temperature. This is realized by shortly waking up the chip at regular intervals at which the ADC is measuring the chip's temperature.
- When the temperature decreased or increased 8 ºC or more, an RF recalibration is triggered and executed.
- Only in the DTM mode, these temperature triggered RF recalibrations are not active. This is intentionally, making sure the RF recalibration is not interfering with a running RF test, leading to a failing test.
- When RF testing at low and high temperatures is desired, issue a hardware-reset to the chip at which the chip reboots and executes a RF recalibration at the new temperature before the RF test starts. This makes sure the radio is in optimal condition.
- In this situation it is convenient to have the firmware programmed in the flash memory of the main board since it is reloaded from the flash automatically after a reset.
- Normally the RF recalibration would not be needed in the temperature range -20 °C to +80 °C, but it is advised to trigger a RF recalibration after a 20 °C temperature change.
- The RX sensitivity is affected first, degrading a bit at low and high temperatures. The TX performance is more robust and does not vary much over temperature.
- As mentioned, in Bluetooth LE mode – advertising or connected – the temperature triggered RF recalibrations are in place. The radio is in optimal condition at any temperature.

4.2 Hardware setup

4.2.1 Main board

The jumpers on the 376-18-B motherboard must be set as shown in Figure 4, Figure 5, or Figure 6.

Note the following:

- P20 on the main board is routed to P00 on the DA14531 daughter card.
- P21 on the main board is routed to P01 on the DA14531 daughter card.
- P23 on the main board is routed to P03 on the DA14531 daughter card.

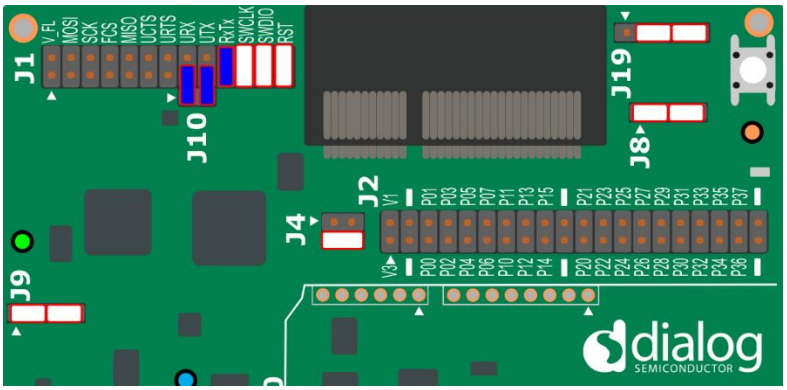

Figure 4. Jumper settings for 1-wire UART P05

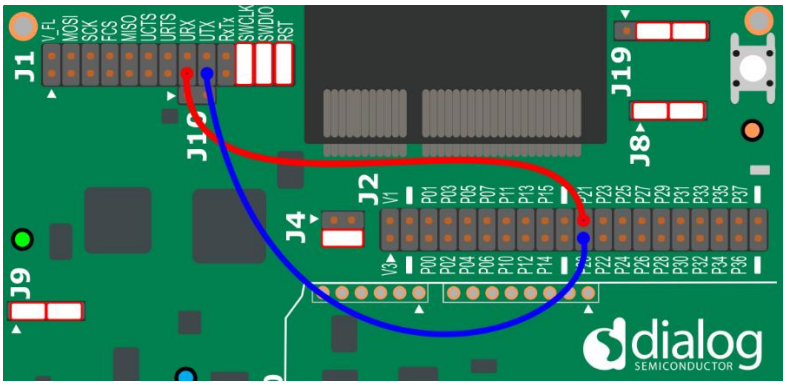

Figure 5. Jumper setting for 2-wire UART P00 P01

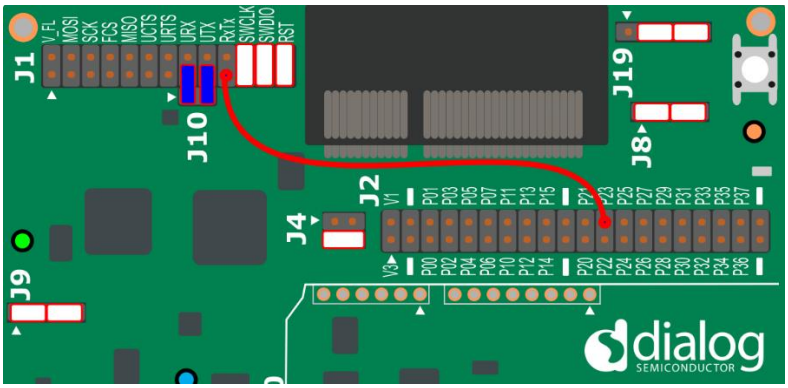

Figure 6. Jumper setting for 1-wire UART P03

The jumpers on the DA1453x 610-01-B motherboard must be set as shown in Figure 7Figure 4, Figure 8, or Figure 9.

Note the following:

- P0-0 on the main board is routed to P00 on the DA14535 daughter card.
- P0-1 on the main board is routed to P01 on the DA14535 daughter card.
- P0-3 on the main board is routed to P03 on the DA14535 daughter card.

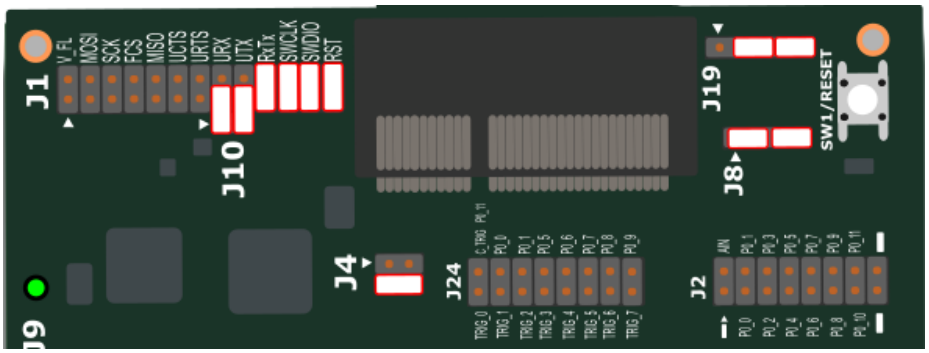

Figure 7. Jumper settings for 1-wire UART P05 DA1453x

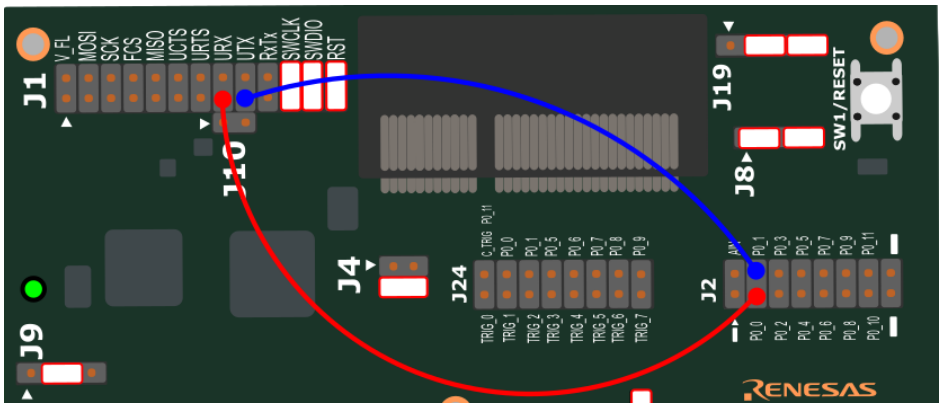

Figure 8. Jumper setting for 2-wire UART P00 P01 DA1453x

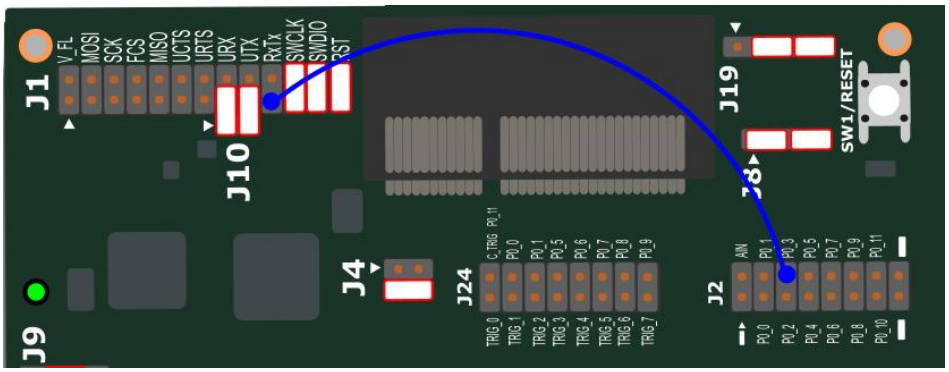

Figure 9. Jumper setting for 1-wire UART P03 DA1453x

Other relevant jumper settings, for example, the supply, are shown in Appendix A. Check whether the board used for DTM RF testing is configured as shown in Figure 20.

The USB1 connector on the DA14531 Pro-DK motherboard provides the supply and the serial communication to the DA14531 daughterboard.

4.2.2 Daughterboard

The RF connection between the DA1453x Daughterboard and the Bluetooth tester can be established using an SMA connector. The modifications of the board are shown in Figure 10. The

connection to the on-board antenna must be opened by removing Z9 and the connection to the SMA connector must be made by soldering a 10-pF capacitor on position Z7.

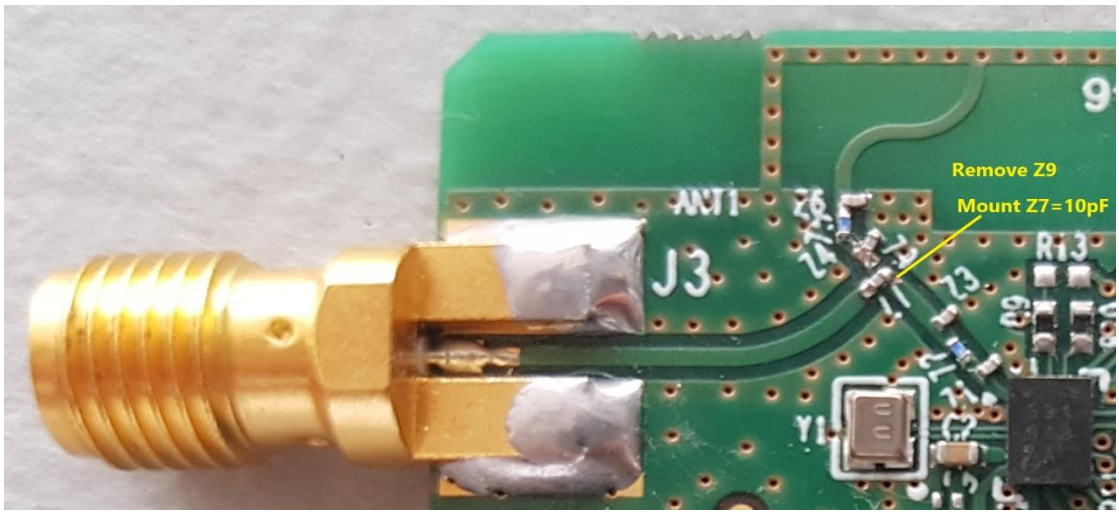

Figure 10. Modifications required for performing conducted measurements

4.2.3 Bluetooth LE tester

Four RF test setups are shown and discussed:

- First the R&S CMW270 Bluetooth 5 tester is discussed, where the DA14531 or DA1453x DEVKT-P is connected and supplied by a (front) USB port of the CM270. Bluetooth LE signaling is executed over the same USB port. Section 4.2.4.
- Secondly, the setup with the Anritsu MT8852B Bluetooth 5 tester is shown.
  Here a PC supplies the Pro-DK board and connects the Bluetooth tester and the DUT through a COMM Tunnel tool running on the PC. Section 4.2.5.
- Third, the R&S CBT setup and connections are shown. Using again the COMM Tunnel tool for convenience instead of an otherwise required level-shifter, see Ref. [2]. The PC additionally supplies the Pro-DK board through its USB connector. Section 4.2.6.
- Finally, the RTX2254 setup and connections are shown. The DA14531 or DA1453x DEVKT-P is connected and supplied by a (front) USB port of the RTX2254. Bluetooth LE signaling is executed over the same USB port. Section 4.2.7.

These examples are using a 2-wire UART connection between the DUT and the tester. Use `prod_test_531_2wire_P00` and `P01.bin` when doing these tests.

4.2.4 R&S CMW270 Bluetooth tester setup

For the discussed setup, the FTDI USB-to-Serial driver for the FTDI chip on the Pro-DK must be installed on the CMW270. When the Pro-DK board is connected, two virtual COM ports are created, for example, COM4 and COM5. The first port, COM4 in this example, provides the UART 2-wire connection and this one should be selected in the CMW270's Connection setup (Bluetooth Connection Setup for LE).

For information on how to do this, see Section 3.3 and Section 4.2 of Ref. [8].

Overview of the required CMW270 Connection Settings:

- USB to RS232 adapter as hardware Interface
- HCI in EUT Communication Protocol
- RS232 COM port: the virtual COM port, for example, COM4
- Baud Rate: 115200
- Flow Control Protocol: None
- Parity: None
- Stop Bits: 1.

The FTDI driver for the FT2232 FTDI chip used on the Pro-DK motherboard can be found at following download link: https://www.ftdichip.com/Drivers/D2XX.htm

When using front-panel operation, connecting the Pro-DK debug USB port to a front USB-port of the CMW270 and a RF cable from the CMW270 RF port (for example, RF1 COM) to the Pro-DK RF connector is all what is needed to run some basic Bluetooth LE TX and RX tests. As such, the GPIB connection is not needed.

For script testing using the R&S CMWRUN scripting tool, a GPIB connection between the PC and CMW270 must be established. See Figure 11.

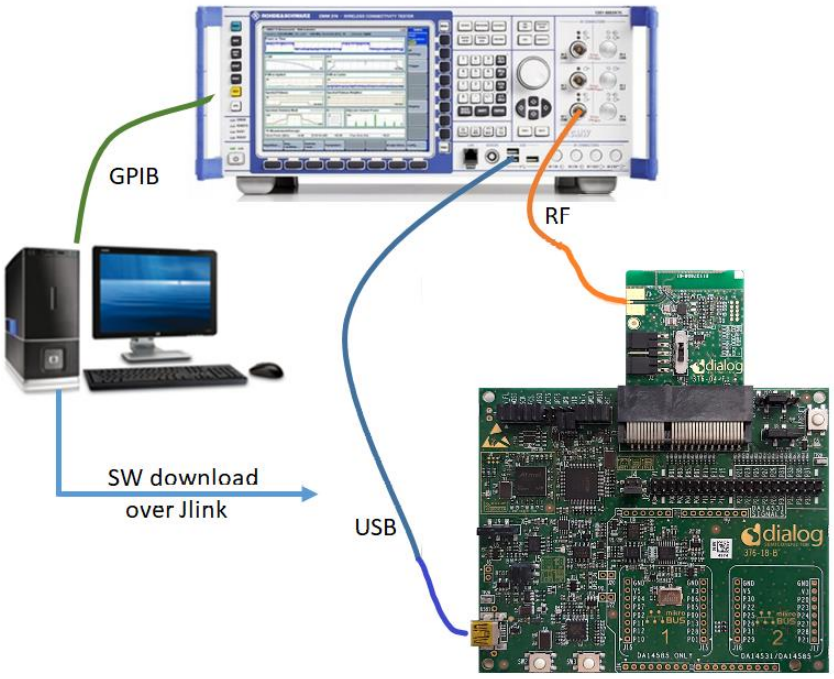

Figure 11. R&S CMW270 connections

4.2.5 Anritsu MT8852B Bluetooth tester setup

For this setup case shown in Figure 12, the MT8852B's EUT Control-port cable (supplied with the tester) is to be connected to a physical serial port of the PC, or to an USB port when using a Serial-to-USB converter, for example, UC232R-10 or Chipi-X10 (Ref. [9]).

The COMM Tunnel tool (Figure 15 and Figure 14) running on the PC connects the PC's serial port (for example, COM1) at which the MT8852B EUT port is connected to the Pro-DK's virtual COM port (for example, COM4). The DA14531 or DA1453x DEVKT-P creates two virtual COM ports on the PC: for example, COM4 and COM5.

The COM port having the lowest number (COM4 in this example) must be selected for UART. The second virtual COM port is the SPI channel, used for transmitting the PowerProfiler data from the motherboard to the SmartSnippets™ Power Profiler tool running on the PC.

For the version that was used for this document, see Ref. [10].

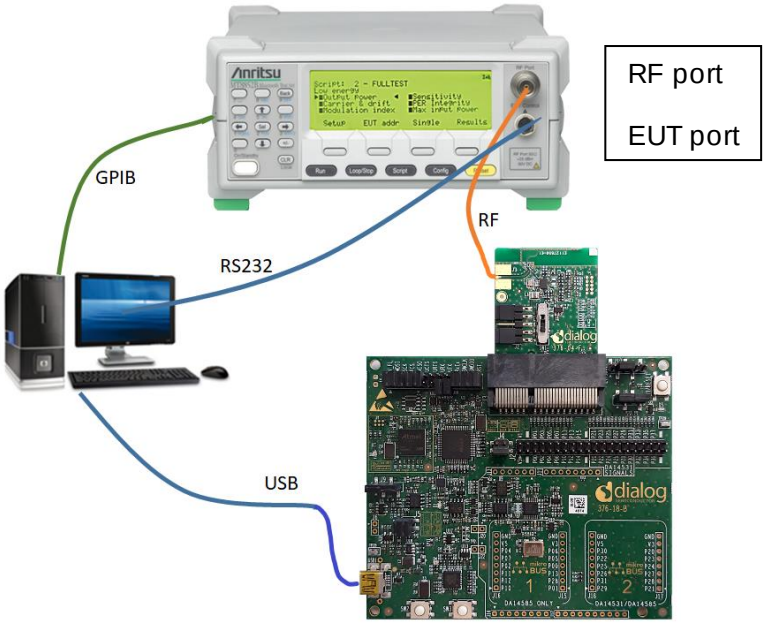

Figure 12. Anritsu MT8852B connections

Figure 12 shows the connections between the MT8852B tester, the DUT, and the PC. A COMM Tunnel tool as described before is running on the PC, connecting the MT8852B's EUT Control port to the virtual UART COM port of the Pro-DK board.

Before starting the Comm Tunnel program, the RF test firmware can be downloaded using the same PC USB port and the Pro-DK virtual COM port. See Section 4.1.

After the firmware download, the COMM Tunnel can be started, and RF testing can begin.

Front-panel operation is available for basic TX and RX tests. For this, the COMM Tunnel should be started, but the GPIB connection is not needed.

When, for example, running Anritsu's Bluetooth LE Measurement Software, script testing can be executed and a test-report could be created, see Ref. [2]. The GPIB connection between the tester and the PC is required for this test case.

Figure 13 shows the MT8852B Connection settings in the Anritsu Bluetooth LE Measurement Software.

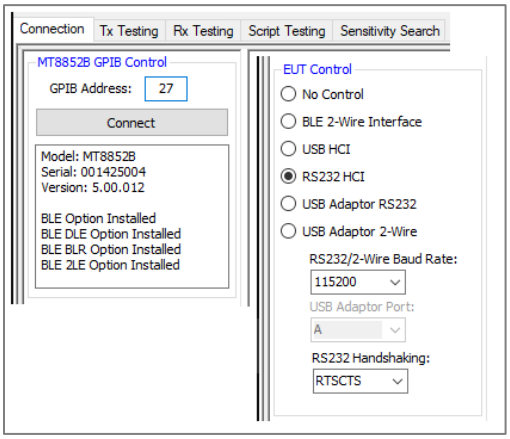

Figure 13. MT8852B Connection settings

Comm Tunnel settings in Figure 15 (Setting) appears when selecting **Setting** in ″Endpoint 1″ (tester) or ″Endpoint 2″ (DUT) in Figure 14. After entering the correct values, click the **Start** button.

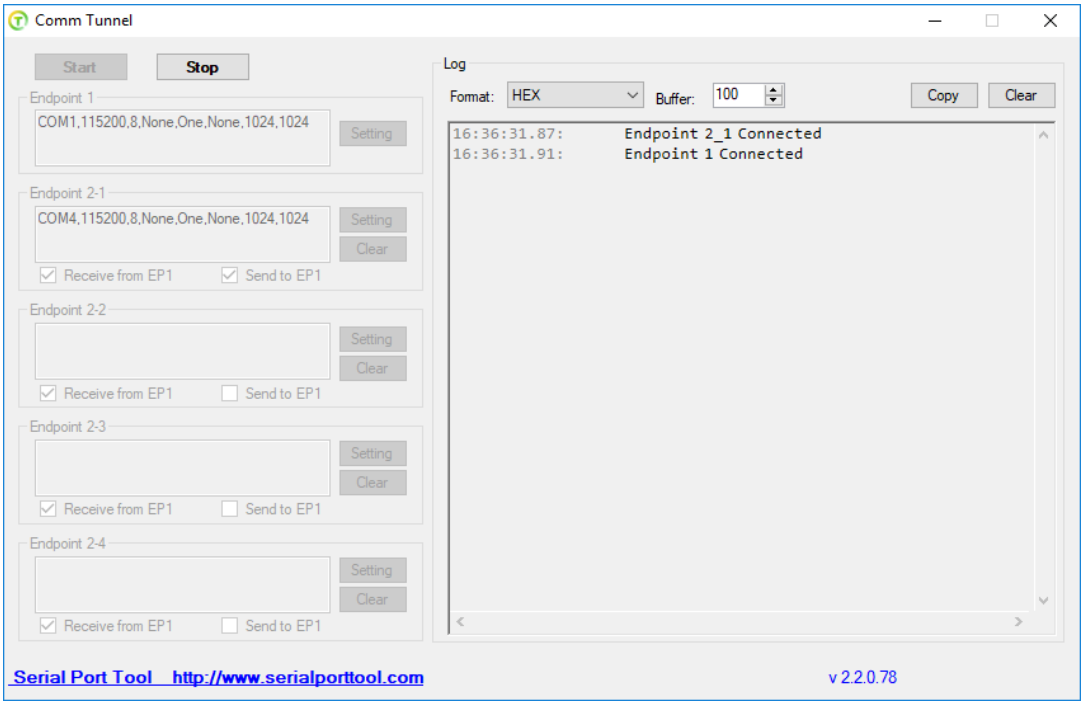

Figure 14. COMM Tunnel tool

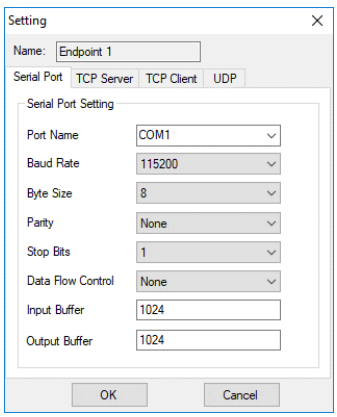

Figure 15. COMM Tunnel setup

4.2.6 R&S CBT Bluetooth tester setup

The R&S CBT setup is like the MT8852B setup in Section 4.2.5. The CBT's COM port at the back is connected to a serial port on the PC, and the Comm Tunnel program connects the CBT COM port to the UART/HCI port of the DA14531 DUT by means of the virtual COM port created by the DA14531 Pro-DK board. For the connections, see Figure 16.

In case the PC does not have a physical serial port, a Serial-to-USB converter can be applied. For details on this and the Comm Tunnel usage, see Section 4.2.5.

The PC can be used to download the RF test firmware to the DA14531 chip. After starting the Comm Tunnel tool, the same USB port is used for Bluetooth signaling.

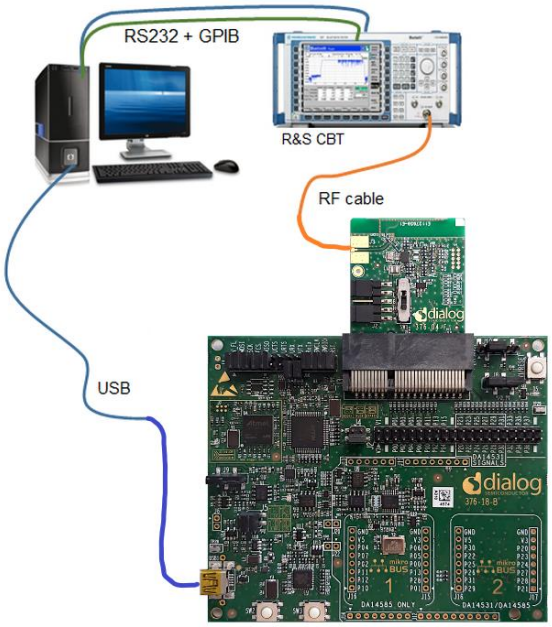

Figure 16. R&S CBT connections

Basic tests like LE TX modulation performance can be executed from the front panel and viewed in the CBT's display. GPIB interfaces and a GPIB cable are not needed. Extended script testing can be done using the R&S CBT-Go tool, which runs on the PC.

The CBT-Go tool can also generate an extensive test report. A GPIB cable must be connected between the PC and the CBT for using CBT-Go.

The CBT communication settings, to be set in the CBT or in the CBT-Go control program.

- EUT Protocol: HCI
- Baud Rate: 115200
- Bits: 8
- Stop bits: 1
- Parity: None
- Flow Control: None.

4.2.7 RTX2254 Bluetooth tester setup

For this setup case shown in Figure 19, the USB connector on the DA14531 or DA1453x DEVKT-P must just be connected to the USB connector (DUT 0 or 1) on the RTX2254 front panel and the RF connector to the RF connector (DUT 0 or 1) on the front panel.

The FTDI USB-to-Serial driver for the FTDI chip on the Pro-DK must be installed on the applied PC (Ref. [9]).

When the Pro-DK board is connected, two virtual COM ports are created, for example, COM35 and COM36. In this example, the first port COM35 provides the UART 2-wire connection, and this one should be selected in the RTX2254 Settings pane.

Overview of the required connection settings:

- HCI in EUT Communication Protocol (Figure 17).
- RS232 COM port: the virtual COM port, for example, COM35 (Figure 18).
- Baud Rate: 115200 (Figure 18).
- HW Flow Control: None (Figure 18).
- Parity: None.
- Stop Bits: 1.

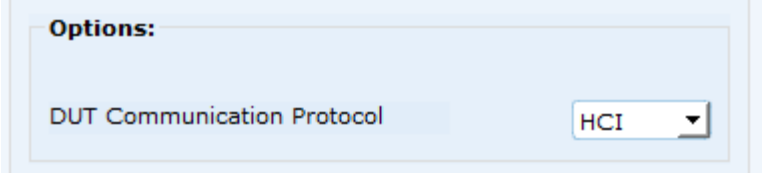

Figure 17. DUT Communication Protocol setting in RTX2254 GUI

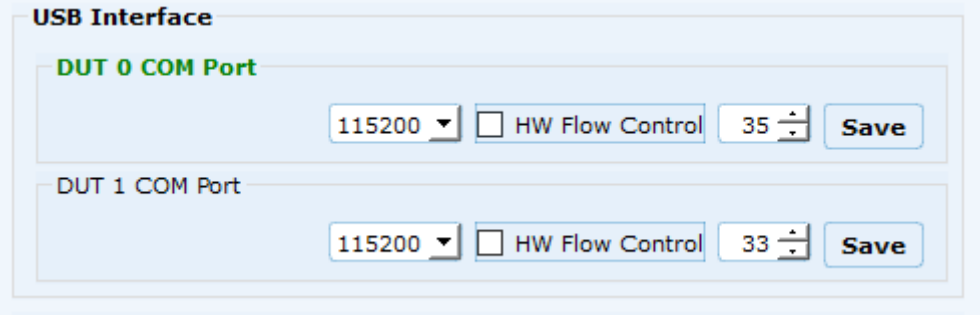

Figure 18. Virtual comport setting in RTX2254 GUI (Pro-DK connected to DUT0)

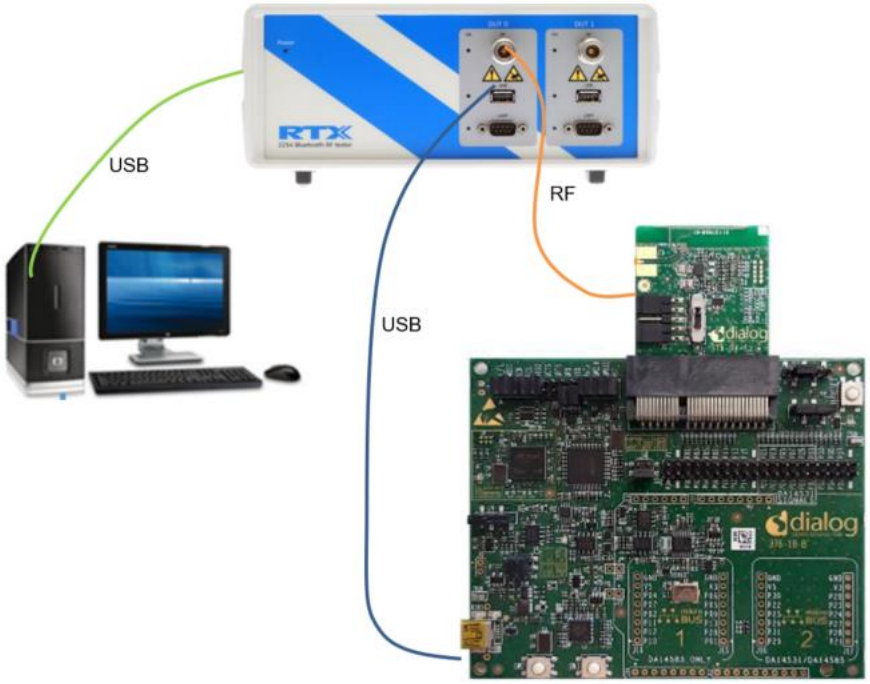

Figure 19. RTX2254 connections

Figure 19 shows the connections between the RTX2254 tester, the DA14531 or DA1453x DEVKT-P and the PC. The communication to the Pro-DK and RF tests are all handled by the RTX2254 while the PC is executing the RTX2254 GUI and logging of RF measurements.

5 Bluetooth PHY Qualification

To release a Bluetooth application to the market, the application needs to be Qualified. The Renesas Bluetooth Low Energy SoCs have Qualified Design Listings (Ref. [11]) with corresponding Qualified Design Identification (QDID) for all Host Subsystems and Controller Subsystems. Enter "Renesas Electronics" in the search field to find all Renesas listings. By referring to the Renesas QDIDs, the amount of testing required to list a Bluetooth Low Energy application is greatly reduced.

Typically, Bluetooth PHY testing must be done for new hardware, meaning that Bluetooth PHY testing done by Renesas Electronics on the evaluation kits cannot be re-used. This PHY testing must be done by an authorized test house.

Table 1 displays the Protocol Implementation Extra Information for Test (PIXIT) entries, that the test house needs for PHY qualification.

Table 1. PIXIT entries for Bluetooth Low Energy 1 Mbps

PIXIT reference	Identifier	Subidentifier (optional)	Value	Units
RF-PHY:P1:1	Inband Image frequency	Low frequency	2	MHz
RF-PHY:P1:2		Middle frequency	2	MHz
RF-PHY:P1:3		High frequency	2	MHz
RF-PHY:P2:1	Value n for Intermodulation test	Low frequency	3	Integer
RF-PHY:P2:2		Middle frequency	3	Integer
RF-PHY:P2:3		High frequency	3	Integer
RF-PHY:P3	Type of power source			
RF-PHY:P4:1	Power source voltage	Nominal (NOC)	End product spec	V
RF-PHY:P4:2		Maximum (EOC)	End product spec	V
RF-PHY:P4:3		Minimum (EOC)	End product spec	V
RF-PHY:P5:1	Operating temperature	Nominal (NOC)	End product spec	°C
RF-PHY:P5:2		Maximum (EOC)	End product spec	°C
RF-PHY:P5:3		Minimum (EOC)	End product spec	°C
RF-PHY:P6:1	Air humidity range (relative)	Maximum (EOC)	End product spec	%
RF-PHY:P6:2		Minimum (EOC)	End product spec	%
RF-PHY:P6:3		Air humidity level for NOC/EOC tests	End product spec	%
RF-PHY:P7:1	Test interface implementation	HCI or 2-wire UART	HCI	
RF-PHY:P7:2		Datarate	115000	bps
RF-PHY:P8	Antenna gain	Low	End product spec	dBi
		Middle	End product spec	dBi

PIXIT reference	Identifier	Subidentifier (optional)	Value	Units
		High	End product spec	dBi
RF-PHY:P9:1	Maximum TX packet length		251	Byte
RF-PHY:P9:2	Maximum RX packet length		251	Byte

Appendix A Motherboard

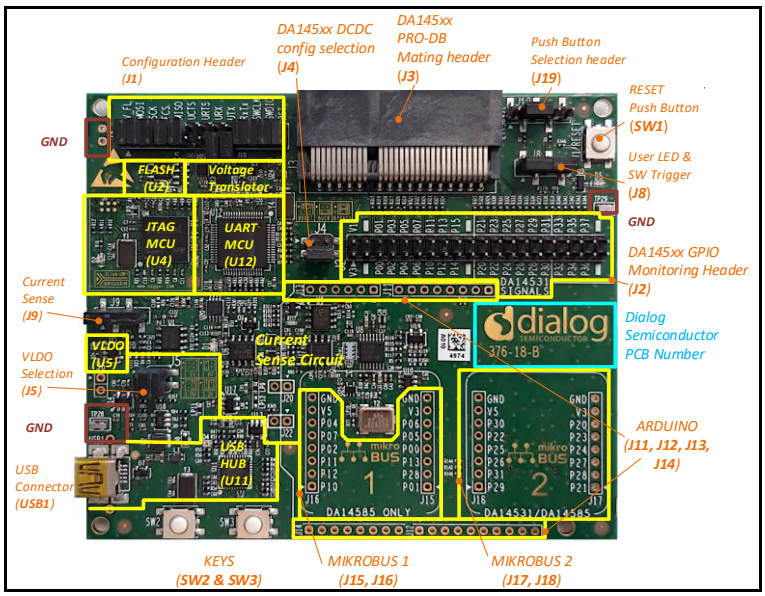

Figure 20. DA14531 DEVKT-P Motherboard

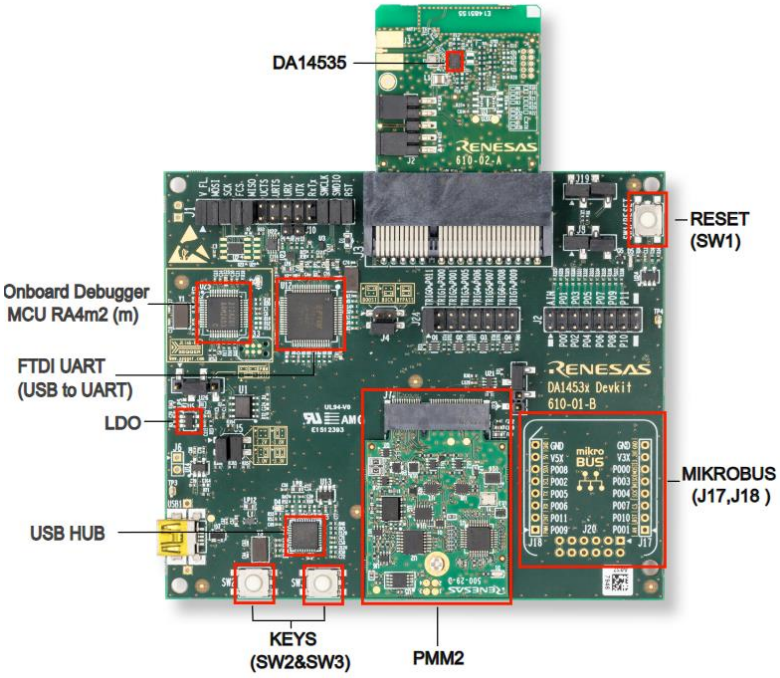

Figure 21. DA1453x DEVKT-P Motherboard

Appendix B Daughterboard

Figure 22. DA14531 QFN24 Daughterboard

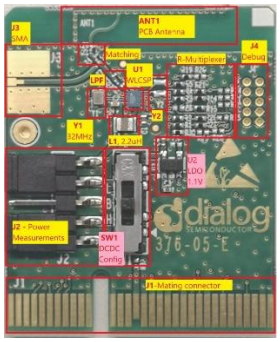

Figure 23. DA14531 WLCSP Daughterboard

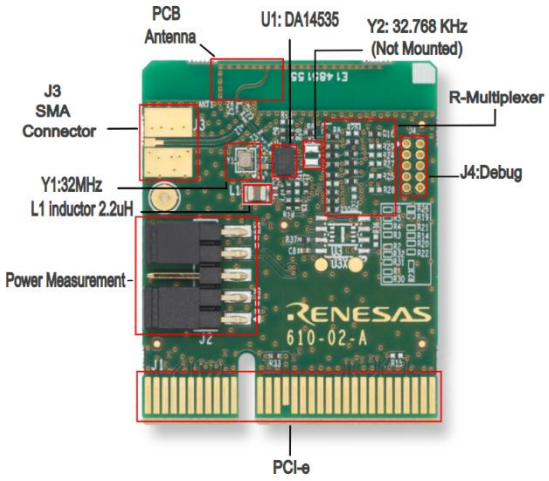

Figure 24. DA14535 QFN24 Daughterboard

Appendix C COMM Tunnel and 1-wire UART

COMM Tunnel causes an issue, when used in 1-wire UART mode. The reason is the connection of the RX and TX line on the motherboard. Every command transmitted from COMM Tunnel to the motherboard is directly received in the RX buffer. When the motherboard sends the reply, it is added to the wrongly received data (see Figure 25).

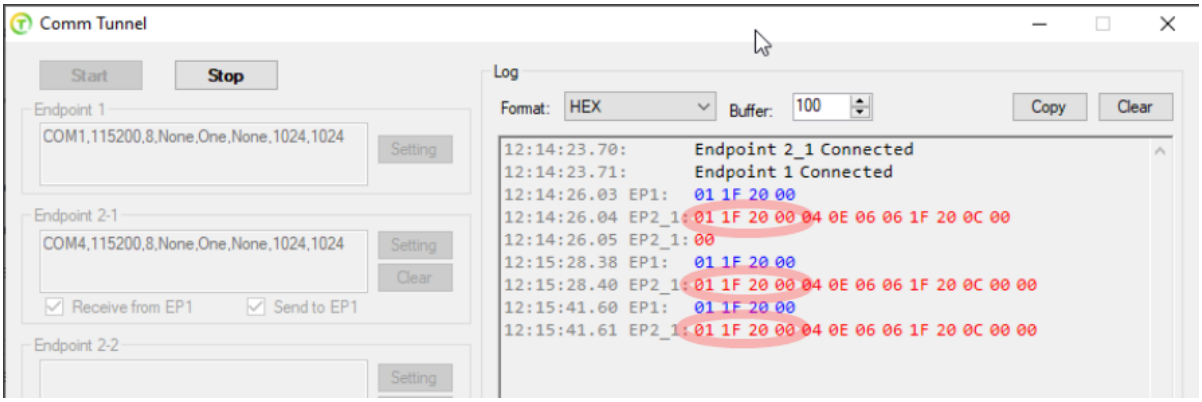

Figure 25. COMM Tunnel 1-wire UART issue

To avoid this problem, the RX buffer must be deleted after transmitting data to the motherboard. Currently COMM Tunnel is not able to do this. Renesas is working on additional tooling to support 1-wire UART in combination with Bluetooth testers.

Revision History

Revision	Date	Description
1.5	Apr 15, 2024	Added the support for DA14535.
1.4	Feb 14, 2023	Updated PIXIT.
1.3	Jan 21, 2022	Updated logo, disclaimer, copyright.
1.2	Feb 26, 2020	RTX tester added.
1.1	Nov 5, 2019	Link updated.
1.0	Nov 1, 2019	Initial version.

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.

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD-PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers who are designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only to develop an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third-party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising from your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Disclaimer Rev.1.01 Jan 2024)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit www.renesas.com/contact-us/.

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.