AN13639

Calibration Structure for RW61x

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Document information

Information	Content
Keywords	Wi-Fi sub-bands, crystal frequency, Wi-Fi transmit power, Wi-Fi front-end, Wi-Fi thermal compensation, Wi-Fi thermal crystal frequency compensation, Bluetooth transmit power, BD address, Bluetooth front-end loss, one-time programmable (OTP)
Abstract	Describes the RF calibration parameters and data structure used to store the calibration and configuration data for RW61x. The document also details the steps to generate and update the calibration data.

1 Introduction

This document describes the RF calibration parameters and data structure used to store calibration/ configuration data for RW61x. The document explains how to adjust the RF calibration parameters to attain tighter tolerances. The document also details the procedure to generate and update the calibration data.

Note: *References to IEEE 802.15.4 features apply to RW612 device.*

The calibration data can be stored in the on-chip OTP memory or in an external configuration file.

2 Calibration data

Calibration data includes Wi-Fi, Bluetooth, and IEEE 802.15.4 (RW612 only) configuration and calibration parameters.

Calibration data is design specific and includes the following:

- Frequency calibration
- Wi-Fi RSSI calibration
- Wi-Fi transmit power calibration
- Thermal compensation for Wi-Fi transmit power
- Thermal compensation for crystal frequency
- Wi-Fi MAC address
- RF front-end control configuration
- Wi-Fi system configuration
- Bluetooth/Bluetooth Low Energy (LE) configuration
  - Initial Bluetooth transmit power
  - Bluetooth TX Power Class Setting
  - Bluetooth device (BD) address
  - Bluetooth RF front end (FE) Loss
  - Bluetooth frequency calibration
  - Bluetooth UART baud rate
- 802.15.4 configuration (RW612 only)
  - 802.15.4 maximum power limit
  - 802.15.4 MAC address
  - SPI clock frequency
  - 802.15.4 FE loss

3 Getting calibration files

The calibration data can be stored in one of the following locations:

- Configuration file
- On-chip OTP memory

Examples of configuration files for RW61x NXP evaluation kits (EVK) are included in the manufacturing software release package. The configuration files are detailed in Table 1.

Table 1. Calibration files

File	Description
WlanCalData_ext.conf	Configuration file containing Wi-Fi, Bluetooth LE, and 802.15.4 calibration data. This file is used to create calibration data text files for Wi-Fi, Bluetooth LE, and 802.15.4.
BtCalData_ext.conf	Configuration file containing Bluetooth LE calibration data.
15p4CalData_ext.conf[1]	Configuration file containing 802.15.4 calibration data. ***Note:*** *This file is reserved for future use and is not be used to load 802.15.4 calibration data.*

[1] (RW612 only)

It is recommended to use NXP EVK example configuration files as a starting point to optimize the calibration data for your end-product design.

3.1 Procedure to get editable text files

To edit the calibration data, first convert the *.conf* files to *.txt* format (recommended).

Step 1 - Place the *WlanCalData_ext.conf* file in the Labtool executable directory.

Step 2 - Open the *SetUp.ini* file located in Labtool executable directory. Check for `NO_EEPROM` parameter value in *SetUp.ini* file.

`NO_EEPROM` parameter is used to select the location where the calibration data is stored. It has the following values:

- 1 = Config file (NO_EEPROM) support
- 2 = OTP memory support

Step 3 - Launch Labtool.

Step 4 - Enter the Labtool command `88` to read back the firmware version.

- Verify that the firmware version matches the software release being used.

Step 5 - Enter Labtool command `54` to get the calibration data from the storage location.

Command `54` converts the calibration data from hexadecimal into text format and stores the data in the following text files. The text files are created in the Labtool executable directory.

- *CalWlanDataFile_Upload.txt*
- *PwrTable_Otp_Path0_Upload.txt*
- *CalBtDataFile_Upload.txt*
- *Cal15_4DataFile_Upload.txt*(RW612 only)

Step 6 - Rename the text files as follows:

- *CalWlanDataFile.txt*
- *PwrTable_Path0.txt*
- *CalBtDataFile.txt*
- *Cal15_4DataFile.txt*(RW612 only)

4 Updating the calibration data

This section details how to update the calibration data for specific designs.

Table 2 lists the calibration data available for RW610 and RW612 devices.

Table 2. Calibration data for RW610 and RW612 devices

Calibration item	RW610	RW612
Frequency calibration	☑	☑
RF front-end control configuration	☑	☑
Wi-Fi RSSI calibration	☑	☑
Wi-Fi transmit power calibration	☑	☑
Wi-Fi thermal TX power compensation	☑	☑
Wi-Fi thermal crystal frequency compensation	☑	☑
Wi-Fi MAC address	☑	☑
Bluetooth Low Energy (LE) configuration	☑	☑
802.15.4 configuration	☐	☑

4.1 Frequency calibration

The frequency calibration is used to calibrate the frequency accuracy when an external crystal is used as reference clock source.

The frequency calibration process involves tuning the load capacitance value integrated in the wireless SoC using the crystal compensation parameter *RFXTAL*.

The procedure to obtain the *RFXTAL* value using Labtool is detailed below.

Frequency calibration procedure

- Bring up Labtool
- Enter into Wi-Fi menu and enable Wi-Fi transmit using Labtool command `35`

5 GHz example:

```
22     // Load the calibration data file with thermal compensation parameters removed
6 3  // Set the band to 5GHz
112 0 0  // Set the bandwidth to 20MHz
12 0 36  // Set the channel to 36
35 0 1 22 10  // Start TX at target power set to 10dBm, MCS7 rate
< Measure the Frequency Error using a VSA>
35 0 0  // Stop TX
```

- Use Labtool command `95` to read the current *RFXTAL* value.
- Adjust the *RFXTAL* value using Labtool command `96` to fine-tune the frequency error

Example:

```
95  // Return value in hex
96 6D  // Set the value in hexadecimal format; it is a 8-bit signed number
```

- Record the final optimized value for *RFXTAL*.

Note: *RFXTAL value is common for all integrated radios of the device since there is only one external reference clock source.*

Figure 1 shows an example of the `Main_Table` section with `RFXTAL` parameter value set to 0x6D.

```
[StructureInfo]
STRUCTURE_REV=0x0F
[Main_Table]
Ref_Design_Type=0x00
Device_ID=0x00
SPI_Size=0x40
Ant_TX=0xFF
Ant_RX=0xFF
Soc_OR_Rev=0x12
TMP_At_Cal=0x0025
RFXTAL=0x6D
Region_Code=0x10
MISC_Flag=0x00
TEST_VERSION=0x43FCB
MFG_VERSION=0x200003F
DLL_VERSION=0x100000C
```

Figure 1. `Main_Table` section in *CalWlanDataFile.txt* file

4.2 Wi-Fi RSSI calibration

The Wi-Fi RSSI calibration is used to tune the reported signal strength referenced at the antenna connector. The process is as follows:

- The DUT receives a specific signal level from the tester.
- The DUT stores the RSSI offset value.

The offset value is the difference between the tester signal level and the DUT read-back value.

RSSI calibration is run with internal LNA turned on (high gain) and with internal LNA turned off (low gain). If using an external LNA, run RSSI calibration with the combination of four LNA high/low gains per sub-band. A maximum of four LNA high/low gains per sub-band is allowed.

Table 3. Recommended RSSI calibration channels

Band	Sub-band	RSSI calibration channel
2.4 GHz	0	2437 MHz
5 GHz	1	5180 MHz
	2	5600 MHz
	3	5825 MHz

Figure 2 shows the RSSI offset entries under the *[RSSI_CALEX]* section in *CalWlanDataFile.txt* file.

Each sub-band has four RSSI offset entries for each LNA gain state as highlighted in Figure 2. Note that RSSI is calibrated on one channel per sub-band.

- ***RSSI_CAL_5G_SUBBAND1_ELNA_LO_ILNA_HI_Path0_ENTRIES1*** is for 5 GHz sub-band 1 external-low and internal-high LNA gain state.
- ***RSSI_CAL_5G_SUBBAND1_ELNA_HI_ILNA_HI_Path0_ENTRIES1*** is for 5 GHz sub-band 1 external-high and internal-high LNA gain state.
- ***RSSI_CAL_5G_SUBBAND1_ELNA_LO_ILNA_LO_Path0_ENTRIES1*** is for 5 GHz sub-band 1 external-low and internal-low LNA gain state.
- ***RSSI_CAL_5G_SUBBAND1_ELNA_HI_ILNA_LO_Path0_ENTRIES1*** is for 5 GHz sub-band 1 external-high and internal-low LNA gain state.

RW61x reference design does not use an external LNA. The internal LNA high and low gain states are linear. As a result, one value is used for every gain state. See Figure 2.

```
[RSSI_CALEX]
RSSI_CAL_Path0_Entries=5
RSSI_CAL_Path0_OFFSET_ENTRIES0=0x3F
RSSI_CAL_2G_ELNA_LO_ILNA_HI_Path0_ENTRIES0=0x00
RSSI_CAL_2G_ELNA_HI_ILNA_HI_Path0_ENTRIES0=0x00
RSSI_CAL_2G_ELNA_LO_ILNA_LO_Path0_ENTRIES0=0x00
RSSI_CAL_2G_ELNA_HI_ILNA_LO_Path0_ENTRIES0=0x00
RSSI_CAL_Path0_OFFSET_ENTRIES1=0x3F
RSSI_CAL_5G_SUBBAND0_ELNA_LO_ILNA_HI_Path0_ENTRIES1=0x00
RSSI_CAL_5G_SUBBAND0_ELNA_HI_ILNA_HI_Path0_ENTRIES1=0x00
RSSI_CAL_5G_SUBBAND0_ELNA_LO_ILNA_LO_Path0_ENTRIES1=0x00
RSSI_CAL_5G_SUBBAND0_ELNA_HI_ILNA_LO_Path0_ENTRIES1=0x00
RSSI_CAL_Path0_OFFSET_ENTRIES2=0x3F
RSSI_CAL_5G_SUBBAND1_ELNA_LO_ILNA_HI_Path0_ENTRIES2=0x00
RSSI_CAL_5G_SUBBAND1_ELNA_HI_ILNA_HI_Path0_ENTRIES2=0x00
RSSI_CAL_5G_SUBBAND1_ELNA_LO_ILNA_LO_Path0_ENTRIES2=0x00
RSSI_CAL_5G_SUBBAND1_ELNA_HI_ILNA_LO_Path0_ENTRIES2=0x00
RSSI_CAL_Path0_OFFSET_ENTRIES3=0x3F
RSSI_CAL_5G_SUBBAND2_ELNA_LO_ILNA_HI_Path0_ENTRIES3=0x00
RSSI_CAL_5G_SUBBAND2_ELNA_HI_ILNA_HI_Path0_ENTRIES3=0x00
RSSI_CAL_5G_SUBBAND2_ELNA_LO_ILNA_LO_Path0_ENTRIES3=0x00
RSSI_CAL_5G_SUBBAND2_ELNA_HI_ILNA_LO_Path0_ENTRIES3=0x00
RSSI_CAL_Path0_OFFSET_ENTRIES4=0x3F
RSSI_CAL_5G_SUBBAND3_ELNA_LO_ILNA_HI_Path0_ENTRIES4=0x00
RSSI_CAL_5G_SUBBAND3_ELNA_HI_ILNA_HI_Path0_ENTRIES4=0x00
RSSI_CAL_5G_SUBBAND3_ELNA_LO_ILNA_LO_Path0_ENTRIES4=0x00
RSSI_CAL_5G_SUBBAND3_ELNA_HI_ILNA_LO_Path0_ENTRIES4=0x00
```

Figure 2. RSSI offset entries in the calibration file

The procedure to obtain the Wi-Fi RSSI offset value using Labtool is as follows.

Wi-Fi RSSI calibration procedure

- Bring up Labtool.
- Enter Wi-Fi menu, start RSSI data collection, and report the results.

5 GHz example:

```
22 // Load the calibration data file with thermal compensation parameters removed
6 3   // Set the band to 5GHz
112 0 0   // Set the bandwidth to 20MHz
12 0 36   // Set the channel to 36
198 0   // Start RSSI data collection
< Transmit Wi-Fi packets from tester with -50dBm power level OFDM-6 signal>
199 0   // Stop RSSI data collection and report the result including the packet count
 received, RSSI, and noise floor
```

- Record the RSSI offset using the formula below:
  RSSI_offset = 2(CalPwrLev – Path_0_RSSI_Val)*
  Where:
  CalPwrLev is the RF tester signal level.
  Path_0_RSSI_Val is the RSSI readback value of the DUT using Labtool command `199`.
- Update the *CalWlanDataFile.txt* file with the calculated RSSI_offset value for each required entry under the *[RSSI_CALEX]* section.

Note: *Convert RSSI offset decimal values to hexadecimal values prior to updating CalWlanDataFile.txt file.*

4.3 Wi-Fi transmit power calibration

The Wi-Fi transmit power calibration is used to tune the Wi-Fi transmit power for accurate output power at the antenna connector.

The transmit power calibration process involves measuring the output power at the antenna connector for eight power indexes. Each power index corresponds to a specific output power.

The measured output power (in dBm) for all the eight power indexes are recorded in the configuration file called *PwrTble_Otp_Path0.txt* along with the temperature sensor reading and power detector offset value.

The transmit power is measured for each sub-band. A maximum of two 20 MHz channels per sub-band are allowed.

The *PwrTble_Otp_Path0.txt* file has multiple entries to set the band, sub-band, channel, temperature sensor reading, measured power levels at given power indexes, and the power detector offset value.

Figure 3 shows an example of *PwrTble_Otp_Path0.txt*. Table 4 describes the *Power table* file parameters.

PwrTble_Otp_Path0_Upload.txt

; BAND	SubBand	Channel	BM_INDEX	Temperature	PWRLevelBMRF0	PWRLevelBMRF1	PWRLevelBMRF2
0	0	5	1	29	-15.250	-9.500	-3.375
0	0	11	1	30	-14.750	-8.875	-2.875
1	1	40	1	31	-16.375	-11.375	-5.250
1	1	56	1	33	-14.750	-9.875	-3.750
1	2	108	1	33	-16.125	-11.125	-5.125
1	2	132	1	33	-13.500	-8.625	-2.500
1	3	153	1	34	-12.000	-7.125	-1.000
1	3	165	1	35	-11.625	-6.625	-0.625

PWRLevelBMRF3	PWRLevelBMRF4	PWRLevelBMRF5	PWRLevelBMRF6	PWRLevelBMRF7	PwrDetOffset
2.500	8.250	13.875	19.750	23.875	243
3.000	8.875	14.500	20.375	24.000	243
0.500	6.250	11.375	16.250	20.875	245
2.000	7.375	12.250	17.000	21.250	0
0.625	6.250	11.500	16.375	20.750	31
3.375	8.875	13.875	18.750	22.125	14
4.875	10.250	15.000	19.750	21.500	22
5.000	10.250	14.375	19.125	21.375	27

Figure 3. Power table file *PwrTble_Path0.txt*

Table 4. Power table file parameters

Parameter	Description
Band	Band of operation. 0 = 2.4 GHz band 1 = 5 GHz band
Sub-band	2.4 GHz and 5 GHz sub-bands. See Table 5.
Channel	20 MHz channel for which the power calibration is done
BM_INDEX	Reserved parameter. Set to 1
Temperature	Represents the on-chip temperature sensor reading (in degree Celsius, decimal) measured during calibration.
PWRLevelBMRF0 through PWRLevelBMRF7	Represents the power level measured at the antenna connector (in dBm) at a given power index. Eight power indexes are supported (0 to 7). The power resolution is 0.125 dB.
PwrDetOffset	Represents the measured power detector value at power index 5 during calibration. The range is 0 to 255. This parameter is a 7-bit signed number converted in decimal.

Table 5 shows the sub-band information.

Table 5. Sub-band information

Band	Sub-band	Channel range
2.4 GHz	0	1 to 13 (2412 to 2472 MHz)
5 GHz	1	36 to 64 (5180 to 5320 MHz)
	2	100 to 144 (5500 to 5720 MHz)
	3	149 to 177 (5745 to 5885 MHz)

The Wi-Fi transmit power calibration procedure using Labtool is as follows:

- Bring up Labtool.
- Go to the Wi-Fi menu and set the band, bandwidth and desired channel for calibration
- Set the radio in transmit power calibration mode using Labtool command `102 10`
- Enable transmit and set the power index using command `35`

Table 6 shows how to set the power index using command `35`

Table 6. Setting the power index with Labtool command `35`

Labtool command	Command output
`35 0 1 22 <Index>`	Sets Power <Index> value and transmits at MCS7 rate

- Measure and record the output power (in dBm) at the antenna connector for all the eight power indexes
- Record the temperature sensor reading only for power index 0 using Labtool command `120`
- Record power detector offset value only for power index 5 using Labtool command `121`

Table 7 shows how to read the temperature sensor value using command `120` and the power detector offset value using command `121`.

Table 7. Temperature sensor and power detector offset reading using commands `120` and `121`

Labtool command	Command output
`120 1`	Reads the temperature sensor value
`121 0 0`	Reads the power detector offset value

Example of transmit power calibration for 2.4 GHz band and channel 6:

```
22 // Load the calibration data file with thermal compensation parameters removed
6 11           // Set the band to 2.4GHz
112 0 0        // Set the bandwidth to 20MHz
12 0 6         //    Set the channel to 6
102 10         // Set the device into power calibration mode
35 0 1 22 0    // Start Tx at MCS7 rate using power index 0
120 1          // Read the temperature sensor value
<Measure the output power & temperature sensor reading. Note the values>
35 0 0         // Stop Tx
35 0 1 22 1    // Start Tx at MCS7 rate using power index 1
<Measure the output power. Note the value>
35 0 0         //  Stop Tx
35 0 1 22 2    // Start Tx at MCS7 rate using power index 2
<Measure the output power. Note the value>
35 0 0         //  Stop Tx
35 0 1 22 3    // Start Tx at MCS7 rate using power index 3
<Measure the output power. Note the value>
35 0 0         //  Stop Tx
35 0 1 22 4    // Start Tx at MCS7 rate using power index 4
<Measure the output power. Note the value>
35 0 0         //  Stop Tx
35 0 1 22 5    // Start Tx at MCS7 rate using power index 5
121 0 0 <measured power value>      // Read the power detector offset value
<Measure the output power and power detector offset reading. Note the values.>
35 0 0         //  Stop Tx
35 0 1 22 6    // Start Tx at MCS7 rate using power index 6
<Measure the output power. Note the value>
35 0 0         //  Stop Tx
35 0 1 22 7    // Start Tx at MCS7 rate using power index 7
<Measure the output power. Note the value>
35 0 0         //  Stop Tx
102 0          //  Set the device to normal operation mode
```

- Repeat the above steps for the other channels
- Record the measured power values, the temperature sensor values, and power detector offset values in the power table file as shown in Figure 3:
  - Capture the power values in dBm
  - Convert the temperature sensor and power detector offset readback values from hexadecimal to decimal
  - Capture the temperature sensor and power detector offset readback values in decimal format

4.4 Wi-Fi thermal TX power compensation

The Wi-Fi thermal power compensation parameter is used to maintain the transmit power accuracy across the operating temperature range.

The power compensation parameter is expressed as a slope of a linear equation for power correction. As the temperature changes, the slope compensation will be applied to maintain the transmit power accuracy.

The thermal power compensation uses two slope parameters for each sub-band and antenna path:

- Low power slope parameter (*CCK_SLOPE_XXX*) for output power ≤ 12 dBm
- High power slope parameter (*OFDM_SLOPE_XXX*) for output power >12 dBm

Table 8 shows the thermal power compensation parameters.

Table 8. Thermal power compensation parameters

Thermal power compensation	Power region	Band	Sub-band
CCK_SLOPE_2G_Path0	Low power	2.4 GHz	0
OFDM_SLOPE_2G_Path0	High power	2.4 GHz	0
CCK_SLOPE_5G_SUBBAND1_Path0	Low power	5 GHz	1
OFDM_SLOPE_5G_SUBBAND1_Path0	High power	5 GHz	1
CCK_SLOPE_5G_SUBBAND2_Path0	Low power	5 GHz	2
OFDM_SLOPE_5G_SUBBAND2_Path0	High power	5 GHz	2
CCK_SLOPE_5G_SUBBAND3_Path0	Low power	5 GHz	3
OFDM_SLOPE_5G_SUBBAND3_Path0	High power	5 GHz	3

These parameters may be further fine-tuned for various system designs to optimize the transmit power accuracy.

This section details how to characterize the thermal TX power for the device. The measured power versus temperature sensor reading slope across multiple temperatures is recorded for the thermal power calibration offset.

4.4.1 Hardware test setup

To calculate TX thermal slope, set up the equipment as shown in Figure 4.

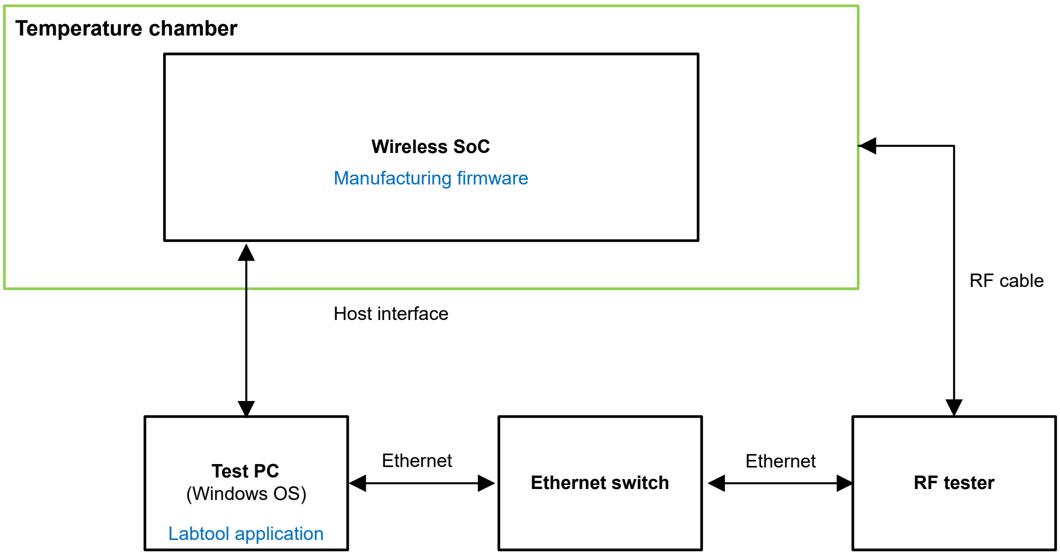

Figure 4. Thermal TX power compensation hardware setup

4.4.2 Labtool setup and command sequence

The TX output power versus temperature sensor reading needs to be measured over several temperatures, data rates, bandwidth, and sub-bands on a per path basis.

The example of Labtool procedure below measures TX output power over temperature while keeping the gain code constant (~12 dBm at the antenna connector):

Step 1 – Open *SetUp.ini* file in the Labtool directory and disable EEPROM in the `DUTInitSet` section.

```
[DutInitSet]
      ;0 - EEPROM support
      ;1 - NO_EEPROM support
      ;2 - OTP support
      NO_EEPROM = 1 // NO_EEPROM support
```

Step 2 – Turn on the DUT.

Step 3 – Open Labtool and navigate to the Wi-Fi command menu.

Step 4 - Open *WlanCalData_ext.conf* and delete `[THERMAL_POWER_RSSI_COMPENSATION]` and `[THERMAL_XTAL_V2]` parameters (see the example below). These parameters will be configured later.

```
[THERMAL_XTAL_V2]
Third_Order = 1.25482124E-04
Second_Order = -1.43699874E-02
First_Order = 5.46357137E-02
Constant_Order = 1.43561726E+01

[THERMAL_POWER_RSSI_COMPENSATION]
THERMAL_POWER_RSSI_REV=255
THERMAL_POWER_RSSI_Path0_Entries=5
CCK_SLOPE_2G_Path0=0xDA
OFDM_SLOPE_2G_Path0=0xD6
.
.
.
THERMAL_POWER_RSSI_5G_SUBBAND3_TEMPREF_SLOPE_BYPASS_Path0=0x00
```

Step 5 – Apply the following example of command sequence in Labtool to measure the TX power and thermal sensor reading.

Note: *For low power slope, use power index 4. For high power slope, use power index 6.*

```
22 // Load the calibration data file with all thermal compensation parameters removed
6 11    // Set the band to 2.4GHz
112 0 0 // Set the bandwidth to 20MHz
12 0 6  // Set the channel to 6
96 xx   // Adjust the XTAL offset if necessary
95      // Readback XTAL offset
102 0x10     // Enable RF calibration mode
35 0 1 15 4  // Transmit with SIFS gap at power index 4 (~10dBm)
<Measure the output power using a VSA. Note the value>
120    // Get thermal sensor reading. Note the value.
35 0        // Stop the transmission
```

Step 6 – Repeat Step 5 over the operating temperature range for all paths and each sub-band of interest and record the corresponding measured TX power and temperature. It is recommended to measure in 10°C increments.

Figure 5 shows an example plot of TX output power versus the temperature sensor reading.

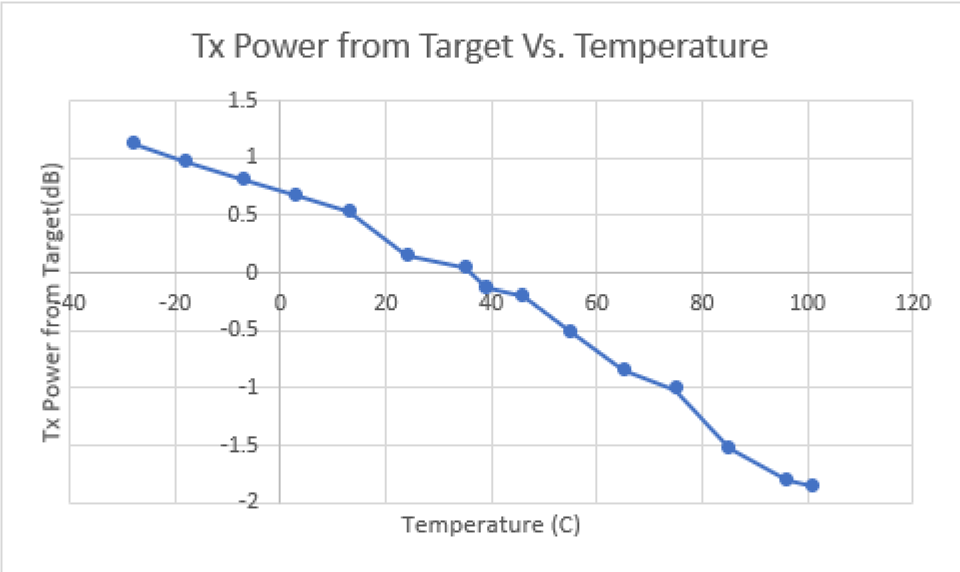

Figure 5. TX output power vs temperature sensor reading

Once the data collection is complete for all points of interest (channel, bandwidth, data rates, and more), a TX thermal slope must be defined for each path and sub-band.

4.4.3 Calculating the thermal power slope

The formula for TX power thermal slope is shown below:

$$Thermal\ \ slope = \frac{[(\text{Output Pwr @Hot})-(\text{Output Pwr @Cold})]\times 1000}{[(\text{Tsens @Hot})-(\text{Tsens @Cold})]}$$

Where:

- *Tsen* is the temperature sensor reading.
- *Output Pwr* is the Tx power measured at the RF connector of the DUT.

Based on the example data above, the TX power thermal slope is calculated as follows:

$$\frac{(1.851-1.1198)\times 1000}{(101-(-28))} = -23.03$$

To get the low power and high power slope parameters for each sub-band, convert the calculated TX power thermal slope to a hex number rounded to the nearest whole number in the `THERMAL_POWER_RSSI_COMPENSATION` section (Figure 6).

```
[THERMAL_POWER_RSSI_COMPENSATION]
THERMAL_POWER_RSSI_REV=255
THERMAL_POWER_RSSI_Path0_Entries=5
CCK_SLOPE_2G_Path0=0xDA
OFDM_SLOPE_2G_Path0=0xD6
THERMAL_POWER_RSSI_2G_SWITCH_POINT_TEMP_Path0=0x00
THERMAL_POWER_RSSI_2G_DEMOM_Path0=0x00
THERMAL_POWER_RSSI_2G_TEMPREF_SLOPE_NORMAL_Path0=0x00
THERMAL_POWER_RSSI_2G_TEMPREF_SLOPE_BYPASS_Path0=0x00
CCK_SLOPE_5G_SUBBAND1_Path0=0xDD
OFDM_SLOPE_5G_SUBBAND1_Path0=0xDB
THERMAL_POWER_RSSI_5G_SUBBAND1_SWITCH_POINT_TEMP_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND1_DEMOM_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND1_TEMPREF_SLOPE_NORMAL_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND1_TEMPREF_SLOPE_BYPASS_Path0=0x00
CCK_SLOPE_5G_SUBBAND2_Path0=0xD9
OFDM_SLOPE_5G_SUBBAND2_Path0=0xD6
THERMAL_POWER_RSSI_5G_SUBBAND2_SWITCH_POINT_TEMP_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND2_DEMOM_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND2_TEMPREF_SLOPE_NORMAL_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND2_TEMPREF_SLOPE_BYPASS_Path0=0x00
CCK_SLOPE_5G_SUBBAND3_Path0=0xCD
OFDM_SLOPE_5G_SUBBAND3_Path0=0xCF
THERMAL_POWER_RSSI_5G_SUBBAND3_SWITCH_POINT_TEMP_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND3_DEMOM_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND3_TEMPREF_SLOPE_NORMAL_Path0=0x00
THERMAL_POWER_RSSI_5G_SUBBAND3_TEMPREF_SLOPE_BYPASS_Path0=0x00
```

Figure 6. `THERMAL_POWER_RSSI_COMPENSATION` parameters

4.4.4 Wi-Fi thermal crystal frequency compensation

The Wi-Fi thermal crystal frequency compensation parameter is used to maintain the crystal frequency accuracy across the operating temperature range.

The crystal frequency compensation parameter is expressed in a third order polynomial equation for crystal frequency correction (see below). As the temperature changes, the compensation is applied to maintain the crystal frequency accuracy.

Third order polynomial equation used for the crystal frequency parameter:

$Y(t) = A*X^3 + B*X^2 + C*X + D$

Where:

- Y is the crystal frequency offset
- X is the thermal sensor (Tsen) reading
- A is the third order coefficient
- B is the second order coefficient
- C is the first order coefficient
- D is the constant coefficient

Example of crystal frequency thermal coefficients in *CalWlanDataFile.txt* file:

```
THERMAL_XTAL_V2]
Third_Order = 1.25482124E-04
Second_Order = -1.43699874E-02
First_Order = 5.46357137E-02
Constant_Order = 1.43561726E+01
```

These parameters may be further fine-tuned to optimize the crystal frequency variation over temperature.

This section details how to characterize the thermal behavior of XTAL to fit to the 3rd order polynomial. The frequency error versus temperature sensor reading across multiple temperatures is recorded for the XTAL calibration offset.

Before starting thermal crystal frequency compensation, ensure that XTAL calibration has been performed on the DUT. The XTAL calibration offset, `RFXTAL`, can be found in the `[Main_Table]` section in *CalWlanDataFile.txt* file, as shown in Figure 7.

```
[StructureInfo]
STRUCTURE_REV=0x0F
[Main_Table]
Ref_Design_Type=0x00
Device_ID=0x00
SPI_Size=0x40
Ant_TX=0xFF
Ant_RX=0xFF
Soc_OR_Rev=0x12
TMP At Cal=0x0025
RFXTAL=0x6D
Region_Code=0x10
MISC_Flag=0x00
TEST_VERSION=0x43FCB
MFG_VERSION=0x200003F
DLL VERSION=0x100000C
```

Figure 7. XTAL calibration offset parameter

4.4.4.1 Calculating the thermal crystal frequency coefficients

Step 1 – Follow the setup shown in Section 4.4.1.

Step 2 - Power cycle the DUT and open Labtool.

Step 3 - Measure the frequency change with XTAL calibration offset change:

Use the following command sequence to transmit with a fixed gain code that provides ~12 dBm at the antenna connector at room temperature:

```
22          // Load the calibration data file with all thermal compensation parameters
 removed
6 3        // Set the band to 5GHz
112 0 0    // Set the bandwidth to 20MHz
12 0 100   // Set the channel to 100 (5500MHz)
102 0x10   // Disable thermal compensation
96 0x6D    // Set XTAL calibration offset (0x6D is an example value)
95         // Readback XTAL offset
35 0 1 15 4  // Transmit with SIFS gap at power index 4 (~10 dBm)
<Measure the frequency using a VSA. Note the value>
96 0x6E    // Increase XTAL offset by one step
<Measure the frequency using a VSA. Note the value>
```

Step 4 - Continue to increase the XTAL offset and record the frequency until at least 10 frequency values have been recorded.

Step 5 - Stop the transmission with Labtool command `35 0`.

Step 6 - Determine the frequency offset delta between each XTAL calibration offset step and convert the value to ppm.

Step 7 - Calculate the average frequency offset delta from **step 6** to obtain the average ppm/step and record the value. Table 9 shows an example.

Table 9. Average XTAL frequency change per XTAL calibration code

XTAL offset (room temperature)	Frequency offset (kHz)	Frequency offset (ppm)	Delta
55	85	18.33	0.92
56	86	17.41	0.99
57	87	16.42	0.9
58	88	15.52	0.98
59	89	14.54	0.86
5a	90	13.68	0.94
5b	91	12.74	0.73
5c	92	12.01	0.93
…	…	…	…
7c	124	-10.76	0.66
7d	125	-11.42	0.54
7e	126	-11.96	0.62
7f	127	-12.58	0.55
80	128	-13.13	0.59
81	129	-13.72	0.57
82	130	-14.29	0.57
83	131	-14.86	0.44
84	132	-15.3	0.58
85	133	-15.88	
Average frequency offset delta ppm/code			**0.71270833**

Step 8 – Measure the frequency error with the change of temperature.

Use the following command sequence to transmit with a fixed gain code that provides ~12 dBm at the antenna connector.

```
22   // Load the calibration data file with all thermal compensation parameters removed
6 3  // Set the band to 5GHz
112 0 0   // Set the bandwidth to 20MHz
12 0 100  // Set the channel to 100 (5500MHz)
102 0x10  // Disable thermal compensation
96 0x6D   // Set XTAL calibration offset (0x6D is an example value)
95        // Readback XTAL offset
35 0 1 15 4  // Transmit with SIFS gap at power index 4 (~10 dBm)
<Measure the frequency error using a VSA. Note the value>
120      // Get thermal sensor reading. Note the value.
35 0     // Stop transmission
```

Step 9 – Repeat **step 8** over the operating temperature range.

Step 10 – Convert the measured frequency error in kHz to ppm and record the value.

Step 11 – Divide the frequency error in ppm value by the average frequency offset delta from **step 7** to obtain the XTAL correction code at each temperature step. Table 10 shows an example.

Table 10. XTAL correction code and temperature reading

Temperature (°C)	Temp sensor reading	Frequency error (ppm)	XTAL correction code
-40	-28	-0.76	-1.067411498
-30	-18	5.87	8.234668738
-20	-7	9.19	12.89745791
-10	3	10.02	14.05479799
0	13	9.00	12.63055985
10	24	6.49	9.107522503
20	35	3.18	4.464704683
25	39	1.48	2.081564796
30	46	-0.43	-0.609635024
40	55	-3.59	-5.042397977
50	65	-6.05	-8.486023214
60	75	-7.09	-9.950162151
70	85	-5.93	-8.31673198
80	96	-1.28	-1.794561768
85	101	2.15	3.020531285

Step 12 - Once the data collection is complete for all points of interest, plot XTAL frequency error versus temperature reading using MS Excel scatter plot. See an example in Figure 8. The polynomial equation appearing on the plot should be updated with an accuracy of 8 decimal places.

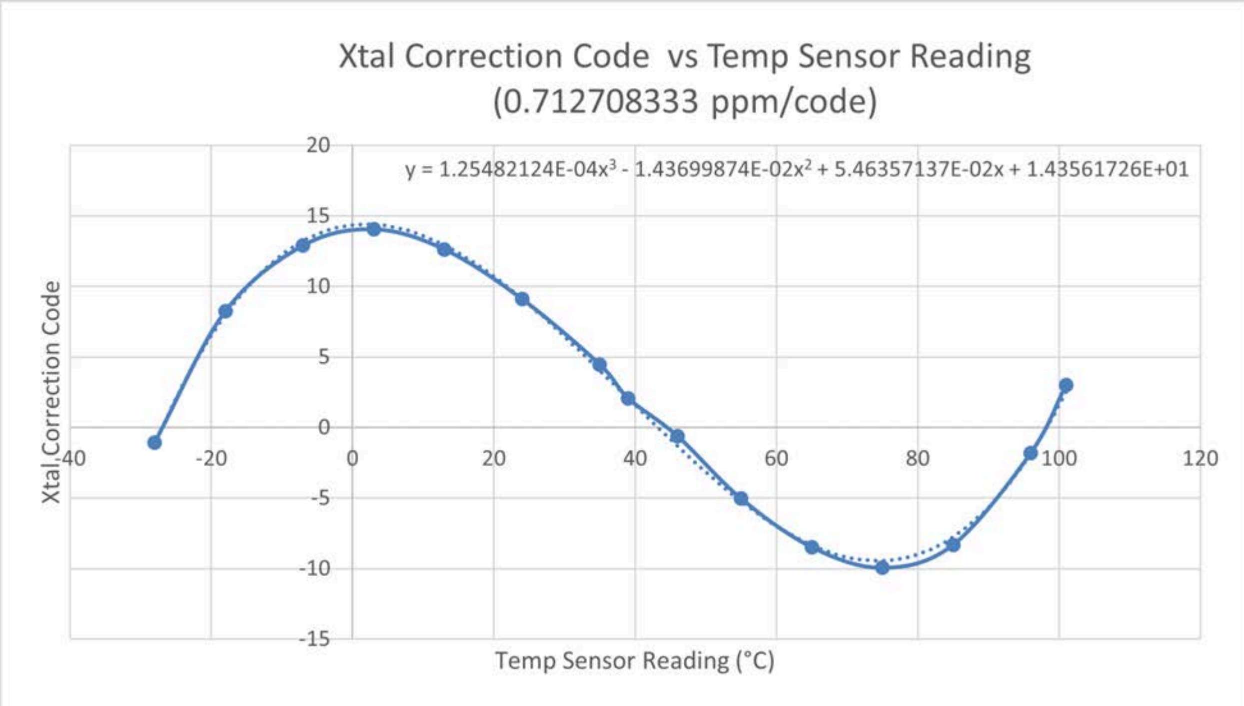

Figure 8. XTAL correction code vs temperature with 3rd order polynomial equation

4.4.4.2 Incorporating the crystal thermal coefficients into the calibration data

To ensure thermal compensation is performed, include the 3rd order polynomial coefficients determined in Figure 8 in the *CalWlanDataFile.txt* file. The coefficients are expressed in scientific number format.

For example, using Figure 8, enter the XTAL thermal coefficients for the radio into the *CalWlanDataFile.txt* file.

Thermal_XTAL_V2

>>>>>>Third_Order= 1.25482124E-04

>>>>>>Second_Order = -1.43699874E-02

>>>>>>First_Order = 5.46357137E-02

>>>>>>Constant_Order = 1.43561726E+01

4.5 Wi-Fi MAC address

The Wi-Fi MAC address is a unique 6-byte number. It is not included in the calibration data file and needs to be programmed separately into the on-chip OTP memory of the device using Labtool.

Enter the Labtool command `46` to write the Wi-Fi MAC address into the OTP.

Note: *The MAC address cannot be written or stored in WlanCalData_ext.conf file.*

Example:

```
46 0 00.50.43.22.33.B4
```

4.6 Wi-Fi front-end configuration

The front-end configuration parameters are under the `FEM_SETTING` section of the *CalWlanDataFile.txt* file.

If the front-end configuration of your design differs from NXP evaluation board configuration, contact your NXP representative to discuss which updates are required in your calibration data file.

4.6.1 FEM data entry

Table 11 describes FEM parameters.

Update the FEM section in *CalWlanDataFile.txt* for your design using the information in Table 11.

Table 11. FEM parameters

Parameter	Description
`FEM_DATA_Entries`	Number of FEM entries for the FEM design.
`FE_VER`	FEM data revision Set to 4 (default).
`FEMCap2G`	Set 2.4 GHz FEM capability. 0x0 = disable 0x1 = enable (default)
`FEMCap5G`	Set 5 GHz FEM capability. 0x0 = disable 0x1 = enable (default)
`FEM_INTERNAL_BT`	Set the use of internal Bluetooth. 0x0 = disable 0x1 = enable (default)
`FEM_BT_LOCATION`	Reserved. Set to 0x00.
`FEM_EXTERNAL_2G_LNA`	Set the use of 2.4 GHz external LNA. 0x0 = disable (default) 0x1 = enable
`FEM_EXTERNAL_5G_LNA`	Set the use of 5 GHz external LNA. 0x0 = disable (default) 0x1 = enable

Table 11. FEM parameters...*continued*

Parameter	Description
`FEM_EXTERNAL_2G_PA`	Set the use of 2.4 GHz external PA. 0x0 = disable (default) 0x1 = enable
`FEM_EXTERNAL_5G_PA`	Set the use of 5 GHz external PA. 0x0 = disable (default) 0x1 = enable
`FEM_CONCURRENCY`	Reserved. Set to 0x00.
`FEM_2G_TVXR_A_BIT_MASK`	Hex value of 16-bit RF control line bit mask for 2.4 GHz for Path A bit[0] = 1 //enable RF control line 0 bit[1] = 1 //enable RF control line 1 bit[2] = 1 //enable RF control line 2 bit[3] = 1 //enable RF control line 3 … bit[15] = 1 //enable RF control line 15
`FEM_2G_TVXR_B_BIT_MASK`	Reserved. Set to 0x0000.
`FEM_5G_TVX_A_BIT_MASK`	Hex value of 16-bit RF control line bit mask for 5 GHz for Path A bit[0] = 1 //enable RF control line 0 bit[1] = 1 //enable RF control line 1 bit[2] = 1 //enable RF control line 2 bit[3] = 1 //enable RF control line 3 … bit[15] = 1 //enable RF control line 15
`FEM_5G_TVXR_B_BIT_MASK`	Reserved. Set to 0x0000.
`FEM_2G_ANT_DIVERSITY_MASK`	Hex value of 16 bit used to set 2.4 GHz antenna diversity. bit[0] = 1 //enable RF control line 0 bit[1] = 1 //enable RF control line 1 bit[2] = 1 //enable RF control line 2 bit[3] = 1 //enable RF control line 3 … bit[15] = 1 //enable RF control line 15 ***Note:*** *Set the value to 0x0000 if your device is not configured for antenna diversity.*
`FEM_5G_ANT_DIVERSITY_MASK`	Hex value of 16 bit used to set 5 GHz antenna diversity. bit[0] = 1 //enable RF control line 0 bit[1] = 1 //enable RF control line 1 bit[2] = 1 //enable RF control line 2 bit[3] = 1 //enable RF control line 3 … bit[15] = 1 //enable RF control line 15 ***Note:*** *Set the value to 0x0000 if your device is not configured for antenna diversity.*

Table 11. FEM parameters*...continued*

Parameter	Description
`FEM_OPERATION_MODE_MASK_ENTRIES`**`(Y)`** ***Note:*** *`Y` is the FEM entry number starting at index 0.*	Hex value of the 16-bit FEM entry that defines the operation mode. 0 = enable - 1 = disable Bit[0]: reserved. Set to 0. Bit[1]: 2.4 GHz 1x1 A 802.11ax/802.11ac (default) Bit[2]: reserved. Set to 0. Bit[3]: reserved. Set to 0. Bit[4]: reserved. Set to 0. Bit[5]: 5 GHz 1x1 A 802.11ax/802.11ac (default) Bit[6]: reserved. Set to 0. Bit[7]: reserved. Set to 0. Bit[8]: 5 GHz 1x1A zero-wait DFS Bit[9]: reserved. Set to 0. Bit[10]: reserved. Set to 0. Bit[11]: reserved. Set to 0. Bit[12-15]: reserved. Set to 0. Example FEM configuration for 2.4 GHz 1x1 (Path A) 802.11ax/802.11ac device (FEM entry 0): `FEM_OPERATION_MODE_MASK_ENTRIES0 = 0x0002` Example FEM configuration for 5 GHz 1x1 (Path A) 802.11ax/802.11ac device (FEM entry 1): `FEM_OPERATION_MODE_MASK_ENTRIES1 = 0x0020` Example FEM configuration for 2.4 GHz and 5 GHz 1x1 (Path A) 802.11ax/802.11ac device (FEM entry 0): `FEM_OPERATION_MODE_MASK_ENTRIES0 = 0x0022`
`FEM_RF_CTRL_INFO`**`(X)`**`_ENTRIES`**`(Y)`** ***Note:*** • *`X` is the state number starting at index 0. The number corresponds to the respective FEM entry defined by `Y`.* • *`Y` is the FEM entry number starting at index 0. See Table 12.*	Hex value of 16-bit RF control lines, which correspond to the respective `FEM_OPERATION_MODE_MASK_ENTRIESY` entry. A total of 20 SoC modes can be mapped. The SoC modes define how to toggle the front-end lines to switch between Wi-Fi and Bluetooth. Refer to Table 12. When configuring FEM entries for Wi-Fi 5 GHz in single antenna setup, it is recommended to set the RF switch to the Bluetooth path, except when in Idle state.

Table 12 shows how to configure the RF control lines.

Table 12. RF control line configuration

SoC mode index	SoC mode description	Bit[16]	...	Bit[3]	Bit[2]	Bit[1]	Bit[0]
0	Idle (Wi-Fi RX)	0	0	0	0	0	1
1	Bluetooth RX	0	0	0	0	1	0
2	Wi-Fi RX	0	0	0	0	0	1
3	Wi-Fi RX + Bluetooth RX	0	0	0	0	0	1
4	Wi-Fi TX	0	0	0	0	0	1
5	Wi-Fi TX + Bluetooth RX	0	0	0	0	0	1
6	Bluetooth TX	0	0	0	0	1	0
7	Wi-Fi RX + Bluetooth TX	0	0	0	0	0	1

Table 12. RF control line configuration...*continued*

SoC mode index	SoC mode description	Bit[16]	...	Bit[3]	Bit[2]	Bit[1]	Bit[0]
8	Wi-Fi TX + Bluetooth TX	0	0	0	0	0	1
9	Reserved	0	0	0	0	0	1
10	Reserved	0	0	0	0	0	1
11	Reserved	0	0	0	0	0	1
12	Reserved	0	0	0	0	0	1
13	Reserved	0	0	0	0	0	1
14	Reserved	0	0	0	0	0	1
15	Reserved	0	0	0	0	0	1
16	Reserved	0	0	0	0	0	1
17	Reserved	0	0	0	0	0	1
18	Reserved	0	0	0	0	0	1
19	Reserved	0	0	0	0	0	1

Figure 9 shows an example of schematic with the RF switch. The corresponding truth table is shown in Table 13.

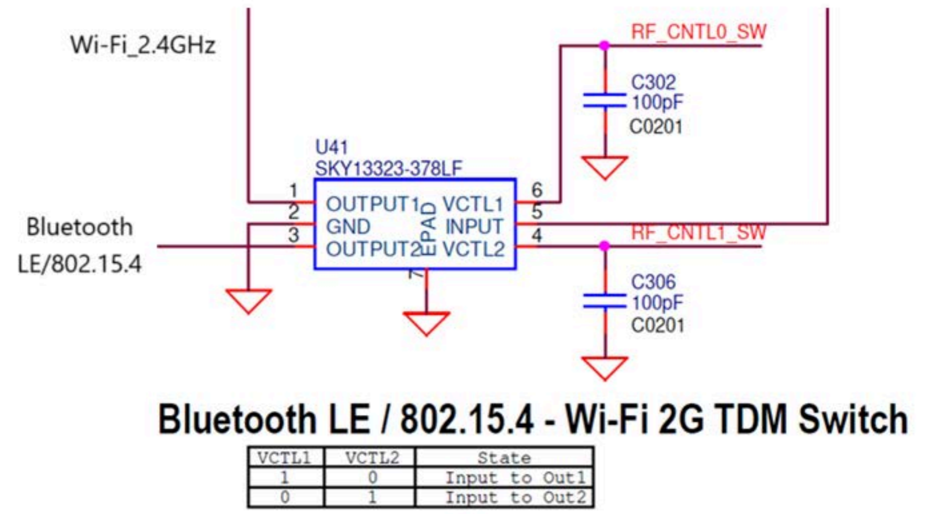

Figure 9. Example of schematic with RF switch for a single-antenna design

Table 13 shows the control line values of RW61x reference design (RD-RW61X-BGA-IPA-2A-V4) with RF switch.

Table 13. Truth table forRW61x single-antenna design with RF switch

SKY13323-378LF state	Bit[16:4]	Bit[3]	Bit[2]	Bit[1]	Bit[0]
INPUT to OUTPUT 1 (Wi-Fi 2.4 GHz)	0	0	0	0	1
INPUT to OUTPUT 2 (Bluetooth LE/802.15.4)	0	0	0	1	0

4.6.2 FEM data examples

This section includes examples of FEM configuration settings. Contact your NXP representative for more guidance on how to configure FEM settings.

4.6.2.1 Single antenna configuration without antenna diversity

```
[FEM_SETTING]
FEM_DATA_Entries=2
FE_VER=4
FEMCap2G=0x01
FEMCap5G=0x01
FEM_INTERNAL_BT=0x01
FEM_BT_LOCATION=0x00
FEM_EXTERNAL_2G_LNA=0x00
FEM_EXTERNAL_5G_LNA=0x00
FEM_EXTERNAL_2G_PA=0x00
FEM_EXTERNAL_5G_PA=0x00
FEM_CONCURRENCY=0x00
FEM_2G_TVXR_A_BIT_MASK=0x000F
FEM_2G_TVXR_B_BIT_MASK=0x0000
FEM_5G_TVXR_A_BIT_MASK=0x000F
FEM_5G_TVXR_B_BIT_MASK=0x0000
FEM_2G_ANT_DIVERSITY_MASK=0x0000
FEM_5G_ANT_DIVERSITY_MASK=0x0000
FEM_OPERATION_MODE_MASK_ENTRIES0=0x0002
FEM_RF_CTRL_INFO0_ENTRIES0=0x0001
FEM_RF_CTRL_INFO1_ENTRIES0=0x0002
FEM_RF_CTRL_INFO2_ENTRIES0=0x0001
FEM_RF_CTRL_INFO3_ENTRIES0=0x0001
FEM_RF_CTRL_INFO4_ENTRIES0=0x0001
FEM_RF_CTRL_INFO5_ENTRIES0=0x0001
FEM_RF_CTRL_INFO6_ENTRIES0=0x0002
FEM_RF_CTRL_INFO7_ENTRIES0=0x0001
FEM_RF_CTRL_INFO8_ENTRIES0=0x0001
FEM_RF_CTRL_INFO9_ENTRIES0=0x0001
FEM_RF_CTRL_INFO10_ENTRIES0=0x0001
FEM_RF_CTRL_INFO11_ENTRIES0=0x0001
FEM_RF_CTRL_INFO12_ENTRIES0=0x0001
FEM_RF_CTRL_INFO13_ENTRIES0=0x0001
FEM_RF_CTRL_INFO14_ENTRIES0=0x0001
FEM_RF_CTRL_INFO15_ENTRIES0=0x0001
FEM_RF_CTRL_INFO16_ENTRIES0=0x0001
FEM_RF_CTRL_INFO17_ENTRIES0=0x0001
FEM_RF_CTRL_INFO18_ENTRIES0=0x0001
FEM_RF_CTRL_INFO19_ENTRIES0=0x0001
FEM_OPERATION_MODE_MASK_ENTRIES1=0x0020
FEM_RF_CTRL_INFO0_ENTRIES1=0x0002
FEM_RF_CTRL_INFO1_ENTRIES1=0x0002
FEM_RF_CTRL_INFO2_ENTRIES1=0x0002
FEM_RF_CTRL_INFO3_ENTRIES1=0x0002
FEM_RF_CTRL_INFO4_ENTRIES1=0x0002
FEM_RF_CTRL_INFO5_ENTRIES1=0x0002
FEM_RF_CTRL_INFO6_ENTRIES1=0x0002
FEM_RF_CTRL_INFO7_ENTRIES1=0x0002
FEM_RF_CTRL_INFO8_ENTRIES1=0x0002
FEM_RF_CTRL_INFO9_ENTRIES1=0x0002
FEM_RF_CTRL_INFO10_ENTRIES1=0x0002
FEM_RF_CTRL_INFO11_ENTRIES1=0x0002
FEM_RF_CTRL_INFO12_ENTRIES1=0x0002
FEM_RF_CTRL_INFO13_ENTRIES1=0x0002
FEM_RF_CTRL_INFO14_ENTRIES1=0x0002
FEM_RF_CTRL_INFO15_ENTRIES1=0x0002
FEM_RF_CTRL_INFO16_ENTRIES1=0x0002
FEM_RF_CTRL_INFO17_ENTRIES1=0x0002
FEM_RF_CTRL_INFO18_ENTRIES1=0x0002
FEM_RF_CTRL_INFO19_ENTRIES1=0x0002
```

4.6.2.2 Single antenna configuration with antenna diversity

```
[FEM_SETTING]
FEM_DATA_Entries=2
FE_VER=4
FEMCap2G=0x01
FEMCap5G=0x01
FEM_INTERNAL_BT=0x01
FEM_BT_LOCATION=0x00
FEM_EXTERNAL_2G_LNA=0x00
FEM_EXTERNAL_5G_LNA=0x00
FEM_EXTERNAL_2G_PA=0x00
FEM_EXTERNAL_5G_PA=0x00
FEM_CONCURRENCY=0x00
FEM_2G_TVXR_A_BIT_MASK=0x000F
FEM_2G_TVXR_B_BIT_MASK=0x0000
FEM_5G_TVXR_A_BIT_MASK=0x000F
FEM_5G_TVXR_B_BIT_MASK=0x0000
FEM_2G_ANT_DIVERSITY_MASK=0x000C
FEM_5G_ANT_DIVERSITY_MASK=0x000C
FEM_OPERATION_MODE_MASK_ENTRIES0=0x0002
FEM_RF_CTRL_INFO0_ENTRIES0=0x0005
FEM_RF_CTRL_INFO1_ENTRIES0=0x0006
FEM_RF_CTRL_INFO2_ENTRIES0=0x0005
FEM_RF_CTRL_INFO3_ENTRIES0=0x0005
FEM_RF_CTRL_INFO4_ENTRIES0=0x0005
FEM_RF_CTRL_INFO5_ENTRIES0=0x0005
FEM_RF_CTRL_INFO6_ENTRIES0=0x0006
FEM_RF_CTRL_INFO7_ENTRIES0=0x0005
FEM_RF_CTRL_INFO8_ENTRIES0=0x0005
FEM_RF_CTRL_INFO9_ENTRIES0=0x0005
FEM_RF_CTRL_INFO10_ENTRIES0=0x0005
FEM_RF_CTRL_INFO11_ENTRIES0=0x0005
FEM_RF_CTRL_INFO12_ENTRIES0=0x0005
FEM_RF_CTRL_INFO13_ENTRIES0=0x0005
FEM_RF_CTRL_INFO14_ENTRIES0=0x0005
FEM_RF_CTRL_INFO15_ENTRIES0=0x0005
FEM_RF_CTRL_INFO16_ENTRIES0=0x0005
FEM_RF_CTRL_INFO17_ENTRIES0=0x0005
FEM_RF_CTRL_INFO18_ENTRIES0=0x0005
FEM_RF_CTRL_INFO19_ENTRIES0=0x0005
FEM_OPERATION_MODE_MASK_ENTRIES1=0x0020
FEM_RF_CTRL_INFO0_ENTRIES1=0x0006
FEM_RF_CTRL_INFO1_ENTRIES1=0x0006
FEM_RF_CTRL_INFO2_ENTRIES1=0x0006
FEM_RF_CTRL_INFO3_ENTRIES1=0x0006
FEM_RF_CTRL_INFO4_ENTRIES1=0x0006
FEM_RF_CTRL_INFO5_ENTRIES1=0x0006
FEM_RF_CTRL_INFO6_ENTRIES1=0x0006
FEM_RF_CTRL_INFO7_ENTRIES1=0x0006
FEM_RF_CTRL_INFO8_ENTRIES1=0x0006
FEM_RF_CTRL_INFO9_ENTRIES1=0x0006
FEM_RF_CTRL_INFO10_ENTRIES1=0x0006
FEM_RF_CTRL_INFO11_ENTRIES1=0x0006
FEM_RF_CTRL_INFO12_ENTRIES1=0x0006
FEM_RF_CTRL_INFO13_ENTRIES1=0x0006
FEM_RF_CTRL_INFO14_ENTRIES1=0x0006
FEM_RF_CTRL_INFO15_ENTRIES1=0x0006
FEM_RF_CTRL_INFO16_ENTRIES1=0x0006
FEM_RF_CTRL_INFO17_ENTRIES1=0x0006
FEM_RF_CTRL_INFO18_ENTRIES1=0x0006
FEM_RF_CTRL_INFO19_ENTRIES1=0x0006
```

4.6.3 Antenna isolation configuration

The antenna isolation configuration parameters are in the `ANT_ISO_INFO` section of the *CalWlanDataFile.txt* file. The parameters are used to define the antenna setup and the isolation between antennas.

4.6.3.1 Antenna isolation parameters

Table 14 describes the parameters for antenna isolation. Set the parameter values for your design in the ANT_ISO_INFO section of *CalWlanDataFile.txt* file.

Table 14. Antenna isolation parameters

Parameter	Description
`ANT_ISO_INFO_Entries`	Antenna configuration. • 0 = single-antenna configuration • 1 = dual-antenna configuration
`ANT_ISO_INFO_Revision`	Annex version for antenna isolation Set to 0x01.
`ANT_ISO_INFO_NUM_WLAN_ANT`	Number of Wi-Fi antennas. Set to 1
`ANT_ISO_INFO_NUM_BT_ANT`	Number of Bluetooth antennas. Set to 1
`ANT_ISO_INFO_NUM_ZB_ANT`	Number of 802.15.4 antennas. Set to 1
`ANT_ISO_INFO_ANT_SHARING_INFO`[1]	Antenna sharing information for 2.4 GHz Wi-Fi, Bluetooth, and 802.15.4. For the bitmask information, refer to Table 15.
`ANT_ISO_INFO_TECH_A_FORMAT_ENTRIES0`[1]	Configure RF signal A: • Set to 0 for Wi-Fi • Set to 1 for Bluetooth ***Note:*** • *If `ANT_ISO_INFO_TECH_B_FORMAT_ENTRIES0` = 0, set this entry to "1".* • *If `ANT_ISO_INFO_TECH_B_FORMAT_ENTRIES0` = 1, set this entry to "0".*
`ANT_ISO_INFO_ANT_A_FORMAT_ENTRIES0`[1]	Antenna ID for RF signal A. Set to 0.
`ANT_ISO_INFO_TECH_B_FORMAT_ENTRIES0`[1]	Configure RF signal B: • Set to 0 for Wi-Fi. • Set to 1 for Bluetooth. ***Note:*** • *If `ANT_ISO_INFO_TECH_A_FORMAT_ENTRIES0` = 0, set this entry to "1".* • *If `ANT_ISO_INFO_TECH_A_FORMAT_ENTRIES0` = 1, set this entry to "0".*

Table 14. Antenna isolation parameters*...continued*

Parameter	Description
`ANT_ISO_INFO_ANT_B_FORMAT_ENTRIES0`[1]	Antenna ID for RF signal B. Set to 0
`ANT_ISO_INFO_ISOLATION_FORMAT_ENTRIES0`[1]	Antenna isolation value in dB between RF signals A and B. Range: [0 - 255] dB (1dB resolution unsigned integer) ***Note:*** *The firmware automatically applies the Wi-Fi and Bluetooth antenna isolation value to Wi-Fi and 802.15.4*

[1] The parameter is for dual-antenna designs only.

Note: *The bitmask must be entered as an hexadecimal value for `ANT_ISO_INFO_ANT_SHARING_INFO` parameter.*

Table 15 shows the settings for antenna sharing.

Table 15. Antenna sharing information

Byte	Configuration	Bit	Description
0	LNA	0	Wi-Fi and Bluetooth share the LNA
		1	Reserved. Set to 0.
		2	Wi-Fi and 802.15.4 share the LNA
		3	Bluetooth and 802.15.4 share LNA
		4	Reserved. Set to 0.
		5	Reserved. Set to 0.
		6	Reserved. Set to 0.
		7	
1	Antenna	8	Wi-Fi and Bluetooth share antenna
		9	Reserved. Set to 0.
		10	Wi-Fi and 802.15.4 share antenna
		11	Bluetooth and 802.15.4 share antenna
		12	Reserved. Set to 0.
		13	Reserved. Set to 0.
		14:15	Reserved. Set to 0.
2	Shared path [1]	16:23	Reserved. Set to 0.
3	—	24:31	Reserved. Set to 0.

[1] Refer to Ref.[2]

4.6.3.2 Examples of antenna isolation configurations

Single antenna configuration with Wi-Fi, Bluetooth LE, and 802.15.4 sharing the same antenna:

```
[ANT_ISO_INFO]
ANT_ISO_INFO_Entries=0
ANT_ISO_INFO_Revision=0x01
ANT_ISO_INFO_NUM_WLAN_ANT=1
ANT_ISO_INFO_NUM_BT_ANT=1
ANT_ISO_INFO_NUM_ZB_ANT=1
ANT_ISO_INFO_ANT_SHARING_INFO=0x00000D08
```

Dual-antenna configuration with 20 dB isolation between the Wi-Fi and Bluetooth LE/802.15.4 antennas:

```
[ANT_ISO_INFO]
ANT_ISO_INFO_Entries=1
ANT_ISO_INFO_Revision=0x01
ANT_ISO_INFO_NUM_WLAN_ANT=1
ANT_ISO_INFO_NUM_BT_ANT=1
ANT_ISO_INFO_NUM_ZB_ANT=1
ANT_ISO_INFO_ANT_SHARING_INFO=0x00000808
ANT_ISO_INFO_TECH_A_FORMAT_ENTRIES0=0
ANT_ISO_INFO_ANT_A_FORMAT_ENTRIES0=0
ANT_ISO_INFO_TECH_B_FORMAT_ENTRIES0=1
ANT_ISO_INFO_ANT_B_FORMAT_ENTRIES0=0
ANT_ISO_INFO_ISOLATION_FORMAT_ENTRIES0=0x14
```

Note: *If the front-end configuration of your design differs from NXP evaluation board configuration, contact your NXP representative about how to update your calibration data file.*

4.7 Bluetooth LE configuration

The *CalBtDataFile.txt* file includes sections with the parameters to configure Bluetooth LE calibration settings.

Example of configuration parameters for Bluetooth LE:

```
[BT_Config]
ANNEX56_EXIST=0
Version=0x1
Xtal=0x79
InitPwrIndBm_Pwr=4
FELoss=0x4
ForceClass2Op=0
Class1OpSupport=1
DisablePwrControl=0
MiscFlag=0
UsedInternalSleepClock=1
AOALocaltionSupport=0
AOANumberOfAntennas=0x0
RssiGoldenRangeLow=0x0
RssiGoldenRangeHigh=0x0
UartBaudRate=3000000
BdAddress=C0.95.DA.21.12.14
MinEncrKeyLen=0x0
MaxEncrKeyLen=0x0
RegionCode=0x10
[BT_HW_INFO]
BT_HW_INFO_EPA_Present=1
BT_HW_INFO_EPA_Gain=0x00
BT_HW_INFO_EPA_FEM_Mask=0x0004
BT_HW_INFO_ELNA_Present=1
BT_HW_INFO_ELNA_Gain=0x00
BT_HW_INFO_ELNA_FEM_Mask=0x0004
```

4.7.1 Initial Bluetooth transmit power

The parameter `InitPwrIndBm_Pwr` is used to set the initial operating power (in dBm with step size of 1 dB) for Bluetooth/Bluetooth LE.

Example:

`InitPwrIndBm_Pwr = 4` // Bluetooth initial operating power is 4 dBm.

4.7.2 Bluetooth TX power class setting

The parameters `ForceClass2Op` and `Class1OpSupport` are used to configure Bluetooth TX power class operation.

Table 16 shows the power class configurations.

Table 16. Bluetooth TX power class parameters

Bluetooth TX power class	Configuration parameter
Class 1 (up to 15 dBm)	`ForceClass2Op=0` `Class1OpSupport=1`
Class 1.5 (up to 10 dBm)	`ForceClass2Op=0` `Class1OpSupport=0`
Class 2 (up to 4 dBm)	`ForceClass2Op=1` `Class1OpSupport=0`

4.7.3 Bluetooth device (BD) address

The BdAddress parameter is a unique 6-byte number.

For Wi-Fi and Bluetooth combo radio design, the BdAddress is the Wi-Fi MAC address plus 1 bit.

BdAddress = Wi-Fi MAC address + 1

For example, if Wi-Fi MAC address is C0.95.DA.21.12.13, BdAddress = C0.95.DA.21.12.14.

4.7.4 Bluetooth front-end loss

The Bluetooth FE loss (FELoss) parameter is used to tune the Bluetooth/Bluetooth LE transmit power (with step size of 0.5 dB) at the antenna connector.

Increasing FELoss results in increasing the output power from the radio. Similarly, decreasing FELoss decreases the output power from the radio.

For example, Bluetooth FELoss = 0x5 // Bluetooth FELoss is 2.5 dB.

4.7.5 Bluetooth frequency calibration

The Bluetooth frequency (RFXTAL) parameter is used to tune the frequency accuracy. Set the Bluetooth RFXTAL value to the same value as the RFXTAL value in Wi-Fi calibration data file (Section 4.1).

Note: *Bluetooth RFXTAL parameter is used for applications that do not use Wi-Fi.*

4.7.6 Bluetooth host interface Baud rate

The UartBaudRate parameter is used to set the baud rate of the Bluetooth host interface. This parameter is defined in bits per second. The Bluetooth host interface will use this baud rate after the firmware download is completed.

For an example, UartBaudRate=3000000 will set the UART baud rate to 3 Mbps.

Note: *If the host supports a baud rate of 3 Mbps, it is recommended to set the baud rate to 3000000.*

4.7.7 Bluetooth hardware info

The BT_HW_INFO section is used to configure the front-end configuration for Bluetooth-only designs.

Table 17 lists the parameters in the BT_HW_INFO section.

Table 17. Parameters in BT_HW_INFO section

Parameter	Description
BT_HW_INFO_EPA_Present	Enable external TX control 0x0 = not present 0x1 = present
BT_HW_INFO_EPA_Gain	Gain of the external power amplifier (EPA) in dB
BT_HW_INFO_EPA_FEM_Mask	Bit mask used to define the state of the RF control line for TX. For example, the bit mask of RF_CNTL2_N is 0x0000_0000_0000_0100.
BT_HW_INFO_ELNA_Present	Enable external RX control 0x0 = not present 0x1 = present
BT_HW_INFO_ELNA_Gain	External LNA gain in dB

Table 17. Parameters in `BT_HW_INFO` section*...continued*

Parameter	Description
`BT_HW_INFO_ELNA_FEM_Mask`	Bit [4:0]: the bit mask used to define the state of RF control line for RX For example, the bit mask of RF_CNTL2_N is 0x0000_0000_0000_0100.
`BT_HW_INFO_EANT_Present`	External antenna (eANT) presence. Set to 0
`BT_HW_INFO_EANT_Gain`	Gain of the external antenna. Set to 0
`BT_HW_INFO_MULTIPURPOSE_MASK`	The bit mask that identifies the multi-purpose control lines for special control. Set to 0

Example of Bluetooth hardware info configuration for an NXP reference design with single antenna and narrowband only radio.

```
[BT_HW_INFO]
      BT_HW_INFO_EPA_Present=1
      BT_HW_INFO_EPA_Gain=0x00
      BT_HW_INFO_EPA_FEM_Mask=0x000A
      BT_HW_INFO_ELNA_Present=1
      BT_HW_INFO_ELNA_Gain=0x00
      BT_HW_INFO_ELNA_FEM_Mask=0x000A
      BT_HW_INFO_EANT_Present=0
      BT_HW_INFO_EANT_Gain=0x00
      BT_HW_INFO_MULTIPURPOSE_MASK=0x00
```

Example of Bluetooth hardware info configuration for an NXP reference design with external FEM on narrowband only radio.

```
[BT_HW_INFO]
      BT_HW_INFO_EPA_Present=1
      BT_HW_INFO_EPA_Gain=0x16
      BT_HW_INFO_EPA_FEM_Mask=0x0089
      BT_HW_INFO_ELNA_Present=1
      BT_HW_INFO_ELNA_Gain=0x0B
      BT_HW_INFO_ELNA_FEM_Mask=0x0005
      BT_HW_INFO_EANT_Present=0
      BT_HW_INFO_EANT_Gain=0x00
      BT_HW_INFO_MULTIPURPOSE_MASK=0x00
```

Note: *If the front-end configuration of your design differs from NXP evaluation board configuration, contact your NXP representative about how to update your calibration data file.*

4.8 802.15.4 configuration (RW612 only)

The section `15.4_Config` in *Cal15_4DataFile.txt* includes the parameters used to configure 802.15.4 settings.

4.8.1 802.15.4 TX power limit

The `_15_4_TxPowerLimit` parameter is used to set the max operating TX power for 802.15.4 in steps of 0.5 dB. The valid parameter value range is 1 to 44 (0.5 dBm to 22 dBm). If TX power limit parameter is set to 0, there will be no limit on TX power.

For example, `_15_4_TxPowerLimit = 20` sets the max 802.15.4 TX power to 10 dBm.

4.8.2 802.15.4 MAC address

The `_15_4_Address` parameter is used to set the 64-bit MAC address of the 802.15.4 radio.

For example, `_15_4_Address = 88.77.66.55.44.33.22.11` sets the MAC address to 11.22.33.44.55.66.77.88.

Note: *Once the extended unique identifier (EUI) MAC address is programmed into the OTP, Labtool command `46` can NOT update the MAC address at runtime.*

4.8.3 SPI clock frequency

The `_15_4_SPIClk` parameter is used to set the range of the SPI clock frequency.

The default range is up to 4 MHz (`_15_4_SPIClk=0`). To enable support for a higher SPI clock frequency up to 10 MHz, set `_15_4_SPIClk=1`.

4.8.4 802.15.4 front-end loss

The (`FELoss`) parameter in *CalBtDataFile.txt* file is used to compensate the 802.15.4 radio front-end loss.

4.9 Miscellaneous calibration data

If other calibration data of your design differs from NXP sample calibration data, contact your NXP representative to discuss further updates.

5 Golden calibration data

If per -board calibration is not needed, use one set of calibration data as representative of all of your boards. This calibration data is commonly referred to as golden calibration data.

To create golden calibration data:

Step 1 - Collect the calibration data for your device. See Section 4.

Step 2 - Repeat step 1 for X number of boards.

You should have a unique text file for each of your boards.

Step 3 - Average the calibration results of your samples into a single text file for each radio.

Step 4 - Follow Section 7 and Section 8 to convert these text files to a configuration file and use the files.

6 Converting the calibration data

Before using the calibration data, store the data as configuration files. Follow the steps below to save the calibration data as a configuration file:

Step 1 – Save the updated calibration data text files listed below in the Labtool executable directory.

- *CalWlanDataFile.txt*
- *PwrTable_Path0.txt*
- *CalBtDataFile.txt*
- *Cal15_4DataFile.txt*(RW612 only)

Step 2 – Set `NO_EEPROM` parameter (`No_EEPROM =1`) in the *SetUp.ini* file to configuration file as calibration data storage type.

Step 3 – Enter command `53` in the Labtool Wi-Fi menu.

Command `53` creates new configuration files:

- *WlanCalData_ext.conf*
- *BtCalData_ext.conf*
- *15p4CalData_ext.conf*(RW612 only)

The created files are located in the same directory as Labtool executable.

7 Using the calibration data

The use of the calibration data will vary based on which firmware will be loaded: production or manufacturing.

7.1 Production firmware

Wi-Fi

Refer to [3].

Bluetooth

Refer to [3].

802.15.4 (RW612 only)

Refer to [1].

7.2 Manufacturing firmware

Wi-Fi

Place the converted WlanCalData_ext.conf file in the same directory as the Labtool executable and load the file using Labtool command `22`. Refer to [2] .

Bluetooth

Place the converted BtCalData_ext.conf file in the same directory as the Labtool executable and load the file using Labtool command `232`. Refer to [2].

802.15.4 (RW612 only)

Refer to Section 8.

8 Programming the calibration data into the OTP

As an alternative to a calibration file, calibration data can be stored into the on-chip OTP memory. Follow the procedure below to program the calibration data into the OTP memory:

Step 1 – Save the calibration data text files listed below in the Labtool executable directory.

- *CalWlanDataFile.txt*
- *PwrTable_Path0.txt*
- *CalBtDataFile.txt*
- *Cal15_4DataFile.txt*(RW612 only)

Step 2 – Set `NO_EEPROM` parameter (`No_EEPROM =2`) in the *SetUp.ini* file to select OTP as calibration data storage type.

Step 3 – Enter command `53` in the Labtool Wi-Fi menu to program the calibration data text files into the OTP.

9 Abbreviations

Table 18. Abbreviations

Abbreviations	Description
BT	Bluetooth
EEPROM	Electrically erasable programmable read only memory
EUI	Extended unique identifier
LNA	Low noise amplifier
OTP	One-time-programmable
VSA	Vector signal analysis
XTAL	Crystal

10 References

[1] User manual – UM11861: NXP 802.15.4 Demo Applications for RW612 (link)

[2] User manual – UM11801: Manufacturing Software User Manual for RW61x (link)

[3] User manual – UM11799: NXP Wi-Fi and Bluetooth Demo Applications for RW61x (link)

11 Note about the source code in the document

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12 Revision history

Table 19. Revision history

Document ID	Release date	Description
AN13639 v.4.0	10 February 2025	• Changed the access to the document to public. • Section 4.4 "Wi-Fi thermal TX power compensation": updated the value of the low power slop parameter to ≤ 12 dBm. • Section 4.4.2 "Labtool setup and command sequence": updated the code sample in step 5. • Section 4.6 "Wi-Fi front-end configuration": – Section 4.6.1 "FEM data entry": added. – Section 4.6.2 "FEM data examples": added. – Section 4.6.3 "Antenna isolation configuration": added. – Section 4.6.3.2 "Examples of antenna isolation configurations": added. • Section 4.7.1 "Initial Bluetooth transmit power": updated. • Section 4.7.2 "Bluetooth TX power class setting": updated the definitions of class 1 and calss 1.5. • Section 4.7.7 "Bluetooth hardware info": updated. • Section 4.8.2 "802.15.4 MAC address": updated. • Section 7.1 "Production firmware": updated the references to other documents. • Section 10 "References": updated.
AN13639 v.3.0	27 August 2024	• Section 4.4.4.1 "Calculating the thermal crystal frequency coefficients": corrected the unit of the frequency error in Table 10. • Section 10 "References": moved the section.
AN13639 v.2.0	4 December 2023	• Reorganized the content • Section 10 "References": updated • Section 4.1 "Frequency calibration": added. • Section 4.2 "Wi-Fi RSSI calibration": updated. • Section 4.3 "Wi-Fi transmit power calibration": – Updated the description of *Temperature* and *PWRLevelBMRF0 through PWRLevelBMRF7*. – Updated Table 5 "Sub-band information" • Section 4.4 "Wi-Fi thermal TX power compensation": added. • Section 4.8 "802.15.4 configuration (RW612 only)": added. • Section 4.9 "Miscellaneous calibration data": added. • Section 5 "Golden calibration data": added. • Section 6 "Converting the calibration data": added. • Section 7 "Using the calibration data": added. • Section 8 "Programming the calibration data into the OTP": added. • Section 9 "Abbreviations": added. • Section 11 "Note about the source code in the document": added.
AN13639 v.1.0	13 May 2022	• Initial version

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