AN12794

IW416 Calibration Structure

Rev. 1 — 1 April 2021 Application note

Document information

Information	Content
Keywords	Frequency calibration, Wi-Fi FE loss, Wi-Fi RSSI calibration, Wi-Fi MAC address, initial Bluetooth transmit power, Force class 2 operation, Bluetooth FE loss
Abstract	Describes the calibration parameters for Wi-Fi and Bluetooth/LE, and details the procedure to update the calibration data

Revision history

Rev	Date	Description
v.1	20210401	Initial version

1 Introduction

This document describes the RF calibration parameters used to tune the carrier frequency, transmit power, received signal strength, front-end control and design specific configuration settings. The document also details the procedure to update the calibration data.

2 Calibration data

Calibration data includes Wi-Fi parameters and Bluetooth/LE configuration parameters.

Wi-Fi parameters:

- Wi-Fi frequency calibration (RFXTAL)
- Wi-Fi RF front-end loss (FE Loss)
- Wi-Fi RSSI calibration (optional)
- RF front-end control settings
- Thermal compensation for transmit power (optional)
- Thermal compensation for RSSI (optional)
- Thermal compensation for crystal

Bluetooth/Bluetooth Low Energy (BLE) configuration parameters:

- Initial Bluetooth transmit power
- Force class 2 operation
- Bluetooth device (BD) address
- Bluetooth RF front-end loss
- Bluetooth frequency calibration (for Bluetooth-only applications)
- Baud rate for UART interface
- Encryption key length

2.1 Wi-Fi sub-bands

Some calibration parameters are tuned across frequency. To facilitate this, the 5 GHz band is divided into multiple sub-bands and some calibration parameters are tuned for each individual sub-band. Table 1 shows the sub-band information.

Note: *Refer to IW416 data sheet for the list of supported Wi-Fi channels.*

Table 1. Wi-Fi sub-bands

Band	Sub-band	Channel range
2.4 GHz	0	1 to 13 (2412 to 2472 MHz)
5 GHz	0	183 to 16 (4915 to 5080 MHz)
	1	36 to 64 (5180 to 5320 MHz)
	2	100 to 144 (5500 to 5720 MHz)
	3	149 to 181 (5745 to 5905 MHz)
	4	68 to 96 (5340 to 5480 MHz)

2.2 Wi-Fi parameters

2.2.1 Frequency calibration

The frequency calibration is used to calibrate the frequency accuracy when an external crystal is used as clock source. Adjust the external crystal compensation (RFXTAL) parameter to fine-tune the frequency error.

2.2.2 Wi-Fi RF front-end loss (FE Loss)

The Wi-Fi FE Loss parameter is used to calibrate the Wi-Fi transmit power. The Wi-Fi FE Loss is adjustable in 0.0625 dB steps. There is one FE Loss parameter for each sub-band.

To increase the Wi-Fi transmit power, increase the value of the Wi-Fi FE Loss parameter. Similarly, to decrease the Wi-Fi transmit power, decrease the value of the Wi-Fi FE Loss parameter.

NXP provides the configuration files with the Wi-Fi FE Loss parameter values based on the characterization of the IW416 reference design. The parameters may be tuned for other board designs.

2.2.3 Wi-Fi RSSI calibration (optional)

The Wi-Fi RSSI calibration parameter is used to calibrate the reported RSSI value. This parameter may be tuned per sub-band, and in 0.5 dB steps.

To increase the reported RSSI value, increase the value of the RSSI calibration parameter. Similarly, to decrease the RSSI value, decrease the value of the RSSI calibration parameter.

NXP provides the configuration files with RSSI calibration parameters based on the characterization of the IW416 reference design. The parameters may be tuned for other board designs.

2.2.4 RF front-end control settings

Wi-Fi calibration data contains control settings for external RF front-end switches and front-end module.

NXP provides the configuration files with RF front-end settings for the RF front-end switches used in IW416 reference design. These settings can be adjusted for other front-end circuits as per board design. Contact your local NXP field application engineer (FAE) for additional information.

2.2.5 Thermal compensation for transmit power, RSSI and crystal (optional)

Thermal compensation is used to improve the transmit power, RSSI and frequency accuracy over the operating temperature range.

NXP provides the configuration files with thermal compensation for transmit power, RSSI and external crystal for IW416 reference design. These settings can be tuned for specific board design. Contact your local NXP FAE for additional information.

2.3 Bluetooth/Bluetooth LE configuration parameters

2.3.1 Initial Bluetooth transmit power

The initial Bluetooth transmit power parameter is used to set the initial Bluetooth transmit power level (in dBm with step size of 1 dB).

2.3.2 Force Class 2 operation

Set the `ForceClass2Op` parameter to force Class 2 operation (maximum 4 dBm output power).

2.3.3 BD address

The `BDAddress` parameter value is a 6-bytes of Bluetooth device address (MAC address for Bluetooth radio). See Table 2 for an example of BD address.

2.3.4 Bluetooth FE loss

The Bluetooth FE Loss parameter is used to tune Bluetooth transmit power (with step size of 0.5 dB). Increasing the FE Loss results in increasing the output power from the device. Similarly, decreasing the FE Loss results in decreasing the output power from the device.

For example:

```
Bluetooth FELoss = 0x5      // Bluetooth FE Loss is 2.5 dB
```

2.4 Calibration data update

The calibration data can be stored in:

- A configuration file
- The on-chip one time programmable (OTP) memory

This section explains how to update the configuration file using the Labtool test application. Figure 1 illustrates the calibration file update procedure.

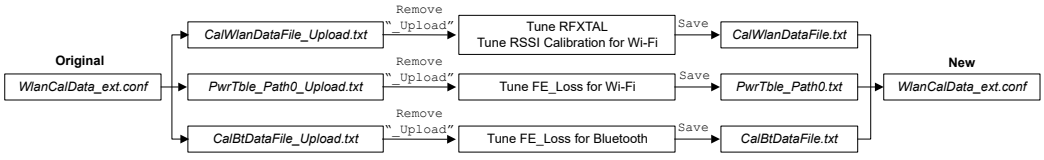

Figure 1. Configuration file update procedure

A calibration data file for each of the IW416 reference designs is available on NXP website under design files packages. The calibration data file has a *.conf* file extension and is referred as *WlanCalData_ext.conf* file. Figure 2 shows the example of RD-IW416-QFN-WIB3-2A-V2 design package content with the *CalibrationData* directory.

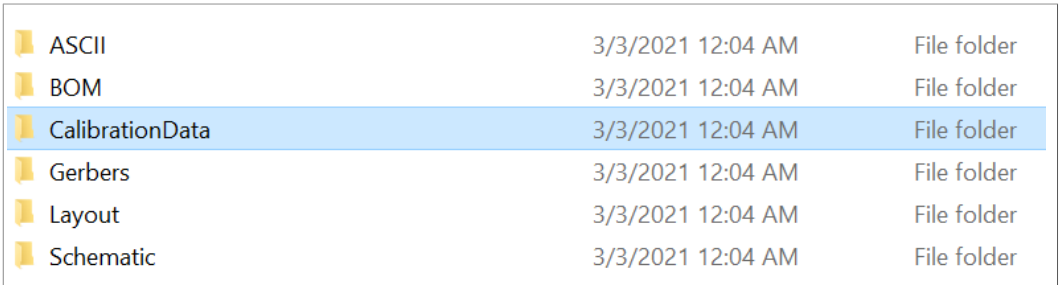

Figure 2. Design package content

Copy the calibration data file from the design package to *Labtool* directory:

1. Identify the calibration data file from the respective IW416 reference design files package on NXP website
2. Copy *WlanCalData_ext_xxx.conf file* file into the *Labtool* directory
3. Rename the file as *WlanCalData_ext.conf*.

Refer to the following steps to update the calibration data.

Step 1 - Open Labtool *SetUp.ini* file

SetUp.ini file is located in *bin/release/labtool* directory. Check that the file includes the following settings:

- NO_EEPROM=1
- NoEepromBtFlexFileName = WlanCalData_ext.conf
- NoEepromWlanFlexFileName = WlanCalData_ext.conf

Step 2 - Look for the calibration data file in *Labtool* directory

Look for *WlanCalData_ext.conf* file in the directory where the Labtool executable is located.

Step 3 - Launch Labtool application

Double click on *DutApiSisoBt.exe* file to start Labtool.

At the command prompt, enter `1` to start testing Wi-Fi radio PHY level RF performance, or enter `2` to start testing Bluetooth radio PHY level RF performance.

Step 4 - Check the firmware and Labtool version numbers

Issue the Labtool command `88` to read back the MFG firmware version. This is to ensure the correct firmware version is used.

Step 5 - Issue the Labtool command `54`

Use the Labtool command `54` to generate the following text files to the directory where the Labtool executable is located:

- *CalBtDataFile_Upload.txt*
- *CalWlanDataFile_Upload.txt*
- *PwrTble_Path0_Upload.txt*

Step 6 - Rename the text files

Rename the three files as:

- *CalBtDataFile.txt*
- *CalWlanDataFile.txt*
- *PwrTble_Path0.txt*

Step 7 - Update the Wi-Fi Calibration parameters

- Frequency calibration parameter (RFXTAL):
  This parameter is stored in *CalWlanDataFile.txt* file under the [Main_Table] section. It is an hexadecimal value. See Figure 3.

```
[Main_Table]
Ref_Design_Type=0x00
Device_ID=0x00
SPI_Size=0x20
Ant_TX=0x01
Ant_RX=0x01
Soc_OR_Rev=0x19
TMP_At_Cal=0x02BE
RFXTAL=0xA0
Region_Code=0x10
MISC_Flag=0x00
TEST_VERSION=0x25881
MFG_VERSION=0x200003E
DLL_VERSION=0x1000036
```

Figure 3. RFXTAL in *CalWlanDataFile.txt* file

- Wi-Fi FE Loss parameters:
  These parameters are in *PwrTble_Path0.txt* file (Figure 4). There is one FE Loss parameter per sub-band. The FE Loss parameters are in the VGA_GAIN column where VGA_OPTION=1 (highlighted in Figure 4). The FE Loss parameters are integer values in step sizes of 0.0625 dB.
  For example the value 28 corresponds to 1.75 dB of front-end loss correction for channel 120 in sub-band 2.

BAND	SubBand	Channel	pwrLvl	VGA_GAIN	VGA_OPTION	POWER_INFO_BW	POWER_INFO_MODUL	DPD_MAX_Code
0	0	6	16	421	0	3	1	255
1	0	16	16	403	0	3	1	255
1	1	48	16	415	0	3	1	255
1	2	120	16	407	0	3	1	255
1	3	157	16	402	0	3	1	255
1	4	80	16	402	0	3	1	255
0	0	6	16	10	1	3	1	255
1	0	16	16	28	1	3	1	255
1	1	48	16	28	1	3	1	255
1	2	120	16	28	1	3	1	255
1	3	157	16	30	1	3	1	255
1	4	80	16	28	1	3	1	255

Figure 4. Wi-Fi FE Loss in *PwrTble_Path0.txt* file

- Wi-Fi RSSI compensation parameters:
  These parameters are stored in *CalWlanDatafile.txt* file under the [RSSI_CAL] section.
  The RSSI compensation parameters are per sub-band.
  The “RSSI_CAL_5G_SUBBANDx_REGULAR_Pathy” -where x is the sub-band- or “RSSI_CAL_2G_REGULAR_Pathy” -where y is the path number. See Figure 5.
  The value of “RSSI_CAL_5G_SUBBANDx_LOW_GAIN_Pathy” or “RSSI_CAL_2G_LOW_GAIN_Pathy” are the same as the “REGULAR” value. The parameter is expressed as hexadecimal values in step sizes of 0.5 dB.
  For example the value 0x04 corresponds to 2 dB.

```
[RSSI_CAL]
RSSI_CAL_Path0_Entries=6
RSSI_CAL_2G_LOW_GAIN_Path0=0x02
RSSI_CAL_2G_REGULAR_Path0=0x02
RSSI_CAL_2G_INFO_Path0=0xFF
RSSI_CAL_5G_SUBBAND0_LOW_GAIN_Path0=0x08
RSSI_CAL_5G_SUBBAND0_REGULAR_Path0=0x08
RSSI_CAL_5G_SUBBAND0_INFO_Path0=0xFF
RSSI_CAL_5G_SUBBAND1_LOW_GAIN_Path0=0x09
RSSI_CAL_5G_SUBBAND1_REGULAR_Path0=0x06
RSSI_CAL_5G_SUBBAND1_INFO_Path0=0xFF
RSSI_CAL_5G_SUBBAND2_LOW_GAIN_Path0=0x04
RSSI_CAL_5G_SUBBAND2_REGULAR_Path0=0x04
RSSI_CAL_5G_SUBBAND2_INFO_Path0=0xFF
RSSI_CAL_5G_SUBBAND3_LOW_GAIN_Path0=0x06
RSSI_CAL_5G_SUBBAND3_REGULAR_Path0=0x06
RSSI_CAL_5G_SUBBAND3_INFO_Path0=0xFF
RSSI_CAL_5G_SUBBAND4_LOW_GAIN_Path0=0x06
RSSI_CAL_5G_SUBBAND4_REGULAR_Path0=0x06
RSSI_CAL_5G_SUBBAND4_INFO_Path0=0xFF
```

Figure 5. RSSI Calibration value in *CalWlanDatafile.txt* file

Step 8 - Update the Bluetooth calibration data parameters:

The parameters are in *CalBtDatafile.txt* file under the [BT_Config] section. Figure 6 shows the Bluetooth calibration data parameters.

```
[BT_Config]
ANNEX56_EXIST=0
Version=0x1
Xtal=0xa0
InitPwrIndBm_Pwr=4
FELoss=0x2
ForceClass2Op=0
DisablePwrControl=0
MiscFlag=0
UsedInternalSleepClock=1
RssiGoldenRangeLow=0x0
RssiGoldenRangeHigh=0x0
UartBaudRate=3000000
BdAddress=11.22.33.44.55.66
MinEncrKeyLen=0x0
MaxEncrKeyLen=0xf
```

Figure 6. Bluetooth/Bluetooth LE configuration in *CalBtDatafile.txt* file

Table 2 shows the Bluetooth configuration parameters.

Table 2. Bluetooth/Bluetooth LE configuration parameters

Parameter	Description
`InitPwrIndBm_Pwr`	Initial Bluetooth transmit power level Integer value (dBm) For example value `0x4` means 4 dBm initial Bluetooth transmit power level.
`FELoss`	Bluetooth FE Loss Hexadecimal (dB) in steps of 0.5 dB For example value 0x2 means 1 dB FE Loss.
`ForceClass2Op`	Force Class 2 operation Set to 1 to force Class 2 operation. Maximum 4 dBm Tx power.
`BdAddress`	Bluetooth Device address For example `BdAddress=11.22.33.44.55.66`

Step 9 - Save all files

Save all the changes in the edited files.

Step 10 - Rename *WlanCalData_ext.conf* file

Rename the existing *WlanCalData_ext.conf* file from step 2 as *WlanCalData_ext.conf.orig*.

Step 11 - Issue Labtool command `53`

Issue the Labtool command `53` to upload the text files and generate a new *WlanCalData_ext.conf* file. This file includes the changed parameters.

Step 12 - Power cycle the device and re-launch Labtool

Power cycle the wireless SoC, re-launch Labtool, issue CMD `22` in Wi-Fi menu to load a new configuration file.

3 Acronyms and abbreviations

Table 3. Abbreviations and abbreviations

Acronym	Description
BD	Bluetooth Device
EEPROM	Electronically Erasable Programmable Read Only Memory
FE	Front End
LE	Low Energy
MAC	Medium/Medium Access Controller
MFG	Manufacturing
NVRAM	Non-Volatile Random Access Memory
OTP	One Time Programmable
PCB	Printed Circuit Board
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
Rx	Receive
SoC	System-on-Chip
Tx	Transmit
WLAN	Wireless Local Area Network
XTAL	Crystal

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