PIC32CX-BZ2 Calibration User's Guide

Introduction

This user guide describes the test setup and the list of calibrations required to be performed on the DUT (Device Under Test) PIC32CX-BZ2 device before running an RF test either during prototype validation or in a production test line.

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1. Quick References

1.1 Hardware Prerequisites

- External Programmer/Debugger – MPLAB® ICD 4 In-Circuit Debugger to Flash HUT firmware
- USB to UART converter (MCP2200 Breakout Board or equivalent)

1.2 Software Requirements

- MPLAB Integrated Programming Environment (IPE) – To flash the firmware to the DUT
- Test Tool Package:
  - MCHPRT3 Microchip Radio Testing Tool:
    - MCHPRT3 tool supports many devices including PIC32CX-BZ2
    - MCHPRT3 tool package consists of:
      - PIC32CX-BZ2 HUT Firmware
      - MCHPRT3 GUI
      - MCHPRT3 CLI
      - MCHPRT3 DLL

    Note: It is recommended that the MCHPR3 GUI be used for manual testing and the MCHPRT3 CLI/DLL for an automated test.

1.3 Acronyms and Abbreviations

Table 1-1. Acronyms/Abbreviations

Acronyms/Abbreviations	Description
API	Application Programming Interface
CLI	Command Line Interface
DLL	Dynamic Link Library
DUT	Device Under Test
ED	Energy Detect
GUI	Graphical User Interface
HUT	Hardware Under Test
IB	Information Block
IC	Integrated Circuit
IRR	Image Rejection Ratio
LPA	Low Power Amplifier
MCHPRT3	Microchip Radio Test Tool 3rd Generation
MPA	Medium Power Amplifier
OTP	One Time Programmable
PCB	Printed Circuit Board
PMU	Power Management Unit

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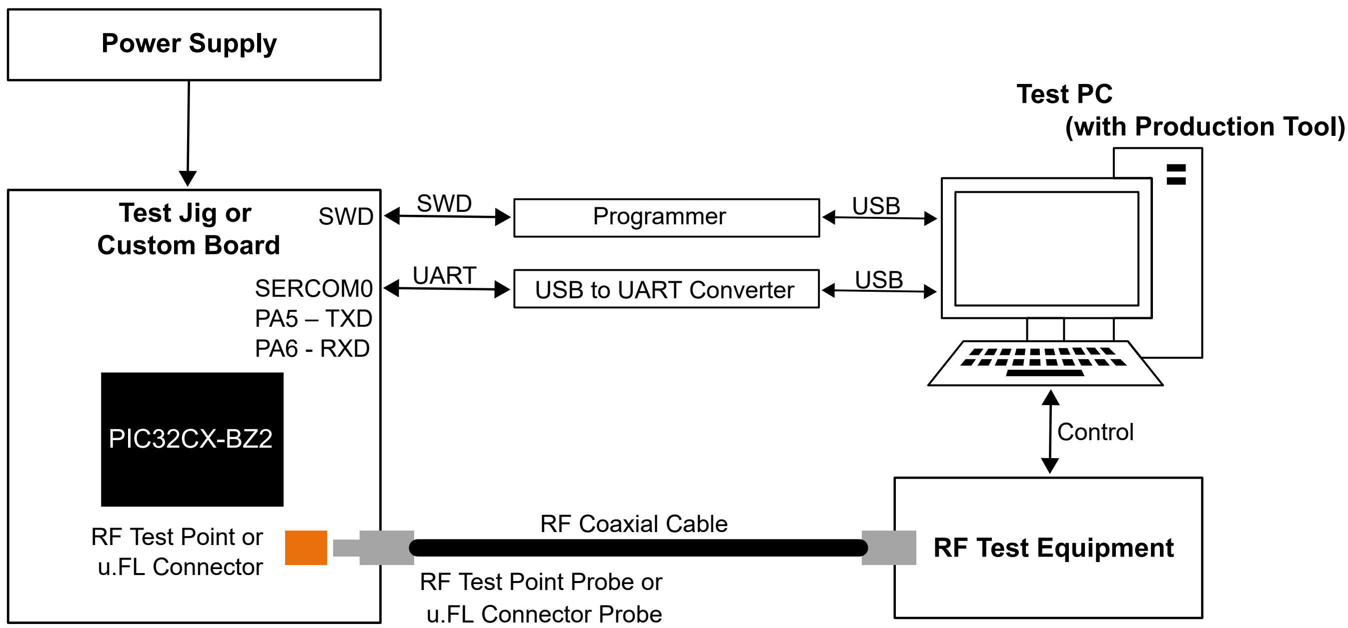
Acronyms/Abbreviations	Description
RF	Radio Frequency
RX	Receiver
SAR	Successive Approximation Register
SWD	Serial Wire Debug
TPC	Transmit Power Control
TX	Transmitter
UART	Universal Asynchronous Receiver-Transmitter
USB	Universal Serial Bus
VTA	Voltage Adjustment

2. Test Setup

The following figure illustrates the reference test setup.

Figure 2-1. Test Setup

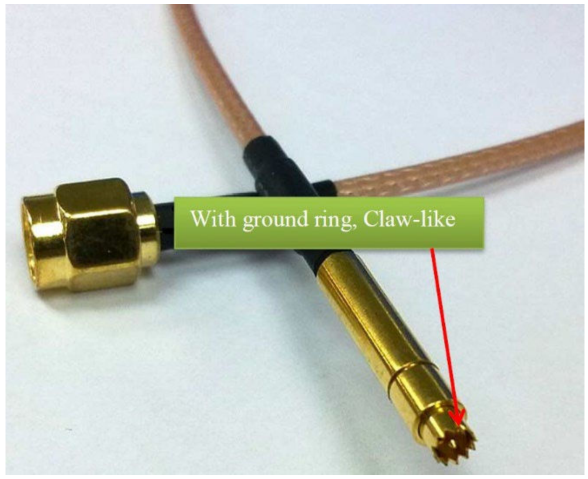


- **Test Jig or Custom Board:**
  PCB designed with the PIC32CX-BZ2 can be directly interfaced to the Test PC and RF test equipment. The user can also design their own test jig that interconnects the DUT to the PC and the RF Test equipment. Refer to the *PIC32CX-BZ2 based module - WBZ451/WBZ450 Curiosity Board* for the I/O interface to develop a test jig.
- **Programming and Control Interface:**
  PCB designed with the PIC32CX-BZ2 must have the following interfaces to connect to the PC:
  - SWD (for firmware programming).
  - SERCOM0 (PA5-TXD and PA6-RXD) UART interface to connect the DUT to the test tool on the PC, to control the test mode of the device
- **RF Test Interface:**
  The type of interface to the DUT for RF testing can determine the accuracy and repeatability of the measurements. Ensure the right RF test interface is used with the DUT because of the sensitivity of these signals.

  For example, a product with a 50Ω terminated Sub-miniature Type A (SMA) or u.FL connector populated on the board can be connected directly to a coaxial cable with a known loss. Repeatability in this scenario is very good.

  Another example is a product with an embedded antenna that is designed with test points for RF and ground that can be connected with an RF probe with ground ring as shown in the following figure.

Figure 2-2. RF Probe with Ground Ring



The path loss from the RF test point to the cabled connections of the setup needs to be calibrated, and, also, the path loss for the test fixture due to the radiating antenna loading might be calibrated to determine accurate performance. Place a ground metal plate close to the device antenna to detune the antenna and/or open circuit the antenna to improve the power measurement accuracy in the case of a board with an embedded antenna.

The repeatability of this setup is dependent on the board layout. The RF and ground signals should have test points in close proximity to one another. The repeatability is also more dependent on the shielded enclosure in this case because the RF signal is exposed at the test point and radiating through the antenna rather than enclosed within an SMA or u.FL connector as in the first example.

- **Test Equipment:**
  Bluetooth® Low Energy and Zigbee tester like LitePoint® IQxel
- **Production Test Tool:**
  Use the MCHPRT3 GUI during the initial prototype validation. For production, develop the test script based on the MCHPRT3 CLI or DLL.
- **Programmer:**
  ICD4 programmer/debugger to flash the device
- **Power Supply:**
  To provide the required supply to the test jig or a custom board designed with the PIC32CX-BZ2 device

3. HUT Firmware Download

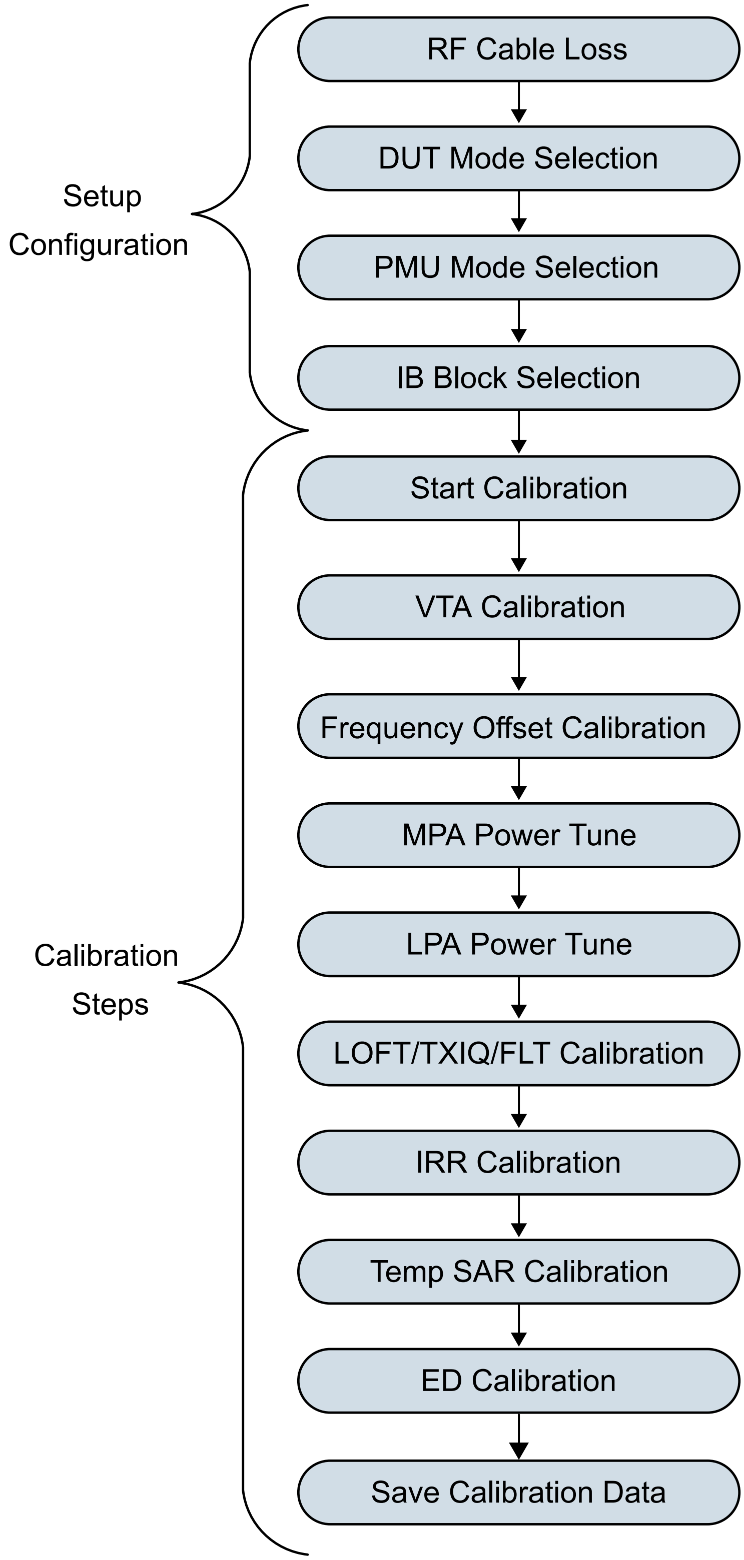
Before running the calibration steps, flash the PIC32CX-BZ2 HUT firmware into the DUT using MPLAB X IPE.

Note: The PIC32CX-BZ2 HUT firmware is included in the MCHPRT3 Radio Test Tool package.

4. Calibration Flow Sequence

The calibration sequence is mandatory to be same as follows:

Figure 4-1. Calibration Flow Sequence



4.1 RF Coaxial Cable Loss

Before running the calibration, estimate the cable loss of the RF co-axial cable and RF test point/probe, or u.FL probe loss by testing.

4.2 DUT Mode Selection

The PIC32CX-BZ2 has both MPA and LPA RF output. Select the appropriate mode (LPA Only or MPA+LPA) based on the PIC32CX-BZ2 silicon variant used in the design before running the calibration. For the selection of mode, refer to the Table 4-1 and Table 4-2.

4.3 PMU Mode Selection

The PIC32CX-BZ2 PMU operates in two modes:

- Buck mode
- MLDO mode

The MLDO mode is the preferred mode for calibration.

4.4 Information Block (IB) Selection

The Information Block (IB) is used to store all the calibration and system configuration information.

The calibration parameters can be stored in either Flash memory or OTP memory:

- As the OTP memory is not sufficient, consider using Flash memory during initial prototype validation because it allows for multiple rewrites. Finally, when all of the testing is complete, save the calibration to the OTP memory.
  Note: The IB content stored in the Flash will be erased when programming another firmware.
- Use OTP memory to store the calibration parameter during production.

4.5 Calibration Test

4.5.1 Start Calibration

While starting the calibration, the MCHPRT3 DLL/HUT firmware performs the VCO calibration automatically.

4.5.2 VTA Calibration

VTA calibration is a Voltage Adjustment of searching a minimum voltage setting of PLL circuit that can detect PLL is locked internally. The purpose of this calibration is to save current consumption with PLL lock assurance minimum voltage.

The user needs to initiate this test and wait for completion. The algorithm inside the MCHPRT3 DLL/HUT firmware performs the calibration automatically.

4.5.3 Frequency Offset Calibration

By initiating this test, the PIC32CX-BZ2 DUT will transmit Bluetooth Low Energy packets at 2440 MHz. The user or the production tool has to check the carrier frequency measured by the RF test equipment and fine tune the transmit frequency until the measured carrier frequency offset is minimal.

Note: This fine tuning is intended for only correcting the frequency offset due to the process variation of crystal and IC. During prototype validation, the user has to validate the frequency offset and adjust the external crystal load capacitance to optimal values.

4.5.4 MPA Power Tune

MPA support is available in two variants for the PIC32CX-BZ2 device as detailed in the following table. The following table also lists the maximum MPA TX power and calibration target power.

Note: For higher accuracy in power control, the MPA target power is set at +8 dBm ±0.5 dB. In contrast, the maximum MPA transmit power of the device is still+12 dBm.

Table 4-1. MPA Power Tune

Device	MPA	MPA Max. TX power	Calibration Target Power
PIC32CX1012BZ25048	Yes	+12 dBm ±0.5 dB	+8 dBm ±0.5 dB

Initiate this test. Then, read the power level in the RF test equipment. Then, feed the measured power back to the test tool (MCHPRT3 DLL/HUT firmware). Then, re-initiate the power measurement/update until the power level reaches the target power.

4.5.5 LPA Power Tune

The maximum LPA TX power and calibration target power is detailed in the following table.

Table 4-2. LPA Power Tune

Device	LPA	LPA Max. TX Power	Calibration Target Power
PIC32CX1012BZ25048	Yes	+4 dBm ±0.5 dB	Same as LPA maximum TX Power

Initiate this test. Then, read the power level in the RF test equipment. Then, feed the measured power back to the test tool (MCHPRT3 DLL/HUT firmware). Then, feed the MPA power tune instruction until the power level reaches the target power.

4.5.6 LOFT/TXIQ/FLT Calibration

- LOFT – Local Oscillator Feed Through calibration
- TXIQ – TX path IQ imbalance correction
- FLT – Bandwidth and Center frequency adjustment of the TX and RX filter

The user does this to initiate this test and waits for completion. The algorithm inside the HUT firmware performs the calibration automatically.

4.5.7 IRR Calibration

Perform the Image Rejection Ratio Calibration (IRR) as per the following steps.

Note: The test may end in-between and the IRR Cal Done might appear early if the device finds a calibration in a fewer number of loops.

- Initiate the IRR calibration test.
- Generate the 2440 MHz CW tone with the power level of -75 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -75 Loop Test 1**.
- Generate the 2436 MHz CW tone with the power level of -50 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -50 Loop Test 1**.
- Generate the 2440 MHz CW tone with the power level of -75 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -75 Loop Test 2**.
- Generate the 2436 MHz CW tone with the power level of -50 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -50 Loop Test 2**.
- Generate the 2440 MHz CW tone with the power level of -75 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -75 Loop Test 3**.
- Generate the 2436 MHz CW tone with the power level of -50 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -50 Loop Test 3**.
- Generate the 2440 MHz CW tone with the power level of -75 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -75 Loop Test 4**.
- Generate the 2436 MHz CW tone with the power level of -50 dBm from the RF test equipment and feed it to the DUT and then initiate the **IRR -50 Loop Test 4**.
- Initiate IRR Cal. Done instruction.

The four iterations are for calibrating the IRR for different duty cycle configurations. After every test iteration, check if the test code returns PASS or FAIL. If it returns PASS, consider the IRR test complete. If FAIL, go for the next test iteration in the Test 1-4. While finishing these four iterations of the IRR calibration test, the MCHPRT3 DLL/HUT FW calculates the IRR calibration settings.

4.5.8 Temperature SAR Calibration

This is to calibrate the temperature sensor and the SAR ADC used to read the internal temperature sensor.

Note: This internal temperature sensor is used only for the Transmit Power Control (TPC) feature and is not accessible for external application use cases.

The user needs to initiate this test and wait for completion. The algorithm inside the HUT firmware does the calibration automatically.

4.5.9 Energy Detect Calibration

Generate the CW tone at 2440 MHz with a power level of -70 dBm from the RF test equipment and feed it to DUT. Then, initiate the Energy Detect (ED) Calibration test.

4.5.10 Save Calibration Data

At the end of the calibration, the calibration data has to be committed to a Flash/OTP Information Block.

5. Document Revision History

Revision	Date	Section	Description
A	08/2022	Document	Initial revision

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