This document provides an easy guide for evaluating the TRF2443 integrated IF transceiver for broadband wireless applications. Included in this guide are equipment setup procedures, software GUI configurations, and test procedures that allow a user to quickly and accurately measure the TRF2443 performance.

The TRF2443 is a fully integrated IF transceiver operating at a transmitter IF of 340 MHz (or 170 MHz) and a receiver IF of 140 MHz (or 280 MHz). The IF transceiver is used to for up-conversion of signals from the transmit chain digital-to-analog convertor (DAC) to the RF upconverter device and for down-conversion of received IF signals to baseband for processing by the analog-to-digital convertor (ADC). The receiver allows for switching in an external SAW filter if needed or by-passing this filter and processing the signal completely internally. The TRF2443 also provides an Auxiliary Receiver which can be used for cross-polarization interference cancellation (XPIC). This document describes how to test the TRF2443 as well as the many options for trimming the device configuration to meet your application needs.

![Figure 1. TRF2443 Block Diagram](image-url)
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1 EVM Circuit Overview

1.1 DC POWER

The TRF2443 EVM requires a 3.3V dc power-supply connected to between J1 (3.3V) and J2 (GND). The TRF2443 allows for analog or digital control of the transmitter power supply. Pin 1 (TXPWD) of the device provides the analog control and is connected to header JP1 (TXPWD) on the EVM. When pins 1 and 2 of header JP1 are shorted, 3.3V is fed to the TXPWD pin and the transmitter is disabled. When pins 2 and 3 of header JP1 are shorted, 0V is fed to the TXPWD pin and the transmitter is enabled (see Figure 2 and Figure 3). With header JP1 enabling the transmitter, it is still possible for the transmitter to be off due to the state of the digital TX control.

![Figure 2. TXPWD Header JP1 Schematic](image)

![Figure 3. EVM DC Power: J1, J2, and JP1](image)
1.2 **Reference Clock**

The TRF2443 EVM allows for either an external reference chosen by the user or an internal oscillator at 20 MHz provided on the EVM board. If an external reference is to be used the signal should be fed into SMA connector J3 (EXTREF) and jumpers W1 and W12 should be removed (see Figure 4).

![Figure 4. EVM Reference Clock J3 and USB Port J5](image)

1.3 **Communications**

The EVM is equipped with USB communications which provide the interface between a computer’s USB port and the TRF2443s SPI port via J5 as shown in Figure 4. A CD containing the GUI to control the TRF2443 is provided within the EVM kit. An overview of the GUI is provided in this document.

1.4 **Transmitter**

The EVM is configured for differential I/Q input signals via four SMA connectors. For the upper sideband, the I signals are connected to J12 (TXBBIP) and J17 (TXBBIN). The Q signals are connected to J23 (TXBBQN) and J20 (TXBBQP) (see Figure 5). SMA connector J6 (TXOUT), not shown below, is used to monitor the RF output signal from the transmitter.
1.5 Receiver

The EVM is configured for single ended RX input signal via SMA connector J7 (RXIN). This input is taken through a 1:1 balun to provide differential inputs to the device. The device presents 50 Ω so no external termination resistor is required.

Figure 5. TX Baseband Inputs

Figure 6. J7 (RXIN)
The baseband I/Q signals can be measured balanced or unbalanced. The I output is taken from the unbalanced port J15 (RXBBI) through balun T5 or from the balanced ports of J13 (I+) and J18 (I-). Likewise, the Q output is taken from the unbalanced port J24 (RXBBQ) through balun T7 or the balanced ports of J21 (Q+) and J26 (Q-). For balanced mode measurements, jumpers W3, W5, W7 and W9 must be removed.

Figure 7. RX Baseband Outputs
The TRF2443 RX path allows the use of an external SAW filter. An internal switch, which is programmable through the serial interface, gives the flexibility to utilize the external filter (see Figure 1). The internal switch is controlled via the serial programming interface through bit EN_SAW. By programming EN_SAW to 1, the external path is selected, whereas a 0 engages the internal bypass switch. When EN_SAW is set to 1 the IF signal will be routed out of the IC to SMA connector J30 (IFOUT) (see Figure 8). At this point, the user has the flexibility to insert a filter of choice outside the TRF2443 EVM. (The board does contain a place holder (FL1) for a SAW filter but is not populated. In this way, the user has the flexibility to use a filter of his choice). For initial evaluation, an 8-10 dB pad can be used in lieu of a filter to emulate the insertion loss of a typical filter. The user must route the signal from J30 (IFOUT) to J31 (IFIN) with the filter or pad included.

Figure 8. SAW Filter Path
1.6 **XPIC Receiver**

The TRF2443 provides an auxiliary receiver chain that can be used for cross-polarization interference cancellation purposes. The EVM is configured for a single-ended output signal (intended for the secondary XPIC RX path) at J33 (XPICOUT). The input to the XPIC receiver (from the XPICOUT of the secondary XPIC RX path) is available at SMA connector J32 (XPICIN). This input is taken through a 1:1.5 balun to provide differential inputs to the device. The device presents 75 ohms so no external termination resistor is required. The XPIC baseband I and Q signals can be measured balanced or unbalanced. The I output is taken from the unbalanced port J16 (XPICI) through balun T6 or from the balanced ports of J14 (I+) and J19 (I-). Likewise, the Q output is taken from the unbalanced port J25 (XPICQ) through balun T8 or the balanced ports of J22 (Q+) and J27 (Q-). For balanced mode measurements, jumpers W4, W6, W8, and W10 must be removed (see Figure 9).

![XPIC RX](image-url)
GUI Overview

The TRF2443 EVM kit includes a graphical user interface for controlling the device. The GUI contains two tabs labeled "Quick-set" and "Advanced" (see Figure 10 and Figure 11).

Figure 10. TRF2443 GUI Quick-Set Tab
Evaluation and testing of the device can be done entirely using on the "Quick-set" tab. The "Advanced" tab is used for debugging and specific optimization of the device if required by an application. Using the "Advanced" tab without an understanding of what is being controlled can result in an unrecoverable state of the IC whereby a power reset would be required.
When an input to the GUI is changed, the GUI should send this new value to the device automatically once the cursor has clicked on another field besides the field being changed. It is good practice, however, to reload all registers once changes to inputs have been made. This can be achieved by clicking on the "OFF" button below "Load All" in the bottom right corner of the GUI (see Figure 12).

![Load All Registers](image1)

**Figure 12. Load All Registers**

If there is ever a doubt as to the integrity of the communications between the GUI and the device, a USB reset is in order. Press the Reset USB button near the top left corner of the GUI and then reload all registers again (see Figure 13).

![Reset USB](image2)

**Figure 13. Reset USB**

An explanation of all the fields within the Quick-set tab is provided by device functionality beginning with the synthesizers.

### 2.1 GUI for Synthesizers

The TX and RX synthesizers are controlled using the group of dialog boxes under "Quick-Synth" (see Figure 14).

![Synthesizer Programming](image3)

**Figure 14. Synthesizer Programming**
**Ref Freq [MHz]**
Specify the reference frequency being provided to the EVM. If the on-board oscillator is used, this will be 20MHz. If an external oscillator is to be used, specify its frequency in this field.

**TX VCO [MHz]**
This field is a calculation based on the other inputs provided. The TX VCO is guaranteed to operate between 2640MHz and 2800MHz.

**TX Freq. [MHz]**
The TX LO Frequency can be programmed to a frequency within the TX Synth Range selected previously. Entering a value outside of this range is not permitted and will default to the closest value within this range. When TX Freq. is specified, the corresponding TX VCO will be calculated.

**PFD_TX [MHz]**
Specify the channel resolution desired of the LO by selecting the PFD frequency. Note that the PLL loop filters are optimized for a PFD frequency of 20MHz. Deviating from 20MHz will impact the phase noise of the system.

**RX VCO [MHz]**
This field is a calculation based on the other inputs provided. The RX VCO is guaranteed to operate between 2240MHz and 2640MHz.

**RX Freq. [MHz]**
The RX LO Frequency can be programmed to a frequency within the RX Synth Range selected previously. Entering a value outside of this range is not permitted and will default to the closest value within this range. When RX Freq. is specified, the corresponding RX VCO will be calculated.

**PFD_RX [MHz]**
Specify the channel resolution desired of the LO by selecting the PFD frequency. Note that the PLL loop filters on the EVM are optimized for a PFD frequency of 20MHz. Deviating from 20MHz will impact the stability and phase noise of the system.

**T/RX Cal Enable**
Toggling this invokes a calibration of the RX and TX PLLs and initiates locking the synthesizers. This field must be toggled ON in order to lock the synthesizers. Loading all registers using the button on the bottom right corner of the GUI does not perform this task.

**TX Synth Range**
The TRF2443 transmitter LO can be programmed to a frequency between 165–175MHz or 330–350MHz. Select the range that covers the desired to program the appropriate dividers.

**RX Synth Range**
The TRF2243 receiver LO can be programmed to a frequency between 140–165MHz or 280–330MHz. Select the range that covers the desired application to program the appropriate dividers.
2.2 GUI for Receiver

The TRF2243 receiver is controlled using the group of dialog boxes to the left half of the Quick-TRX section (see Figure 15).

![Figure 15. RX GUI](image)

**LNA Attn [dB]**
Specifies the LNA attenuation desired in dB.

**Enable SAW**
Specifies whether the external SAW filter path or the internal bypass path is used for the receiver.

**RX BB Gain Set**
Specifies the gain setting for the RX baseband section. The value entered here is a gain setting and not gain in dB. This value is 9 dB less than the actual gain (i.e., enter 0 for 9dB of gain; enter 24 for 33dB of gain on the RX baseband).

**RX DC Offset En**
Toggling this button invokes a DC offset calibration of the RX baseband circuitry. This is recommended after changing the RX BB Gain.

**RX LPF Bypass**
Specify whether to bypass the internal low pass filter or not.

**LPF BW Adj**
If RX LPF Bypass is OFF then the low pass filter is enabled and its corner frequency can be programmed to any of 128 states specified to cover 2 MHz to 11MHz corner frequency [see TRF2443 datasheet for detailed explanation (SLWS217)]

**RX BB 3dB Attn**
Specify whether to enable a 3 dB attenuator at the output of the device. This can be used to tradeoff noise and IP3 in some configurations.

**RX AGC**
The analog gain control of the receiver chain is located in the upper right corner of the GUI and is in mV (see Figure 16).

![Figure 16. RX AGC GUI](image)
2.3 **GUI Transmitter**

Control of the transmitter is located in the second column within the Quick-TRX section (see Figure 17).

![Figure 17. Transmitter GUI](image)

**TX Attn [dB]**

Controls the attenuation from maximum gain of the transmitter chain.

**T/RX Loopback**

Enables the path for looping back the TX signal into the receiver with a 0 dB loss or a 20 dB loss in the path depending on selection. This can be used for calibrating the RX baseband low pass filter corner frequency or calibrating the TX modulator LO leakage calibration [see TRF2443 datasheet for detailed explanation (SLWS217)].

2.4 **GUI for XPIC Receiver**

Control of the XPIC receiver is located in the second column within the Quick-TRX section (see Figure 18).

![Figure 18. XPIC Receiver GUI](image)

**XPIC BB Gain [dB]**

Specifies the gain setting for the XPIC RX baseband section. The value entered here is a gain setting and not gain in dB. This value is 9 dB less than the actual gain (i.e., enter 0 for 9dB of gain or enter 5 for 14dB of gain).

**XPIC DC Offset En**

Toggling this button invokes a DC offset calibration of the XPIC RX baseband circuitry. This is recommended after changed the XPIC BB Gain.

**RX AGC**

The analog gain control of the XPIC receiver chain is located in the upper right corner of the GUI and is in mV (see Figure 19).

![Figure 19. XPIC AGC GUI](image)
TRF2443 EVM Operating Procedures

This section will outline step by step the procedures necessary to test the following functions of the TRF2443:

3.1 Power Up

a. Initial ICC
   i. Apply 3.3V DC between J1 and J2 connections on board.
   ii. Approximately 760mA should be drawn from the power supply.

b. Programmed ICC
   i. Apply reference clock either externally or using on board oscillator (see section Reference Clock)
   ii. Apply USB connection between computer with loaded GUI and USB port J5 on the EVM and press the Reset USB button in the upper left corner of the GUI.
   iii. Change the GUI inputs as shown in Figure 20.

iv. Load all registers by pressing the OFF button below Load All in the bottom right corner of the GUI to load all registers to the device (see Figure 21).

v. Toggle the T/Rx Cal Enable button to lock the synthesizers.

vi. Approximately 1070mA of current should be drawn from the power supply with this device configuration.
3.2 Receiver

a. SAW path disabled
   i. Program GUI as shown in Figure 22.
   ii. Toggle the T/Rx Cal Enable button to lock the synthesizers.

iii. Apply CW signal to J7-RXIN port at 140.1MHz, -88dBm.
iv. Measure output on spectrum analyzer at J15 (RXBBI) or J24 (RXBBQ) at 100kHz.
v. In this configuration, the chip typically shows about 84dB gain. Therefore, one should typically see
   -4dBm at the output of the TRF2443. However, transformers T5 and T7 at the RX baseband
   outputs transform 800-ohms to 50-ohms resulting in a 12dB loss factor. There is an additional 1-dB
   of losses in the path. Therefore, -4dBm at the output of the TRF2443 will be -17dBm at the 50-ohm
   input of the spectrum analyzer. Gain is calculated as Power at the spectrum analyzer + 13dB - Pin.

Figure 22. Receiver SAW Disabled GUI Settings

v. In this configuration, the chip typically shows about 84dB gain. Therefore, one should typically see
   -4dBm at the output of the TRF2443. However, transformers T5 and T7 at the RX baseband
   outputs transform 800-ohms to 50-ohms resulting in a 12dB loss factor. There is an additional 1-dB
   of losses in the path. Therefore, -4dBm at the output of the TRF2443 will be -17dBm at the 50-ohm
   input of the spectrum analyzer. Gain is calculated as Power at the spectrum analyzer + 13dB - Pin.
2. SAW path enabled
   i. Configure EVM with a cable connecting J30 (IFOUT) to J31 (IFIN). Insert a SAW filter or a 10dB pad if desired (see Section 1.5).
   ii. Program GUI as shown in Figure 23.
   iii. Toggle the T/Rx Cal Enable button to lock the synthesizers.

![Figure 23. Receiver SAW Enabled GUI Settings](image)

iv. Apply CW signal to J7(RXIN) port at 140.1MHz, -90dBm.

v. Measure output on spectrum analyzer at J15(RXBBI) or J24(RXBBQ) at 100kHz.

vi. In this configuration, the chip typically shows about 86dB gain. Therefore, one should typically see -4dBm at the output of the TRF2443. However, transformers T5 and T7 at the RX baseband outputs transform 800-Ω to 50-Ω resulting in a 12dB loss factor. There is an additional 1-dB of losses in the path. Therefore, -4dBm at the output of the TRF2443 will be -17dBm at the 50-Ω input of the spectrum analyzer. Gain is calculated as Power at the spectrum analyzer + 13dB - Pin.

3.3 XPICOUT Amplifier
   a. GAIN
      i. Program GUI as shown in Figure 24.
      ii. Toggle the T/Rx Cal Enable button to lock the synthesizers.
3.4 Transmitter

a. GAIN
   i. Program GUI as shown in Figure 25.
   ii. Toggle the T/Rx Cal Enable button to lock the synthesizers.

iii. Using a DAC or Arbitrary Waveform generator to create IQ baseband signals, apply IQ signals to J23 (TXBBQN), J20 (TXBBQP), J17 (TXBBIN), J12 (TXBBIP). Set instrument to 50-Ω output impedance. Each of the four IQ signals should be 1MHz, -16dBm (corresponding to -13dBm differentially on 100-Ω differentially, or, -23dBVrms-diff.)

iv. Measure output on spectrum analyzer at J6 (TXOUT) at 341MHz. The chip typically shows 4dBm
output power.

b. GAIN RANGE

i. Change the TX ATTN [dB] setting in the GUI to determine that the output power is dropping approximately 1.0 every 2nd step.

3.5 EEPROM

a. The purpose of this section is to Readback EEPROM content and verify EEPROM contains the stored trim values to optimize TX Carrier leakage. See TRF2443 EEPROM User's Guide for detailed explanation of the EEPROM within the TRF2443 (SLWU064).

i. Program GUI as shown in Figure 26.

![Figure 26. GUI Settings for TX Carrier Leakage](image)

ii. At bottom of GUI on Quick-set page, click on Show Readback Button as shown in Figure 27.

![Figure 27. GUI Show Readback](image)

iii. Set the RdBk Reg field to EEPROM and click the Readback Button.

iv. The contents of EEPROM register 1 and 2 will be shown as is evident by the first five address bits (LSB) to the left as shown in Figure 28.

![Figure 28. GUI Select EEPROM Readback](image)

v. The data from REG 1<10,5> is Q-trim data and from REG2<10,5> is the I-trim data. One can scroll to bit 5 by using the bottom scroll dialog box as shown in Figure 29 below.
vi. Record the decimal equivalent of REG 1<10,5> as the Q-trim data and the decimal equivalent of REG2<10,5> as the I-trim data (in this example I=45 and Q=2).

vii. The two decimal trim values obtained above must be translated. If the decimal value is between 0 and 31, no translation is necessary and the decimal value is the value needed for the subsequent operation. However, if the decimal value is between 32 and 63, translate the value by 31 - Decimal Trim Value (ie. in this example, I=-14 and Q=2).

viii. Click the Advanced tab at the top of the GUI. The second subsection of the first column contains two fields called TX DC OFFSET I and TX DC OFFSET Q. Set these two fields to the corresponding values that were translated in the previous step. Figure 30 shows a value of -14 for the I-trim value and 2 for the Q-trim value. Determine that the data has been written to the device by clicking the mouse in some other field other than these two fields.

ix. With the input signal setup as in 4.a.iii, measure the carrier leakage at SMA connector J6 (TXOUT). The typical value should be lower than -40dBm.

3.6 XPIC RECEIVER

a. GAIN Max
   i. Program GUI as shown in Figure 31.
   ii. Toggle the T/Rx Cal Enable button to lock the synthesizers.
iii. Apply CW signal to J32 (XPICIN) of 140.1 MHz, -32dBm.
iv. Measure output at 100kHz at J16 (XPICI) or J25 (XPICQ) on a spectrum analyzer.
v. Calculate Gain = (Pout at spectrum analyzer + 13) - Pin. Typical gain value should be greater than 25dB.

b. MIN GAIN
i. Change XPIC AGC voltage from 700mV to 0mV as shown in Figure 32.

ii. Adjust Pin until -17dBm is measured on output spectrum analyzer.
iii. Calculate Gain = (Pout at spectrum analyzer +13) - Pin. Typical value should be around 4dB.
4 Physical Description

4.1 EVM Top Layer Drawing

Figure 33. TRF2443 EVM Top Layer
4.2 Bill of Materials

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Notes: 1. USE WATER SOLUBABLE FLUX DURING BOARD ASSEMBLY.
2. DNI = DO NOT INSTALL COMPONENT.
3. INSTALL ITEM 71 JP1 SHUNT 2-3
4. RoHS COMPLIANT AND LEAD FREE ASSEMBLY.

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4.3 Schematics

Figure 34. Schematic (1 of 5)
Figure 35. Schematic (2 of 5)
Figure 36. Schematic (3 of 5)
Figure 38. Schematic (5 of 5)
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