SC2200
FW5.0.09.04 Release Notes

UG6337; Rev 0; 9/16

Abstract

This document provides a user's guide to evaluate the operation and performance of the SC2200 with different given power amplifiers.

CONTENTS

Table of Figures

List of Tables

1. Introduction

1.1. Overview

Firmware 5.0.09.04 is a production firmware release targeted for 698MHz –2700MHz applications with class AB and Doherty power amplifiers. The SC2200 is a dual-path linearizer optimized for wide range of amplifiers, power levels, and communication protocols. It is designed to fully address the linearization requirements for MIMO cellular infrastructure systems (FDD-LTE, TD-LTE, WCDMA) including small cells, Remote Radio Heads (RRH), Antenna Array Systems (AAS), and other MIMO applications.

The SC2200 includes the following three levels of features:

- The following external clock system clock rates: 10MHz, 13MHz, 15.36MHz, 19.2MHz, 20MHz, 26MHz, and 30.72MHz
- Instantaneous signal bandwidths from 1.2MHz to 60MHz
- Frequency bands between 698MHz and 2700MHz

GUI 3.0.10 is required to operate Firmware 5.0.09.04 and Evaluation Kits (EVK).

Evaluation Kits available on Maxim Integrated web pages *https://www.maximintegrated.com/* or by email to Maxim Integrated Sales, *sales@maximintegrated.com*:

- 2300MHz–2700MHz (P/N SC2200-EVK2400)
- 1800MHz–2200MHz (P/N SC2200-EVK1900)
- 698MHz–960MHz (P/N SC2200-EVK900)

This document is meant to provide a user's guide to the SC2200 to evaluate the operation and performance with a given power amplifier. The documents referenced in section 1.3 are companion documents to be used when implementing the SC2200 in a design. Please contact your local sales representative for access to these documents.

1.2. Limitations

- (Max Frequency - Min Frequency) ≤ 100MHz is required.
- Spectrum Monitoring is a debug function, not supported for production
  - o It is required to reset SC2200 after using the Spectrum Monitoring function.
  - o Frequency span selection, "Selected FFT Bins" option and Internal Attenuator RFFB are not supported.
  - o RFIN and RFFB PMU offset are not applied to the PSD levels.
  - o Only available from the GUI
- The PMU parameters are only provided for debugging purposes—not supported for production. The RFIN and RFFB PMU offsets of path A are used for both path A and path B RFIN and RFFB PMU values.
- SC2200 can't be used for systems requiring two different simplex bands
- For signal bandwidth < 5MHz, it is required to change the default ADC Sample Rate to 25MHz. Please refer to the SPI Programming Guide [2] for details.

1.3.   Reference Documents

1. SC2200 Hardware Design Guide
2. SC2200 SPI Programming Guide
3. SC2200 Data Sheet
4. Designing Linearizable RF PA using RFPAL
5. SC2200_PA_Results folder on Sharefile

1.4.   Acronyms

Acronyms	Description
AGC	Automatic Gain Control
EEPROM	Electrically Erasable, Programmable, Read-Only Memory
EVB	Evaluation Board
PAR	Peak-to-Average Ratio
PDET	Power Detector. Refer to RFIN AGC value.
PMU	Power Monitoring Unit.
PVT	Process, Voltage and Temperature.
RFFB	RF Feedback
RFIN	RF Input
RFOUT	RF Output
RFPAL	RF PA Linearization
SPI	Serial Peripheral Interface
SSN	SPI Slave Select Enable
XTAL	Crystal

1.5.   Revision History

Revision	Date	Description
1.0	April 2015	Production Release
1.1	July 2015	Updated GUI to fix minor issues, added wideband performance data and updated collateral with minor clarifications. No firmware changes, only updated .sci file for GUI comments.
1.2	June 2016	Clarification on RFIN PMU values, general edits to clarify instructions. Performance data moved to SC2200_PA_results folder. Performance optimization moved to SPI programming guide. Updated .sci file to expose extra parameters.
1.3	September 2016	General edits to remove requirement for NDA to access SC2200 collateral.

2. Quick Start Guide

To get started with the evaluation, the following steps are recommended:

- Install the GUI as described in section 2.
- Set up the SC2200 Evaluation Kit with PA lineup, as described in section 4.
- SC2200 operation is described in section 0.
- The different debugging features available are described in section 6.
- Performance optimization guidelines are provided in SPI programming guide 2.
- SC2200 performance data are provided in SC2200_PA_Results folder 5.

3. GUI Installation Guide

IMPORTANT: It is required to uninstall all previous GUI versions and all previously installed firmware, before installing new GUI versions

3.1. Uninstallation Procedure for Any Previous GUI

1. It is required to first uninstall any previously installed GUI before installing a new GUI
2. This can be done by using "Add or Remove Programs" in the "Control Panel." Select SC2200GUI or previous GUI and select "Remove"
3. During the uninstallation process, it is required to delete previous log files and installed firmwares selecting "Yes".

3.2. New GUI Installation Procedure

IMPORTANT: Do not connect the SC-USB-SPI2 adapter or SC2200-EVK to the PC during the GUI installation

1. Run the latest SetupMaximSC2200_GUI_X.Y.Z.EXE with X.Y.Z being the latest revision.
2. Click on "Run"
3. Select the Installation Folder and press Next for the next few windows
4. Click on "Close"
5. Connect USB cable to SC2200-EVK or SC-USB-SPI2 adapter and wait for the driver to be installed before proceeding to the next step
6. Power on SC2200-EVK or customer board with the SC-USB-SPI2 adapter.
7. Start SC2200GUI under All Programs->MaximSC2200->SC2200GUI
8. An Red Error Message will be displayed at the bottom of the GUI:
a. Could not find any firmware installed on your computer compatible with this part. Please install one.
9. Under Device, select Add Firmware and select the latest .sci file and Click on "open".
a. Please be patient as this can up to 30 seconds.
10. Close the SC2200GUI
11. Start SC2200GUI

IMPORTANT: Under "Options" it is recommended to select "Open panes pinned" and then open "ACCP tab"

4.   SC2200 Evaluation Kit Setup
4.1.   SC2200 Evaluation Board
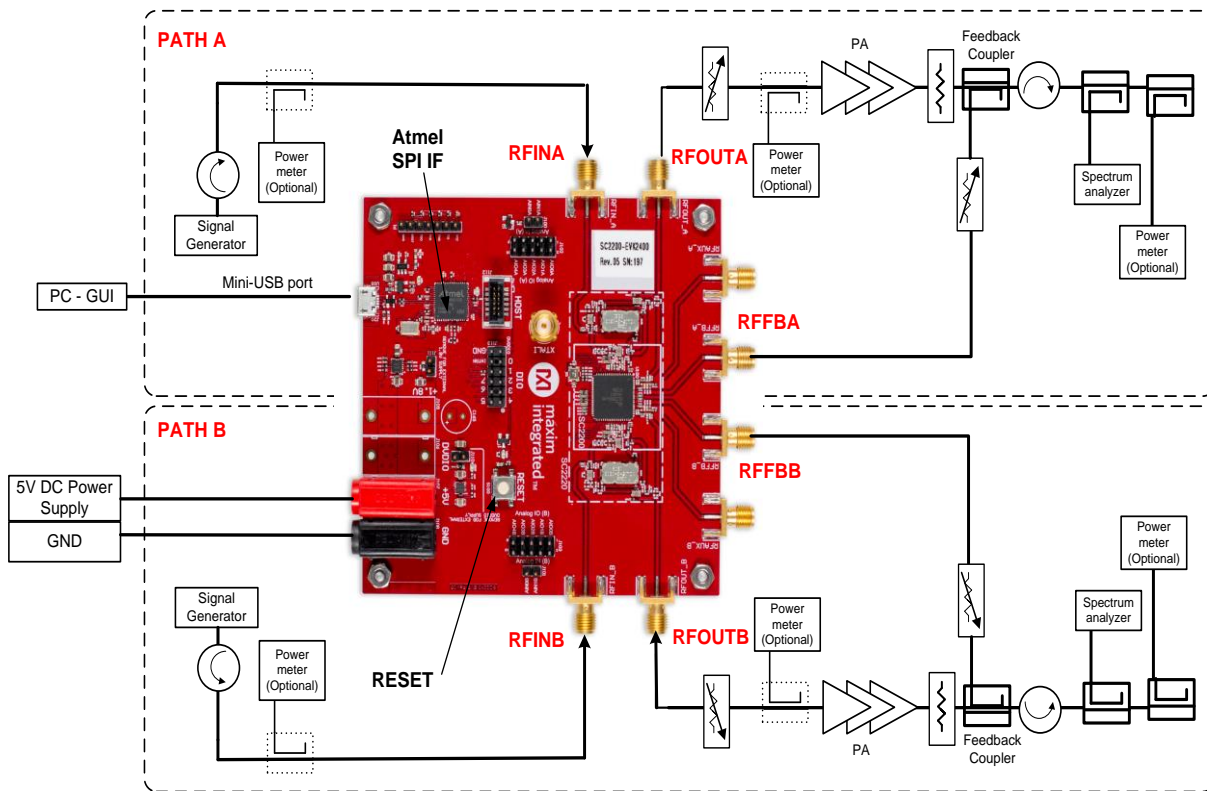
Figure 1: SC2200 Evaluation Board Connection Diagram

Bring up instructions:
1. The SC2200 Evaluation Board must be powered from a +5V DC power supply capable of providing 0.8A (although the actual average power consumption of SC2200 is lower). Connect the power supply to the banana jacks on the SC2200 Evaluation Board labeled +5V (red) and GND (black).
2. RFOUTA/B is connected to the power amplifier input. The attenuator between the RFOUTA/B and the PA is useful for setting the RFINA/B level of the Linearizer (assuming that the PA is adjusted to a fixed output power) and should be set using the RFINA/B AGC slider on the GUI. It is recommended that an adjustable attenuator is used for setting the power level of the RF power amplifier.
3. RFFBA/B is connected to the power amplifier feedback coupler. While not required, it is convenient to use a variable attenuator in the feedback path. It allows setting the RFFBA/B level into the evaluation board by using the RFFBA/B AGC slider. Please refer to section 5.4 for details.

IMPORTANT: RFINA/B and RFFBA/B power level must follow the recommendations from section 5.4

4. Connect the USB cable from SC2200-EVK to the PC. Maxim recommends using a USB cable less than 4 feet long.
5. Reset SC2200 using either the GUI or the RESET button on the evaluation board.

4.2. RFIN and RFFB Maximum Power Calibration Target Power Ranges

For optimal performance, it is required to set the correct RFIN and RFFB levels into SC2200 as described in the SC2200 data sheet 3 at the PA maximum output power. If the system is set up as described in Figure 2 and Table 1, the linearization provided by the SC2200 should be sufficient over the entire output power operating range of a typical power amplifier. The amount of correction required by the amplifier generally decreases as the PA output power is backed off (constant SEM specifications).
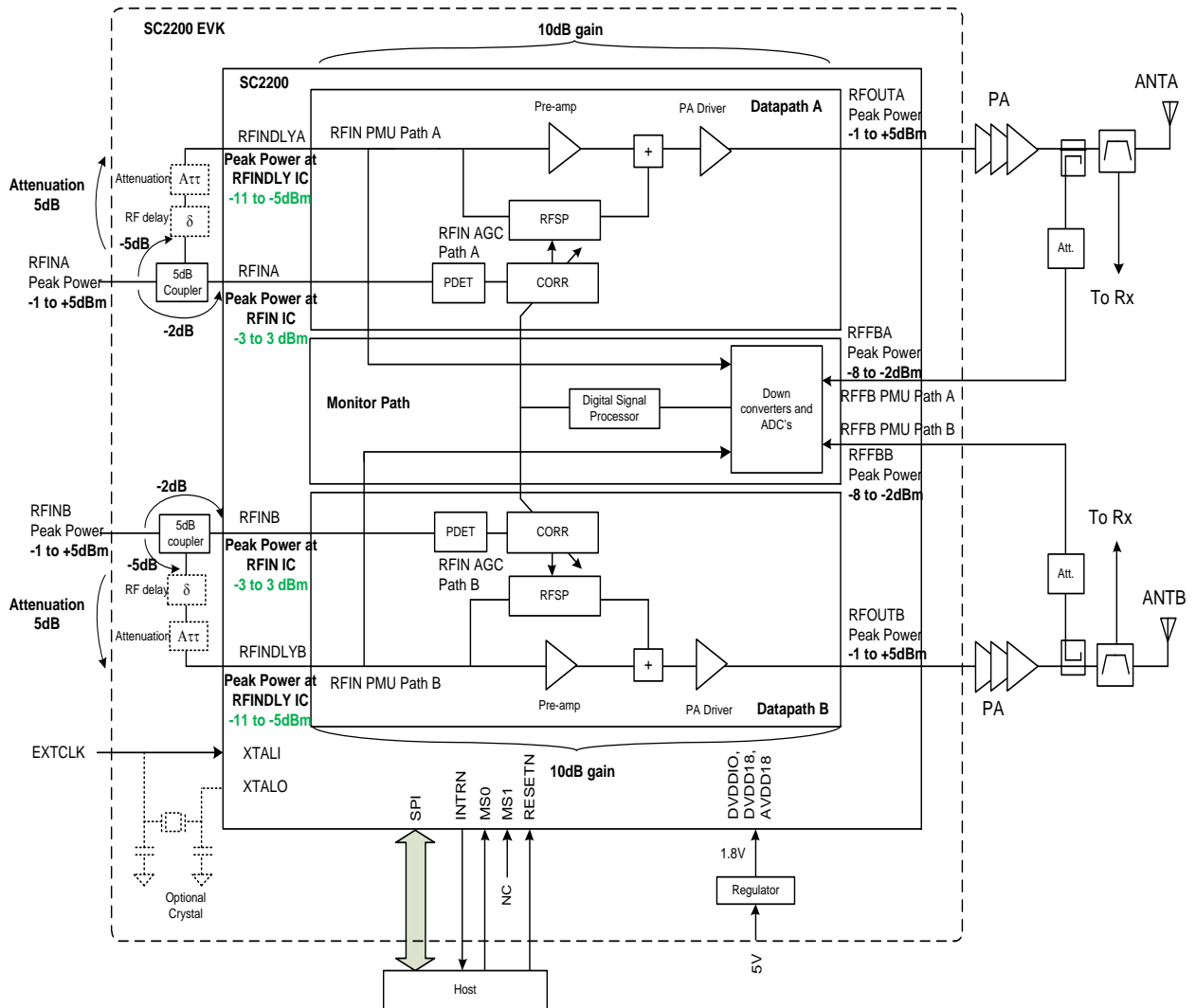
Figure 2: RFIN and RFFB Maximum Peak Power Calibration Target Power Ranges

Table 1: RFIN and RFFB SC2200-EVK SMA Calibration Peak Power Level Ranges at SMA Connector

SMA Port	Min (dBm)	Recommended (dBm)	Max (dBm)	Comments
RFIN	-1	+2	+5	Recommended RFIN Peak power level range when PA is at the maximum Peak and RMS output power level for smooth Calibration at room temperature to allow for PA gain variation over temperature
RFFB	-8	-5	-2	Recommended RFFB Peak power level range when PA is at the maximum Peak and RMS output power level for smooth Calibration at room temperature to allow for PA gain variation over temperature

RFIN values are peak power values referred to Board SMA Connector. Refer to Figure 2 for levels referred to the IC pins.

IMPORTANT: Power levels are assuming a ~3ns delay line and coupler having a total (approximate) thru path loss of 10dB. Delay line insertion loss variation over temperature should be similar to or less than the Anaren Delay line XDL15-3-030S

The optimal delay or attenuation can vary with PA and frequency. Please refer to section 4.3 for more details.

At the maximum peak and RMS PA output power, ensure RFIN and RFFB peak power level ranges are at the optimal levels.

These ranges do not correspond to the dynamic range. Please refer to the SC2200 datasheet 3 for the SC2200 dynamic range.

RFIN PMU value reflects the RFINDLY pin power level, while the RFIN AGC value reflects the RFIN pin power level.

Please refer to section 5.5.2 for more details about smooth mode calibration.

4.3.   Through Path Delay Line and Attenuation

The RF delay is used to align the SC2200 predistortion processing delay with the through path RF signal. The external delay must be close to the SC2200 memory polynomial average delay to fully take advantage of the integrated memory effect compensation.

For most Doherty PAs and wideband class AB PAs, the optimal delay is approximately 3ns, but we encourage experimentation with this value for each new PA design and after any PA tuning. Please refer to [4]. For wideband PAs with more narrowband signals (BW ≤ 20MHz, typ), it might be possible to replace the delay line by 4dB attenuation with acceptable performance.

The relative power levels between RFIN and RFINDLY shall be maintained at all frequencies:

IMPORTANT: If a delay line is not used in the design, place a 4dB attenuator in the RFINDLY RF path as described in Table 2

As the signal bandwidth increases, the RF delay line becomes more critical to compensate for PA memory effects and achieve optimal linearization performance. PA design, especially video bandwidth and memory effect, will be critical to determine the impact of not using the delay line.

The insertion loss of a delay line is not sufficient at 900MHz. For designs in this frequency band, add a 2dB attenuator in the RFINDLY RF path. (The relative power levels between RFIN and RFINDLY shall be maintained.

For example of performance with and without delay line with Doherty PA, please refer to the PA result folder 5 on Sharefile. For different SC2200 evaluation board configurations, please refer to the following Table 2.

Table 2: Evaluation Board Delay Line Configuration Options

Component Reference Designator	Delay Line Configuration Options					
	EVK900 (698-960MHz)		EVK1900 (1800-2200MHz)		EVK2400 (2300-2700MHz)	
	No Delay Line	With Delay Line (Default)	No Delay Line	With Delay Line (Default)	No Delay Line	With Delay Line (Default)
R194	0Ω	**NL**	0Ω	**NL**	0 Ohm	**NL**
R222	NL	**0Ω**	NL	**0Ω**	NL	**0Ω**
R223	NL	**0Ω**	NL	**0Ω**	NL	**0Ω**
C292	221Ω	**432Ω**	221Ω	**1.3pF**	221Ω	**NL**
R192	24.3Ω	**11.5Ω**	24.3Ω	**1nH**	24.3Ω	**0Ω**
C160	221Ω	**432Ω**	221Ω	**NL**	221Ω	**1.2pF**
R201	0Ω	**NL**	0Ω	**NL**	0 W	**NL**
R195	NL	**0Ω**	NL	**0Ω**	NL	**0Ω**
R241	NL	**0Ω**	NL	**0Ω**	NL	**0Ω**
C293	221Ω	**432Ω**	221Ω	**1.3pF**	221Ω	**NL**
R193	24.3Ω	**11.5Ω**	24.3Ω	**1nH**	24.3Ω	**0Ω**
C163	221Ω	**432Ω**	221Ω	**NL**	221Ω	**1.2pF**

NOTE: Default configuration in bold. Please refer to the Hardware Design Guide for details.

4.4. SC2200 EVK SMA to IC Pin RF Losses

The RFIN and RFFB power ranges shown in the SC2200 data sheet are referenced to the IC pins. The table below is an estimate of the RF losses from the evaluation PCB SMA connectors to the SC2200 IC pins. Add the losses shown here to the IC pin power levels to determine the equivalent levels at the SMA connectors.

Table 3: SC2200 EVK SMA to IC Pin RF Losses

SC2200 Evaluation PCB Part #		SC2200-EVK900					SC2200-EVK1900						SC2200-EVK2400				
Frequency	MHz	700	800	900	1000	1200	1500	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
RFIN PCB loss, 2"	dB	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
RFIN Coupling Loss	dB	1.9	2.0	2.0	2.1	2.3	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
RFIN Total	dB	2.0	2.1	2.2	2.2	2.4	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
RFINDLY PCB Loss, 2"	dB	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
RFINDLY Coupling Loss	dB	5.6	5.2	5.1	5.2	6.0	5.3	5.2	5.1	5.1	5.1	5.2	5.0	4.9	4.9	4.9	4.9
Anaren Delay Line Loss	dB	1.5	1.6	1.7	1.8	2.0	2.3	2.6	2.7	2.8	2.9	3.0	3.3	3.5	3.7	3.7	3.7
RFINDLY Attenuator Loss	dB	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anaren RFINDLY Total	dB	9.2	9.0	9.0	9.2	10.2	7.9	8.2	8.2	8.2	8.4	8.6	8.7	8.8	9.0	9.0	9.0
RFINDLY PCB loss, 2"	dB	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
RFINDLY Coupling Loss	dB	5.6	5.2	5.1	5.2	6.0	5.3	5.2	5.1	5.1	5.1	5.2	5.0	4.9	4.9	4.9	4.9
RN2 Cemax Delay Line Loss	dB	1.9	2.0	2.2	2.3	2.6	2.9	3.4	3.5	3.6	3.7	3.8	3.9	4.1	4.2	4.4	4.6
RFINDLY attenuator Loss	dB	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RN2 Cemax RFINDLY Total	dB	9.6	9.4	9.5	9.7	10.8	8.5	9.0	9.0	9.0	9.2	9.4	9.3	9.4	9.5	9.7	9.9
RFFB or RFAUX PCB loss, 1"	dB	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

4.5.   What to Look for if Performance is Lower Than Expected?

- Check the linearity of the signal source provided to the linearizer. It is recommended that the input linearity be at least 5 to 10 dB better than the desired linearity at the PA output.
- Check that RFIN and RFFB Peak levels are set correctly into SC2200 as described in SC2200 data sheet 3 and section 4.2.
- Check the RFIN and RFFB AGC values as described in section 5.4. RFIN AGC value reflects the RFIN pin level.
- Check the RFIN and RFFB PMU values as described in section 6.1. RFIN PMU value reflects the RFINDLY pin level.
- Make sure the spectrum analyzer internal attenuation is not too high, increasing the noise floor and limiting performance. Reduce the spectrum analyzer attenuation as much as possible while not overdriving the analyzer.
- In Engineering mode, the convergence is a little slower and may take up to 120s. Please refer to section 5.5 for definition of engineering and smooth mode.

IMPORTANT: Check performance in Engineering Mode first with stable signal conditions, before testing performance in Smooth Mode with changing signal power level conditions.

In Engineering Mode, it is required to use Hardware Reset or Software Reset when changing the signal conditions (power level, signal bandwidth or center frequency) or PA conditions (bias, voltage).

See SC2200 SPI Programming Guide 2 for further performance optimization recommendations.

4.6.   Signal Generator Considerations for Power Level Change Performance tests

To prevent the signal generator from transmitting undesirable peaks during power level changes, it is required to take the following precautions.

- With some signal generators, it is important to turn ALC OFF and to configure "*Power Search*" properly.
  - Select "*Manual*" option if available.
  - With some signal generators, "*Power Search*" doesn't have a "*Manual*" option. In this case, select "*Span*". Then select "*Configure Span Power Search*" and select "User" for "Span Type" and configure "Start Frequency" and "Stop Frequency" to the center frequency of the signal test.

5. SC2200 Linearization Operation

This section describes how to change certain parameters within the SC2200 as well as access status information over the SC2200 SPI. The supplied GUI enables the user to access the SC2200 SPI through the SPI-to-USB converter.

5.1.   SC2200 GUI

Figure 3: SC2200 Main GUI Window Annotated with Reference Sections

ACCP Config

EEPROM ▾   APP_EEPROM ▾

▲ EEPROM Access

Variable Type: ◯ Write access   Address(hex):   Value:

UINT8 ▾   ● Read access | 0 | | 0 | Execute

Load Parameters   Save Parameters

Group	Variable Name	Address	Value	Commands
Path B/CalFreq1	MaxPWRCALParam13	0xFC38	Edit	
Path B/CalFreq1	MaxPWRDCALCoefficients	0xFC50	Edit	
Path B/CalFreq1	MaxPWRCALParam14	0xFC82	Edit	
Path B/CalFreq1	MaxPWRCALParam15	0xFC8D	217	
Path A/CalFreq1	MaxPWRCALParam1_RFIN_MAX_PWR	0xFCF4	-1826	
Path A/CalFreq1	MaxPWRCALParam2_RFFB_MAX_PWR	0xFCF6	-5322	
Path A/CalFreq1	MaxPWRCALParam3_PDET	0xFCF8	1	
Path A/CalFreq1	MaxPWRCALParam4	0xFCF9	1	
Path A/CalFreq1	MaxPWRCALParam5_IC_temp	0xFCFA	184	
Path A/CalFreq1	MaxPWRCALParam6_CorrVgaIdx	0xFCFC	5	
Path A/CalFreq1	MaxPWRCALParam7	0xFCFD	16	
Path A/CalFreq1	MaxPWRCALParam8	0xFCFE	125	
Path A/CalFreq1	MaxPWRCALParam9	0xFCFF	127	
Path A/CalFreq1	MaxPWRCALParam10_Freq	0xFD00	3720	
Path A/CalFreq1	MaxPWRCALParam11	0xFD02	201	
Path A/CalFreq1	MaxPWRCALParam12	0xFD03	17	
Path A/CalFreq1	MaxPWRCALParam13	0xFD04	Edit	
Path A/CalFreq1	MaxPWRDCALCoefficients	0xFD1C	Edit	
Path A/CalFreq1	MaxPWRCALParam14	0xFD4E	Edit	
Path A/CalFreq1	MaxPWRCALParam15	0xFD59	199	
Device/Config	RefFreqInkHz	0xFDC0	0	Ref clock Freq in kHz. 0 = 20MHz. 19200 kHz = 19.2MHz
Device/Config	ShutDownTime_10ms	0xFDC2	10	
Device/AdvConfig	Back Off Freeze Threshold	0xFEFE	0	
Device/AdvConfig	Corr VGA Idx	0xFF01	0	Default = 5. Recommend value between 1 and 5.
Device/AdvConfig	PDET AGC Threshold	0xFF02	100	
Device/AdvConfig	Guard Band	0xFF0A	2	
Device/AdvConfig	ADC Sampling Rate	0xFF0D	0	0=100MHz, 1=25MHz
App	Checksum	0xFFFF	191	

Figure 4: SC2200 GUI ACCP Config: APP EEPROM Parameters

ACCP Config

SCRATCH ▾   GLOBAL_SCRATCH ▾

⌃ SCRATCH Access

Variable Type: ◯ Write access   Address(hex):   Value:

UINT8 ▾ ⦿ Read access   0   0   Execute

Load Parameters   Save Parameters

Group	Variable Name	Address	Value	Commands
Device/Info	Firmware Product Version	0x5	2200	
Device/Info	FW Build	0x2	9	
Device/Info	FW Hot Build	0x3	4	
Device/Info	FW Version	0x1	80	
Path A/CalAdaptDataPathA	Ic Temp	0x110	217	
Path A/FW Status	Center Freq	0x3D	5400	
Path A/FW Status	Cost Function	0x41	-4208	
Path A/FW Status	Error Index	0x3B	0	
Path A/FW Status	Info Index	0x3C	0	
Path A/FW Status	Signal BW	0x3F	204	
Path A/FW Status	Status	0x3A	5	
Path A/PMU	PA Gain	0xD0	12277	
Path A/PMU	RFFB RMS	0xC4	-1416	
Path A/PMU	RFIN RMS	0xCA	-13693	
Path A/RF Status	RFFB AGC	0x57	49	
Path A/RF Status	RFIN AGC	0x59	4	
Path B/FW Status	Center Freq	0x4B	5400	
Path B/FW Status	Cost Function	0x4F	-3922	
Path B/FW Status	Error Index	0x49	0	
Path B/FW Status	Info Index	0x4A	1	
Path B/FW Status	Signal BW	0x4D	204	
Path B/FW Status	Status	0x48	6	
Path B/PMU	PA Gain	0xC2	12390	
Path B/PMU	RFFB RMS	0xB6	-1460	
Path B/PMU	RFIN RMS	0xBC	-13850	
Path B/RF Status	RFFB AGC	0x69	49	
Path B/RF Status	RFIn AGC	0x6B	4	
PAth B/CalAdaptDataPathB	Ic Temp	0x176	216	

Connected to SC-USB-SPI2 (COM4) | IC Temperature: 54.00

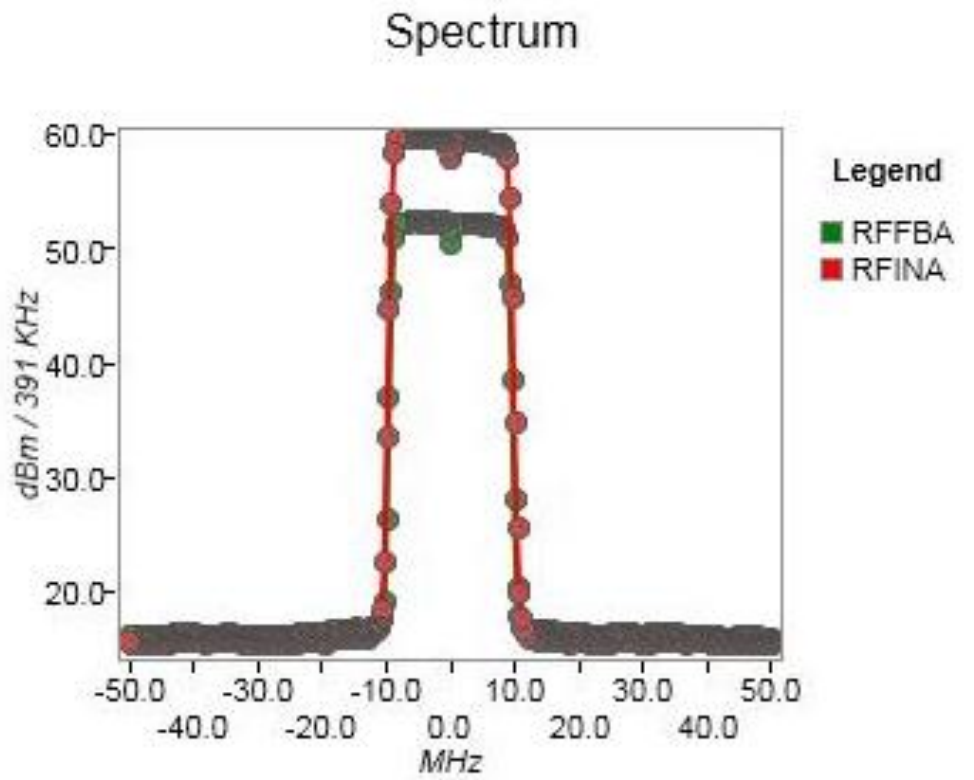*Figure 5: SC2200 GUI ACCP Config: GLOBAL_SCRATCH Parameters*

Figure 6: SC2200 GUI Debug Tab: Spectrum Plots

Please refer to section 6.2 for limitations and details.

5.2.   IC Configuration

The IC Configuration includes product Version, FW Version and FW Sub Version. See 2 for more details on these device information parameters. See section 5.7 to change the firmware.

5.2.1.   Polling/Update Rate

The Polling Rate (Under Device) corresponds to the GUI refresh rate to update parameters displayed. It can be set to
- No refresh
- 0.5 seconds
- 1 seconds

IMPORTANT: To update EEPROM parameters in APP tab or GLOBAL SCRATCH parameters, it is required to select "Update Data" under Device option.

5.2.2.   Hardware Reset

The SC2200 supports a hardware reset pin as outlined in the hardware design guide. The HW reset is implemented on the evaluation board as a push button as show in Figure 1. There is a GUI command button which is equivalent to the HW reset. When using the GUI, it is not recommended to use the push button reset on the PCB.
Hardware Reset triggers the following:
1. Internal registers (Analog and Digital) are reset to hardware reset values. Internal driver is reset.
2. FW downloaded from EEPROM to PRAM
3. If FW Checksum is correct, then Software Reset is triggered. See section 5.2.3 for details.

5.2.3.   Software Reset

The SC2200 Software Reset triggers the following

1. Software is initialized and start running
2. Analog and Digital registers are initialized to software default values
3. Application parameters are downloaded from EEPROM to PRAM.

5.3.   FW Status

The SC2200 supports various status commands from the GUI to aid during development and monitor the SC2200 status during operation. It is recommended that the GUI be used to monitor the SC2200 status during development.
The GUI displays the SC2200 status. The rate at which the GUI is updated is controlled by the Update Rate. See section 5.2.1 for more details.
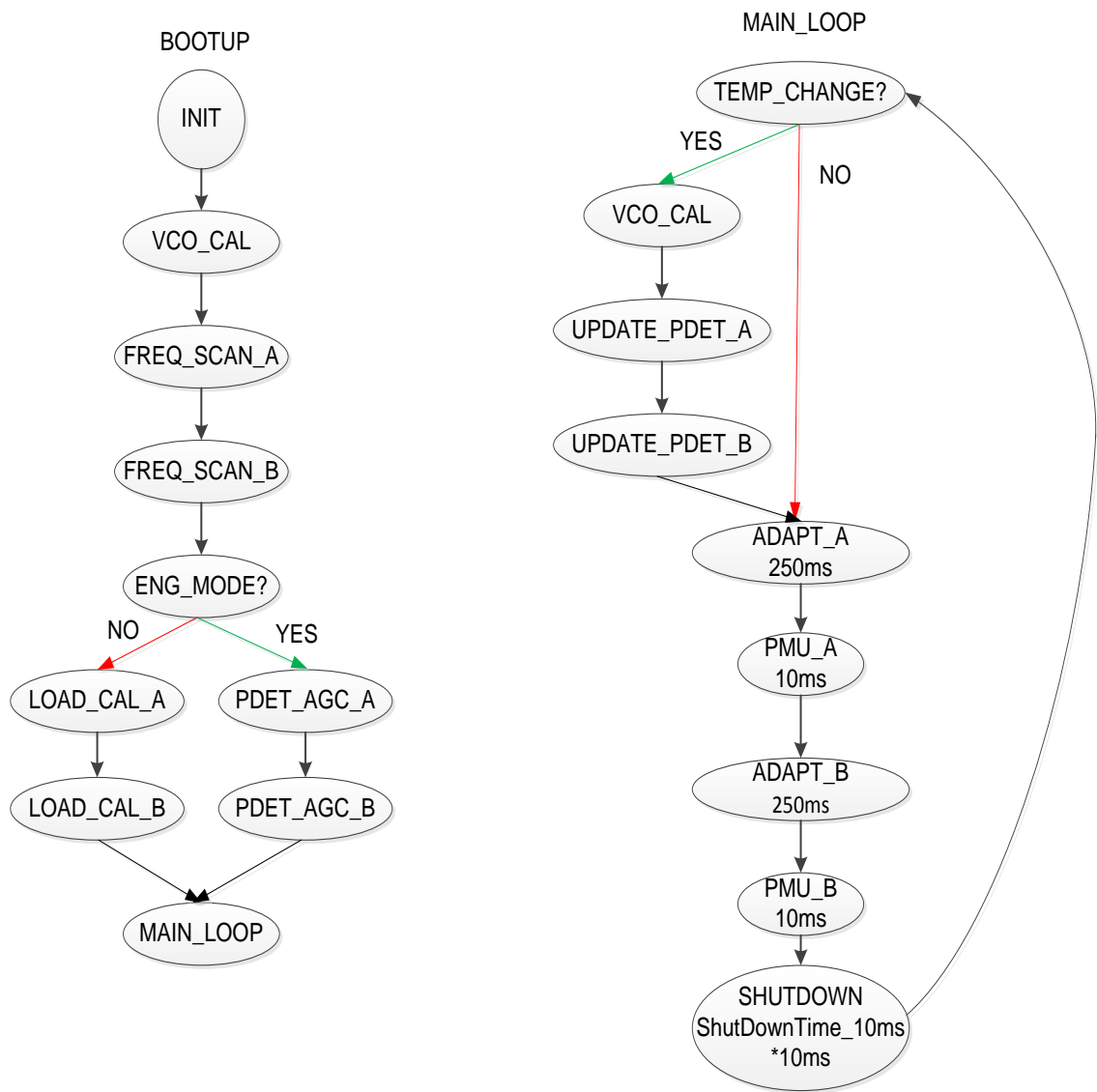
5.3.1.   Firmware States

Figure 7: SC2200 Firmware State Machine

Figure 7 describes the SC2200 firmware state machine.
- INIT:
  - Initialize microprocessor
  - Initialize all internal data memories
  - Analog and Digital registers are initialized to software default values
  - Application parameters are downloaded from EEPROM to PRAM.

- VCO CAL: Calibrate internal VCO/PLL
- FREQ SCAN:
  - Sweep from Min Frequency minus 100 MHz to Max Frequency plus 100 MHz
  - Detect the carrier center frequency and bandwidth
  - If Min Frequency = Max Frequency, no sweep is done. LO set to this frequency
- PDET (PDET AGC)
  - Optimize gain settings and DC offset for optimum performance
  - Only done in Engineering Mode after reset or boot up
- Update PDET
  - Updates the PDET index based on calibrated value, temperature, and PA gain
  - Not reflected in Overall Status as this takes less than 100µs to complete.
- PMU: measure RFIN and RFFB PMU values (10ms for each path). See section 6.1 for details.
- TRACK = ADAPT (250ms for each path)
  - Varies the coefficient that are applied to each of the non-linear terms to optimize the out of band cost function
  - Center Frequency, Average Power, and Signal Bandwidth are monitored during this state
  - Center Frequency or bandwidth changes cause a re-running of FREQ SCAN
  - Power changes cause an updating of PDET AGC value based on current temp, and PA gain
- FROZEN
  - Only one path can be active at a time. In that case the other path is in FROZEN state, waiting for its turn.
  - Adaptation coefficients are frozen and pre-Correction signal is on.
- SHUTDOWN (reported as State "7" in GUI)
  - Only if DeviceConfig.ShutDownTime_10ms > 0
  - ShutDownTime_10ms is the amount of time in 10mS increments to turn off the system for power saving. Adaptation is frozen and predistortion is applied during shutdown time.

5.3.2. Min Frequency and Max Frequency

The Min Frequency and Max Frequency define the frequency scanning range over which the SC2200 will scan for the RF signal on RFIN and RFFB. Min Frequency (MHz) and Max Frequency (MHz) are the EEPROM parameters that define the scanning bounds. The current settings for these values can be read over the SPI. The GUI displays these values in the Status box.

The Min Frequency is the lowest frequency that the SC2200 scans when searching for the signal center frequency and Max Frequency is the highest frequency that the SC2200 scans when searching for the signal center frequency. It is good practice to set the Min Frequency and the Max Frequency to the actual values required for the operating range of your application. Setting an unnecessarily wide range can lead to intermittent spurs in the band of interest.

Setting the Min Frequency and Max Frequency will write the values to the internal EEPROM and it is only required to set them once. There is no limit to the number of times these parameters can be configured.

IMPORTANT: If Max Frequency > 2700MHz or if Min Frequency < 698MHz, then an error 12 will be generated from SC2200 firmware. It is required to keep (Max Freq – Min Freq) ≤ 100MHz.

5.3.3. Center Frequency and Bandwidth

Once the SC2200 exits the FREQ SCAN state, the detected signal center frequency (±0.5 MHz) and -24dBc signal bandwidth (±0.75 MHz for BW <5 MHz, ±1.5 MHz for BW ≥5 MHz) may be obtained from the GUI. The SC2200 considers signals within this displayed bandwidth as "in band" and does not include this signal power as distortion to be corrected. If the distortion products of your amplifier are above -24dBc, the SC2200 may consider them as signal and not operate properly. The SC2200 will not attempt to correct signals that are less than 1.2 MHz of modulated signal bandwidth. If the detected signal bandwidth does not reflect system or test equipment settings, it may indicate that the SC2200 is not operating under the correct conditions.

5.3.4. Error and Information Codes

The SC2200 will provide error codes if these registers are polled over the SPI.
Error Codes are described in Table 4.
Info Codes are described in Table 5. Info codes (Also referred to as Warning codes) are just indications intended to provide information to the user.

Table 4: Error Codes

Error Code	Meaning
0	No Error
3	'EEPROM corrupted' Improper use of the part resulted in corruption of the Application EEPROM section. Changing Min or Max Frequency using the GUI might fix this error.
9	Internal Temperature is too high (> 140°C)
10	Internal Temperature is too low (< -60°C)
12	EEPROM Application parameter out of the expect range. For example, Max Freq > 2700MHz and Min Freq < 698MHz will create an error 12.
Others	Internal Chip Error" Please contact Maxim support if you get any other error that doesn't get fixed after Reset or re-downloading the firmware using the GUI.

Note: *Please contact Maxim if any of these rare errors are encountered.*

Table 5: Information Codes

Info Code	Meaning
0	No Information
12	WatchDog Reset Event. If the 8051 microcontroller has reset at any given time due to a FW timeout occurrence. When loading new firmware, this code might appear. This only gets cleared with hardware reset or "Clear Info" command.
14	Max Calibration RFFB power level is too low (Below -45dBm)
16	Max Calibration RFIN power level is too low (Below -30dBm)

5.3.5. GUI Log Files
The GUI allows the Error codes to be logged. Each time the GUI is started an "Error" log file will be created.

For Windows XP: it is created with a unique name based on when it was started under:
C:\Documents and Settings\All Users\Application Data\MaximSC2200\MaximSC2200GUI\Log

For Windows 7: the log file will be created under
C:\ProgramData\MaximSC2200\MaximSC2200GUI\Log

Please note that, with Windows 7, ProgramData directory is hidden by default. To make it visible, open "Windows Explorer and select the C drive. Press "Alt", select tools, and then "Folder Options" to select "Show hidden files, folders, and drivers to display it". Click "Apply" or "OK".

The format will be: etrace20110517_182622.csv indicating date and time of the log file start. The first eight characters are date in yyyymmdd format (May 17 2011 in this case) and the last six digits are time of day in 24 hour hhmmss format (6PM 26minutes and 22s in this case).
All errors will be captured in this log file.

The New Log File button allows starting a new log file without having to close the GUI.

5.4. RFIN and RFFB AGC Sliders
The RFIN AGC (PDET) parameter is an attenuator in an AGC loop within the SC2200 analog circuitry. This RFIN AGC loop ensures that the peak voltage into the correction block stays within the desired range across RFIN level and temperature.

- At maximum PA output power, if RFIN AGC (PDET)>4, then the RFIN level is too high and needs to be lowered.
- At maximum PA output power, if RFIN AGC (PDET)<1, then need to check RFIN peak power level versus the datasheet to make sure the RFIN level is not too low.
- So at maximum PA output power, it is recommended to have RFIN AGC around 2 for optimum dynamic range and include some margin over PVT.

The RFFB AGC is an AGC loop within the SC2200 used to hold the RFFB signal to the optimum level. The higher the RFFB power level, the lower the RFFB AGC value.

- At maximum PA output power, if RFFB AGC > 28, then the RFFB level is too low and needs to be increased
- At maximum PA output power, if RFFB AGC < 21, then the RFFB level is too high and needs to be lowered
- So at maximum PA output power, it is recommended to have RFFB AGC around 24 for optimum dynamic range and include some margin for over PVT.

IMPORTANT: RFIN/RFFB power level limits stipulated in the datasheet must be met. See section 4.2 for additional details.

5.5. Operation Modes

Firmware supports two operating modes: Engineering Mode and Smooth Adaptation Mode. The SPI interface is used to read the calibration parameters to determine which operating mode the SC2200 is in. The GUI does this periodically and displays the operating mode in the Status box based on MaxPWRCALParam2 for both channels.

5.5.1. Engineering Mode

This is the default mode of operation and used during initial evaluation, PA optimization or debugging of a system. It allows for quick evaluations of the SC2200 by pressing RESET after the linearized PA is operating at a stable power, frequency and bandwidth.

IMPORTANT: This mode cannot be used in a production system as a RESET is needed every time the PA operating state changes (after changing the power level, center frequency or signal bandwidth).

In Engineering Mode, convergence to optimum performance can take up to 120s.

In Engineering Mode, all the calibration parameters are cleared and no absolute power reference levels are recorded in the EEPROM. When the power changes in Engineering Mode, the only way to safely set gains and offsets is to execute a power-cycle, Hardware Reset or Software Reset.

5.5.2. Smooth Adaptation Mode

Smooth adaptation requires an initial factory calibration of SC2200 with the power amplifier system operating at the maximum RMS and peak output power. Figure 8 describes the smooth adaptation calibration procedure at a given center frequency for path A or path B.

IMPORTANT: Smooth Calibration must be done with:
Maximum Peak power at the RFFB input (PA output power) with the lowest PAR signal (For maximum RMS level)
Set Calibration Parameter command should be sent when SC2200 adaptation has reached acceptable linearization performance

The PMU is used to measure of the current power level ***relative to the power level at calibration time***. To do this, it is necessary to know the maximum power level. These levels and many other parameters are recorded in the EEPROM at factory test time. The PA is operated at the highest planned RMS power level and then this Smooth Adaptation Mode calibration is performed.
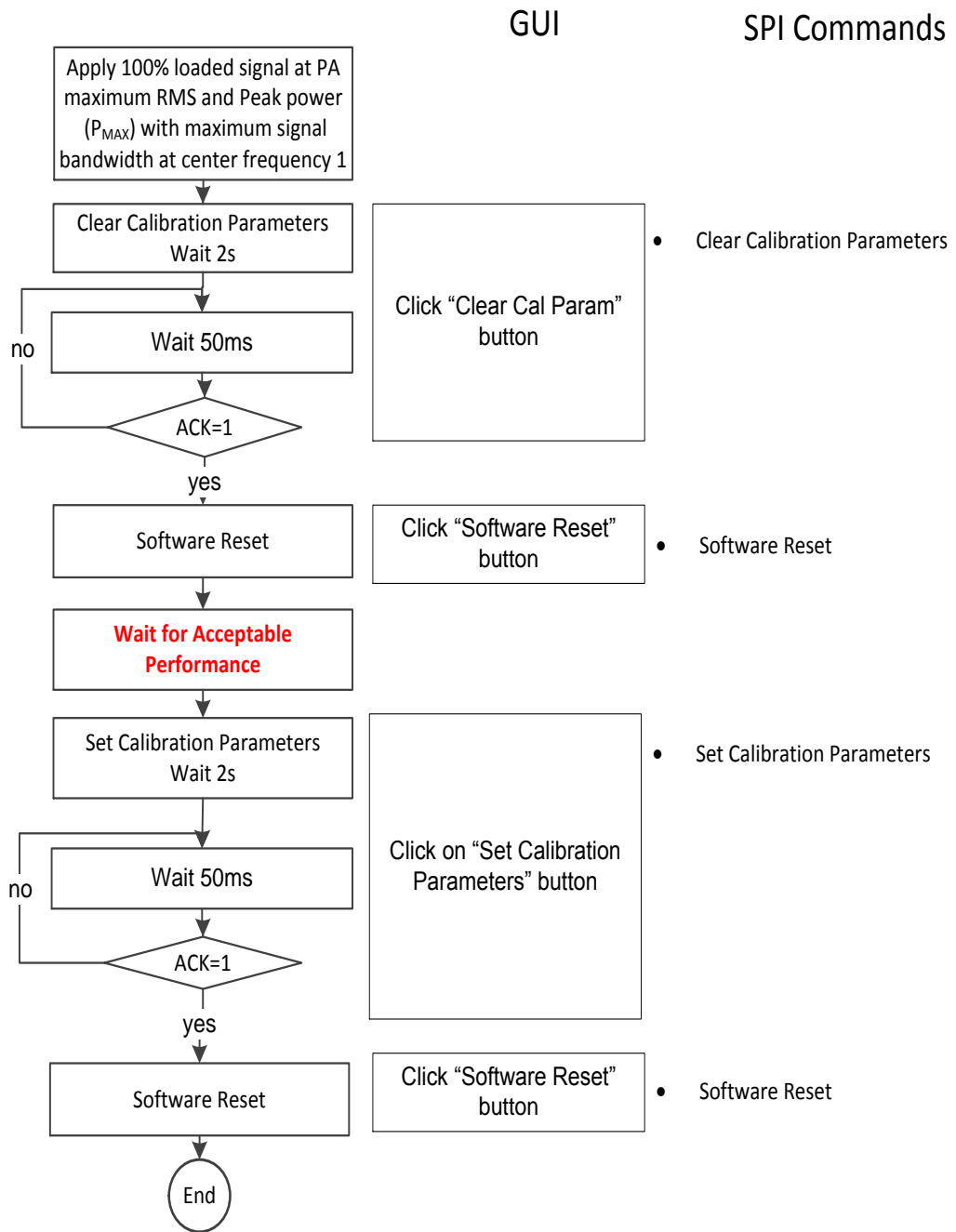
Figure 8: Smooth Adaptation Calibration Procedure at Center Frequency 1

5.6.   Adaptation and Correction Options

5.6.1. Adaptation States

The adaptation engine can be stopped to freeze the current coefficients. This is typically used for debug and lab evaluation purposes only. The last calculated coefficients are applied to the correction signal processor and are not updated.

- Running: Default state. Adaptation mode running as described above.
- Frozen: Freeze coefficient adaptation. All other circuits are left in the state they were in at application of freeze command.

5.6.2. Enabling and Disabling Correction

Once in TRACK, it is possible to turn off the pre-distortion signal. This is set to "FW Control" by default and can be used to toggle between corrected and uncorrected performance of the PA. It is typically used during evaluation and development.

Disabled: Predistortion signal is disabled and coefficients are not adapted. All other circuits are left in the state they were in at the application of disable command.

FW Control: Predistortion signal is enabled.

5.7.   Upgrading SC2200 Firmware

The internal EEPROM in the SC2200 supports field upgrades of the firmware. The firmware can be upgraded using the GUI or from the micro-controller. See 2 for details on how to upgrade the firmware from the host.

5.7.1.   Adding New Firmware to "Available Firmware" List

"Add Firmware" will allow adding future firmware versions to the "Available Firmware" list. New Firmware version is included in the CD provided with EVB kit and can easily be added to "Installed Firmware" list.   New firmware versions will be provided in encrypted format ".sci".

Click on "Add Firmware" and navigate to the file which is to be added.

Select the .sci file and click Open. Firmware will be added to the available firmware drop down and downloaded to the SC2200 chip.

5.7.2.   Change Firmware

To download firmware to SC2200, select one of the "Available Firmware" and click "Load Firmware."

5.8.   Cost Function

The cost function is measured at the RFFB input and is a scalar value proportional to ACLR measurement. The magnitude of this scalar will depend on the modulation type. Monitoring the relative change of this scalar will provide an indication of a given PA's ACLR.

The values reported by the GUI are averaged over 30 measurements.

5.9.   ACCP Config Tab

IMPORTANT: Under "Options" it is recommended to select "Open panes pinned" and then open "ACCP tab"

Under the ACCP config tab, it is possible to see the EEPROM mapping for the application parameters as shown in

Figure 4. When selecting the different parameters, a description will be displayed on the GUI.

For more details, please refer to the SC2200 SPI programming guide 2.

Similarly, under the ACCP config tab, it is possible to switch to Global Scratch mapping for the different scratch parameters as shown in Figure 5. When selecting the different parameters, a description will be displayed on the GUI.

For more details, please refer to the SC2200 SPI programming guide 2.

IMPORTANT: To update EEPROM parameters in APP tab or GLOBAL SCRATCH parameters, it is required to select "Update Data" under Device option.

6. Debug Features

6.1. Power Measurement Unit (PMU)

The SC2200 integrates two sets of analog power detectors, analog to digital converters and sampling integration. As soon as the SC2200 has detected the signal center frequency and signal bandwidth, it will periodically provide the following RFIN and RFFB power measurements using the SPI interface.

- RFIN and RFFB RMS Power (dBm/10ms) over a 10ms measurement window.

In order to provide enough integration samples to allow precise measurements of signals with high peak to average values, the default measurement time for the power detector is set to 10 ms. Please refer to Figure 7 for detail state machine.

IMPORTANT: Once SC2200 has detected the signal center frequency and signal bandwidth, then the RFIN values will be measured even if the RFFB is off (PA disabled or failed) for more than 10ms.

SC2200 does not adapt the pre-distortion coefficients during measurement time.

6.1.1. PMU Calibration

The reference points for the RFIN and RFFB PMU are the inputs of the chip. For relative power measurement accuracy, the PMU will require a single point calibration in manufacturing. The PMU calibration typically consists of setting the PA at maximum output power. An external calibrated power meter is used to read the PA power. The SC2200 is allowed to converge and reach TRACK. The PMU value is then read over the SPI for RFFB and used as the reference point. A similar procedure can be used to calibrate the RFIN value as well. These reference values can be stored in the host and used as an offset to calculate absolute power from the PMU values read from SC2200. See the SPI programming guide for examples and usage. This calibration can be done at the same time as the calibration for Smooth Adaptation Mode if desired.

$$P\,[REF] = P\,[Chip] + Offset$$

IMPORTANT: RFIN and RFFB power indicators must be calibrated.

6.1.2. TDD Considerations – Operation with <100% duty cycle

The SC2200 PMU operates continuously over the measurement window – it does not discard samples which may have been taken when the PA is off. This will affect the reading for waveforms with less than 100% duty cycle as would be seen in TDD applications. For example, the PMU value read for a 50% PA on time (duty cycle) will be 3 dB lower than the value with 100% duty cycle. It is straightforward to calculate the PA on time power from the PMU value:

1. For systems with a fixed duty cycle, it is recommended to calibrate the PMU with the procedure above using a waveform with proper Rx/Tx duty cycle. This is the preferred method.

2. For systems with variable Rx/Tx duty cycle, the host controller will need to scale the measurement value by the duty cycle (D_{CYCLE}) and calibrate the PMU values with the duty cycle with the highest ON time (D_{CAL}). Then the conversion of read PMU values into dBm values will be as follow:

$$P_{RFIN} = \frac{RFIN\_PMU \times 3.01}{1024} + OFFSET_{RFIN} - 10 \times \log 10 \left(\frac{D_{CYCLE}}{D_{CAL}} \right)$$

$$P_{RFFB} = \frac{RFFB\_PMU \times 3.01}{1024} + OFFSET_{RFFB} - 10 \times \log 10 \left(\frac{D_{CYCLE}}{D_{CAL}} \right)$$

6.2. Power Spectrum Density Plot (PSD)

It is possible to select RFIN or RFFB or both for path A and path B as shown in Figure 6.

Then every time the button "Plot" is pressed, the selected power spectrum density plots will be captured and displayed.

This can be used to check the RFIN linearity and to trouble-shoot signal integrity issues.

IMPORTANT: Spectrum Monitoring is a debug function.

It is required to reset SC2200 after using the Spectrum Monitoring function.

RFIN and RFFB PMU offset are not applied to the PSD levels. The absolute power levels indicated in the plots should be ignored.

6.3. IC Temp

SC2200 provides on-chip temperature measurement with values reported in 0.25°C units.

So if Global Scratch IC Temp is 217, this means that the IC Temp = 217/4 = 24.25°C.

The on-chip temperature measurement value is provided for debug purpose only and is not intended to provide absolute accurate temperature reading.