Application Note
Self-Calibration in TI's mmWave Radar Devices

![Texas Instruments](TEXAS INSTRUMENTS)

ABSTRACT

TI's mmWave radar sensors include an internal processor and hardware architecture to enable self-calibration and monitoring. Calibration ensures that the performance of the radar front end is maintained across temperature and process variation. Monitoring enables the periodic measurement of RF/analog performance parameters and the detection of potential failures.

This application note briefly describes the calibration and monitoring mechanisms and focuses mainly on the software configurability of the calibration routines run by the internal processor.

Abbreviations

Abbreviation	Description
APLL	Analog Phase Locked Loop
BIST	Built-in Self Test
CLPC	Closed Loop Power Control
DFE	Digital Front End
HPF	High Pass Filter
IF	Intermediate Frequency
IFA	Intermediate Frequency Amplifier
LNA	Low Noise Amplifier
LO	Local Osscilator
LPF	Low Pass Filter
LUT	Lookup Table
OLPC	Open Loop Power Control
PA	Power Amplifier
VCO	Voltage Controlled Oscillator

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1 Introduction

TI's mmWave radar sensors include an internal processor to stabilize the radar front end performance across temperature and process by running calibration routines. The processor also enables the sensor's functional safety by periodically determining RF/analog performance parameters and detecting functional failures by running monitoring routines. The processor is programmed by TI and is dedicated for RF calibration and functional safety monitoring.

This document describes the various calibration mechanisms available in TI's mmWave radar sensors and their configurability.

1.1 Purpose of Calibrations

Figure 1-1 illustrates the radar front-end architecture in a TI mmWave radar device. The performance parameters of the RX LNA, IF amplifiers, TX PA, X4 (frequency multiplier), LO distribution buffers, and the clock sources shown all vary with process and temperature.
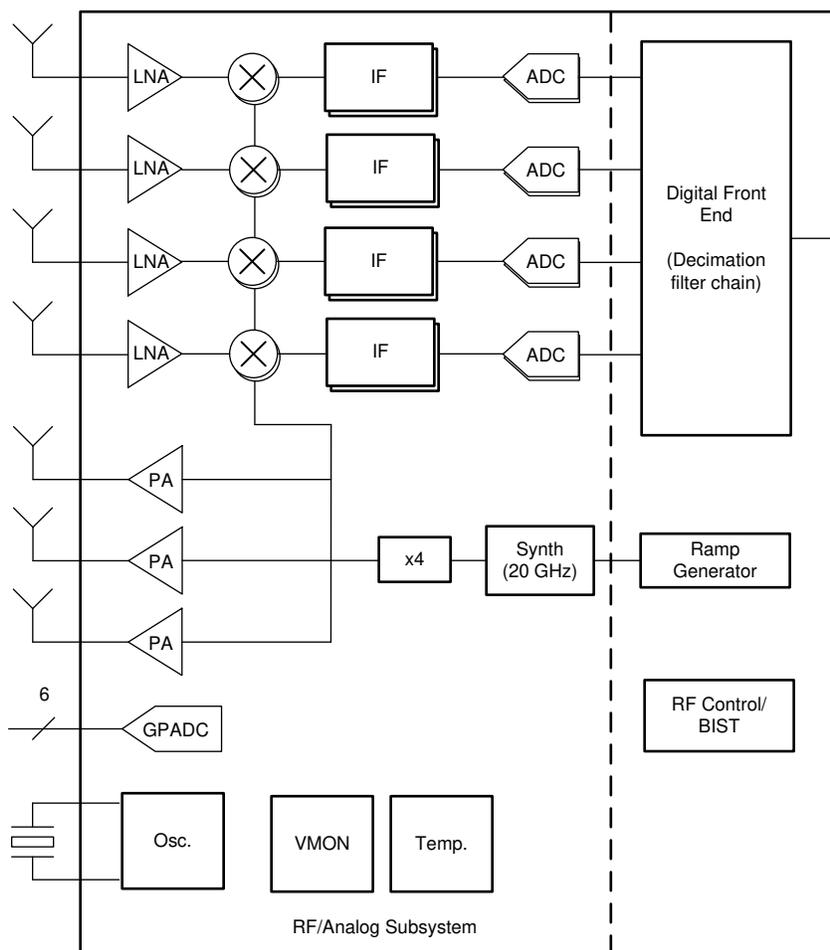
Figure 1-1. Radar Front-End Architecture in a TI mmWave Device

The purpose of calibrations is illustrated in Figure 1-2 using RX gain and TX power as examples. The gain of the RX LNA and the TX PA vary from device to device due to manufacturing process variations and also across temperature. The purpose of calibration is to ensure the RX gain and output power are maintained as configured by the user despite variations in process and temperature. To achieve this, the internal processor adjusts the mmWave circuit configurations at initialization (to mitigate effects of process variation) and periodically at runtime (to mitigate effects of temperature drifts). Figure 1-2 illustrates how calibration can be used to maintain the RX Gain and TX Power close to the configured settings across temperature drifts. These charts are illustrative and may not reflect actual device performance. Even with these calibrations done across temperature there would be some gain variations between devices, which must be considered in the user application.
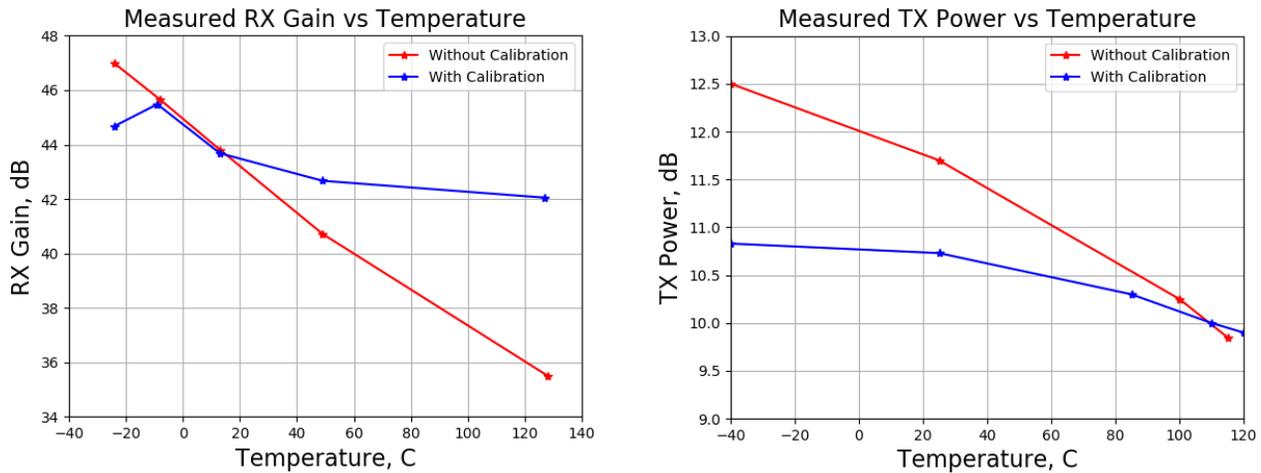
Figure 1-2. RX Gain and TX Power With and Without Calibration

These are representative plots on TI's first generation radar devices. Some of the calibrations (for example, the gain and power calibrations) are implemented as adjustments of circuit configurations based on measurement of RF/analog parameters. Other calibrations are implemented as adjustments based on process/temperature look up tables.

1.2 Purpose of Monitoring Mechanisms

To enable functional safety, such as in automotive applications, the monitoring mechanisms in the device can be configured to periodically provide the host processor with RF/analog health and diagnostic information. These mechanisms enable determination of RF/analog performance parameters and detection of failures arising from transistor and interconnect faults in the field. The diagnostic information they provide can also be helpful during development and optimization of designs integrating TI mmWave radar devices.

2 Hardware Infrastructure to Support Calibration and Monitoring

The calibration and monitoring mechanisms in TI's mmWave devices are implemented using a combination of hardware and firmware. Some of the hardware infrastructure blocks enabling these are illustrated here.

Several TX, RX RF and IFA parameter measurements are enabled by the mmWave power detectors coupled to the TX PA outputs and RX LNA inputs, and the TX-RX RF and RX IF loopback structures in the device, illustrated in Figure 2-1.
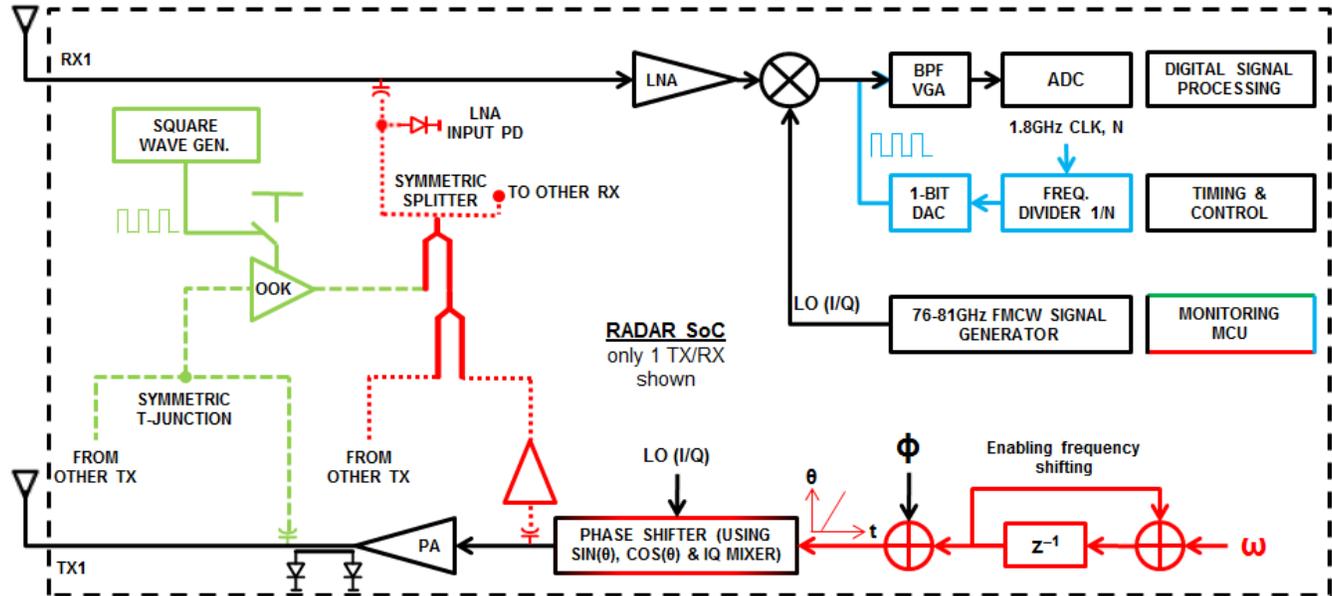
Figure 2-1. On-Chip TX-RX Test Signal Loopback Architecture: TX Monitoring, RX Monitoring, RX Baseband Monitoring

For example, the Tx output power calibration is enabled by measuring the internal Tx power using the power detector at the Tx power amplifier output port. The voltage level of the power detector is read using internal general purpose ADCs. These ADCs are also used for measuring other internal voltage levels, such as PLL control voltages, during VCO and APLL calibrations.

Some calibrations, such as RX IF filter calibrations, use the internal IF loopback structure. The loopback signal at different IF frequencies is fed, the IF frequency response analyzed, and appropriate resistor and capacitor bank adjustments are made to realize desired cutoff frequencies. Other calibrations, such as Rx gain calibration, use internal RF loop structures to feed a known amplitude of signal level from the TX chain to the Rx chain. The Rx gain is analyzed by processing the ADC data amplitude and accordingly the Rx chain biases are set to calibrate the gain.

In some other calibrations, fixed look up tables (LUTs, derived from nominal design simulations) are evaluated in the firmware based on measured temperature and analog bias settings adjusted.

3 List of Calibrations

TI's mmWave radar devices support the calibrations described in the following sections. All calibrations can be performed at the RF initialization phase (when the RfInit() API is called during the power up), and some can also be carried out at runtime. The user can select the calibrations to be executed at RfInit and runtime using the AWR_RF_INIT_CALIBRATION_CONF_SB API (to be called before RfInit API) and the AWR_RUN_TIME_CALIBRATION_CONF_AND_TRIGGER_SB API. Two of these calibrations (APLL and Synthesizer VCO calibrations) are always enabled at boot time and at runtime, and cannot be disabled. The time required for these two calibrations, and for all enabled periodic runtime calibrations, must be budgeted for when defining the frame configuration. More details can be found in the Interface Control Document available as part of the mmwave DFP package.

If a calibration is disabled at the RF initialization phase, it cannot be enabled at run time. In this case, the corresponding blocks always use fixed settings and will not compensate for changes device process variation and in temperature.

Note

The term "boot time" in this document refers to the RF initialization phase.

3.1 APLL Calibration

The APLL (or cleanup PLL) is a closed loop PLL that takes the 40-Mhz reference clock as input and generates the clocks required for the processor, digital logic as well as the ADCs, DACs, and FMCW synthesizer. APLL calibration is done to keep the system clock always locked at a constant frequency irrespective of process and temperature. It is done at the RF initialization phase by measuring the VCO's control voltage and adjusting the VCO tuning.

This is periodically and incrementally repeated at run time to account for the temperature drift. Runtime APLL calibration is triggered when the age of the last calibration result exceeds 1 second. Due to the importance of the system clock, APLL calibration cannot be disabled by the user and the calibration periodicity is not user controllable. The user should account for this calibration time while programming the frame timing.

3.2 Synthesizer VCO Calibration

Synthesizer VCO, which generates the RF frequency, calibration is done at boot time, and is also triggered when the age of the last calibration result exceeds 1 second. The calibration algorithm measures the synthesizer control voltage VCOs, and acts to maintain these voltages within a fixed range at all times.

Again, due to the importance of the synthesizer VCO frequency, this calibration cannot be disabled by the user and the calibration periodicity is not user controllable. The user should account for this calibration time while programming the frame timing.

3.3 LO Distribution Calibration

A set of buffers are used to distribute the high frequency RF clock to the Rx and Tx sections. In TI's first generation MMICs (xWR1243, xWR1642, xWR1443, xWR6843, xWR6443, and xWR1843), there is a fixed look up table (LUT) based on the temperature that controls the bias setting of the buffers. In second generation MMICs (xWR2243), the buffer output signal swing is maintained and optimized using a combination of closed loop calibration using mmWave power detectors (for mitigating process variation) and temperature-based look up tables.

3.4 ADC DC Offset Calibration

The ADC DC offset is only calibrated once, at boot time. This calibration is carried out without any signal at the RF LNA input. The LNA input is terminated to block reception of any RF signal during the calibration, and the DC power is measured using the DFE statistics collection. The measured DC offsets are programmed into the digital DC correction block for cancellation.

3.5 HPF Cutoff Calibration

The HPF1 and HPF2 high pass filters are only calibrated once, at boot time. The RX IFA square wave loopback is used to feed a known tone at the IFA input, and the ADC output's FFT component at the same frequency is measured. The filter is tuned to achieve the desired attenuation at the desired cutoff frequency.

3.6 LPF Cutoff Calibration

The LPF1 and LPF2 low pass filters are only calibrated once, at boot time. In Gen 1 MMICs from TI (xWR1243/1443/1642/1843/6843/6443), the IFA square wave loopback is used to feed a known tone at the IFA input, and the filter is tuned to achieve the desired attenuation at the desired cutoff frequency. In the Gen 2 MMICs (xWR2243), a fixed lookup table is used based on the sampling rate DFE mode of operation (Complex 1x/2x/, real).

3.7 Peak Detector Calibration

The peak detectors aim at providing an absolute voltage and power reference throughout the radar chip. They allow monitoring of voltage stress on the RF nodes, and quantify the output power at both the TX output and RF inputs. This allows for accurate RF BIST and impedance detector measurements. To make these measurements accurate, the peak detectors must be calibrated for variation in temperature. This calibration is carried out for all critical peak detectors, especially the ones used for TX power calibration.

The peak detectors are calibrated at boot time, and can also be recalibrated at runtime. TI recommends enalbing the Peak Detector runtime calibrations if monitors are enabled. The monitoring circuits also uses these Peak Detectors.

3.8 TX Power Calibration

TX power calibration is carried out to ensure that the device is transmitting at exactly the specified transmit power for a given profile.

TX power calibration can be done in Open Loop Power Control (OLPC) or Closed Loop Power Control (CLPC) modes. In OLPC mode, the TX stage codes are set based on a coarse measurement and a LUT is generated for every temperature range. The final stage codes are picked from the LUT and applied to the device based on the temperature at the time of calibration.

In CLPC mode, the TX stage codes are picked from the coarse LUT as in the OLPC step. Then, the actual TX power is measured using the peak detectors and the TX stage codes are refined to achieve the desired TX power accuracy. In many cases, the CLPC mode could provide better control on the TX output power because the gains are updated based on again performing a loopback measurement. This also leads to intentional transmission on the PA and higher calibration time. Refer to the Interface Control Document for calibration times.

The LUT used for TX power calibration can be read back from the device using an API. The LUT can also be replaced with a user-programmed LUT (for example, with an LUT that was previously read back from the device). The APIs to read and write the TX power calibration LUT are covered in Section 7.8.

Note

In CLPC mode, the LUT used for TX power calibration may be updated by the device after run time calibration events. The updated LUT can be read back from the device if needed.

TX power calibration is carried out at boot time for all enabled TXs, and can be carried out again at runtime. When recalibrating at runtime, the TX power calibration is done per-profile, per-TX.

3.9 RX Gain Calibration

The RX RF gain is calibrated to ensure that the overall RX gain is retained across changes in temperature. The RF gain is measured once, at boot time, before any profiles are configured. The boot time temperature at which the gain is measured is also stored for use during run time recalibration.

The current RF gain for a profile is computed using the device temperature at the time of calibration, the temperature at boot time, and the measured RX RF gain at boot time. Variation in the RX gain is compensated in the RX IFA and DFE, to achieve the desired overall gain for the profile.

The LUT used for RX gain calibration can be read back from the device using an API. The LUT can also be replaced with a user-programmed LUT (for example, with an LUT that was previously read back from the device). The APIs to read and write the RX gain calibration LUT are covered in Section 7.9.

3.10 IQ Mismatch Calibration

TI's MMICs have a complex receiver chain with both I and Q channels available for each receiver. The RF loopback structures are used to measure the any inter-IQ gain and phase mismatch and correct for it. This calibration is done only at RfInit (boot time).

3.11 TX Phase Shifter Calibration

The AWR1843 and AWR2243 devices allow configuration of the transmit phase in steps of 5.625 deg, and there are 64 code settings available to cover the 0 to 360 deg phase shift. To provide accurate phase shift corresponding to each of the codes (5.625 deg * code), the phase sifters can be calibrated at RF INIT using the RF loopback structures. This is done only at boot time.

To include correction across temperature and including additional external calibration by the user for better accuracy, refer to the *Cascade Coherency and Phase Shifter Calibration* application note.

4 Impact of Calibration on Gain and Phase

As the temperature of the device changes, the gains of the RX and TX blocks also change. If the gain settings are not corrected over temperature, the Rx and Tx gains continue to reduce as the temperature increases. For example, on the AWR2243 device, Rx gain variation for a fixed gain setting is roughly 0.4 dB per 10deg change in temperature. The Tx gain variation for a fixed bias setting and 0-dB backoff scenario is 0.2 dB per 10deg change in temperature. To reduce the impact of this gain change with temperature, run time calibrations can be used in either periodic mode or one shot mode issued by the user application based on temperature change.

When a calibration adjustment is done, there is a possibility of a step change in the Rx or Tx gain or phase. The step change in the gain depends on the change in gain codes caused due to calibration. One gain code change in RX gain causes a 2dB change in gain. Because the same calibration codes are applied to all the receiver or transmit chains within a single MMIC, there is typically minimal gain/phase mismatch change between the channels. However, the absolute gain/phase before and after the calibrations can be different.

Some processing algorithms (such as Historical static clutter estimate) which rely on coherence or amplitude/ phase consistency across frames can be sensitive to this abrupt change in absolute gain/phase resulting from calibrations. They should account for this by resetting their estimates just after calibration. In a single chip configuration, if gain/phase coherence is needed between frames, then the periodic run time calibrations can be avoided. Application can use the Run time calibrations in One Time Calibration mode, as explained in Section 6.3. The application can monitor the internal temperature and in case of significant change in temperature (for example 30°C change), it can issue a one time calibration. At this point, the gain and phase would change for the subsequent frames, hence the application must reset the algorithm if it is using any phase estimates from previous frames.

In a cascade use case, where the gain/phase mismatch across multiple MMICs becomes critical, the absolute gain/phase change in one MMIC can cause a mismatch across multiple MMICs. To handle this change, refer to the *Cascade Coherency and Phase Shifter Calibration* application note (https://www.ti.com/lit/pdf/spracv2).

5 Impact of Interference on the Calibrations and Emissions Caused Due to Calibrations

When an internal measurement is being performed for the calibrations, a presence of strong interference from outside the device could possibly impact the measurements and degrade the calibrations. Most calibrations are robust to such interferences: Tx power calibration, DC offset calibration, APLL calibration, VCO calibration, LO distribution calibration, HPF/LPF calibrations, and power detector calibrations would not be impacted by high power level (< -10 dBm) inband interferers. All the run time calibrations are also robust and are tolerant to such large interference.

Certain calibrations, including Rx gain boot time calibration, Rx IQ mismatch boot time calibration, and phase shifter calibration can potentially be impacted if there is an inband interference during the period of measurement. These are executed only during the Rfinit (boot time). Avoid any interference caused corruption by performing these only at the customer factory in an interference-free environment, and use the device calibration data save and restore APIs to inject that information back to the device in the interference-prone in-field operation. The following steps illustrate this approach:

1. Perform all the Rfinit calibrations on the sensor in a clean factory environment where interference is not expected.
2. Save the Rfinit calibrations results in a non-volatile memory of the sensor using the "AWR_CAL_DATA_SAVE_SB" and "AWR_PHASE_SHIFTER_CAL_DATA_SAVE_SB" API.
3. When the sensor is installed, during the operation of the sensor, the Rx IQ mismatch, Rx gain calibrations, and phase shifter calibration are disabled in Rfinit using the "AWR_RF_INIT_CALIBRATION_CONF_SB" API. This is called before the Rfinit API is issued.
4. Call the "AWR_CAL_DATA_RESTORE_SB " and "AWR_PHASE_SHIFTER_CAL_DATA_RESTORE_SB" APIs linking to the previously stored calibration files.
5. When the restore is complete, the Rfinit API can be called to perform the other enabled calibrations.

The TX power amplifier is enabled for certain boot calibrations (Tx power boot calibration, Tx phase shifter boot calibration, and Rx IQMM boot calibration). This leads to some signals being emitted on air during this process. If this causes a concern for any of the regulatory standards being targeted for the sensor, then the save - restore scheme explained above could be extended to avoid these emissions during bootup. For this, Tx power boot calibration should also be disabled as part of Step 3 in the above sequence.

The TX output power run time calibration in CLPC mode also enables the TX power amplifier. The TX power backoff setting used for this calibration chirp is the same as the one in the profile configuration, thus the total power emitted during this run time calibration is the same as the regular chirps of the same profile. However, the calibration chirp sweep bandwidth is between 75 - 100Mhz, thus the spectral density could be different from the functional chirps. If this is a concern for emissions, the TX power run time calibrations can be set to OLPC mode, where there is no transmission involved.

6 Scheduling of Runtime Calibration and Monitoring

The device receives the desired chirp and frame configuration from the corresponding API messages, and schedules transmission of chirps accordingly. Chirps are transmitted in bursts or frames, as per the configuration programmed.

All periodic calibrations and monitoring are scheduled by the device in the large inter-frame (or inter-burst, for advanced frames) idle time periods in every frame. Run time calibrations in One Time mode must scheduled and triggered manually by the application based on the internal temperature sensor reading. They must trigger a frame prior to the frame where the change is intended. Individual monitors and calibrations can be enabled or disabled as needed in the application. The periodicity of calibration and monitoring is configurable by two programmable parameters: CALIB_MON_TIME_UNIT and CALIBRATION_PERIODICITY.

One cycle of monitoring covering all enabled monitors is carried out every CALIB_MON_TIME_UNIT frames, (as programmed by the user). Therefore:

$$\text{MonitoringPeriod (in µs)} = \text{FramePeriod (in µs)} \times \text{CALIB\_MON\_TIME\_UNIT} \tag{1}$$

Periodic calibrations (except APLL and Synthesizer VCO calibrations) are carried out at a configurable multiple of CALIB_MON_TIME_UNIT. This multiple is configured using the CALIBRATION_PERIODICITY parameter.

$$\text{CalibrationPeriodicity (in µs)} = \text{MonitoringPeriod (in µs)} \times \text{CALIBRATION\_PERIODICITY} \tag{2}$$

Note

APLL and Synthesizer VCO calibrations are always carried out in the next available idle period after every 1 second; this is not controllable by the host. APLL and Synthesizer VCO calibrations are always enabled.

The value of CALIB_MON_TIME_UNIT must be large enough to accommodate all enabled monitors, all enabled periodic runtime calibrations and some software overheads. Even though calibration may not necessarily be carried out in every monitoring period, it must still be budgeted for when selecting CALIB_MON_TIME_UNIT.

Every CALIBRATION_PERIODICITY, the processor reads the temperature and performs a calibration update if needed. This update is done only if the temperature deviates by ±10 degrees compared to the temperature when the last calibration was done. LO Distribution calibration updates are done only if the temperature deviates by ±20 degrees from the temperature at last update.

This temperature measurement and calibration happens during the idle time between frames (or bursts). If any calibration results in an update to the device registers, the host is notified about the calibration update through an asynchronous event message.

The device determines the available idle time before the start of each frame (or burst) to ensure that there is enough idle time to complete each calibration.

Figure 6-1 shows an example where CALIB_MON_TIME_UNIT is 2 and CALIBRATION_PERIODICITY is 3. Note that monitoring activity can be spread across several inter-frame idle times. For detailed examples on programming CALIB_MON_TIME_UNIT and CALIBRATION_PERIODCITY, refer to the Interface Control Document in the mmave DFP.
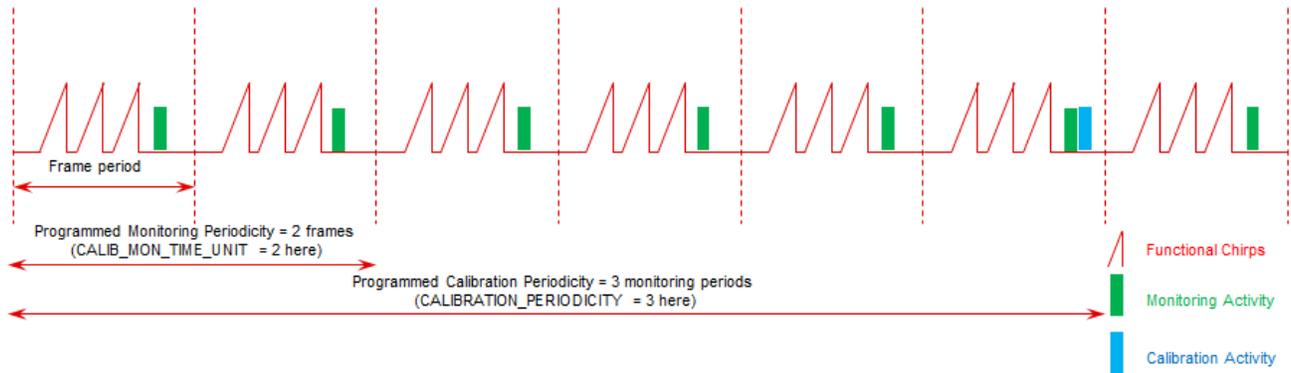
Figure 6-1. Calibration and Monitoring Activity During Inter-Frame Idle Times

6.1 Selection of CALIB_MON_TIME_UNIT

The first step is to compute the total available idle time per frame. For advanced frames, this includes all inter-burst idle times, inter-subframe idle times, and the inter-frame idle time. From this number, 100 μs should be reserved to allow for the preparation time for the next frame.

The next step is to compute the duration of all enabled periodic calibrations, all enabled monitors, and the software overheads. The duration of each of the monitors and calibrations are listed in Appendix A.

Then, the smallest allowed value of CALIB_MON_TIME_UNIT is the number of frames needed to accommodate the above duration in the available idle time per frame. The software overhead for the windowed watchdog depends on the CALIB_MON_TIME_UNIT, and thus this calculation must be iterative.

CALIB_MON_TIME_UNIT can be chosen to be any number higher than this, as required by the application. Refer to the Interface Control Document for some example computations of the calibration time and configuring the CALIB_MON_TIME_UNIT.

6.2 Selection of CALIBRATION_PERIODICITY

The calibration periodicity must be at least 1 second or higher. The smallest allowed value for CALIBRATION_PERIODICITY is:

$$\text{CALIBRATION\_PERIODICITY} >= \text{CEIL}(1/(\text{FramePeriod (in s)} \times \text{CALIB\_MON\_TIME\_UNIT})) \qquad (3)$$

Refer to the Interface Control Document for some example computations of the calibration time and configuring the CALIBRATION_PERIOCITY.

6.3 Application-Controlled One Time Calibration

In scenarios where the user does not want the periodic calibrations to be automatically triggered by the device firmware, the application can use the ONE TIME CALIBRATION feature where it can control the instance at which the calibration must be performed and the value of the gain change. The application can use the internal temperature sensor readings to trigger the one time calibrations OR could trigger it always before starting the radar measurement if the measurement cycle is expected to be short and no significant temperature change is expected during the measurement. When the one time calibration mode is triggered, the calibration of various RF/analog aspects are triggered based on the configured bits of in the "ONE_TIME_CALIB_ENABLE_MASK" field. The response is in the form of an asynchronous event. The calibrations, if enabled, are performed after the completion of any ongoing FTTI cycle, and the calibration results take effect from the next FTTI.

The ONE TIME CALIBRATIONS can be used in two ways:

1. ONE TIME CALIBRATION without temp index over ride; In this mode, when the application triggers the one time calibration, the firmware measures the internal temperature and sets the gain index based on the measured temperature. The application has control on the timing of the calibration but not the exact gain setting that the firmware picks.
2. ONE TIME CALIBRATION with temp index over ride: This mode is available in the xWR2243 device. In this mode, along with controlling the time of calibration, the application also selects the gain index to be picked by the firmware irrespective of the internal temperature reading. This way the application have full control on the gain changes. This mode is typically required only in cascade environment to ensure the gain and phase mismatch across the channels of multiple devices changes in a predictable manner.

7 Software Controllability of Calibration

This section lists the calibration-related software APIs available in mmWaveLink. The most up to date information on these APIs is available in the AWR1xx Radar Interface Control Document.

7.1 Calibration and Monitoring Frequency Limits

The rlRfSetCalMonFreqLimitConfig function can be used to program the lower and higher RF frequency limits for calibration and monitoring. These limits are applied to all TXs. TI recommends using the rlRfTxFreqPwrLimitConfig function instead, as it allows for greater flexibility.

Note

If both rlRfSetCalMonFreqLimitConfig and rlRfTxFreqPwrLimitConfig functions are called, then the function that is called later decides the limits used during calibration and monitoring.

7.2 Calibration and Monitoring TX Frequency and Power Limit

The user can select the frequency band and Tx power level to be used during the calibrations and monitoring. This is done using the rlRfTxFreqPwrLimitConfig API. The Tx power level and chirp frequency range for the active chirp is selected by the Profile Config. These two are not automatically interlinked to each other within the firmware, so the user could choose to use same settings for both calibrations and active chirps or keep them different.

To get the best accuracy from the calibrations, TI recommends always using Tx power setting of 0-dB backoff for calibrations/monitoring, even if the active chirps use a higher backoff setting. The calibration frequency range can be kept the same as that of the active chirps.

If using a 0-dB backoff setting during calibrations impacts the emission requirements, then TI recommends performing the Tx output power calibration with 0-dB backoff at the factory environment and using the save-restore feature of the calibration in the field operation. Refer to Section 5 for details on the save -restore process steps. During the factory calibration, a 0-db backoff can be used and the

calibrations saved, during the operation the RfInit calibrations are disabled and the saved calibrations results can be restored. The functional chirps can still use larger than 0dB backoff even if the calibrations were done using 0dB backoff.

7.3 Calibration Status Reports

7.3.1 RF Initialization Calibration Completion

When rlRfInit is called, the boot time calibrations are run and the application should wait for the RF initialization/ calibration completion asynchronous event AWR_AE_RF_INITCALIB_STATUS_SB.

This report indicates the pass/fail status for all enabled boot time calibrations, and whether any calibration data were updated in the hardware as a result of the calibration. The report also contains the timestamp at which calibration was carried out, and the measured temperature at the time of calibration (this is the average of the temperature sensor readings from the temperature sensors located near the TX and RX channels).

7.3.2 Runtime Calibration Status Report

If calibration reports are enabled using the rlRfRunTimeCalibConfig API, the AWR_RUN_TIME_CALIB_SUMMARY_REPORT_AE_SB asynchronous event message is sent by the mmWave device upon completion of any run-time calibrations (both one-time and periodic).

This report indicates the status of each enabled runtime calibration, and whether any calibration data were updated in the hardware as a result of the calibration. The report also contains the timestamp at which calibration was carried out, and the measured temperature at the time of calibration (this is the average of the temperature sensor readings from the temperature sensors located near the TX and RX channels).

7.3.3 Calibration/Monitoring Timing Failure Status Report

The AWR_CAL_MON_TIMING_FAIL_REPORT_AE_SB asynchronous event message is sent by the mmWave device if the total monitoring and calibration times do not fit in one CALIB_MON_TIME_UNIT.

This report is also sent when there is a run-time violation wherein the monitoring and calibrations could not be carried out in one CAL_MON_TIME_UNIT.

7.4 Programming CAL_MON_TIME_UNIT

The rlRfSetCalMonTimeUnitConfig function is used to set the CALIB_MON_TIME_UNIT. CALIB_MON_TIME_UNIT is the basic time unit for calibration and monitoring, and determines the period over which the various monitors are cyclically executed.

7.5 Calibration Periodicity

The CALIBRATION PERIODICITY parameter is set by the rlRunTimeCalibConf API. This governs the total time interval between two run time calibrations.

7.6 RF Initialization Calibration

The rlRfInitCalibConfig function can be used to control the set of calibrations carried out when rlRfInit is called. By default, all calibrations are carried out at RF initialization. This function must be called before rlRfInit is called.

7.7 Runtime Calibration

The rlRfRunTimeCalibConfig function can be used to:
- Trigger one-time calibrations instantaneously
- Schedule periodic run time calibrations
- Configure the calibration periodicity
- Enable the calibration summary reports
- Configure the TX power calibration mode (OLPC+CLPC or OLPC only)

The runtime calibration API can be issued during the framing; the firmware internally performs the calibration at the end of the present FTTI period and the change is applied for frames in the next FTTI.

7.8 Overriding the TX Power Calibration LUT

The LUT used for TX power calibration can be read back using the rlTxGainTempLutGet function. This returns the lookup table that is applied for TX power calibration for a given profile. The function should only be called after the profile has been configured in the device.

The LUT structure is described in the AWR1xx Radar Interface Control document. The LUT for a given profile consists of a set of 19 TX gain codes for each TX, with each code corresponding to a particular 10 degree temperature bin. Each TX gain code is a 6-bit number with higher values corresponding to higher gain.

If the CLPC mode is enabled, then the entries in the LUT may be updated automatically by the device as a consequence of run time calibration.

The rlTxGainTempLutSet function can be used to replace the LUT used by the device for TX power calibration with a different set of gain codes. This function should be called once for each profile for which the LUT needs to be replaced. This function should only be called after the profile has been configured in the device.

7.9 Overriding the RX Gain Calibration LUT

The LUT used for RX gain calibration can be read back using the rlRxGainTempLutGet function. This returns the lookup table that is applied for RX gain calibration for a given profile. The function should only be called after the profile has been configured in the device.

The LUT structure is described in the AWR1xx Radar Interface Control document. The LUT for a given profile consists of a set of 19 RX gain codes, each corresponding to a particular 10 degree temperature bin. Each RX gain code is further divided into an IF gain code and a RF gain code.

The rlRxGainTempLutSet function can be used to replace the LUT used by the device for Rx gain calibration with a different set of gain codes. This function should be called once for each profile for which the LUT needs to be replaced. This function should only be called after the profile has been configured in the device.

7.10 Retrieving and Restoring Calibration Data

The rlRfCalibDataStore and rlRfCalibDataRestore functions allow the retrieval and reprogramming of all calibration data from the device. These APIs can be used to store all calibration data to non-volatile memory at the factory and restore them at each power up.

The calibration data consist of 3 chunks of 228 bytes each. The rlRfCalibDataStore function reads one chunk of calibration data from the device at a time, and the rlRfCalibDataRestore function restores one chunk of calibration data to the device at a time.

The rlRfCalibDataRestore API must be called before rlRfInit is called.

Once the calibration data are restored properly and validated, the device will issue the AWR_AE_RF_INITCALIB_STATUS_SB report indicating the result of the calibrations based on the restored calibration data.

8 References

- [mmWave Radar Interface Control Document](#)

A Calibration and Monitoring Durations

A.1 Duration of Boot Time Calibrations

For the duration required to complete the each of the bootime calibrations, run time calibrations, and monitors, refer to the *Calibrations and Monitoring Durations* section of the Interface Control document. Apart from the time for each of the calibrations and monitors, the firmware also has some fixed overheads which must be accounted for while computing the total interframe time requirements in an FTTI. These can be found in the *Calibrations and Monitoring Durations* section of the Interface Control document.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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