Self-Calibration in TI's mmWave Radar Devices

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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.

Table 1. Abbreviations

Abbreviation	Description
BIST	Built-in Self Test
CLPC	Closed Loop Power Control
LNA	Low Noise Amplifier
LUT	Lookup Table
OLPC	Open Loop Power Control
VCO	Voltage Controlled Oscillator

Contents

List of Figures

List of Tables

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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 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.

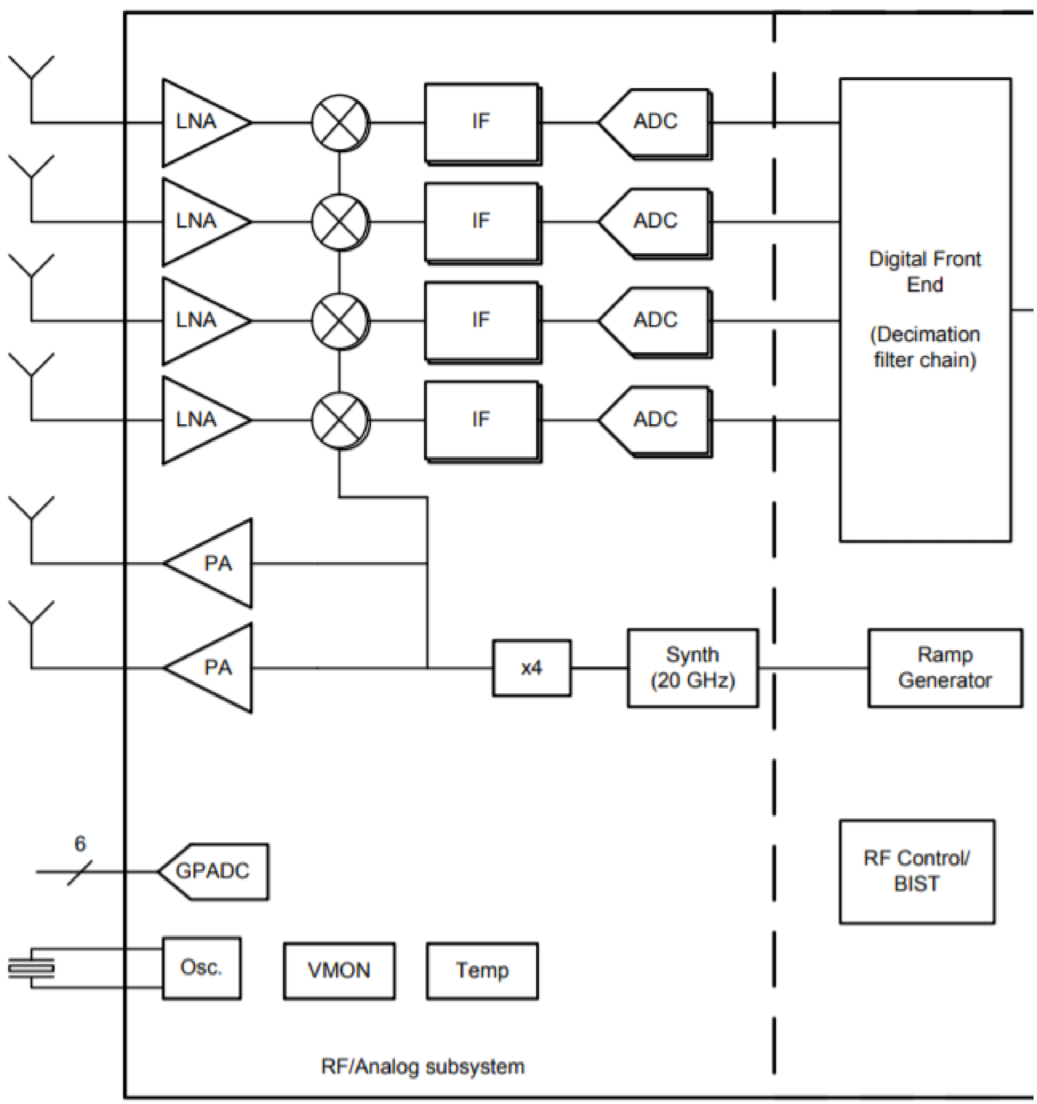

Figure 1. Radar Front-End Architecture in a TI mmWave Device

The purpose of calibrations is illustrated in Figure 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 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.

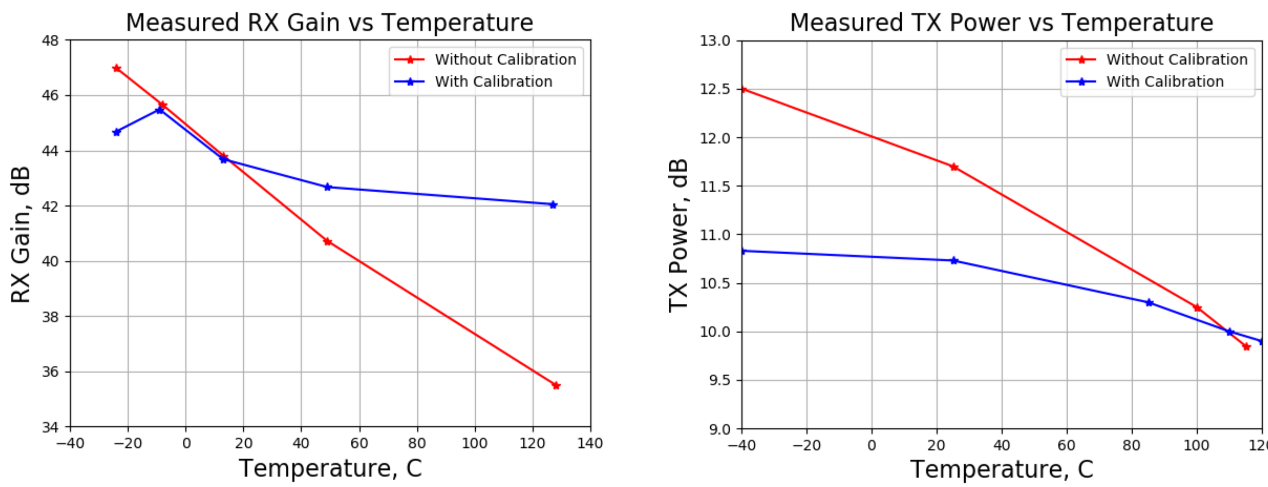

Figure 2. RX Gain and TX Power With and Without Calibration

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 3.

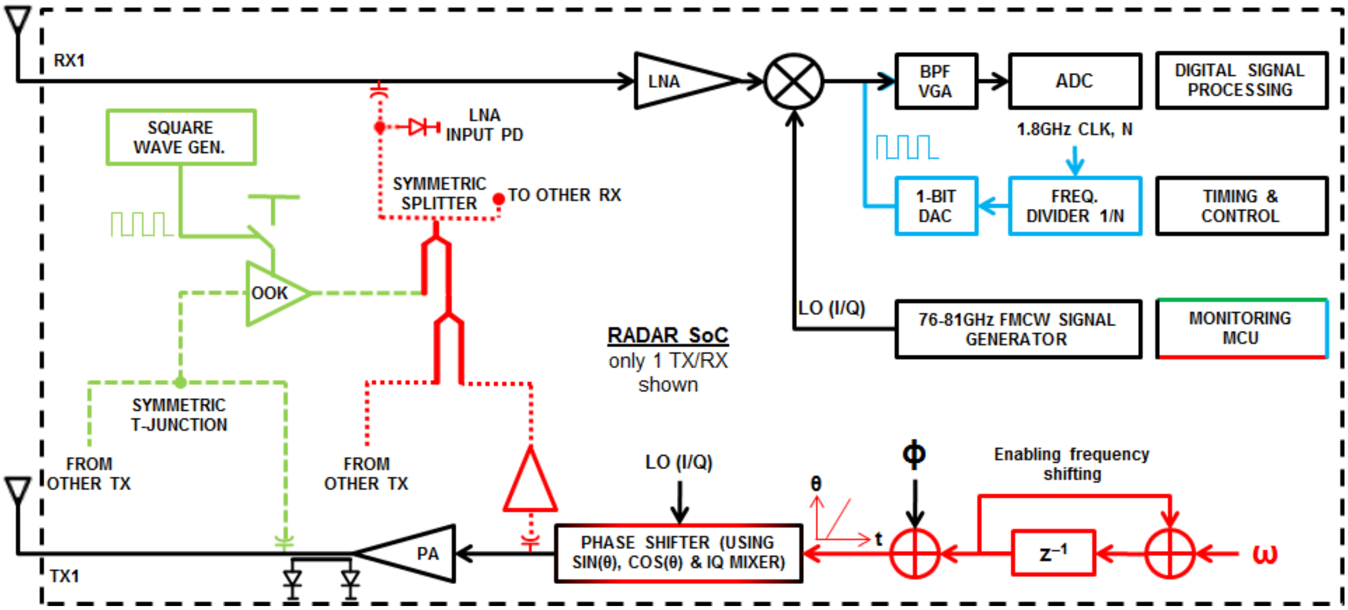

Figure 3. On-Chip TX-RX Test Signal Loopback Architecture: TX Monitoring, RX Monitoring, RX Baseband Monitoring

For example, the RX RF gain and inter-RX imbalance measurement is enabled by the RX RF loopback architecture. For this, an RF loopack signal with a slight frequency offset from the RX mixer LO frequency is created using a frequency shifter in the TX and coupled symmetrically to the RXs. The firmware measures the loopback signal power at the RX LNA input (using the mmWave power detectors) and at the RX ADC output (by digital signal processing of the RX ADC output). From these, the RX gains and inter-RX gain and phase imbalances are determined.

Similarly, to enable TX monitoring, power detectors are instantiated at the TX PA outputs. Also, inter-TX imbalance and TX phase modulation measurements are enabled by the TX RF loopback architecture. For this, all TX PA outputs are symmetrically coupled to the RX input through a square wave on-off-keying modulator, which provides a frequency offset between the signal at the RX LNA input and the RX mixer LO. The firmware measures the loopback signal amplitude and phase (by digital signal processing of the RX ADC output). From these, the inter-TX imbalance and TX phase modulation parameters are determined.

To enable RX baseband monitoring (for example, filter responses), an IF loopback test signal is generated and fed to the RX IF amplifiers. The firmware uses digital signal processing of the loopback signal at the RX ADC output to calibrate and monitor the RX IF filter frequency response.

The device also includes a shared general purpose ADC (GPADC) to measure various internal voltage levels for monitoring. For example, various supply voltages, circuit bias voltages, PLL VCO control voltages, temperature sensor output voltages, and mmWave power detector output voltages are all multiplexed and forwarded to the GPADC. The firmware uses this multiplexor and GPADC to detect transistor and interconnect faults through internal voltage monitoring. It also uses them for calibration adjustments: for example, the firmware observes the PLL and synthesizer VCO control voltages to tune their VCOs and enable them to always remain in lock across process and temperature.

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 (typically after every power cycle), and some can also be carried out at runtime. 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.

Except for APLL and Synthesizer VCO calibrations, all the other calibrations can be individually disabled at the RF initialization phase. 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 in temperature.

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

3.1 APLL Calibration

The APLL supplies the clock to 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 calibration is done for both VCOs 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 for both 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

The LO Distribution chain registers are updated using an internal lookup table based on temperature. This calibration is carried out at boot time, and can also be carried out at runtime.

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. 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.

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.

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.

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 5.7.

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 5.8.

4 Scheduling of Periodic 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. 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:

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

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. The minimum idle time needed to schedule any calibration is 200 µs.

Figure 4 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.

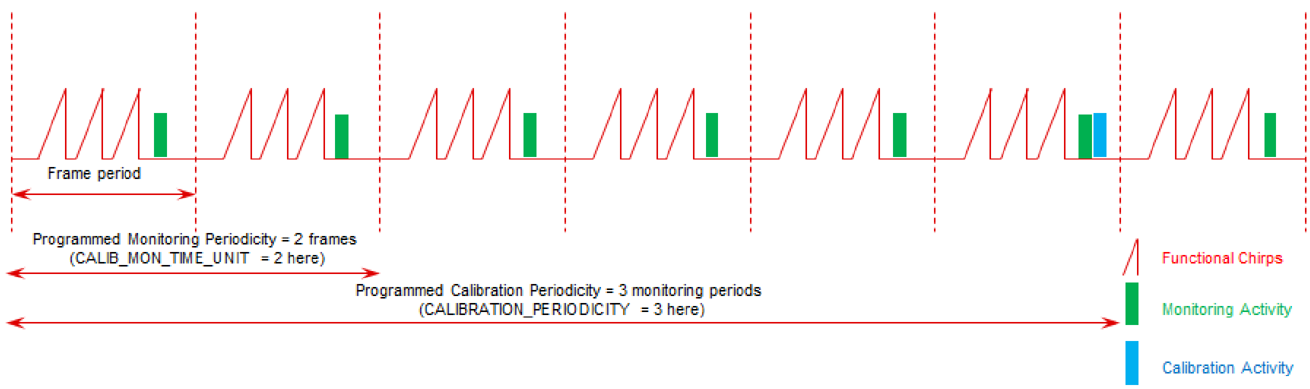

Figure 4. Calibration and Monitoring Activity During Inter-Frame Idle Times

4.1 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.

4.2 Selection of CALIBRATION_PERIODICITY

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

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

4.3 Examples to Select CAL_MON_TIME_UNIT and CALIBRATION_PERIODICITY

The following examples illustrate the process of selecting CAL_MON_TIME_UNIT and CALIBRATION_PERIODICITY. In each case, the minimum allowed value of these two parameters is shown. CAL_MON_TIME_UNIT will usually be chosen based on the desired monitoring interval for the application, subject to the minimum allowed value. CALIBRATION_PERIODICITY will then be chosen such that calibrations are attempted once in slightly more than 1 second.

4.3.1 Example 1

A use case has 2 TX enabled, uses only 1 profile, frame configuration consists of 64 chirps, each chirp is of duration is 66 µs (56-µs ramp time and 10-µs chirp idle time), and frame periodicity is 10 ms. All run time calibrations are enabled. None of the analog monitorings are enabled.

Idle time per frame is 10000 - (56 + 10) × 64 = 5776 µs

Idle time available for calibration and monitoring per frame is 5676 µs (100 µs is for frame preparation).

Time needed for all run-time calibrations is 150 + 300 + 30 + 500 + (800 × 2) + 30 + 150 = 2760 µs

The minimum time needed for software overheads is 20 + 1000 + 500 + 10000 × 1/8 = 2770 µs, if CALIB_MON_TIME_UNIT=1

Total time needed per frame for calibration is 2760 + 2770 = 5530 µs, which is less than the frame idle time available (5676 µs); thus, setting CALIB_MON_TIME_UNIT to 1 is honored by the AWR1XXX device.

Set CALIB_MON_TIME_UNIT to 1 and CALIBRATION_PERIODICITY to 100. With this setting, monitoring is carried out every 10 ms, and calibrations are triggered once every 100 frames (in other words, every 1 s).

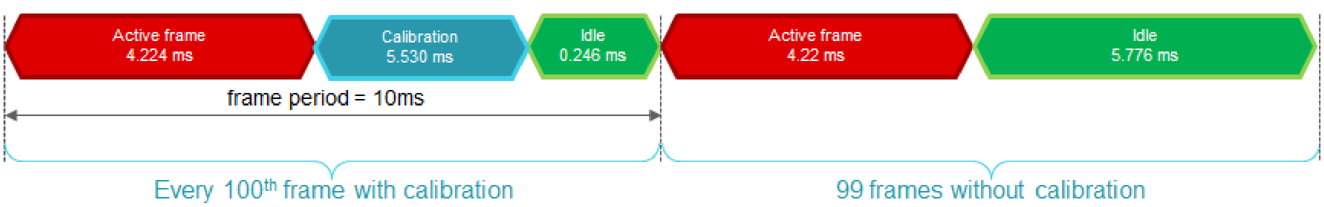

Figure 5. Example 1

4.3.2 Example 2

Consider another example where the frame configuration remains the same as in example 1, but frame periodicity is reduced to 8 ms.

Idle time per frame is 8000 - (56 + 10) × 64 = 3776 µs

Idle time available for calibration and monitoring per frame is 3676 µs (100 µs is for frame preparation).

Time needed for all run time calibrations is 150 + 300 + 30 + 500 + (800 × 2) + 30 + 150 = 2760 µs

The minimum time needed for software overheads is 20 + 1000 + 500 + 8000 × 1/8 = 2520 µs, if CALIB_MON_TIME_UNIT=1

Total time needed per frame for calibration is 2760 + 2520 = 5280 µs. which is more than the available frame idle time (3676 µs), and thus setting CALIB_MON_TIME_UNIT to 1 is not honored by the AWR1XXX device. If CALIB_MON_TIME_UNIT is set to 1 and framing is started, the device issues the AWR_CAL_MON_TIMING_FAIL_REPORT_AE_SB report indicating insufficient available idle time.

Set CALIB_MON_TIME_UNIT to 2 and CALIBRATION_PERIODICITY to 63. With this setting, monitoring is carried out every 16 ms, and calibrations are triggered every 126 frames (in other words, every 1.008 s).

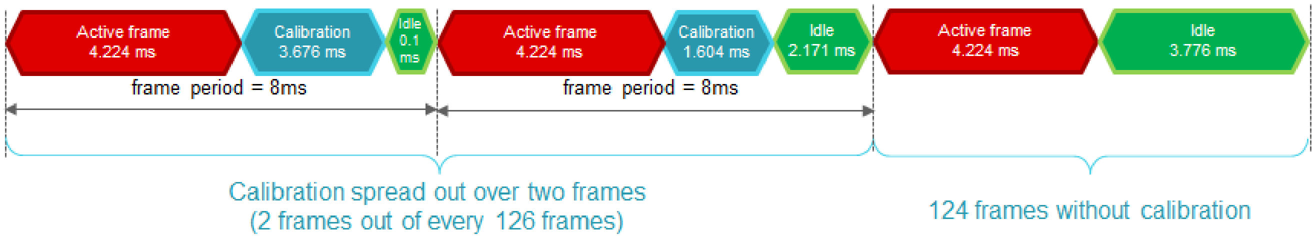

Figure 6. Example 2

4.3.3 Example 3

Consider a use case which has 2 TX enabled, uses 2 profiles, frame configuration consists of 32 chirps, each chirp is of duration is 90 µs (80-µs ramp time and 10-µs chirp idle time), and frame periodicity is 6 ms. All run time calibrations are enabled. None of the analog monitorings are enabled.

Idle time per frame is 6000 - (80 + 10) × 32 = 3120 µs

Idle time available for calibration and monitoring per frame is 3020 µs (100 µs is for frame preparation).

Time needed for all run time calibrations is 150 + 300 + 30 + 500 + (800 × 2 × 2) + 30 + 150 = 4360 µs

The minimum time needed for software overheads is 20 + 1000 + 500 + (6000 × 1/8) = 2270 µs, if CALIB_MON_TIME_UNIT=1

Total time needed per frame for calibration is 4360 + 2270 = 6630 µs, which is more than the available frame idle time (3020 µs), and thus setting CALIB_MON_TIME_UNIT to 1 is not honored by the AWR1XXX device. If CALIB_MON_TIME_UNIT is set to 1 and framing is started, the device issues the AWR_CAL_MON_TIMING_FAIL_REPORT_AE_SB report indicating insufficient available idle time.

Set CALIB_MON_TIME_UNIT to 3 and CALIBRATION_PERIODICITY to 56. With this setting, the minimum required idle time is 8130 µs, and the available time across 3 frames is 9160 µs. Calibrations are triggered every 168 frames (in other words, every 1.008 s).

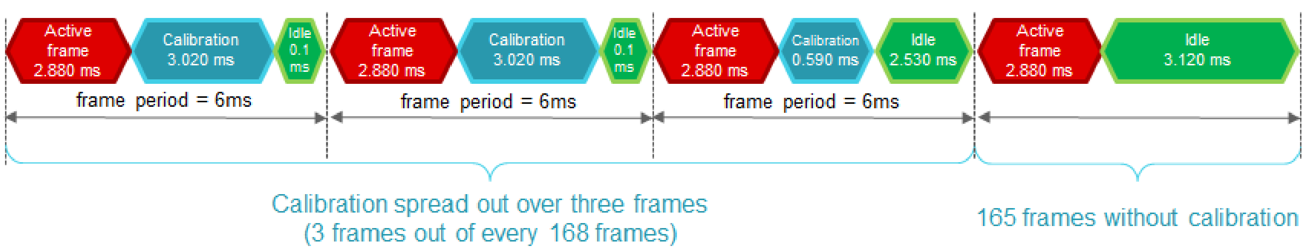

Figure 7. Example 3

4.3.4 Example 4

Consider another example where the frame configuration remains the same as in Example 3. All run time calibrations are enabled. The following analog monitorings are enabled: (a) TX output power monitor for TX0 and TX1 (b) TX BPM monitor for TX0 and TX1 (c) RX gain phase monitor and (d) RX noise figure monitor. Each of the monitors are configured to be run for 1 profile and 3 RF frequencies (low, mid and high) as defined by the profile.

Idle time per frame is 6000 - (80 + 10) × 32 = 3120 µs

Idle time available for calibration and monitoring per frame is 3020 µs (100 µs is for frame preparation).

Time needed for all run time calibrations is 150 + 300 + 30 + 500 + (800 × 2 × 2) + 30 + 150 = 4360 µs

Time needed for all monitoring is (1250 × 3) + (250 × 3) + (200 × 3 × 2) + (575 × 2) = 6850 µs

The minimum time needed for software overheads is 20 + 1000 + 500 + (6000 × 1/8) = 2270 µs, if CALIB_MON_TIME_UNIT=1

Total time needed per frame for calibration and monitoring is 4360 + 6850 + 2270 = 13480 µs, which is more than the available frame idle time (3020 µs), and thus setting CALIB_MON_TIME_UNIT to 1 is not honored by the AWR1XXX device. If CALIB_MON_TIME_UNIT is set to 1 and framing is started, the device issues the AWR_CAL_MON_TIMING_FAIL_REPORT_AE_SB report indicating insufficient available idle time.

Set CALIB_MON_TIME_UNIT to 6 and CALIBRATION_PERIODICITY to 28. With this setting, the minimum required time for calibration and monitoring is 17230 µs, and the available idle time across 6 frames is 18120 µs. Monitoring is triggered once in 6 frames, and calibrations are triggered once in 168 frames (in other words, every 1.008 s).

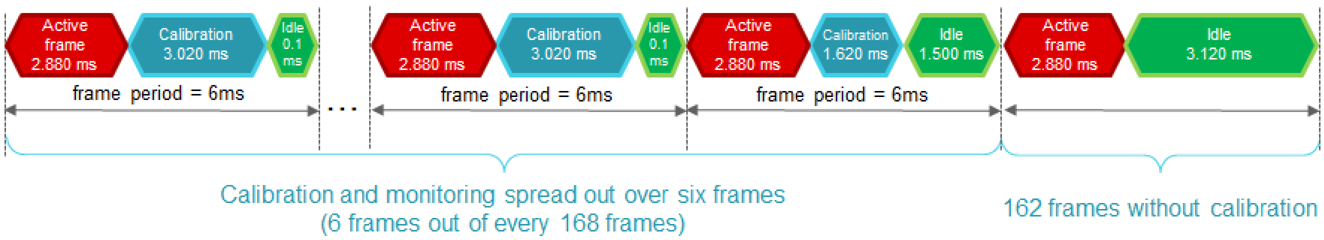

Figure 8. Example 4

5 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.

5.1 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.

5.2 Calibration and Monitoring TX Power Limits

There might be a need to restrict the frequency bands and power levels at which the device transmits. During normal framing, this is enforced by limits in the configured profile. However, profiles are configured only after boot time.

In order to restrict the frequency bands and power levels during boot time calibration, the rlRfTxFreqPwrLimitConfig function can be used to program the lower and higher RF frequency limits and the TX power backoff for each TX individually. The frequency limits and TX power backoff settings configured using this function are used during boot time calibrations. These limits should be programmed explicitly before calling rlRfInit as profiles are not defined until after rlRfInit is called.

If this API is not explicitly called, then the frequency range used for boot time calibrations is 76 to 81 GHz, and the TX power backoff is 0.

5.3 Calibration Status Reports

5.3.1 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).

5.3.2 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).

5.3.3 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.

5.4 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.

5.5 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.

5.6 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)

This function should be issued only when the device is not framing.

If enabled in the API call, the one-time calibration will run as soon as the function is called. If reporting is also enabled at the same time as one-time calibration, a run-time calibration summary report will also be immediately issued.

5.7 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.

5.8 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 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.

5.9 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.

6 References

- AWR1xx Radar Interface Control Document, Rev 0.96, Texas Instruments, April 2018

Appendix A

SPRACF4–June 2018

Calibration and Monitoring Durations

A.1 Duration of Boot Time Calibrations

Table 2. Duration of Boot Time Calibrations

Sl. No	Calibration	Duration (µs)
1	APLL	330
2	Synth VCO	1300
3	LO DIST	12
4	ADC DC	600
5	HPF cutoff	3500
6	LPF cut off	3200
7	Peak detector	4200
8	TX power (per TX, per profile)	6000
9	RX gain	2300

A.2 Duration of Run Time Calibrations

Table 3. Duration of Run Time Calibrations

Sl. No	Calibration	Duration (µs)
1	APLL	150
2	Synth VCO	300
3	LO DIST	30
4	Peak detector	500
5	TX power (per TX, per profile)	800
6	RX gain	30
7	Application of calibration to hardware (This must always be included)	150

A.3 Monitoring Durations

Table 4. Duration of Analog Monitors

Sl. No	Monitors	Duration (µs)
1	RX gain phase (per RF frequency)	1250
2	RX noise figure (per RF frequency)	250
3	RX IF stage (per RF frequency)	1000
4	TX power (per TX, per RF frequency)	200

Table 4. Duration of Analog Monitors (continued)

Sl. No	Monitors	Duration (µs)
5	TX ballbreak (per TX)	250
6	TX gain phase mismatch (per TX, per RF frequency)	400
7	TX BPM (per TX)	575
8	Synthesizer frequency	0
9	External analog signals (all 6 GPADC channels enabled)	150
10	TX Internal analog signals (per TX)	200
11	RX internal analog signals	1700
12	PM, CLK, LO internal analog signals	400
13	GPADC internal signals	50
14	PLL control voltage	210
15	Dual clock comparator (all 6 clock comparators)	110
16	RX saturation detector	0
17	RX signal and image band monitor	0
18	RX mixer input power	350

Table 5. Duration of Digital Monitors

Sl. No	Monitors	Duration (µs)
1	Periodic configuration register read back	100
2	ESM monitoring	50
3	DFE LBIST monitoring	1000
4	Frame timing monitoring	10

A.4 Duration of Software Overheads

Table 6. Duration of Software Overheads

Sl. No	Software Overhead	Duration (µs)
1	Periodic monitoring of stack usage	20
2	Minimum monitoring duration (report formation, digital energy monitor read, temperature read)	1000
3	Minimum calibration duration (report formation, temperature read)	500
4	Idle time needed for windowed watchdog	Frame period * CALIB_MON_TIME_UNIT/8

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