

Real-Time Calibration and Monitoring Based on the AWR2x44x Series



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Abstract

This document was translated from a simplified Chinese source. ([ZHCAG89](#))

The AWR2x44x series SoC is specifically designed for ADAS millimeter-wave radar. To address challenges such as temperature drift, device aging, and electromagnetic interference, the system introduces runtime calibration and real-time monitoring mechanisms. Runtime calibration dynamically compensates for RF link deviations to ensure stable radar operation within the range of -40°C to 140°C; the monitoring module continuously tracks key metrics based on Built-In Self-Test (BIST) and issues timely alerts upon anomalies. Combining the AWR2944P OOB example, this paper introduces relevant API configuration methods, execution time calculation examples, and parameter setting precautions, providing a reference for the reliability design of radar systems.

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1 Introduction

As a core sensor for advanced autonomous driving and intelligent perception, the performance stability of millimeter-wave radar is directly related to system reliability. However, radar chips face complex operating conditions in practice: on the one hand, factors such as ambient temperature and humidity changes, and device aging will cause parameters such as RF link gain and phase to drift, thereby affecting detection accuracy; on the other hand, uncertain factors such as vibration and electromagnetic interference in vehicular scenarios may also cause performance degradation. In the absence of effective calibration and monitoring mechanisms, the radar may suffer from target missing, false alarms, or even functional failure, posing a serious threat to driving safety.

Therefore, millimeter-wave radar systems need to introduce runtime calibration and monitoring technology. By collecting internal chip parameters such as temperature and voltage in real-time, combined with preset calibration algorithms to dynamically compensate for link deviations, it can ensure that the radar maintains stable detection performance within the temperature range of -40°C to 140°C. Meanwhile, the monitoring module based on the Built-In Self-Test (BIST) mechanism continuously tracks key metrics (such as signal-to-noise ratio and spurious level). Once an abnormality is detected (such as phase error exceeding the limit caused by sudden temperature changes), an alarm is immediately triggered and reported to the system controller, providing a foundational guarantee for the stability of the radar system.

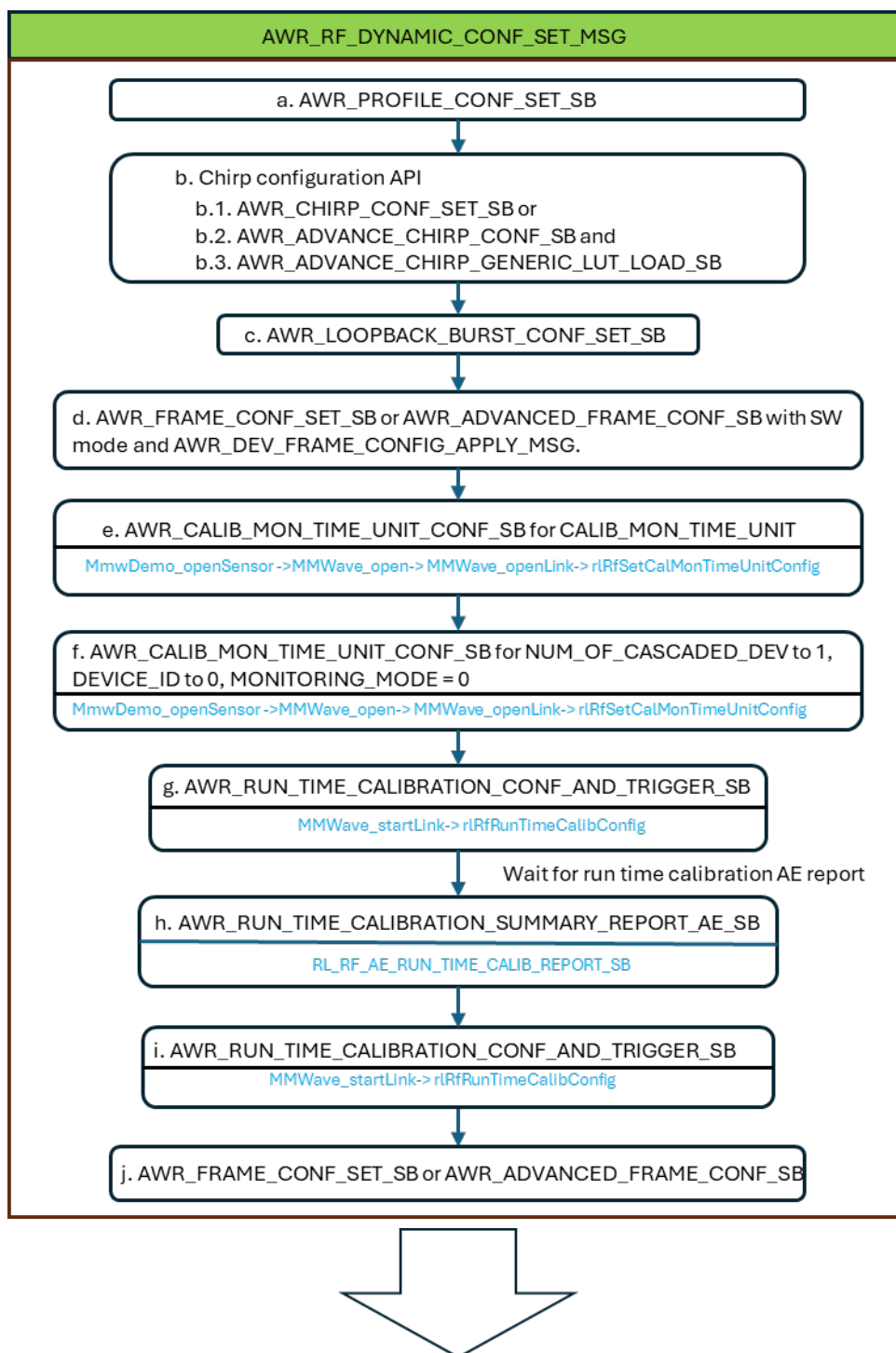
2 Real-Time Calibration and Monitoring Based on the AWR2x44x Series

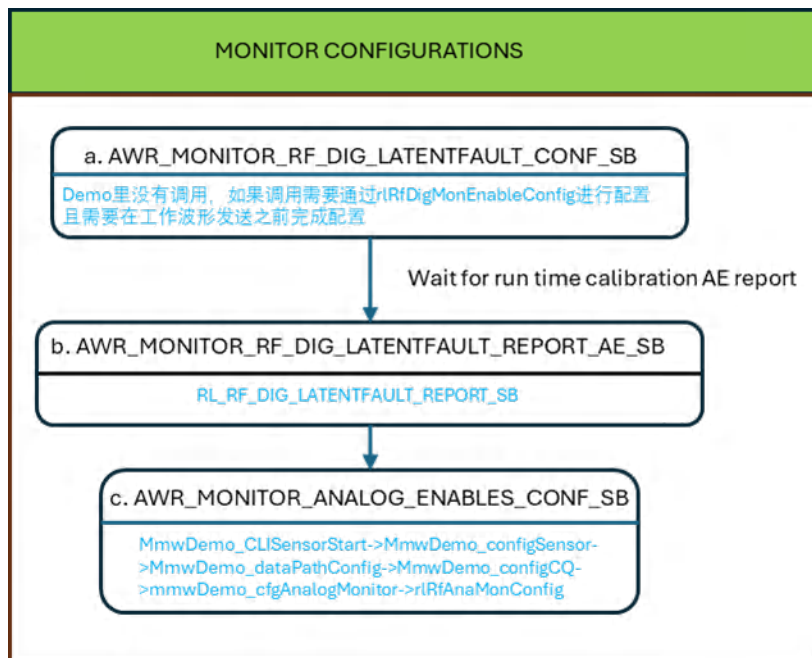
2.1 Runtime Calibration and Monitoring Implementation in AWR2944P OOB Example

2.1.1 APIs and Their Meanings

- a. AWR_CALIB_MON_TIME_UNIT_CONF_SB Configure runtime calibration/monitoring period
 - a.1 CALIB_MON_TIME_UNIT is used to configure the minimum periodic unit for completing runtime calibration/monitoring, which is an integer multiple of the frame period
 - a.2 NUM_OF_CASCADEDEV Configures the number of cascaded devices. The scope described in this article is 1
 - a.3 DEVICE_ID The scope described in this article is 0
 - a.4 MONITORING_MODE The scope described in this article is 0 (default configuration)
- b. AWR_RUN_TIME_CALIBRATION_CONF_AND_TRIGGER_SB Configure one-time calibration and runtime calibration
 - b.1 ONE_TIME_CALIB_ENABLE_MASK: Trigger the corresponding calibration option once based on the flag bits. If other calibrations are still executing, calibration will be performed after the previous calibrations are completed. Calibration takes effect in the frame starting after the asynchronous event is issued
 - b.2 PERIODIC_CALIB_ENABLE_MASK: Periodically execute calibration items of the corresponding calibration options,
 - b.3 CALIBRATION_PERIODICITY: The calibration period, which needs to be ≥ 1 s. The unit of the calibration period is the monitoring period, and the calibration results are as described in b.1
 - b.4 ENABLE_CAL_REPORT: Controls whether calibration results are reported via asynchronous events
 - b.5 TX_POWER_CAL_MODE: Calibration mode for transmission power
 - b.6 CAL_TEMP_INDEX_OVERRIDE_ENABLE: Configure the corresponding calibration item to overwrite the calibration value automatically obtained by the chip internally based on temperature with the specified temperature calibration value.
 - b.7 CAL_TEMP_INDEX_TX Calibration values corresponding to different temperatures for the transmitter module
 - b.8 CAL_TEMP_INDEX_RX Calibration values corresponding to different temperatures for the receiver module
 - b.9 CAL_TEMP_INDEX_LODIST Calibration values corresponding to different temperatures for LODIST
 - b.10 CAL_TEMP_INDEX_TXPHASE Calibration values corresponding to different temperatures for transmission phase
- c. AWR_RUN_TIME_CALIBRATION_SUMMARY_REPORT_AE_SB Asynchronous event for runtime calibration results.
 - c.1 CALIBRATION_ERROR_FLAG Each bit corresponds to the calibration result of a calibration item, where 1 represents pass and 0 represents fail
 - c.2 CALIBRATION_UPDATE_STATUS Each bit corresponds to whether the calibration item is updated, where 1 represents updated and 0 represents not updated
 - c.3 TEMPERATURE Calibration temperature
 - c.4 TIME_STAMP Timestamp of calibration
- d. AWR_MONITOR_RF_DIG_LATENTFAULT_CONF_SB Used to configure and detect whether there are potential faults in the digital part of the RF front-end, usually completed before framing because it requires transmitting a specific waveform built into the chip.
 - d.1 DIG_MONITORING_ENABLER Corresponding digital part detection items
 - d.2 TEST_MODE Detection mode
- e. AWR_MONITOR_RF_DIG_PERIODIC_CONF_SB Used to configure periodic monitoring of whether the digital part of the RF front-end is normal.
 - e.1 REPORTING_MODE 0 for periodic reporting, 1 for reporting only when an abnormality occurs
 - e.2 PERIODIC_DIG_MON_EN Corresponding digital part detection items
- f. AWR_MONITOR_ANALOG_ENABLER_CONF_SB Used to monitor whether all analog parts are working properly, and completed within one CALIB_MON_TIME_UNIT time.

2.1.2 AWR2x44P Real-Time Calibration and Monitoring Process





2.2 Execution Time of Calibration and Monitoring

2.2.1 FTTI Explanation

FTTI can be understood as the time when all monitoring + calibration periods are completed, during which normal transmission and reception will not be affected. It is divided into two parts:

- a. CALIB_MON_TIME_UNIT, 1 LSB = Duration of one frame.
- b. CALIBRATION_PERIODICITY, 1 LSB = 1 CALIB_MON_TIME_UNIT.

The total time is usually composed of CALIB_MON_TIME_UNIT.

2.2.2 Runtime Calibration Execution Time

Sl. No.	Calibration	Total Duration (μ s)	Total Critical Time (μ s)
1	APLL	150	145
2	Synth VCO	300	290
3	LO DIST	30	0
4	Peak detector	600	580
5	TX power CLPC (for each TX and for 1 profile)	720	580
6	TX power OLPC (In case CLPC is disabled)	30	0
7	RX gain	30	0
8	TX phase	700	0
9	Application of calibration to hardware (This needs to be included always)	60	60

Figure 2-1. Runtime Calibration Execution Time

2.2.3 Analog Monitoring Execution Time

Sl. No.	Monitors	Total Duration (μ s)	Total Critical Time (μ s)	Num of mon chirps
1	RX gain phase (assumes 1 RF frequency)	480	290	2
2	RX noise figure (assumes 1 RF frequency)	270	145	1
3a	RX IF stage (LPF monitor disabled)	750	580	4
3b	RX IF stage (LPF monitor enabled. Debug only)	2490	2320	16
4	TX power (assumes 1 TX, 1 RF frequency)	240	145	1
5	TX balbreak (assumes 1 TX)	250	145	1
6	TX gain phase mismatch (assumes 1 TX, 1 RF frequency)	310	130	1
7	TX phase shifter (assumes 1 TX and 1 phase)	300	130	1
8	Synthesizer frequency Live	50	0	0
9	TX Internal analog signals (assumes 1 TX)	230	130	1
10	TX Phase shifter DAC monitor	2650	2610	18
11	RX internal analog signals	670	520	4
12	PMCLKLO internal analog signals	250	145	1
13	GPADC internal signals	80	70	0
14	PLL control voltage (APLL and SYNTH)	230	200	0
15	Dual clock comparator	190	190	0
16	RX saturation detector	50	0	0
17	Synthesizer frequency Non-live monitor (Single VCO)	235	145	1
18	Temperature (Critical time is accounted in Software overheads)	150	100	0

Figure 2-2. Analog Monitoring Execution Time

2.2.4 Digital Monitoring Execution Time

Sl. No.	Monitors	Total Duration (μ s)	Total Critical Time (μ s)
1	Periodic configuration register readback	50	50
2	DFE LBIST monitoring	580	580
3	Frame timing monitoring	10	0

Figure 2-3. Digital Monitoring Execution Time

2.2.5 Other Software Execution Time

Sl. No.	Software overhead	Total Duration (μ s)	Total Critical Time (μ s)
1	Periodic monitoring of stack usage	20	20
2	Minimum monitoring duration (report formation, digital energy monitor at the end of CALIB_MON_TIME_UNIT, temperature read every CALIB_MON_TIME_UNIT)	600	100
3	Minimum run time calibration duration (report formation, temperature read every CALIB_MON_TIME_UNIT)	300	100
4	Idle time needed per FTTI for windowed watchdog (WDT)	Frame period $\times$ CALIB_MON_TIME_UNIT/8 i.e. $\sim$ 12.5% of Frame period $\times$ CALIB_MON_TIME_UNIT is reserved for watchdog clearing time	0

Figure 2-4. Other Software Execution Time

2.3 Execution Order of Monitoring Functions

When the corresponding monitoring flag bits are set, monitoring will be performed in the following order.

In xWR294x, xWR254x, xWR2x4xECO, xWR2x4xP, the enabled monitors are executed in the below order.

1. TEMPERATURE_MONITOR.
2. RX_GAIN_PHASE_MONITOR.
3. RX_IFSTAGE_MONITOR.
4. SYNTH_FREQ_MONITOR_NON_LIVE.
5. INTERNAL_RX_SIGNALS_MONITOR.
6. INTERNAL_PMCLKLO_SIGNALS_MONITOR.
7. INTERNAL_GPADC_SIGNALS_MONITOR.
8. PLL_CONTROL_VOLTAGE_MONITOR.
9. DCC_CLOCK_FREQ_MONITOR.
10. RX_SATURATION_DETECTOR_MONITOR.
11. TX_PHASE_SHIFTER_DAC_MONITOR.
12. TX0_POWER_MONITOR.
13. TX1_POWER_MONITOR.
14. TX2_POWER_MONITOR.
15. TX3_POWER_MONITOR.
16. TX0_BALLBREAK_MONITOR.
17. TX1_BALLBREAK_MONITOR.
18. TX2_BALLBREAK_MONITOR.
19. TX3_BALLBREAK_MONITOR.
20. INTERNAL_TX0_SIGNALS_MONITOR.
21. INTERNAL_TX1_SIGNALS_MONITOR.
22. INTERNAL_TX2_SIGNALS_MONITOR.
23. INTERNAL_TX3_SIGNALS_MONITOR.
24. TX_GAIN_PHASE_MISMATCH_MONITOR.
25. TX0_PHASE_SHIFTER_MONITOR.
26. TX1_PHASE_SHIFTER_MONITOR.
27. TX2_PHASE_SHIFTER_MONITOR.
28. TX3_PHASE_SHIFTER_MONITOR.

Figure 2-5. Execution Order of Monitoring Functions

2.4 Impact of Monitoring Items on Interference

Divided into 3 categories according to whether the monitoring item is susceptible to interference:

Type0: No transmission, causing no interference to other radars.

Type1: Transmission without reception; at this time, the interference has a minor impact on the radar itself, but will affect other radars with reception enabled.

Type2: Both transmission and reception are enabled; interference will be received at this time.

Monitor Type	Monitors																																				
Type 0	The run time digital monitors in AWR_MONITOR_RF_DIG_CONF_SB <table> <tr> <th>Bit</th><th>Definition</th></tr> <tr> <td>b0</td><td>PERIODIC_CONFIG_REGISTER_READ_EN</td></tr> <tr> <td>b2</td><td>DFE_STC_EN</td></tr> <tr> <td>b3</td><td>FRAME_TIMING_MONITORING_EN</td></tr> </table> The analog monitors in AWR_MONITOR_ANALOG_ENABLES_CONF_SB <table> <tr> <th>Bit</th><th>Definition</th></tr> <tr> <td>b0</td><td>TEMPERATURE_MONITOR</td></tr> <tr> <td>b1</td><td>RX_GAIN_PHASE_MONITOR</td></tr> <tr> <td>b2</td><td>RX_NOISE_FIGURE_MONITOR</td></tr> <tr> <td>b3</td><td>RX_IFSTAGE_MONITOR</td></tr> <tr> <td>b14</td><td>SYNTH_FREQ_MONITOR</td></tr> <tr> <td>b15</td><td>EXTERNAL_ANALOG_SIGNALS_MONITOR</td></tr> <tr> <td>b19</td><td>INTERNAL_RX_SIGNALS_MONITOR</td></tr> <tr> <td>b20</td><td>INTERNAL_PMCLKLO_SIGNALS_MONITOR</td></tr> <tr> <td>b21</td><td>INTERNAL_GPADC_SIGNALS_MONITOR</td></tr> <tr> <td>b22</td><td>PLL_CONTROL_VOLTAGE_MONITOR</td></tr> <tr> <td>b23</td><td>DCC_CLOCK_FREQ_MONITOR</td></tr> <tr> <td>b24</td><td>RX_SATURATION_DETECTOR_MONITOR</td></tr> <tr> <td>b25</td><td>RX_SIG_IMG_BAND_MONITOR</td></tr> </table>	Bit	Definition	b0	PERIODIC_CONFIG_REGISTER_READ_EN	b2	DFE_STC_EN	b3	FRAME_TIMING_MONITORING_EN	Bit	Definition	b0	TEMPERATURE_MONITOR	b1	RX_GAIN_PHASE_MONITOR	b2	RX_NOISE_FIGURE_MONITOR	b3	RX_IFSTAGE_MONITOR	b14	SYNTH_FREQ_MONITOR	b15	EXTERNAL_ANALOG_SIGNALS_MONITOR	b19	INTERNAL_RX_SIGNALS_MONITOR	b20	INTERNAL_PMCLKLO_SIGNALS_MONITOR	b21	INTERNAL_GPADC_SIGNALS_MONITOR	b22	PLL_CONTROL_VOLTAGE_MONITOR	b23	DCC_CLOCK_FREQ_MONITOR	b24	RX_SATURATION_DETECTOR_MONITOR	b25	RX_SIG_IMG_BAND_MONITOR
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Figure 2-6. Interference Types of Monitoring Functions

2.5 Precautions for Parameter Setting

- The calibration period must be greater than 1s.
- CALIB_MON_TIME_UNIT typically corresponds to an actual time of 40~250ms.
- Although APLL and SYNTH perform internal calibration at a 1s cycle and cannot be configured externally, the time required for calibration must be considered simultaneously.
- Calibration is executed when inter-burst/sub frame idle time >250us.
- It must be ensured that calibration and monitoring items are completed within the calibration/monitoring period.
- If any bit in CAL_TEMP_INDEX_OVERRIDE_ENABLE is enabled for override, AWR_RF_INIT_SB can no longer be called, which will cause the override to fail.

- AWR_RUN_TIME_CALIBRATION_CONF_AND_TRIGGER_SB configuration can be performed during framing (where the radar transmits and receives normally in frame cycles), and the calibration period will be updated synchronously.
- FRAME_TIMING_MONITORING_EN cannot be used when RSS dynamic frequency switch is enabled.

2.6 Calculation Example

2.6.1 Example of Calibration Execution Time Settings

Waveform configured as DDMA, using 2Tx, 4Rx, 3 profiles, CLPC mode, frame is 50ms, chirp period is 66us, chirp number is 384, CALIB_MON_TIME_UNIT is 2, enabling all calibration items but disabling monitoring items:

Duty cycle = $66\mu s \times 384 / 50\text{ms} = 50.68\%$

Idle time per frame = $50\text{ms} - 66\mu s \times 384 = 24.65\text{ms}$

Idle time available per frame = $24.65\text{ms} - 100\mu s = 23.65\text{ms}$

Enable all runtime calibration items.

According to the [Figure 2-1](#) runtime calibration execution time:

$150 + 300 + 30 + 600 + (720 \times 2 \times 3) + 30 + 700 \times 2 + 60 = 6890\mu s$

[Figure 2-4](#) other software execution time:

$20 + 600 + 300 + (50000 \times 2/8) = 13420\mu s$

Total execution time per FTTI: Runtime calibration execution time + Other software execution time:

$6890\mu s + 13420\mu s = 20.31\text{ms}$

Analysis: Total available calibration time: $23.65 \times 2 = 47.3\text{ms} > 20.31\text{ms}$. Meanwhile, the actual time corresponding to CALIB_MON_TIME_UNIT is 100ms, which meets the requirement of 40~250ms. Therefore, this configuration can take effect. Since the calibration period needs to meet the requirement of 1s, CALIB_MON_TIME_UNIT needs to be set to 10.

2.6.2 Example of Monitoring + Calibration Execution Time Settings

Waveform configured as DDMA, using 2Tx, 4Rx, 3 profiles, CLPC mode, frame is 50ms, chirp is 66us, chirp number is 384, CALIB_MON_TIME_UNIT is 2, enabling all calibration items and monitoring items:

Duty cycle = $66\mu s \times 384 / 50\text{ms} = 50.68\%$

Idle time per frame = $50\text{ms} - 66\mu s \times 384 = 24.65\text{ms}$

Idle time available per frame = $24.65\text{ms} - 100\mu s = 23.65\text{ms}$

According to the [Figure 2-1](#) runtime calibration execution time:

$150 + 300 + 30 + 600 + (720 \times 2 \times 3) + 30 + 700 \times 2 + 60 = 6890\mu s$

[Figure 2-2](#) analog monitoring execution time:

$(480 \times 3) + (270 \times 3) + (750 \times 3) + (240 \times 2 \times 3) + (250 \times 2) + (310 \times 2 \times 3) + (300 \times 2 \times 4) + 50 + (230 \times 2) + (2650 \times 2) + 670 + 250 + 80 + 230 + 190 + 50 + 150 = 18130\mu s$

[Figure 2-4](#) other software overhead execution time:

$20 + 600 + 300 + (50000 \times 2/8) = 13420\mu s$

Total execution time per FTTI: $13420\mu s + 6890\mu s + 18130\mu s = 38.44\text{ms}$

Analysis: Total available calibration time: $23.65 \times 2 = 47.3\text{ms} > 38.44\text{ms}$. Meanwhile, the actual time corresponding to CALIB_MON_TIME_UNIT is 100ms, which meets the requirement of 40~250ms. Therefore, this configuration can take effect. Since the calibration period needs to meet the requirement of 1s, CALIB_MON_TIME_UNIT needs to be set to 10.

3 Conclusion

By introducing runtime calibration and real-time monitoring mechanisms, the AWR2x44x series millimeter-wave radar SoC effectively addresses challenges such as temperature drift, device aging, and electromagnetic interference, ensuring stable and reliable operation of the radar system throughout its lifecycle. During design, key parameters such as CALIB_MON_TIME_UNIT and the calibration period must be reasonably configured to ensure that all calibration and monitoring tasks are completed within the FTTI cycle. Combined with the AWR2944P example, this paper provides engineers with practical API configuration methods and execution time calculation guidance.

4 References

1. [AWR2943/AWR2944 Single-Chip 76 to 81GHz FMCW Radar Sensor datasheet \(Rev. E\)](#)
2. [Self-Calibration in TI's mmWave Radar Devices](#)
3. [mmWave Radar Interface Control Document](#)

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