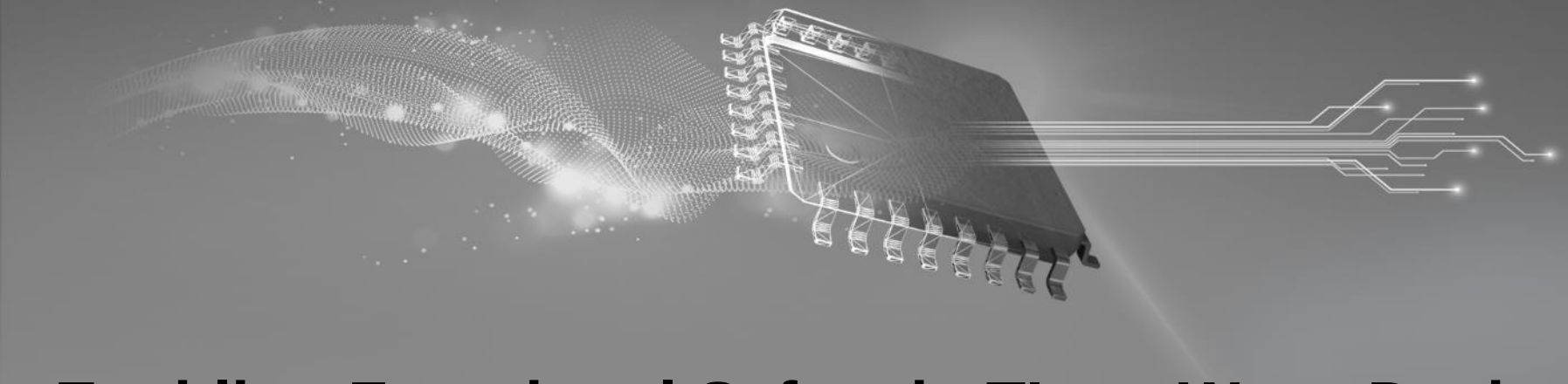
TI TECH DAYS



Enabling Functional Safety in TI mmWave Devices

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Radar Business Unit

Texas Instruments

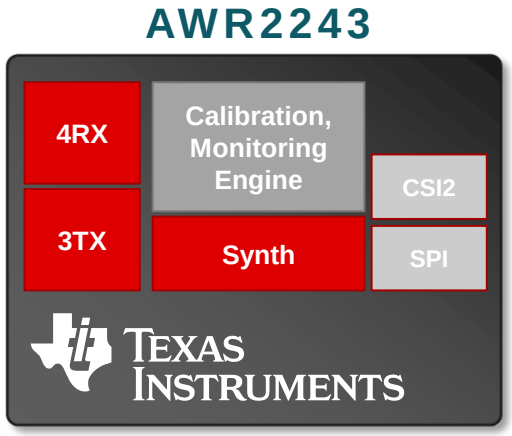
Agenda

- mmWave Device Introduction
- mmWave Functional Safety Concept
- Safety Features in mmWave devices
  - Analog/RF modules with in-built monitors
  - Digital modules
- Customer Safety Enablers
  - SDL (Software Diagnostics Library)
  - FMEA / FMEDA
  - Monitoring Application notes
  - Safety Manual
  - TUV Functional Safety Certificates and assessment reports
- Q&A

mmWave Device Introduction

AWR2243 – High Performance Front End

- Integrated transceiver with 4 Rx and 3 Tx
- Higher sampling frequency (45 Msps) & IF BW (20 MHz)
- Enhanced RF performance vs. Gen1
  - Better phase noise
  - Lower noise figure
  - Superior bumper handling
- 0.65 mm 10.4x10.4 mm^2 FCBGA
- ASIL-B capable
- Use cases:
  - MRR, LRR: 1x AWR2243 + External MCU
  - Imaging Radar Sensor: 2x or 4x AWR2243 (cascade) + External MCU



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mmWave Functional Safety Concept

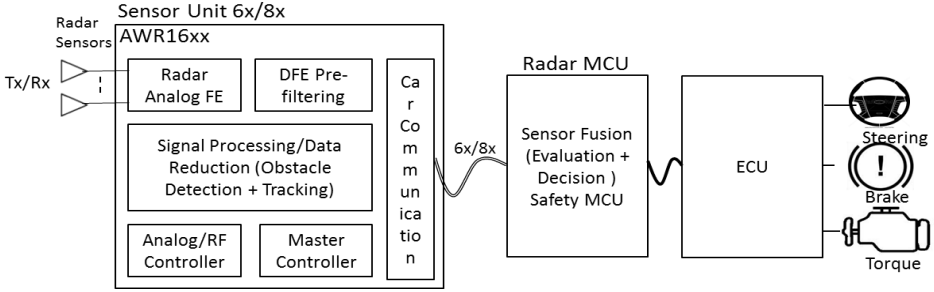
SEooC and Safety Concept

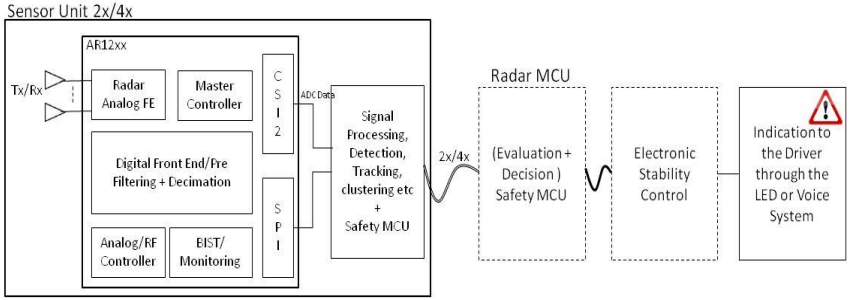
Industrial Applications	Automotive Applications
• Building Automation	• Blind Spot Detection
• Displacement Sensing	• Lane Change Assistance
• Gesture	• Cross Traffic Alert
• Robotics	• Parking Assistance
• Traffic Monitoring	• Occupancy Detection
• Proximity and Position Sensing	• Simple Gesture Recognition
• Security and Surveillance	• Car Door Opener Applications
• Factory Automation	• City Auto Breaking
• Safety Guards	• Low Speed Adaptive Cruise Control
• People Counting	• Autonomous Emergency Breaking
• Motion Detection	
• Occupancy Detection	

Identified Safety Goals for the Sensor

- Do not miss an Object when it is present
- Timely identification of Object if it is present
- Do not detect/ misidentify an object if it is not present

"TI mmWave Sensor Safety Concept and requirements are driven to address the above Safety Goals"

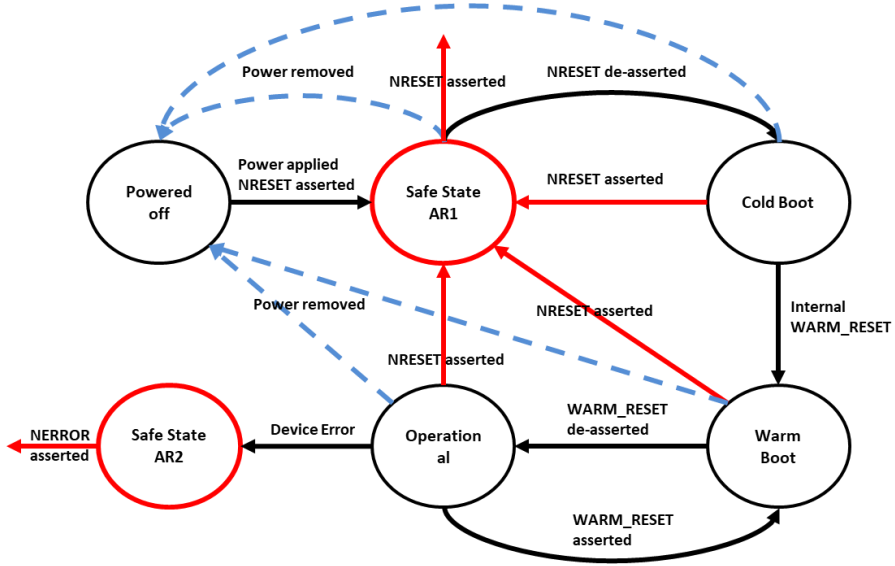




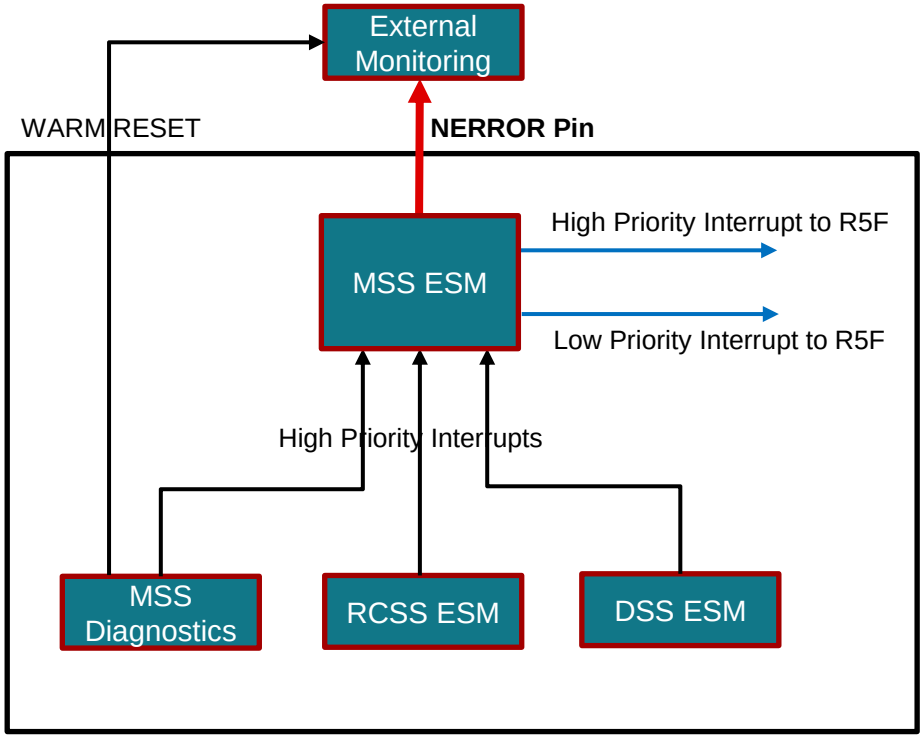
Architecture For Management of Random Faults

- **Operating States**
  - Power Off → Safe State AR1 → Cold Reset → Warm Reset → Operational
  - Safe States
    - AR 1 – Reset Assertion
    - AR 2 – “NERROR” Error Signal Indication.
- **Safety Concept**
  - Hardware Diagnostics
  - HW + SW Diagnostics
  - Software Diagnostics
  - System Level Diagnostics Recommendation.
- **Management of Errors**
  - Error Reporting / Signaling
  - Error Response

Safety Island Philosophy

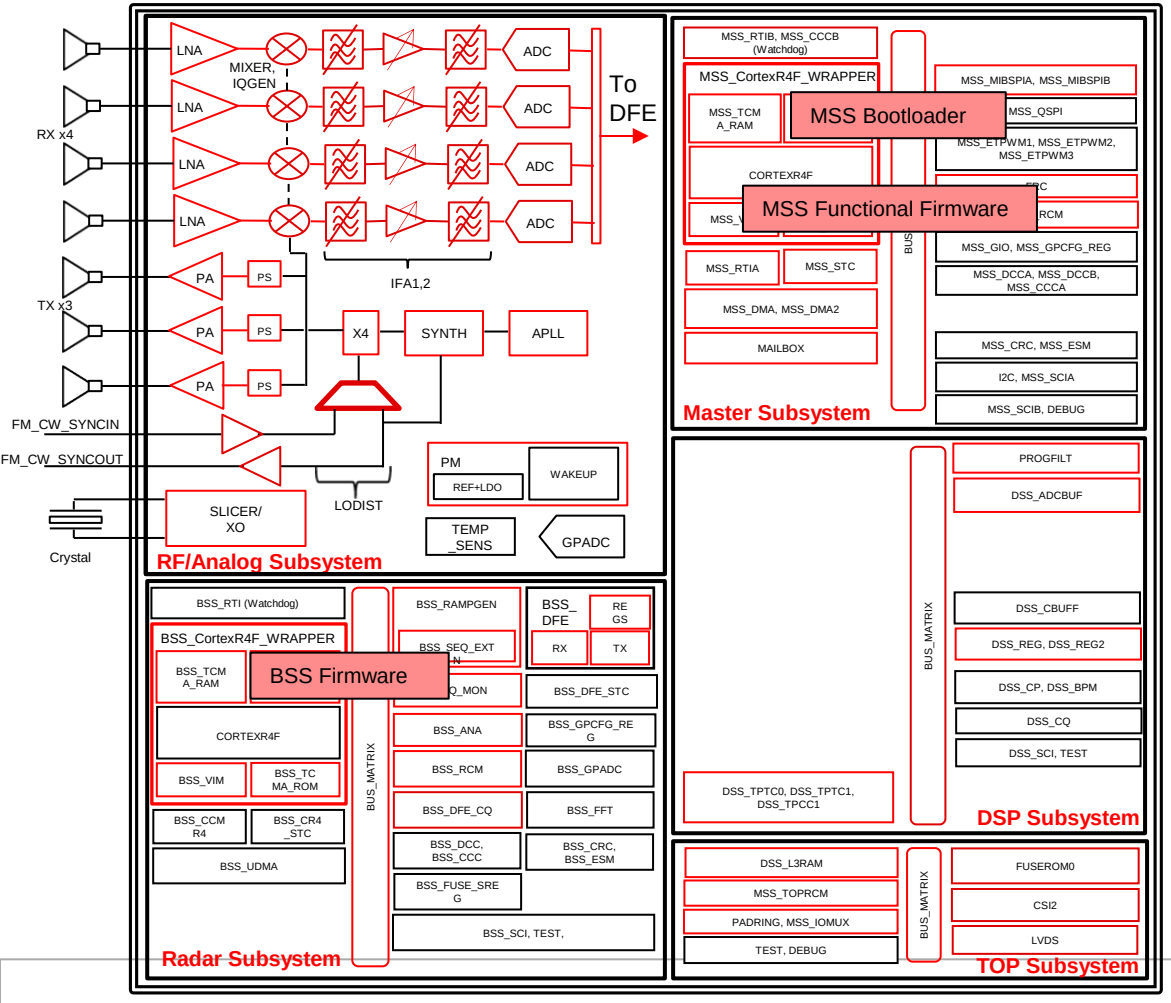


Error Signaling Module



Different Error Response

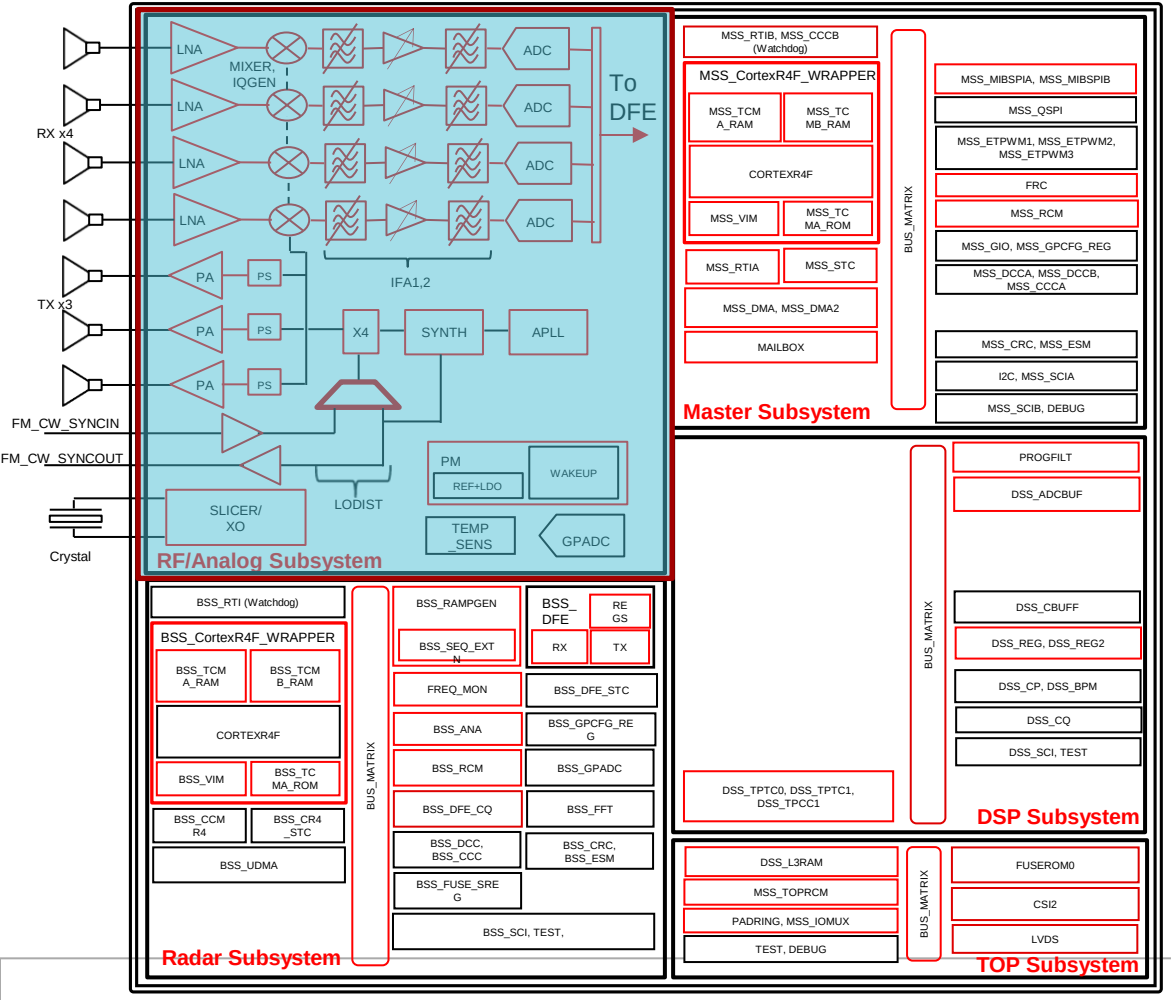
- NERROR Pin
- Generation of WARM RESET
- Generation of NRESET
- CPU Abort
- CPU Interrupts



Safety Critical Functions

- ***Power supplies***
- ***Clock generation***
- ***Reset***
- ***RF/Analog Modules***
- ***Digital Front-end filters***
- ***Ramp generation***
- ***Enhanced Direct Memory Access***
- ***ADC Buffer***
- ***DSS Interconnect***
- ***Master Microcontroller Elements***
- ***BIST Microcontroller Elements***
- ***BSS Interconnect***
- ***MSS Real Timer Interrupt***
- ***MSS Interconnect***
- ***Direct Memory Access modules***
- ***Inter-processor communication***
- ***SPI Master interface***
- ***Input Outputs***
- ***Error Signaling Module***

Safety Island Diagnostics



Safety Critical Functions

Power

- Internal VMON, Temp Sensor

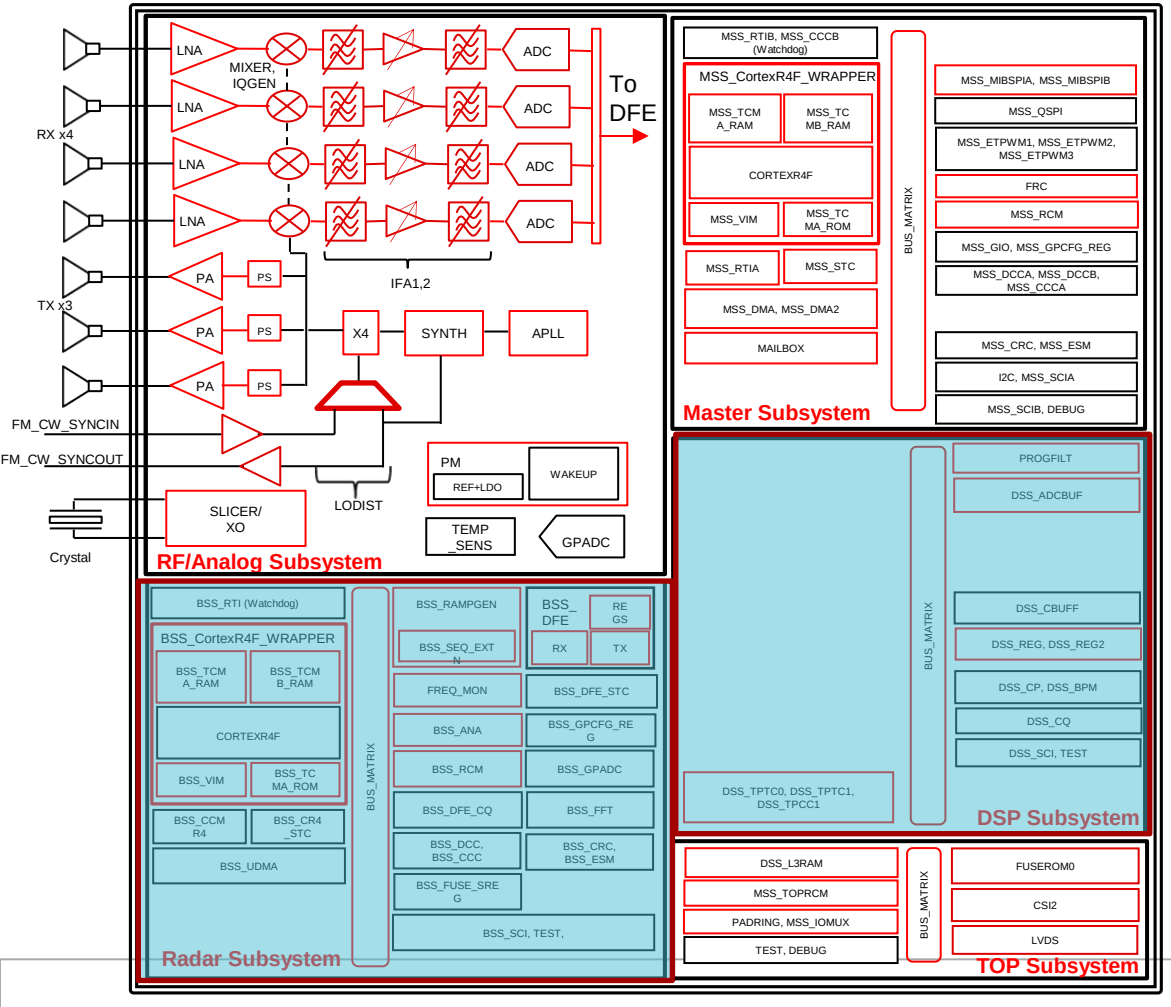
Clock

- DCC , Internal & External Watchdog
- APLL Lock Detection

RF / Analog Modules

- Internal Analog Signal Monitoring
  - PLL Control VMON
  - TX Internal
  - RX Internal
  - PM, CLK & LO
  - GPADC Monitoring
- External Analog Signals Monitoring
- Temperature Sensors
- TX Power Monitoring
- TX Ball Break Monitoring
- RX Loopback Test
  - RX Gain, Phase & Noise Monitoring
- RX IF Loopback Test
- Synthesizer Chirp Freq Monitoring
- BSS Clock Monitoring
- RX Saturation Detector & Monitoring
- TX Loopback Test
- Analog Fault Injection

Safety Critical Functions



DFE Filters

- Boot time PBIST & LBIST
- Parity

Ramp Generation

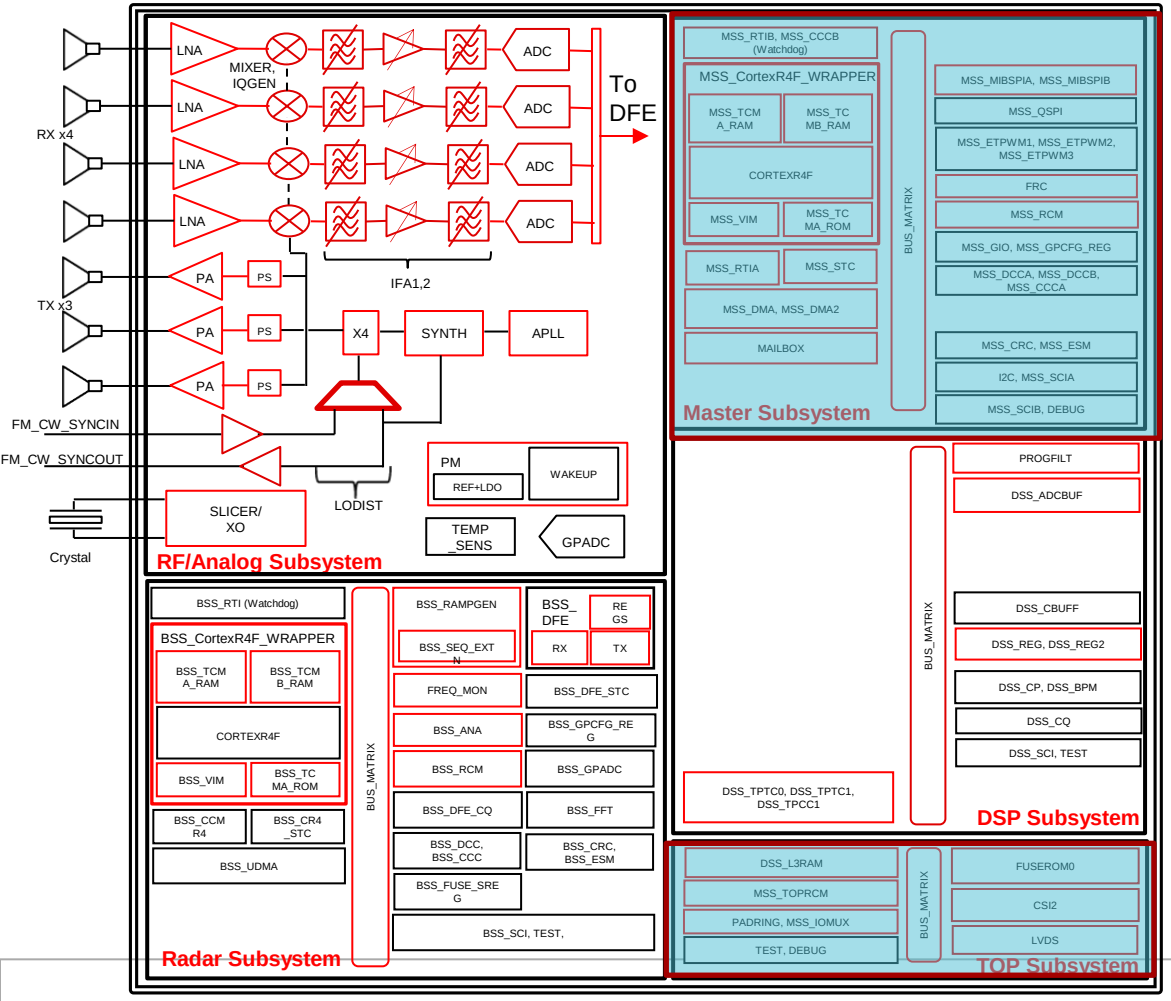
- Boot Time PBIST of Chirp RAM's
- ECC on RAM
- Lock Step for Sequencer Logic
- Periodic SW Read back of Config Reg.
- SW read back of written configuration

BSS Microcontroller Element

- Boot time LBIST – CPU , VIM
- Boot time PBIST – TCM , VIM
- E2E ECC – TCM , VIM
- Redundant Address Decode
- MPU, PMU
- Illegal Operation & Instruction Trapping
- Periodic SW read back of Config Reg
- Internal Watchdog

ADC BUFFS

- Boot Time PBIST
- ECC on RAM



Safety Critical Functions

MSS Microcontroller Element

- Boot time LBIST – CPU , VIM
- Boot time PBIST – TCM , VIM
- E2E ECC – TCM , VIM
- Redundant Address Decode
- MPU, PMU
- Illegal Operation & Instruction Trapping
- Periodic SW read back of Config Reg
- Internal Watchdog

DMA

- SRAM Data Parity
- Boot Time PBIST
- Periodic SW Read back of Config Reg.
- SW Watchdog Timer
- MPU, Non-Privileged Bus Master Access

IPC

- CRC, ECC on SRAM
- Error Monitoring (ACK, Stuff, Form & Bit)

SPI

- End to End Staffing, using CRC.
- Error Signal Monitoring.

IO

ESM

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Safety Features in mmWave devices

Analog/RF And Digital Monitoring

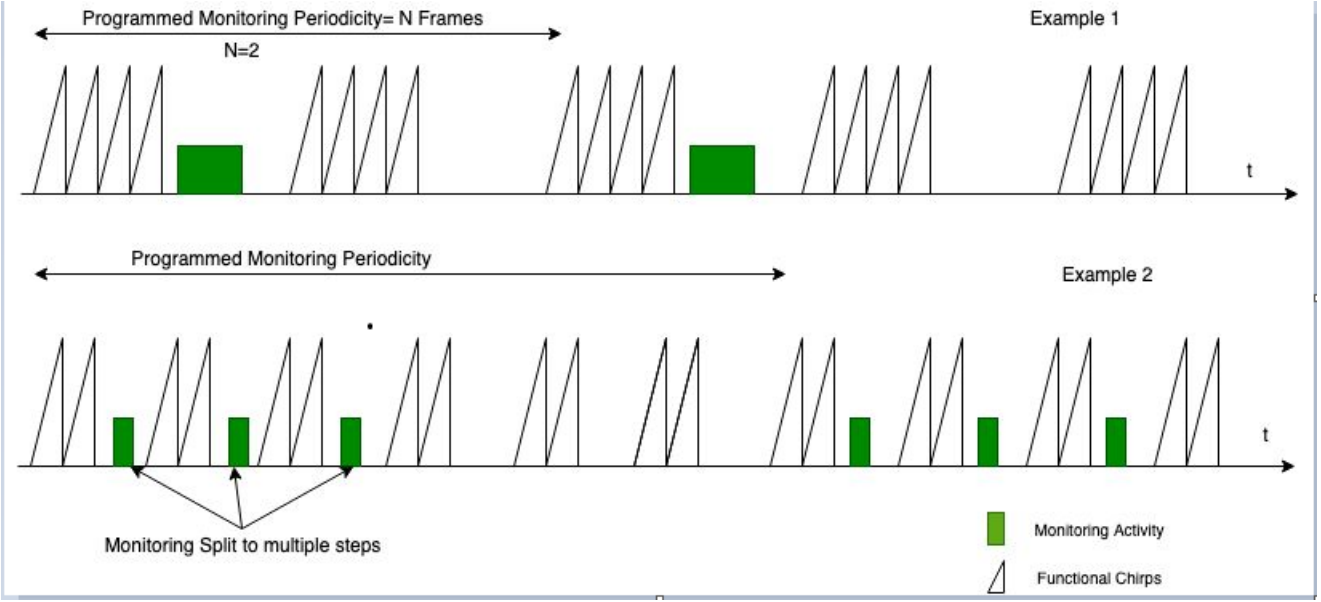
- RF/Analog monitoring is an important aspect to consider in the context of Safety.
- mmWave device include hardware and firmware elements to enable monitoring of its analog and digital sections.
- These built-in features are exposed to users through firmware APIs.
- Help users build their software to program and use these APIs to achieve their end-product's safety goals.
- The APIs offer a high amount of programmability:
  - The built-in monitoring features the customer wants the device to execute
  - The periodicity of such execution
  - The verbosity of the monitor reports,
  - Measurement comparison thresholds the device should use in reporting.

Analog/RF and Digital Monitor Supported

- Key monitors in mmwave devices include:
  - RX Gain/phase monitor
  - IF stages monitor
  - TX power monitors
  - TX ball break detection
  - Synth (chirp) frequency error monitor
  - Clock monitors
  - Temperature sensors
  - Internal signals monitors

Programming of Monitors

Monitoring Concept/Scheduling



Common Configuration Messages

- Setting the CALIB_MON_TIME_UNIT
  - The periodicity of monitoring is configured by setting the calibration and monitoring time unit using “AWR_CALIB_MON_TIME_UNIT_CONF_SB”.
- Analog Monitors Configuration
  - The set of analog monitors to execute cyclically at this periodicity is configurable through “AWR_MONITOR_ANALOG_ENABLES_CONF_SB”
- Digital Monitor Configuration
  - The consolidated configuration of all the digital monitoring is done using AWR_MONITOR_RF_DIG_LATENTFAULT_CONF_SB.

RX Gain, Phase Monitoring

- API
  - AWR_MONITOR_RX_GAIN_PHASE_CONF_SB
- Thresholds
  - Tolerable thresholds for deviation of gain from the programmed value and the imbalances in gain and phase.
- Monitoring Report
  - AWR_MONITOR_RX_GAIN_PHASE_REPORT_AE_SB.
- Report
  - Measured RX gain and phase values of receivers across RF frequencies

RX IF Stage Monitor

- API
  - AWR_MONITOR_RX_IFSTAGE_CONF_SB
- Thresholds
  - tolerable gain error and cutoff frequency error (thresholds).
- Monitoring Report
  - AWR_MONITOR_RX_IFSTAGE_REPORT_AE_SB.
- Report
  - Measured RX IF amplifier gain and cutoff frequency errors.

TX Power Monitoring

- API
  - AWR_MONITOR_TXn_POWER_CONF_SB (TXn)
- Thresholds
  - Absolute Power and the flatness
- Monitoring Report
  - AWR_MONITOR_TXn_POWER_REPORT_AE_SB (TXn)
- Report
  - The measured TX power for each enabled channel at each enabled RF frequency.

TX Ball Break Monitoring

- API
  - AWR_CAL_MON_FREQUENCY_TX_POWER_LIMITS_SB
  - AWR_MONITOR_TXn_BALLBREAK_CONF_SB(TXn)
- Thresholds
  - Maximum allowable threshold for the TX reflection coefficient
- Monitoring Report
  - AWR_MONITOR_TXn_BALLBREAK_REPORT_AE_SB (TXn)
- Report
  - Status of the ball-break. TX ball breaks are assumed to result in a high degradation in the reflection coefficient.

PM, CLK, and LO Systems Internal Analog Signals Monitoring

- API
  - AWR_MONITOR_PMCLKLO _INTERNAL_ANALOG_SIGNALS_CONF_SB
- Thresholds
  - 20G signal min and max threshold.(In case of Cascade Configuration)
- Monitoring Report
  - AWR_MONITOR_PMCLKLO_INTERNAL_ANALOG_SIGNALS_REPORT_AE_SB
- Report
  - Supply voltage/DCBIAS of the PM, CLK, LO distribution circuits

TX and RX Internal Analog Signals Monitoring

- API
  - AWR_MONITOR_TXn_INTERNAL_ANALOG_SIGNALS_CONF_SB(for TXn)
  - AWR_MONITOR_RX_INTERNAL_ANALOG_SIGNALS_CONF_SB (for all RXs)
- Thresholds
  - Phase shifter DAC monitor delta threshold.
- Monitoring Report
  - AWR_MONITOR_TXn_INTERNAL_ANALOG_ SIGNALS_REPORT_AE_SB(For TXn)
  - AWR_MONITOR_RX_INTERNAL_ANALOG_ SIGNALS_REPORT_AE_SB (for all RXs)
- Report
  - Status flags indicating the supply voltage failures

PLL Control Voltage Monitoring

- API
  - AWR_MONITOR_PLL_CONTROL_VOLTAGE_SIGNALS_CONF_SB
- Thresholds
  - None
- Monitoring Report
  - AWR_MONITOR_PLL_CONTROL_VOLTAGE REPORT_AE_SB
- Report
  - Measured control voltage values and failure flags

Synthesizer Frequency Monitoring

- API
  - AWR_MONITOR_SYNTHESIZER_FREQUENCY_CONF_SB
- Thresholds
  - Tolerable frequency error
- Monitoring Report
  - AWR_MONITOR_SYNTHESIZER_FREQUENCY_REPORT_AE_SB
- Report
  - Number of threshold violations in a monitoring duration and maximum frequency error during the monitoring duration

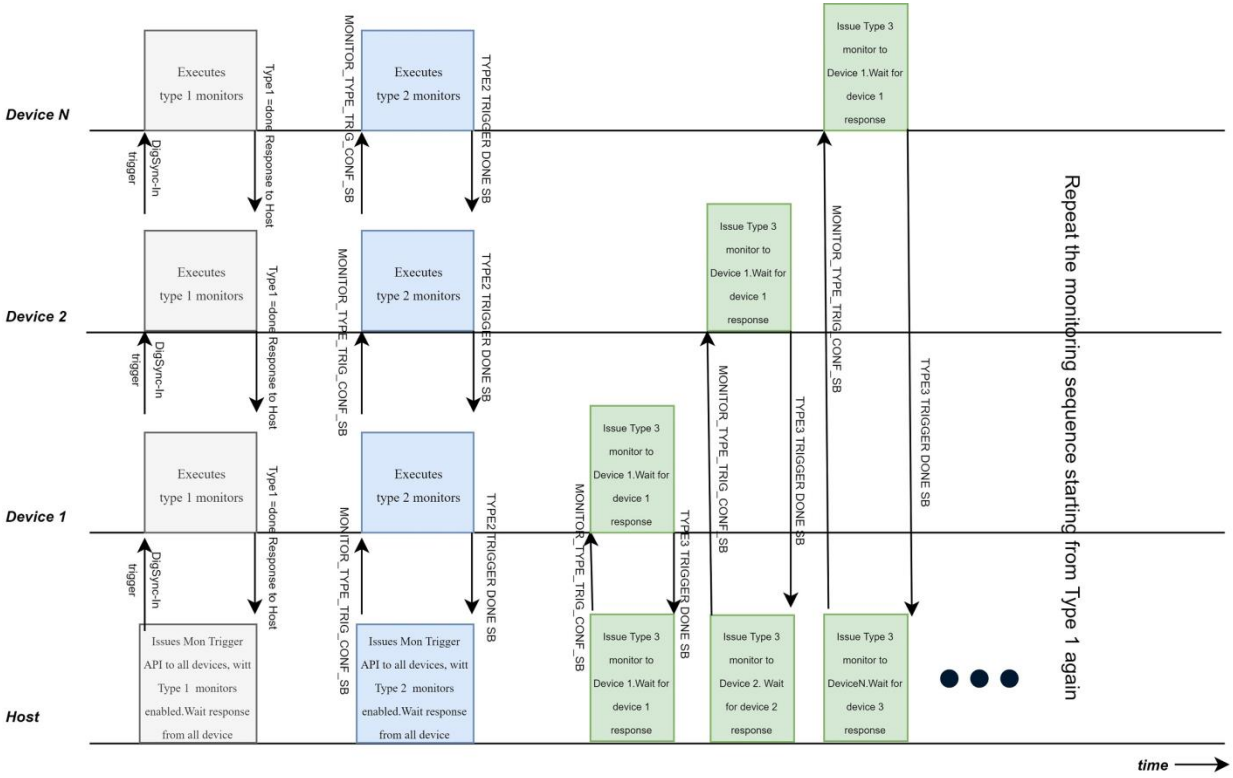
DCC-Based Clock Frequency Monitoring

- API
  - AWR_MONITOR_DUAL_CLOCK_COMP_CONF_SB
- Thresholds
  - None
- Monitoring Report
  - AWR_MONITOR_DUAL_CLOCK_COMP_REPORT_AE_SB
- Report
  - Measured clock frequency from the enabled clock pairs

Monitoring in Cascaded Configuration

- In Cascaded application, monitoring execution in one device may interfere with those executing in another device
  - Simultaneous execution of the non-interfering monitors
  - Time Division and Frequency Division based separation of mutually interfering monitors among the cascaded AWR devices.
- Categorization of Monitors
  - Type 1
    - These are predominantly non-transmitting(TX is Off) monitors.
  - Type 2
    - These are monitors that transmit but don’t receive any test signal through RX LNA.
  - Type 3
    - These are monitors that transmit and receive test signal through the RX LNA and are susceptible to interference .

Host-based monitoring scheduling for cascaded applications



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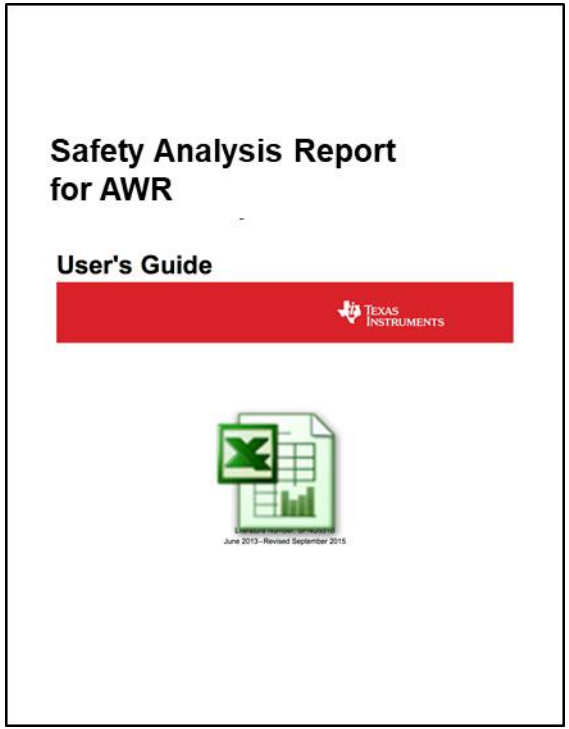
Customer Safety Enablers

Safety Diagnostics Library(SDL)

- SDL is a collection of functions for access to safety functions and response handlers for various safety mechanisms for TI mmWave sensors.
- Diagnostic runs in the context of the caller's protection environment and all responses are handled in the context of interrupt or exception.
- It implements diagnostic mechanism that are indicated in the device safety manual.
- The SDL is provided to customers in source code form.(.c and .h) along with the quality artifacts(Compliance Support Package)
- Released via mySecureSoftware .

FMEDA worksheet

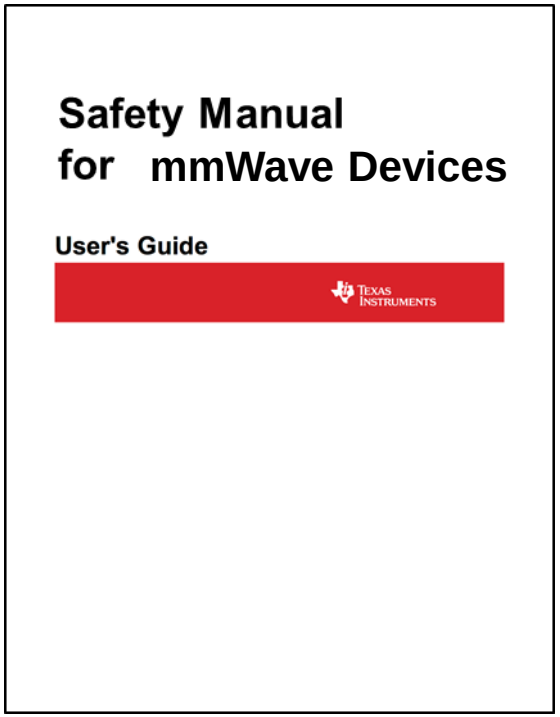


Available under Safety NDA

Detailed Safety Analysis Report

- Assumptions of use applied in calculation of safety metrics
- Summary of IEC 61508 or ISO 26262 standard safety metrics at the AWR Device component level
- A fault model used to estimate device failure rates and an example of customizing this model for use with the example application.
- FMEDA with details to the sub-module level of the Device, that enables calculation of safety metrics based on customized application of diagnostics
- Use of FMEDA worksheet
  - **FIT Estimation sheet** to tailor use conditions
  - **Product Function Tailoring sheet** to select AWR modules used in safety function
  - **Pin Level Tailoring sheet** to select AWR pins used in safety function
  - **Safety Mechanism Tailoring sheet** to select applied Safety mechanisms
  - **Summary and Details-ISO26262 or IEC61508 sheets** to determine if AWR and modules safety metrics are met.

Safety Manual



Provided under Safety NDA

- An overview of the safety architecture for management of random failures
- The details of architecture partitions, implemented safety mechanisms, and recommended usage
- Failure modes and failure rates
- Use Diagnostics Mechanism Summary Table to determine applicable safety mechanisms by AWR module such as modules in Safe Island region, RF Analog, SPI, CAN, etc. with API Level details

Monitoring Application Notes

- This application note aims to help customers build their software to program and use these APIs to achieve their end-product's safety goals.
- This application note describes these monitoring mechanisms, explains the programming options offered by the APIs.
- Illustrates example post-processing of the monitoring reports produced by these APIs, and illustrates the reports in example programming conditions in TI's internal labs.
- Shared with customers under Safety NDA and via the mySecureSoftware Link.

SPRACN8: ***Using Monitoring Features in TI mmWave Radar Devices***

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Q&A


thank you
danke
謝謝
ngiyabonga
teşekkür ederim
gracias
спасибо
Баярлалаа
рахмат
dank je
bedankt
dziękuję
hvala
maururu
mochchakkeram
go raibh maith agat
obrigado
sukriya
kop khun krap
sagolun
terima kasih
arigatō
ありがとう
grazie
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