TI mmWave Sensors
AWR1x Family Device Overview

Agenda

- Device Overview
  - TI mmWave sensor portfolio
  - AWR1x Signal processing chain
  - Example System topologies
- Functional Blocks
  - Device Block Diagram
  - RF and Analog Subsystem
  - Radar Subsystem (aka BSS or **BIS**T **S**ubsystem)
  - Master Subsystem (MSS)
  - DSP Subsystem (DSS: AWR16xx only)
  - Radar Hardware accelerator
- Boot modes
- Software Platform

Device Overview

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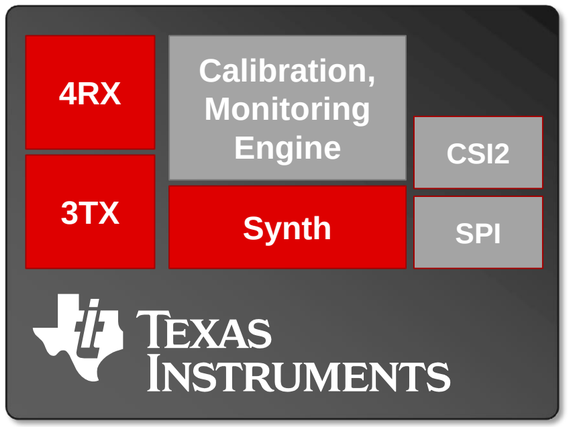
Automotive mmWave Sensors 76 – 81 GHz

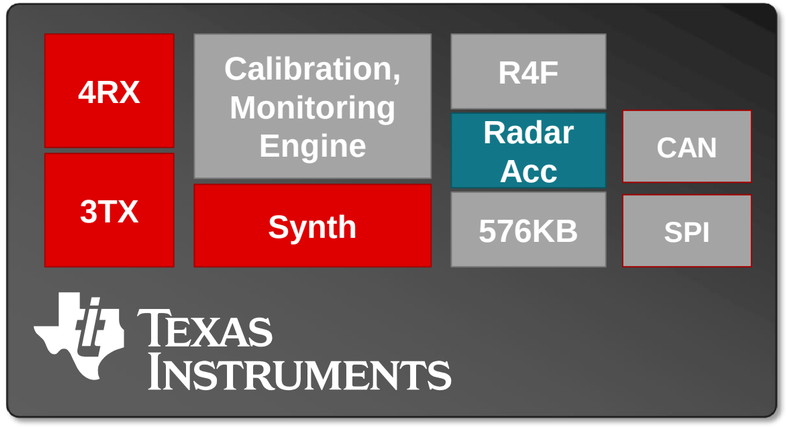
AWR12433



Radar Sensor

- **Use Cases**
  - Imaging Radar Sensor
    - 2x AWR12 (cascade) + External DSP
    - 4x AWR12 (cascade) + External DSP

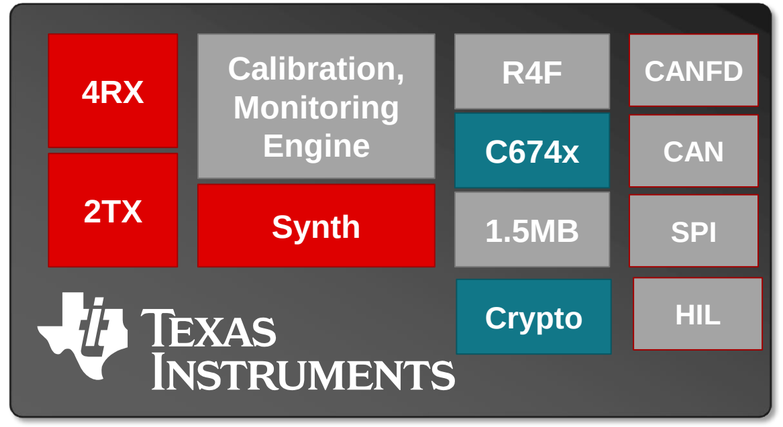
AWR1443



Radar Sensor + HW Accelerator

- **Use Cases**
  - Entry-level Single-chip Radar
    - Proximity warning, Blind spot

AWR1642



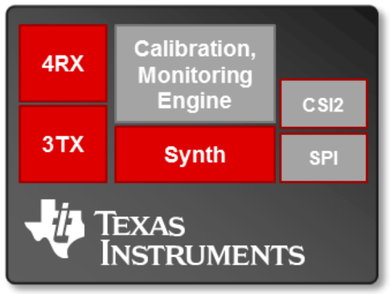
Radar Sensor + DSP

- **Use Cases**
  - USRR Single Chip Radar
    - 160 Degree, 40m
  - SRR Single chip Radar
    - 120m Cross traffic Alert

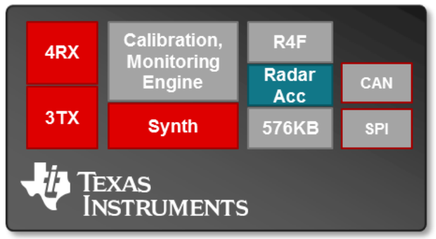
Key Features

- FMCW Radar transceiver with 76-81 GHz operating frequency and 4 GHz chirp bandwidth
- Scaling from Front-end only to complete Single Chip Radar solution
- MIMO: Up to three transmitter and four receiver chains
- Programmable, flexible chirp profiles for both long and short range sensing in the same radar frame
- 200MHz ARM Cortex R4F MCU for user application processing
- Radar Hardware accelerator for FFT and CFAR processing (AWR14xx only)
- C674x DSP for advanced tracking, clustering and object classification (AWR16xx only)
- Continuous monitoring and calibration of Analog/RF through a second dedicated Cortex R4F MCU
- CAN and CAN-FD (AR1W6xx only) support for ECU Interface
- QSPI Serial Flash support for autonomous boot
- MIBSPI, SPI, I2C, and UART Serial Interfaces Support
- CSI2 (AWR12xx only) interface for high speed raw data transfer
- LVDS/Debug interface for measurements.
- ASIL-B Capable

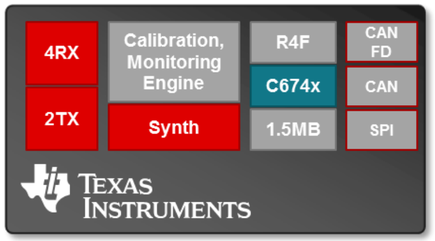
AWR1243



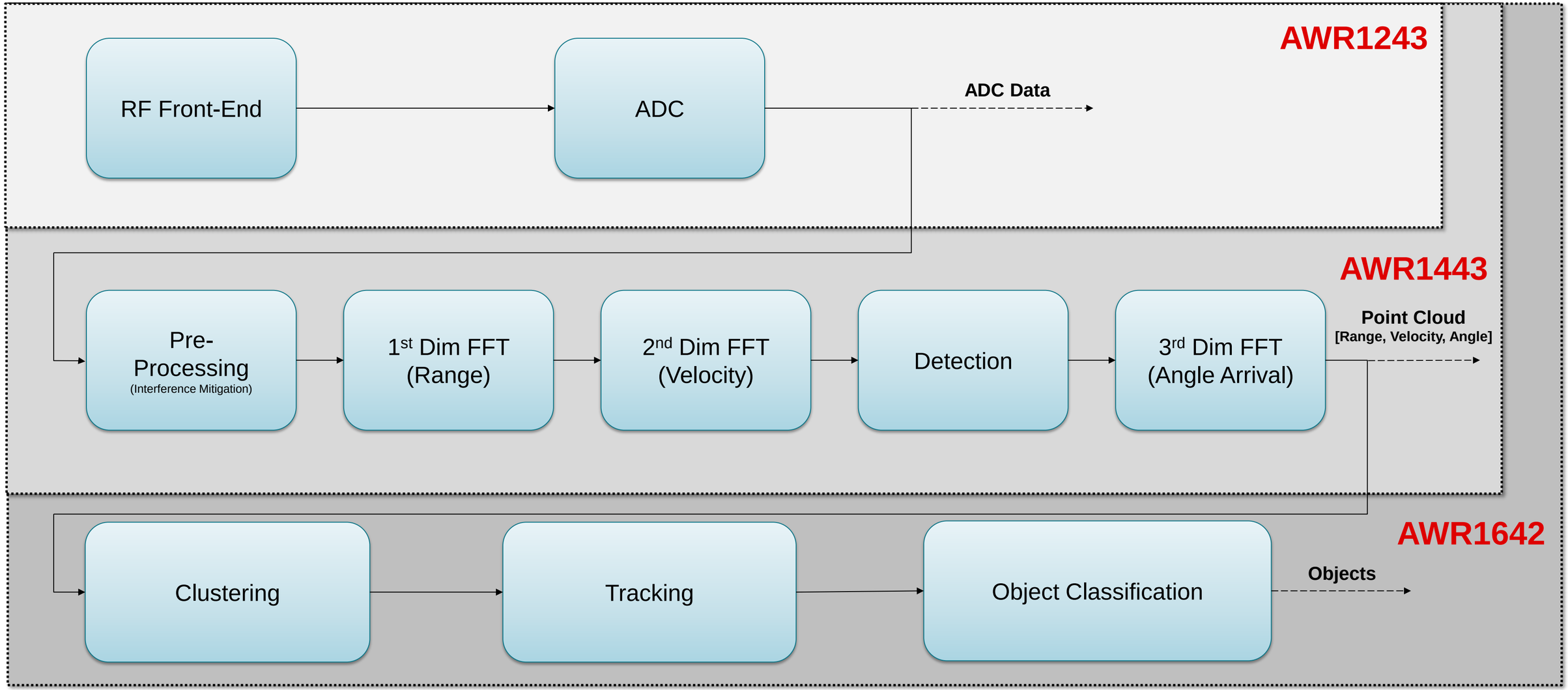
AWR1443



AWR1642



AWR1x mmWave Signal Processing



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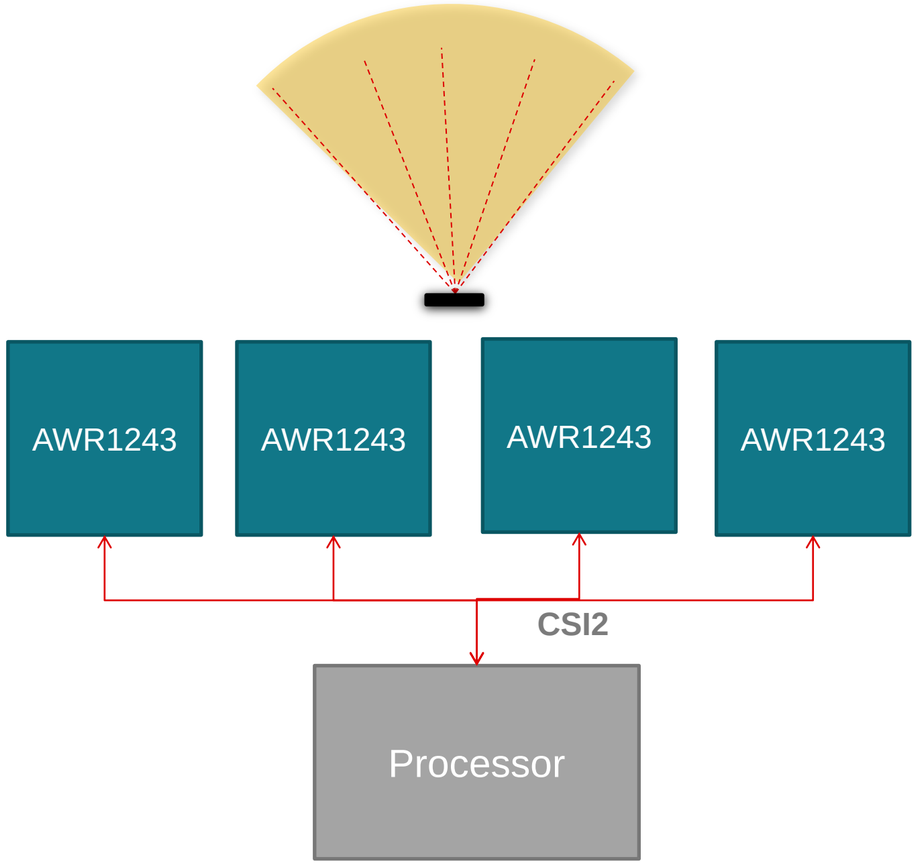
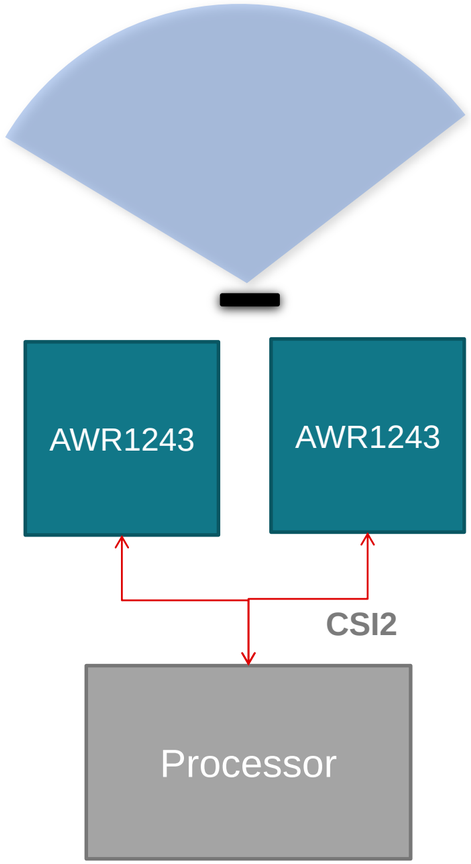
Example System Topologies

High resolution Imaging (Cascaded)



Corner / MRR (Cascaded)



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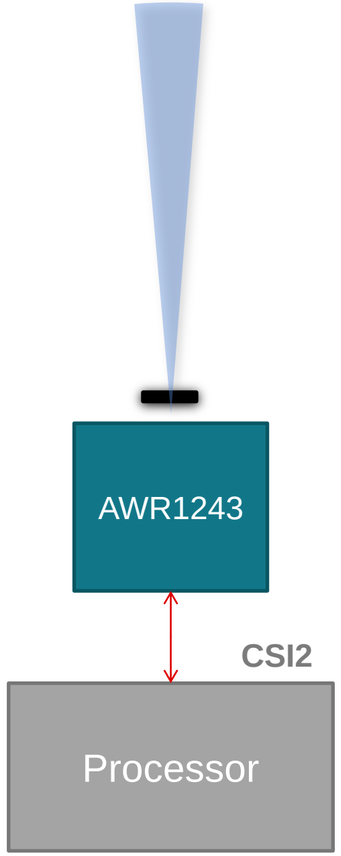
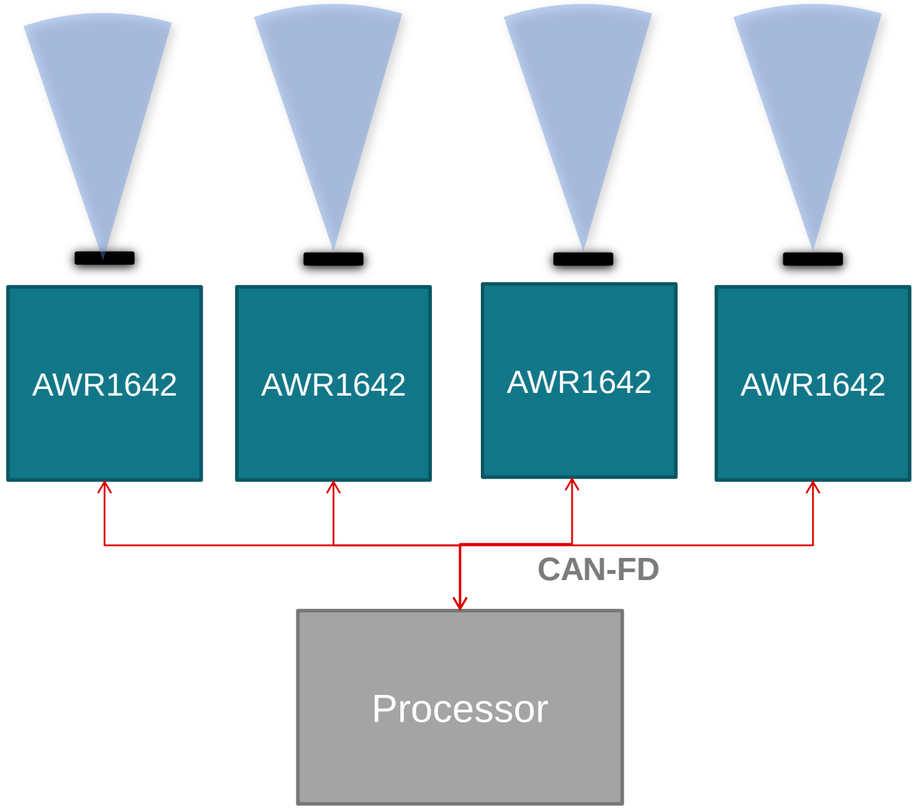
Example System Topologies

Long Range Radar (LRR)



Satellite Configuration



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Functional Blocks

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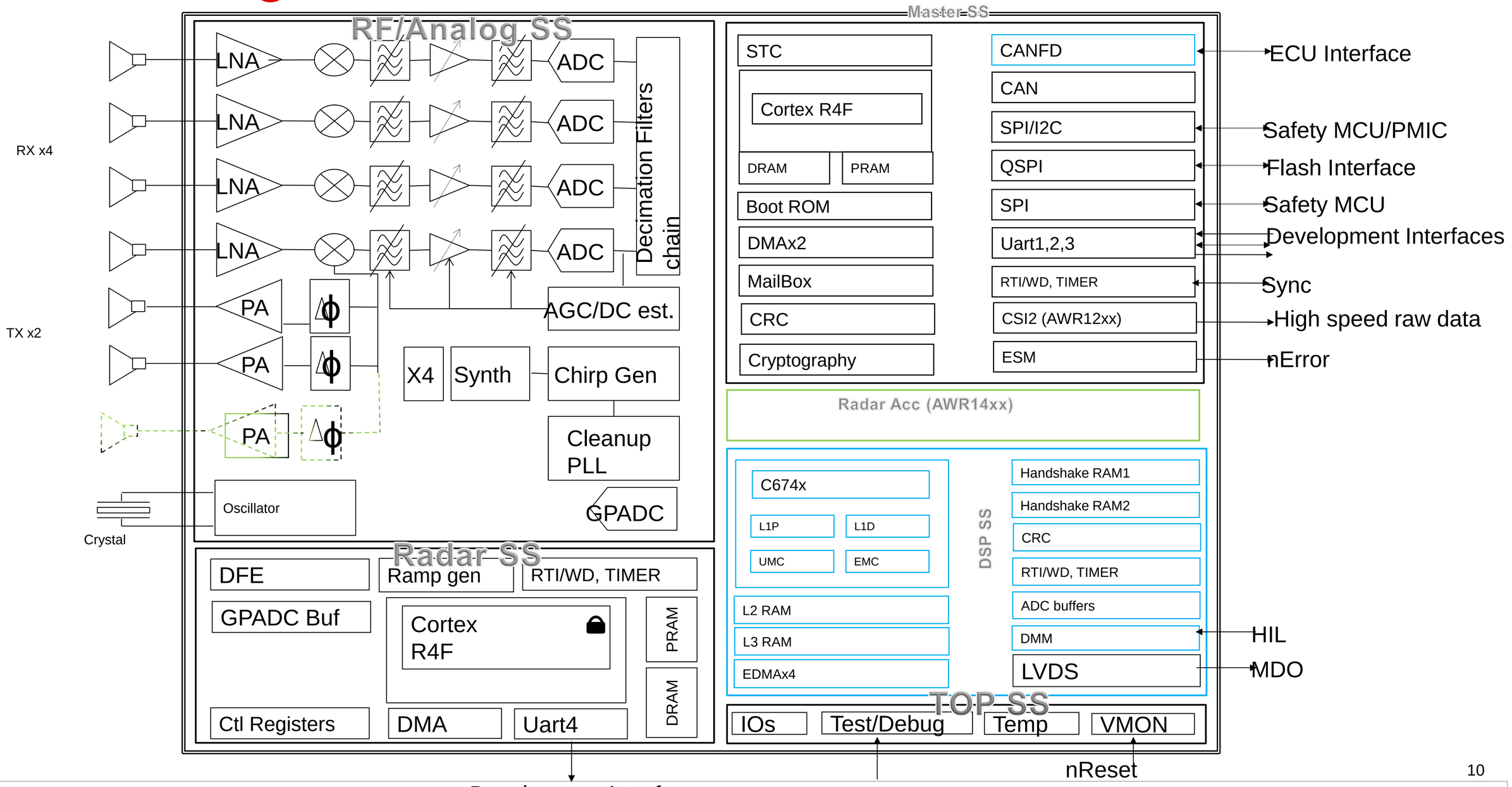
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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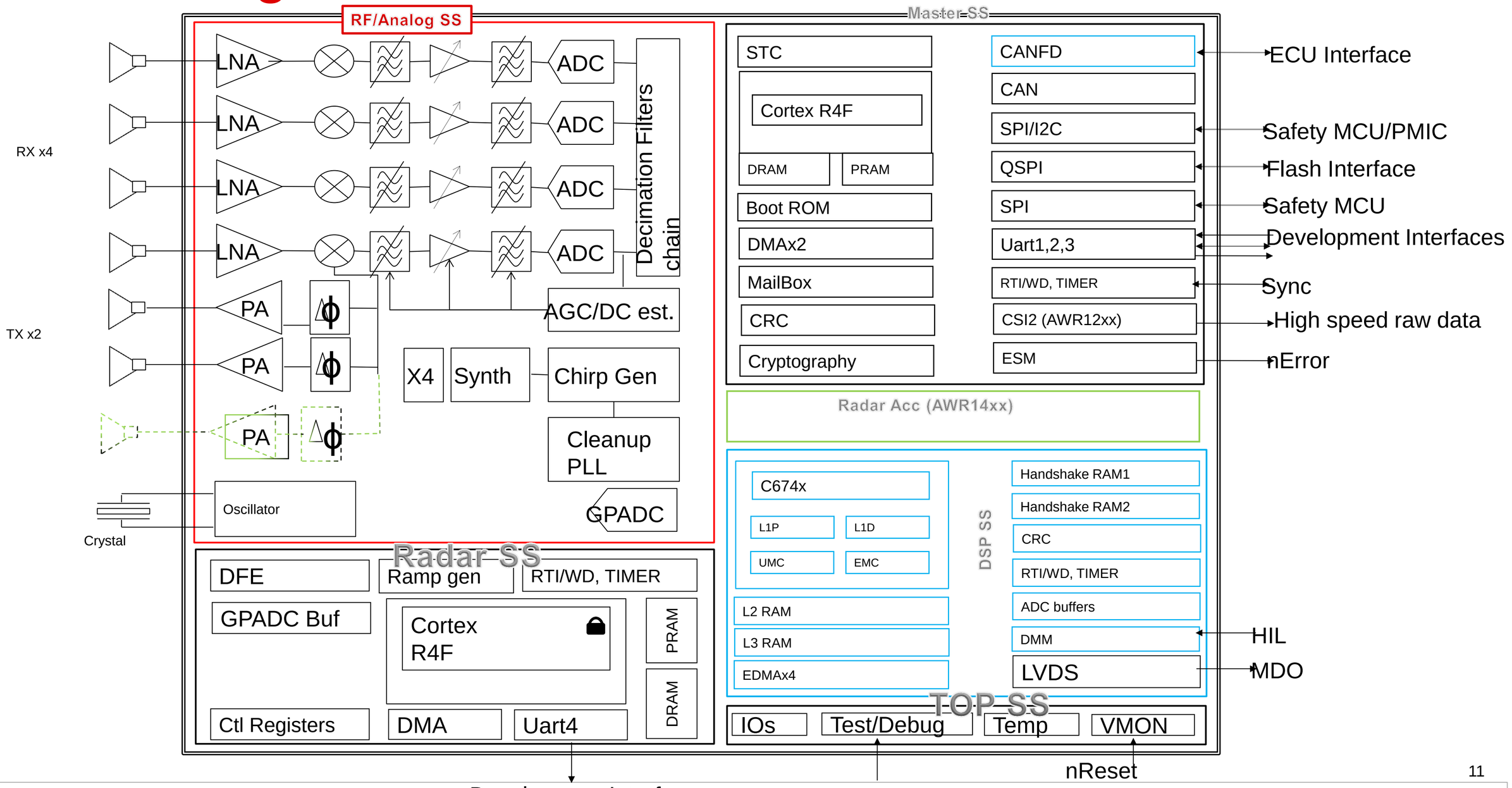
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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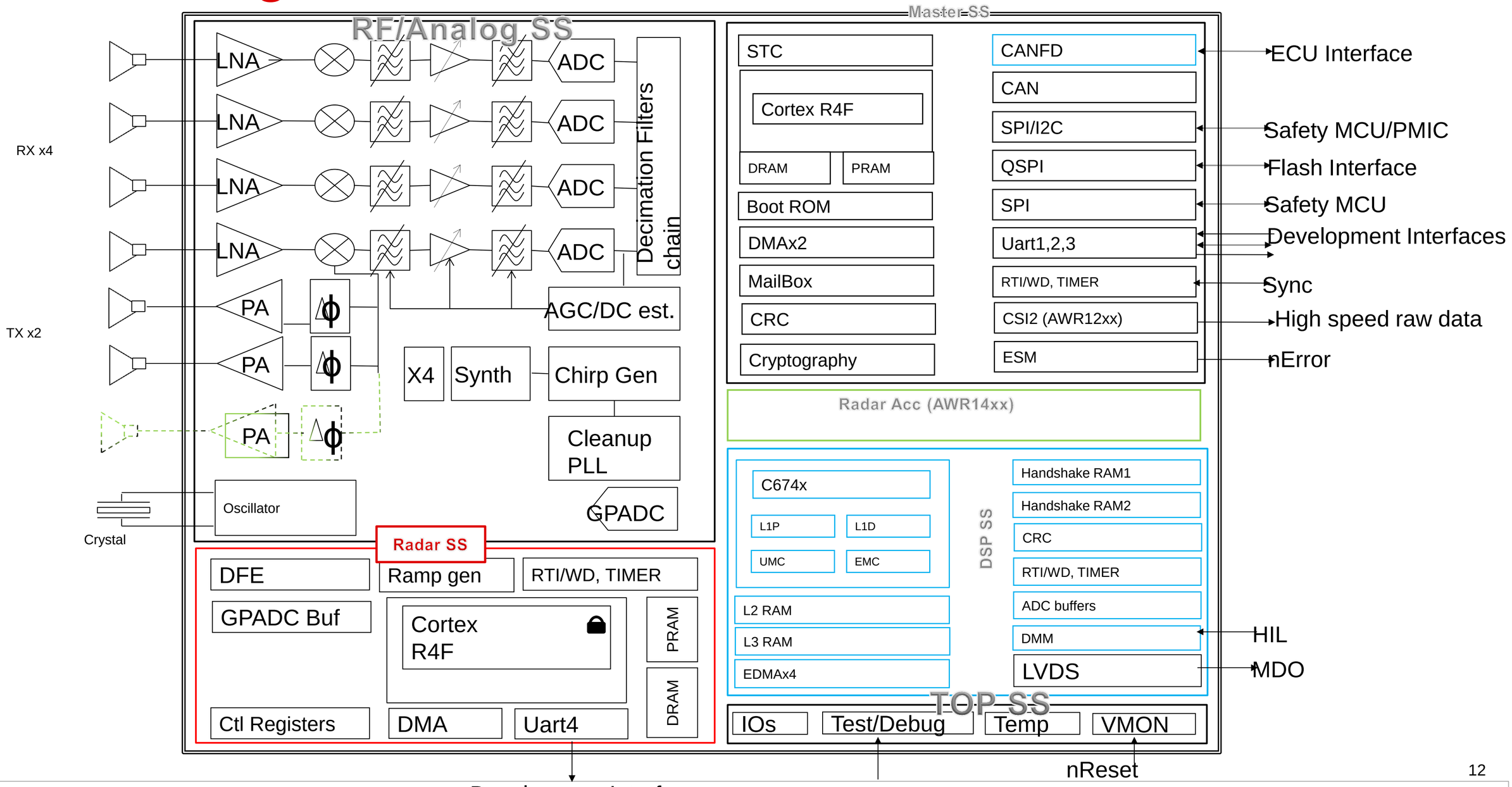
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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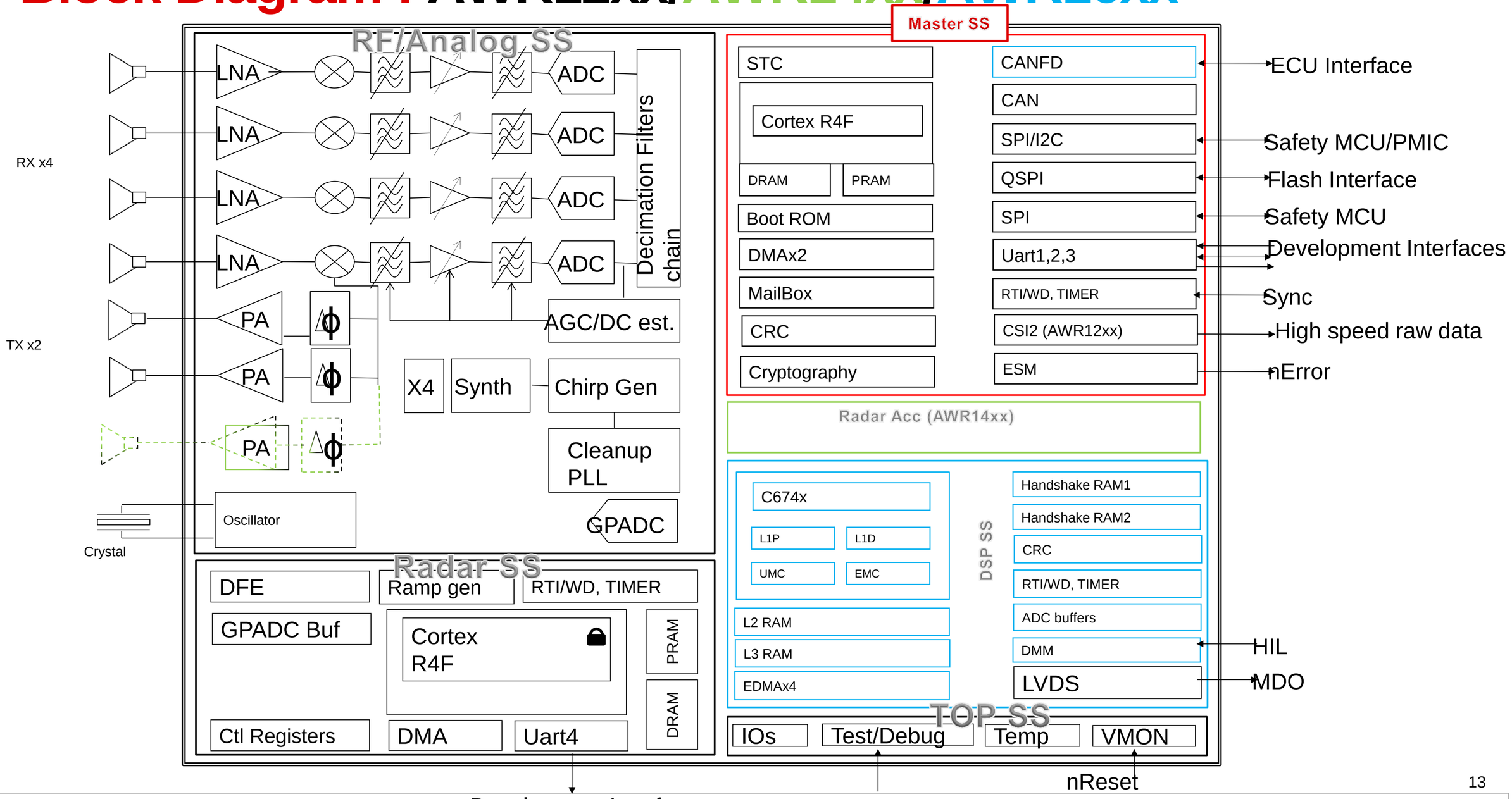
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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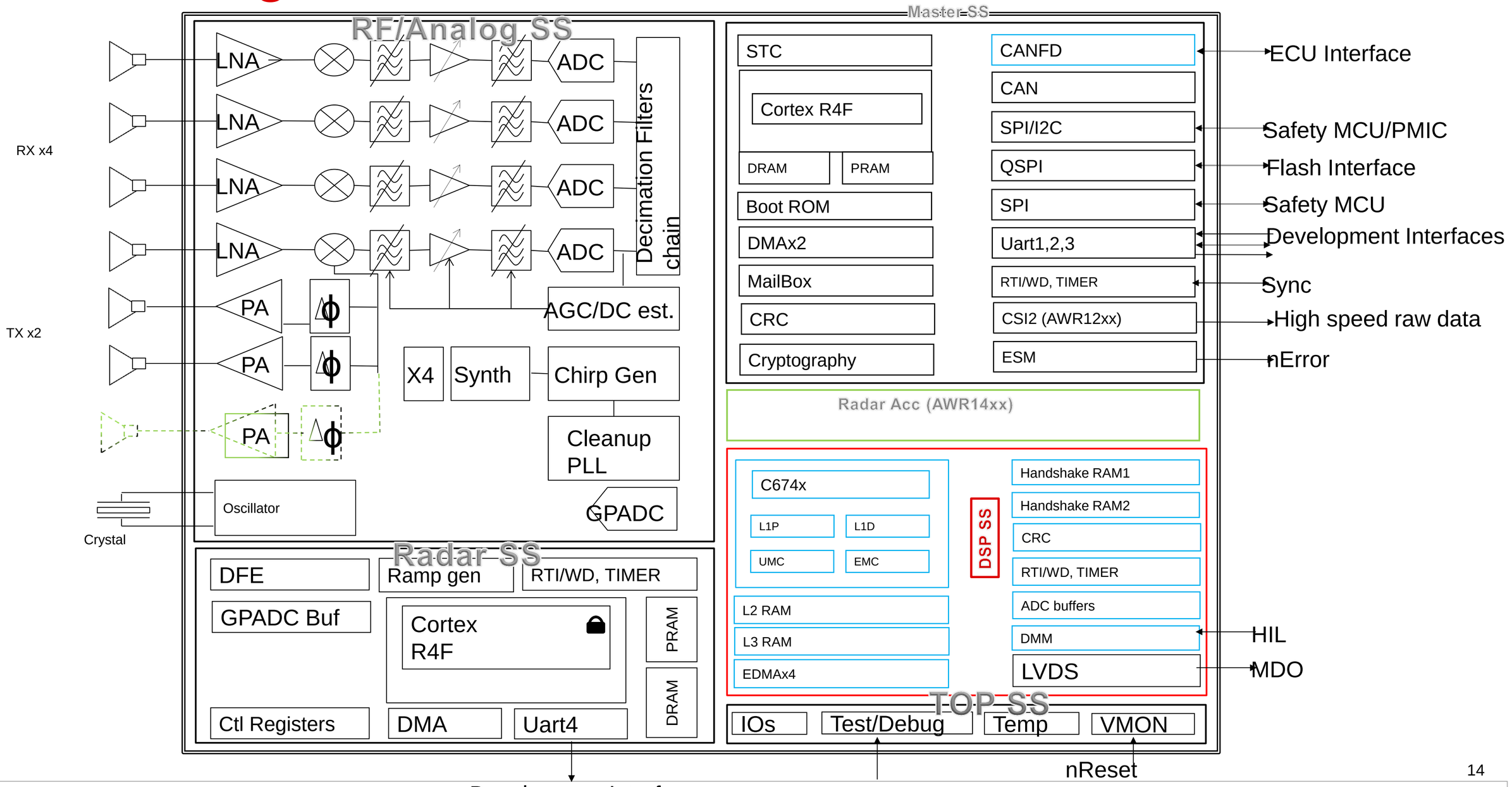
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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RF and Analog Subsystem

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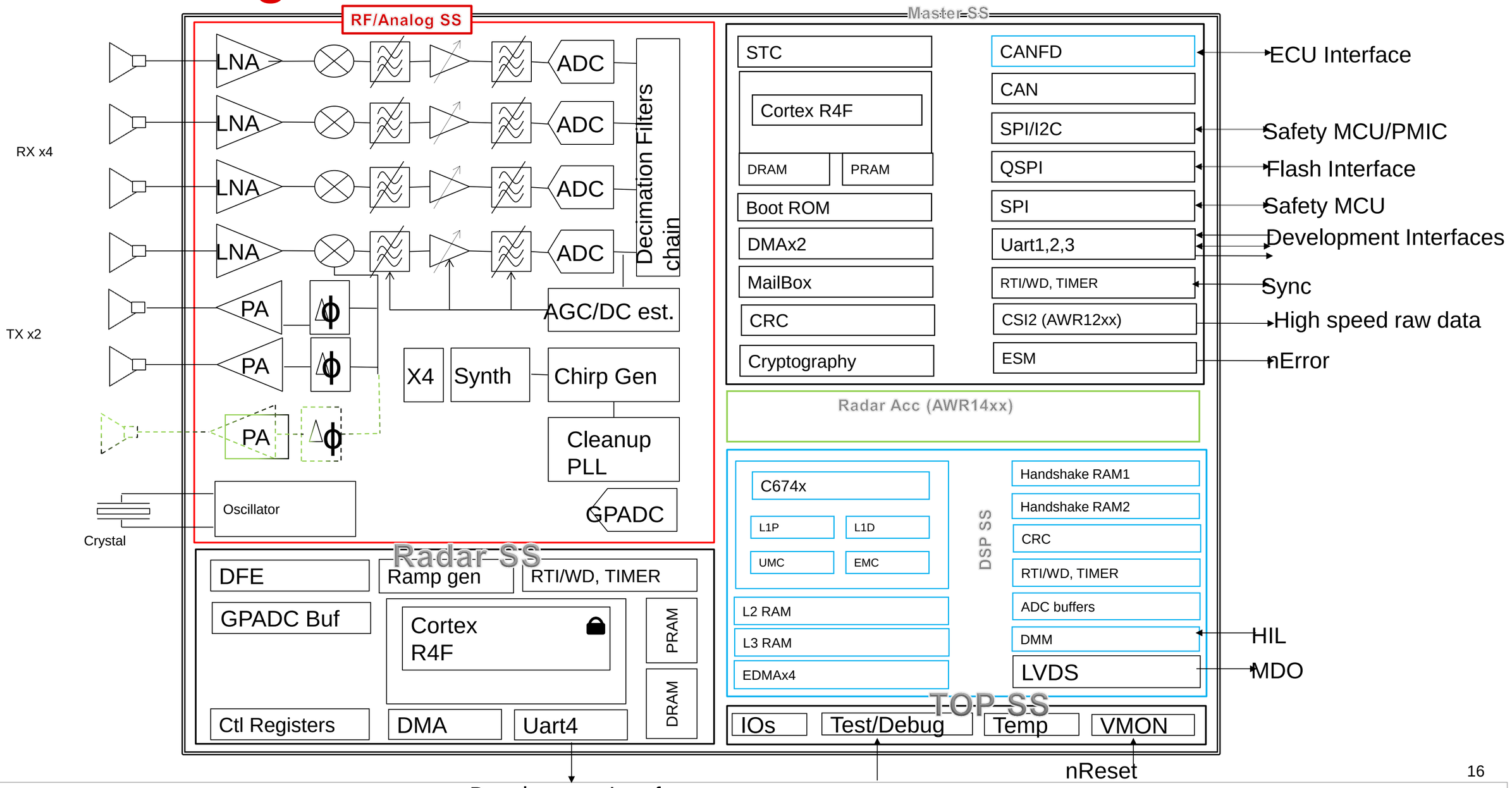
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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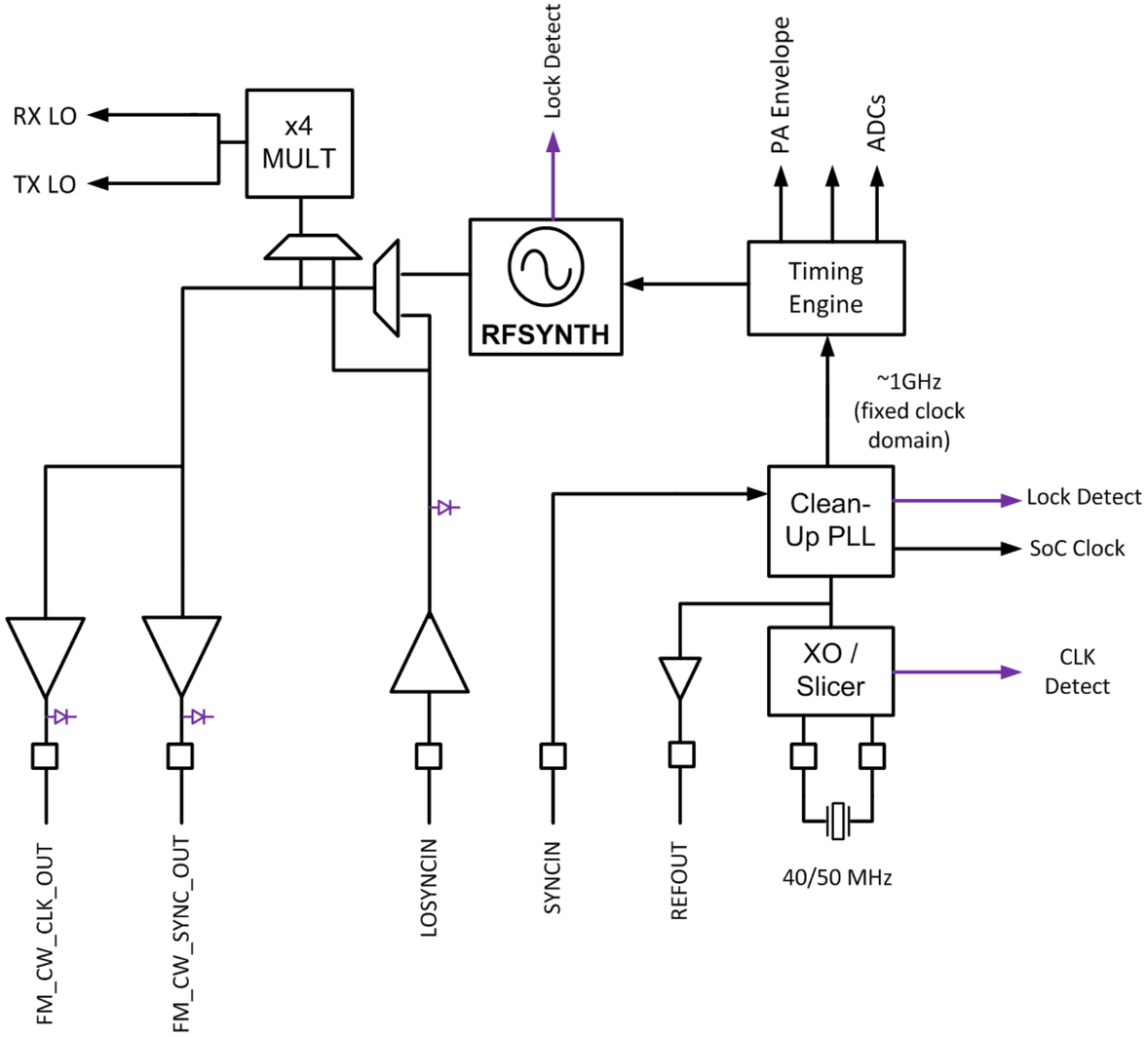
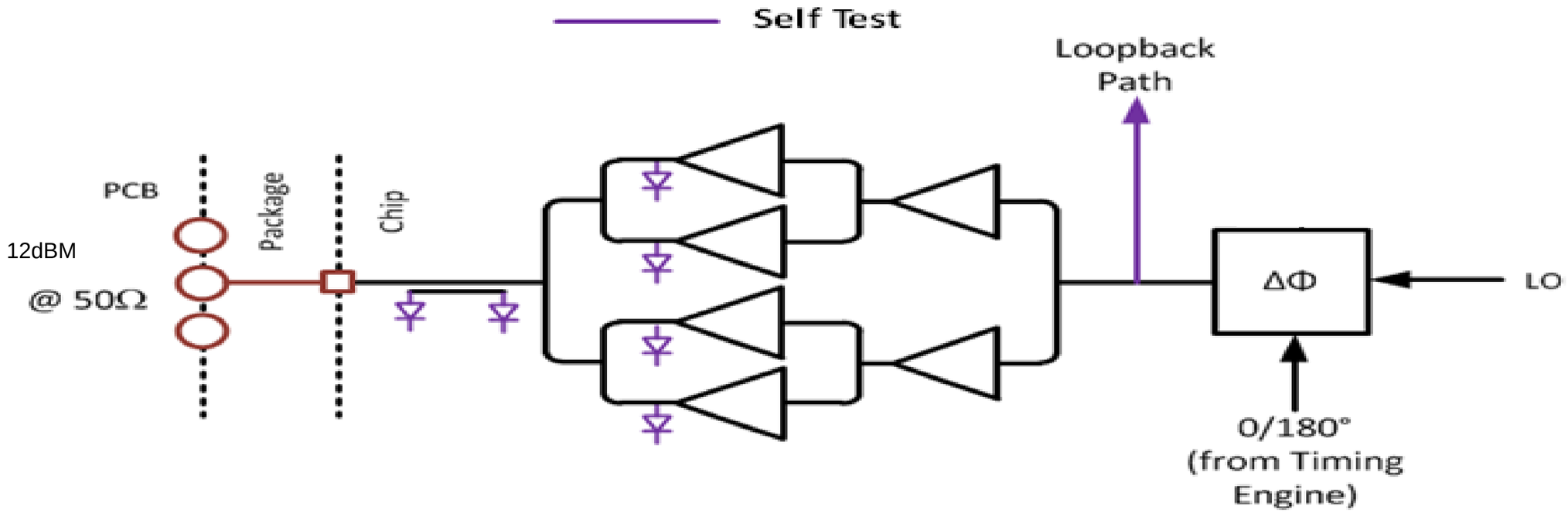
RF and Analog: Clock Subsystem

- Supports 40MHz crystal.
- Clean-up PLL provides high-frequency reference for modulated synthesizer and clocks to digital, ADCs.
- FMCW waveforms synthesized in a 19-20.25GHz closed loop frequency synthesizer.



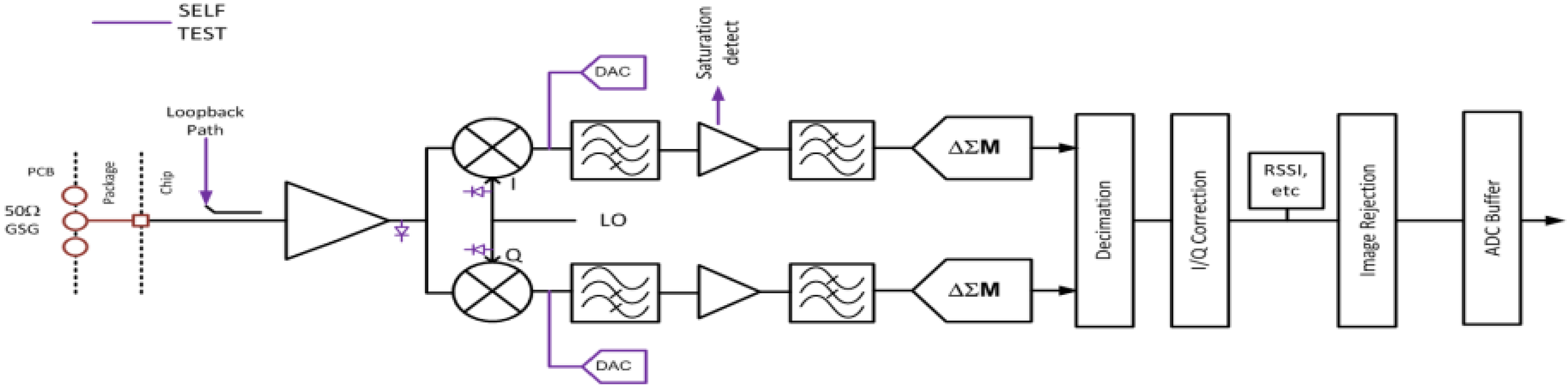
RF and Analog: Transmit Subsystem

- Single-ended antenna interface matched to a 50 ohm GCPW on the PCB at the edge of the package.
- Power/impedance monitors at the edge of the die.
- Binary (0/180) phase modulation for MIMO radar and interference mitigation.



RF and Analog: Receive Subsystem

- Complex (I/Q) baseband.
- Programmable high pass filters to compensate for channel loss.
- CTSDM ADC supports IF bandwidths up to 15MHz.



Radar Subsystem (aka BSS)

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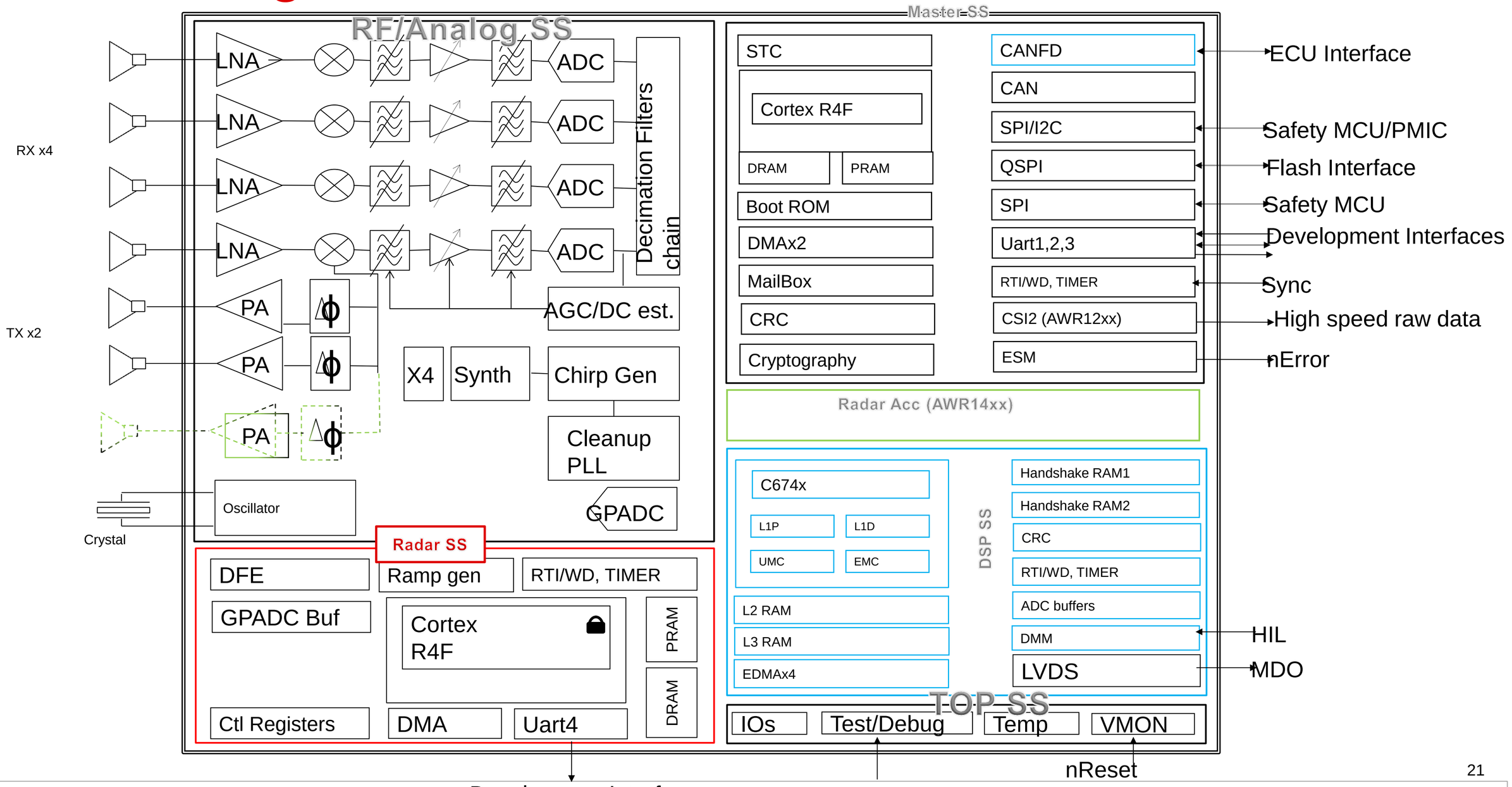
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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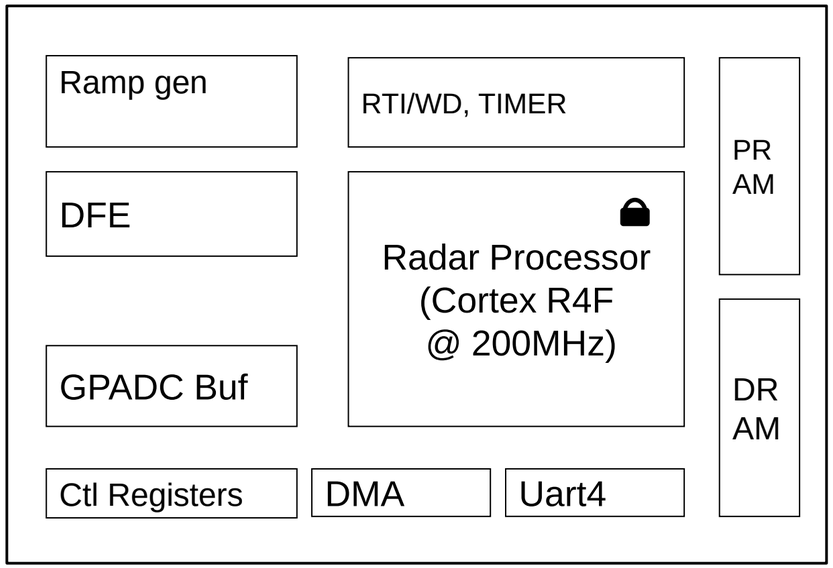
Radar Subsystem (BSS)

- Also known as the BSS, includes the DFE (digital front-end) and Ramp Generator
- Includes a dedicated Cortex R4F MCU for configuration, monitoring, and calibration of the low-level RF/Analog components
- Access to the Radar subsystem provided through hardware mailboxes and a well defined API



Radar Subsystem

Master Subsystem (MSS)

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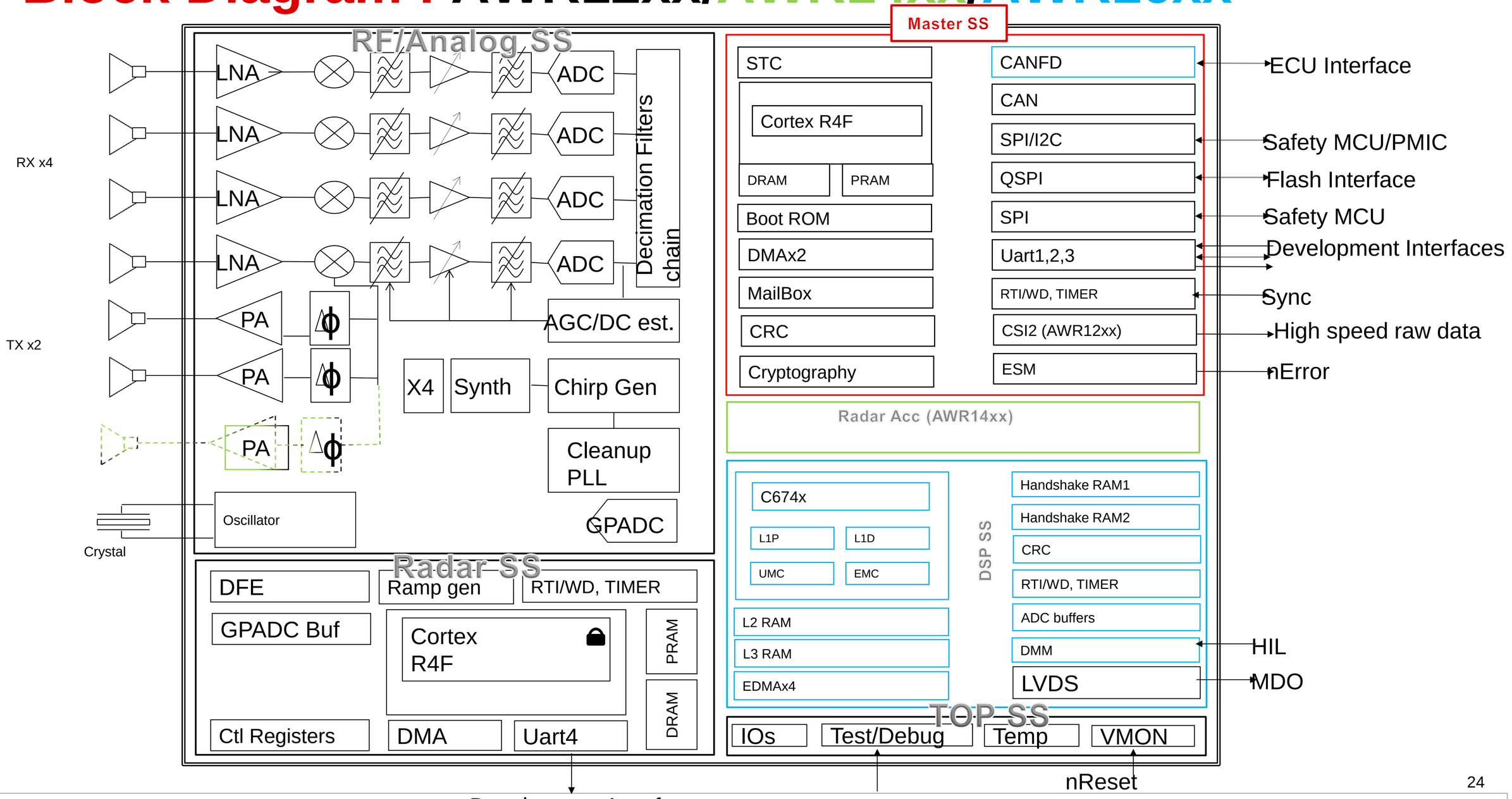
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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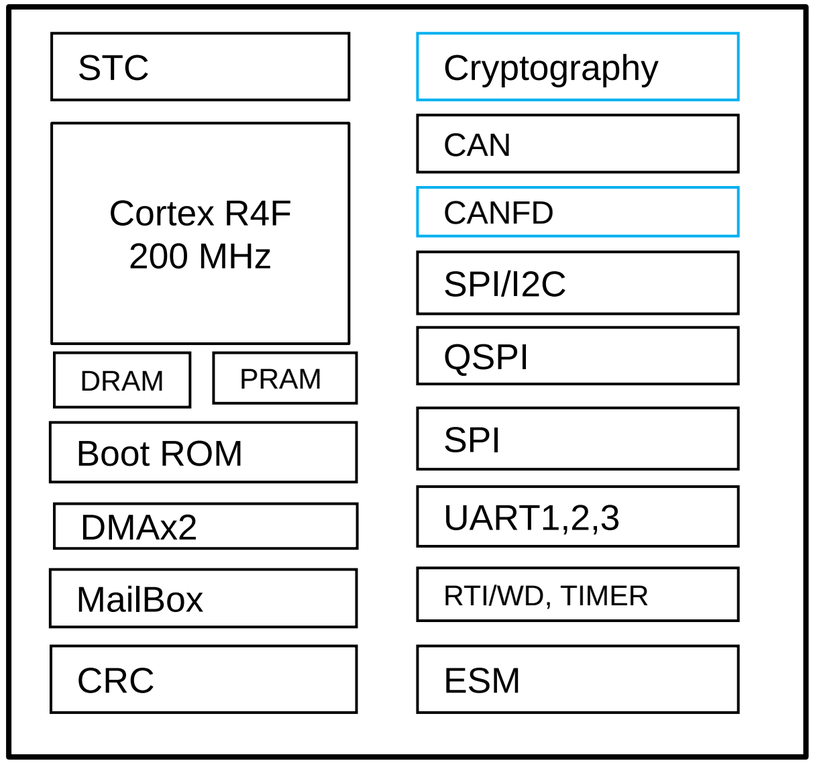
Master (Control) Subsystem

- The MSS includes an ARM Cortex R4F processor clocked at 200 MHz for running application code.
- User application running on MSS controls overall operation of the device, including Radar subsystem (BSS) control via well-defined API messages and perform radar signal processing.
- This subsystem also includes the various external interfaces available on the 14 or 16xx devices.



Master Subsystem

DSP Subsystem (DSS)

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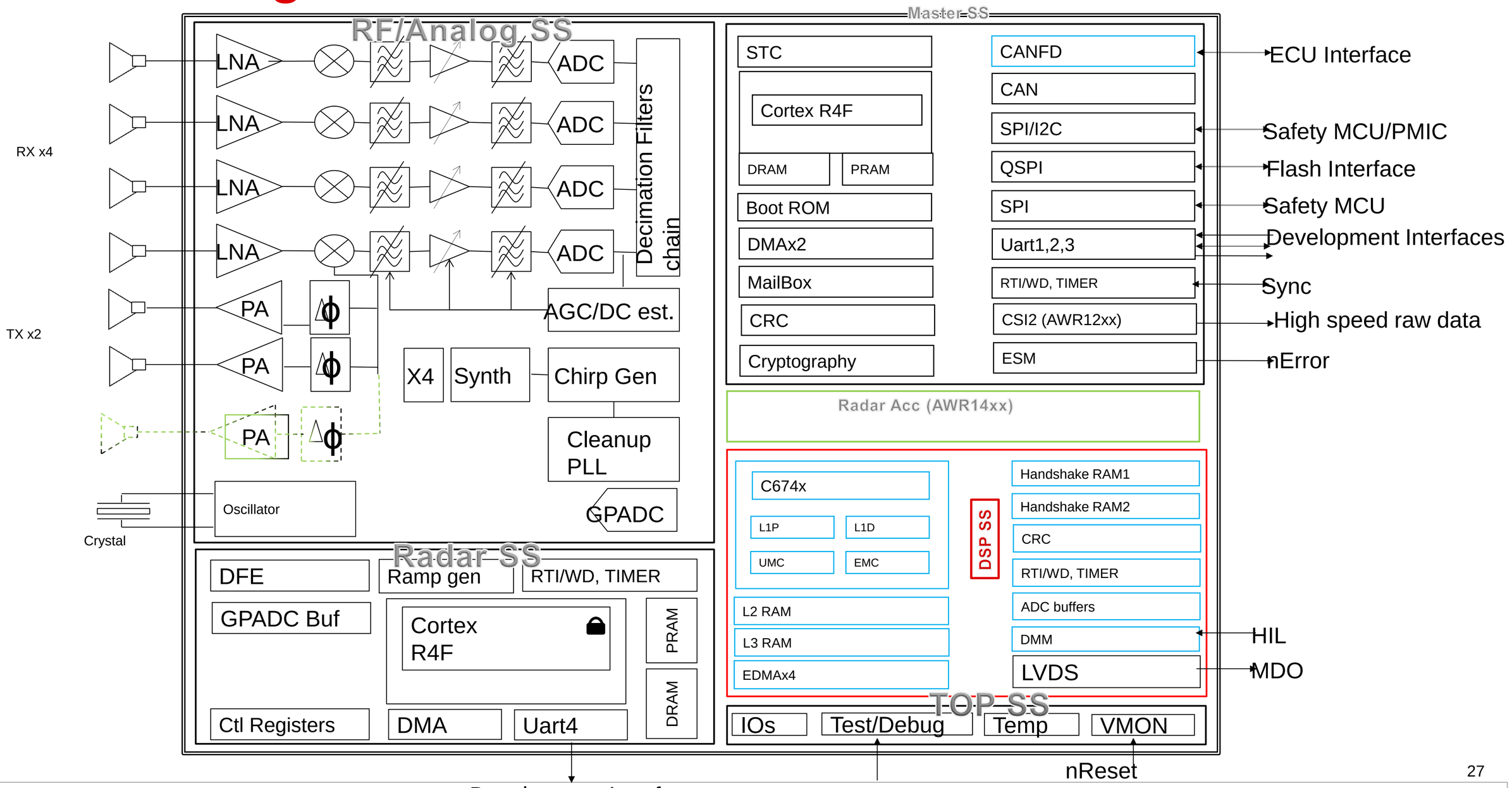
Block Diagram : AWR12xx/AWR14xx/AWR16xx



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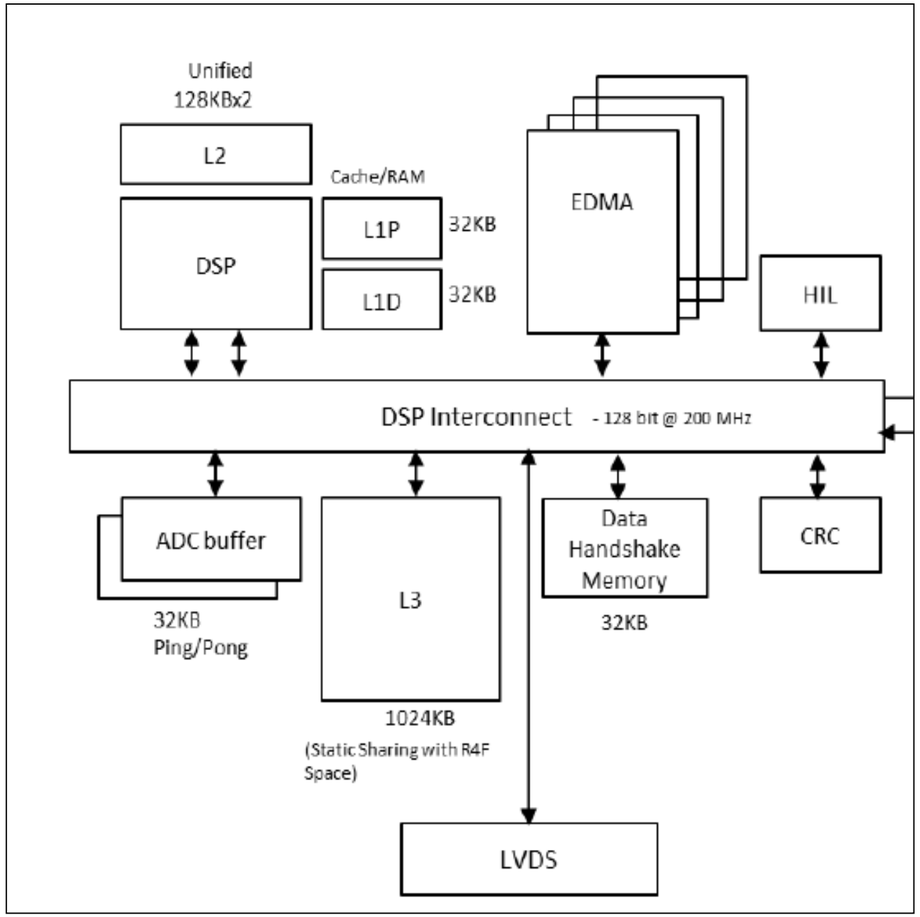
DSP Subsystem (DSS): AWR16xx only

- C674x DSP clocked at 600 MHz for advanced Radar signal processing
- High bandwidth interconnect for high performance (128-bit, 200MHz)
- 256 KB L2 and 1 MB of L3 memory
- Four DMAs for data transfer, LVDS interface for Measurement data output, ADC buffers, CRC engine and data handshake memory



DSP Subsystem (DSS)

Radar Hardware Accelerator

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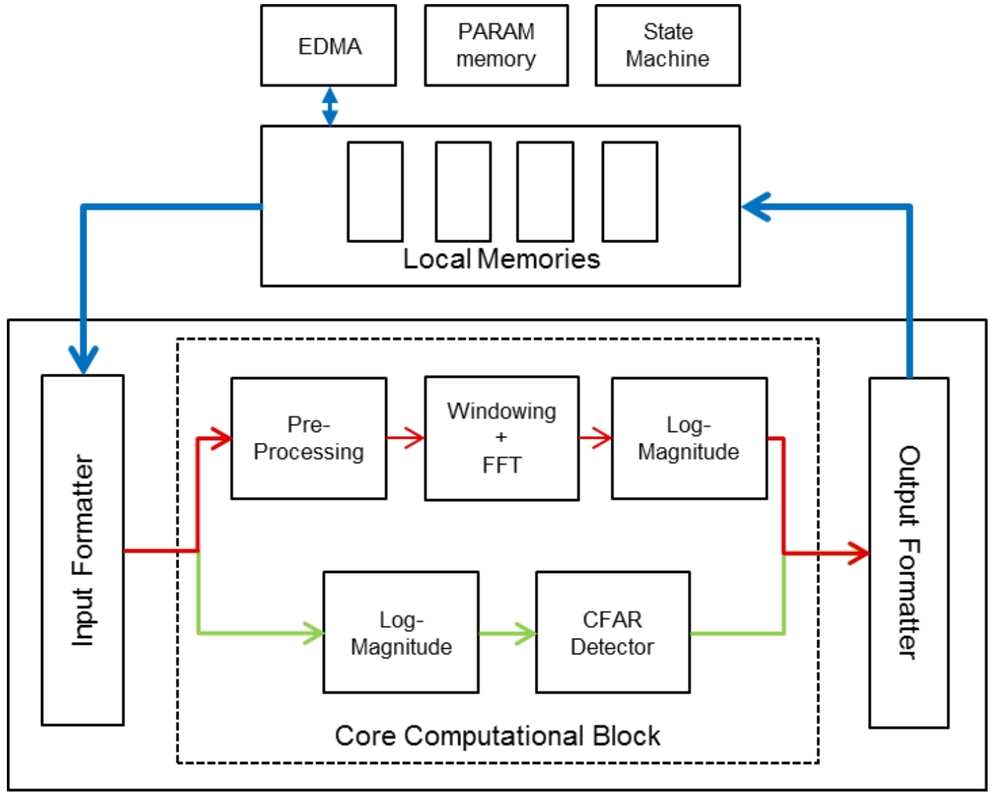
Radar Hardware Accelerator

- Accelerates FFT and CFAR detection operations
- Simple pre-FFT processing and Magnitude and Log-Magnitude computation capability
- Flexible data flow and data sample arrangement to support efficient multi-dimensional FFT operations and transpose accesses
- Chaining and Looping mechanism to sequence accelerator operations with minimal intervention from the main processor
- CFAR-CA detector support (linear and logarithmic)



Boot Modes

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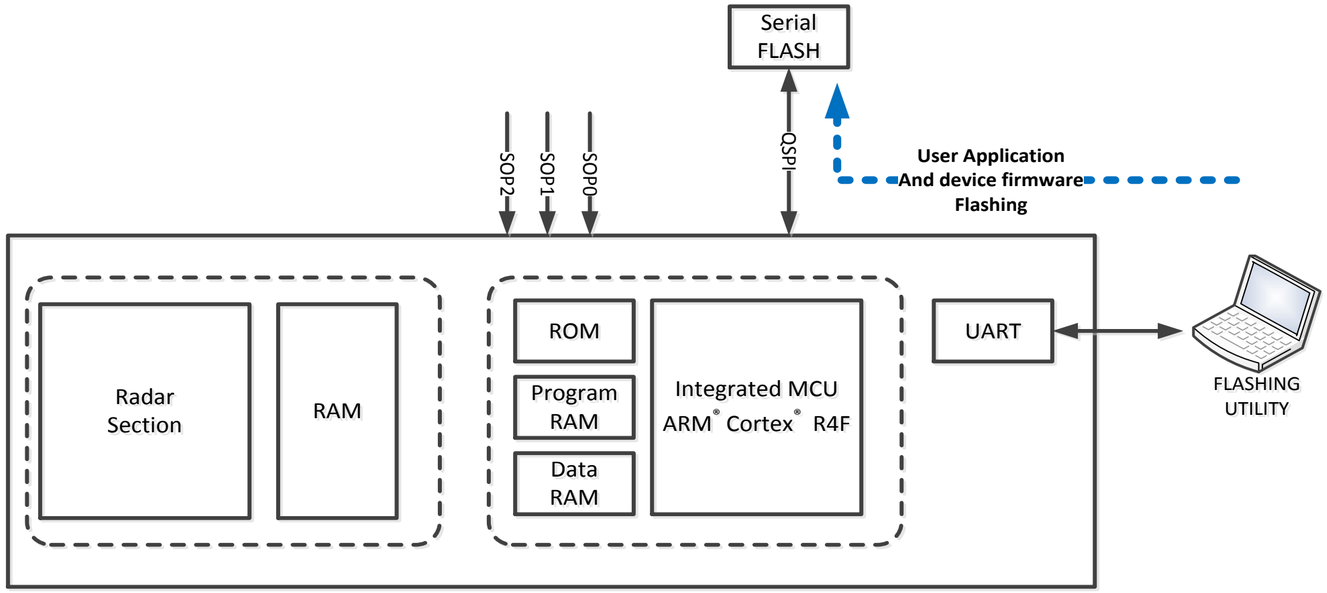
Boot Modes

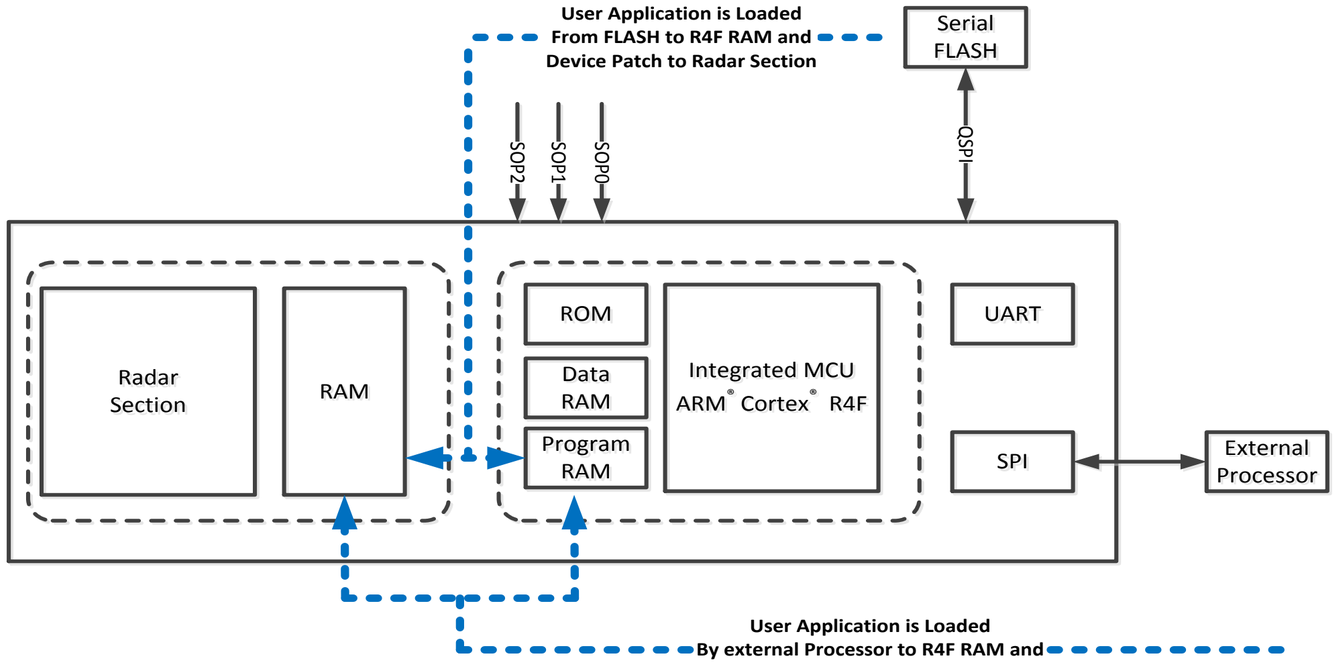


Flashing Mode:

- Bootloader enables the UART driver
- Expects a data stream comprising of User Application (Binary Image)
- Loads data to appropriate sections of the serial FLASH

Functional Mode:

- Bootloader looks for a valid image in the serial flash memory, interfaced over the QSPI port.
- Bootloader transfers the same to Master System's memory sub-system



Software Platform

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mmWave Software
Simplified evaluation and development

mmWave SDK

Includes:

- TI RTOS
- Drivers
  - SPI
  - CAN/CANFD
  - LVDS / CSI-2
  - EDMA
  - UART
  - I2C
  - GPIO
  - Timers
  - FFT HW
- Signal Processing Library
  - On DSP
  - On HW Accelerator
- mmWaveAPI
- mmWaveLink
- mmWaveLib

mmWave Examples

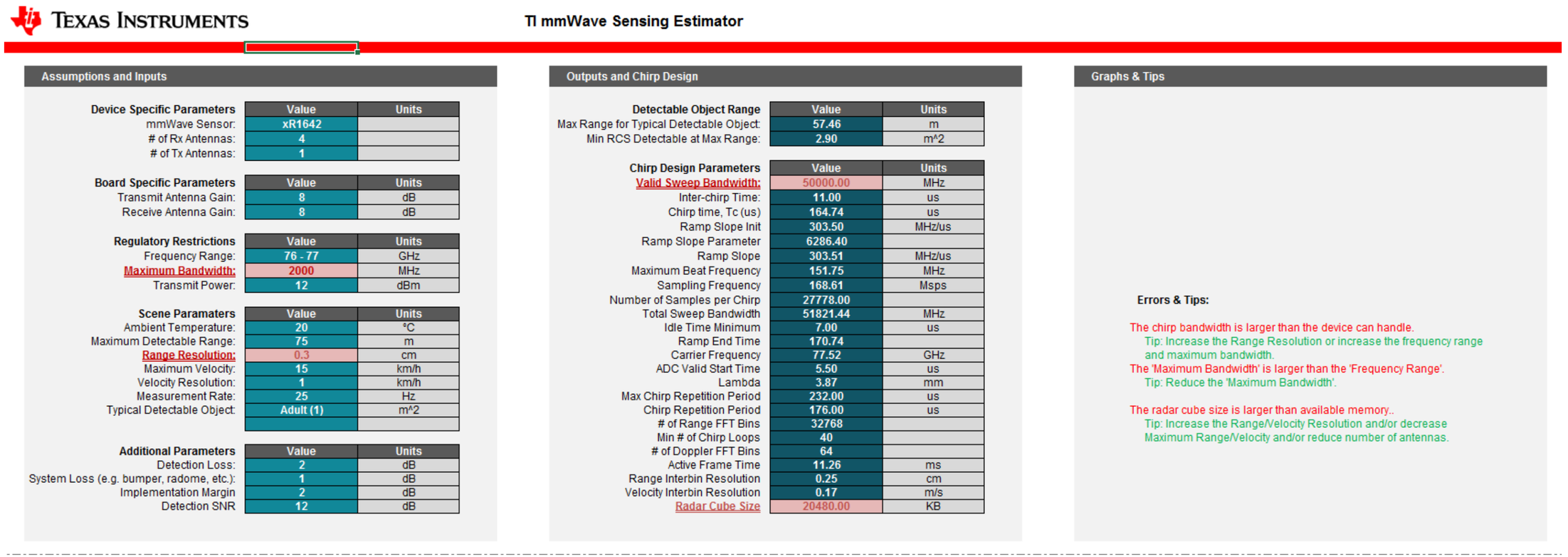
- TI Designs:
  - AWR14xx Proximity Sensor
  - AWR16xx Short-Range Radar
- Examples:
  - mmWaveDemo (OOB)

mmWave Studio

Includes:

- Visualizer – visualize output (point-cloud and proximity grid) from the sensor on the PC
- System Estimator – define chirp configuration through abstracted parameters like max range, minimum range, etc
- Capture – capture raw ADC data from capture HW onto the PC

mmWave Sensing Estimator



TEXAS INSTRUMENTS

TI mmWave Sensing Estimator

Assumptions and Inputs

Device Specific Parameters	Value	Units
mmWave Sensor:	xR1642	
# of Rx Antennas:	4	
# of Tx Antennas:	1	

Board Specific Parameters	Value	Units
Transmit Antenna Gain:	8	dB
Receive Antenna Gain:	8	dB

Regulatory Restrictions	Value	Units
Frequency Range:	76 - 77	GHz
Maximum Bandwidth:	2000	MHz
Transmit Power:	12	dBm

Scene Paramaters	Value	Units
Ambient Temperature:	20	°C
Maximum Detectable Range:	75	m
Range Resolution:	0.3	cm
Maximum Velocity:	15	km/h
Velocity Resolution:	1	km/h
Measurement Rate:	25	Hz
Typical Detectable Object:	Adult (1)	m^2

Additional Parameters	Value	Units
Detection Loss:	2	dB
System Loss (e.g. bumper, radome, etc.):	1	dB
Implementation Margin	2	dB
Detection SNR	12	dB

Outputs and Chirp Design

Detectable Object Range	Value	Units
Max Range for Typical Detectable Object:	57.46	m
Min RCS Detectable at Max Range:	2.90	m^2

Chirp Design Parameters	Value	Units
Valid Sweep Bandwidth:	50000.00	MHz
Inter-chirp Time:	11.00	us
Chirp time, Tc (us)	164.74	us
Ramp Slope Init	303.50	MHz/us
Ramp Slope Parameter	6286.40	
Ramp Slope	303.51	MHz/us
Maximum Beat Frequency	151.75	MHz
Sampling Frequency	168.61	Msps
Number of Samples per Chirp	27778.00	
Total Sweep Bandwidth	51821.44	MHz
Idle Time Minimum	7.00	us
Ramp End Time	170.74	
Carrier Frequency	77.52	GHz
ADC Valid Start Time	5.50	us
Lambda	3.87	mm
Max Chirp Repetition Period	232.00	us
Chirp Repetition Period	176.00	us
# of Range FFT Bins	32768	
Min # of Chirp Loops	40	
# of Doppler FFT Bins	64	
Active Frame Time	11.26	ms
Range Interbin Resolution	0.25	cm
Velocity Interbin Resolution	0.17	m/s
Radar Cube Size	20480.00	KB

Graphs & Tips

Errors & Tips:

The chirp bandwidth is larger than the device can handle.
Tip: Increase the Range Resolution or increase the frequency range and maximum bandwidth.
The 'Maximum Bandwidth' is larger than the 'Frequency Range'.
Tip: Reduce the 'Maximum Bandwidth'.

The radar cube size is larger than available memory..
Tip: Increase the Range/Velocity Resolution and/or decrease Maximum Range/Velocity and/or reduce number of antennas.

- Sensing Estimator enables prototyping chirp configuration through scene parameters
- Error checking and tips provide a convenient check on any out of bound or impossible values
- Helps customers jump start evaluation of their usecase for the mmWave sensors

mmWave SDK – The TI components

TI code

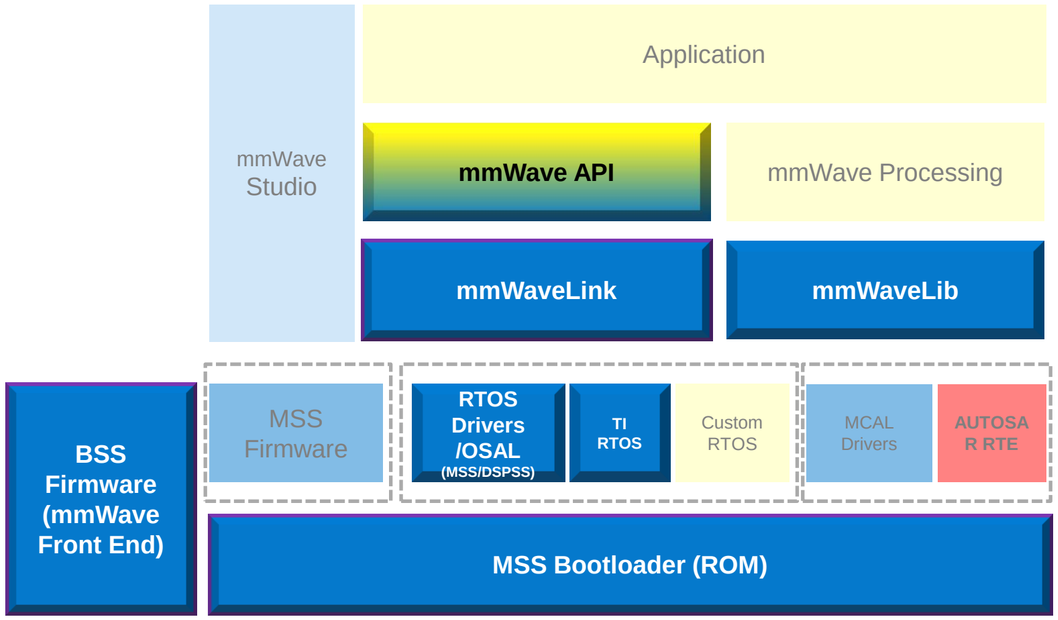
Partner code

Customer code

ISO 26262 enabled code

mmWave SDK

- Modular design
- Well defined APIs
- Documentation – doxygen, release notes, user guide
- MISRA-C compatibility for all foundational components



RTOS Drivers

- Encapsulate the functionality of the hardware IPs in the SOC
- Provide a well defined API to the higher layers.
- OS-agnostic via the OSAL layer

OSAL

- An abstraction layer for some of the common OS services. (Semaphore, Interrupts, Clock)
- Sample TI RTOS based port in mmWaveSDK
- Customers can port the OSAL for their custom OS, as per their requirements

BSS Firmware

- ROM Firmware for mmWave Front End
- Provides well defined APIs to configure, start and monitor mmWave Front End
- Communicates with MSS via Mailbox and proprietary protocol

mmWaveLink

- Low level control for mmWave Front End
- Communicates over Mailbox to BSS (front end)
- Implements the communication protocol between the BIST subsystem and Master subsystem

mmWave API

- Simple APIs for application to perform the task of radar sensing
- High level control for mmWave Front End and DSS
- Runs on top of mmWaveLink/IPC and Drivers.

mmWaveLib

- Provides functions for elements or sub functions of typical radar processing chain
- Optimized for C674x
- Speed customer development and reduce the SW effort to achieve a working radar processing chain

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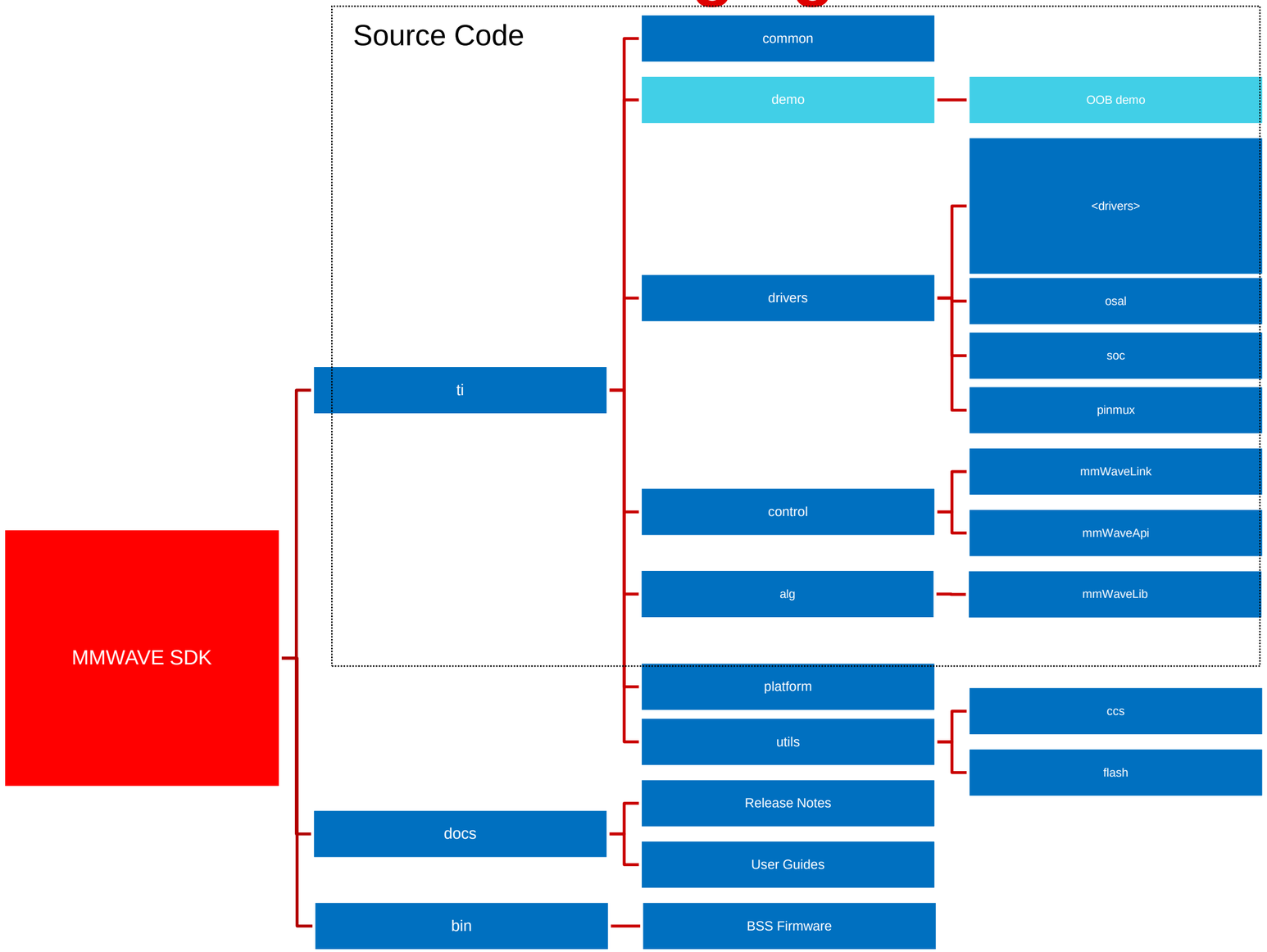
mmWave SDK - Packaging



- Uses TI compiler tools (Cortex-R4F, C674X) provided as part of CCS
- Demo built over TI RTOS
- Simple makefile based build system

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Learn more about TI Automotive mmWave Sensors

- Learn more about AWR1x devices, please visit the product pages
  - AWR1243: http://www.ti.com/product/AWR1243
  - AWR1443: http://www.ti.com/product/AWR1443
  - AWR1642: http://www.ti.com/product/AWR1642
- Get started evaluating the platform with AWR1x EVMs, purchase EVM at
  - AWR1243 EVM: http://www.ti.com/tool/AWR1243BOOST
  - AWR1443 EVM: http://www.ti.com/tool/AWR1443BOOST
  - AWR1642 EVM: http://www.ti.com/tool/AWR1642BOOST
- Download mmWave SDK @ http://www.ti.com/tool/MMWAVE-SDK
- Ask question on TI's E2E forum @ http://e2e.ti.com