WHITE PAPER

Designing SDR System with Zynq™ UltraScale+™ RFSoC

A Blueprint for Real-Time, Reconfigurable RF Design



iWave Global

Introduction

Modern wireless communication systems from next-gen radar and 5G infrastructure to tactical electronic warfare demand hardware platforms that are agile, high-performance, and reconfigurable. At the heart of this transformation lies the Field Programmable Gate Array (FPGA).

What is FPGA?

An FPGA is a reprogrammable semiconductor device consisting of logic cells, routing fabric, and configurable I/Os that can be programmed to implement virtually any digital function. Unlike fixed-function ASICs, FPGAs allow custom hardware acceleration for specific workloads while retaining flexibility for updates or design changes. This makes them ideal for evolving applications such as signal processing, AI acceleration, and communications. FPGAs are used across diverse sectors such as defense, telecom, aerospace, automotive, medical, and even consumer electronics; thanks to their ability to provide hardware-level performance with software-like adaptability. Their architecture allows parallelism, low-latency processing, and deterministic timing all crucial features for real-time RF systems.

What is Zynq™ UltraScale+™ RFSoC?

Radio Frequency System-on-Chip (RFSoC) technology integrates high-speed RF-class data converters (ADCs/DACs), programmable FPGA logic, and embedded processors into a single monolithic device. By consolidating multiple discrete components into one chip, Zynq™ UltraScale+™ RFSoCs simplify board design, reduce latency, and enable real-time, reconfigurable RF systems such as SDR, radar, and wireless test platforms.

What is Software Defined Radio?

Software Defined Radio (SDR) is a paradigm in radio communication where traditional analog signal processing components are replaced by software-driven digital signal processing. Functions like filtering, modulation, demodulation, and decoding are implemented in software, allowing radio systems to be reprogrammed for different standards, frequencies, or use cases without changing hardware.

SDRs have become the backbone of modern communication systems and are widely used in defense, aerospace, 5G infrastructure, satellite communications, and test & measurement. Their adaptability enables rapid prototyping, over-the-air upgrades, and multi-mode operation, making SDR the go-to architecture for next-generation wireless systems.

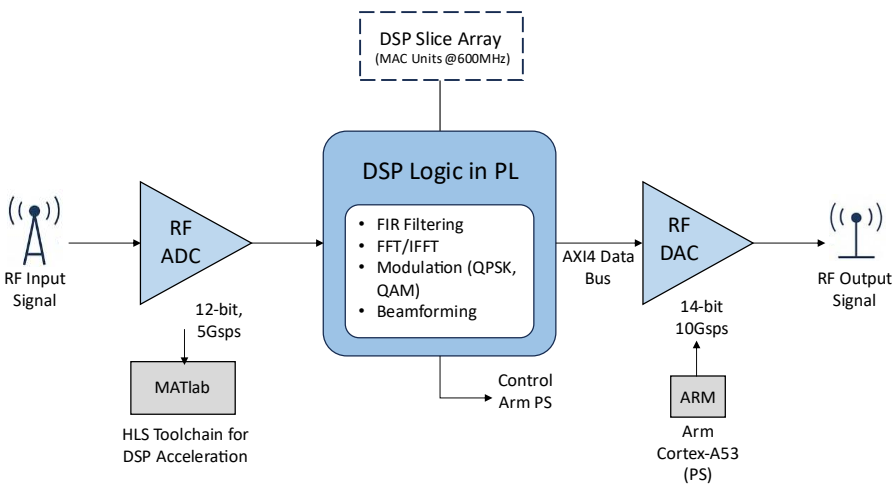


Figure: Real-time RF signal chain in an Zynq™ UltraScale+™ RFSoC-based SDR, featuring high-speed ADC/DAC conversion, programmable DSP logic, and integrated ARM cores for control. The system supports wideband waveform processing at sub-microsecond latency.

Why FPGA Based Zynq™ UltraScale+™ RFSoC for SDR?

SDR offers unmatched flexibility, but implementing it at scale introduces significant hardware challenges. Traditional SDR platforms built from discrete ADCs/DACs, FPGAs, and processors face constraints in **latency, SWaP (Size, Weight, and Power), synchronization, and data throughput.**

Zynq™ UltraScale+™ RFSoC devices directly address these challenges by integrating the entire SDR signal chain onto a single chip:

Latency – Eliminates JESD204x and board-to-board transfer delays, reducing end-to-end latency to sub-microsecond levels (<1 µs vs. 5–10 µs in discrete systems).
SWaP Efficiency – Cuts board footprint by ~50% and power consumption by up to 40%, enabling deployment in UAVs, soldier radios, and compact test systems.
Multi-Channel Synchronization – Built-in Multi-Tile Synchronization (MTS) and Multi-Chip Synchronization (MCS) achieve <100 ps skew, critical for MIMO, phased-array, and beamforming systems.
High Data Throughput – Integrated DDR4, PCIe Gen3/4, and 10–100GbE interfaces handle multi-Gbps data streams efficiently, avoiding bottlenecks common in external FPGA setups.

By combining programmable FPGA fabric, RF-class converters, and embedded ARM processors in a single SoC, Zynq™ UltraScale+™ RFSoCs deliver the ideal balance of real-time performance, reconfigurability, and integration making them the natural fit for next-generation SDR platforms.

Technical Deep Dive

This section provides the detailed architecture and specifications that define Zynq™ UltraScale+™ RFSoC performance in real-world RF systems, including:

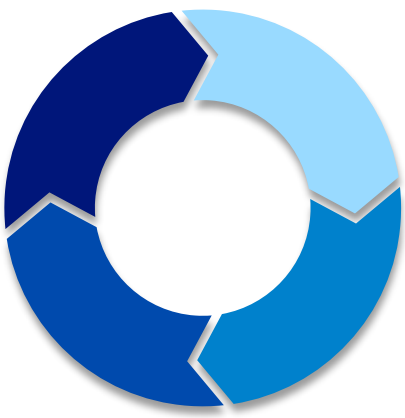
ADC/DAC Performance – 14-bit converters with up to 5 Gsps (ADC) and 10 Gsps (DAC), supporting direct-RF digitization and generation.
Clocking & Synchronization – on-chip PLLs, jitter management, Multi-Tile Synchronization (MTS), and Multi-Board Synchronization (MBS) with sub-100ps alignment.
Latency Metrics – end-to-end loopback latency as low as <1 µs with deterministic startup.
High-Speed Interfaces – JESD204B/C, PCIe Gen3/4, and 10–100GbE through GTY transceivers for efficient data transfer.
DSP Resources – thousands of DSP48E2 slices for parallelized filtering, FFTs, modulation/demodulation, and beamforming.
Power & Thermal – typical TDP up to 60W with support for both active and passive cooling.

Zynq™ UltraScale+™ RFSoC Advantages

Compared to traditional multi-chip SDR architectures, Zynq™ UltraScale+™ RFSoCs offer:

SWaP Reduction
Up to 50% smaller footprint and 30–40% lower power than discrete designs.

Scalable Architecture Supports multi-channel synchronization and a wide portfolio of Zynq™ UltraScale+™ RFSoC variants.

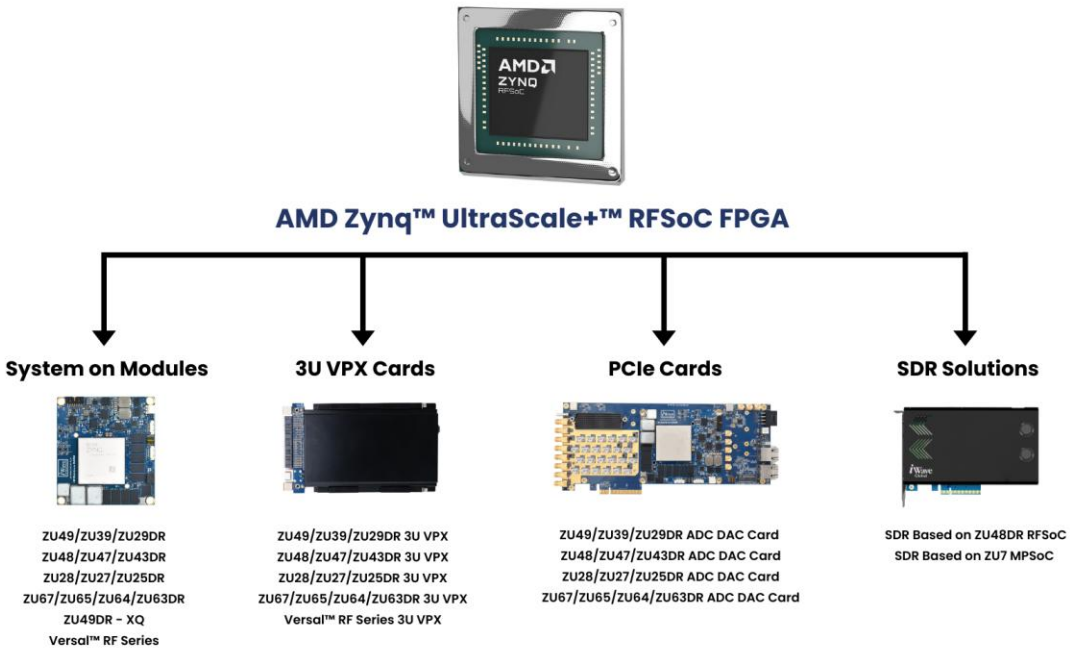


Direct-RF Sampling
Eliminates external IF chains and analog mixers.

Ultra-Low Latency Sub-microsecond signal chain performance for real-time responsiveness.

Zynq™ UltraScale+™ RFSoC Product Family

Built on a scalable SoM architecture, iWave's Zynq™ UltraScale+™ RFSoC solutions are available in standard form factors like PCIe and 3U VPX — enabling seamless integration into both evaluation platforms and custom carrier designs.



Case Study: Deploying Zynq™ UltraScale+™ RFSoC SoM in a Tactical SDR System

Overview:

A global defense technology provider approached iWave to accelerate the development of a rugged Software Defined Radio (SDR) system designed for tactical edge deployment. The key requirements were:

- Compact form factor suitable for airborne platforms
- Low-latency signal chain for real-time threat detection
- Multi-channel, coherent RF data acquisition and transmission
- FPGA-level customization for adaptive waveforms
- Rapid development cycle with hardware/software co-design

To address the customer's demanding requirements for a real-time SDR system, iWave delivered a high-performance solution centered around the ZU49DR-based iG-G42M System on Module.

The solution integrated 16-channel 12-bit RF ADCs operating up to 2.058Gsps and 14-bit RF DACs achieving up to 6.554Gsps, enabling direct RF digitization and generation. The modular SOM was mounted on a ruggedized carrier card with PCIe Gen3 and SFP+ interfaces for low-latency, high-bandwidth communication. The platform was optimized for compact integration and thermal stability, achieving performance within a 60W power envelope. The collaboration ensured faster time-to-market, reduced development complexity, and an efficient path from evaluation to deployment.

Outcome:

- **Latency achieved:** End-to-end RF loopback latency < 1.5 µs
- **Channel-to-channel phase mismatch:** Calibrated to < 2° RMS
- **Size/Weight reduction:** 40% lower than the customer's previous 3-chip solution
- **Deployment:** Successfully integrated into a field-deployable ISR (Intelligence, Surveillance, Reconnaissance) unit

Carrier Board Integration Guidelines

When designing custom carrier boards for Zynq™ UltraScale+™ RFSoC SoMs, engineers should consider:

Key Consideration	Design Guidelines
Signal Integrity	Controlled impedance routing for LVDS, transceivers (GTY/GTR); matched trace lengths for JESD lanes
Power Supply	Multi-rail power sequencing aligned with AMD guidelines (VCCINT, VCCAUX, VCCBRAM, etc.)
Clocking	Low-jitter clock sources; support for external sync input (e.g., 10 MHz or PPS) for phase coherence
RF Interfaces	Clean routing to/from SMA connectors; use of shielded RF paths and inline filtering
Thermal Management	Active cooling (fan sink) or conduction-cooled chassis depending on TDP; iWave SoMs support both
Debug & Programming	Access to JTAG, USB-UART, and boot modes via jumpers and debug headers

To simplify development, iWave also offers customizable carrier board design services, supporting mechanical constraints, I/O expansion, and ruggedization for harsh environments.

Reference Designs for Rapid Prototyping

iWave provides production-tested reference designs tailored for Zynq™ UltraScale+™ RFSoC SoMs. These include:

- Bitstream-ready projects using Vivado Design Suite
- Pre-validated RF Analyzer configurations for loopback and spectral analysis
- Examples integrating Multi-Tile Synchronization (MTS) and Digital Up/Down Conversion (DUC/DDC)
- RF chain building blocks such as programmable gain control, filters, and digital mixers

These reference designs help customers evaluate the board capabilities, accelerate early development, and serve as a launchpad for custom IP integration.

ODM/Customization Support

iWave offers ODM (Original Design Manufacturing) services for customers requiring deeper hardware customization:

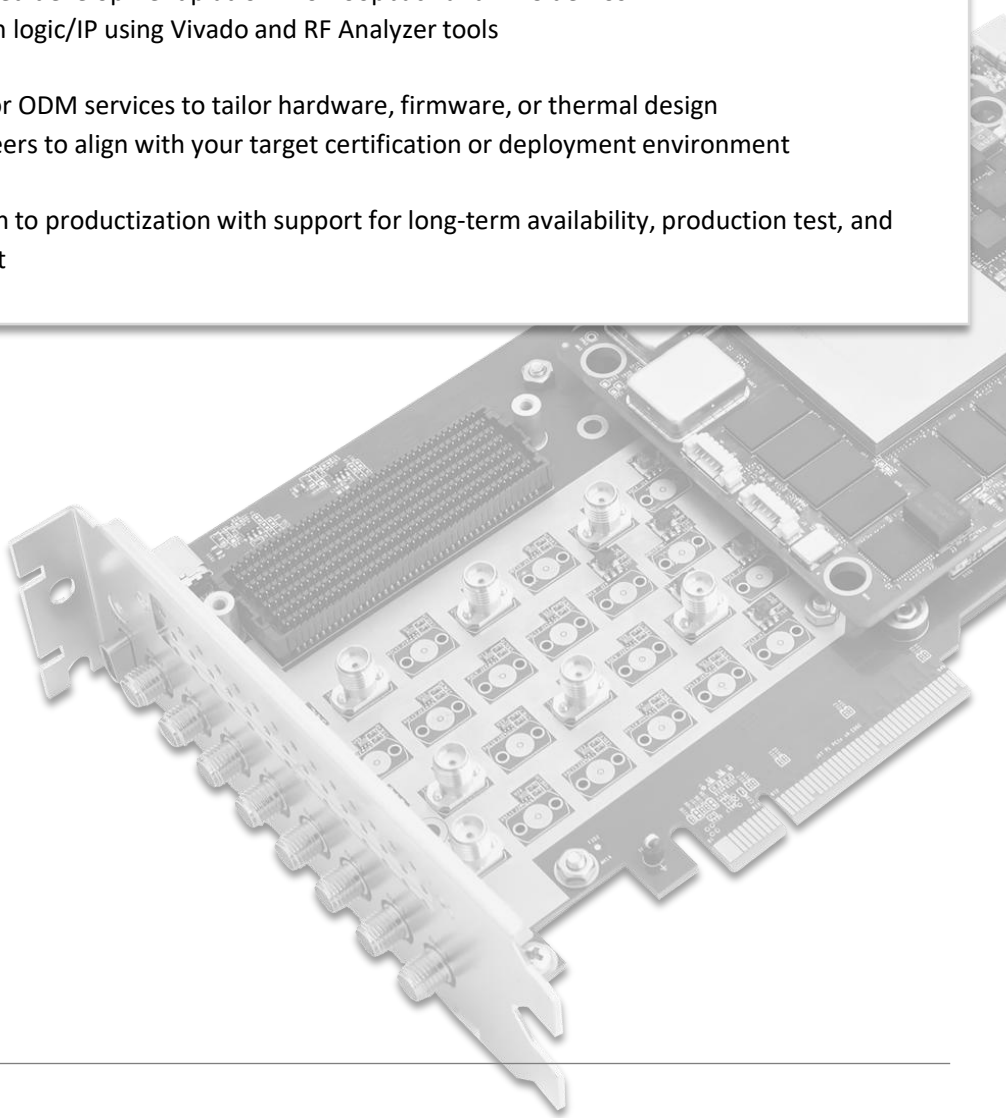
- SoM population with custom part numbers (e.g., ZU29DR, ZU48DR based on availability and project need)
- BOM optimization for cost, power, or performance
- Tailored mechanical enclosures for thermal and EMI control
- Board-level testing & validation including high-speed compliance and thermal profiling
- Long lifecycle support aligned with defense and industrial-grade reliability requirements

With in-house capabilities in FPGA design, RF validation, PCB layout, and embedded software, iWave helps customers move from concept to deployable hardware faster.

Next Steps for Engineers & System Designers

Here's how you can begin building your SDR or RF application with iWave's Zynq™ UltraScale+™ RFSoC platform:

1. **Evaluate:**
   - Explore the product brief and datasheets of iG-G42M / iG-G60M / iG-G79M SoMs
   - Request access to the reference design package and starter guide
2. **Prototype:**
   - Use iWave's high-speed development platform for loopback and MTS demos
   - Interface your custom logic/IP using Vivado and RF Analyzer tools
3. **Customize:**
   - Engage with iWave for ODM services to tailor hardware, firmware, or thermal design
   - Work with our engineers to align with your target certification or deployment environment
4. **Deploy:**
   - Move from evaluation to productization with support for long-term availability, production test, and lifecycle management



Corporate Headquarters
iWave Global
#7/B, 29th Main,
BTM Layout 2nd Stage,
Bangalore 560076,IN.
Ph: +91-80-26683700, 26786245

International Headquarters
iWave Global EMEA FZ-LLC
T1-5F-7B, RAKEZ Center,
Al Hamra Industrial Zone-FZ,
Ras Al Khaimah, UAE.
Ph: +971-543-685776

Take the Next Steps
Visit: RFSoC Portfolio Page
For technical questions,
Contact mktg@iwave-global.com