WHITE PAPER

Software Defined Radio:

Past, Present, and Future

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The Past—30 Years of SDRs

It's hard to believe that the term "software defined radio" (SDR) has been around for about 30 years. That's a long time in the technology world. And though it's still a common topic of discussion to this day, SDR carries more than its share of misconceptions. According to the Wireless Innovation Forum (formerly the SDR Forum), SDR is "a radio in which some or all of the physical-layer functions are software defined." Though the term focuses on the physical-layer (PHY) processing of the waveform, it is not related to the radio frequency (RF) front end. This is one of the common misconceptions around SDR.

Thirty years later, it's almost a given that any radio is an SDR. In fact, the SDR is now such a dominant industry standard—from military tactical radios to cellular handsets—that there's seemingly no end in sight to their potential. Continued SDR innovations in semiconductor and software technology drive higher development productivity and more cost-effective products. These factors indicate that SDRs are really a solved problem and that radios are now evolving into frequency-agile intelligent communication systems.

The Present—SDRs Become the De Facto Industry Standard

In markets such as signals intelligence (SIGINT), electronic warfare, test and measurement, public-safety communications, spectrum monitoring, and military communications (MILCOM), SDRs have become the de facto industry standard. Traditionally, many of these markets used hardwired application-specific integrated circuits (ASICs), while others already used programmable digital signal processors (DSPs). Figure 1 shows the progress of SDR adoption over the last 30 years. Closest to the center, the dark blue section represents the first set of markets to move from hardware radio architectures to SDR architectures, regardless of whether they used the term SDR.

The advent of RF integrated circuits (RFICs) by companies like Analog Devices and cost-effective DSP-intensive FPGAs by companies like Xilinx drove the move to SDR in many markets. These two technologies converged to address a multibillion dollar need in the military tactical radio market, but they had an impact on the evolution of SDR technology far beyond the MILCOM market.

Meanwhile, the Joint Tactical Radio System (JTRS) program funded the development and productization of SDRs for military radios, which created a strong ecosystem of vendors including semiconductor, tools, and software companies. On the tools front, specifically, SDR required waveforms to be as portable as possible between different hardware platforms, which resulted in the Software Communications Architecture (SCA) Core Framework and better programming tools from electronic design automation (EDA) and semiconductor companies.

The advancement of RFICs, FPGAs, and EDA tools was significant in enabling the second generation of SDRs to be driven by 4G LTE infrastructure. Virtually all LTE base stations were developed with RFICs and FPGAs. Some of the larger infrastructure vendors eventually moved to ASICs, but even then, the baseband ASICs were largely programmable. They used processors coupled with hardened blocks called hardware accelerators for compute-intensive functions, such as turbo decoding, that typically exceeded the performance or power limitations of the processors.

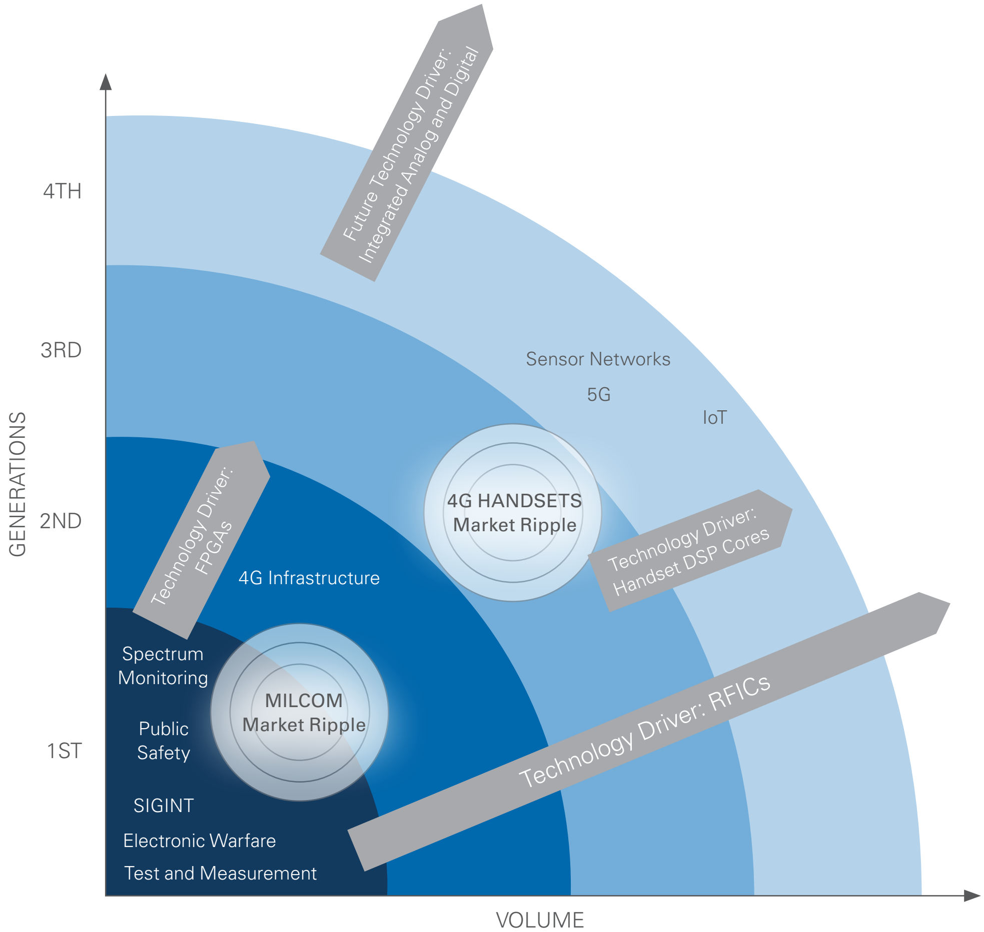

Figure 1. Successive generations of SDRs now dominate the radio industry and continue to evolve.

The next market ripple, shown in the third generation, occurred when 4G LTE handsets moved consistently to SDR architectures. This shift was enabled by low-power, high-performance DSP cores optimized for handsets offered by companies such as Ceva, Tensilica, and Qualcomm. Like baseband ASICs for infrastructure, these cores were integrated into application-specific standard products (ASSPs) or ASICs for much of the PHY processing and coupled with hardware accelerators. After this changeover, SDR volume increased in orders of magnitude and reach, and SDRs became the de facto industry standard for radios.

The Future—The Next Generation of SDRs

What's next for SDR? As the ubiquity of 4G handsets has propelled SDRs, the prospects of emerging technologies such as 5G, the Internet of Things (IoT), and sensor networks promise to again increase the volume of SDRs by another order of magnitude. What will be the technology driver lifting SDR to these lofty heights? As with previous leaps in SDR adoption, it will likely be a combination of both hardware and software technologies.

One of the next technology drivers in hardware looks to be the combination of analog and digital technology onto a single monolithic chip to reduce cost and size, weight, and power (SWaP). For infrastructure, this driver could be FPGAs with integrated analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). For handsets and sensors, this could be application processors, also with integrated ADCs and DACs.

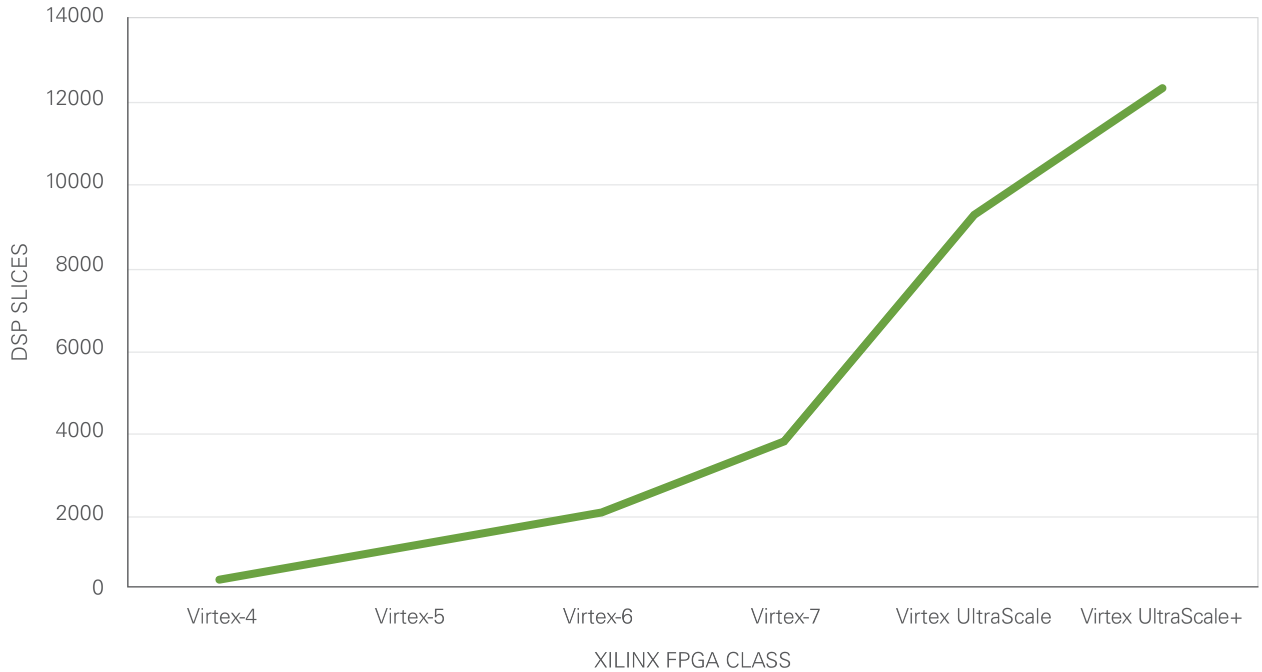

Figure 2. The number of DSP slices in each subsequent FPGA generation continues to grow rapidly.

New innovations in hardware won't be very useful, however, if the software and tools don't follow. That is the whole point of SDR, after all. The development of these chips, as well as the waveforms and application software running on them, will require better system-level tools that can be used to design and debug across the analog and digital domains. As SDRs are used for increasingly complex tasks, they will be designed with more powerful FPGAs for intensive DSP (Figure 2). This will create an inevitable growing need for FPGA tools that can handle rapidly increasing amounts of data and complexity.

Though general-purpose processors (GPPs) have served the SDR community well in the past, they are struggling to meet the performance required for areas like 5G and MILCOM. Software tools such as the LabVIEW FPGA Module offer a streamlined user experience that makes FPGA programming vastly more efficient. In addition, for the open source development flow, RFNoC enables much easier integration of custom VHDL or Verilog IP onto Ettus Research USRP SDRs.

Ultimately, integration will drive the next generation of SDRs. The integration of analog and digital technology into mixed-signal chips will be key, but SDRs have fundamentally reached a point where the primary limitation on growth is in software, not hardware. Without software development environments that can seamlessly program both GPPs and FPGAs, the additional hardware features of next-generation SDRs will be underused and development will stall. The ability of tools like LabVIEW FPGA to enable wireless engineers who are not HDL experts to develop and rapidly iterate on sophisticated designs offer the best opportunity moving forward to unlock the next generation of SDRs.

Learn about NI SDR solutions.