

LEARNING MADE EASY

Arm Special Edition

# Total SoC Compute

for  
**dummies**<sup>®</sup>  
A Wiley Brand



Take a system-  
level solution view

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Handle demanding  
multi-compute workloads

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Focus on use cases  
and experiences

Compliments of  
**arm**

Lawrence C. Miller

## About Arm

Arm technology is at the heart of a computing revolution that is transforming the way people live and businesses operate. Arm's advanced, energy efficient processor designs enable intelligent computing in applications and devices from sensors to the smartphone, enterprise infrastructure, and the Internet of Things.

Arm's innovative technology is licensed by more than 1,000 partners who have shipped more than 170 billion chips containing the company's intellectual property. This technology is driving innovation for developers, designers, and engineers looking to harness the power of secure compute and ensure a fast and reliable route to market.



# Total SoC Compute

Arm Special Edition

**by Lawrence C. Miller**

for  
**dummies**<sup>®</sup>  
A Wiley Brand

# Total SoC Compute For Dummies®, Arm Special Edition

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# Introduction

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**A**dvances in digital immersion are inspiring more natural and intuitive ways to interact with digital information and devices. This, in turn, is creating more advanced, complex, and demanding multi-compute workloads, especially for cutting-edge extended reality (XR), gaming, viewing, and artificial intelligence (AI)-based experiences.

To successfully address these requirements, a massive paradigm shift in the approach to system-on-a-chip (SoC) design is required. Total Compute is a way to move beyond optimizing individual intellectual property (IP) with a system-level solution view of the SoC that focuses on use cases and experiences in the designs.

## About This Book

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*Total SoC Compute For Dummies* consists of six chapters that explore the role of digital immersion in SoC design (Chapter 1), compute performance requirements (Chapter 2), modern security challenges (Chapter 3), developer access needs (Chapter 4), the end-to-end SoC (Chapter 5), and total SoC compute key principles (Chapter 6).

# Foolish Assumptions

It's been said that most assumptions have outlived their usefulness, but I assume a few things nonetheless! Mainly, I assume you are a developer, hardware or software engineer, or an engineering manager. As such, this book is written primarily for technical readers. If these assumptions describe you, then this book is for you.

## Icons Used in This Book

Throughout this book, I occasionally use icons to call out important information. Here's what to expect.



REMEMBER

This icon points out information you should commit to your nonvolatile memory, your gray matter, or your noggin!



TIP

Tips are always appreciated, never expected. I hope you'll appreciate these useful nuggets of information.

## Beyond the Book

If you find yourself at the end of this book thinking, “Gosh, this was an amazing book — where can I learn more?” just go to [www.arm.com/TotalCompute](http://www.arm.com/TotalCompute).

## IN THIS CHAPTER

- » Looking at digital immersion requirements
- » Recognizing developer and end-user needs
- » Introducing Total Compute

# Chapter 1

## Enabling Digital Immersion in SoC Design

In this chapter, you learn how digital immersion is driving next-generation device and application requirements, what developers need to deliver the digital immersion experiences that end users expect, and how a system-level solution view of performance, security, and developer access transforms the system-on-a-chip (SoC) design process.

# What is Digital Immersion?

Today's consumer devices such as the smartphone are the hub of everything we do as people, from everyday tasks and productivity, such as communication, shopping, and banking, through to more complicated workloads and experiences that are driving technology requirements, such as video streaming, gaming and extended reality (XR) — augmented reality (AR) and virtual reality (VR). These experiences are what Arm refers to as *digital immersion*. Alongside these experiences, 5G, Machine Learning (ML), and security are the enabling technologies that make digital immersion richer, more fulfilling, and more secure for the end-user.

## Describing Digital Immersion Requirements

Technology has played a key role in keeping people everywhere connected, productive, and entertained. For many, today's consumer devices are lifelines to the rest of the world.

Digital immersion requirements for next-generation devices and the applications that run on them include:



- » High-speed compute performance
- » Robust end-to-end security
- » Device power efficiency
- » Reliable, low-latency connectivity

Mobile gaming, XR, and other new and improved use cases enabled by ML and 5G technologies will continue to drive the digital immersion requirements of next-generation devices.

## Mobile gaming

The gaming industry is becoming more mobile. According to Newzoo, mobile gaming revenues overtook console- and PC-based gaming revenues in 2018, accounting for more than 46 percent of the global games market with more than \$68 billion in revenue in 2019.

As a result of this growth, premium gaming titles are going mobile. Popular high-fidelity and multi-user games are being played on both mobile devices and consoles — and users expect a consistent experience across platforms.

## Machine learning

Applications and devices continue to be transformed by ML, a subset of AI. Early smartphone functions enabled by ML include facial recognition and voice user

interfaces. Today, ML-powered experiences are expanding to deliver higher-quality photos and videos and AR-based applications.

## **XR**

XR includes both AR and VR technologies and applications. The rapid advancement of AR and VR technologies is leading to a whole new wave of digital immersion experiences on next-generation devices.

AR is increasingly being adopted on smartphones, allowing consumers to transform themselves, their surroundings, and their interactions between physical and virtual worlds. Unlike AR, VR is likely to be experienced primarily on wearable devices. Gaming is a huge market for VR, with many existing console- and PC-based gaming titles adapted for VR.

## **5G**

A vital enabling technology in the evolution of digital immersion is the rollout of 5G networks. 5G brings greater speed, connectivity, and reduced latency, especially for high-bandwidth applications. 5G will substantially improve current digital immersion experiences on mobile devices and enable completely new use cases.

# Understanding the Needs of Developers and End-Users

Understanding the needs of developers, and ultimately end-users, is a key step in the SoC design process. Developers are under constant pressure to control costs and reduce time-to-market. At the same time, increasingly complex security and compliance challenges must be addressed throughout the design and development process. Developers need flexible solutions that enable them to focus on their value-added skills in the software development process, rather than one-off tools and products that require valuable time and effort to learn and use.

## Shifting SoC Design Paradigm

Advances in digital immersion are creating more advanced, complex, and demanding multi-compute workloads, especially for leading-edge XR, gaming, and ML-based experiences.

To address these requirements, the focus must shift from separately optimizing individual intellectual property (IP) blocks to a system-level solution view of the SoC that puts digital immersion use cases and experiences at the heart of the design process.

**This approach is referred to as Total Compute and focuses on three key areas:**

- » Compute performance (Chapter 2) to provide the performance, efficiency, and AI capabilities required to make future digital immersion experiences on the next generation of devices work correctly and run seamlessly.
- » Security (Chapter 3) to provide protections across the entire ecosystem focusing on two key aspects of security: foundational security for hardware and firmware, and application and service security for software.
- » Developer access (Chapter 4) to unleash improved accessibility to key technologies to deliver more performance by default for every developer within his or her own developer environment.



**REMEMBER**

The goal of Total Compute is to deliver higher performing, more immersive, more secure, and design-efficient digital immersion experiences while enabling a better application development process.

- » Addressing market use cases
- » Enabling artificial intelligence and 5G with Total Compute

## Chapter 2

# Delivering Compute Performance

In this chapter, you learn how performance requirements differ for various use cases and how artificial intelligence (AI) and 5G technologies support the growing performance demands of digital immersion.

# Recognizing Market Segment Needs

Multi-faceted, digitally immersive devices and applications require design flexibility and growing performance. For example, smartphones, digital televisions (DTV), extended reality (XR) wearables, laptops, tablets, smart-watches, fitness wearables, and other market segments each have different performance, power, and connectivity requirements.

Ultimately, more complex use cases require greater performance. The challenge with integrating diverse blocks of intellectual property (IP) into the system-on-a-chip (SoC) is that increasing the active die area can lead to an increase in thermal and power budgets.

To address these challenges, an emphasis on the entire system is needed. This ensures that each IP block is developed with a common underlying architectural approach for performance, efficiency, and data exchange so that all components work together seamlessly, with this performance and efficiency being easily accessible to software developers.

This also builds intelligence into the system that goes beyond the individual blocks of compute. It is not just about individual IP; it is about each IP block interconnecting effectively across the system. The result is best-in-class performance and efficiency to enable the

use cases and experiences of the future on next-generation devices.

## **Supporting Evolving AI and 5G Technologies**

AI and 5G are vital enabling technologies that will improve and enhance digital immersion, but both require more compute performance in devices. Total Compute takes a solutions-based approach to accelerating performance gains for SoC design. This approach requires looking at performance across the entire system through a deep analysis of the workloads and analyzing how inter-connecting data and compute is best deployed between the different IP blocks and compute domains.

AI capabilities such as AI camera and computer vision, and augmented reality (AR) experiences such as multi-user AR gaming, are complex use cases that Total Compute will power.

For the different AR use cases and experiences, many compute elements must come together to make them work seamlessly on devices. The central processing unit (CPU) drives performance in a power-efficient manner while the graphics processing unit (GPU) drives the graphics. AI is used for detection — from the user's location to specific objects and landmarks. The combined IP needs to work together seamlessly in the system. This is

where system IP — which includes interconnects, security IP, and controllers — adds significant value by helping to build better systems focused on low-power constraints and high-security protections.

The compute must happen within a future form factor that is likely to be even more lightweight and smaller than today's form factors. For example, the AR smart-glasses of the future will have a limited SoC area and power budget. Therefore, the high performance will need to take place in an even smaller area and power envelope than today's average premium smartphone. With all these different elements, you can see how being able to optimize across the entire system is so important. This will ensure that all the components work together cohesively.

Finally, there must be an extremely fast, high-bandwidth, low latency Internet or network connection to ensure all these capabilities work while the user is on the move. 5G is a transformative technology for the entire mobile ecosystem. It provides far higher network speeds and lower latency, which is already ten times faster than 4G networks. These major advancements in connectivity enable a new wave of digital immersion through new applications and experiences. At the same time, existing applications, use cases, and experiences will become quicker, more convenient, and more immersive for users on the move. The challenge is that 5G will lead to far more data and information being captured on the device, adding to the already complex and compute-intensive workloads of



the future. The combination of high data and performance demands from 5G make a Total Compute solution even more necessary for future designs.

## **CUSTOMIZABLE DESIGNS TO MEET FUTURE USE CASES**

Total Compute enables the ecosystem to incorporate its own accelerator functions, optimizations, and differentiation, which further boosts performance. This means that Total Compute partners can customize their systems, solutions, and SoCs for the workloads and use cases of the future.

## IN THIS CHAPTER

- » Recognizing the total impact of security breaches
- » Building an industry ecosystem to design secure systems
- » Developing security standards for defense-in-depth

# Chapter 3

## Assuring Robust Security

In this chapter, you explore the impact of modern security challenges and how the tech industry can work together to achieve robust, standards-based end-to-end security.

# Addressing Modern Security Challenges

Security is fast-moving and ever-evolving, with the tech industry constantly working to protect digital devices and the broader ecosystem against increasingly sophisticated, dangerous, and evolving security threats.

According to Juniper Research, global system and data breaches cost more than \$2 trillion annually, and the impact goes far beyond economic damage. A loss of confidence in business and industry can destroy companies and jobs. Victims of identity theft and extortion have their lives and reputations destroyed when their private data, including financial and medical information, is sold on the dark web. Health and safety are directly threatened when Internet of Things (IoT) devices and sensors are compromised or services in a hospital or biomedical research company are disrupted by ransomware.

The bottom line is that security is non-negotiable. The tech sector needs to be the trusted authority for security and privacy because users are placing their digital lives in our hands. Consumer devices — particularly smartphones — contain a wealth of personal information and content, which makes them valuable targets for hackers.

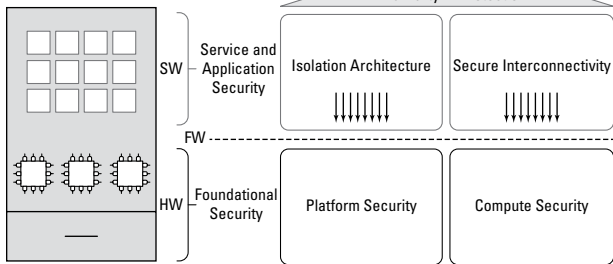
# Working Together and Thinking Holistically

With the increasing reliance on connected devices, security must be considered from the start and designed into the hardware, firmware, and software of a device. This requires different players in the tech industry working together and thinking holistically to deliver robust, end-to-end security across entire systems rather than individual components or intellectual property (IP).

The Total Compute security approach is to protect personal data and/or the IP of applications (such as unique algorithms) by securing devices from the ground up. This starts with the architecture because it is the base design for all compute. The objective is to mitigate vulnerabilities in the device before mass production and greatly reduce the attack vectors in consumer devices. This focuses on two key aspects of security (see Figure 3-1):

- » **Foundational security** for hardware (HW) and firmware (FW) consisting of platform and compute security
- » **Application and service security** for software (SW) including isolation architecture for robust sandboxing of trusted applications and interconnectivity security for concurrent processing across central processing units (CPUs), graphics processing units (GPUs), and neural processing units (NPUs)

## Total Compute Security



**FIGURE 3-1:** The security approach through Total Compute.



REMEMBER

As the complexity of the next generation of consumer devices continues to increase, security must move beyond standalone solutions that only protect one aspect of a device. We need multi-layered solutions with system cooperation from device hardware all the way through to the cloud services that consume the data on our devices.

- » Providing a “one-stop” shop for developer solutions
- » Optimizing performance
- » Working with partners across the entire ecosystem

## Chapter 4

# Maximizing Developer Access

**D**igital immersion use cases and experiences on mobile devices are made possible by the 13 million mobile developers who have created the 8.9 million apps available today. In this chapter, you learn how the developer access feature of Total Compute helps developers create exciting, engaging, and immersive applications and accelerate time-to-market.

# Promoting Flexibility, Choice, and Openness

A challenge for developers is the need to learn different tools that are optimized for each technology or the various components of the system-on-a-chip (SoC). Developers need flexibility, choice, and openness across a range of software and tools to make the app development process easier and more efficient, which leads to lower costs and faster time-to-market.

Total Compute ensures that the features in Arm's technologies are supported and exposed throughout the software ecosystem. Total Compute provides developers with frameworks for programming, debugging, and analyzing across Arm's central processing units (CPUs), graphics processing units (GPUs), and neural processing units (NPUs). The effective delivery of this component is a key part of the Total Compute journey and its overall success.



TIP

Arm partners with third parties to provide a consistent developer experience with tools and software that are supported throughout the entire Arm ecosystem.

Improved access to greater performance right out of the box through technologies, software, and tools helps developers quickly build more complex, performant, and immersive apps including artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) use cases.



TIP

Developer access through Total Compute provides developers with deeper system-level insights — some of which are not available to view today — within their own or preferred development environments. This helps to unblock any issues in the development process and enables greater system efficiency.

## Accelerating the Specification and Selection Process

Total Compute provides developers access to a “one-stop” shop for solutions that speeds the specification and selection process in application development. This offers improved access to performance, security, and program-mability across all compute domains for a seamless developer experience in the developer’s own environment. Software frameworks and compute libraries reduce fragmentation across solutions and improve performance and interoperability across compute domains.

The Arm Neural Network (NN) software development kit (SDK) is a great example of such a software framework. Arm NN is a common application programming interface (API) that maximizes machine learning (ML) program-mability across all Arm intellectual property (IP). Arm NN is being increasingly used by developers looking to



make ML improvements across their applications. Meanwhile, the Arm Compute Library has a repository of low-level optimized software functions for Arm Cortex-A CPUs (using Neon) and Mali GPUs (using OpenCL and OpenGL Compute). These can be used by developers to accelerate the performance of applications. Alongside performance, the library reduces cost and effort for developers targeting ML features in their applications.

## Providing a Path for the Innovators

Accelerating compute performance and developer access is essential for providing a fast path for the innovator by making every bit of performance available. For example, Performance Advisor is an Arm tool that generates easy-to-read performance analysis reports. This allows developers to understand how different workloads function across the different technologies and identifies where bottlenecks occur within the system based on the rich technical performance data gathered from platforms with Arm CPUs, NPU, and GPUs.



TIP

Performance Advisor is part of Arm Mobile Studio 2020, an Arm product that offers the deepest insights across all of Arm's technologies on Android devices.

# Achieving Community-Driven Success

Beyond providing tools, software, and education, Arm is committed to community-driven success through key partnerships focused on improving developer access to Arm technologies.

Arm's partnership with Unity is a great example of working with partners in the ecosystem to improve the developer experience. The Unity game engine powers more than 50 percent of games on Android and 80 percent of all extended reality (XR) — that is, AR and VR — experiences. The partnership between Arm and Unity enables a more seamless developer experience and improves Unity performance on Arm technologies. Ultimately, this partnership benefits end consumers playing their favorite mobile games, using their favorite apps, or even creating their own content.

Although gaming apps represent the largest category of apps available to download (around 33 percent of all app categories overall), many non-gaming apps also benefit from strategic partnerships. For example, Arm is collaborating with Facebook to expand one of the most widely used ML framework capabilities — PyTorch Mobile — beyond the CPU. The combination of the Arm compute platform and PyTorch Mobile enables exciting new ML-based apps on mobile devices.



REMEMBER

Developer access through Total Compute makes the improved performance more accessible to developers so they can build content across a broad range of applications and devices.

## IN THIS CHAPTER

- » Focusing on use cases
- » Providing efficiency and flexibility for developers
- » Ensuring robust end-to-end security
- » Delivering a complete system-level solution

# Chapter 5

## Bringing It All Together

In this chapter, you learn how the Total Compute approach to system-on-a-chip (SoC) design brings together performance, security, and developer access to deliver a complete, system-level solution for digital immersion.

# Designing to Digital Immersion Use Cases

When designing devices and applications for different digital immersion use cases, it is important to remember that one size does not fit all. More advanced use cases, such as machine learning (ML) and extended reality (XR), require more complex devices and systems to address different performance, power, and connectivity requirements.

Total Compute brings the entire ecosystem — including intellectual property (IP), firmware, software, operating systems, and tools together — to enable a paradigm shift in systems design.

## Improving Efficiency with Flexibility

Providing developers with consistent and full performance unlocked at a system level, available out of the box, is essential. The improved choice and flexibility in the selection of development tools enable greater productivity through improved efficiency — which ultimately leads to reduced costs and a faster time-to-market.

# **Delivering Peace of Mind with End-to-End Security**

Consumer devices are composed of hardware components, firmware to run those hardware components, and hundreds of thousands of lines of software code. All these components can be vulnerable to different threats and must be secured. The combinations and implementations of these components are practically unlimited and can be quite fragmented, making it challenging to develop and implement security patches quickly and broadly. It is an endless cycle of finding and patching security holes. To break this cycle, a different approach is needed.

The Total Compute security strategy will provide greater protection across the entire ecosystem, making all aspects less vulnerable to attacks. These benefits will transcend hardware, software, operating systems, applications, and services, delivering end-to-end security protection. This approach focuses on key security use cases that are set to be prominent in next-generation devices and the cloud in the future, while removing fragmentation in the ecosystem.

# **Taking a System-Level Solution View of the Entire SoC**

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Total Compute moves beyond optimizing individual IP, firmware, software, operating systems, and tools; instead Total Compute takes a system-level solution view of the entire SoC. Total Compute focuses on individual use case requirements and end-user experiences on next-generation devices to ensure that the entire system works together seamlessly and provides maximum performance and efficiency to enable digital immersion now and in the future.

By taking a holistic view of SoC design with the Total Compute approach, engineers and developers can quickly build and deliver the digital immersion experiences that end-users expect on their next-generation devices while ensuring end-to-end security and maximizing flexibility and choice with a broad and open ecosystem.

- » Supporting developer needs and advanced use cases
- » Working together to deliver secure solutions for the future

## Chapter 6

# Five Principles to Drive Total Compute

Here are five foundational principles of Total Compute:

- » **Understand developers' needs.** Developers need solutions that help to make app development easier and accelerate time-to-market. They need great performance out-of-the-box across a wide range of consumer devices and need the process



of getting the best possible performance as simple and consistent as possible.

- » **Power new use cases, improved and enabled by AI/ML and 5G.** Artificial intelligence (AI) and machine learning (ML) capabilities in mobile devices are advancing rapidly. Likewise, 5G networks will enable fast and fully immersive digital experiences for users across a broad spectrum of mobile gaming, augmented reality (AR), and virtual reality (VR) use cases. Total Compute provides the compute power and performance for the next wave of advanced enabling technologies.
- » **Ensure in-depth end-to-end security.** Modern threats against devices and applications require robust security built into the entire system lifecycle, not just on the device but across the ecosystem.
- » **Engage the ecosystem.** The tech industry must work together to deliver secure solutions quickly and efficiently to market and enable high-performance digitally immersive experiences. This requires strategic partnerships to leverage experienced, global ecosystems for choice and design efficiency.
- » **Design solutions, not discrete pieces of hardware.** Rather than focusing on individual components and intellectual property (IP), Total Compute focuses on delivering a system-level solution that enables you to design for tomorrow's workloads, not yesterday's benchmarks.



## White Paper: **Arm Total Compute**

Enjoyed the Dummies Guide?  
Get a deeper understanding of Total  
Compute from Arm's white paper

As consumers seek ever richer and more immersive experiences from their mobile devices, the way we design compute systems must change. Arm Total Compute takes a holistic, solution-focused approach to SoC design, moving beyond individual IP elements to optimizing the system as a whole.

Through Total Compute, Arm is ensuring that tomorrow's devices are fully capable of delivering the more advanced, complex and demanding multi-domain workloads.

**Read the white paper at**  
**[Arm.com/TotalCompute](https://Arm.com/TotalCompute)**

# Adopt a Total Compute approach to SoC

Advances in digital immersion are inspiring more natural and intuitive ways to interact with digital information and devices. This in turn is creating more advanced, complex, and demanding multi-compute workloads. To address these requirements, a massive paradigm shift in the approach to system-on-a-chip (SoC) design is required. This book is your guide to Total Compute, a way to move beyond optimizing individual intellectual property (IP) with a system-level solution view of the SoC that focuses on use cases and experiences in the designs.

## Inside...

- Support digital immersion
- Enable AI and 5G
- Assure robust security
- Design for defense in depth
- Provide a “one-stop” shop for developer solutions
- Deliver a complete solution

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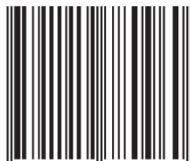
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**Lawrence C. Miller** has worked in information technology for more than 25 years. He has written almost 200 For Dummies books.

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