https://www.forbes.com/sites/tiriasresearch/2018/04/05/what-you-need-to-know-about-processor-architectures/#5a27a2014f57

The Difference Between ARM, MIPS, x86, RISC-V And Others In Choosing A Processor Architecture

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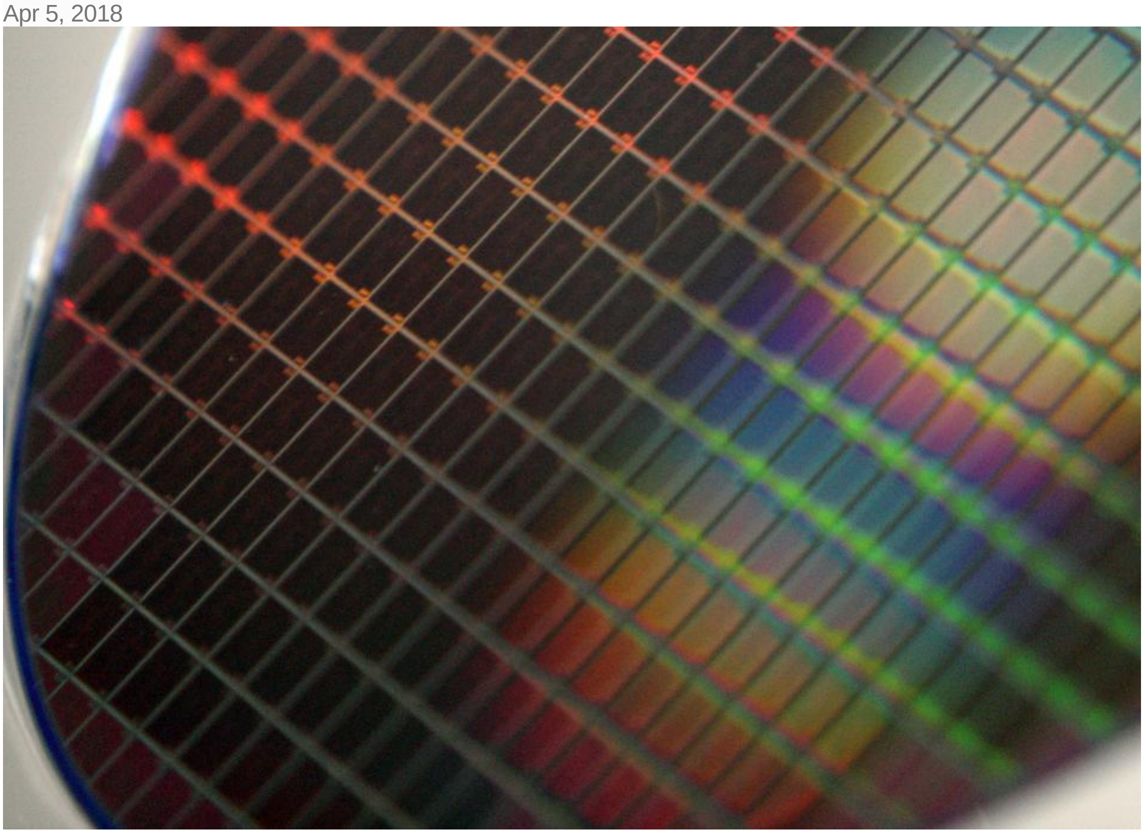


A 300mm semiconductor wafer for mobile phones is displayed at a plant in Japan. Photographer: Tomohiro Ohsumi/Bloomberg

With the continued integration of system functions onto a single chip and the push for more specialized functions like machine learning, the competition between processor architectures is heating up. And, new entrants with new business models are entering the market. However, determining what processor architecture to select is a complex decision.

Today, it is easier to develop a custom Application Specific Integrated Circuit (ASIC) or System-on-Chip (SoC) than ever before. Many companies license silicon blocks (usually referred to as intellectual property (IP) blocks) that perform specific chip or system-level functions. Chip design tools allow for design validation and testing before moving to manufacturing. Most semiconductor manufacturing is performed by foundries with optimized process technologies. And, the majority of system software is now open sourced. As a result, many companies are taking the steps to develop their own SoCs for applications ranging from wearable consumer electronics and embedded systems to high-performance servers for deep learning. At the heart of every design, is an Instruction Set Architecture (ISA) and the accompanying processor hardware architecture.

There have always been many ISA's because no two processing functions or workloads are the same. These ISA's include completely custom or proprietary, licensable, and open-source. Proprietary architectures have become more common in accelerators like the Tensor Processing Unit (TPU) developed for deep learning inference processing by and for Google.

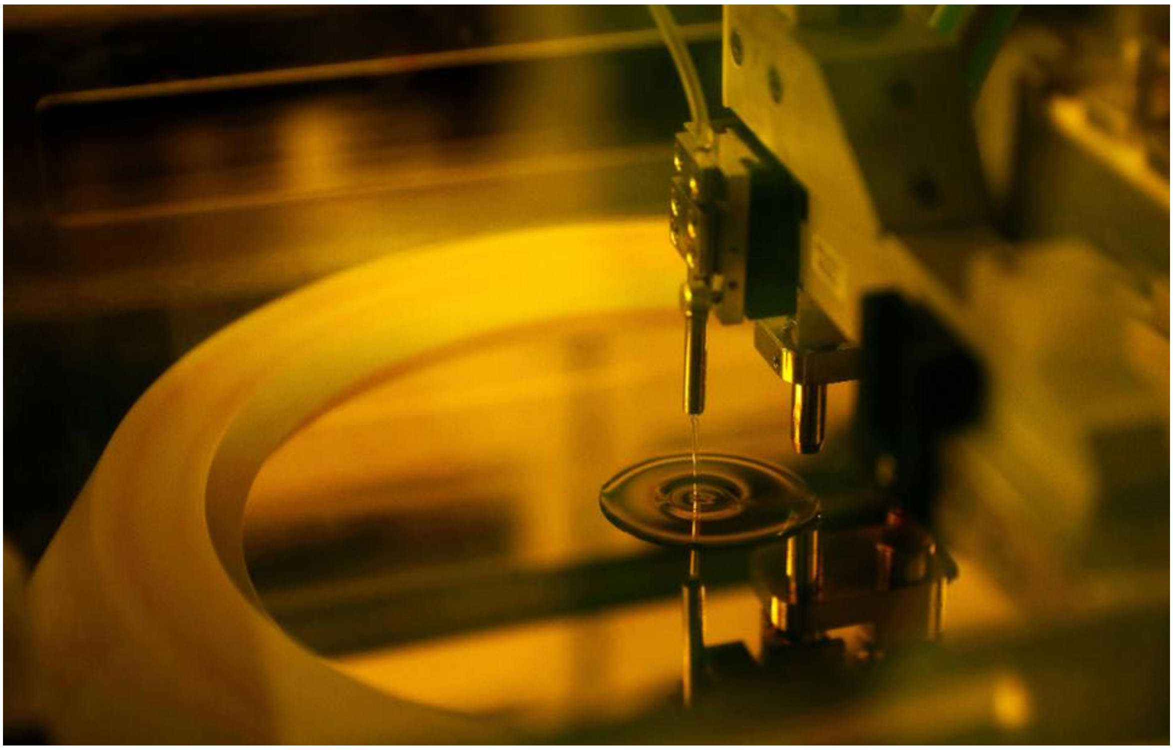
Most ISA's fall into the licensable bucket, but the license structure can vary greatly. On the limited end is Intel, which will license its ISA in very limited cases, such as to AMD at the behest of the courts and U.S. government for an alternative source and to some Chinese vendors for use with Intel designed hardware processing blocks that cannot be modified. Then there are companies like Arm and MIPS that offer a broad range of licenses. An ISA license may include a pre-designed standard processing core that can be embedded directly into an ASIC or SoC design or the ability to modify a standard core or port directly to a custom core, the latter two are referred to as architecture licenses. ISA licenses typically include a license fee and/or royalty fees on the devices using the ISA.

More recently, an open-sourced ISA called RISC-V was introduced. Just like open-source software, anyone can use the ISA without any license or royalty fees. In addition, users can easily add custom instructions for specialized functions, such as machine learning or security. Working with a new ISA also eliminates some of the legacy ISA support requirements. As a result, using an open-source ISA offers greater flexibility, but it does not include any processor designs. It is up to the licensee to develop a custom processor or license one from another IP vendor, such as a company called SiFive, which would then include some form or license and/or royalty fees to the IP vendor.

As a result, no matter what ISA is chosen for a new design, there are expenses that are incurred. However, the greatest factor in choosing an ISA is a risk. Risk comes in the form of hardware development, software development, manufacturability, and time-to-market.

Developing a custom processing core is an expensive proposition that can easily run into the 10s of millions of dollars or more. In addition, developing a new architecture takes time. A new processor design may take at least two to three years, not including the time to design the rest of the ASIC or SoC. By comparison, a SoC design can be completed in under six months with a well-defined licensable core that is also well supported with tools and software libraries.

The greatest benefit of licensing an ISA rather than developing one from scratch is software. Software is so important that even companies known for hardware, such as semiconductor and systems companies, often have more software engineers than hardware engineers. The more popular ISAs like x86 and Arm, have very large ecosystems, mature software stacks (everything from firmware and tools to operating systems and applications), and strict validation suites making it easier for system and application developers to leverage a new device or platform. In addition, the instructions are consistent across SoCs and platforms.



A photo shows the process of manufacturing of electronic chips in the X-Fab semiconductors factory, in Ormoy, near Paris, on November 10, 2016. / AFP / THOMAS SAMSON (Photo credit should read THOMAS SAMSON/AFP/Getty Images)

Manufacturability is also a key concern. Manufacturing any new processor design has risks. However, with a licensable core, most of the risk is with the first few designs. The entire ecosystem benefits from the learning curve from the first devices produced allow future designs to be ramped and optimized more rapidly. In addition, most licensable cores are on an evolutionary trend, meaning that the changes from one generation to another are small compared to a new processor design. This also reduces the risk of having problems with manufacturing. On the other hand, a completely new processor design has a high risk of potential problems.

Note that some problems may be small and corrected through software, but if the problem is significant enough to require design changes, then new mask sets are required. Each mask set can range from a few million dollars with for a simple SoC design using a process node that is several generations old like 90nm to several hundred million dollars for a complex SoC design using the 10nm bleeding-edge process node. In addition, the costs of the mask sets are increasing exponentially with each new process node due to multi-patterning and alternative lithography techniques like immersion and extreme ultraviolet (EUV).

And, the hardware, software, and manufacturability risks add up to time-to-market risk. Being the first to market with a competitive product in the electronics segment could be the difference between a one-year Return-on-Investment (ROI) and a five-year ROI or no ROI. Market timing is critical, which is why the majority of applications ranging from cars to smartphones to PCs use standard or modified licensable cores, not custom cores.

	Custom ISA	Licensed ISA	Licensed ISA with architecture license	Open-Source ISA
Design Flexibility	High	Low	Moderate to high	High
License Fees	None	$0 to millions	$0 to millions	None
Royalty Fees	None	0 to a few %	0 to a few %	0 to a few %
Available Software	None to little	Moderate to extensive	Moderate to extensive	Little to moderate
Processor Cores	Custom	Standard	Standard to custom	Custom or standard
Hardware Engineering Costs	High	Low	Low to moderate	High
Software Engineering Costs	High	Low to moderate	Low to moderate	Moderate to high
Development Time	Long	Short	Short to moderate	Long
Manufacturability Risk	High	Low	Low to moderate	Moderate to high
Time-to-Market	Long	Short	Short to moderate	Moderate to high

Comparison of processor Instruction Set Architectures (ISAs)TIRIAS RESEARCH

So, the cost of hardware and software engineering, additional mask sets, or lost margin can easily offset the value of a lower license fee and/or royalty fees. Also, note that license royalty fees are negotiable. License fees may range from no fee at all to millions of dollars while royalty fees range from nothing to a few percentage points of the value of the final chip.

With that said, there is room for multiple architectures and business models. However, it is important to understand that there are significant risks associated with choosing an ISA and processor architecture. The cost of the fees in choosing a licensable architecture must be offset by the potential risk and design flexibility of developing a custom processor architecture with either a custom or open-source ISA. The decision is not as black and white as some have portrayed it and there is a good reason why the vast majority of current SoCs are based on licensable ISAs.

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