

# SiFive Freedom SoCs: Industry's First Open-Source RISC-V Chips

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Co-Founder and CTO

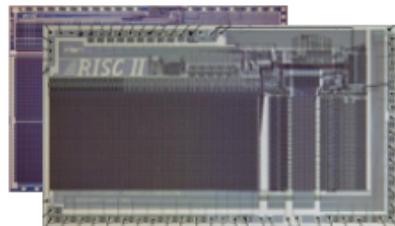


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# What is RISC-V

RISC-V is a high-quality, license-free, royalty-free ISA



- 5<sup>th</sup> Generation RISC design from UC Berkeley (started in 2010)
- Experiencing rapid uptake in both industry and academia
- Standard maintained by non-profit RISC-V Foundation
- Multiple proprietary and open-source core implementations
- Supported by growing software ecosystem
  - binutils/gcc/FreeBSD mainlined, Linux/glibc submitted to upstream
- Appropriate for all levels of computing system, from microcontrollers to supercomputers





Berkeley  
Architecture  
Research

D R A P E R

bluespec



DOVER  
MICROSYSTEMS

Hewlett Packard  
Enterprise

Mellanox  
TECHNOLOGIES

Microsoft

NXP

NVIDIA.

C-SKY



cortus

Micron

SAMSUNG

SiFive

Rambus

Cryptography Research

IBM

Western  
Digital®

Google



Microsemi

QUALCOMM

ORACLE

# RISC-V Foundation: 65+ Members

ESPRESSIF

MEDIATEK

AMD

ANDES  
TECHNOLOGY

IDT

SEGGER  
It simply works!

BAE SYSTEMS

Esperanto  
Technologies

VeriSilicon

LATTICE  
SEMICONDUCTOR

RESEARCH

runtime.io

antmicro  
HARDWARE SYSTEMS

Codasip

GRIDOG  
"Eyes on the Grid, Eyes on the Buck"

SH CONSULTING

INTRINSIX



ETH zürich

TRINAMIC

imperas

ISTUARY  
INNOVATION GROUP

GREENWAVES  
TECHNOLOGIES

MINIMA  
PROCESSOR

MIT CSAIL

ROB  
Logic

Rumble  
Development

lowRISC

UBILITE  
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ICT

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Custom cores and tools

Rumble  
Development

lowRISC

UBILITE  
Hello IoT World

ICT

ultraSOC

:: csem

PRINCETON  
UNIVERSITY

BERKELEY LAB

Blockstream

VectorBlox  
embedded supercomputing

中国科学院  
INSTITUTE OF COMPUTING TECHNOLOGY  
Technolution

# Who is SiFive

- Leading a semiconductor revolution
- Founded by the inventors of RISC-V
- Build & deliver custom chips extremely rapidly
- Solve demand for custom compute with unknown volumes by greatly minimizing up front costs



# SiFive Products: RISC-V IP and RISC-V SoCs

Tailored RISC-V Solutions for both Chip and System Designers

## SiFive Coreplex IP



### Low-power, 32-bit and 64-bit Embedded CPU IP

- Standard RISC-V extensions and privileged modes
- Physical Memory Protection
- Microcontrollers, IOT, Housekeeping cores



### High-performance, Unix-capable, 32-bit and 64-bit CPU IP

- Standard RISC-V extensions and privileged modes
- Virtual Memory Support
- Application Processors, Datacenter Accelerators

## SiFive Freedom SoCs



### Low-power, 32-bit microcontrollers

- TSMC 180nm
- Digital and Analog peripherals
- Edge Computing (AI), Embedded, Smart IOT, Wearables



### High-performance, 64-bit multi-core SoCs

- TSMC 28nm
- Cache coherent accelerator support
- High speed peripherals: PCIe Gen3, GbE, DDR3/4
- Datacenter Accelerators, Storage, SSD Controllers, Networking, Baseband



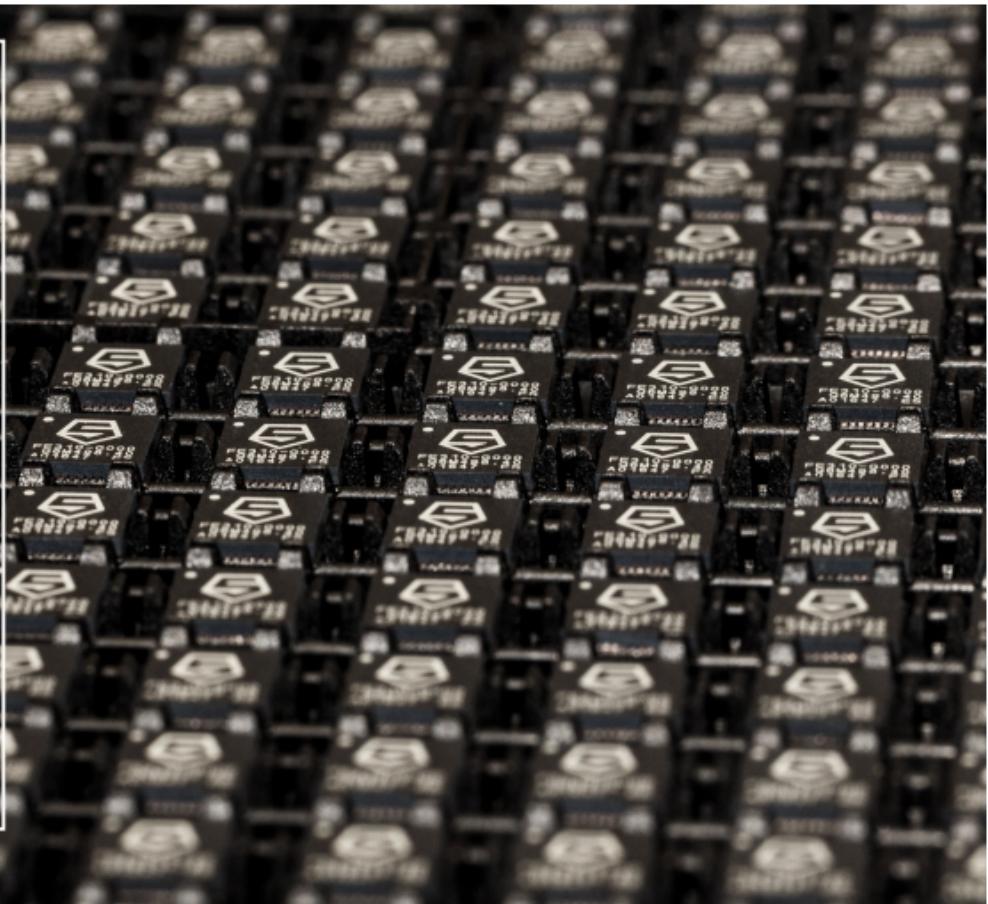
# Freedom Everywhere SoCs

Low power, 32-bit microcontrollers



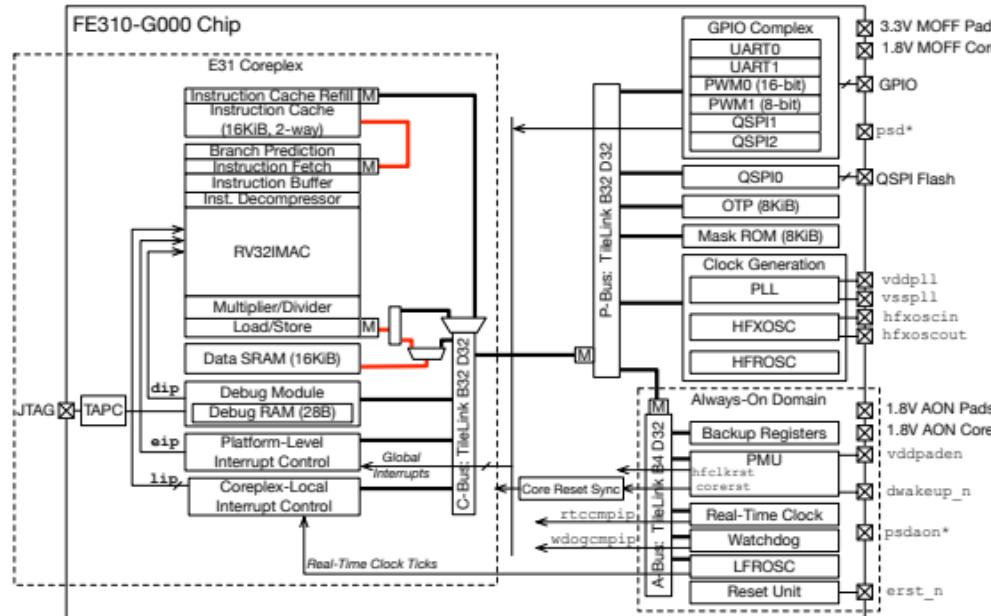
# Freedom E310

- First RISC-V based SoC based on the Freedom Everywhere SoC platform
- Target markets: IoT, Wearables, Embedded
- Low-power, low-cost, high-performance
- Open-source software and tools support



# Freedom E310 Chip Block Diagram

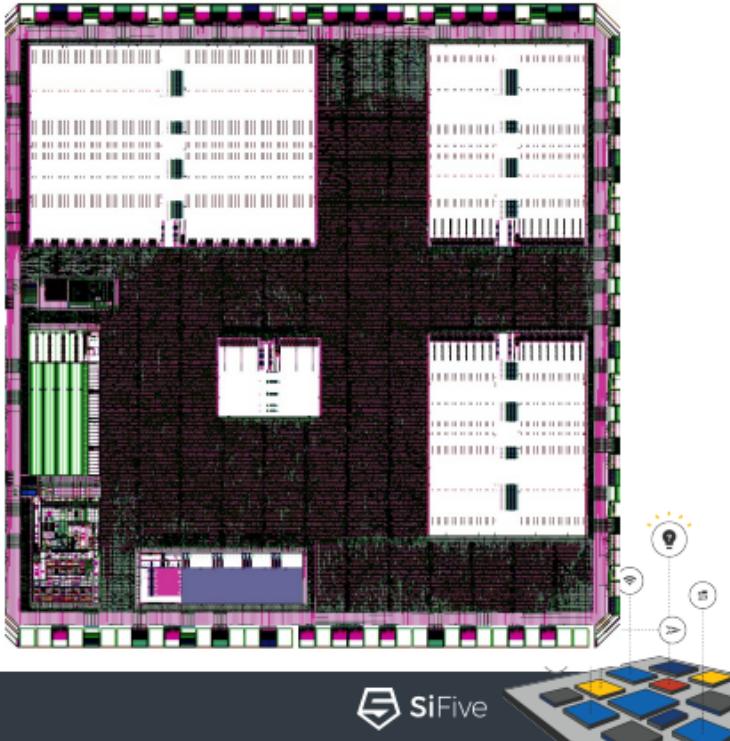
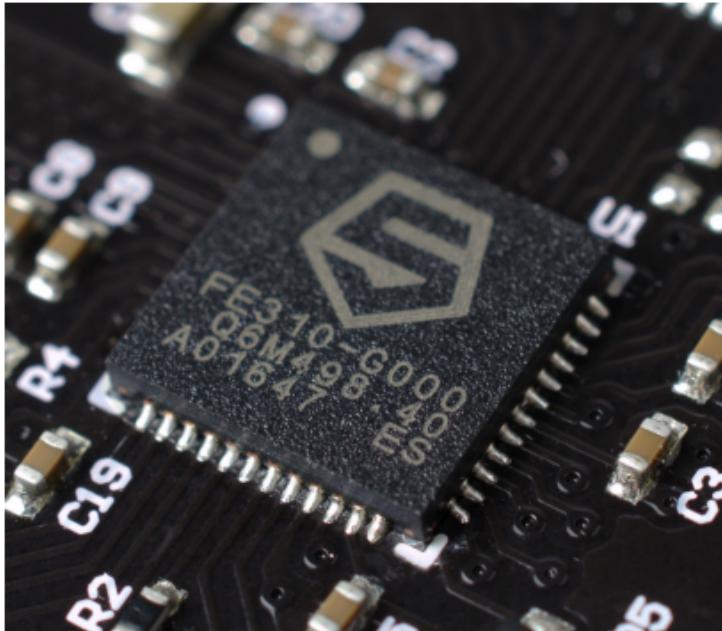
First RISC-V SoC based on the Freedom Everywhere SoC platform



- 320+ MHz SiFive E31 CPU
- 1.61 DMIPs/MHz
- 16KB L1 I\$
- 16KB Data Scratchpad
- Hardware Multiply/Divide
- Debug Module
- Multiple Power Domains
- Low Power Standby
- Wide Range of Clock Inputs
- 6mmx6mm 48-Pin QFN
- TSMC180G



# Freedom E310 Chip



# Freedom E310 Perf/Power Comparison

Microcontroller	CPU Core	CPU ISA	CPU Speed	DMIPS/MHz	Total Dhystones	DMIPS/mW*
Intel Curie Module	Intel Quark SE	x86	32 MHz	1.3	41.6	0.35*
ATSAMD21G18	ARM Cortex M0+	ARMv6-M	48 MHz	0.93	44.6	
Nordic NRF51	ARM Cortex M0	ARMv6-M	16 MHz	0.93	14.9	1.88*
<b>Freedom E310</b>	<b>SiFive E31</b>	<b>RISC-V RV32IMAC</b>	<b>200 MHz 320 MHz (max)</b>	<b>1.61</b>	<b>320.4</b>	<b>3.16*</b>

\*All Power Comparisons are in same 180nm Process Technology

- 10x Faster Clock than Intel's Arduino 101 uController
- 11x More Dhystones than ARM's Arduino Zero (ATSAMD21G18)
- 9x More Power Efficient than Intel Quark
- 2x More Power Efficient than ARM Cortex M0+



# HiFive1: Arduino-Compatible RISC-V Dev Kit

Powered by the Freedom E310 chip



- **Operating Voltage:** 3.3 V and 1.8 V
- **Input Voltage:** 5 V USB or 7-12 VDC Jack
- **IO Voltages:** Both 3.3 V or 5 V supported
- **Digital I/O Pins:** 19
- **PWM Pins:** 9
- **SPI Controllers/HW CS Pins:** 1/3
- **External Interrupt Pins:** 19
- **External Wakeup Pins:** 1
- **Flash Memory:** 128 Mbit Off-Chip (ISSI SPI Flash)
- **Host Interface (microUSB):** Program, Debug, and Serial Communication



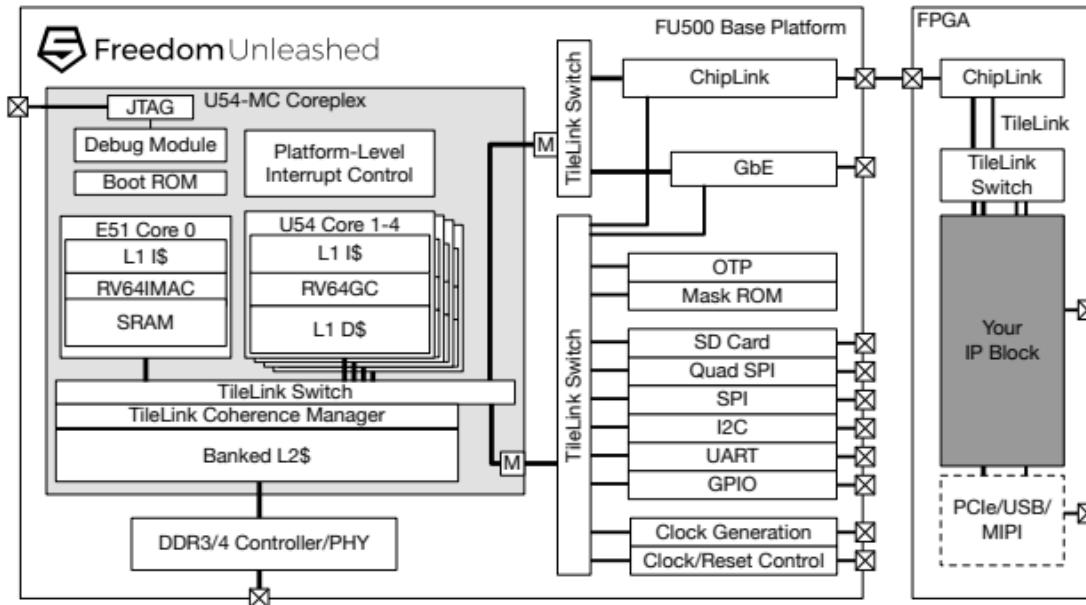
# Freedom Unleashed SoCs

64-bit multi-core SoCs for embedded computing



# Freedom U500 Base Platform Block Diagram

TSMC 28nm Chip for Rapid Customization of the Freedom Unleashed Platform



- **U54-MC Coreplex**
  - E51: 16KB L1I\$ and 8KB DTIM
  - U54: 32KB L1I\$ and 32KB L1D\$
  - Banked 2MB L2\$
- **ChipLink**
  - Serialized Chip-to-Chip TileLink Interconnect
- **GbE**
- **Peripherals**
- **DDR3/4**



# Open-Source Freedom SoCs



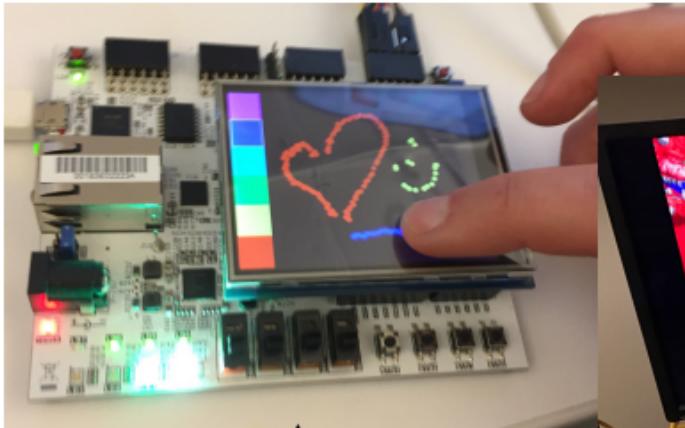
# We Open-Sourced the Freedom E300 Platform!

Including the RTL, FPGA Scripts, BSPs, Tools, Documentation, and Schematics

- RISC-V CPU (Rocket)
- TileLink, a free and open coherent SoC interconnect
- Low-speed Peripherals: SPI, UART, PWM, GPIO, PMU
- High-speed Xilinx FPGA Peripheral Wrappers: DDR, PCIe blocks
- Certain 3<sup>rd</sup>-party IPs such as pads, PLL, OTP, and ROM cannot be open-sourced
- Checkout <https://dev.sifive.com>, <https://github.com/sifive>, and <https://github.com/freechipsproject>

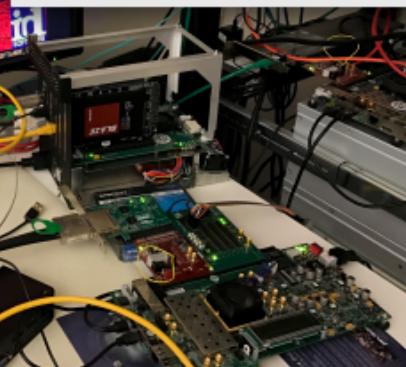
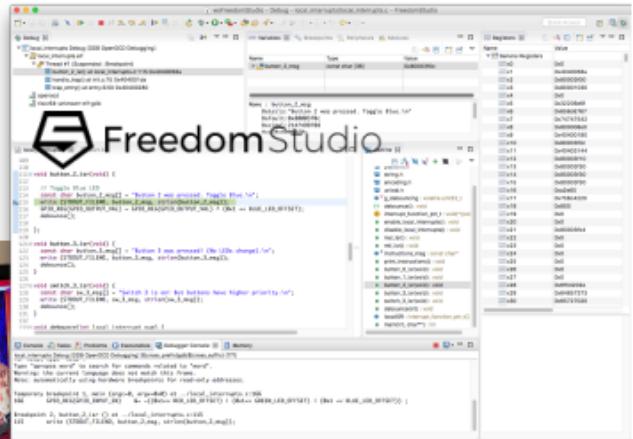
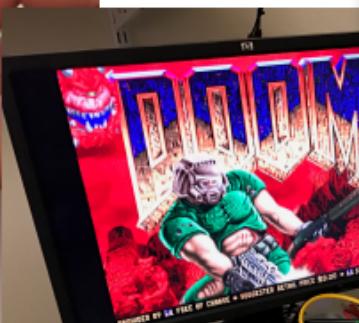


# Freedom FPGA Dev Kits



Freedom E300 Arty FPGA Dev Kit

Freedom U500  
VC707 FPGA Dev Kit



# Why Open-Source the Freedom Platform?

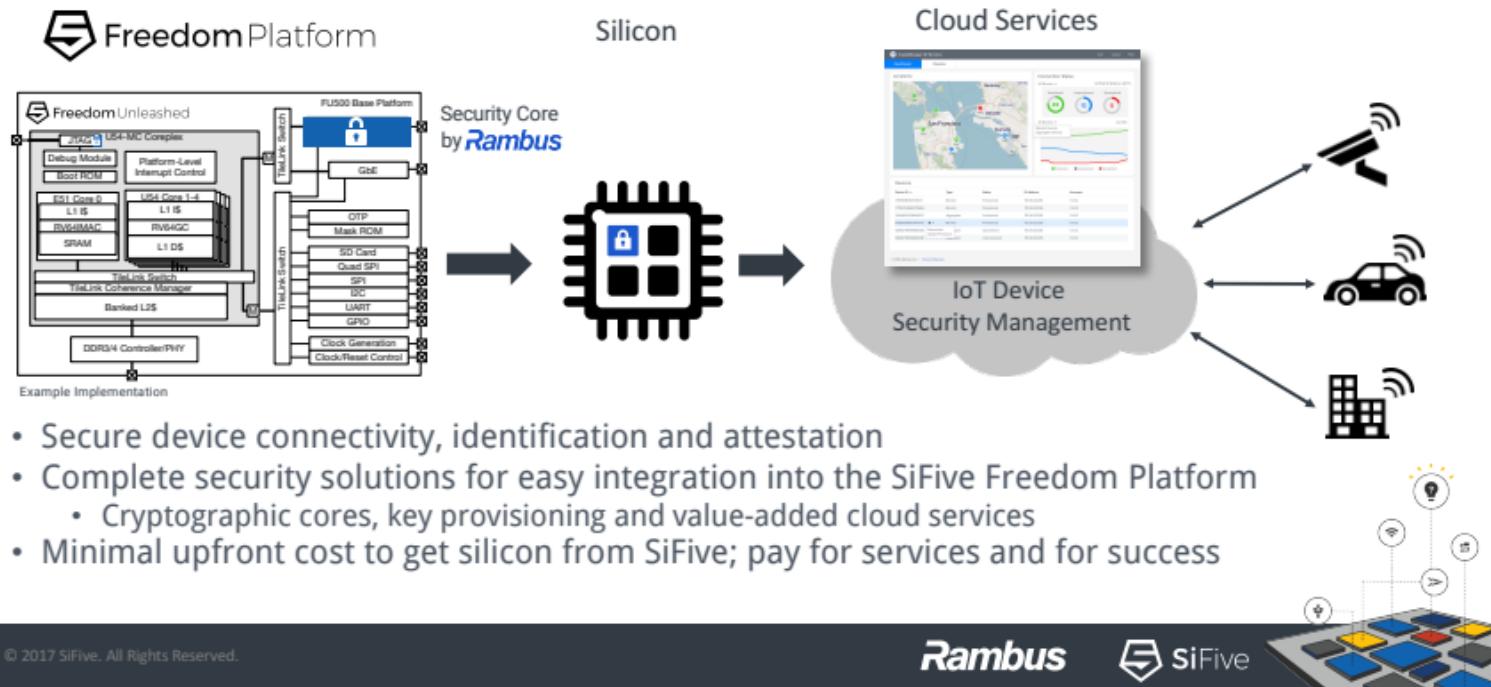
Look at how open-source software changed the world

- High upfront costs is killing innovation in our industry
  - We need more chip design starts
- Open-source platform allows for more innovation, promotes reuse, and attracts developers
  - Developers and IP providers can focus on their value-added innovation
  - Room for both open-source and for-profit IP
  - Leverage the collective effort of the community and industry
- System designers can easily customize their chip and software with full view of the system



# SiFive & Rambus: A Shared Vision

Partnering for end-to-end security solutions



# Join the Revolution!

- For IP designers, who have great technology
  - Work with us to bring your technology to the Freedom SoC platform
  - We will find new customers and markets together
- For system designers
  - You can afford a custom chip from SiFive
  - Start customizing the SiFive Freedom SoC platform
  - Innovate at both the hardware and software level
- Let's lower the upfront cost and increase design starts together
- Start today at <https://sifive.com>

