ARM Cortex

William Gowell
Chris Culpepper
Acorn RISC Machine

Fabless semiconductor company

Licenses chip designs and the ARM ISA

Develops processor cores

Over 60 Billion cores made to date

Cores manufactured by over 300 companies

ARM gets paid for each chip
ARM Core History

The first ARM core ran code in 1985

- Designed to replace a 6502
- 32 bit RISC architecture

RISC

- Reduced Instruction Set Computing
- Less transistors than CISC (x86)
- Low power usage

Cores now incorporate multiple ISAs

- Original ISA
- Optional 16-bit Thumb ISA
- Switch ISAs like a branch
But where are they?

Over 60 Billion made

In almost everything: SSDs, laptops, phones, radios, televisions, servers, cable boxes, bluetooth devices, baby monitors, clocks, watches, SD cards, coffee machines, alarm systems, automotive, calculators, routers and a host of other devices

You probably have one in your pocket
Market Domination

Applications where 8 bits were prominent

Cell phones

Over 60% market share (32 bit) for processors
98% of mobile devices have at least one ARM chip

SSDs

Embedded Systems

60% Market share (32 bit processors)

Televisions

..... Just about anything
Sales of Chips Containing ARM Cores (billions)
Cortex Series Cores

One of the latest ARM Architectures is the ARMv7

Has different versions: ARMv7-A, ARMv7-M, ARMv7-R

Includes:

- Thumb-2 (Variable length instruction set)
- Selectable big or little endianness
- Includes Digital Signal Processing (DSP) extensions
- May include a Floating Point Unit (FPU)
- 13 general purpose 32-bit registers
- Nested Vector Interrupt Controller (NVIC)
  - Supports up to 496 interrupts
  - Supports programmable priority
Why so Popular?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cortex M0+ (KL03)</th>
<th>Arduino (ATMega328)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIOs</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>ADC Channels</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Max Clock (MHz)</td>
<td>48</td>
<td>20</td>
</tr>
<tr>
<td>RAM (Kbyte)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Connectivity (I2C, SPI, UART)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Power Consumption (uA/MHz)</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>Price ($)</td>
<td>1.01</td>
<td>2.43</td>
</tr>
</tbody>
</table>
Cortex-M Series Cores

Cortex M0(+)

Highest energy efficiency processor of the Cortex family

Cortex M1

Small processor designed to be integrated into an FPGA

Cortex M3

Fast interrupt response, automotive and industrial control systems

Cortex M4

Low Power Processor, comes w/ and w/o floating point unit

Cortex M7

Highest performance of the Cortex family, six stage, superscalar pipeline
## Cortex Series Cores

<table>
<thead>
<tr>
<th></th>
<th>90LP (7-track, typical 1.2v, 25C)</th>
<th>40G (9-track, typical 0.9v, 25C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dynamic power (µW/MHz)</td>
<td>Area (mm²)</td>
</tr>
<tr>
<td>Cortex-M0</td>
<td>16</td>
<td>0.04</td>
</tr>
<tr>
<td>Cortex-M0+</td>
<td>9.8</td>
<td>0.035</td>
</tr>
<tr>
<td>Cortex-M3</td>
<td>32</td>
<td>0.12</td>
</tr>
<tr>
<td>Cortex-M4</td>
<td>33</td>
<td>0.17</td>
</tr>
</tbody>
</table>

- Static power <0.7 µW/MHz

## CoreMark® and Dhrystone

<table>
<thead>
<tr>
<th></th>
<th>Dhrystone (official)</th>
<th>Dhrystone (max options)</th>
<th>CoreMark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DMIPS/MHz</td>
<td>DMIPS/MHz</td>
<td>CoreMark/MHz</td>
</tr>
<tr>
<td>Cortex-M0</td>
<td>0.84</td>
<td>1.21</td>
<td>2.33</td>
</tr>
<tr>
<td>Cortex-M0+</td>
<td>0.94</td>
<td>1.31</td>
<td>2.42</td>
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<tr>
<td>Cortex-M3</td>
<td>1.25</td>
<td>1.89</td>
<td>3.32</td>
</tr>
<tr>
<td>Cortex-M4</td>
<td>1.25</td>
<td>1.95</td>
<td>3.40</td>
</tr>
</tbody>
</table>

*CoreMark data from ARM website & CoreMark.org website*
Cortex-M4

Utilizes the ARMv7-M architecture

3-stage pipeline Harvard Architecture

Fetch, Decode, Execute

2 16-bit instructions can be fetched at once

Loads, stores in program order

Memory system is manufacturer specific

Bit banding
Cortex-M4 (Continued)

Includes branch speculation

1-240 interrupts

Only 12 cycles of input latency

Optional Memory Protection Unit with 8 zones

3.4 CoreMark/MHz,
Up to 1.95 DMIPS/MHz
Implementation: Freescale K64F

- 120 MHz ARM Cortex-M4
- Up to 1 MB program flash memory and 256 KB RAM
- 16-channel DMA controller
- 32-bit PITs and 16-bit low-power timers
- Real-time clock
- Programmable delay block
Conclusion

ARM Chips are everywhere

Low power usage RISC

Their Cortex-M are the pinnacle of embedded processors

Are used by almost every embedded company

Freescale/NXP

Toshiba

Actel

Texas Instruments
Sources

http://www.arm.com/products/processors/cortex-m/cortex-m4-processor.php


https://en.wikipedia.org/wiki/ARM_Cortex-M#Cortex-M4

https://web.eecs.umich.edu/~prabal/teaching/resources/eecs373/ARMv7-M_ARM.pdf

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