From little Acorns...

John Biggs

Some “Firsts” – but when?

First transistor?

- 1947: Bardeen, Shockley & Brattain

First Microprocessor?

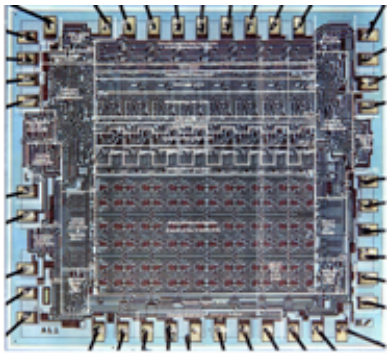
- 1971: Intel 4004 – 4 bits, 2,300 transistors

First email?

- 1971 Ray Tomlinson 1971 – “QWERTYUIOP”

First Mobile Phone call?

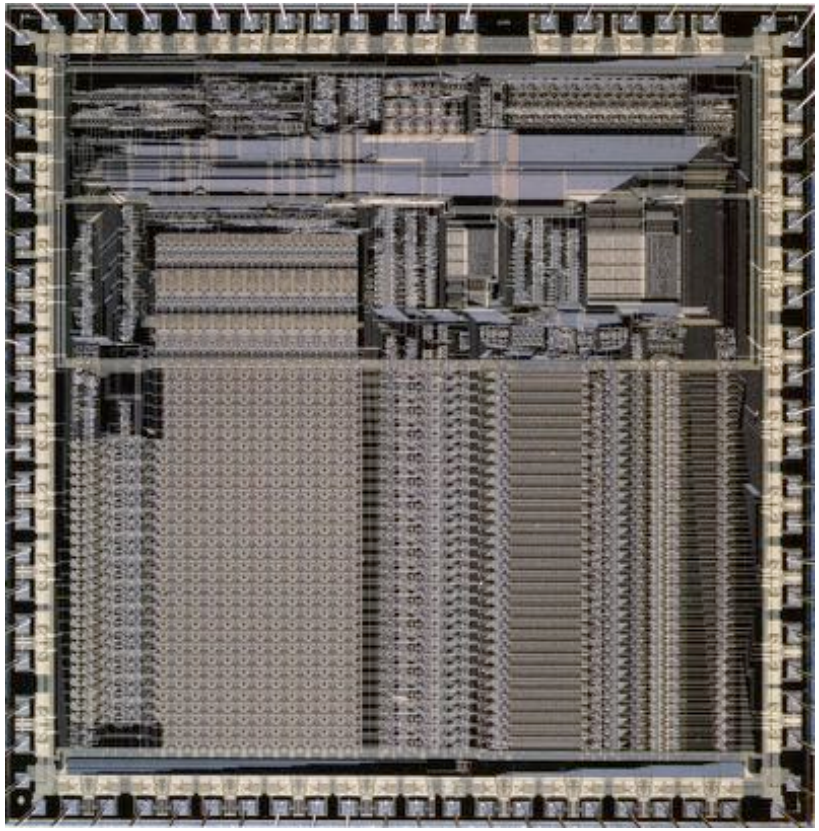
- 1973: Martin Cooper (Motorola) – Called AT&T



arm

First “ARM” Chip? 26th April 1985

- 32bit Microprocessor
- 26 bit address
- 3.0µm (2 Layer Metal)
- 25,000 Transistors
- 6MHz
- <0.1W
- 65mm2
- 84 pins



The worlds first commercially available RISC processor

arm

The Architects of Global Possibilities

The global leader in the development of licensable technology

- R&D outsourcing for semiconductor companies

Focused on freedom and flexibility to innovate

- Technology reused across multiple applications

With a partnership based culture & business model

- Licensees take advantage of learnings from a uniquely collaborative ecosystem

1,690+
licenses, growing by 100+ every year

500
licensees
Industry leaders and high-growth start-ups; chip companies and OEMs

155+bn
Arm-based chips shipped to-date

25+bn
Arm-based chips shipped in 2019

arm

“A” was for Acorn…

1978: Cambridge Processor Unit

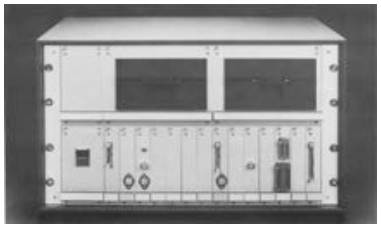
- Founded on 5th December 1978 by Hermann Hauser & Chris Curry
- First contract was with “ACE Coin Equipment” to develop Fruit Machine hardware!

1979: Acorn Computer Ltd

- CPU Ltd acquired Orbis and changed it’s name to “Acorn Computer Ltd”

8 bit 6502 based Acorn machines:

1979: System 1



1980: System 4

1980: Atom

1982: BBC Micro

1983: Electron

1986: Master

Acorn needed more CPU power!

Evaluated 16/32bit processors from Motorola, Nat-Semi, Intel

- All a bit slow and *much* too expensive!
- “Can’t build a £500 micro around a £100 CPU” - *Steve Furber*

Acorn wanted to license the 80286 core but Intel refused!

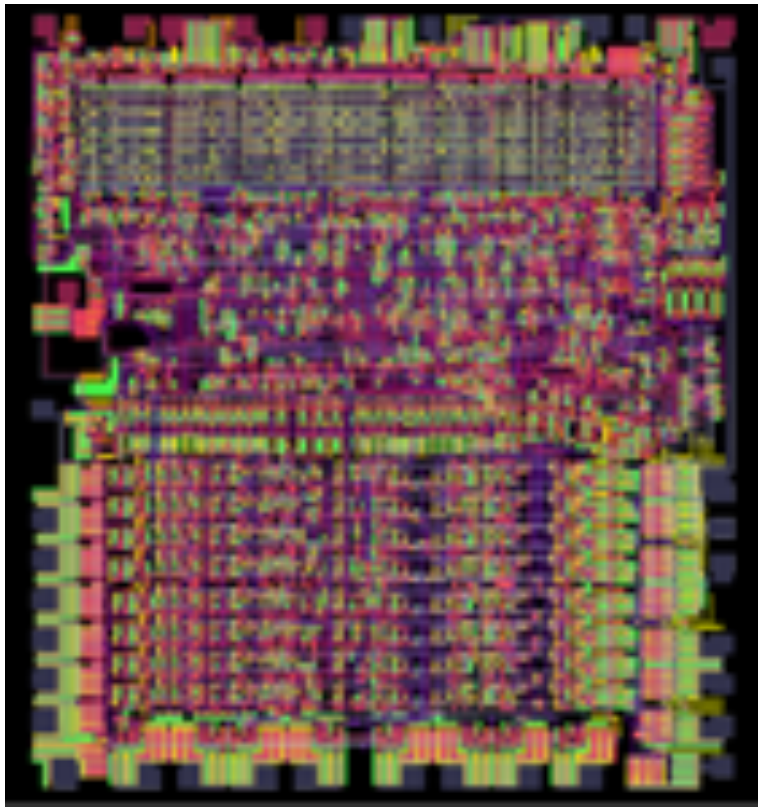
- As a direct result of this refusal a team was set up in Acorn’s Advanced R&D labs to build it’s own 32 bit “Acorn” RISC Machine

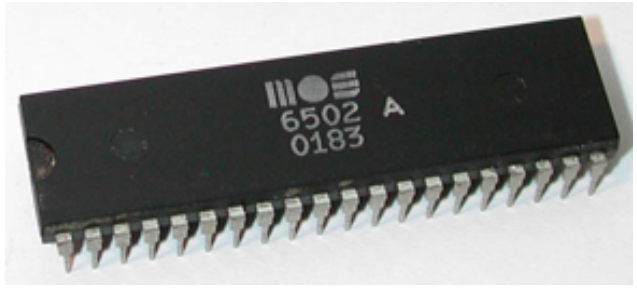
Roger Wilson designed the 6502-like instruction set

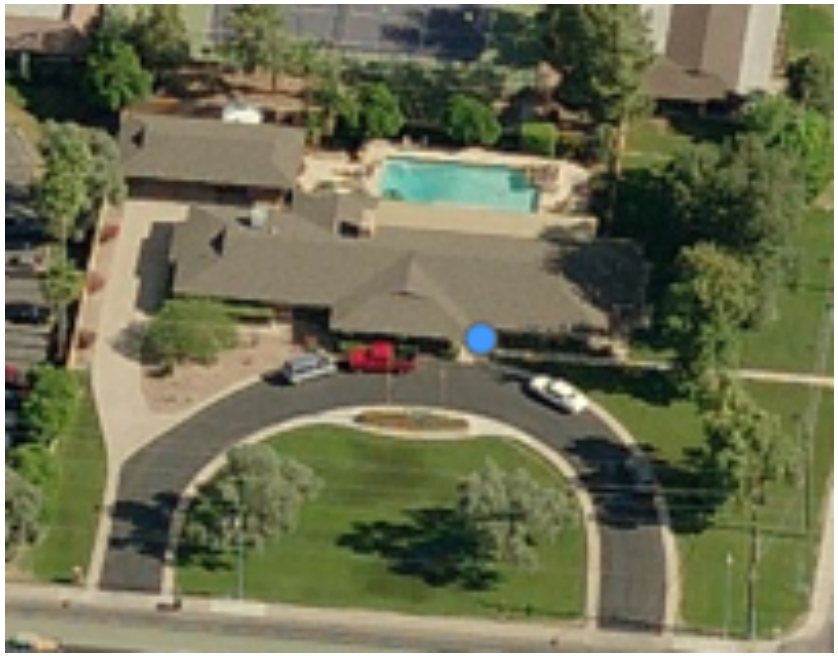
Steve Furber designed the hardware to implement it

arm

1983: Trip to Western Design Centre







arm

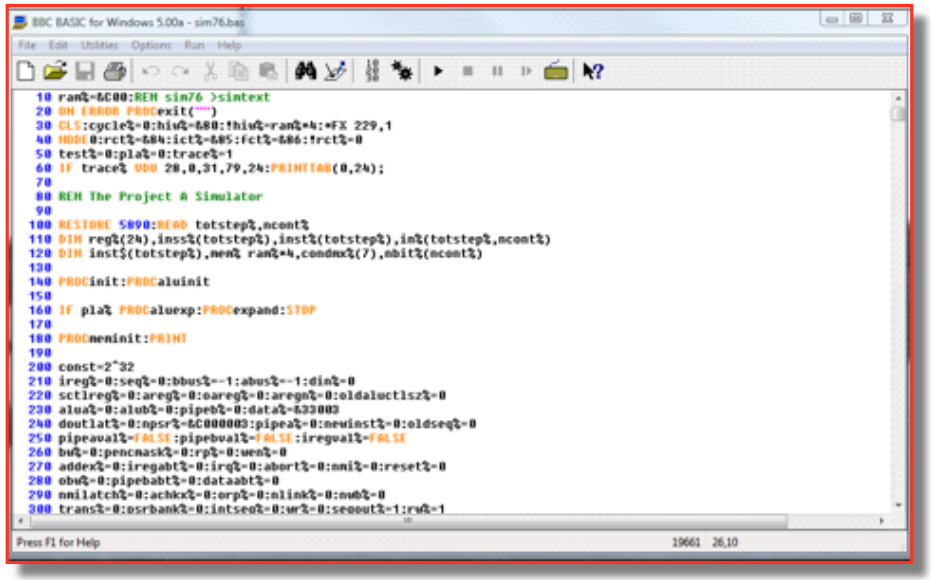
Simplicity, Elegance & Parsimony

Hermann gave the ARM design team two key advantages:

- No people
  - small team meant simplicity in design was an absolute requirement

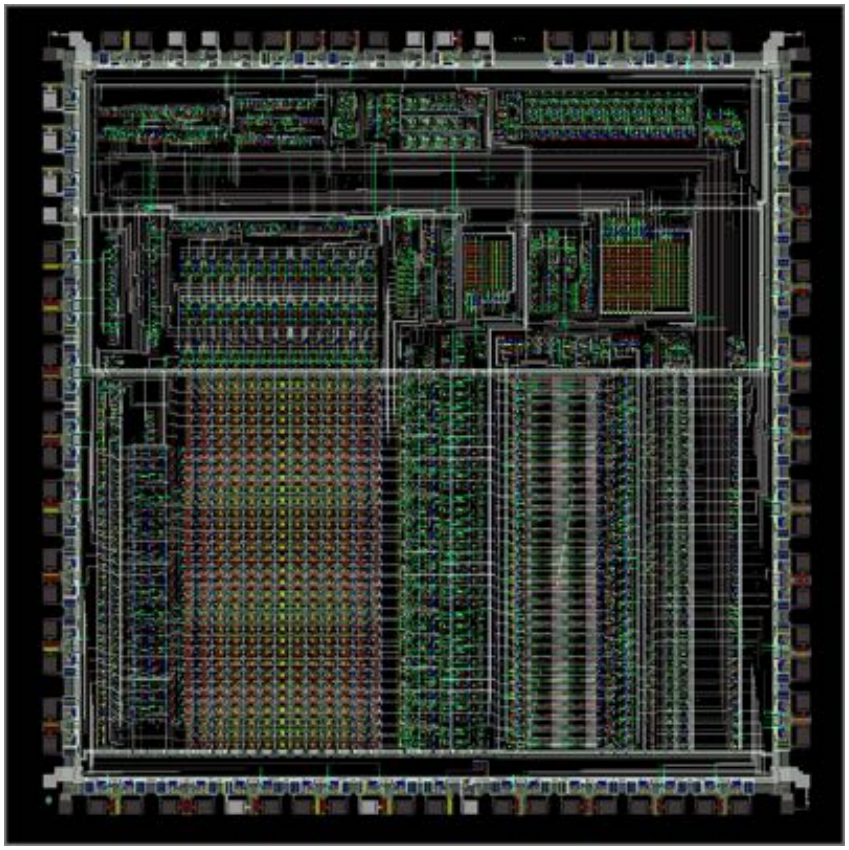
- No money
  - everything was done in-house using simple, home-grown tools

The reference model was just 808 lines of BBC basic!



1985: Acorn RISC Machine (ARM)

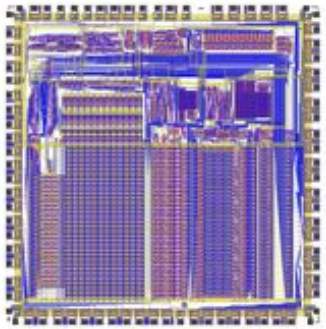
- 32bit Microprocessor
- 26 bit address
- 3.0µm (2 Layer Metal)
- 25,000 Transistors
- 6MHz
- <0.1W
- 65mm2
- 84 pins



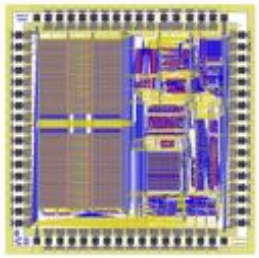
The worlds first commercially available RISC processor

arm

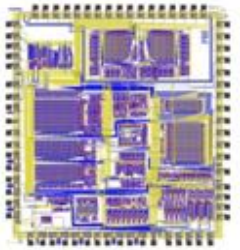
1987: Acorn Archimedes



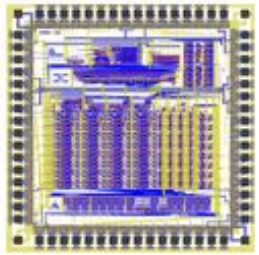
ARM



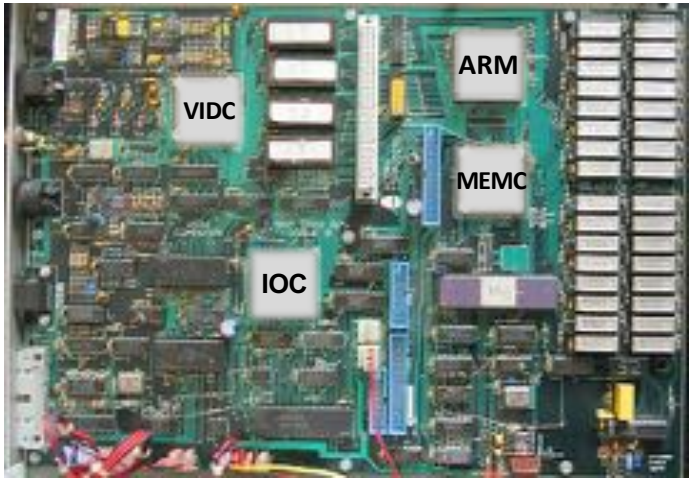
MEMC



VIDC



IOC



“a500”prototype
(1986)

Archimedes
(1987)

arm

The need for Low Power

The ARM was designed to be small (cheap!)

- Low power was a valuable side-effect

The need for low power was driven by battery powered hand-held consumer electronics

Active Book/EO's Personal Communicator

- Designed around an ARM2aS
- Finally shipped with an AT&T Hobbit

Apple's Newton Message Pad

- Prototyped with the AT&T Hobbit
- Final design used an ARM610

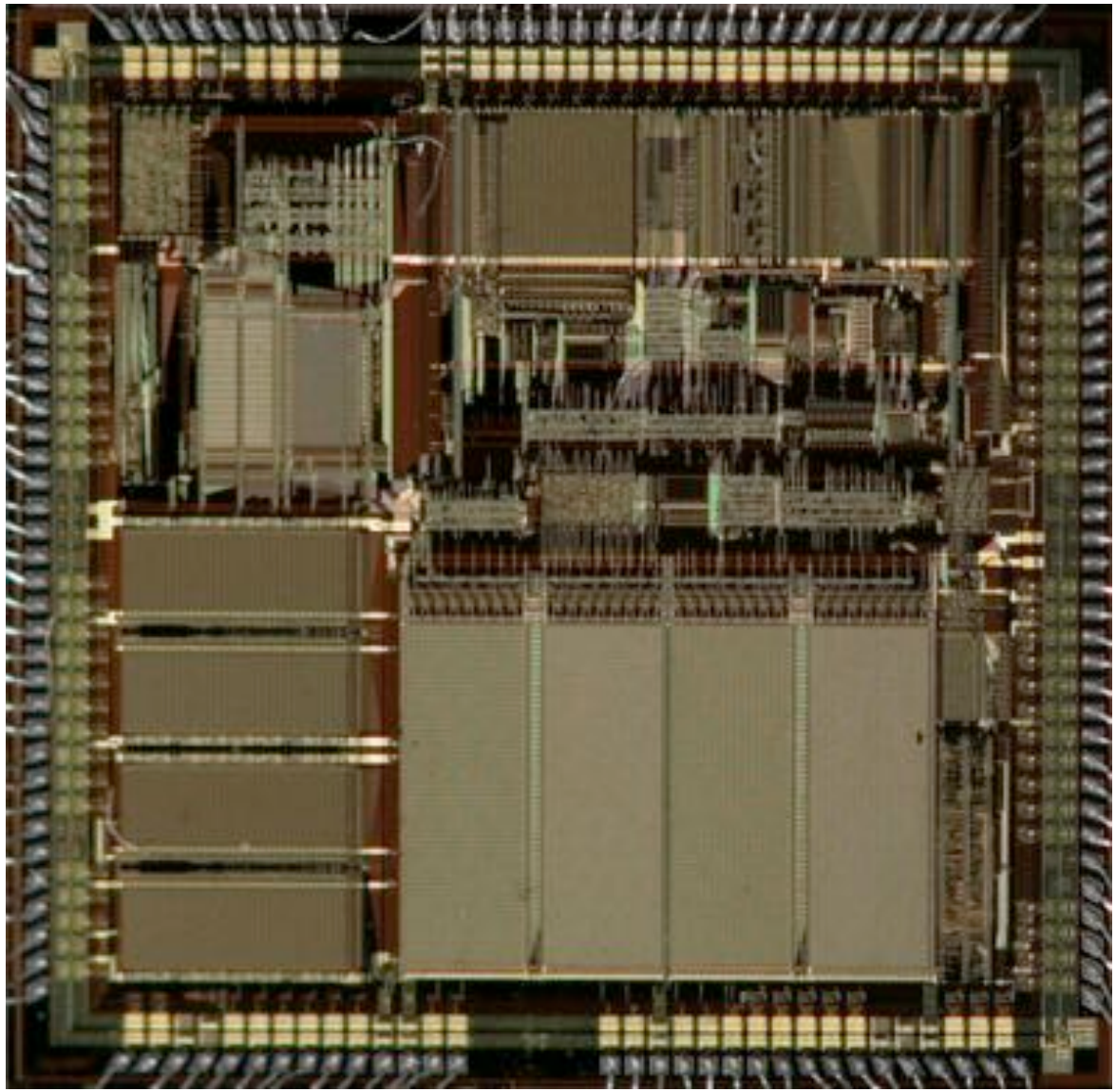
EO Personal Communicator

Apple Newton Message Pad

arm

1992: ARM610

- 1.2um (3 Layer Metal)
- 358,931 transistors
- 20MHz
- 120mW
- 6mW/MHz
- 52mm^2
- 32bit data & address
- Big/Little endian



ARM Founded 27th Nov 1990


ARM Ltd. headquarters

£1.5M cash from Apple

£250K cash from VLSI

£1.5M of IP & 12 engineers from Acorn

Proof of concept Acorn Archimedes

No patents, no independent customers, product not ready for mass market

A barn, some energy, belief, experience

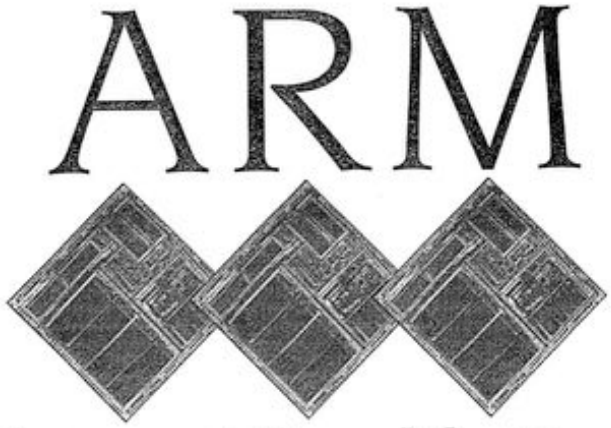
- 1 Partner VLSI Technology
- 1 OS Acorn RISCOS
- Some SW development tools

"We're going to be the global RISC standard"

– Robin Saxby

arm

ARM



Advanced RISC Machines

ARM

Mission

Design competitive, low power consumption, high performance, low cost processors which become the accepted standard in the market they address.

In support of this mission ARM Ltd will develop peripheral cell designs, software, and software tools and provide a design service to third parties.

ARM

ARM Technology Development

1983 - Acorn start RISC processor development
1985 - First 32 bit RISC processor (ARM1) running
1986 - Memory, IO and Video Controllers designed to complete chip set
1986 - VLSI Tech, Licenced to market ARM products
1987 - Volume production of RISC based (ARM2) Archimedes computer
1988 - RISC OS, Multi-tasking, WIMP operating system + Unix available
1988 - Apple Computer start evaluating ARM in various research projects
1989 - Low cost RISC personal computer (A3000) launched
1989 - ARM3 sampling, Static implementation of ARM designed
1989 - Radius introduce ARM based graphics accelerator for Macintosh
1990 - ARM based personal computer sales push past 100,000
1990 - Advanced RISC Machines; Joint Venture formed

ARM

ARM Design Philosophy

ARM Processors are:-
- Small in size
- Low cost
- Suitable as macrocells
- Efficient
  - low power consumption
  - low heat generation

ARM

Robin's approach

Robin was advised:

- "Joint ventures don't work"

SWOT Analysis

- 5 yr Strategy
- 1yr operation plan,
- Monthly reporting

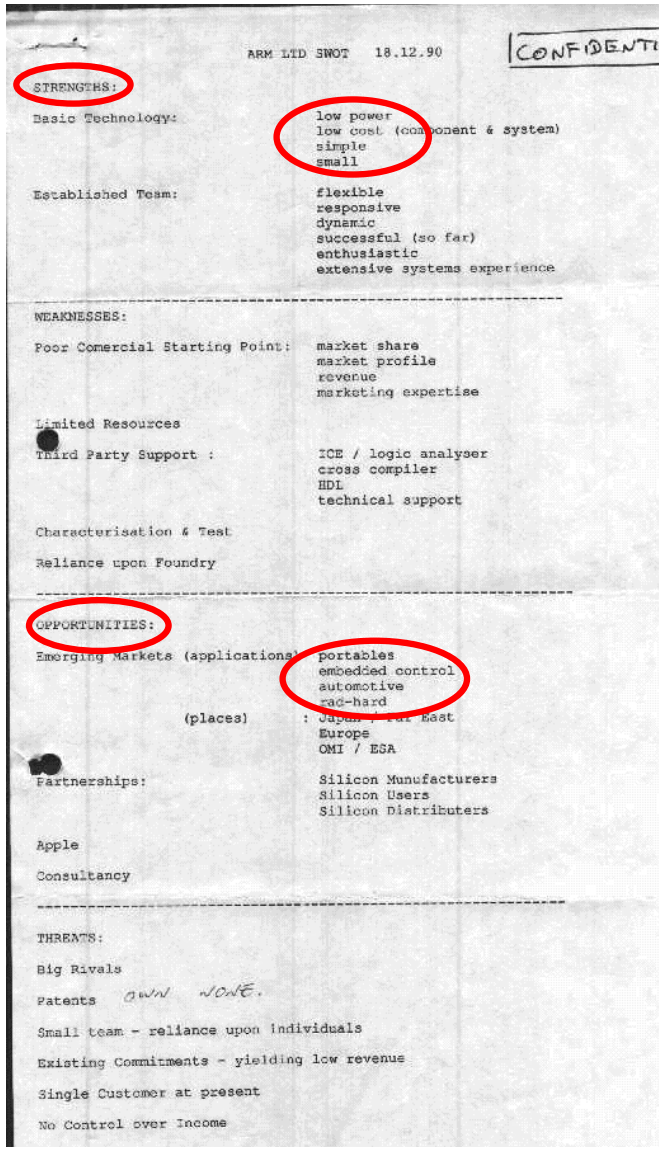
Mean & lean "Cash is King"

- Tight cost control – pay freezes '92
- Profitable, generating cash since '93

Customer focussed

- Partnership model
- First USA, Europe then Japan

Think Global, act local!



ARM LTD SWOT 18.12.90 CONFIDENTI

STRENGTHS:

Basic Technology: low power, low cost (component & system), simple, small

Established Team: flexible, responsive, dynamic, successful (so far), enthusiastic, extensive systems experience

---

WEAKNESSES:

Poor Comercial Starting Point: market share, market profile, revenue, marketing expertise

Limited Resources

Third Party Support : ICE / logic analyser, cross compiler, HDL, technical support

Characterisation & Test

Reliance upon Foundry

OPPORTUNITIES:

Emerging Markets (applications): portables, embedded control, automotive, rad-hard

(places) : Europe, OMI / EGA

Partnerships: Silicon Manufacturers, Silicon Users, Silicon Distributers

Apple

Consultancy

THREATS:

Big Rivals

Patents OWN NONE.

Small team - reliance upon individuals

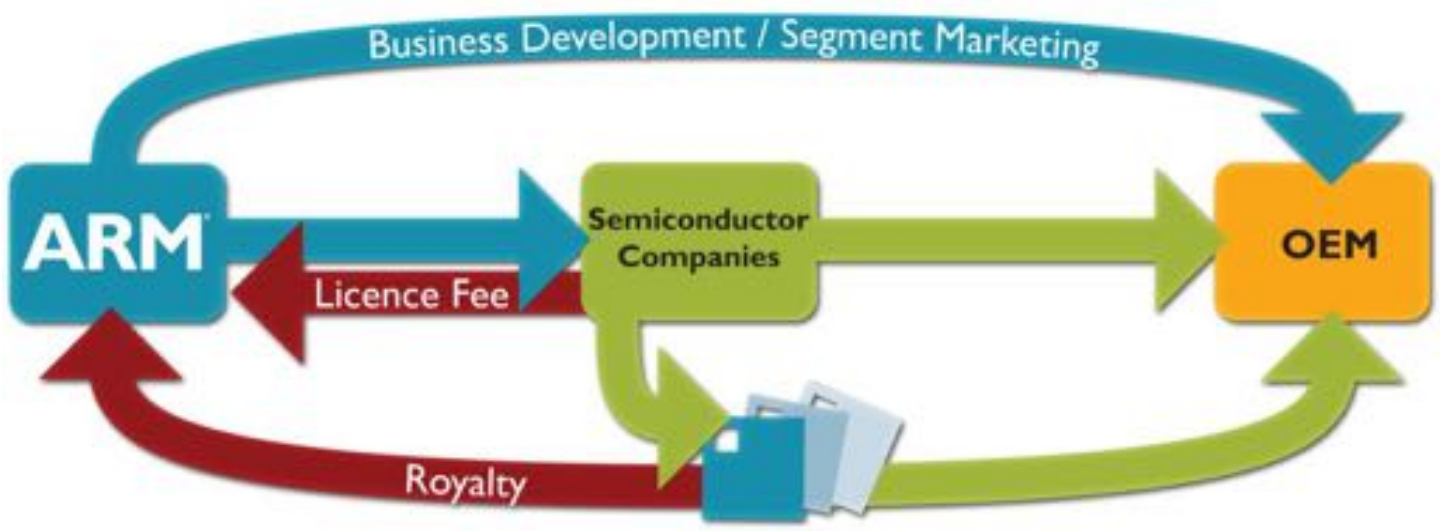
Existing Commitments - yielding low revenue

Single Customer at present

No Control over Income

arm

Business Model Based on Partnership



Shared risk/reward:

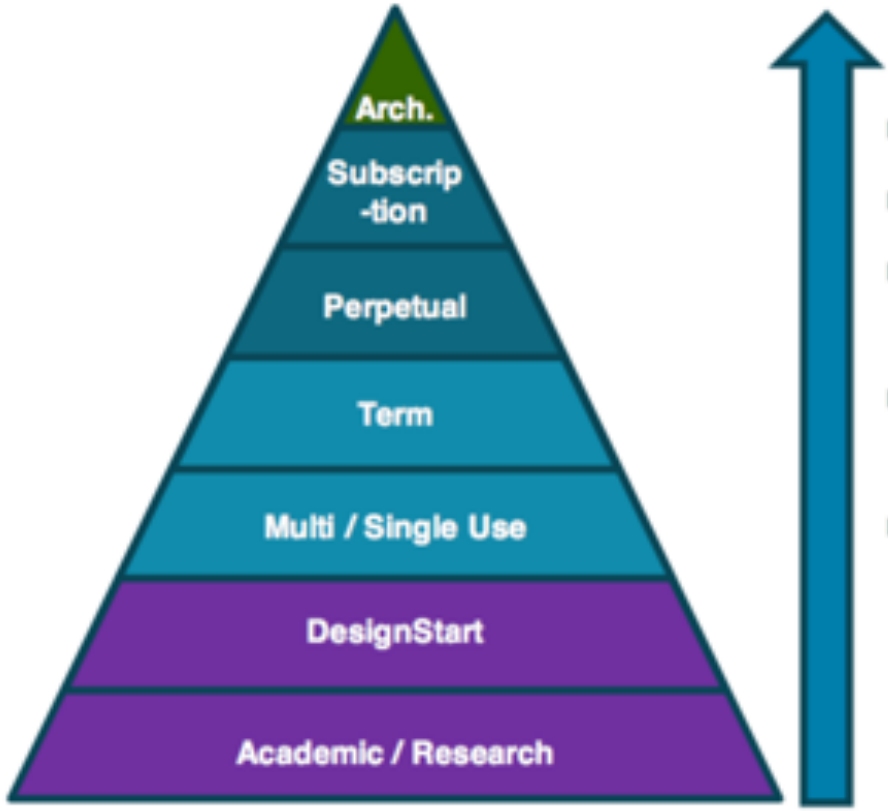
- Licence fee covers proportion of development costs
- Royalties are an incentive help partner get to volume

arm

Early Licensees

arm

Licensing models



- Higher license fee
- Fewer use constraints
- Greater commercial and technical interaction
- Increasing internal investment by Partner
- Increasing ARM / Partner business knowledge

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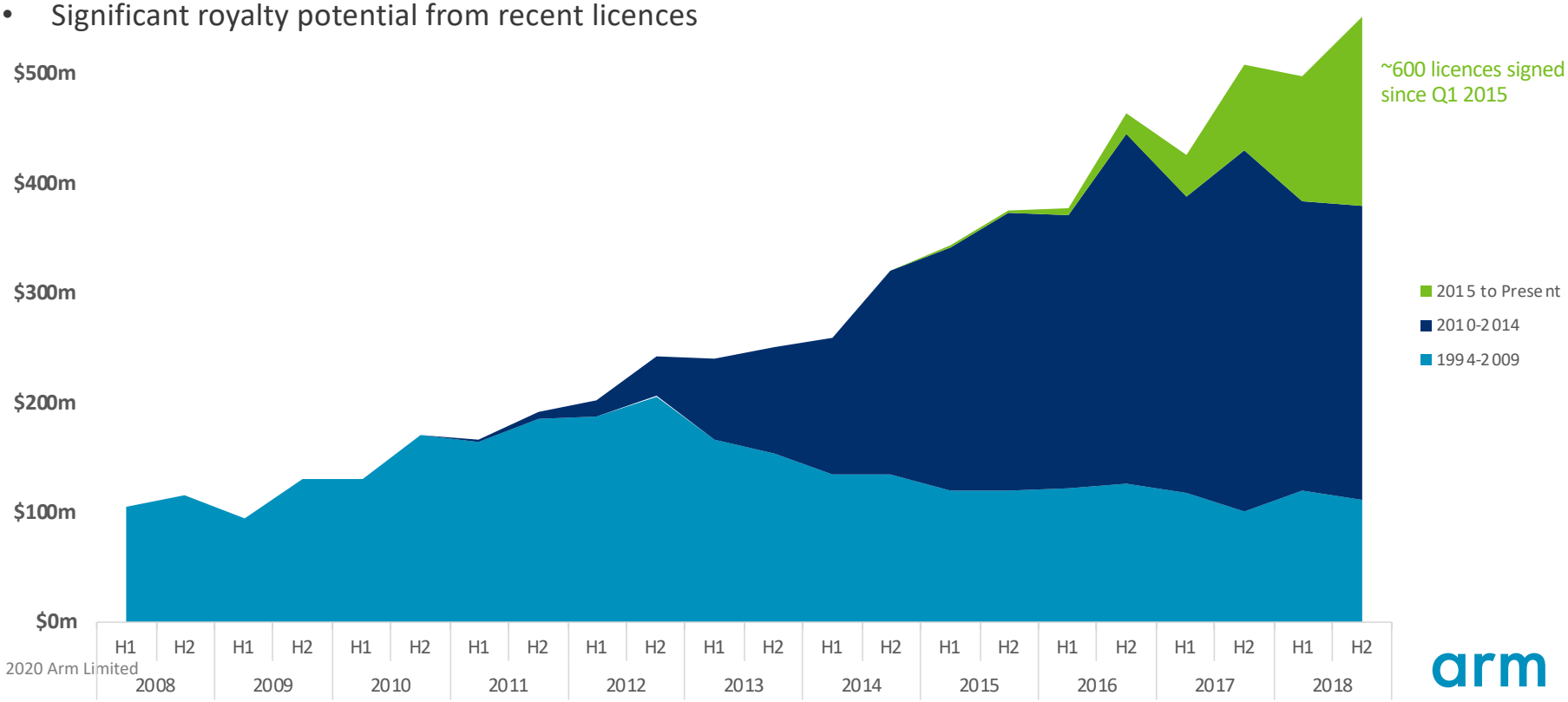
Licensing Underpins Future Royalty

- Arm's current royalty revenues are derived from licences signed many years ago
- Significant royalty potential from recent licences



1993:“Thumb” – a major breakthrough

Pure RISC can go too far in reducing the functionality of each instruction

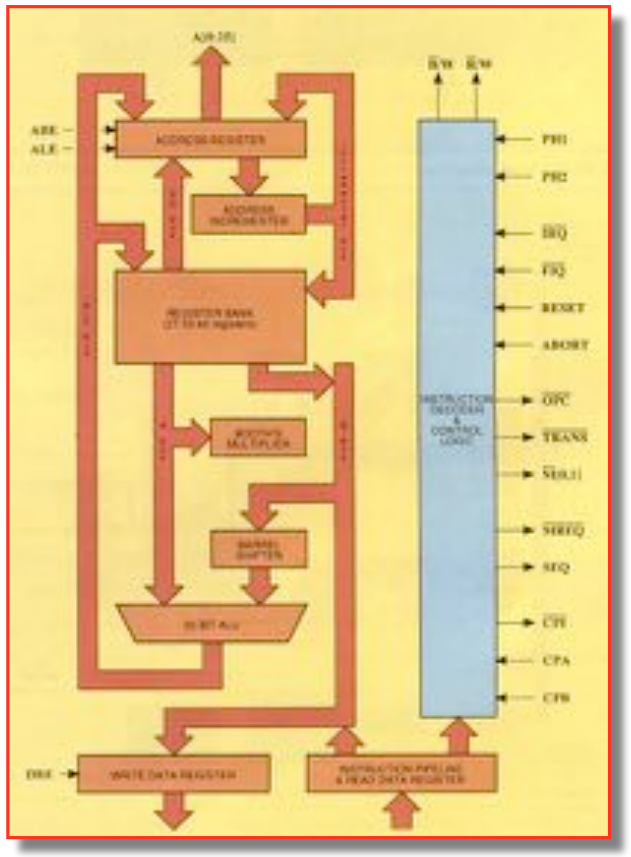
- More instruction fetches, less efficient cache usage (more external fetches)

ARM1 retained some carefully chosen CISC like features

- Conditional instruction execution
- LDM/STM - Load/Store multiple registers
- LDR/STR - Load/Store Register with base plus offset
- Flexible “second operand” on ALU (Barrel Shifter)

ARM7TDMI - 16 bit “Thumb” Instruction Set

- High code density for system size/cost/power savings
- Greater than 30% code size savings over 32-bit ARM code
- Memory footprint comparable to 8/16-bit microcontrollers



Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away.

--Antoine de Saint-Exupery

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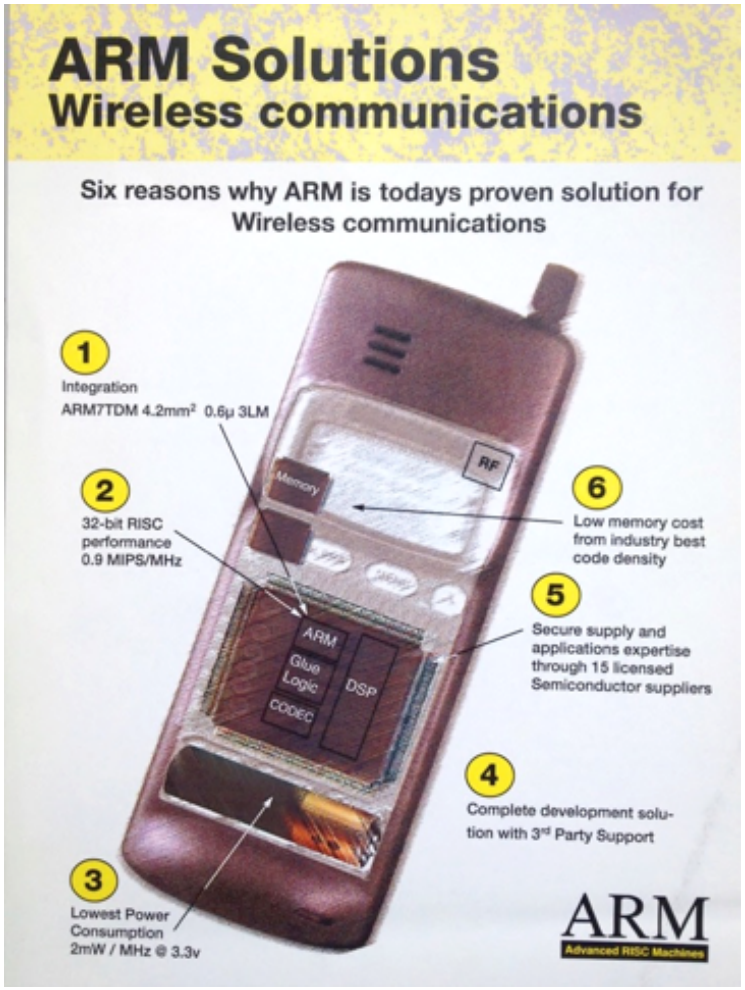
1996: First ARM Powered Digital Phone



NOKIA

8110

No camera

No games

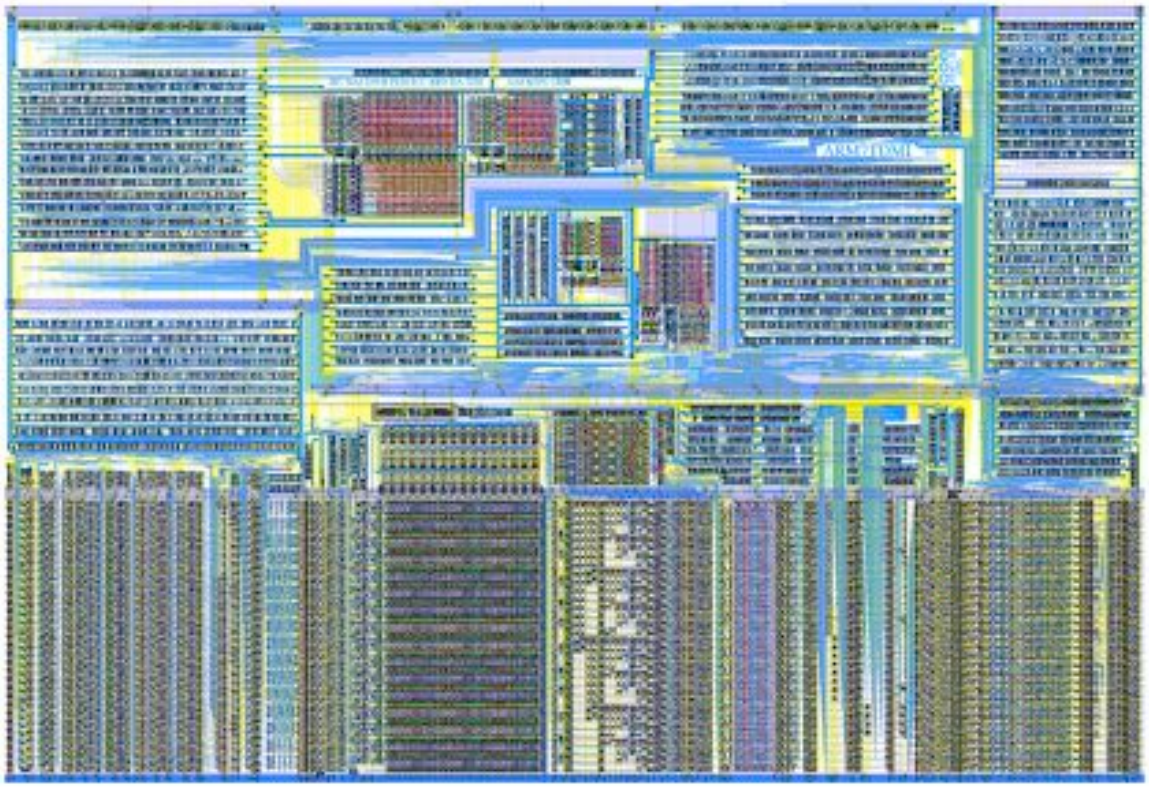
No touch screen

TEXAS INSTRUMENTS

But it did help Keanu Reeves save the world in “The Matrix”

1994: ARM7TDMI – in most 2G Phones

- ARMV4T “Thumb” 16 bit instructions
- 0.6um CMOS (3 layers Metal)
- 74K Transistors
- 4mm2
- 33MHz
- 66mW
- 2mW/MHz



arm

1998: IPO April 17th

1998:

Share £5.75
(£0.29 in todays money)

Mkt Cap £264M

2016:

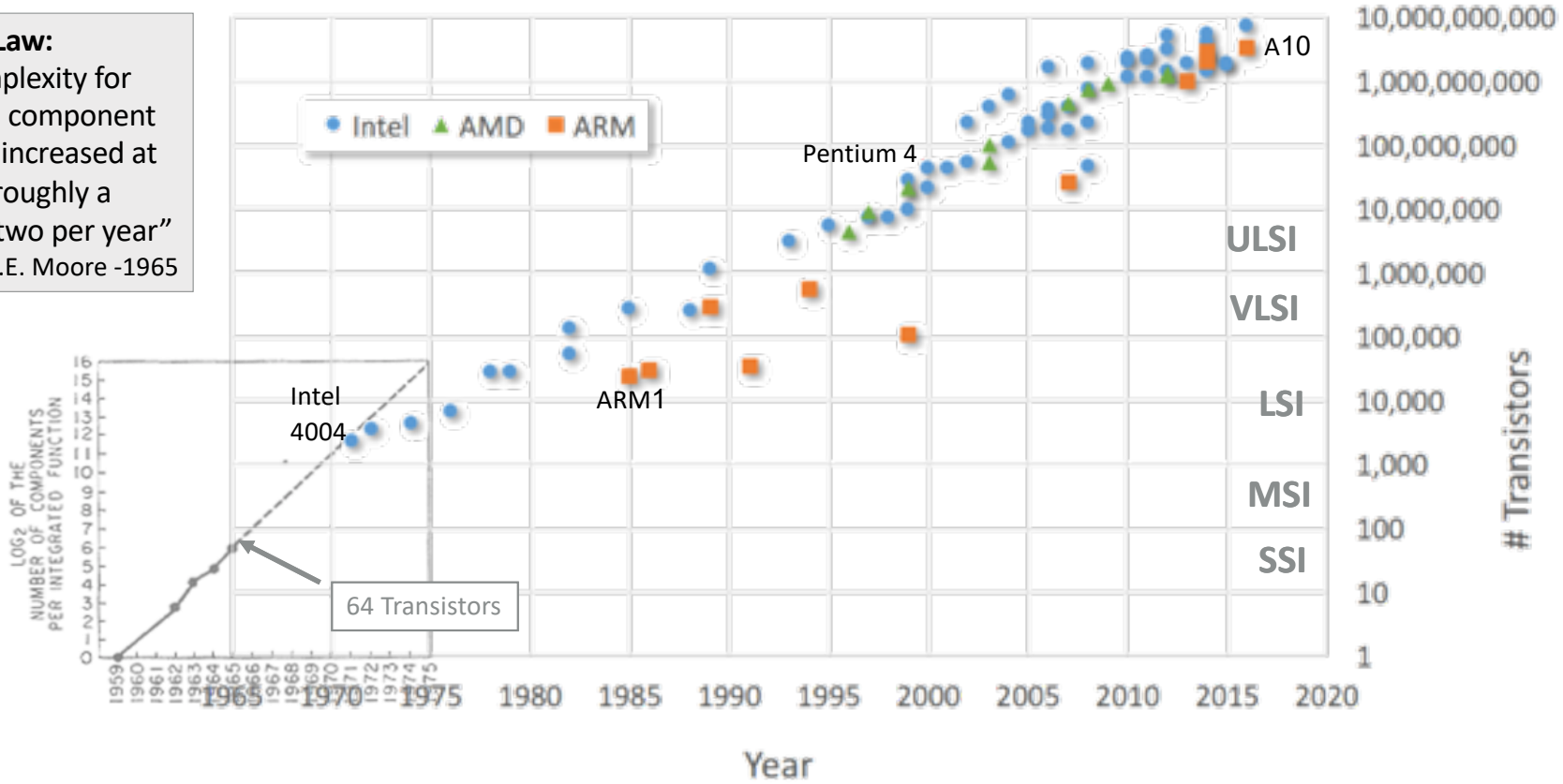
Share £12.00
(£240 in 1998 money)

Mkt Cap £17B

arm

Microprocessor Transistor Count

Moore's Law:
"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year"
G.E. Moore -1965



Source: G. E. Moore "Cramming More Components onto Integrated Circuits,". Electronics, pp. 114–117, April 19, 1965

source: https://en.wikipedia.org/wiki/Transistor_count

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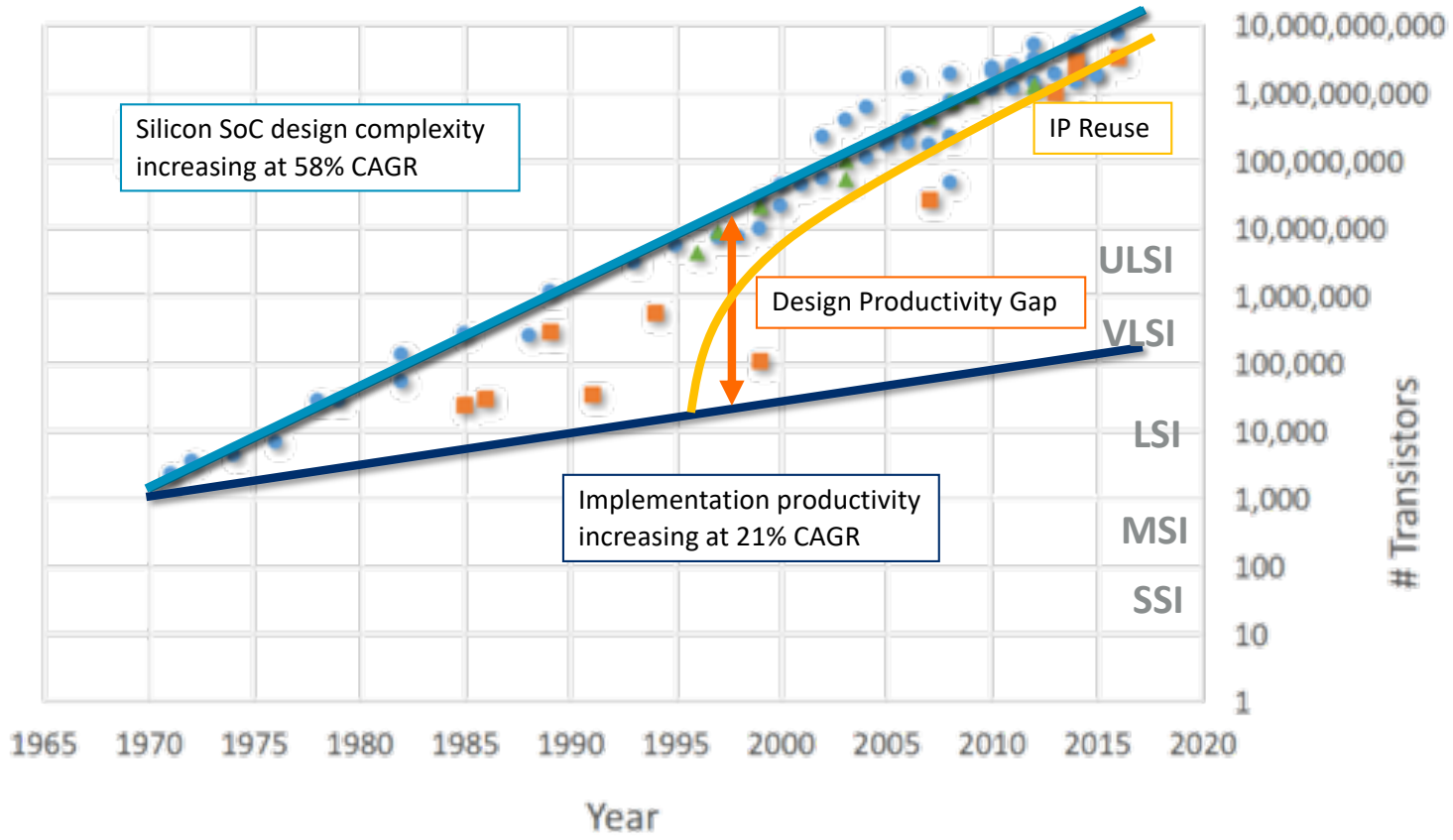
Design Productivity Gap



Source: G. E. Moore "Cramming More Components onto Integrated Circuits,". Electronics, pp. 114–117, April 19, 1965

source: https://en.wikipedia.org/wiki/Transistor_count

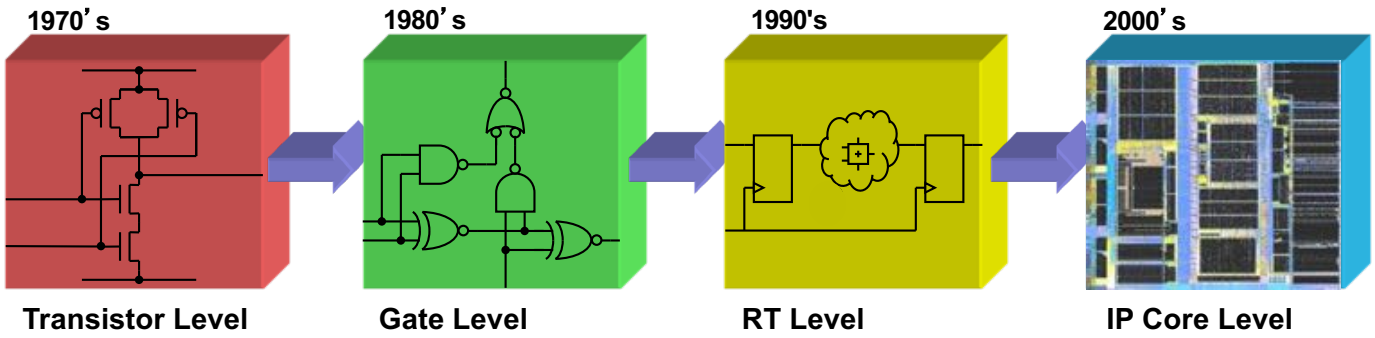
arm

Gordon Moore also said…

"It may prove to be more economical to build large systems out of smaller functions, which are separately packaged and interconnected."

Electronics, volume 38, number 8, April 19, 1965

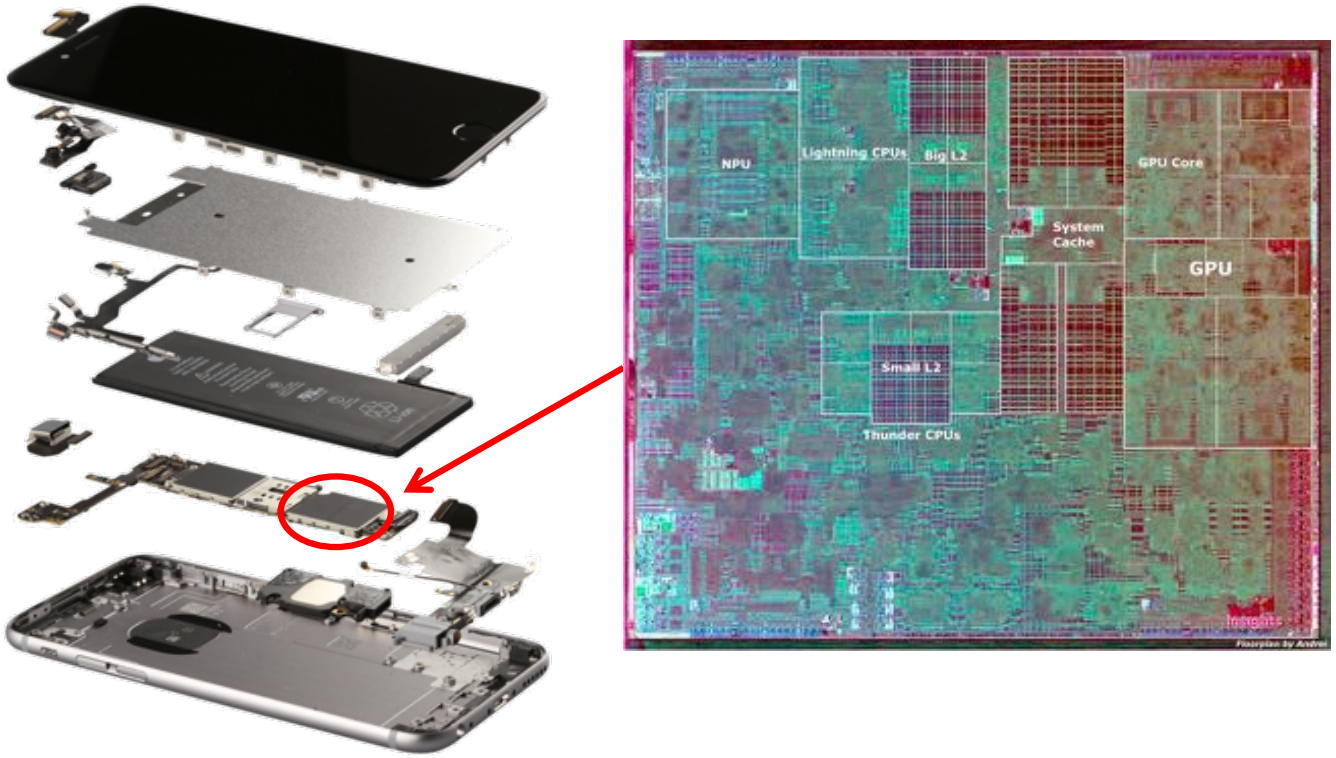
Bigger Building Blocks….



…require higher levels of abstraction

arm

2019: 8.5Bn transistors in a Smart Phone CPU



- 8.5Bn transistors
- 64Bit
- 2.65GHz
- 6 core CPU
- 98.48mm^2
- TSMC 7nm
- 10 layers of metal

arm

Huge Volumes

1990:

- 1 Licensee
- 130,000 in 5yrs

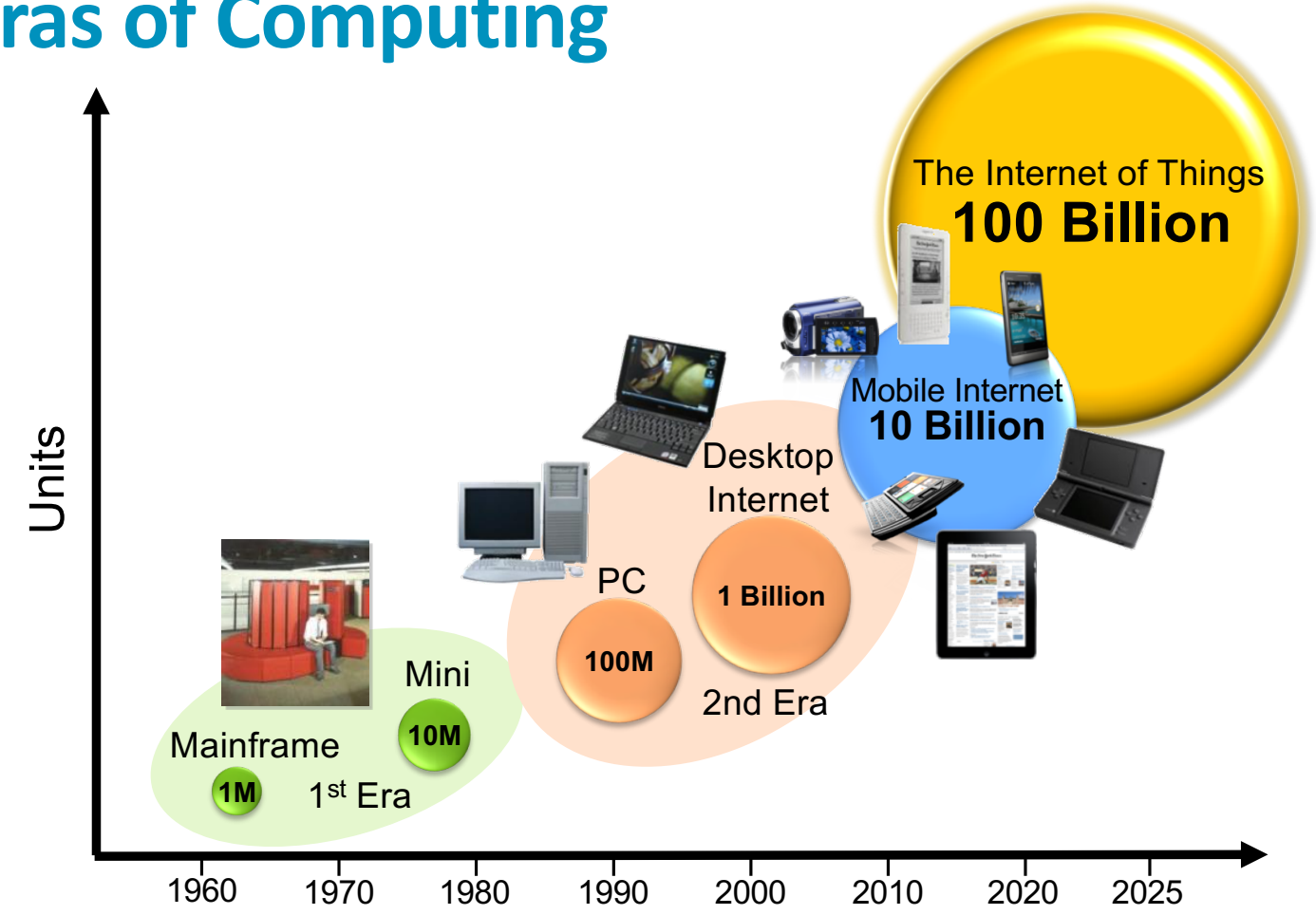
2020:

- 550 Licensees
- 160Bn in 30yrs
- (130,000 in <3mins)

5 Billion in the last quarter!
60 Million per day
740 per sec!

arm

The Eras of Computing

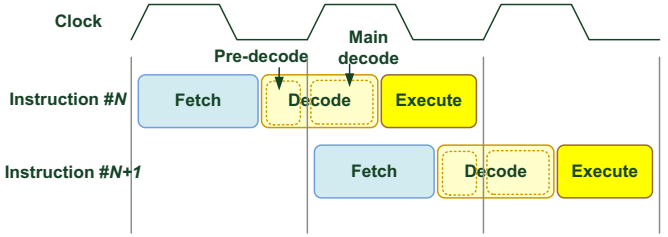


arm

2012: Cortex-M0+ Processor

The most energy efficient 32-bit processor ever designed

- Bringing down processor consumption as low as 3.8µW/MHz
- Outstanding result of 2.46 CoreMark/MHz

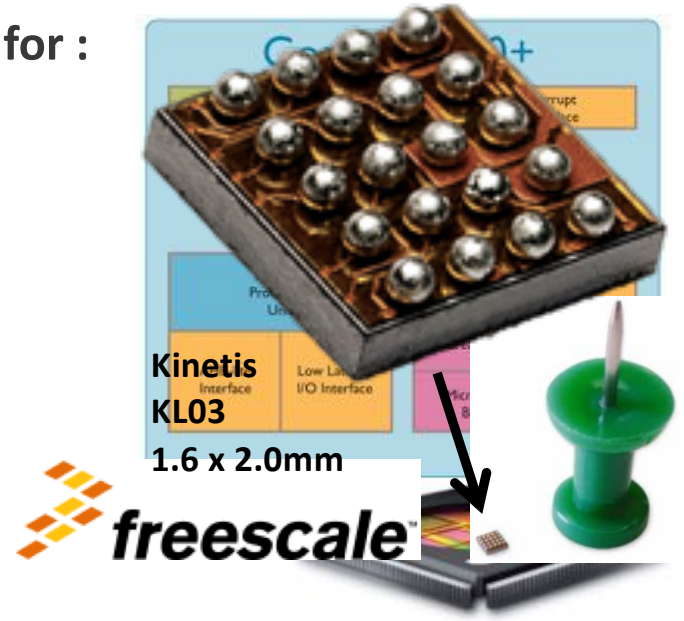


Enabling smaller, smarter and energy friendly solutions for :

- Wireless Sensor Networks
- The Internet of Things

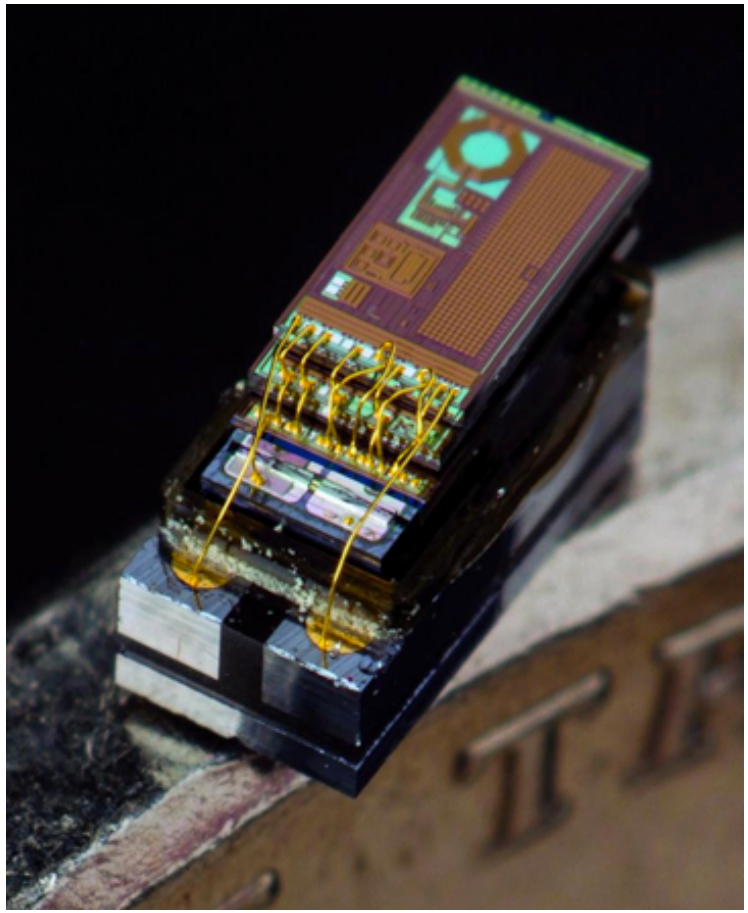
Ultra low power processor design

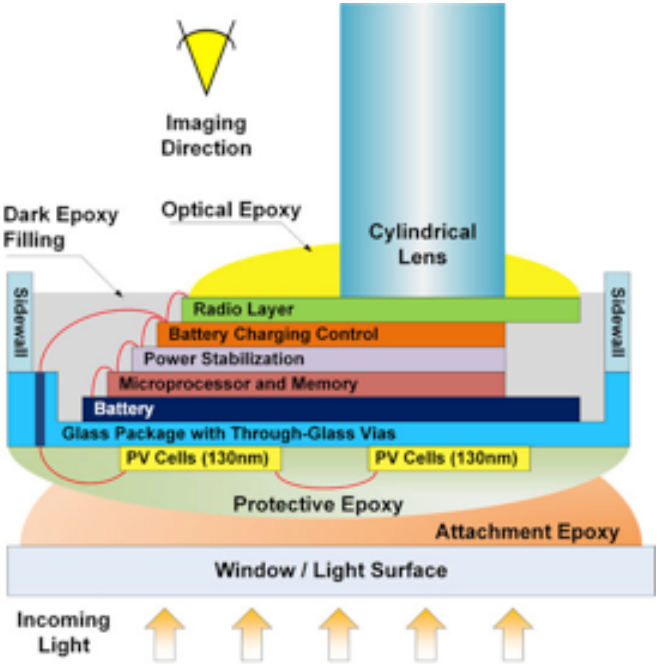
- Two stage pipeline – fewer flops (12K in total)
- Compact instruction set – just 56 instructions
- Extensive clock and power gating



arm

Diversity: A mm^3 ARM Powered Computer

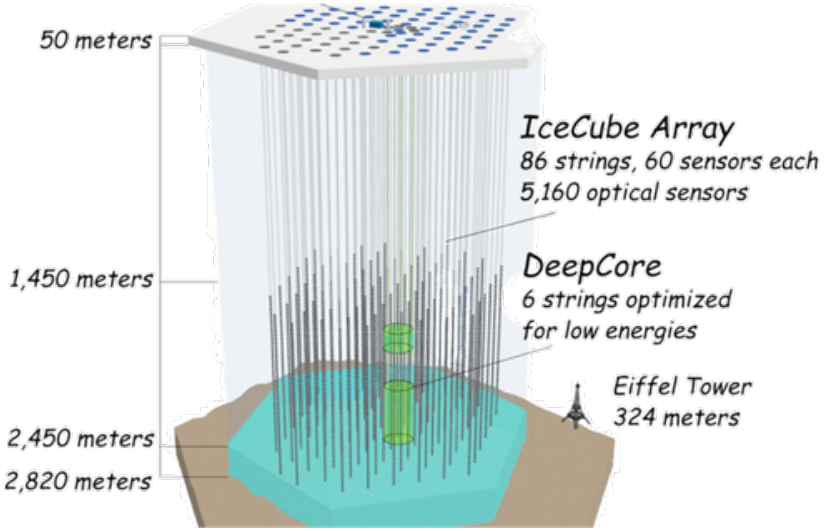




- Cortex-M0 based
- Energy Autonomous Pressure Sensor
- 500pW average power
- Overall size 2x4x4mm^3 - “injectable”!

arm

Diversity: A km^3 ARM Powered Computer



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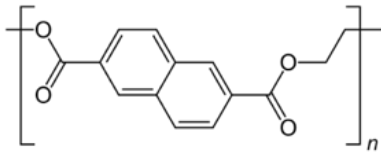
PlasticARM – Blue Sky Research



arm Pragmatic

Vision:

- Enable 1¢ DIY disposable ARM microcontrollers

Opportunity:

- $74Bn TAM for flexible/printed/organic electronics by 2027

Reality today:

- Minimal Cortex-M based SoC with 128B RAM
  - 42K transistors/resistors (NMOS)
- 1.0µm Metal Oxide Semiconductor
  - Big, slow and thirsty! (cf Silicon)

Tomorrow?

- Smart sensors, intelligent packaging, disposable health monitoring systems...

arm

2016: SoftBank buys ARM for £24B

arm

2020: ARM today (6,600 people, 42 offices, 19 countries)

arm

REFLECTIONS

A personal look back at how things have changed in ARM

Chip design then and now (well 2012)

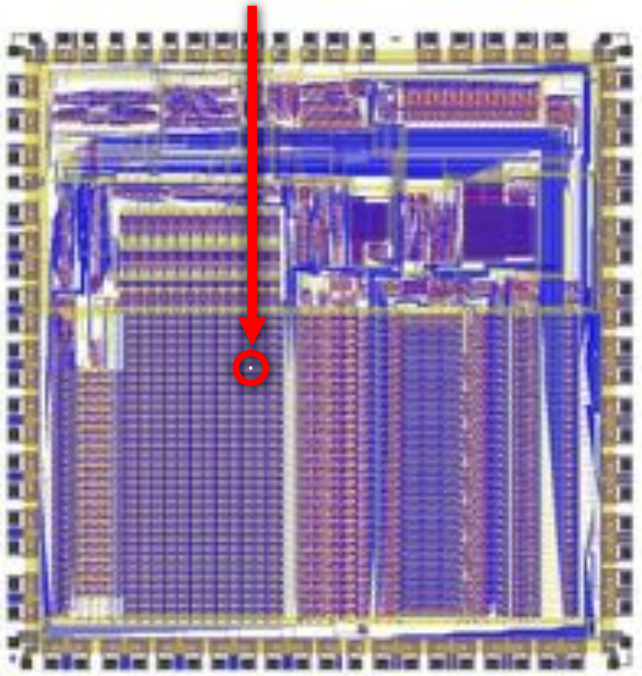
Core	Tech	Gates	Design
ARM1	3µ	6K	6My
Cortex™-M0	20nm	8K	11My

Implementation time: 6 months to 32min = **8192**:1
1985 to 2012 = 13 generations: 2^{13} = **8192**

Area: 50mm^2 to 0.005mm^2 = **10000**:1
Performance: 6MHz to 200MHz = **32**:1
Voltage: 5V to 900mV = **5**:1

Power: 20mW/MHz to 2.5uW/MHz = **8000**:1

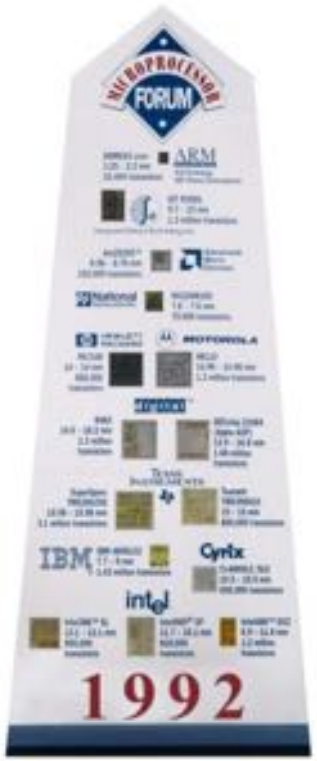
20nm Cortex-M0
1/10,000th size

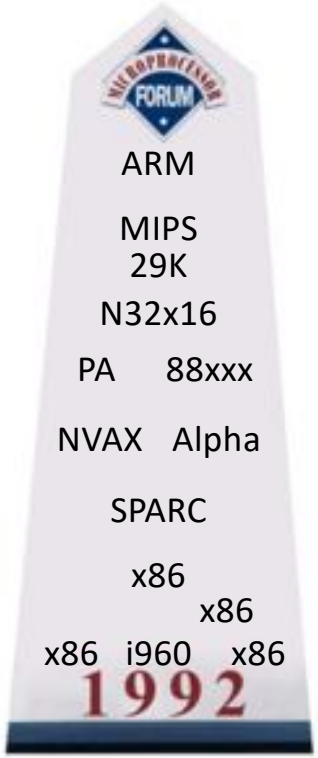


3um ARM1
7mm x 7mm

arm

Microprocessors then and now





arm

My office then (12people)

My office now (1750 people)

Partnership then and now

arm

Partnership then and now

Partner meeting then (10 attendees)

Partner meeting then (1,500+ attendees)

TechCon 2019: 3,500+ attendees!

arm

Some things I have learnt

- Top-right isn't everything
- Design once, use many times
- The partnership is everything
- Listen to your customer…and their customer
- Timescales are long
- People are the biggest asset we have
- It pays to be different
- Look for the simplicity *beyond* the complexity

Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away.

--Antoine de Saint-Exupery

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Thank You!
Danke!
Merci!
谢谢!
ありがとう!
Gracias!
Kiitos!