

## Embedded Systems

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

1

## At the high end of the scale



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

2

## At the low end of the scale



Processor can consume no more than 250-300mW

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

3

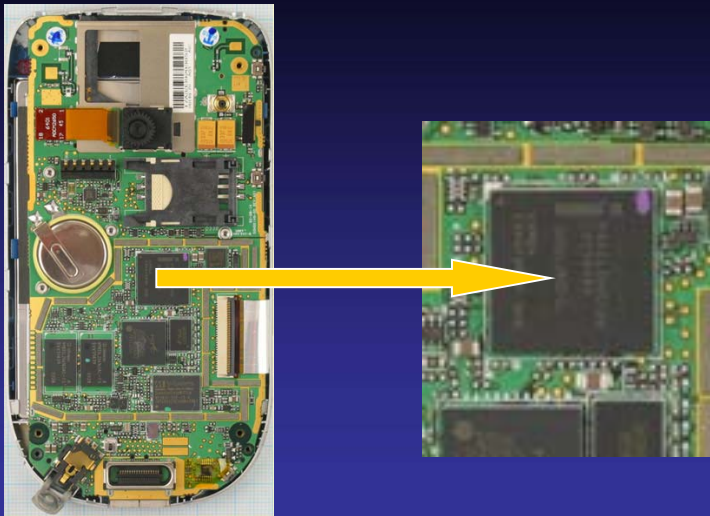


**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

4

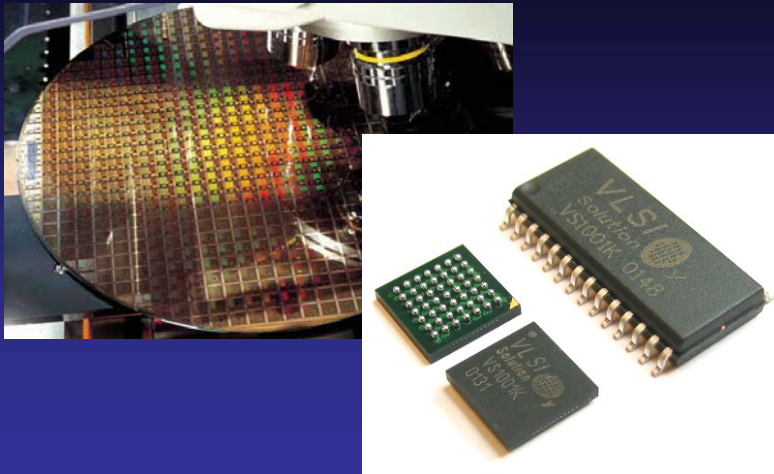
## Under the hood...



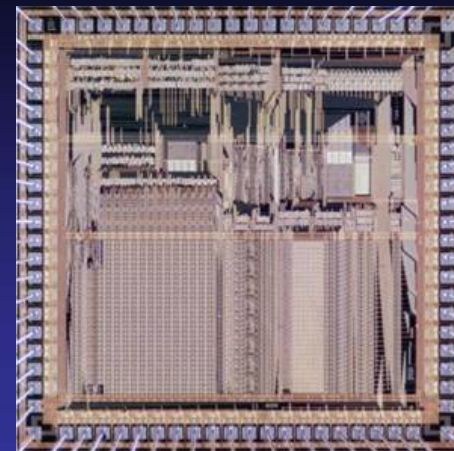
## Requirements of embedded cores

- Reduced package sizes / pin counts
- Power management
- Good code density
- Very fast interrupt handling
- Good debug visibility

## Wafers of chips

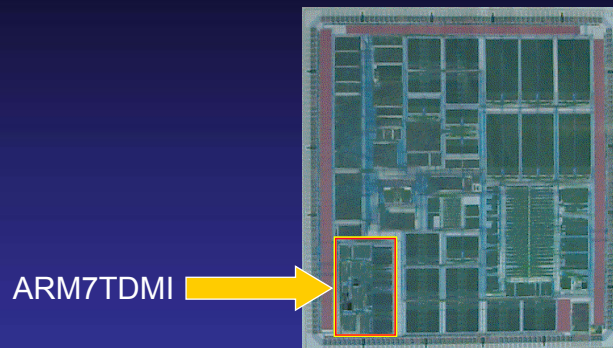


## The first ARM...



- Used in Acorn Archimedes PCs
- RISC architecture
- Had very low power consumption
- Lead to the development of ARM7TDMI

## Embedded microprocessors



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

9

## Requirements of embedded cores

- Reduced package sizes / pin counts
- Power management
- Good code density
- Very fast interrupt handling
- Good debug visibility

**ARM**

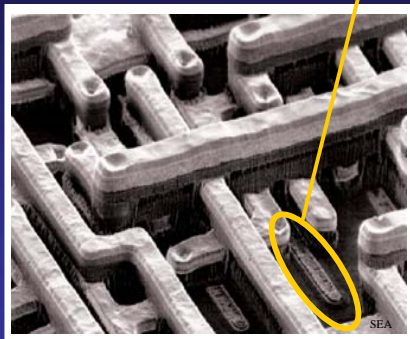
THE ARCHITECTURE FOR THE DIGITAL WORLD™

10

## Smaller and smaller...



1 Transistor

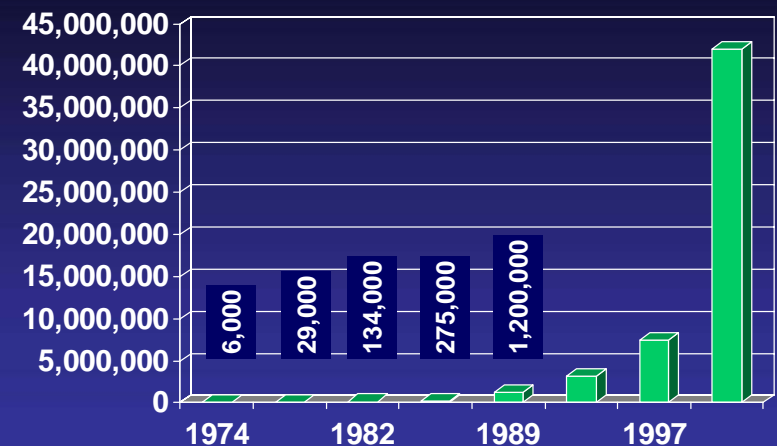


**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

11

## More and more...



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

12

## The immutable laws of physics

$$P \approx C_{\text{eff}} \cdot V_{\text{dd}}^2 \cdot f + P_{\text{stat}}$$

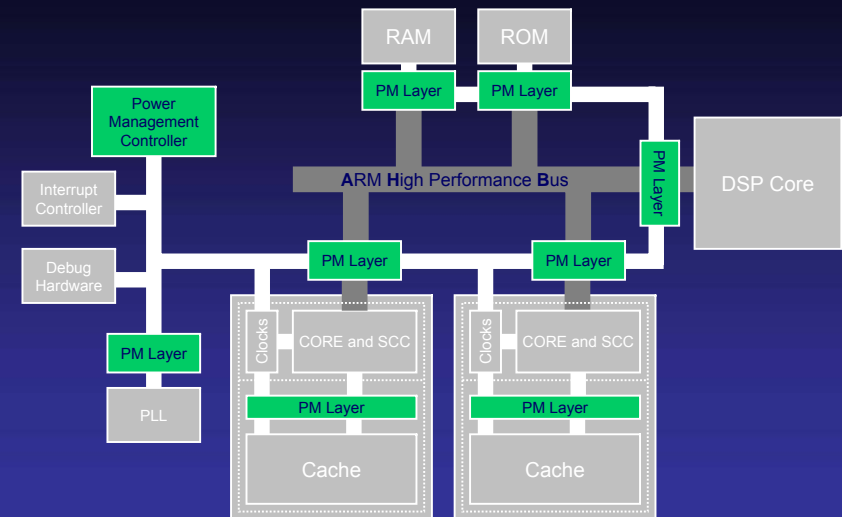
Process (nm)	$P_{\text{stat}}$ as % of $P$
180	0
130	2-3
90	20-25
65	40-50

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

13

## Power management



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

14

## Powerdown options

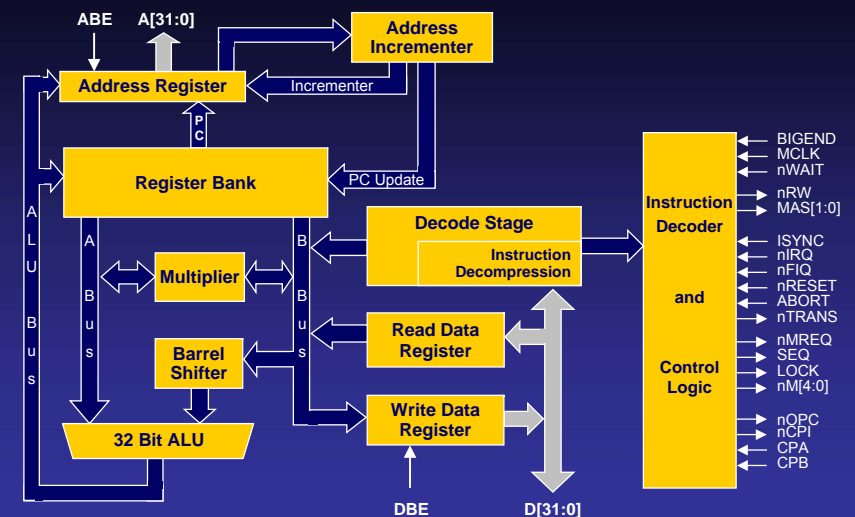
State Name	System Mode	
RUN	Turbo	High speed
	Normal	Default speed
	Slow	Slow speed
STANDBY	Idle	Core halted - minimize dynamic current
DORMANT	Nap	Leakage only - CPU state saved in cache & RAM
SHUTDOWN	Sleep	No leakage from CPU or cache - state in RAM
	Coma	
	Hibernate	
	Off	No power - state in ROM

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

15

## The ARM7TDM Core



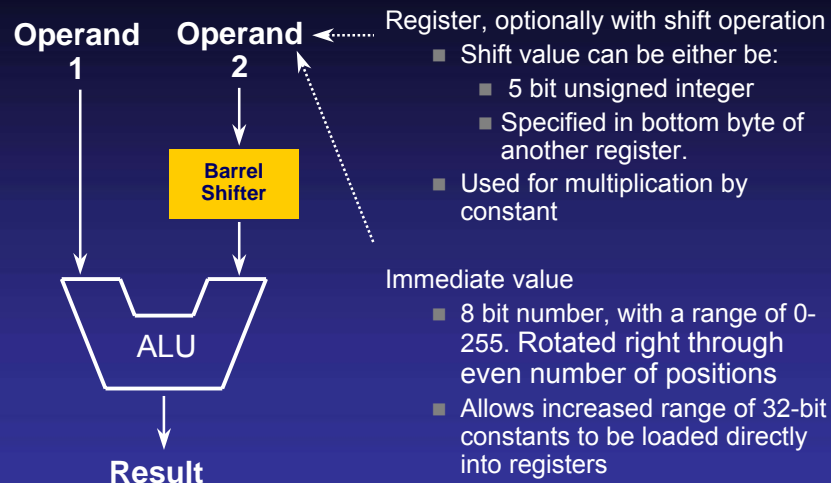
**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

16



## Using the Barrel Shifter

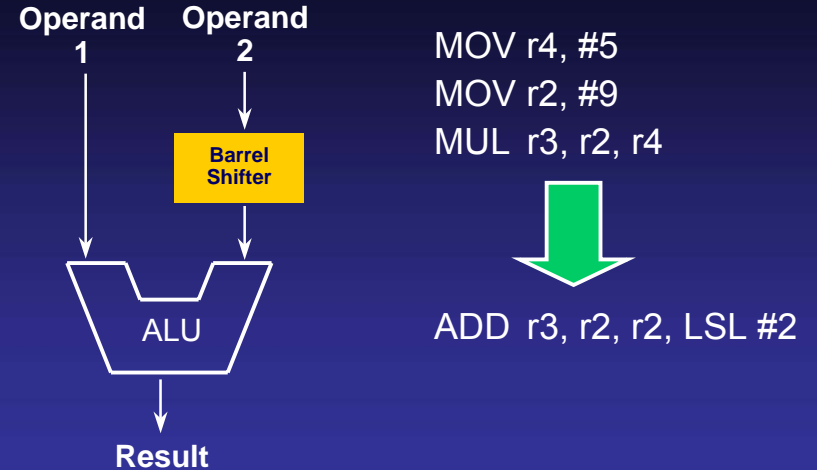


**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

17

## Software tricks

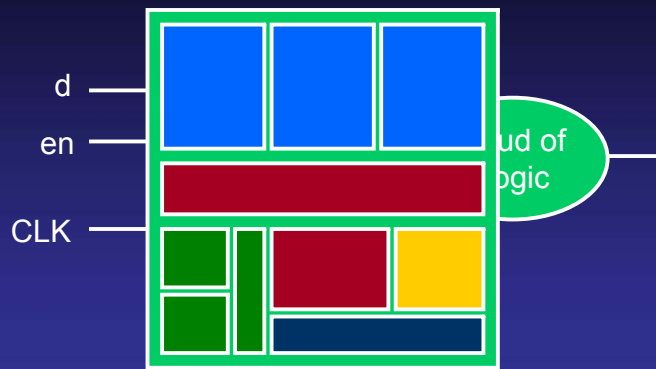


**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

18

## Clock gating



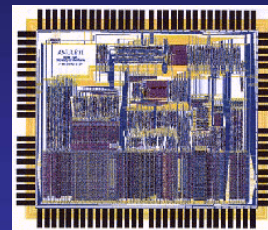
**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

19

## Asynchronous design

- No clocks – handshaking is done between functional blocks
- AMULET1 performance was about 70% of an ARM6 running at 20MHz
- Power consumption very similar to an ARM6
- Delivered about 80 MIPS/W (compared to 120 MIPS/W of ARM6)
- Power consumption of AMULET2 was 150mW



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

20

## Requirements of embedded cores

- Reduced package sizes / pin counts
- Power management
- Good code density
- Very fast interrupt handling
- Good debug visibility

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

21

## Thumb

- Thumb is a 16-bit instruction set
  - Optimised for code density from C code (~65% of ARM code size)
  - Improved performance from narrow memory
  - Subset of the functionality of the ARM instruction set
- Core has additional execution state - Thumb
  - Switch between ARM and Thumb using **BX** instruction

ADDS r2,r2,#1

32-bit ARM Instruction



ADD r2,#1

16-bit Thumb Instruction

**For most instructions generated by compiler:**

- Conditional execution is not used
- Source and destination registers identical
- Only Low registers used
- Constants are of limited size
- Inline barrel shifter not used

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

22

## Requirements of embedded cores

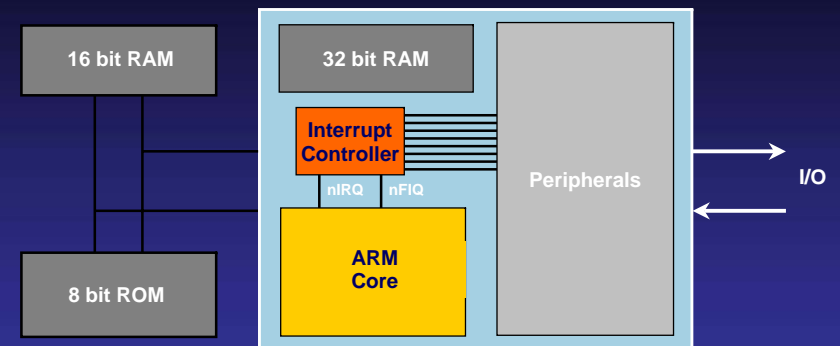
- Reduced package sizes / pin counts
- Power management
- Good code density
- Very fast interrupt handling
- Good debug visibility

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

23

## Example ARM-based System



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

24

## Requirements of embedded cores

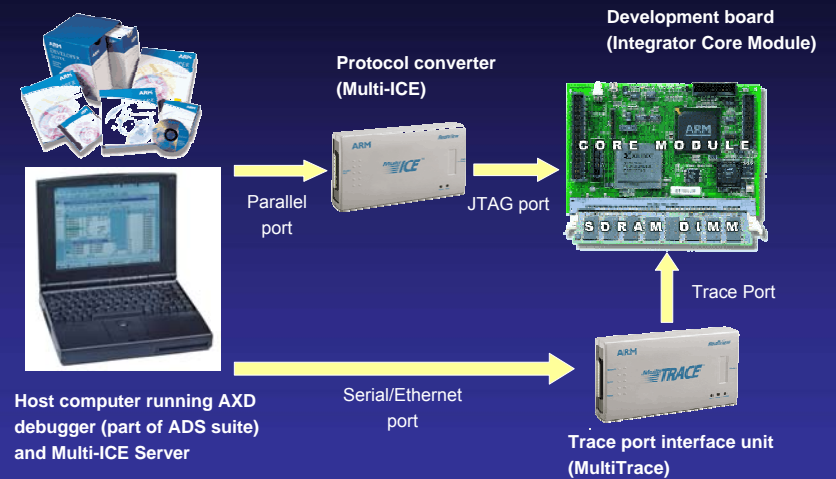
- Reduced package sizes / pin counts
- Power management
- Good code density
- Very fast interrupt handling
- Good debug visibility

**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

25

## ARM Debug Components

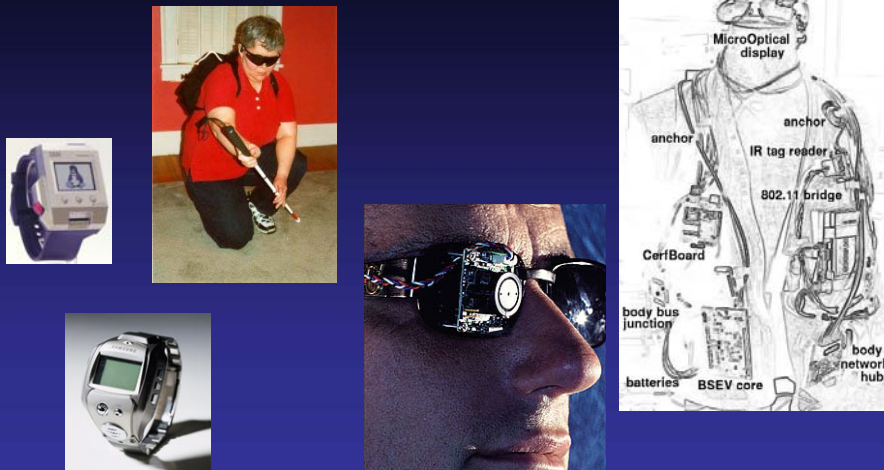


**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

26

## The future?



**ARM**

THE ARCHITECTURE FOR THE DIGITAL WORLD™

27