Digital Electronics and Microprocessor Systems (ELEC211)

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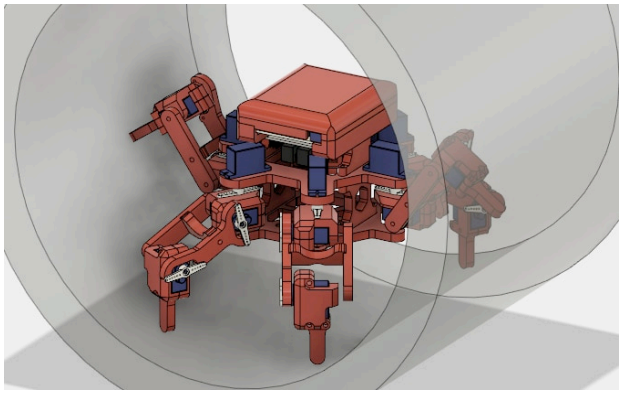
Why are you here today?

50 microprocessors

ATM and game console are computers



Micro-robots for roadworks

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Who are we?

Dave McIntosh
Digital Electronics
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Valerio Selis
Microprocessor Systems
email: V.Selis@liverpool.ac.uk

Office hour:
Wednesday at 2 pm, room 508, EEE (**email first**)

Who are you?

- Avionic Systems
- Avionic Systems with Pilot Studies
- Computer Science and Electronic Engineering
- Electrical Engineering
- Electrical Engineering and Electronics
- Electronic and Communication Engineering
- Electronics
- Mechatronics and Robotic Systems

Outline

- Module overview
  - Course structure
  - Course assessment
  - Course contents and textbooks
  - VITAL and assignments
  - Questions and problems in class
- Introduction to processors and µProcessors
- Revision of binary and hexadecimal
- Revision binary ⇔ hex ⇔ decimal conversion
- Revision of ASCII

Course Structure

- Approx. 32 classes
- 3 lectures per week:
  - Monday at 4 pm (502-LT2)
  - Wednesday at 12 noon (CHAD-BARKLA)
  - Thursday at 2 pm (502-LT2)
- 3 home works on VITAL
- Laboratory experiments 26 and 28
- 3 hour examination - in May

Course Assessment

- 75% Examination in May
- 10% Experiment 28 – Altera FPGA
- 5% Experiment 26 – microprocessor
- 10% VITAL home works
- This is a 15 credit module:
  - It counts for 1/8 of your marks for the year.

Private study

- This module is assigned 150 hours
  - 95 hours should be private study ≈ 8 hours/week
- Private study includes:
  - Studying text book(s)
  - Practicing problems
  - Writing up lecture notes
  - Revising for the tests and exam

Course Content: Digital

- Multiplexers, Decoders and ROM
- Programmable Logic Devices
- Latches, Flip-Flops, Registers and Counters
- Algorithmic State Machines (ASMs)
- Sequential Circuit Design (One Hot & Decoder)
- Quine-McCluskey Method

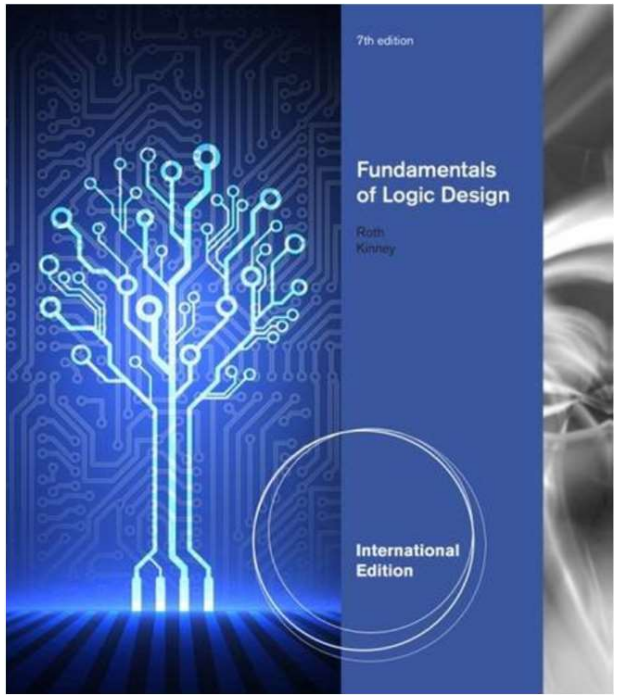
Course Content: µProcessors

- Basic microprocessor organization
  - Buses, registers, instructions
- Assembly language programming
  - Addressing, branches, flags, stacks and interrupts
- More advanced processor architecture
  - Pipelines, memory hierarchy, von Neuman/Harvard architecture, interfacing and memory caches
- ARM processor microarchitecture
  - Processor modes, exception handling

Course Textbooks

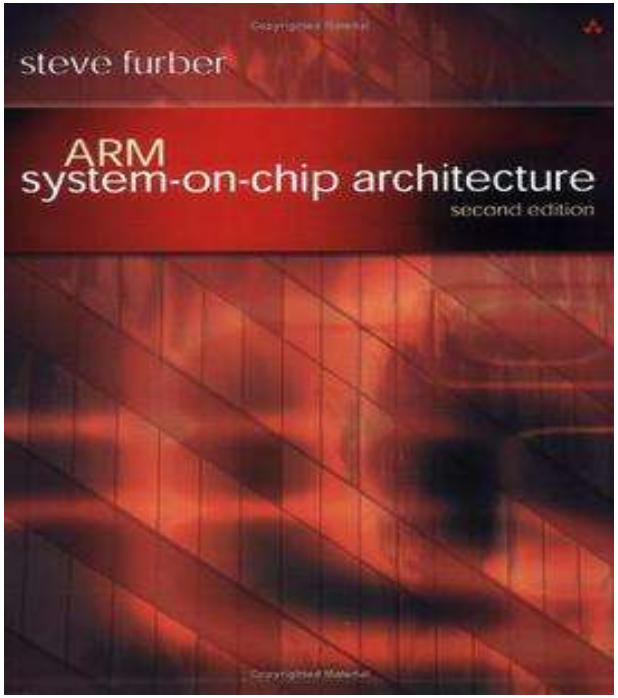
Digital

Fundamentals of Logic Design
C. H. Roth and L. L. Kinney,
7th edition, ISBN: 978-1-133-62848-4



µProcessors

ARM system-on-chip architecture,
Steve Furber, 2nd edition,
ISBN 0-2-1-67519-6



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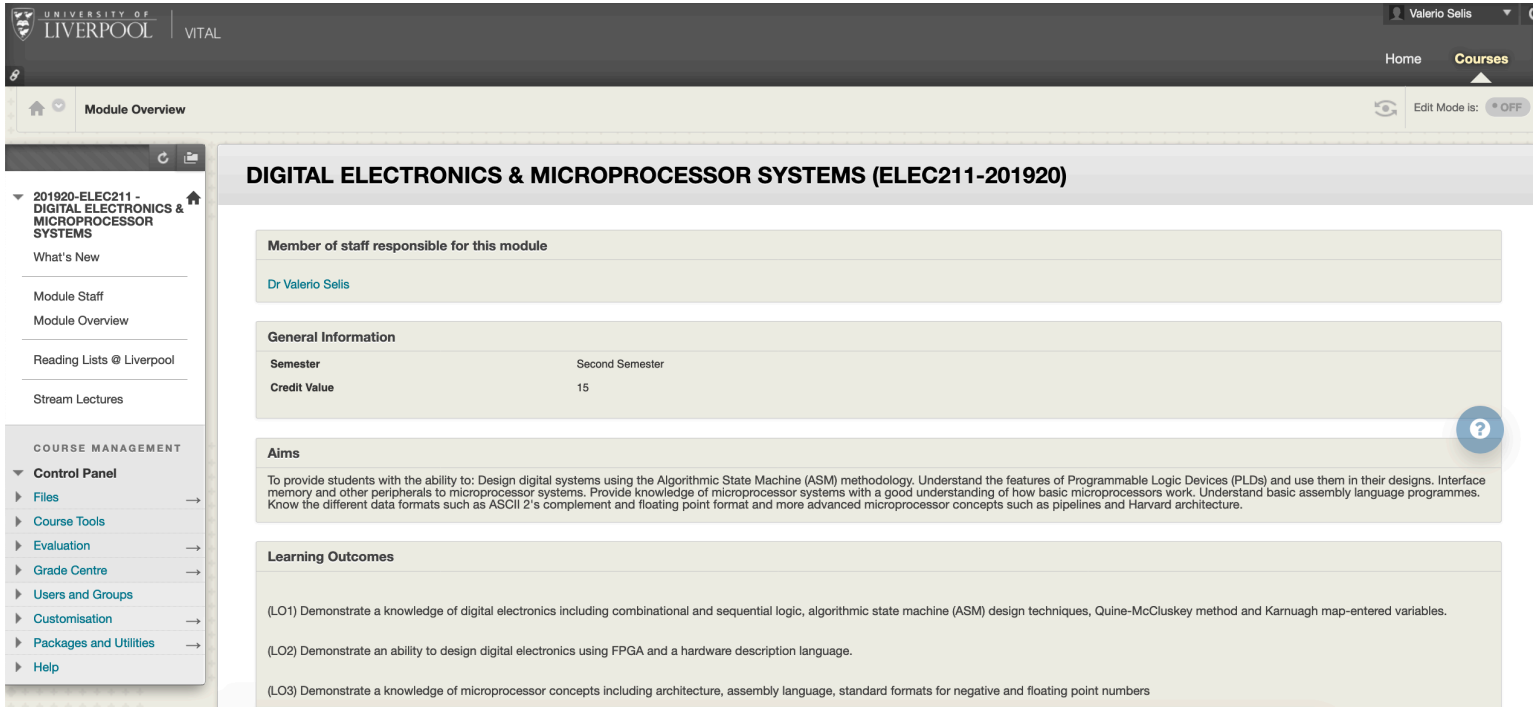
VITAL

- Lecture notes and Handouts
- Homework
- Online exams
- **Discussion board**



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VITAL assignments

- Each online assignment will be available for at least two weeks.
- The tests will go off line at midnight, Fridays.
- The first assignment will be available soon.
- There will be 3 assignments and each one is worth 3.33%.

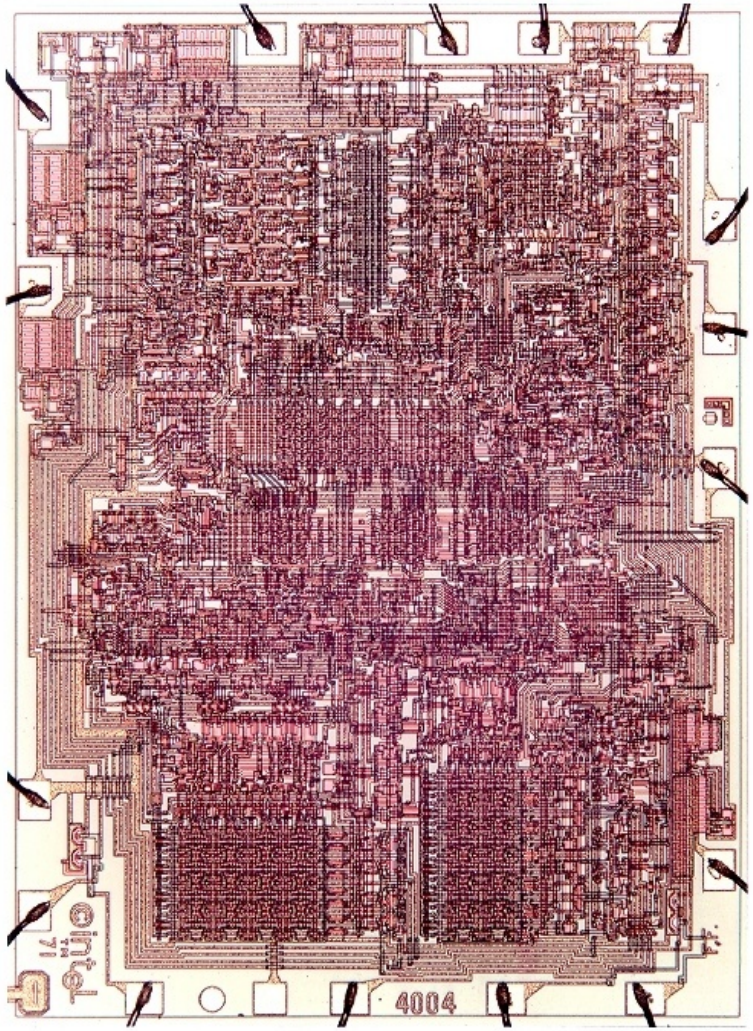
Questions & Problems in class

- When we ask a question or set a problem you should answer on your own or discuss it with one or two neighbours.
- The discussion time will depend upon the difficulty of the question or problem.
- Before the end of the discussion time you should answer to the question by joining PollEv.com/elec211 or using Poll Everywhere's app and inserting elec211 as username.

What is a µProcessor?

- The part of a computer which does all the calculations is called the central processing unit (CPU).
- If a CPU is contained in one integrated circuit (silicon chip) it is called a microprocessor.
- The first microprocessor was the Intel 4004 which appeared in 1971. It was much less powerful than a 1970's computer because at that time integrated circuits only had a fraction of the number of transistors compared to modern integrated circuits.

INTEL 4004



15 November 1971
2,300 transistors
10 micron gate length
4 bit address bus
100 kHz clock

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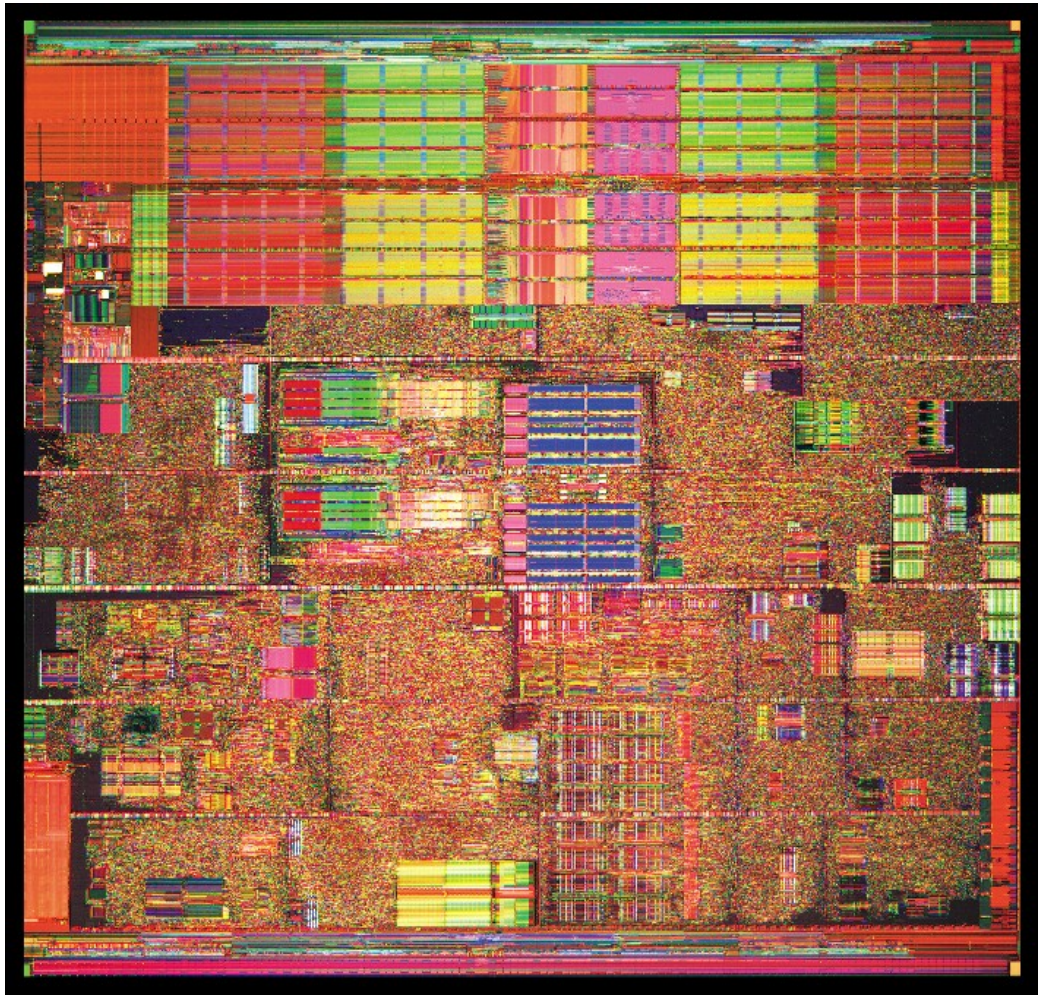
INTEL Pentium



Feb. 2004 (90 nm)
125 million transistors
0.09 μm gate length
36 bit address bus
upto 3.6 GHz clock
112 mm^2 die area
min. power 73 Watts

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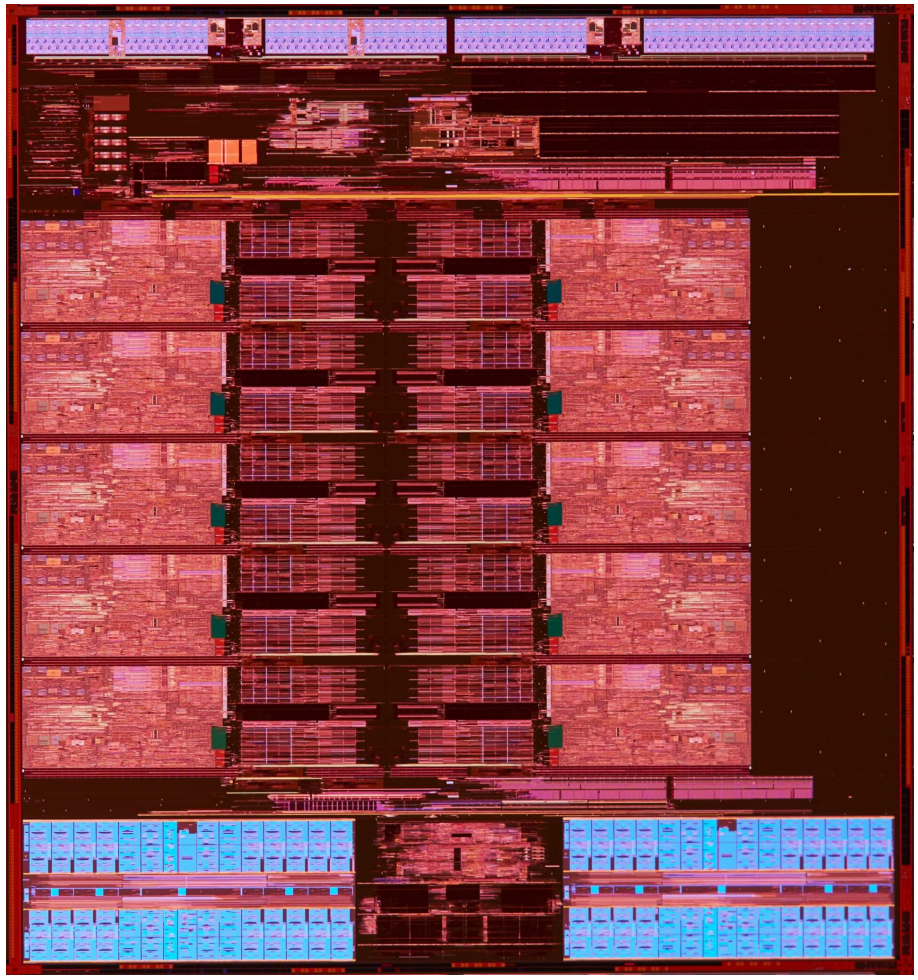
INTEL Core i7 Broadwell-E (5th-gen)



May 2016 (14 nm)
3.3 billion transistors
0.014 μm gate length
64 bit address bus
upto 10 cores @ 3 GHz clock
247 mm^2 die area
power 140 Watts

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Modern µProcessors

- With the advance of integrated circuit technology, microprocessors have become more sophisticated and are now much more powerful than a 1970's computer.
- Now an integrated circuit has enough transistors to contain several microprocessors and associated circuits such as:
  - Memory
  - Interfaces (e.g. USB)
  - Analogue to digital converters (ADC)
  - Digital to analogue converters (DAC)
  - …

The ARM µProcessors

- The ARM microprocessor is an example of a modern microprocessor which can be included (or embedded) in an integrated circuit containing many other circuits.
- It is designed by a British company, ARM Holdings PLC, which licenses the design to any integrated circuit manufacturer.
- All examples used in this course will refer to the **ARM Cortex M0 microprocessor** which is also used in the Year 2 laboratory.

ARM7 µProcessor

74,209 transistors

32 bit address bus

0.13 µm gate length

upto 133 MHz clock

0.26 mm^2 die area

max. power 8 mW

ARM720T: core plus 8 kB cache memory

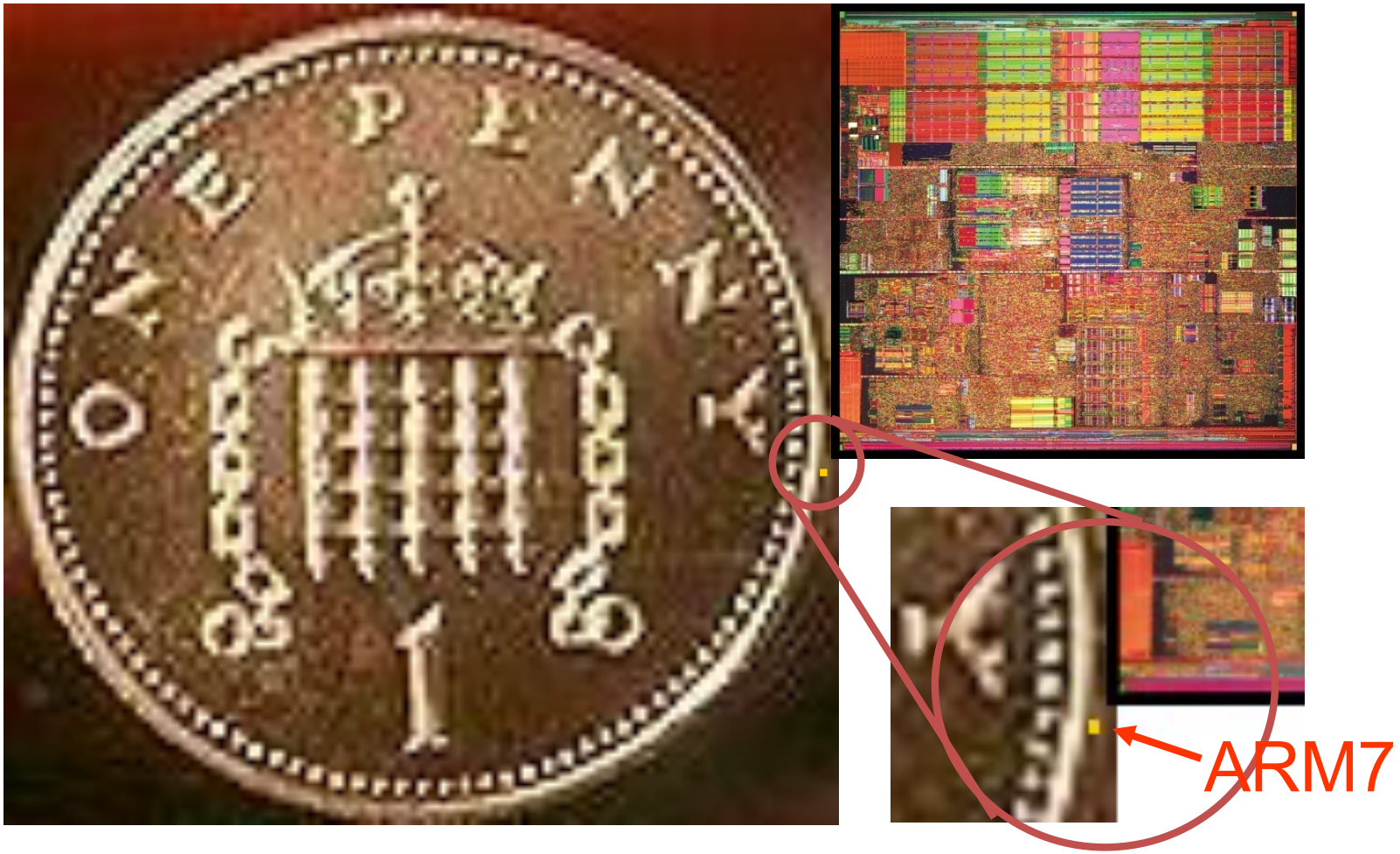
0.13 µm gate length

upto 100 MHz clock

2.4 mm^2 die area

max. power 20 mW

Size matters!



Question

How many ARM microprocessors were sold in the 3 month period that is the financial quarter reported in June 2019?

4,600,000

5,600,000,000

26,000,000

46,000,000

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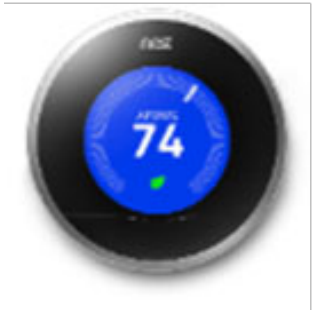
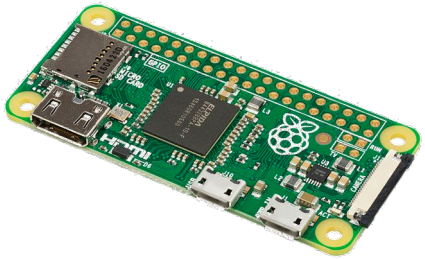
Today's technologies

- Mobile applications
  - Smartphones, tablets and laptops
- Networking infrastructure
  - Routers, servers, …
- Embedded intelligence
  - Microcontrollers, smartcards, …
- Automotive
  - Automotive processors and controllers
- Other mobile chips
  - Modems, Wi-Fi/BT, GPS, sensors, …
- Consumer electronics
  - Desktop PCs, DTVs, …

Today’s technologies





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Future technologies

- Internet of Things
  - Smart objects, smart building management, …
- Autonomous systems
  - Autonomous driving, artificial intelligence, robotics, …
- High performance computing
  - Cloud-based systems, machine learning, big data, …
- Networking
  - Open Platform Network Functions Virtualization, …

Revision - binary

- All computers work on information and data coded in binary; that is base 2.
- The ARM microprocessor is a 32 bit processor so that numbers generally have 32 binary digits e.g.

$$00111100010000010101001001001101_2$$

or

$$b00111100010000010101001001001101$$

which in decimal (base 10) is $1{,}010{,}913{,}869_{10}$

Revision - hexadecimal

- Because 32 bit binary numbers are very long we generally use hexadecimal or base 16.
- You should be familiar with hexadecimal from the first year Digital Electronics course.
- Each hexadecimal digit is equivalent to 4 bits so a 32 bit number will have 8 hexadecimal digits.
- Conversion between hex and binary is simply a matter of substitution.

Decimal ⇔ hex ⇔ binary

Conversion table

Decimal	Hexadecimal	Binary
0	0	0 0 0 0
1	1	0 0 0 1
2	2	0 0 1 0
3	3	0 0 1 1
4	4	0 1 0 0
5	5	0 1 0 1
6	6	0 1 1 0
7	7	0 1 1 1
8	8	1 0 0 0
9	9	1 0 0 1
10	A	1 0 1 0
11	B	1 0 1 1
12	C	1 1 0 0
13	D	1 1 0 1
14	E	1 1 1 0
15	F	1 1 1 1

Decimal ⇔ hex ⇔ binary

Conversion table

Decimal	Hexadecimal	Binary
0	0	0 0 0 0
1	1	0 0 0 1
2	2	0 0 1 0
3	3	0 0 1 1
4	4	0 1 0 0
5	5	0 1 0 1
6	6	0 1 1 0
7	7	0 1 1 1
8	8	1 0 0 0
9	9	1 0 0 1
10	A	1 0 1 0
11	B	1 0 1 1
12	C	1 1 0 0
13	D	1 1 0 1
14	E	1 1 1 0
15	F	1 1 1 1

Very important!
If the conversion table is wrong your results will be wrong:
Make sure this is correct!

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Question

What is the equivalent of

$$0011\ 1100\ 0100\ 0001\ 0101\ 0010\ 0100\ 1101_2$$

in hexadecimal?

✓ 0%

0x8F41664D 0x5231580D3A 0x3C41524D 0x01AE22

ASCII

- Characters must be coded in binary before computers can process them.
- The standard coding for characters is ASCII (American Standard Code for Information Interchange).
- ASCII is a 7 bit code.
- It codes the standard 26 characters of English in both upper and lower case

ASCII

- Characters such as

  ! # $ % & ( ) * + , - . / : ; < = > ? @ [\ ] ^ _

- The characters for numbers from 0 to 9.
- Control ‘characters’
  - Line feed, carriage return, delete, escape, backspace.
- It does not code for é or α or thousands of other non-English characters.

ASCII

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Question

Poll locked. Responses not accepted.

What does the following ASCII code say?

3C41524D2E504F57455245443E0D0A

- < ARM.POWERED > \r\n
- < ARM-POWERED > \n\r
- < EMBEDDED-SYSTEMS >
- < ARM.CODING > \r\n

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Summary

- Module overview
- Introduction to processors and µProcessors
- Revision of binary, decimal, hexadecimal and ASCII

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Next class?

Wednesday at 12 noon in the
Chadwick building,
Barkla Lecture Theatre
(CHAD-BARKLA)


48 61 70 70 79 20 4C 75 6E 61 72 20
4E 65 77 20 59 65 61 72 21