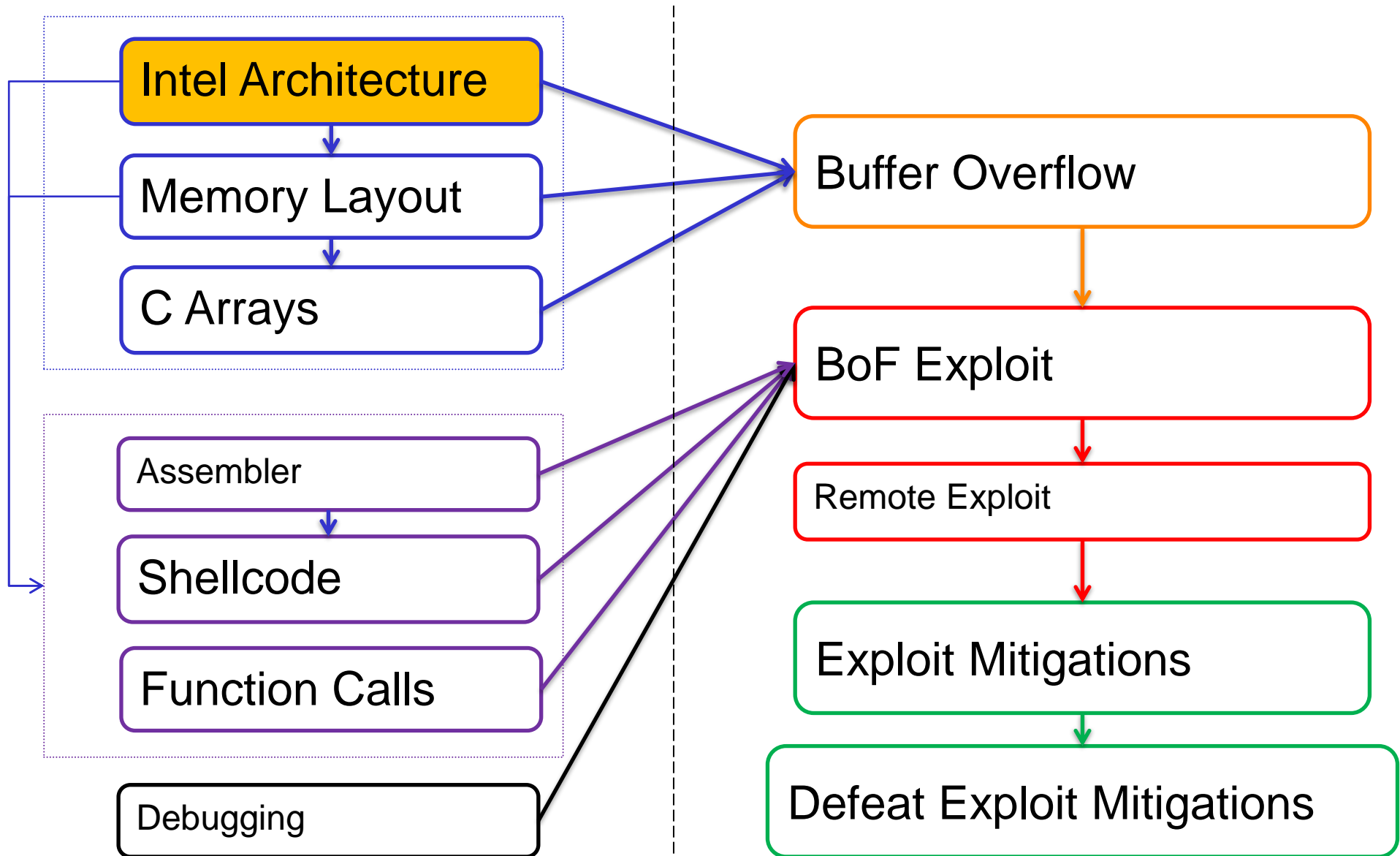


---

# Intel Architecture

# Content

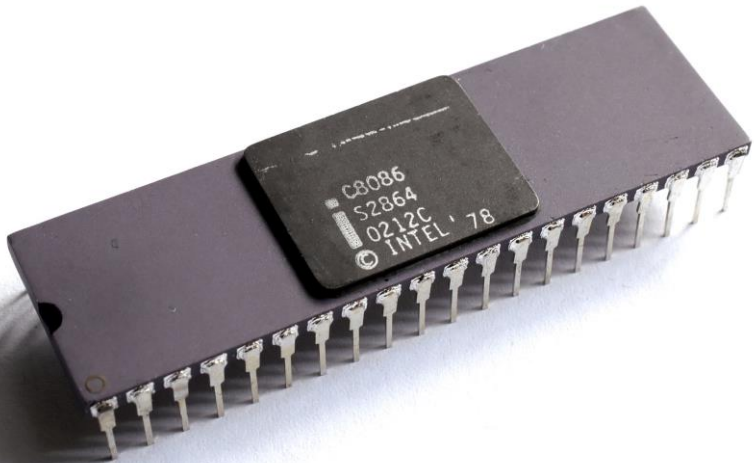


---

# Intel Architecture

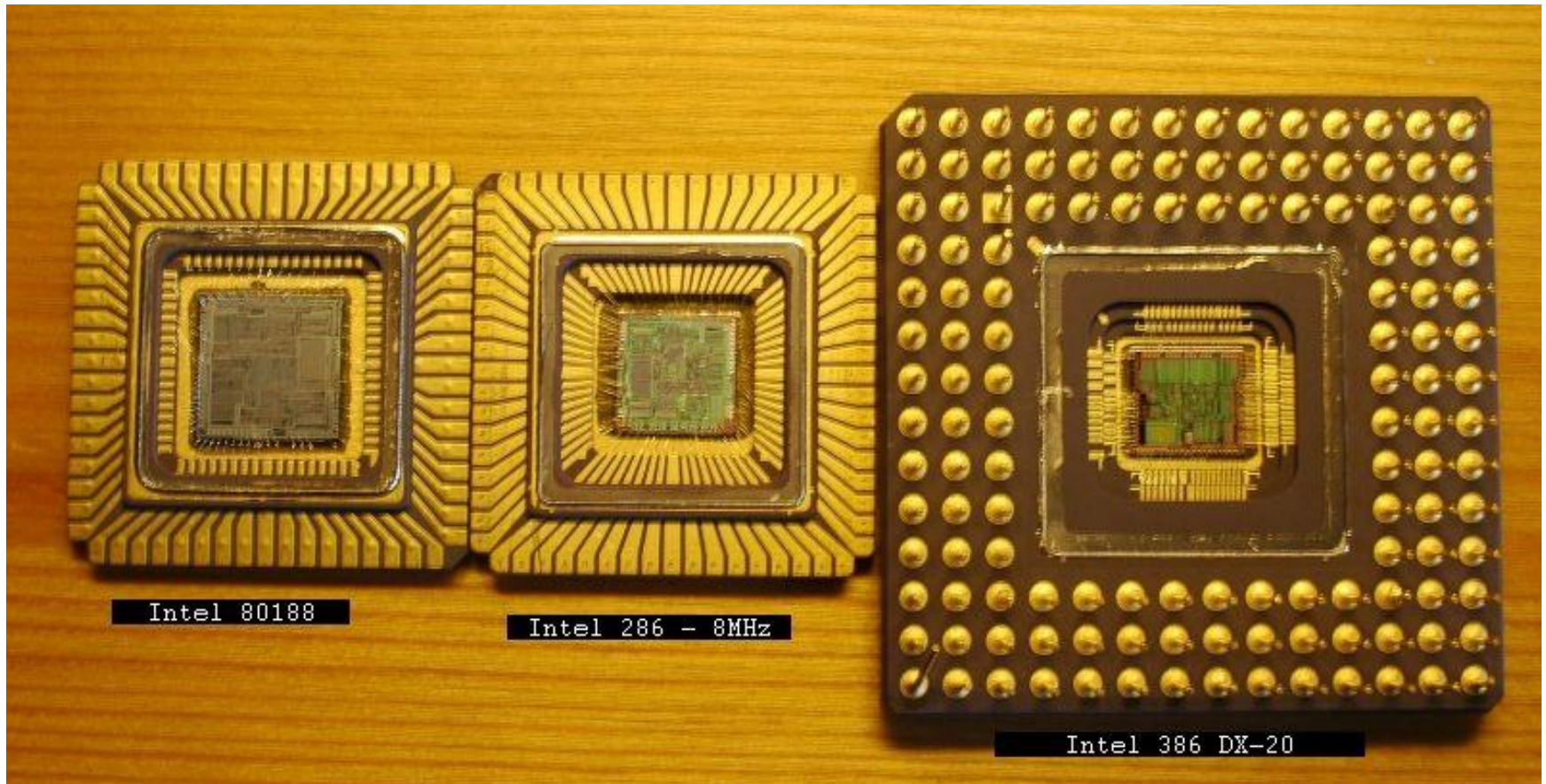
## Intel CPU

# Intel CPU



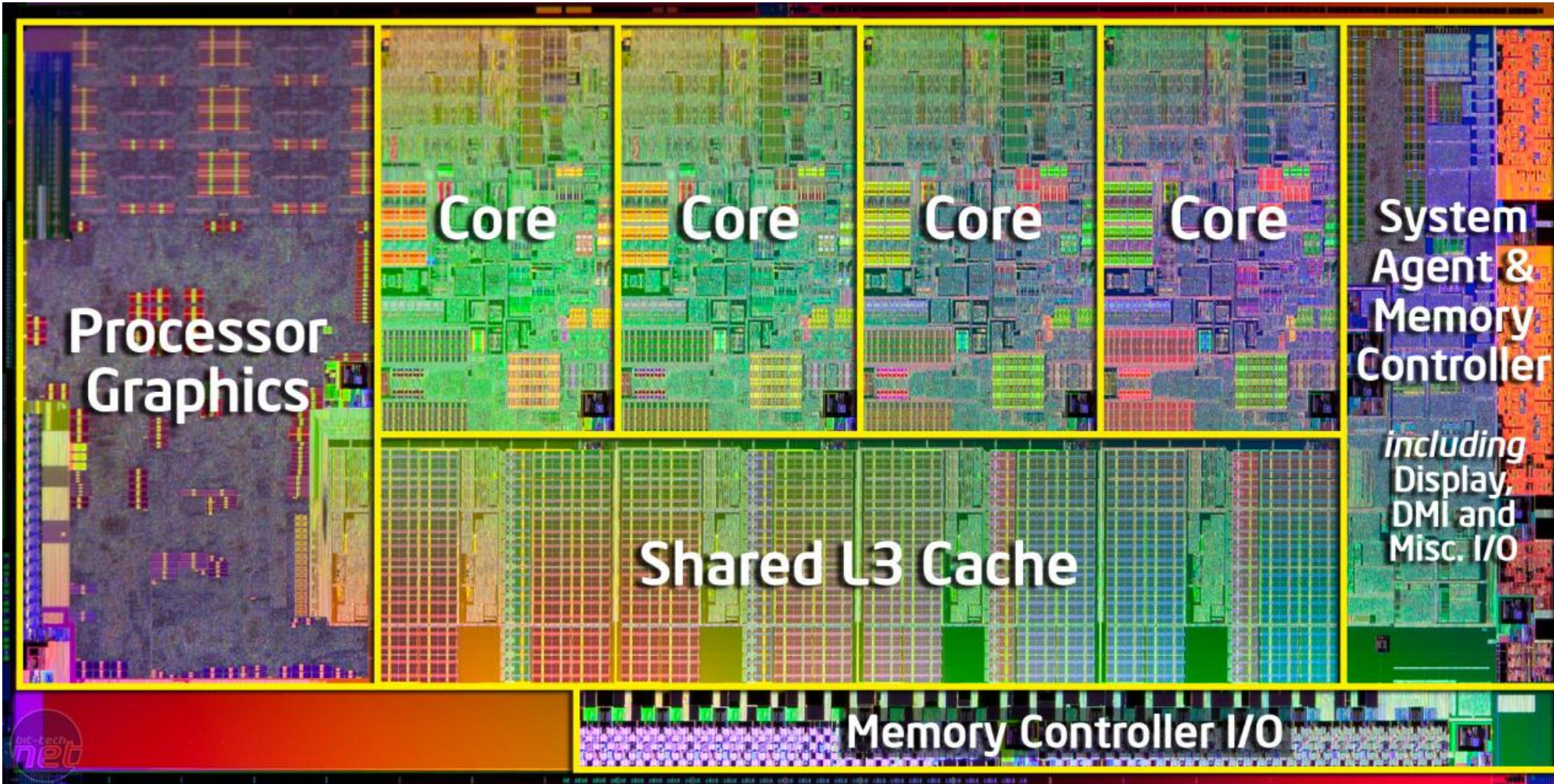
# Intel CPU

---





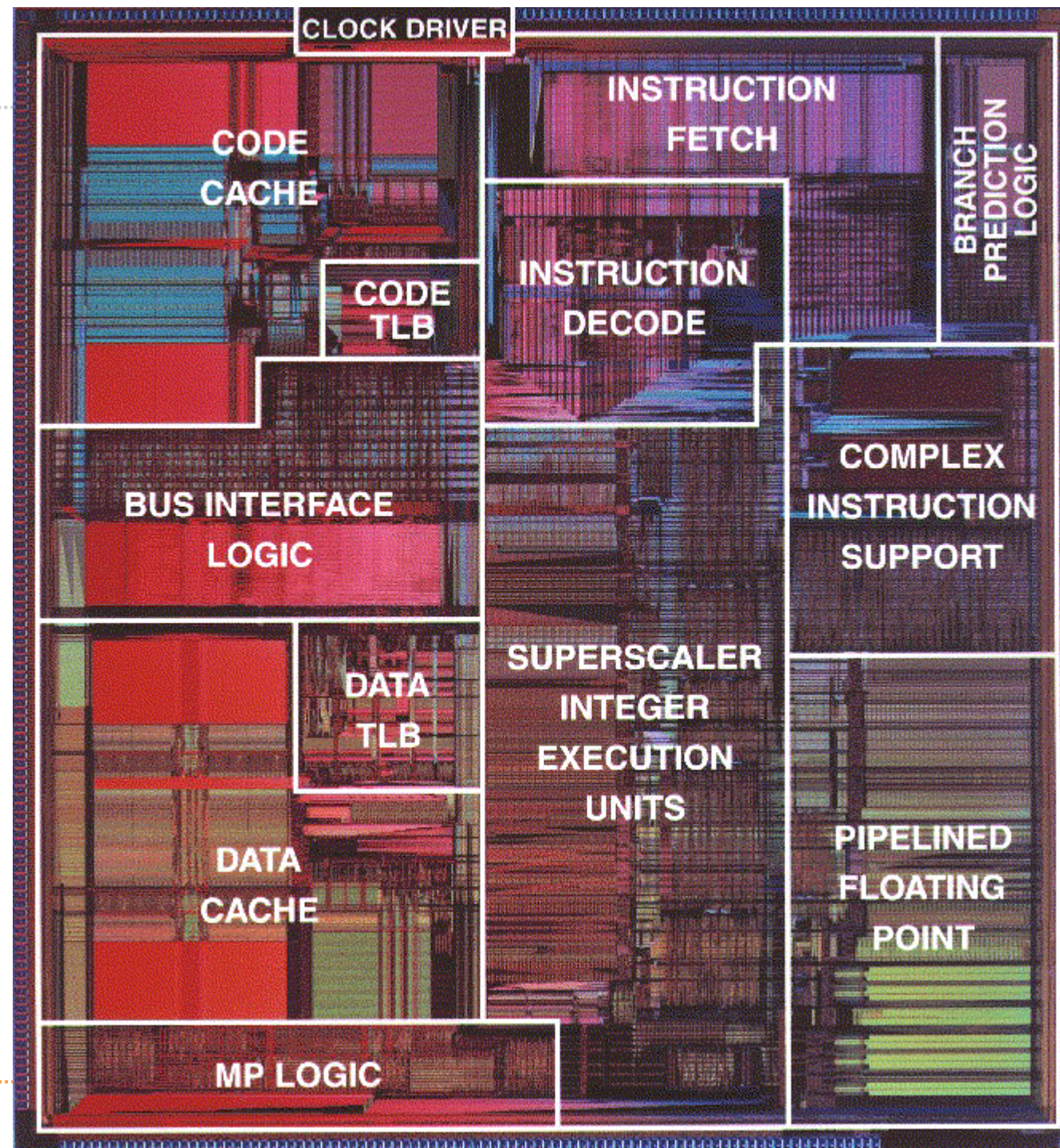
# Intel CPU



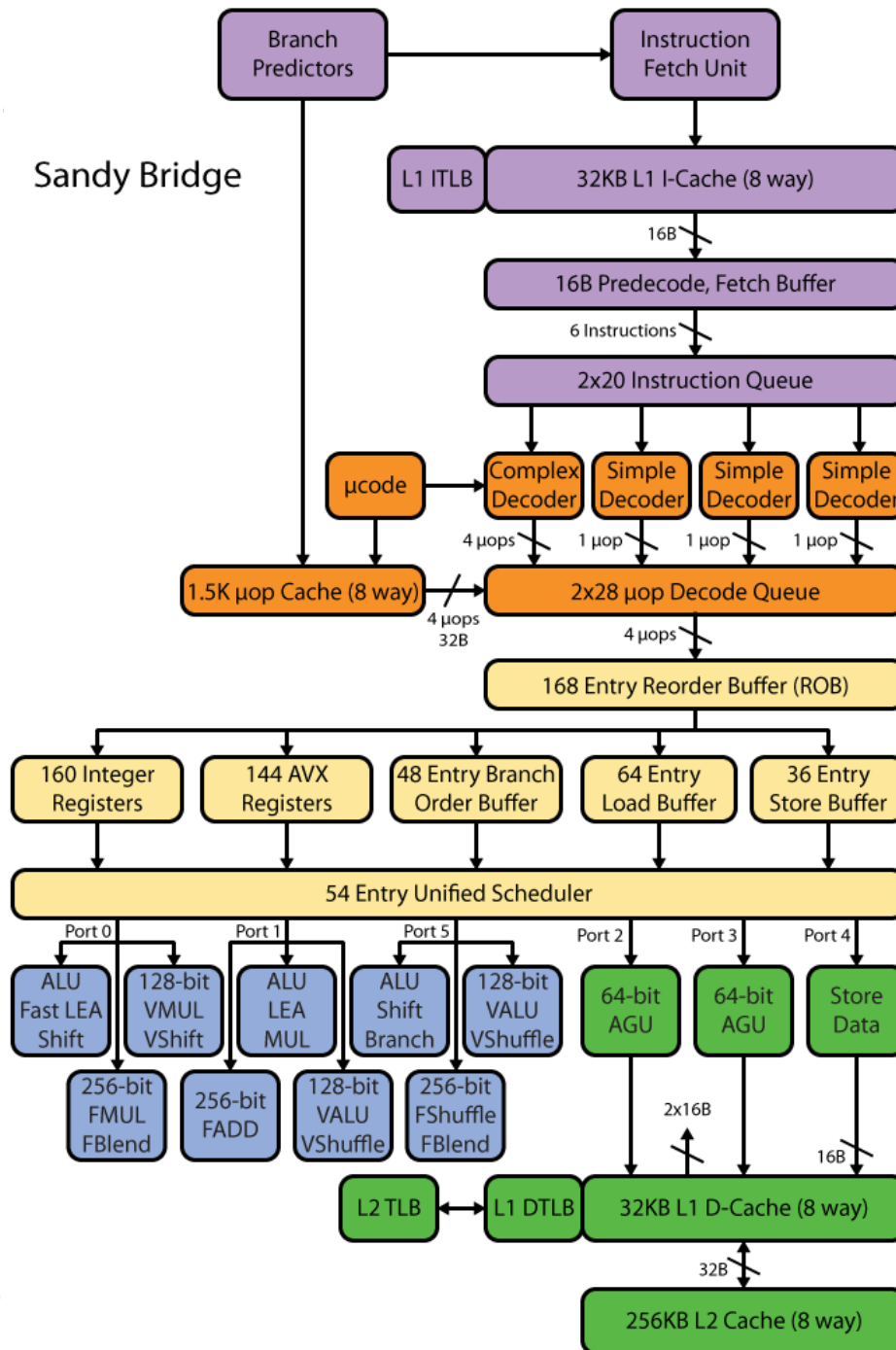


# Intel CPU

## Pentium Die



## Sandy Bridge



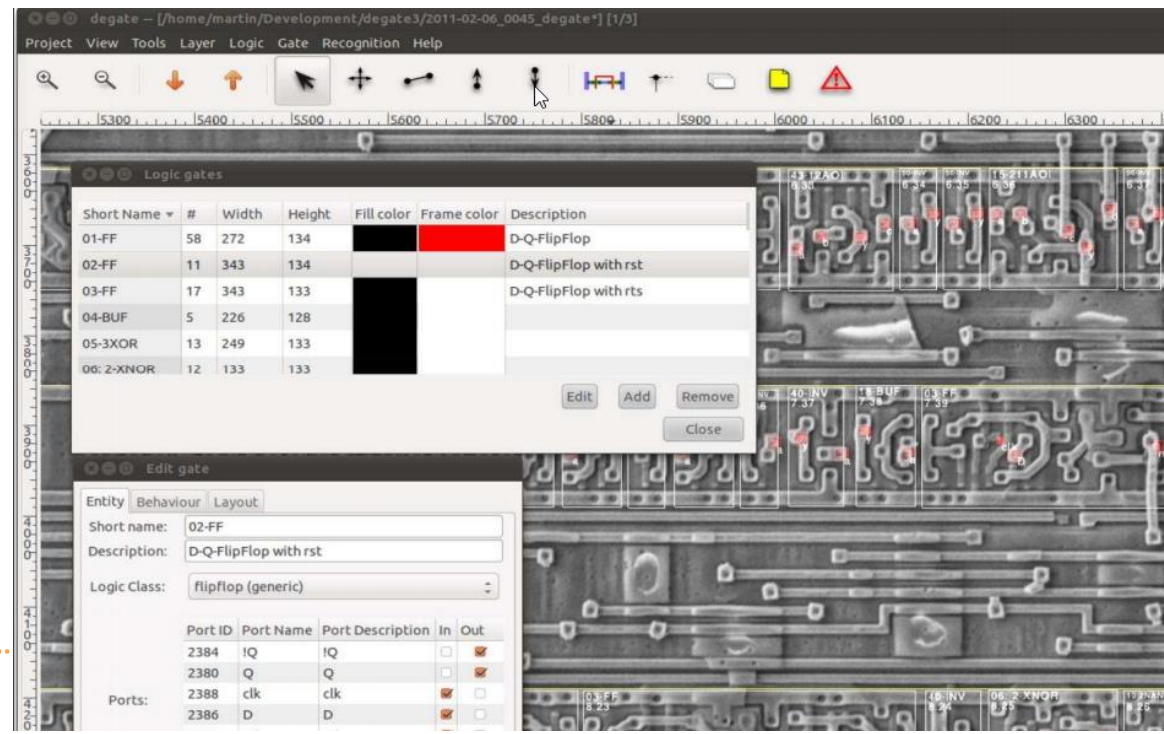
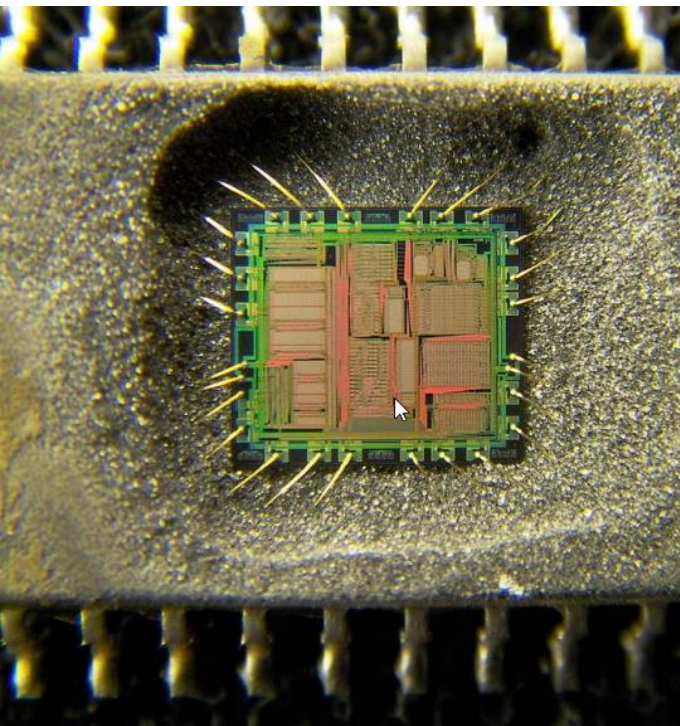


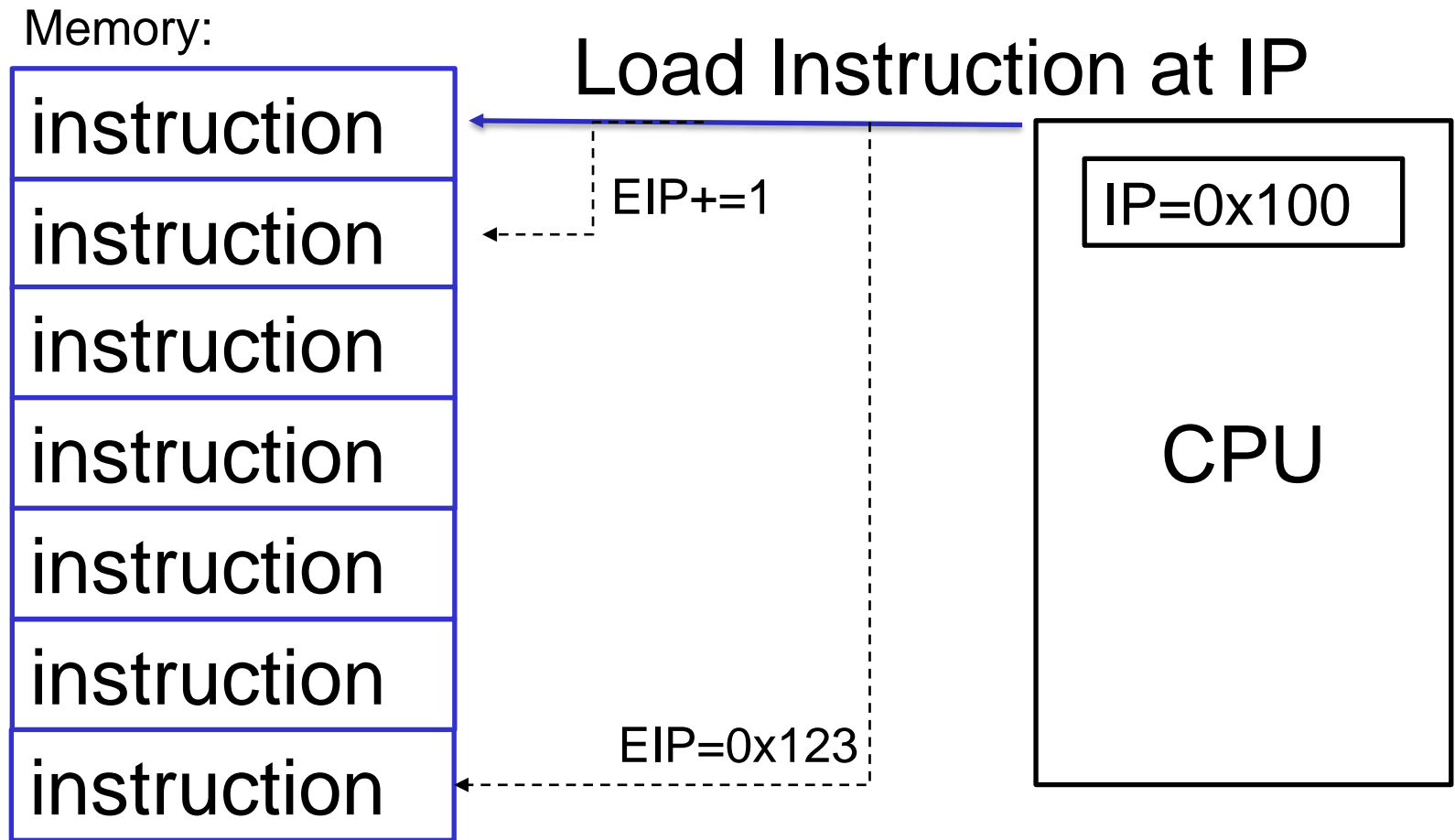
# Intermezzo: Chip De-caping and Analysis

<http://www.bluehatil.com/files/Extracting%20Secrets%20from%20Silicon%20E2%80%93%20A%20New%20Generation%20of%20Bug%20Hunting.pdf>

## Extracting Secrets from Silicon – A New Generation of Bug Hunting

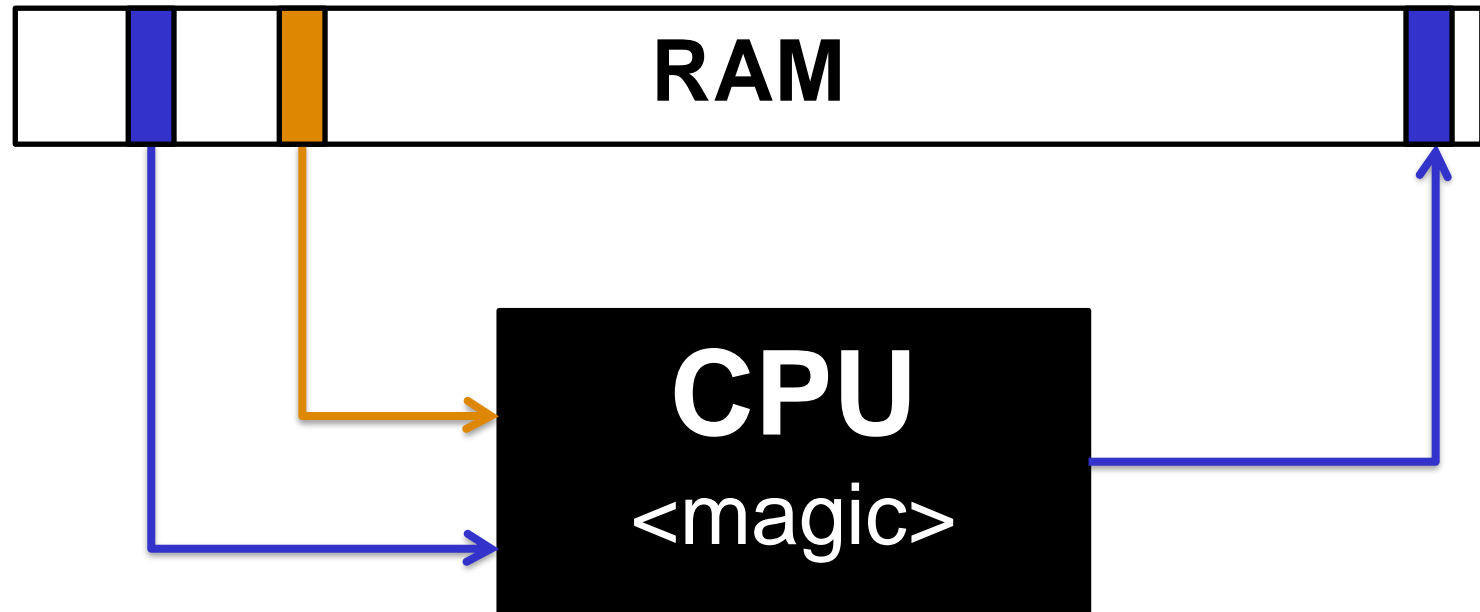
- ✦ Gunter Ollmann, Microsoft
- ✦ Blue Hat Security





## Overview: Computerz

---



Read:

- Data
- Instructions

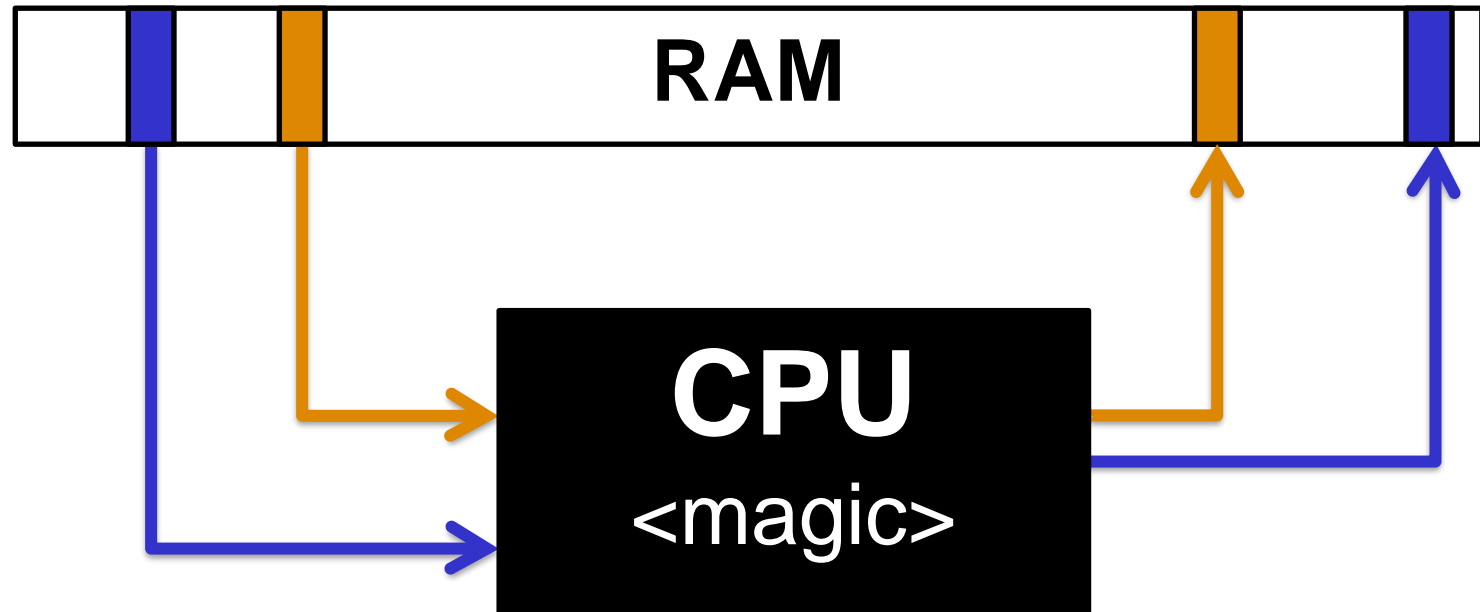
Write:

- Data





## von Neumann Architecture



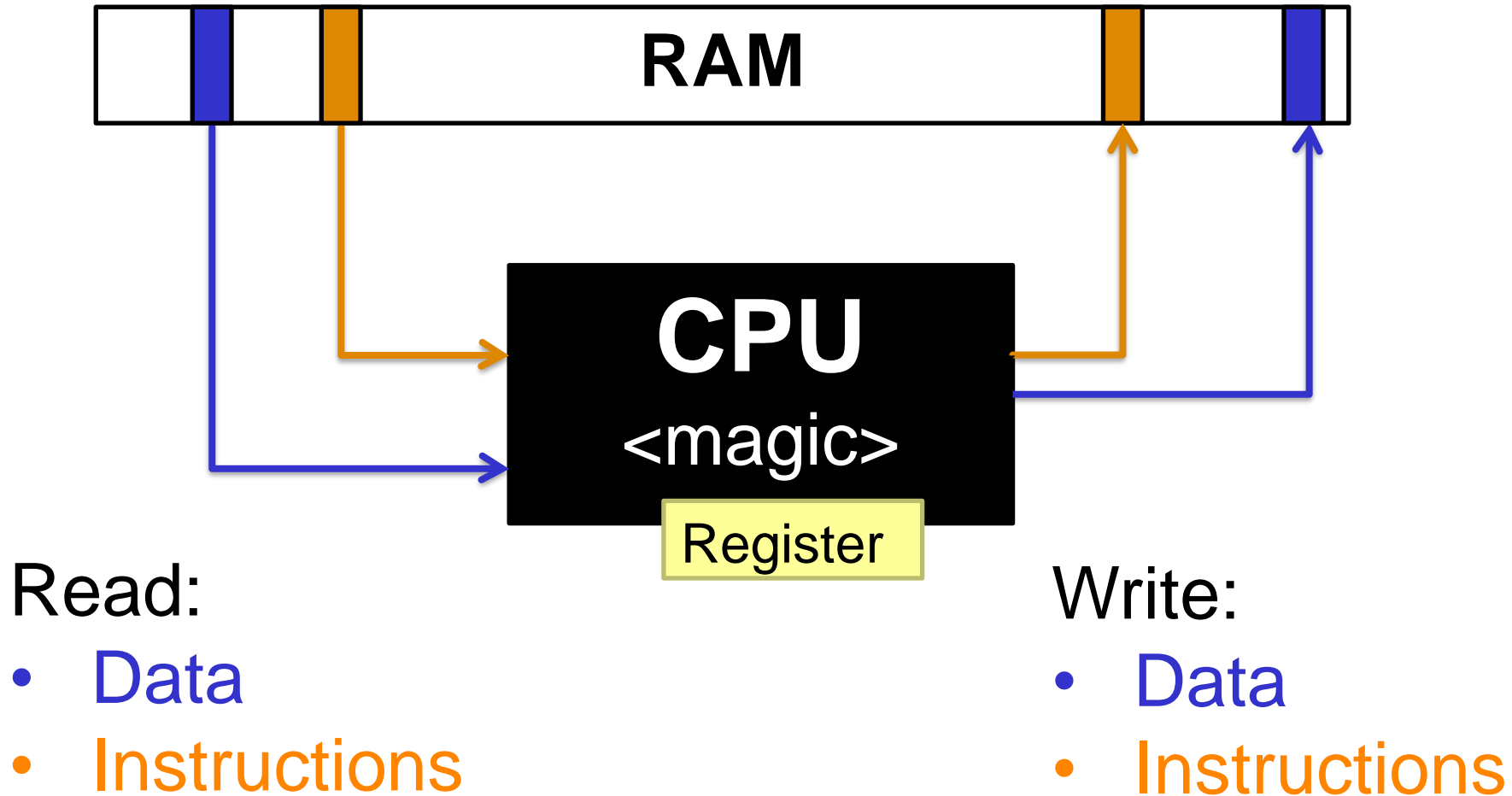
Read:

- Data
- Instructions

Write:

- Data
- Instructions

# Overview: Computerz



## Overview: CPU Registers

---

Register are the “variables” on the CPU

Immediate access for the CPU

Cannot write Memory -> Memory

★ Always: Memory -> Register -> Memory

**Register: <1 cycle**  
**L1: ~3**  
**L2: ~14**  
**RAM: ~240**



## Overview: CPU Register

---

### Register are of a certain size

- ✦ e.g. 64 bit (can hold a number of size 8 bytes)

### Register can hold:

- ✦ Data (numbers)
- ✦ Addresses (also numbers, but with a different meaning)

### Registers can be used to:

- ✦ Perform computations (add, multiply, xor..)
- ✦ Read / Write memory (address in register)
- ✦ Execute instructions (special registers)

## Overview: CPU Registers

32	64	Acronym	What?
EAX	RAX	Accumulator	Adding stuff
EBX	RBX	Base	Referencing stuff
ECX	RCX	Count	Counting stuff
EDX	RDX	Data	Stuff
ESI	RSI	Source Index	Points to a source
EDI	RDI	Destination Index	Points to a destination
	R8-R15		General Purpose



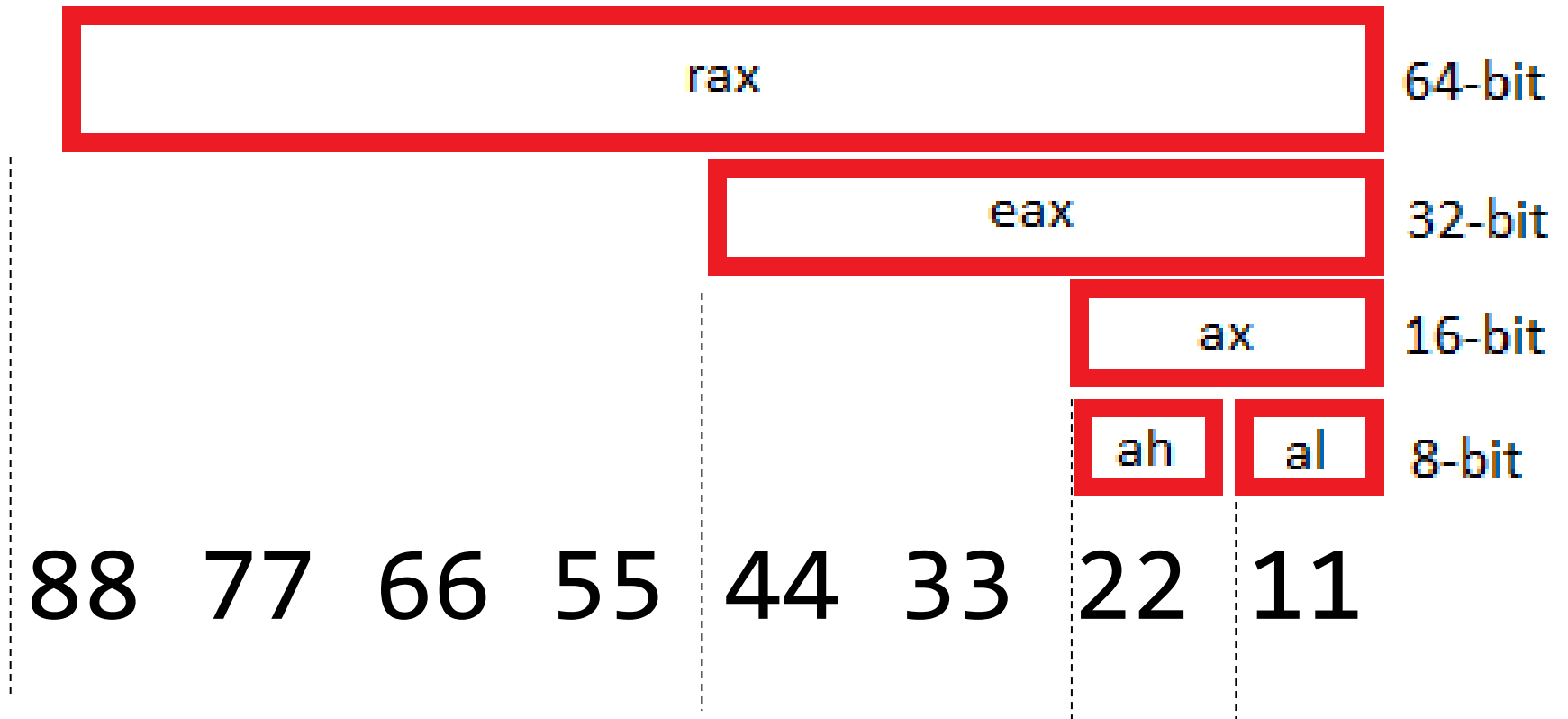
32	64	Acronym	Points to?
EIP	RIP	Instruction Pointer	Next instruction to be executed
ESP	RSP	Stack Pointer	Top of Stack
EBP	RBP	Base Pointer	Current Stack Frame (Bottom)

**Print this slide  
and stick it on your  
bathroom mirror**





# Overview: CPU Registers



# Overview: CPU Registers

Fun Fact: Current Intel CPU's are compatible to the 8086

8086:

- ✦ From 1978
- ✦ 5-10mhz





# Overview: CPU Registers

---

## Recap:

- ✦ CPU work with **registers**
- ✦ Registers can hold **data**
- ✦ Registers can also hold **addresses** of memory locations (to write/read data)
- ✦ They can be 32 bit (**EAX**) or 64 bit (**RAX**)
- ✦ Some registers are multi-purpose
- ✦ Some registers are special (RIP, RBP, RSP)



---

# How a CPU interprets instructions



# CPU Instructions

---

A CPU in a few lines of pseudo code:

```
instr = [ 0x01 0xA0 0xB0 0x02 0xA1 0xA2 .. ]
```

```
ip = 0
```

```
while true:
```

```
    switch instr[ip]:
```

```
        case 0x01:
```

```
            add( instr[ip+1], instr[ip+2] )
```

```
            ip = ip + 3
```

```
            break
```

```
        case 0x02:
```

```
            sub( instr[ip+1], instr[ip+2] )
```

```
        ...
```

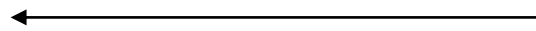


# CPU Instructions

<b>83</b> c4 08	<b>add</b>	\$0x8,%rsp
<b>83</b> c3 01	<b>add</b>	\$0x1,%rbx
<b>83</b> 44 24 0c 01	<b>addl</b>	\$0x1,0xc(%rsp)
<b>83</b> 05 41 94 2c 00 01	<b>addl</b>	\$0x1,0x2c9441(%rip)

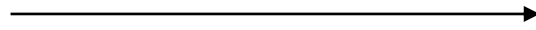
CPU  
Opcodes

Assemble ("compile")



Assembler  
Instructions

Disassemble

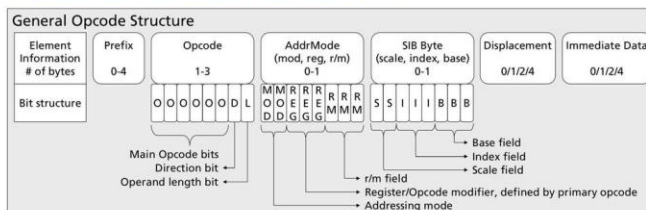


### x86 Opcode Structure and Instruction Overview

2nd 1st	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
0	ADD					PUSH SS	ES SEGMENT OVERRIDE	POP SS	OR					PUSH DS	CS	TWO BYTE	
1	ADC								SBB								
2	AND					ES SEGMENT OVERRIDE	DAA	SUB					CS SEGMENT OVERRIDE	DS	DAS		
3	XOR							CMP								DS	AAS
4	INC							DEC									
5	PUSH							POP									
6	PUSHAD	POPAD	BOUND	ARPL	FS SEGMENT OVERRIDE	GS SEGMENT OVERRIDE	OPERAND SIZE OVERRIDE	ADDRESS SIZE OVERRIDE	PUSH	IMUL	PUSH	IMUL	INS	OUTS			
7	JO	JNO	JB	JNB	JE	JNE	JBE	JA	JS	JNS	JPE	JPO	JL	JGE	JLE	JG	
8	ADD/ADC/AND/XOR OR/SBB/SUB/CMP				TEST		XCHG		MOV REG				MOV SREG	LEA	MOV SREG	POP	
9	NOP	XCHG EAX					CWD		CDQ	CALL	WAIT	PUSHF	POPF	SAHF	LAHF		
A	MOV EAX			MOVS		CMPS		TEST		STOS		LODS		SCAS			
B	MOV																
C	SHIFT IMM		RETN		LES	LDS	MOV IMM		ENTER	LEAVE	RETF		INT3	INT IMM	INTO	IRETD	
D	SHIFT 1		SHIFT CL		AAM		AAD	SALC	XLAT	FPU							
E	ROL/ROR/RL/RR/SHL/SHR/SAL/SAR				AAM		AAD	SALC	XLAT	FPU							
F	LOCK EXCLUSIVE ACCESS	ICE BP	REPNE CONDITIONAL REPETITION	REPE	HLT	CMC	TEST/NOT/NEG (I)MUL/(I)DIV		CLC	STC	CLI	STI	CLD	STD	INC DEC	INC/DEC CALL/JMP PUSH	

2nd 1st	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	(L,S)LDT (L,S)STR VER(R,W)	(L,S)IGDT (L,S)IDT (L,S)MSW	LAR	LSL			CLTS		INVD	WBINVD		UD2		NOP		
1	SSE{1,2,3}								Prefetch SSE1	HINT_NOP						
2	MOV CR/DR								SSE{1,2}							
3	WRMSR	RDTSR	RDMSR	RDPMSR	SYSENTER	SYSEXIT		GETSEC SMX	MOVBE / THREE BYTE		THREE BYTE SSE4					
4	CMOV															
5	SSE{1,2}															
6	MMX, SSE2															
7	MMX, SSE{1,2,3}, VMX													MMX, SSE{2,3}		
8	JO	JNO	JB	JNB	JE	JNE	JBE	JA	JS	JNS	JPE	JPO	JL	JGE	JLE	JG
9	Jcc SHORT															
	SETO	SETNO	SETB	SETNB	SETE	SETNE	SETBE	SETA	SETS	SETNS	SETPE	SETPO	SETL	SETGE	SETLE	SETG
A	SETcc															
	PUSH FS	POP FS	CPUID	BT	SHLD				PUSH GS	POP GS	RSM	BTS	SHRD		*FENCE	IMUL
B	CMPXCHG	LSS	BTR	LFS	LGS	MOVZX		POPCNT	UD	BT BTS BTR BTC		BTC	BSF	BSR	MOVSB	
C	XADD		SSE{1,2}				CMPXCHG		BSWAP							
D	MMX, SSE{1,2,3}															
E	MMX, SSE{1,2}															
F	MMX, SSE{1,2,3}															

Arithmetic & Logic	Prefix
Memory	System & I/O
Stack	No Operation (NOP) / Multiple Instructions / Extended Instruction Set
Control Flow & Conditional	



Addressing Modes

mod	00	01	10	11
r/m	16bit	32bit	16bit	32bit
000	[BX+SI]	[EAX]	[BX+SI+disp8]	[EAX+disp32]
001	[BX+DI]	[ECX]	[BX+DI+disp8]	[ECX+disp32]
010	[BP+SI]	[EDX]	[BP+SI+disp8]	[EDX+disp32]
011	[BP+DI]	[EBX]	[BP+DI+disp8]	[EBX+disp32]
100	[SI]	[SI]	[SI+disp8]	[SI+disp32]
101	[DI]	[DI]	[DI+disp8]	[DI+disp32]
110	[disp16]	[ESI]	[ESI+disp8]	[ESI+disp32]
111	[disp16]	[EDI]	[EDI+disp8]	[EDI+disp32]

SIB Byte Structure

encoding	scale (2bit)	Index (3bit)	Base (3bit)
000	2 <sup>0</sup> =1	[EAX]	EAX
001	2 <sup>1</sup> =2	[ECX]	ECX
010	2 <sup>2</sup> =4	[EDX]	EDX
011	2 <sup>3</sup> =8	[EBX]	EBX
100	---	none	ESP
101	---	[EBP]	disp32 / disp16 / disp8 / ESP
110	---	[ESI]	ESI
111	---	[EDI]	EDI

SIB value = index \* scale + base

# CPU Instructions

## Add

Opcode	Mnemonic	Description
04 ib	ADD AL, imm8	Add imm8 to AL
05 iw	ADD AX, imm16	Add imm16 to AX
05 id	ADD EAX, imm32	Add imm32 to EAX
80 /0 ib	ADD r/m8, imm8	Add imm8 to r/m8
81 /0 iw	ADD r/m16, imm16	Add imm16 to r/m16
81 /0 id	ADD r/m32, imm32	Add imm32 to r/m32
83 /0 ib	ADD r/m16, imm8	Add sign-extended imm8 to r/m16
83 /0 id	ADD r/m32, imm8	Add sign-extended imm8 to r/m32
00 /r	ADD r/m8, r8	Add r8 to r/m8
01 /r	ADD r/m16, r16	Add r16 to r/m16
01 /r	ADD r/m32, r32	Add r32 to r/m32
02 /r	ADD r8, r/m8	Add r/m8 to r8
03 /r	ADD r16, r/m16	Add r/m16 to r16
03 /r	ADD r32, r/m32	Add r/m32 to r32

### Description

Adds the first operand (destination operand) and the second operand (source operand) and stores the result in the destination operand. The destination operand can be a register or a memory location; the source operand can be an immediate, a register, or a memory location. (However, two memory operands cannot be used in one instruction.) When an immediate value is used as an operand, it is sign-extended to the length of the destination operand format.

The ADD instruction performs integer addition. It evaluates the result for both signed and unsigned integer operands and sets the OF and CF flags to indicate a carry (overflow) in the signed or unsigned result, respectively. The SF flag indicates the sign of the signed result.

This instruction can be used with a LOCK prefix to allow the instruction to be executed atomically.

### Operation

$\text{Destination} = \text{Destination} + \text{Source};$

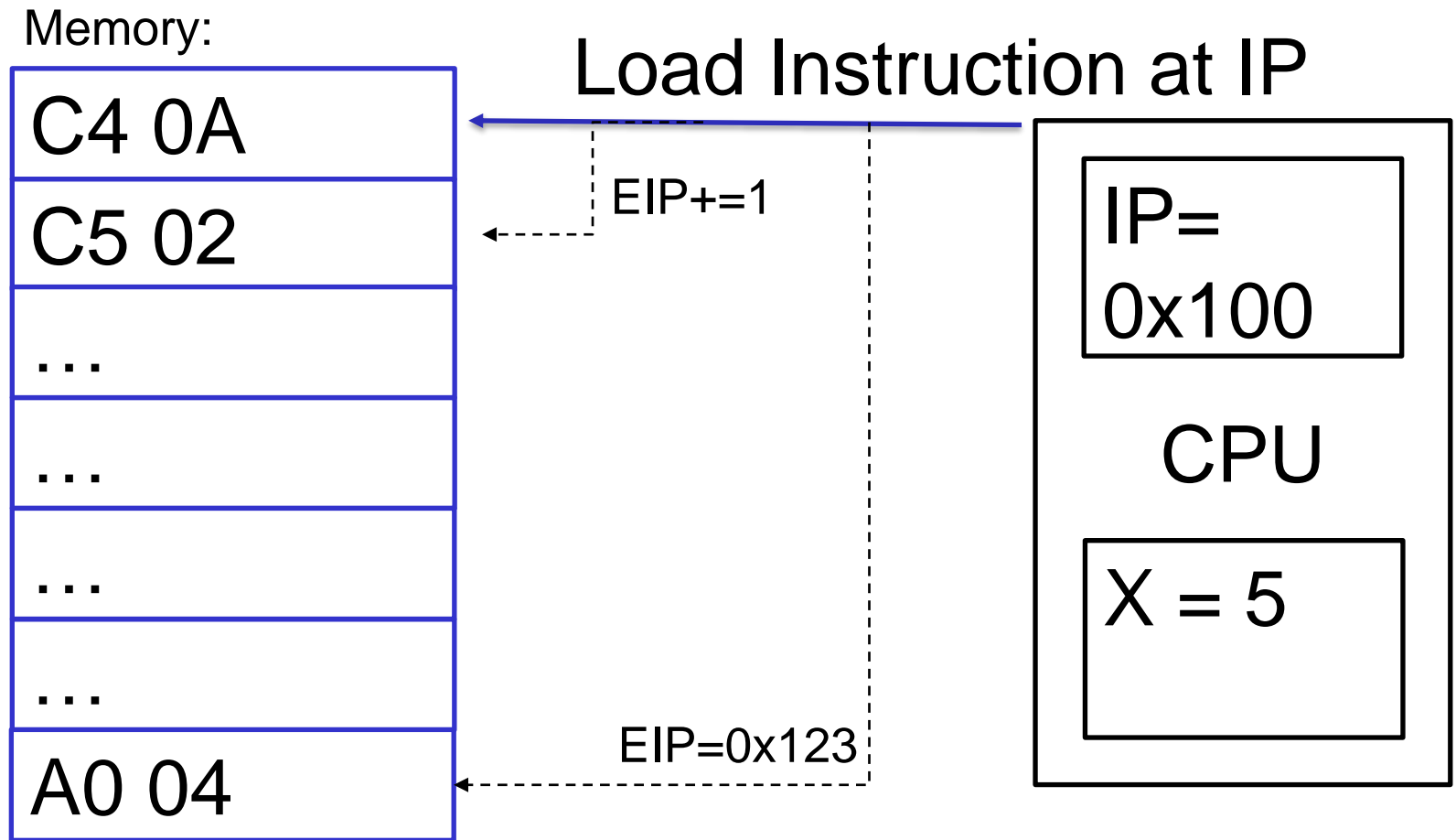




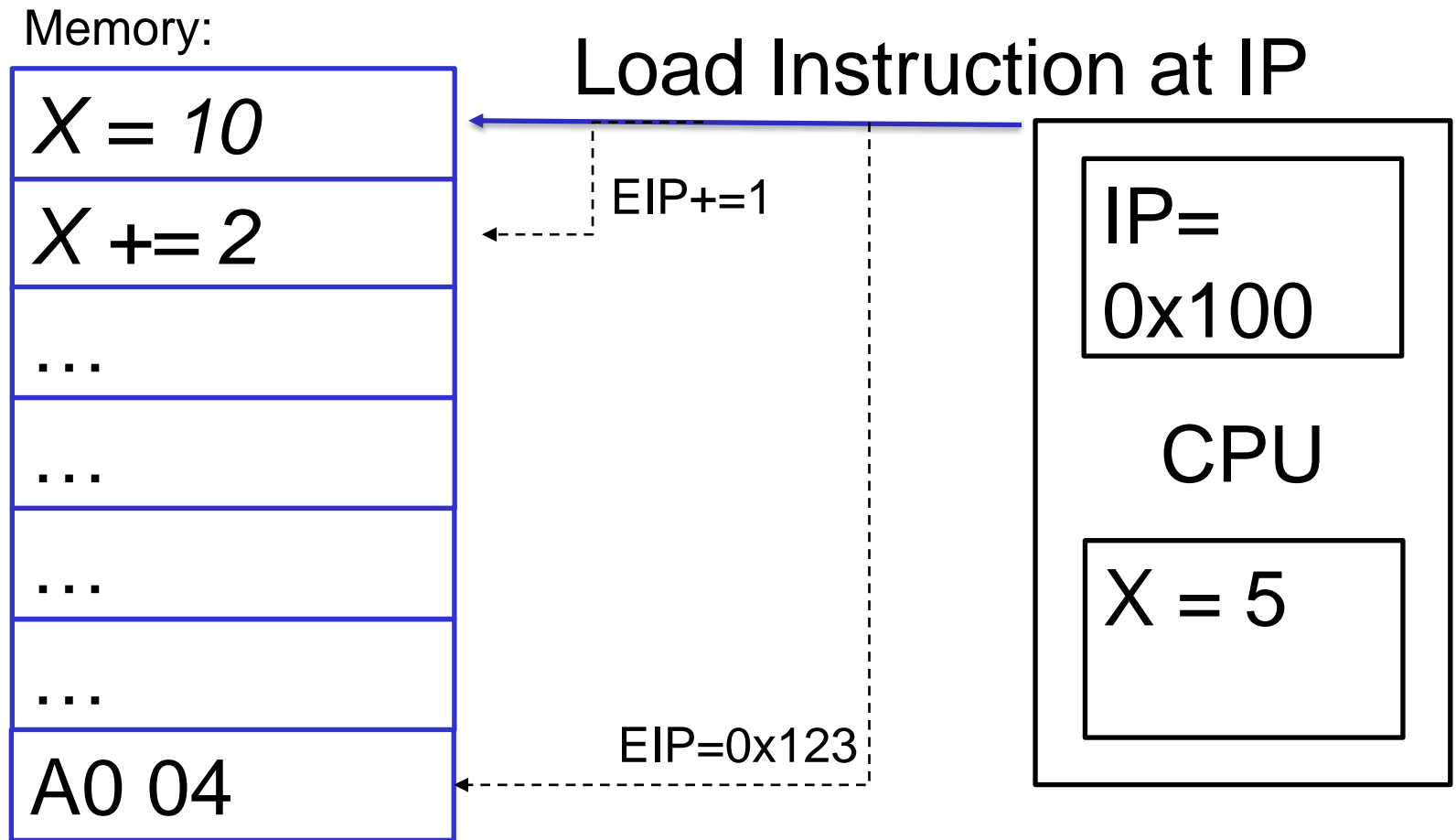
## Recap:

- ★ CPU looks at bytes, and then decides what to execute (“do”) based on them

# Overview: Computerz



# Overview: Computerz



---

# Hex Numbers, and Little Endian

A guide to understand the rest of my slides



# Hex Numbers, and Little Endian

---

## Intel CPU's

- ★ 1 Byte = 8 Bit
- ★ Little endian



# Hex Numbers, and Little Endian

---

How many bits in a byte?

Intel CPU's

- ★ 1 Byte = 8 Bit
- ★ Little endian

Others:

- ★ CDC 6000: 18, 24 and 60 bit
- ★ PDP1/9/15: 18 bit words
- ★ Apollo Guidance Computer: 15 bit
  
- ★ ARM and other RISC: 8 bit Bytes, but in Big Endian

# Decimal Numbers

---

**Decimal: 0 1 2 3 4 5 6 7 8 9**

*1 decimal digit: 10 values*

*2 decimal digits: 100 values*

$$10 * 10 = 100$$



# Hex Numbers

---

**Hex: 0 1 2 3 4 5 6 7 8 9 A B C D E F**

*1 hex digit: 16 values (4 bit,  $2^4$ )*

*2 hex digits: 256 values (8 bit,  $2^8 = 2^4 * 2^4$ )*

$$16 * 16 = 256$$

1 Byte = 8 Bit = 256 values!

# Hex numbers

0x00 = 0

0x01 = 1

0x0f = 15

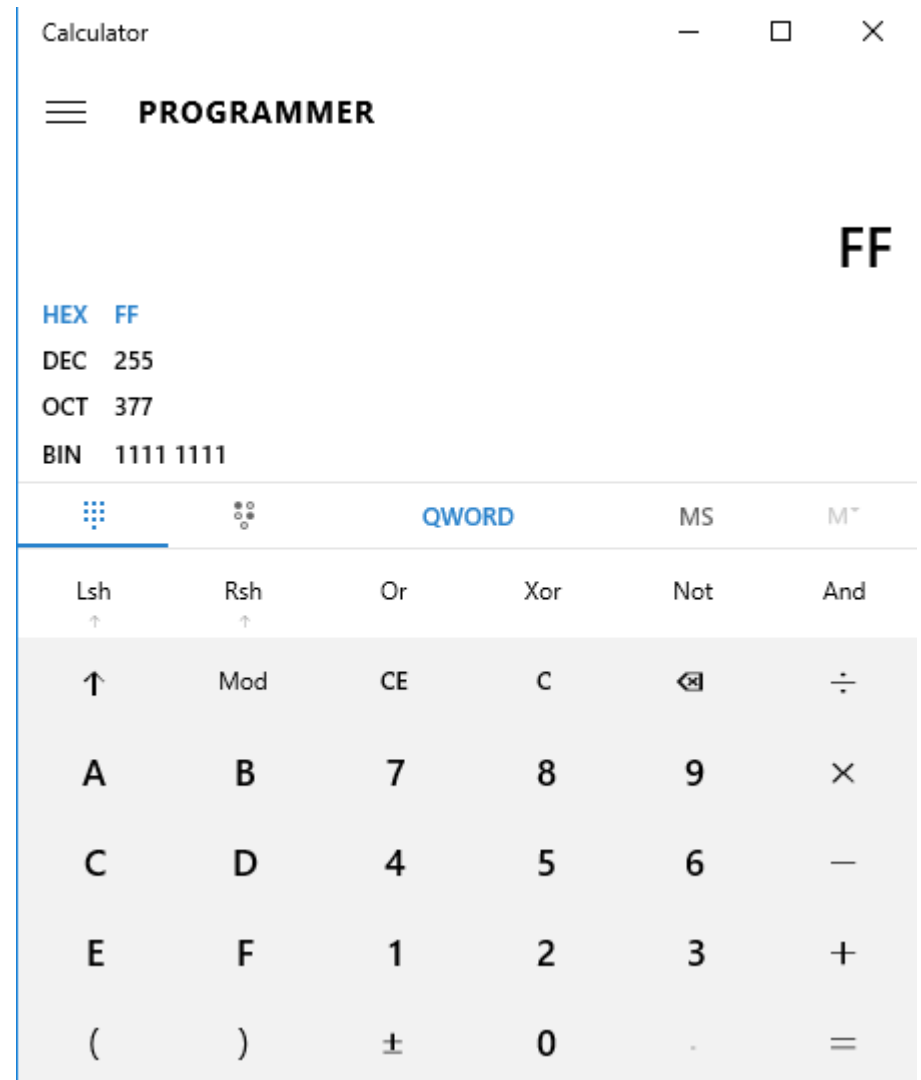
0x10 = 16

0x11 = 17

0x20 = 32

0xf0 = 240

0xff = 255



# Hex Numbers

---

**Base 10**

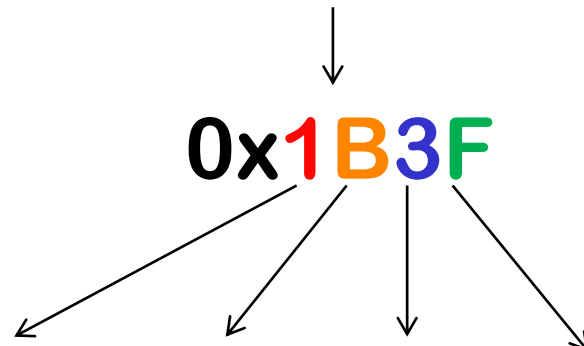
**6975**

**Base 16**

**0x1B3F**

**Nibbles**

**0001 1011 0011 1111**





# Hex Numbers

**Base 10**

**6975**

**Base 16**

**0x1B3F**

**Nibbles**

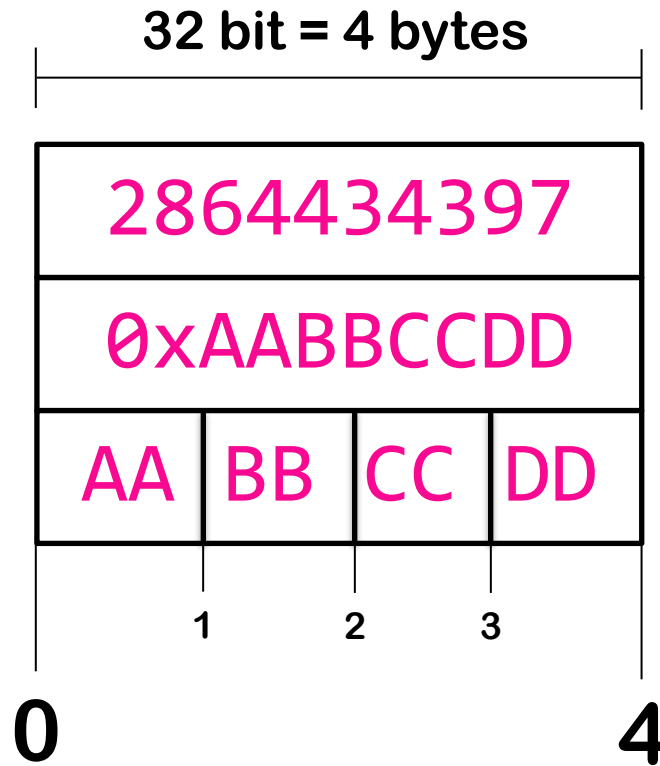
**0001 1011 | 0011 1111**

**Bytes**

**0x1B**

**0x3F**

## Endianness: Big Endian (ARM)



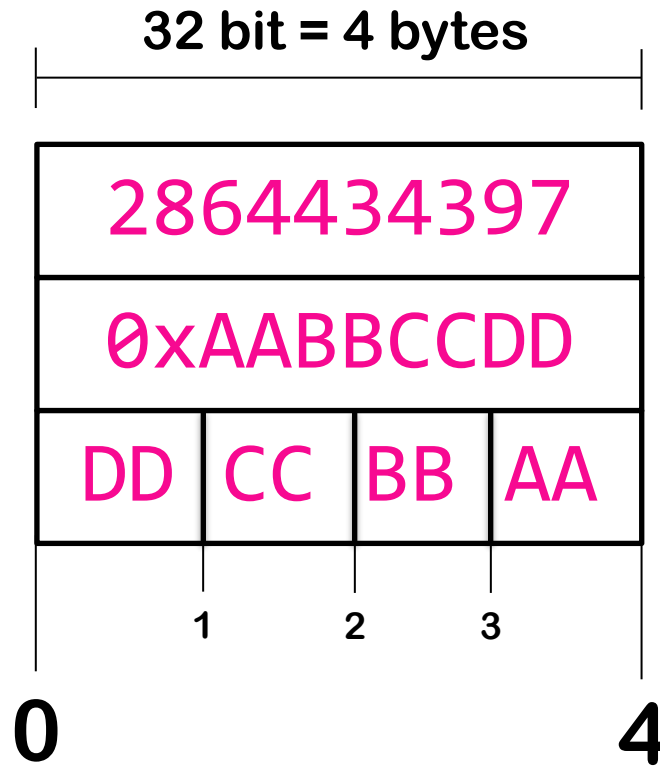
Number in Decimal (10)

Number in Hex (16)

**Big Endian Storage**



## Endianness: Little Endian (Intel)



Number in Decimal (10)

Number in Hex (16)

**Little Endian Storage**



# Endianness

Number: 0x1B3F

Big Endian: 0x1B 0x3F -> 0x1B3F

Little Endian: 0x3F 0x1B -> 0x3F1B

```
f0 32 7d 60 95 48 d0 62 08 80 4b 67 b4 4a 21 dc
80 3f 6c dd 4a f5 a3 d4 ce 32 8d e4 21 d7 a5 5a
92 93 4b f1 ca 0a ce 3c b9 14 20 a5 00 a4 4a 3e
bd 4b 8c b4 d1 90 2b 25 a9 c8 f4 c8 10 85 fb d6
fc 2a 1f c6 8a 7f 25 e7 47 f4 95 01 e2 d7 82 fe
22 95 fa 8e 49 e4 50 98 d3 84 95 a7 97 1d 97 92
25 32 9f 90 0c a9 07 73 c2 2b 49 06 4c 1a 26 69
b2 75 3e 20 db 65 bf 22 68 cf 29 1b 8a 65 8d 54
91 ba 33 f3 05 59 07 39 cd 43 96 6f 5d 88 bb 7a
22 20 d7 04 b1 c6 22 75 8c 60 f3 c7 70 73 af 66
```

# We don't know what type the bytes in memory are



Four 8 bit numbers:

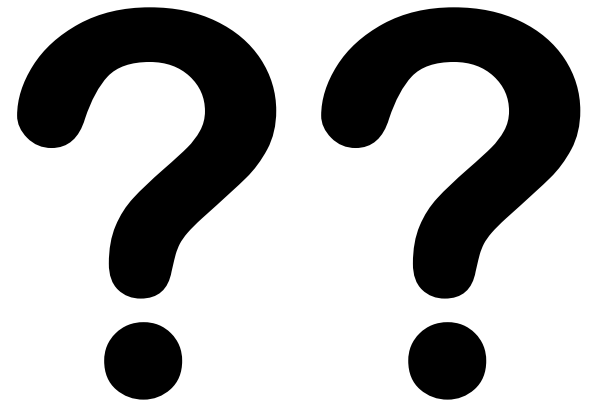
- ★ DD
- ★ CC
- ★ BB
- ★ AA

Two 16 bit numbers:

- ★ 0xCCDD
- ★ 0xAABB

A 32 bit number:

- ★ 0xAABBCCDD





Number:

0x1122334455667788

Little Endian:

88	77	66	55	44	33	22	11
0	1	2	3	4	5	6	7

## Numbers in memory

0	0x11223344
4	0x55556666
8	0x77778888

**32 bit = 4 bytes**

**32 bit = 4 bytes**

**32 bit = 4 bytes**

## Numbers in memory

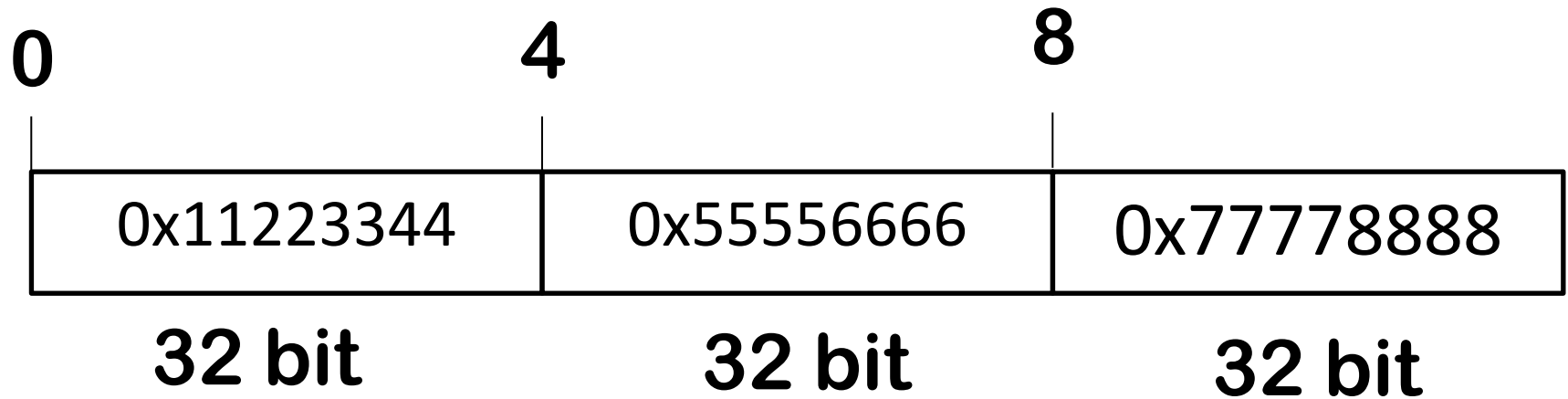


0	0x11223344
4	0x55556666
8	0x77778888

**32 bit = 4 bytes**

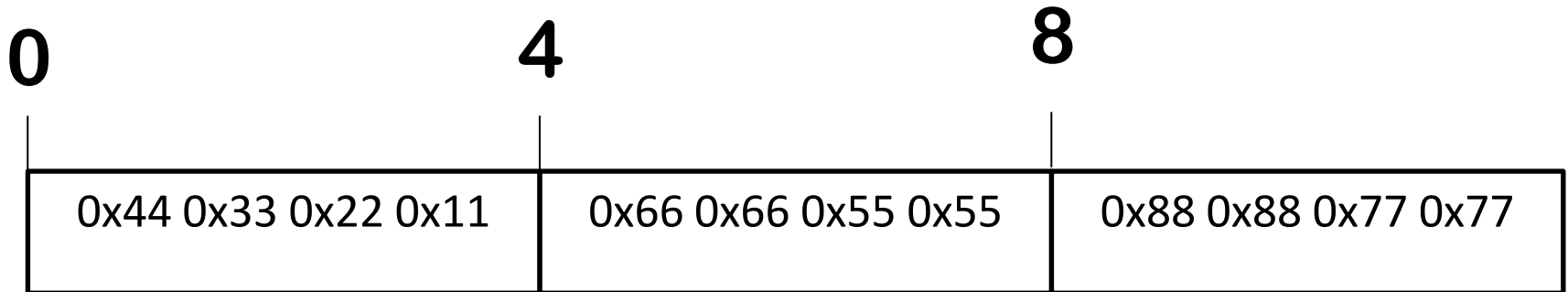
**32 bit = 4 bytes**

**32 bit = 4 bytes**

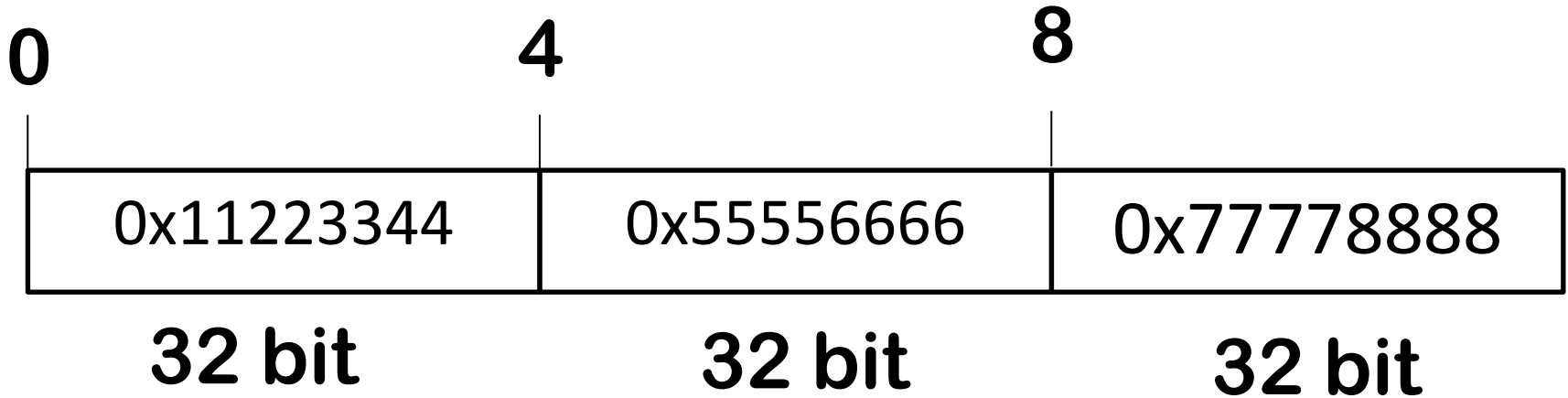




**In memory:**



**For humans:**



# ASCII TABLE

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]

# ASCII - Hexdump

```
0008b400  25 00 e9 cc fd ff ff 66 0f 1f 84 00 00 00 00 00  |%.f.....|
0008b410  e8 2b 21 01 00 e9 c4 fe ff ff 66 0f 1f 44 00 00  |.+!.....f..D..|
0008b420  44 3b 2d f1 fe 25 00 0f 8f 5f fe ff ff 8b 05 d5  |D;-..%..._.....|
0008b430  fe 25 00 3b 05 fb fd 25 00 0f 8d 4d fe ff ff 83  |.%.;...%...M....|
0008b440  c0 01 89 05 c0 fe 25 00 e9 3f fe ff ff 0f 1f 00  |.....%..?.....|
0008b450  41 57 41 56 41 55 49 89 fd 41 54 55 53 48 83 ec  |AWAVAUI..ATUSH..|
0008b460  08 8b 1d cd fd 25 00 8b 6f 20 8d 43 01 4c 63 e3  |.....%..o .C.Lc.|
0008b470  89 ef 89 2d b8 dd 25 00 89 05 b6 fd 25 00 48 8b  |...-..%.....%.H.|
```



# Numbers in memory

---

## Recap:

- ★ Numbers can be displayed in decimal, or hex (0-9, a-f)
- ★ Numbers are stored as 16, 32 or 64 bit values, mostly as little endian
- ★ If we look at little endian numbers as bytes, they are reversed
- ★ If we look at numbers in memory, we can't know if they are 8, 16, 32 or 64 bit
- ★ We can try to interpret bytes as ASCII



# Numbers test!

---

$0x07 + 0x07 = ?$

$0x0a + 0x0a = ?$

$0x22 - 0x10 = ?$

$0x22 - 0x0a = ?$

$0x\ 0b\ b4\ c0\ 0d$  in little endian = ????

ASCII  $0x42\ 0x46\ 0x48 = \text{«}???\text{»}$

The string «leet» in ASCII =  $0x??\ 0x??\ 0x??\ 0x??$

---

# Operating System Basics



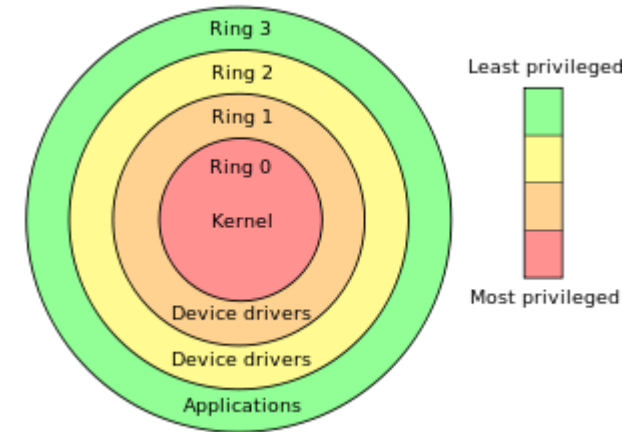
# OS Basics: Rings

## Ring 0: Kernel (Kernelspace)

- ✦ Not covered here
- ✦ Can be interacted with by using “syscalls”

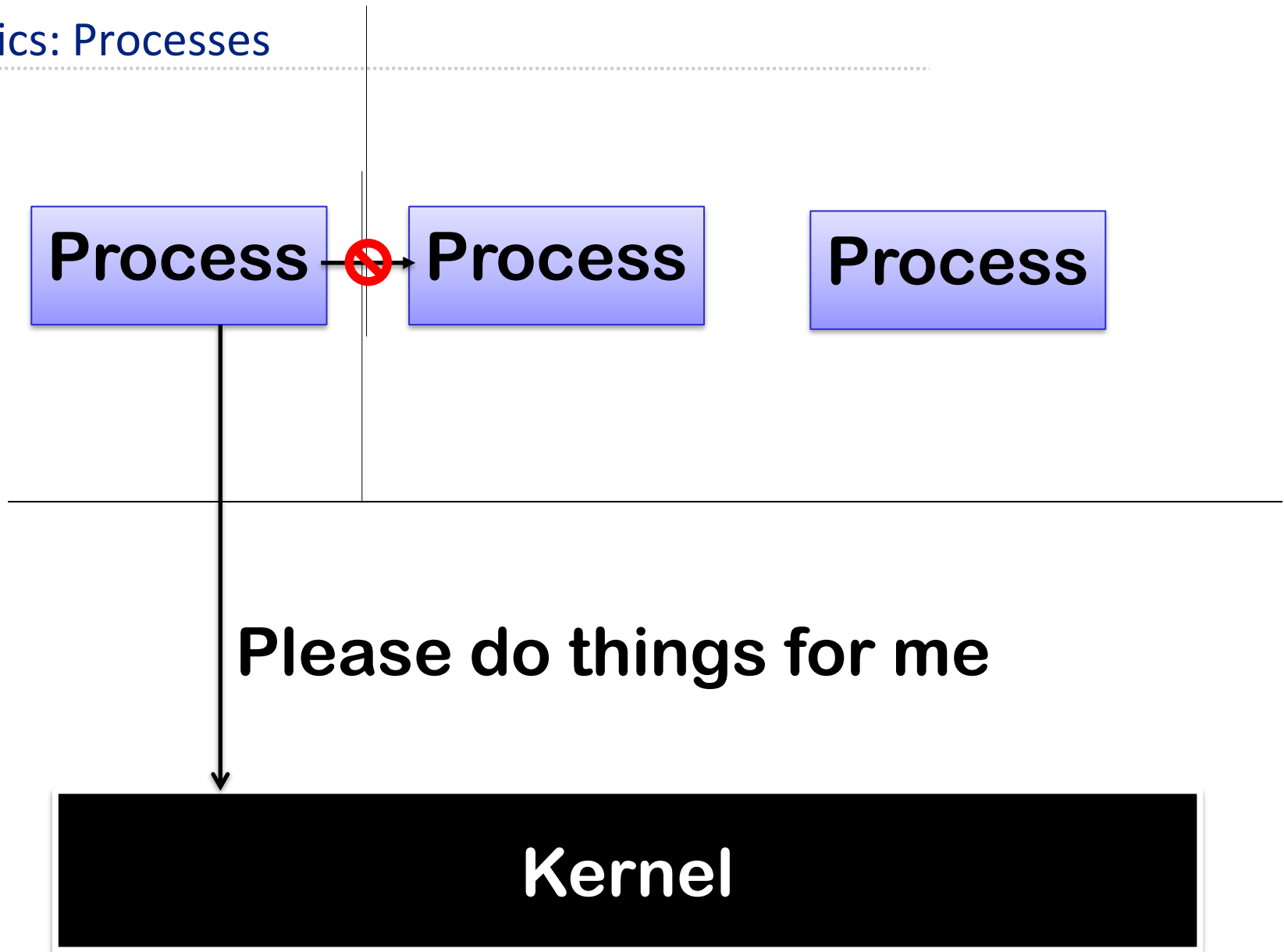
## Ring 3: Userspace

- ✦ Where all programs run
- ✦ ls, Bash, Vim, Apache, Xorg, Firefox, ...



## How to transit from userspace to kernelspace?

- ✦ System Calls (syscall)





## A Process:

- ✦ Is a **running** program
  - ✦ Program lives on disk (static, dead)
  - ✦ Process lives in memory (interpreted, alive)
- ✦ Process thinks he “owns” the hardware
  - ✦ RAM
  - ✦ CPU

## Multiple processes can run simultaneously

- ✦ Everyone thinks he is the only one
- ✦ Like Kanye West

## A Process:

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**I AM THE NUMBER ONE  
HUMAN BEING IN MUSIC.  
THAT MEANS ANY PERSON  
THAT'S LIVING OR BREATHING  
IS NUMBER TWO.**

- KANYE WEST

## Processes can address:

- ★ **4 GB of memory** in 32bit OS
  - ★ (2-3 GB actually)
- ★ Independent on how much memory (RAM) there really is

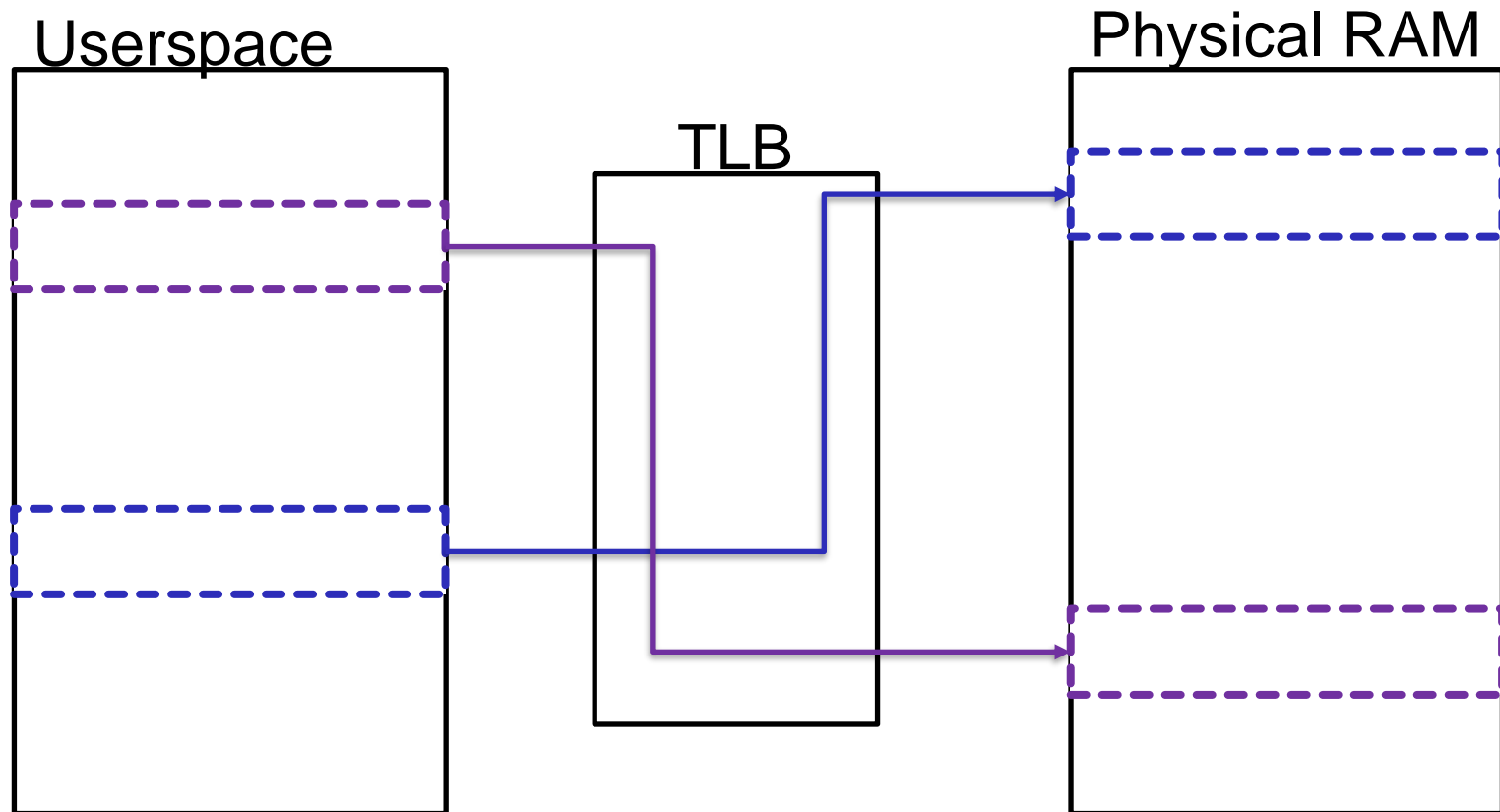
## What if we have:

- ★ Only 2 GB RAM?
  - ★ OOM (Out Of Memory) when too much memory is used
- ★ 8 GB RAM?
  - ★ 2 Processes can use all their 4GB!



## OS Basics – Kernel-space/Userspace

OS/CPU manages mapping between physical pages and process (virtual) pages – called **paging**

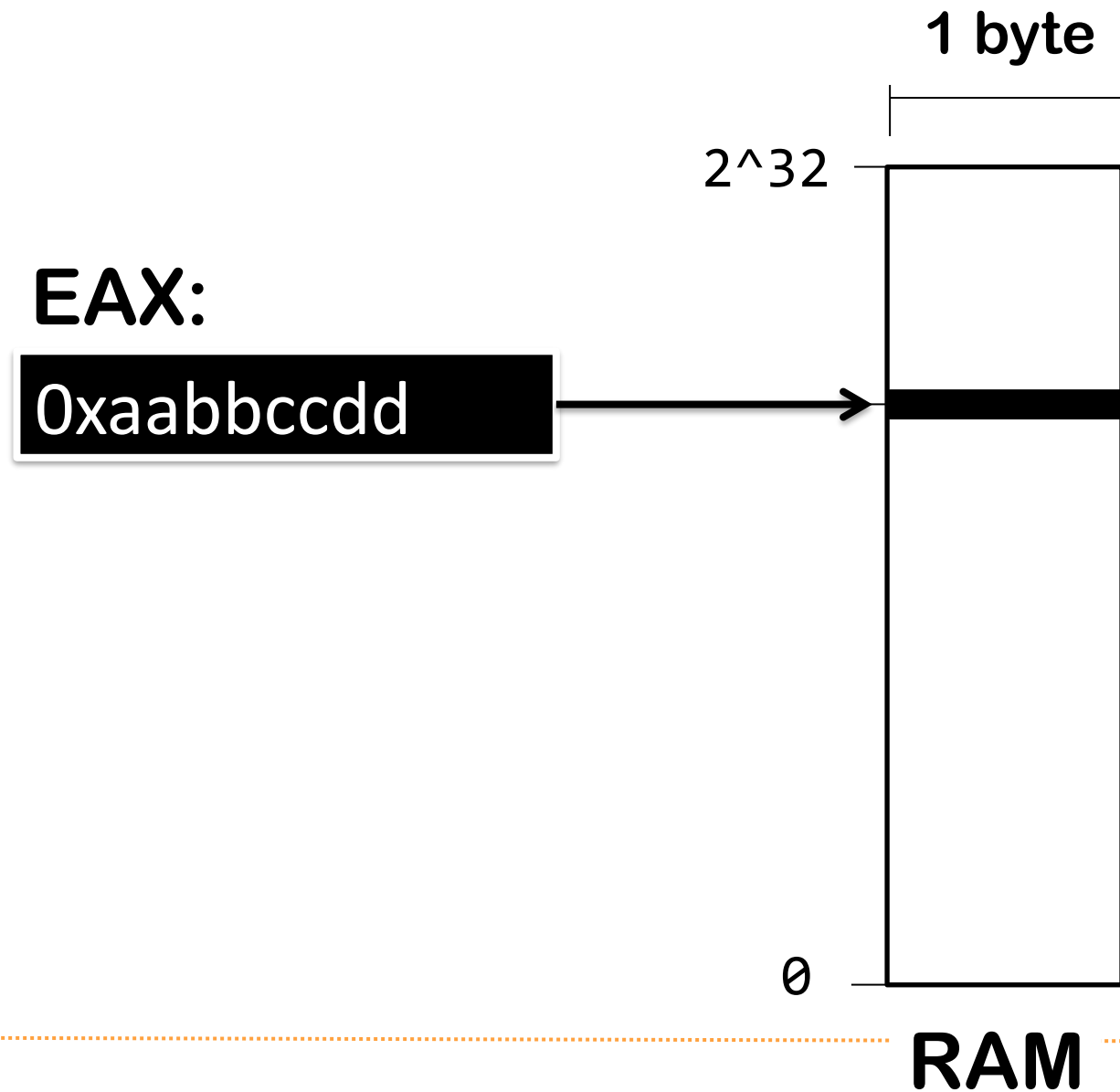


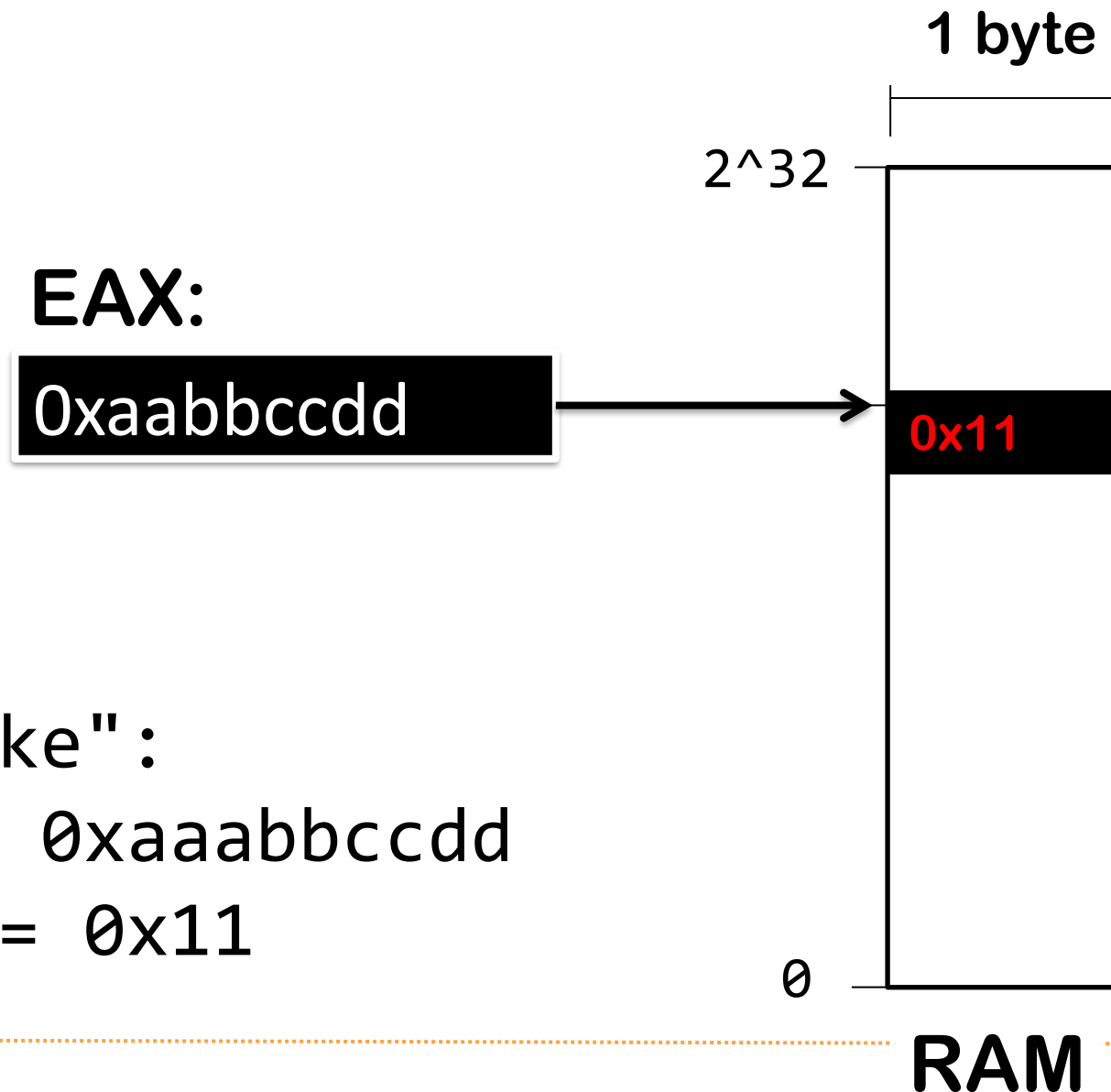


### Why 4 GB?

- ★ 32 bit register size in Intel CPU
- ★ Register are used to address memory
- ★  $2^{32} = 4 \text{ billion} = 4 \text{ gigabyte}$

A process has therefore access to **4 billion one-byte** memory locations



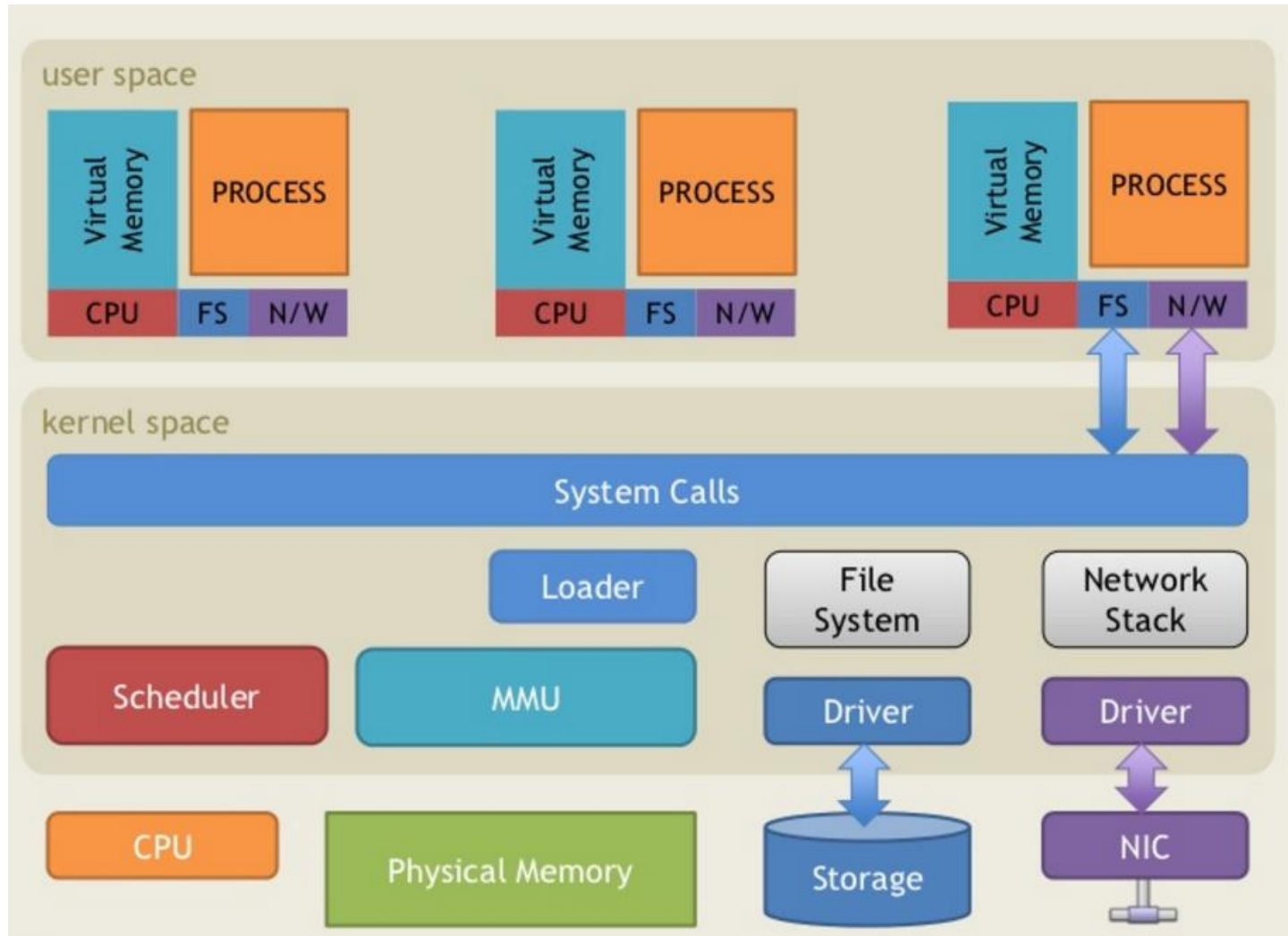


"C like":

```
eax = 0xaaabbccdd
```

```
*eax = 0x11
```

# OS Overview

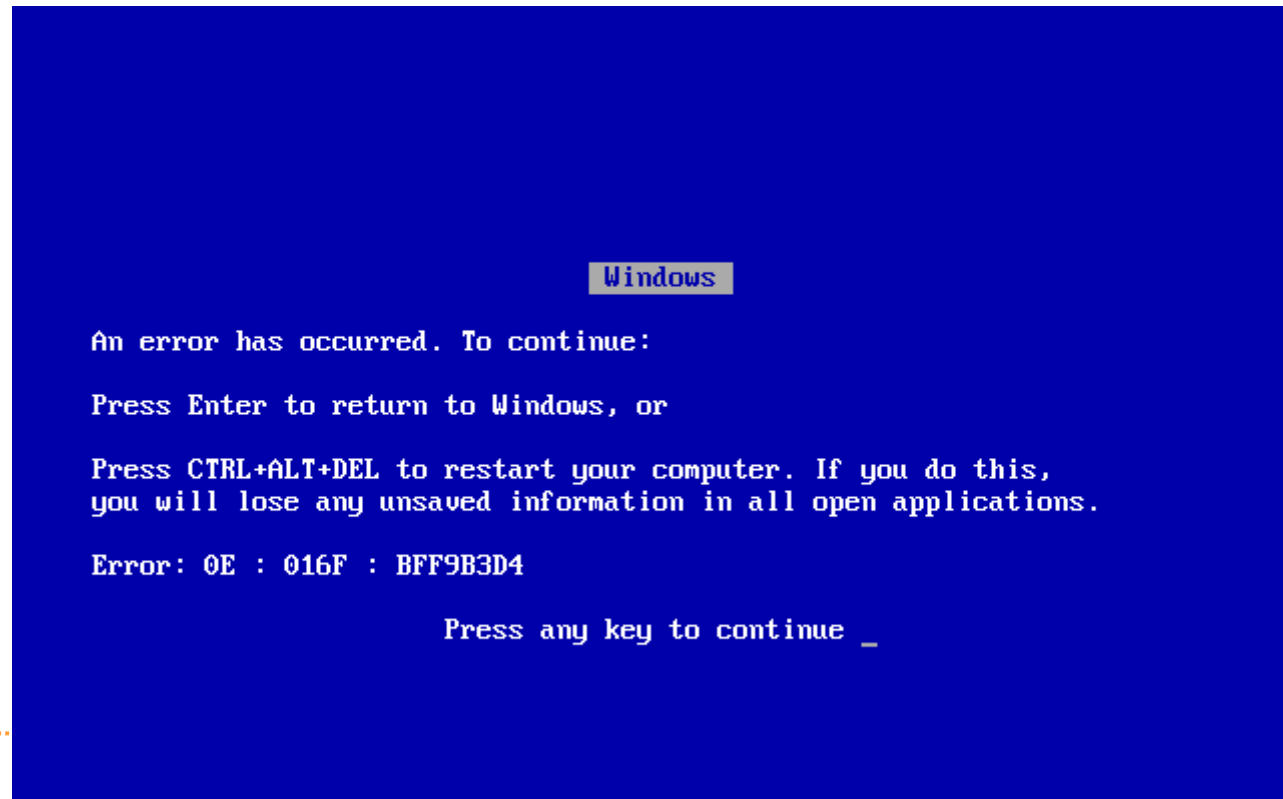


<http://www.slideshare.net/saumilshah/operating-systems-a-primer>

# OS Overview

## History lesson: “The good old times”

- ✦ Windows did not have true protected memory until windows NT/2000
  - ✦ Including all of DOS, Windows 3.1, Windows 95, 98, ME
- ✦ Every process could write into all other processes, or even the OS
- ✦ “Blue screen of death”



There's only one CPU, how can:

- ✦ Multiple programs run at the same time?
- ✦ The OS and the programs run at the same time?

Solution: Interrupts

- ✦ Timer interrupts
- ✦ Interrupts are handled by the kernel "callbacks"
  - ✦ Time / clock
  - ✦ Network interface
  - ✦ USB devices
- ✦ Kernel schedules the different processes





## Recap:

- ✦ Processes are programs which are alive in the RAM
- ✦ Every process thinks he owns the computer (including all the RAM)
- ✦ Every process has access to  $2^{32}$  (~4 billion) memory locations of 1 byte size

---

## 32 bit vs 64 bit

*This chapter may expect some know-how from later chapters  
its more like a reference*

# 32bit vs 64bit

---

## From 32 to 64 bit

- ★ You all are probably too young for this
- ★ But it was kinda big thing
- ★ AMD invented the current 64 bit architecture
  - ★ Intel wanted a new one: Itanium. Failed hard.
  - ★ (AMD was better than Intel in many respects back then. Sigh).
- ★ x86 to x64/amd64
  - ★ 8086, 80286, 80386, 80486, 80586 aka Pentium
- ★ “Is windows 64 bit twice as good/fast than windows 32 bit?”
  - ★ Width of the CPU registers define the amount of addressable memory

# 32bit vs 64bit

---

## 64 bit pros:

- ★ Can address more than 4 gb of memory per computer
  - ★ 18'446'744'073'709'551'616 bytes theoretically
- ★ 64 bit calculations are maybe a bit faster

## 64 bit cons:

- ★ Programs use more space
  - ★ Because pointers and data-types (integer) are twice as big
  - ★ On disk, memory and most importantly: cache

## 32bit vs 64bit

---

64 bit registers are prefixed with “R” (RAX, RIP, ...)

New registers: R8-R15

Pointers are 64 bit

Push/Pop are 64 bit

## 32bit vs 64bit

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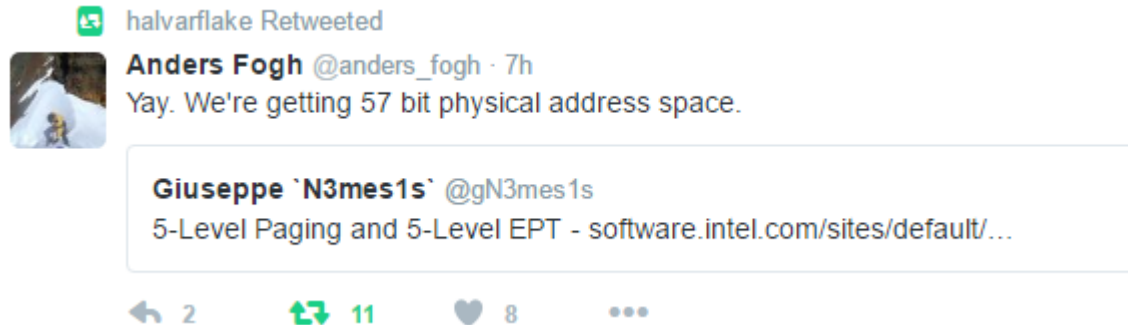
### For 64 bit:

- ✦ 64 bit are 18 exabytes
- ✦ Only 47 bit are used (=140 terabytes)
- ✦ < 0x00007fffffffffffff

# 32bit vs 64bit

## For 64 bit:

- ✦ 64 bit are 18 exabytes
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- ✦ < 0x00007fffffffffff



## 5-Level Paging and 5-Level EPT

White Paper

Revision 1.0

December 2016

## 32bit vs 64bit

---

Linux (and Windows) can execute 32 bit processes on a 64 bit OS

- ★ C:\Program Files
- ★ C:\Program Files (x86)
  
- ★ /lib/lib
- ★ /lib/lib64

The 32 bit process does not realize he's on a 64 bit system

- ★ But needs a 32 bit runtime



## 32bit vs 64 bit

---

For this presentation:

32 bit is “old” and “dead”

- ★ But its much easier to create and explain exploits in it

Old plan was: “Lets be modern, 64 bit only”

Current plan: “Lets be modern, but still use 32 bit to exploit stuff”

Sorry...

# 32bit vs 64bit

---



## Recap

- ★ There are some differences between 32 and 64 bit
- ★ A 32 bit process can run on a 64 bit system as 32 bit

---

## Excursion: C64

# Commodore 64



1 process only

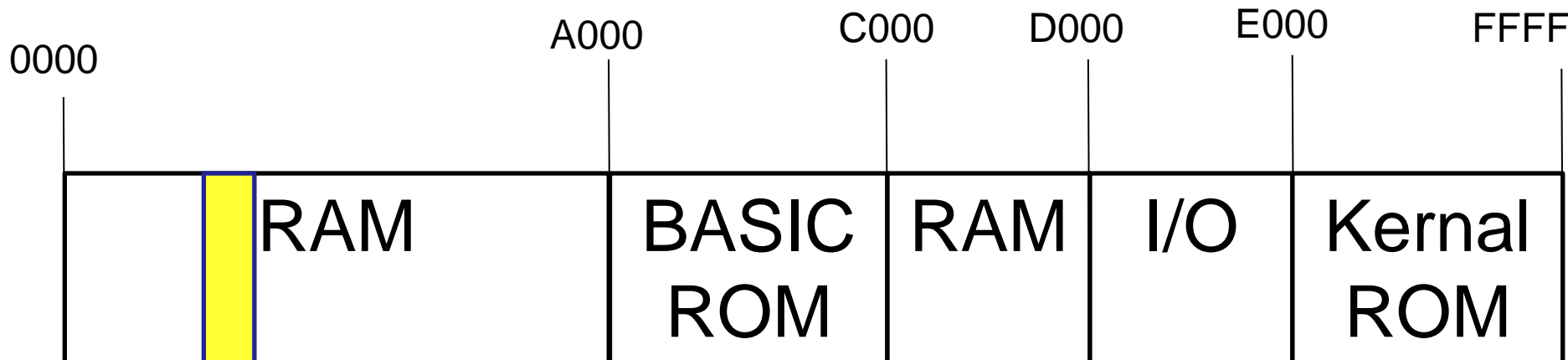
~1 MHz, 64kb RAM ( $2^{16}$ )

3 general purpose registers, 8 bit: A, X, Y

Stack Pointer: 8 bit, IP: 16 bit

Screen memory mapping: 0x0400 (1000 bytes, 40x25)

00	01	02	03
40	41	42	43



## Videos, for the curious

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[https://media.ccc.de/v/34c3-9064-the\\_ultimate\\_apollo\\_guidance\\_computer\\_talk](https://media.ccc.de/v/34c3-9064-the_ultimate_apollo_guidance_computer_talk)

<https://media.defcon.org/DEF%20CON%2025/DEF%20CON%2025%20presentations/DEFCON-25-Christopher-Domas-Breaking-The-x86-ISA.pdf>