The Hardware/Software Interface

CSE 351 Winter 2024

Instructor:
Justin Hsia

Teaching Assistants:
Adithi Raghavan
Aman Mohammed
Connie Chen
Eyoel Gebre
Jiawei Huang
Malak Zaki
Naama Amiel
Nathan Khuat
Nikolas McNamee
Pedro Amarante
Will Robertson

http://xkcd.com/676/

Quarter Specifics

Course Staff

- Instructor: just call me Justin
  - CSE Associate Teaching Professor
  - Raising a toddler takes up energy and dictates my schedule
- TAs:

- More than anything, we want you to feel…
  - ✓Comfortable and welcome in this space
  - ✓Able to learn and succeed in this course
  - ✓Comfortable reaching out if you need help or want change

Bookmarks

- Website: https://courses.cs.washington.edu/courses/cse351/24wi/
  - Schedule, policies, materials, tutorials, assignment specs, etc.
- Ed Course: https://edstem.org/us/courses/50549/
  - Discussion: announcements, ask and answer questions
  - Lessons: lessons, practice problems, homework
- Linked from website and Ed
  - Canvas: surveys, grade book, Zoom links
  - Gradescope: lab submissions, take-home exams
  - Panopto: lecture recordings

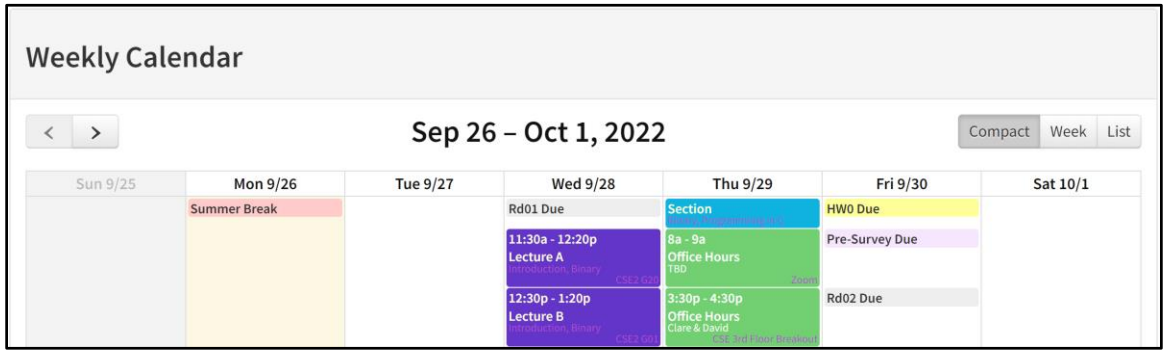
Grading

- **Lesson Problems:** 6%
  - Can reveal solution after one attempt (completion)
- **Homework:** 20% total
  - Unlimited submission attempts (autograded correctness)
- **Labs:** 40% total
  - Last submission graded (correctness)
- **Exams:** Midterm (16%) and Final (16%)
  - Take-home; individual, but some discussion permitted
- **EPA:** Effort, Participation, and Altruism (2%)




Support Hours

- Check Weekly Calendar on website for scheduled support hours:
  - In-person or virtual, but NOT hybrid
  - Zoom meeting links found in Zoom tab within Canvas



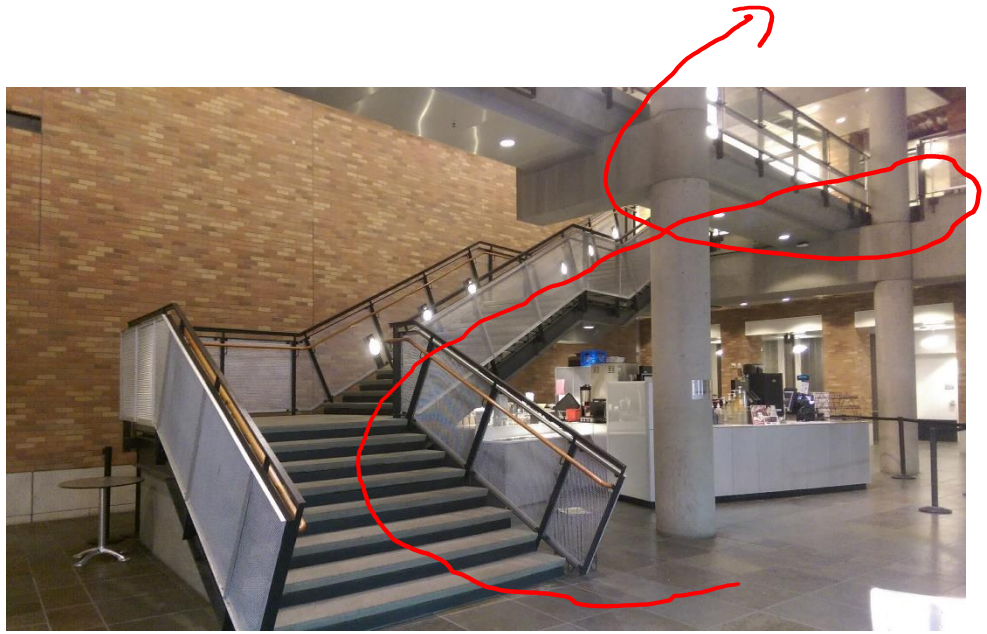
- *All* support hours will use a Google Sheets queue:
  - Fill out first 3 columns to enter queue:

Name(s)	Category	Description	Time Queued	Staff	Status
Example 1	Concept	Question about floating point encoding range.		Justin	Done
Example 2	Debugging	Lab 5: running into a segfault in mm_malloc after reaching end of the heap.		Justin	Done
Example 3	Spec	Lab 1a: confusion over within same block examples		Justin	Done
Example 4	Tools	GDB: how do I examine memory on the stack?		Justin	Done

- We encourage you to chat with other students if the TAs are busy!

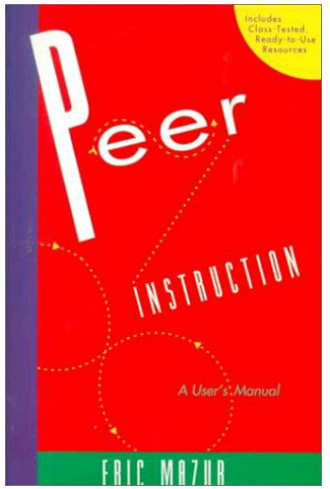
In-Person Support Hours

- Allen 3rd & 4th floor breakouts
  - Up the stairs in the CSE Atrium (Allen Center, not Gates)



  - The open areas with the whiteboard walls are the breakouts!

Lecture Polls and Discussions

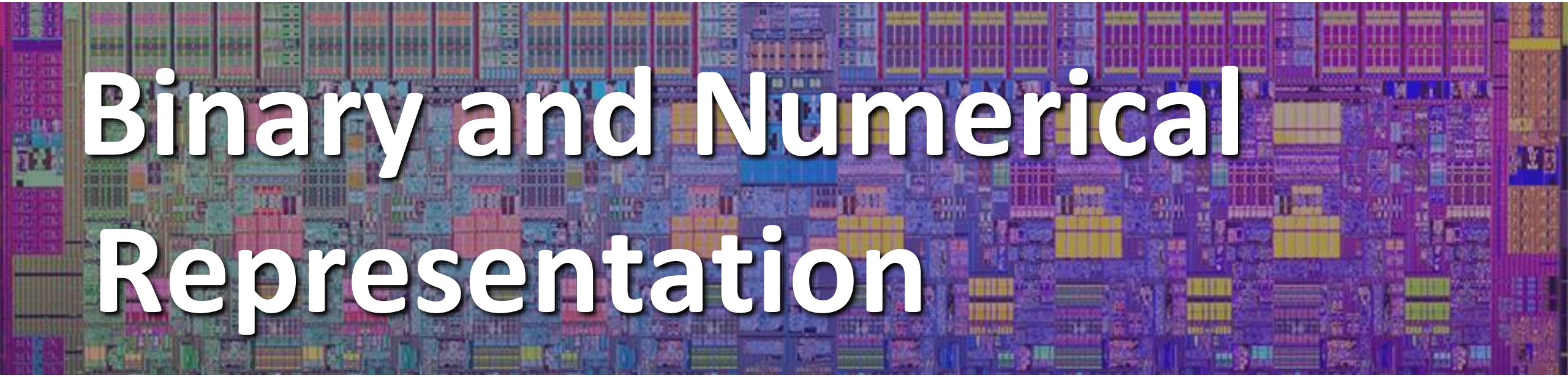


- Increase learning, test your understanding, increase student interactions, makes the class more engaging and fun
  - Lot of research supports its effectiveness:
- Polls on technical material will be multiple-choice and short answer
  - You haven't mastered the material yet; mistakes are part of the process!
- Discussion questions will be more open-ended
  - Be respectful of others' opinions and experiences
- Respond on Lecture Ed lesson for credit (extra late day tokens) and we will use *random call* to solicit live responses from audience
  - Don't need to be correct, just want the feedback of what was discussed

To-Do List

- Admin
  - Explore/read the course website *thoroughly*, especially the syllabus
  - Check that you can access Ed Discussion & Lessons
  - **Get your machine set up to access the CSE Linux environment (`attu` or `cancun`) *as soon as possible***
  - Optionally, sign up for CSE 391: System and Software Tools

- Assignments
  - Pre-Course Survey and hw0 due Friday (1/5)
  - HW1 and Lab 0 due Monday (1/8)
  - Lessons quiz questions due 11:59 pm *after* the associated lecture



Binary and Numerical Representation

Lesson Summary

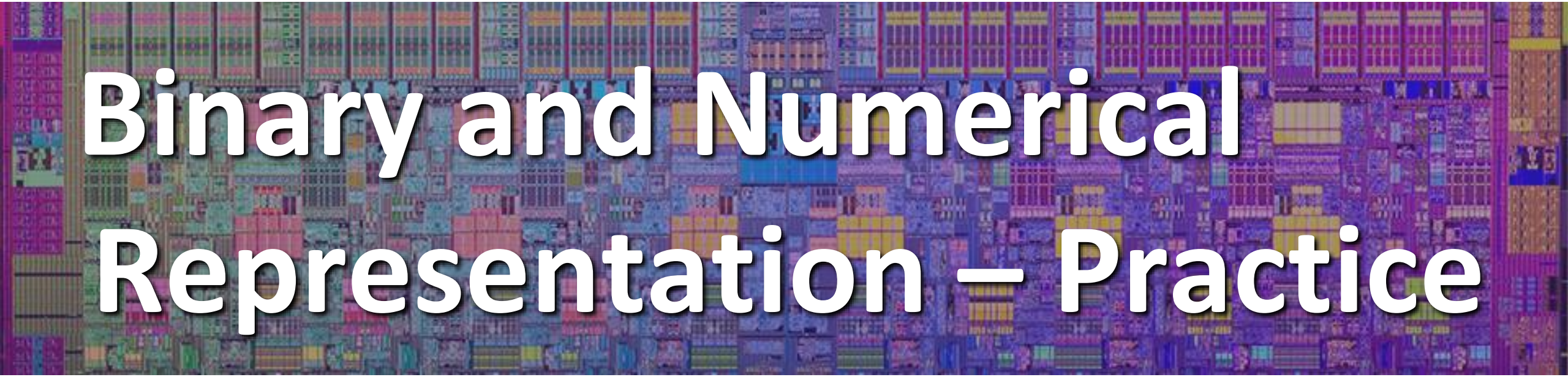
- Humans think about numbers in decimal; computers think about numbers in binary
  - Base conversion: digit d in position i in base b has a decimal value of $d \times b^i$
    - Changing bases does *not* change the value; just a different representation
  - Hexadecimal (base 16, prefix `0x`) is more human-readable than binary (base 2, prefix `0b`)
  - Unit of data in a computer is **1 byte = 8 bits** = 2 hex digits
- Binary encoding can represent *anything*!
  - Computer/program needs to know how to interpret the bits

Base 10	Base 2	Base 16
0	0b0000	0x0
1	0b0001	0x1
2	0b0010	0x2
3	0b0011	0x3
4	0b0100	0x4
5	0b0101	0x5
6	0b0110	0x6
7	0b0111	0x7
8	0b1000	0x8
9	0b1001	0x9
10	0b1010	0xA
11	0b1011	0xB
12	0b1100	0xC
13	0b1101	0xD
14	0b1110	0xE
15	0b1111	0xF

Lesson Q&A

- Learning Objectives:
  - Convert between binary, decimal, and hexadecimal number representations.
  - Given an encoding scheme, decode and encode binary to/from its intended representation.
  - Identify limitations of given encoding schemes.

- What lingering questions do you have from the lesson?
  - Introduce yourself to your neighbors and chat about the lesson for a few minutes to come up with questions



Binary and Numerical Representation – Practice

Polling Questions

- What is the *decimal value* of the numeral 107_8?

position: 2 1 0

$1\times8^2 + 0\times8^1 + 7\times8^0$

$64 + 0 + 7$

$= 71$

A. 71

B. 87

C. 107

D. 568

- Represent 0b1001101101011101 in hex.

0x 4DAD

$16 = 2^4$

1 hex digit ↔ 4 bits

- What is the decimal number 108 in hex?

(base 16) $16^0 = 1$, $16^1 = 16$, $16^2 = 256$

A. 0x6C

B. 0xA8

C. 0x108

D. 0x612

$108 = 96 + 12$

$= 6\times16^1 + 12\times16^0$

$= 0x6C$

- Represent 0x3C9 in binary.

0b 0011 1100 1001

could drop leading zeros

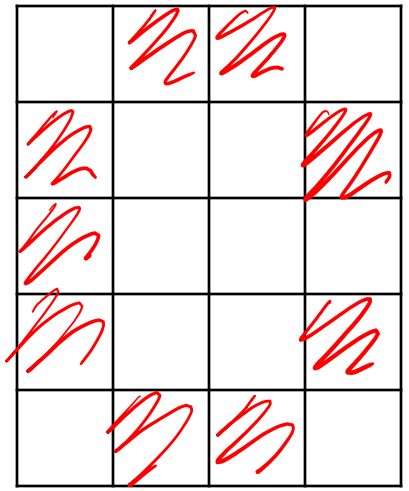
Homework Setup

- Binary alphabet using five 4-bit numbers stacked on top of each other:

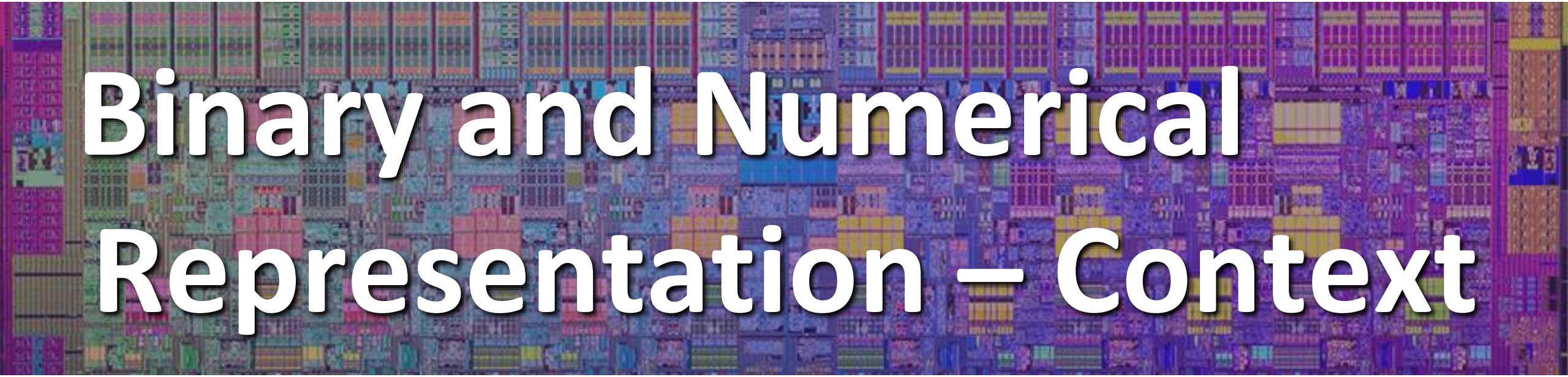
```
                0 1 1 0    □ ■ ■ □
                1 0 0 1    ■ □ □ ■
0x69F99 → 1 1 1 1 → ■ ■ ■ ■
                1 0 0 1    ■ □ □ ■
                1 0 0 1    ■ □ □ ■
```

- What string of 5 hex digits represents a "C"?

other possibilities: 0xF888F
0x78887
0xE989E



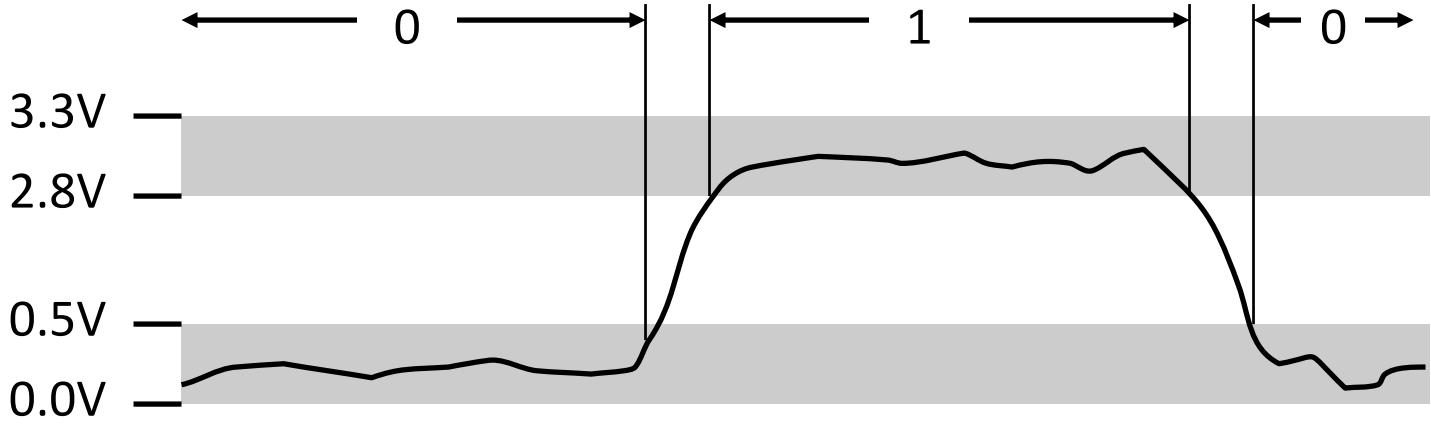
0x69896



Binary and Numerical Representation – Context

Why Base 2?

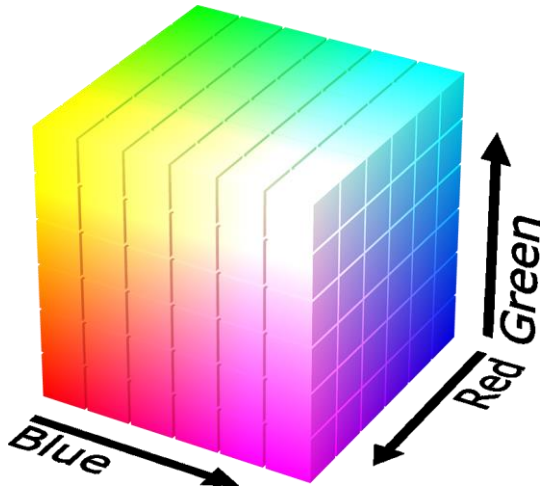
- Electronic implementation
  - Easy to store with bi-stable elements
  - Reliably transmitted on noisy and inaccurate wires

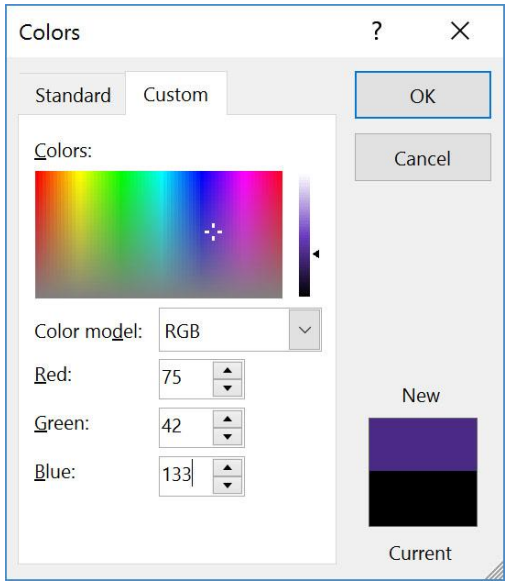


- Other bases possible, but not yet viable:
  - DNA data storage (base 4: A, C, G, T) is hot @UW
  - Quantum computing

Binary Encoding – Colors

- RGB – Red, Green, Blue
  - Additive color model (light): byte (8 bits) for each color
  - Commonly seen in hex (in HTML, photo editing, etc.)
  - Examples: **Blue**→0x0000FF, **Gold**→0xFFD700, **White**→0xFFFFFF, **Deep Pink**→0xFF1493





Binary Encoding – Characters/Text

- ASCII Encoding (www.asciitable.com)
  - American Standard Code for Information Interchange

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

What's Missing?

Binary Encoding – Characters/Text

- ASCII Encoding (www.asciitable.com)
  - *American* Standard Code for Information Interchange
- Created in 1963
  - Memory was expensive, 32KB in brand new machines
  - *Economic incentive* to use fewer bits for encoding
- **Design Goals:**
  - Represent everything on an *American* typewriter as *efficiently* as possible
  - Organize similar characters together
    - Numbers, uppercase, lowercase, then other stuff

Binary Encoding – Unicode & Emoji

- Unicode Standard is managed by the Unicode Consortium
  - "Universal language" that uses 1-4 bytes to represent a much larger range of characters/languages, including emoji
  - Adds new emojis every year, though adoption often lags: 🥷 (ninja)
    - https://emojipedia.org/new/

- Emojipedia demo: http://www.emojipedia.org
  - Taco: 🫓 (added 2015)
  - Code points: U+1F32E
  - Display (as of 2023):


Apple


Google Android


Samsung


Windows 11


WhatsApp


Twitter


Facebook

Discussion Question

- Discuss the following question(s) in groups of 3-4 students
  - I will call on a few groups afterwards so please be prepared to share out
  - Be respectful of others' opinions and experiences

- The Unicode Consortium publicly solicits proposals from the public for new emoji to add to future standards
  - What do you think some of the decision factors are (or should be) in how many and which ones to add?
  - Voting is done by a combination of paid members consisting of companies, institutions, and individuals – how do you feel about who has control and how they gained that control?
    - https://home.unicode.org/membership/members/

Group Work Time

- During this time, you are encouraged to work on the following:
  1) If desired, continue your discussion
  2) Work on the homework problems
  3) Work on the lab (if applicable)

- Resources:
  - You can revisit the lesson material
  - Work together in groups and help each other out
  - Course staff will circle around to provide support