MCT 4334

Embedded System Design

Week 01 Introduction

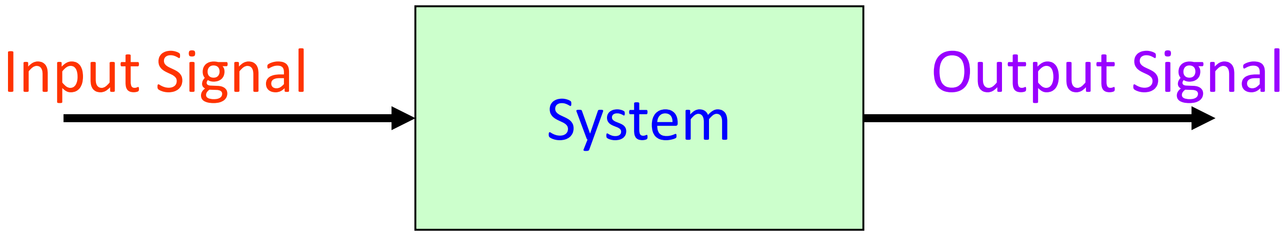
Credit: Some slides were borrowed from Dr. Robert Paz from New Mexico State University

Outline

- Definition of embedded systems
- Types of embedded systems
- Digital representation of information

System

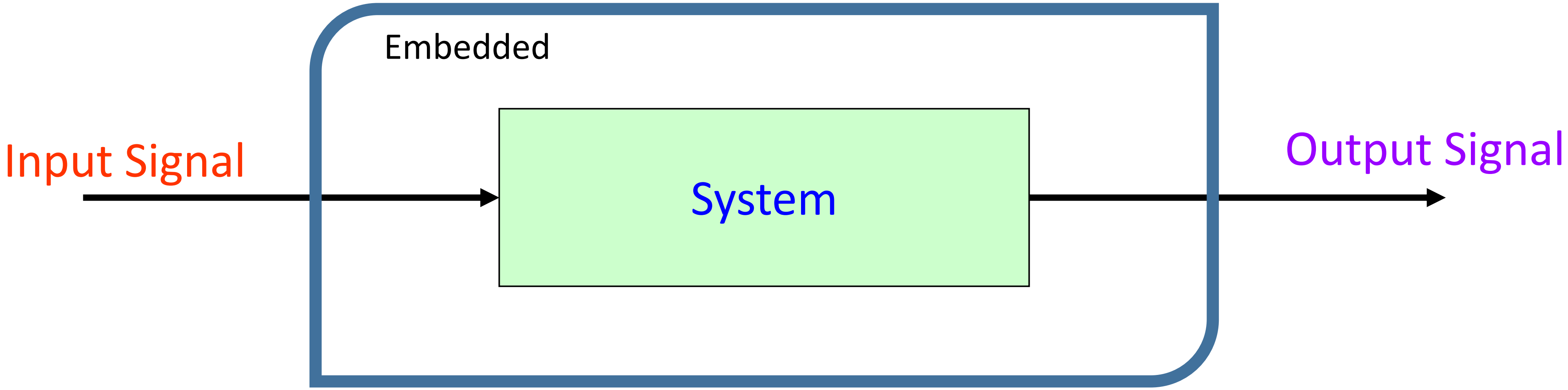
What is a system?



Very generally, a system can be defined as an entity that manipulates one or more signals (**input**), thereby yielding new signals (**output**).

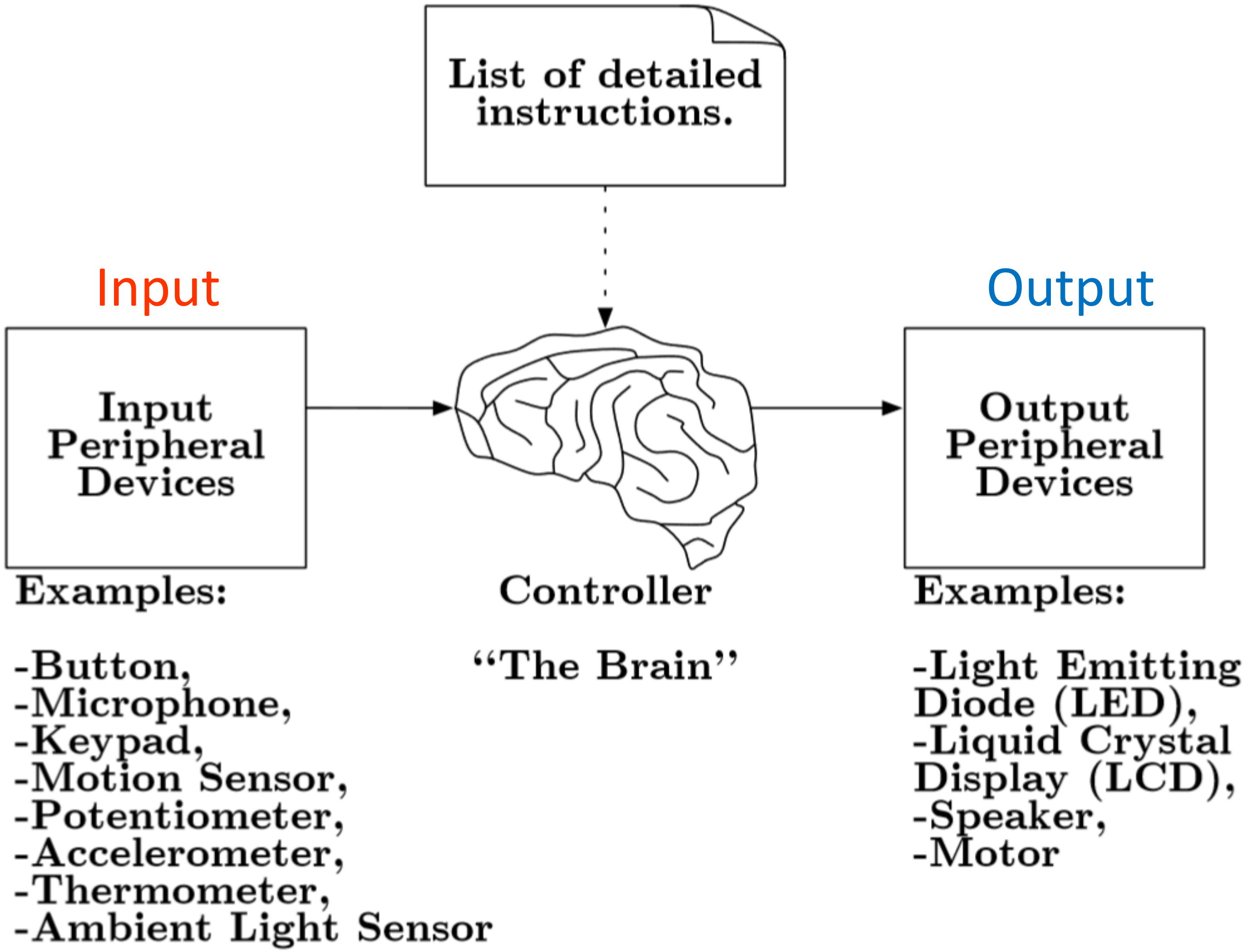
Embedded system

What is an embedded system



An embedded system is an electronic system that is hidden from the end user. That is, the system is embedded in the environment or other systems.

Embedded system



Layman definition of embedded system

The integration of:

- Sensors
- Actuators
- Some form of “intelligence” or mechanism to process sensory information

Examples of embedded systems

- Automobiles
- Household appliances such as microwave, toaster, refrigerator, washer, dryer, TV, etc
- Security system
- Wireless network router
- Traffic light
- Cell phones
- Camera
- MP3 audio player
- DVD player
- Mouse
- Keyboard
- ATM

Example of Embedded System

Traffic Light Controller

Input: Presence sensor

Output: Traffic lights (red, green and yellow)

Brain: It varies.

Example of Embedded System

Engine Control Unit (ECU)

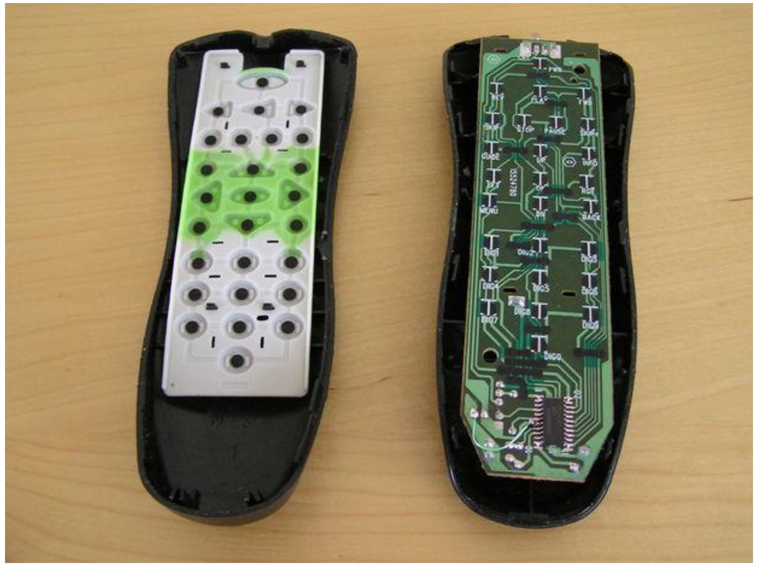
Input: Variety of sensors in the engine bay

Output: Ignition timing,
Idle speed
Air-fuel mixture
Variable value timing

Brain: Usually ASIC, but there are some programmable models

Example of Embedded System

Remote Control

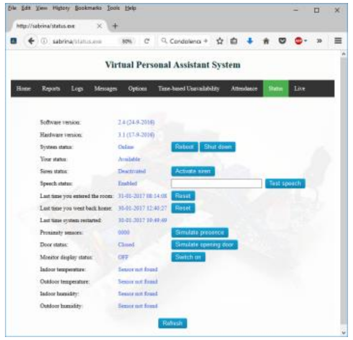


Input: Buttons

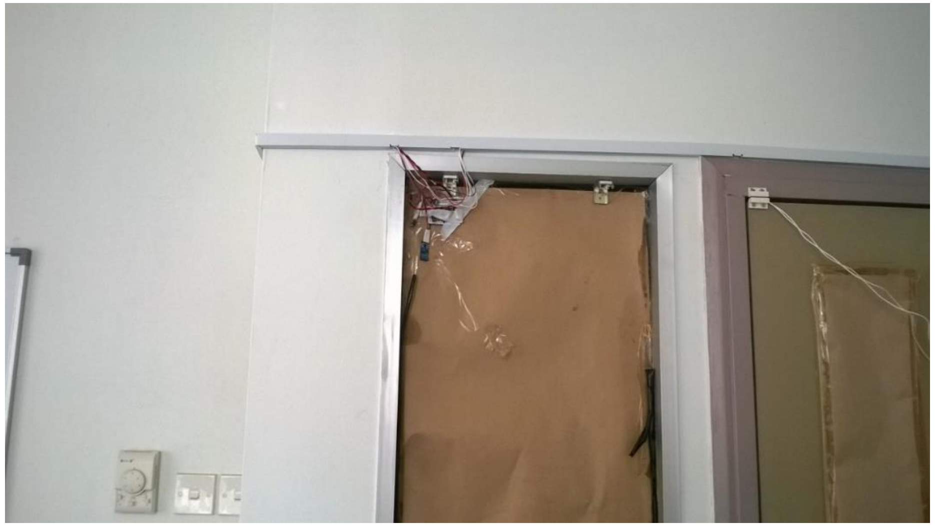
Output: Modulated IR signal around 38 kHz

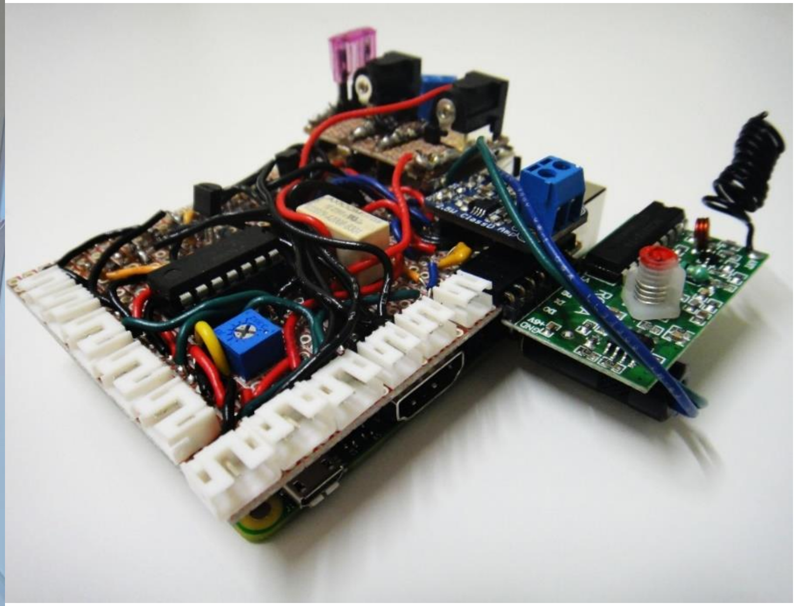
Brain: Usually made of up discrete components (but some remote controls also use microcontrollers)

Example of Embedded System



Virtual Personal Assistant System





Input:

IR sensors
Microphone
Vibration sensor
HTTP request
RF stream
Door sensor
Other sensors

Output:

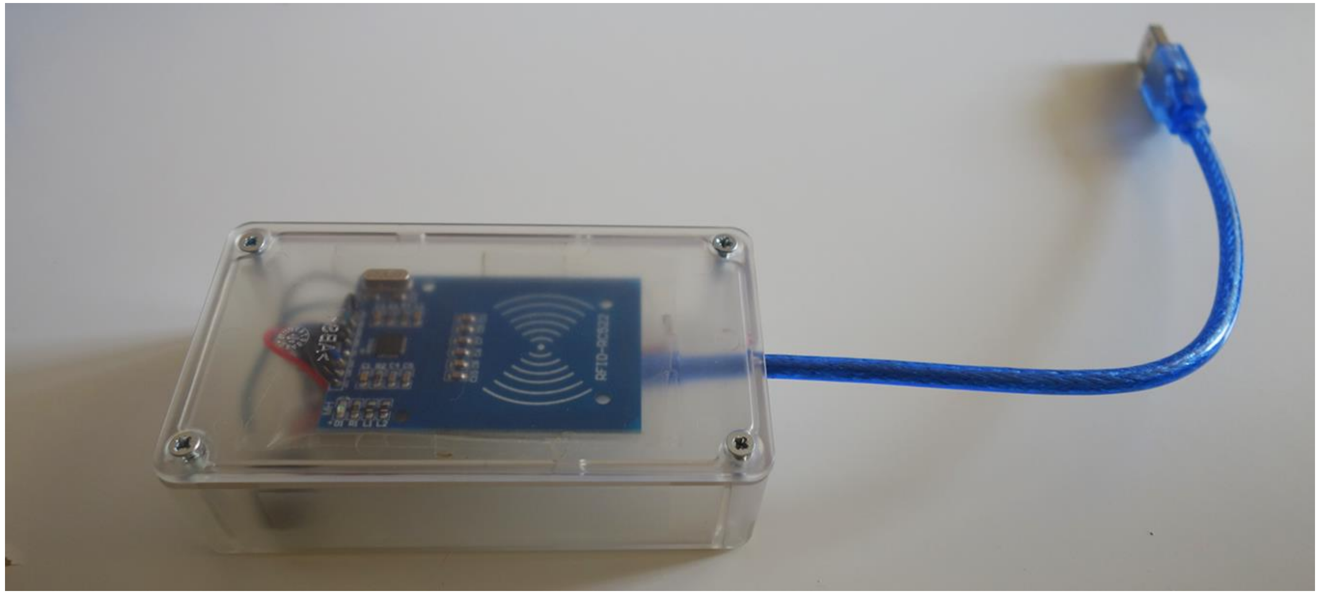
Speech
Sound
Display
HTTP response
Push notification

Brain:

Raspberry pi 2

Example of Embedded System

Smart-card reader



Input: RFID signal

Output: USB
LED
Sound

Brain: Arduino Micro

Microcontroller

- The controller is usually a microcontroller, but it does not have to be.
- The controller can also be made out of discrete components (such as logic gates and op-amps)
- The controller can also be as complex as single-board computers.
- Microcontrollers are common because they have the right amount of balance among speed, development cost and power consumption.

Microcontroller

A microcontroller is a correct tool to use when:

- Intelligence is required in this system.
- The complexity of a system is reduced when using one.
- The cost of the microcontroller is “less” than using discrete components to do the same job.
- A variety of sensors and actuators must be integrated in the system.
- Communication with other devices is necessary.

Microcontroller

A microcontroller is NOT the correct tool to use when:

- The system requires little or no intelligence.
- The system can be made easier and/or cheaper using discrete-components
- The microcontroller is undersized for the problem
    - too slow
    - too much number crunching required
    - too many things going on

Microcontroller Manufacturers

- AMCC
- Atmel
- Comfile Technology Inc.
- Coridium
- Cypress MicroSystems
- Dallas Semiconductor
- Elba Corp.
- Freescale Semiconductor
- Fujitsu
- Holtek
- Infineon
- Intel
- Microchip Technology
- National Semiconductor
- NEC
- Parallax, Inc.
- Philips Semiconductors
- PICAXE
- Renesas Technology
- Silabs
- Silicon Motion
- STMicroelectronics
- Texas Instruments
- Toshiba
- Western Design Center
- Ubicom
- Xemics
- Xilinx
- ZiLOG

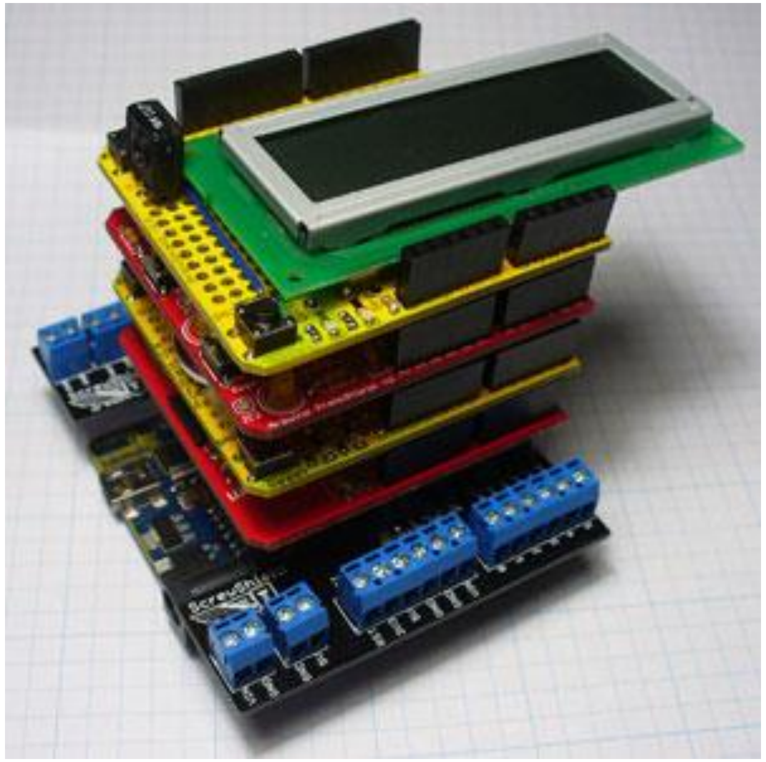
Why the Arduino?

- Improvement over other micro-controllers for hobby usage
- Inexpensive
- IDE on multiple platforms (Mac, PC, Linux)
- Simple, clear programming environment: “C”
- Open source and extensible software/hardware
- The existence of Arduino shields

Arduino Shields

- VGA camera
- GPS
- LCD displays
- Ethernet
- WiFi
- Motor control (dc, stepper)

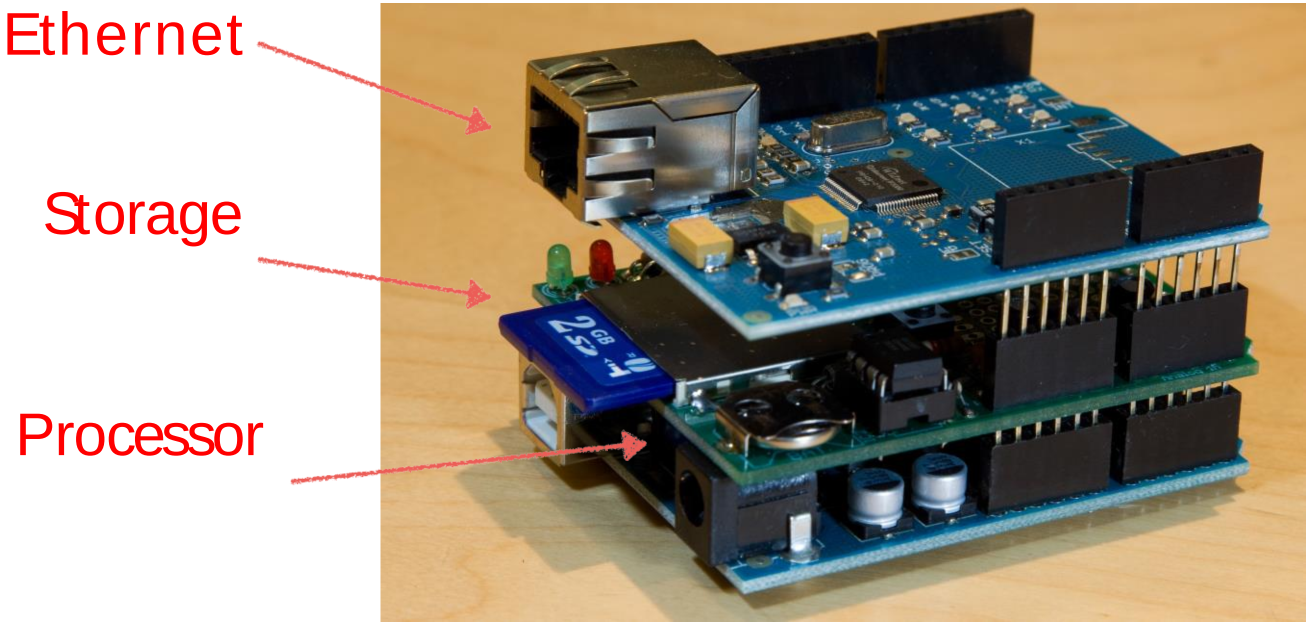
- Load Cell
- Accelerometer/Gyros
- LED displays
- Memory Cards
- Weather Sensors
- Relays



Arduino Applications

Arduino has numerous applications ranging from simple ones to ones as complex as a web server.

Arduino Web Server



Digital representation of information

- The electric signal is either ***on*** or ***off*** at all times.

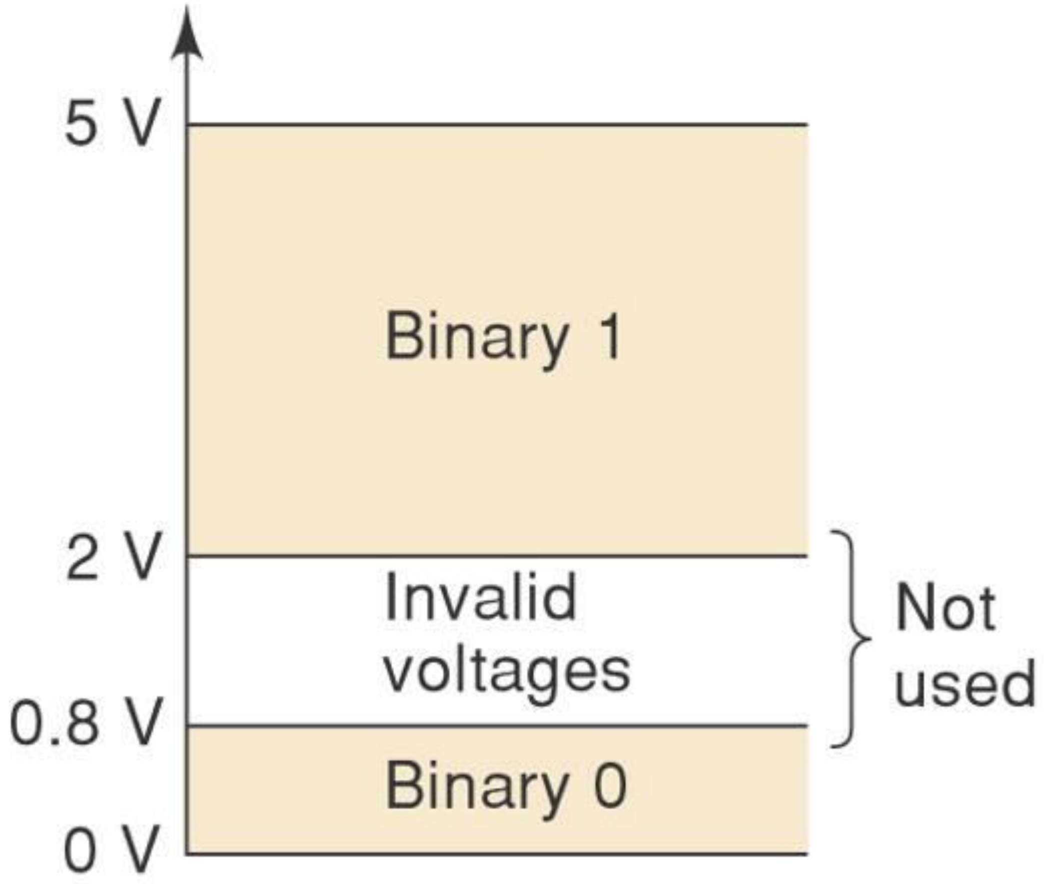
  This relates to modern digital systems that use electrical signals to represent 1s and 0s.

Digital representation of information

A *higher* range of voltages represent a valid 1 and a *lower* range of voltages represent a valid 0.

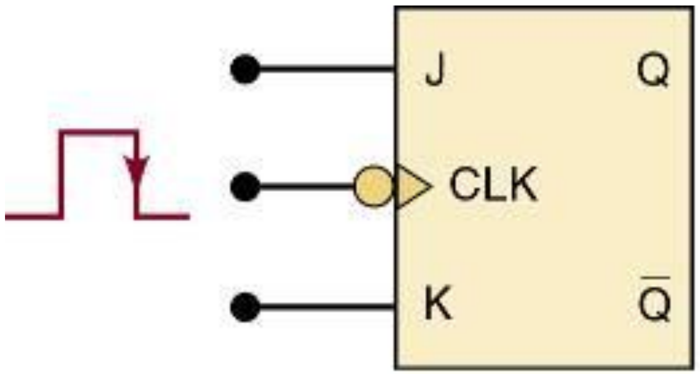
HIGH and LOW are often used to describe the states of a digital system—instead of “1” and “0”

Typical representation of the two states of a digital signal.

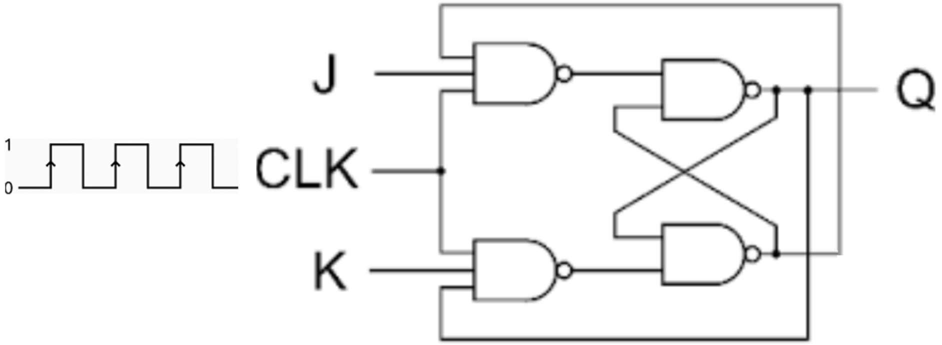


Flip-flop

A flip-flop holds a single bit of information.



J	K	CLK	Q
0	0	↓	Q_0 (no change)
1	0	↓	1
0	1	↓	0
1	1	↓	$\overline{Q_0}$ (toggles)

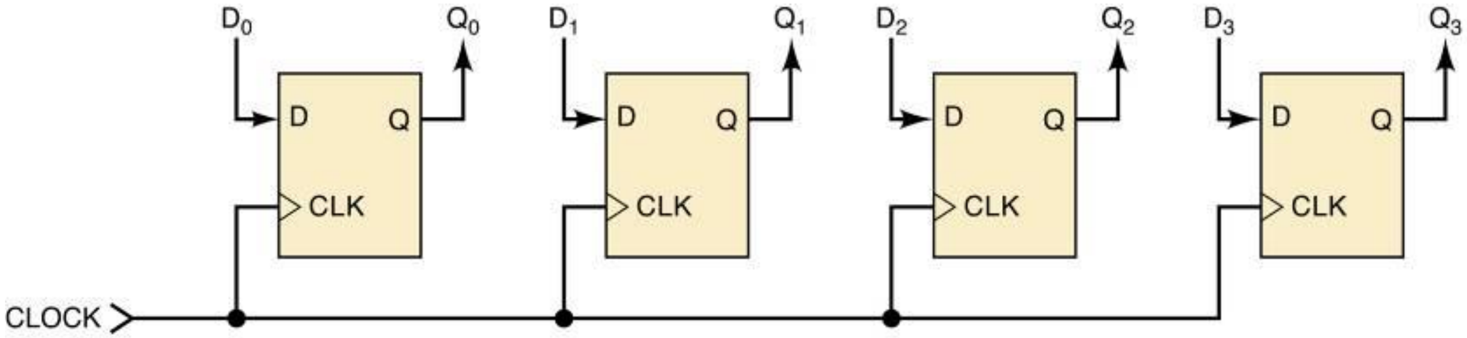


Making J = 1 and K = 0 stores HIGH bit in the memory

Making J = 0 and K = 1 stores LOW bit in the memory

Register

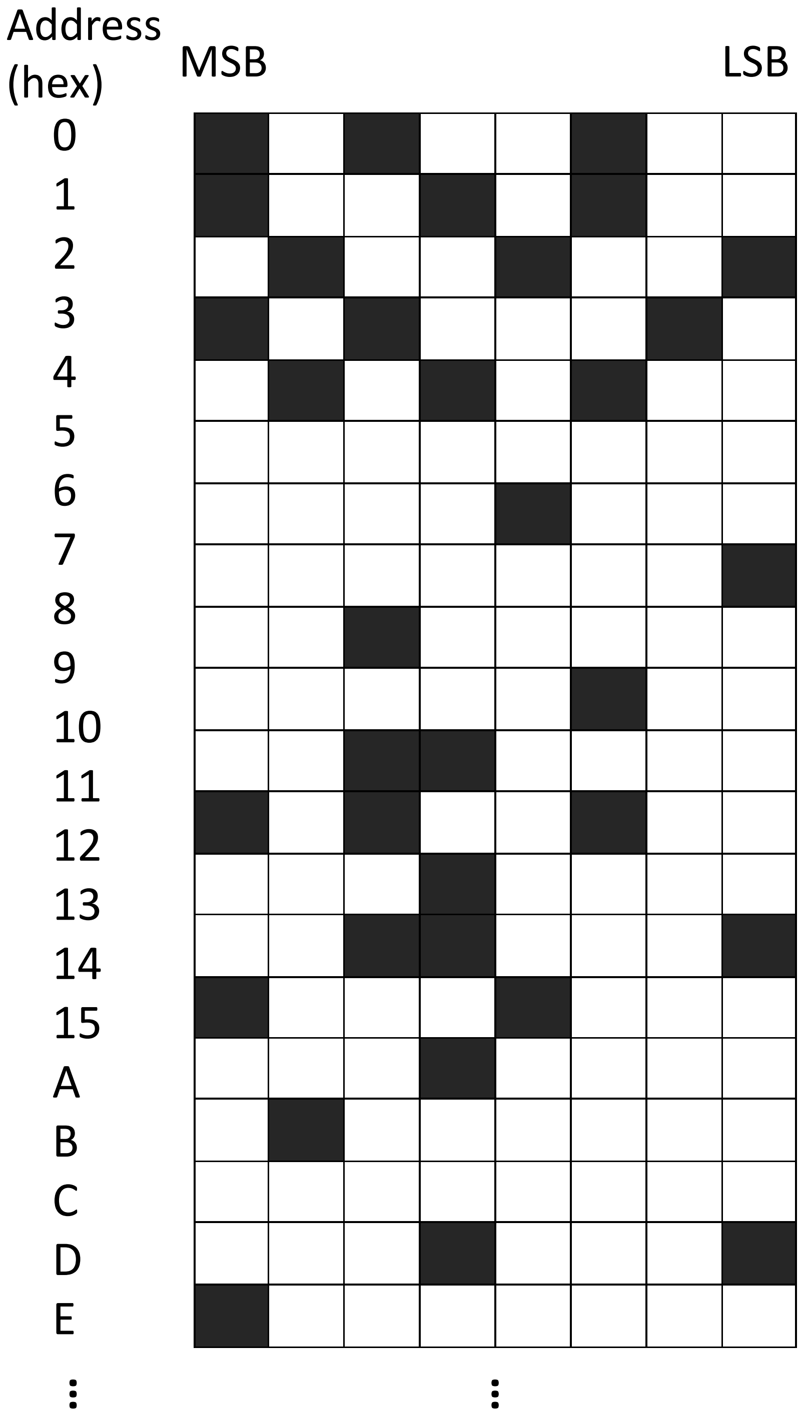
- To store one byte of information, 8 flip-flops are needed.
- An array of flip-flops is called a **register**
- An 8-bit system generally has a register width of 8.



An example of 4-bit PIPO register (using D flipflops)

Memory

- Main memory (RAM) is just an array of registers.
- Each byte is referenced by a unique address



Digital Representation of Information (Unsigned integers)

- Consider an unsigned integer 85. What is the equivalent representation in binary?

  101 0101

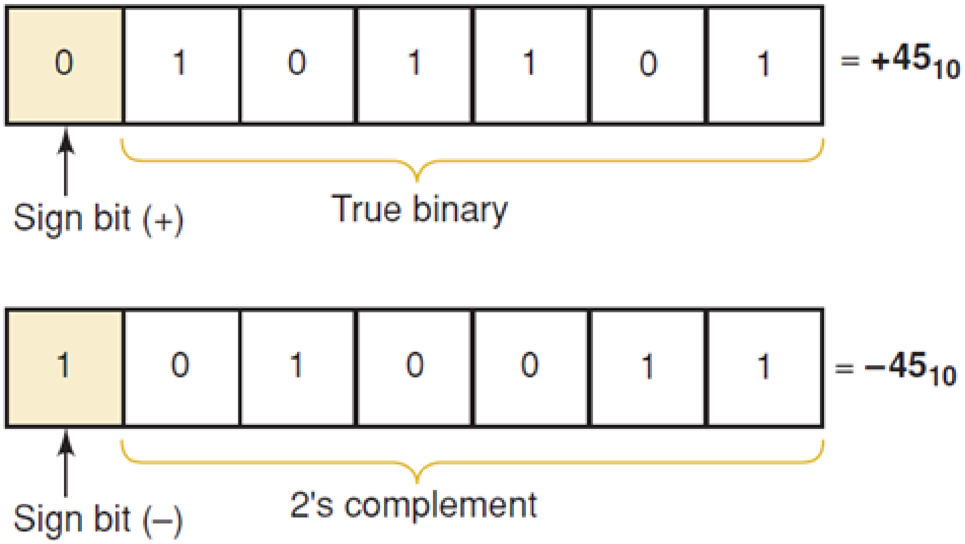
- What is the maximum number that can be represented by an 8-bit unsigned system?

  $2^8-1 = 255$

Digital Representation of Information (Signed integers)

- Two’s complement system is used to represent negative numbers
- The MSB is allocated as a sign bit.

- If the number is positive, the magnitude is represented in its true binary form, and a sign bit of 0 is placed in front of the MSB.
- If the number is negative, the magnitude is represented in its 2’s-complement form, and a sign bit of 1 is placed in front of the MSB.

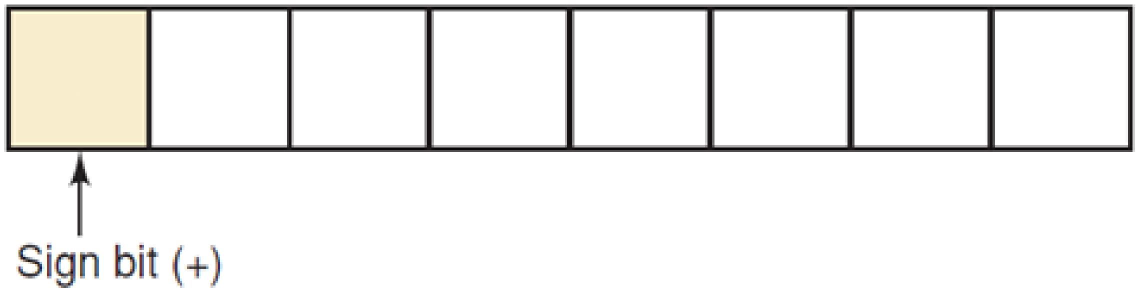


Digital Representation of Information (Signed integers)

- What is the range of numbers that can be represented by an 8-bit signed system?

Maximum positive number = $2^7 - 1 = +127$ (01111111)

Minimum negative number = $-2^7 = -128$ (10000000)



Digital Representation of Information (Floating point)

- There are some standards. The most widely used is IEEE single precision (32-bit) and IEEE double precision (64 bit) formats.

- The IEEE single precision standard (32-bit) specifies
  - Sign bit: 1 bit
  - Exponent: 8 bits
  - Mantissa: 23 bits

b_{31}	b_{30} … b_{23}	b_{22} … b_0
Sign	Exponent(8)	Mantissa(23)

- The IEEE double precision standard (64-bit) specifies
  - Sign bit: 1 bit
  - Exponent: 11 bits
  - Mantissa: 52 bits

b_{63}	b_{62} … b_{52}	b_{51} … b_0
Sign	Exponent(11)	Mantissa(52)

Single Precision:

b_{31}	b_{30} ... b_{23}	b_{22} ... b_0
Sign	Exponent(8)	Mantissa(23)

Value = $(-1)^s \times \left(2^{e-127}\right) \times 1.m$

Double Precision:

b_{63}	b_{62} ... b_{52}	b_{51} ... b_0
Sign	Exponent(11)	Mantissa(52)

Value = $(-1)^s \times \left(2^{e-1023}\right) \times 1.m$

Value = $(-1)^s \times \left(2^{e-127}\right) \times 1.m$

Example on IEEE single precision representation

Sign	Exponent	Mantissa	Value	
0	01111111	00000000000000000000000	1.0	
0	01111110	00000000000000000000000	0.5	
0	10000000	11000000000000000000000	3.5	
0	11111111	11111111111111111111111	6.80564e+38	Largest value
0	00000000	00000000000000000000001	5.87747e-39	Smallest value
0	00000000	00000000000000000000000	0.0	
0	10000000	00111000010100011110101	2.43999	
1	10000010	10000101000111101011100	-12.15999	
1	10000010	00110111000010100011110	-9.71999	

Numerical example 1

Sign	Exponent	Mantissa	Value
0	10000000	11000000000000000000000	3.5

Value = $(-1)^s \times \left(2^{e-127}\right) \times 1.m$

s = 0

e = 128

1.m = 1.11000000000000000000000 = $2^0 + 2^{-1} + 2^{-2}$ = 1.75

Value = 1 × 2 × 1.75 = 3.5

$$(-1)^s \times \left(2^{e-127}\right) \times 1.m$$

Numerical example 2

Sign	Exponent	Mantissa	Value
0	11111111	11111111111111111111111	6.80564e+38

Value =

s = 0

e = 255

1.m = 1.11111111111111111111111= 2^0+ 2^{-1} + 2^{-2} +………= 1.99999…. = 2

Value = 1 × 3.40282 e+38 × 2 = 6.80564 e+28

Digital Representation of Information (Text)

- ASCII – American Standard Code for Information Interchange.
- It is a 7-bit presentation. (Usually added 1 bit parity information to make it 8-bit)

Character	HEX	Decimal	Character	HEX	Decimal	Character	HEX	Decimal	Character	HEX	Decimal
NUL (null)	0	0	Space	20	32	@	40	64	.	60	96
Start Heading	1	1	!	21	33	A	41	65	a	61	97
Start Text	2	2	“	22	34	B	42	66	b	62	98
End Text	3	3	#	23	35	C	43	67	c	63	99
End Transmit.	4	4	$	24	36	D	44	68	d	64	100
Enquiry	5	5	%	25	37	E	45	69	e	65	101
Acknowlege	6	6	&	26	38	F	46	70	f	66	102
Bell	7	7	`	27	39	G	47	71	g	67	103
Backspace	8	8	(	28	40	H	48	72	h	68	104
Horiz. Tab	9	9	)	29	41	I	49	73	i	69	105
Line Feed	A	10	*	2A	42	J	4A	74	j	6A	106
Vert. Tab	B	11	+	2B	43	K	4B	75	k	6B	107
Form Feed	C	12	,	2C	44	L	4C	76	l	6C	108
Carriage Return	D	13	-	2D	45	M	4D	77	m	6D	109
Shift Out	E	14	.	2E	46	N	4E	78	n	6E	110

Shift In	F	15	/	2F	47	O	4F	79	o	6F	111
Data Link Esc	10	16	0	30	48	P	50	80	p	70	112
Direct Control 1	11	17	1	31	49	Q	51	81	q	71	113
Direct Control 2	12	18	2	32	50	R	52	82	r	72	114
Direct Control 3	13	19	3	33	51	S	53	83	s	73	115
Direct Control 4	14	20	4	34	52	T	54	84	t	74	116
Negative ACK	15	21	5	35	53	U	55	85	u	75	117
Synch Idle	16	22	6	36	54	V	56	86	v	76	118
End Trans Block	17	23	7	37	55	W	57	87	w	77	119
Cancel	18	24	8	38	56	X	58	88	x	78	120
End of Medium	19	25	9	39	57	Y	59	89	y	79	121
Substitue	1A	26	:	3A	58	Z	5A	90	z	7A	122
Escape	1B	27	;	3B	59	[	5B	91	{	7B	123
Form separator	1C	28	<	3C	60	\	5C	92	|	7C	124
Group separator	1D	29	=	3D	61	]	5D	93	}	7D	125
Record Separator	1E	30	>	3E	62	^	5E	94	~	7E	126
Unit Separator	1F	31	?	3F	63	_	5F	95	Delete	7F	127

- ASCII standard is only for English characters.
- UNICODE standards are popular as they handle characters from many diverse languages of the world.