Digital

Dec	Bin	Hex	Oct
1	0001	1	001
2	0010	2	002
3	0011	3	003
4	0100	4	004
5	0101	5	005
6	0110	6	006
7	0111	7	007
8	1000	8	010
9	1001	9	011
10	1010	A	012
11	1011	B	013
12	1100	C	014
13	1101	D	015
14	1110	E	016
15	1111	F	017

Hex → Dec
left column = 16 Right = 1
∴ F1
16^2 16¹ 16⁰
... F 1
15x16 + 1x1

4 bit → 8 bit (signed)
put 1111 on left
e.g 1100 → 1111 1100

2's complement
(negative of number)
1's complement + 1
Method:
1 1 0 1 1 0 1 0 1 0 = x
0 0 1 0 0 1 0 1 0 0 1 0 = -x
copy until 1st one
INVERT rest

1's Complement
All bits inverted
1 0 1 0 0
0 1 0 1 0

Max = 1 but can never be: Max = $1-2^{-(N-1)}$
Min = -1
-2^0 2^{-1} 2^{-2}

Signed
highest 2^n is negative
-2^3 2^2 2^1 2^0
∴ max = 7
0 1 1 1
min = -8
1 0 0 0

Binary Representation
Unsigned
2^3 2^2 2^1 2^0
∴ max number for 4 bits = 15
1 1 1 1
min number = 0

will never be more than operand value as 2 fractions multiplied give lower number
used more memory
Use fractional arithmetic
Use double precision

To reduce problem
Saturate
e.g if AxB≤15 = AxB
if AxB > 15 = 15
for 4 bit
multiplication overflow
addition overflow
when using signed and unsigned integers problems
Use floating point arithmetic
less power
Fixed vs. Floating
more range of values

Counter: stores number of times an event has occured

Memory
RAM
Random access memory
ROM
read only memory
Flash memory (non-volatile)

Bus
Electrical connection between electrical devices

Si, Ge
Semiconductor
ambient, conducts better than insulator but worse than conductor
↑T or light, conductive
↓T, insulator

Digital circuit
disadvantages
Sampling error
digital communications require greater bandwidth than analogue
advantages
signals can be represented very accurately
more stable
flexible → modified by software
digital storage easier

Transistors v.s Vacuum Tubes
bulky
long life
small
low cost
slow

Logic Gates
for N-suffix add o
for X- (exclusive) suffix add)
e.g XNOR
exclusive means either one or the other true. but NOT BOTH:

1	2	o
0	0	0
1	0	1
0	1	1
1	1	0

e.g XOR

AND
OR

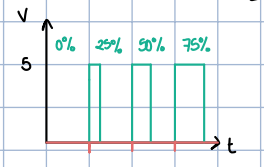
Boolean Functions
From truth table
Sum of products:
- look at rows with 1 output
- multiply variables and add rows
Product of Sums:
- look at 0 output rows
- invert numbers, sum variables and multiply rows

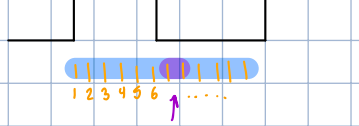
e.g

A	B	C	Out
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1

SOP: $\bar{A}\bar{B}C + \bar{A}B\bar{C}$
POS: $(A+B+\bar{C})(A+\bar{B}+C)$

Communications
power delivery
PWM
fixed signal
varying duty cycle
PWM 'DAC' Bits
Equivalent DAC bits = $\log_2$(number of steps in PWM period)

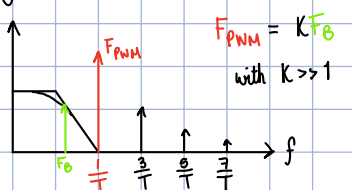




T_S: PWM step

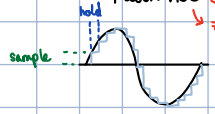
$T = nT_S$
2^n = count
$n = \frac{\log count}{\log 2}$
$f_S = 2^n f$ = required PWM timer frequency

Square Waves
- 1 fundamental, odd harmonic multiples
e.g

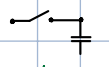


$F_{PWM} = KF_0$ with K >> 1

ADCs
Digital Ramp
Successive approx.
Flash ADC
Fast
↑ power
↓ res.
≠ identical units

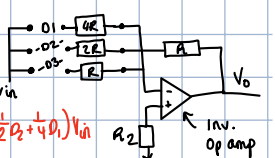


Sample & hold → Flash ADC



switch down
switch up and capacitor stores value

PWM DAC
DACs → R/2nR DAC



$V_{out} = -(\frac{b_3}{2} + \frac{b_2}{4} + \frac{b_1}{8} + \frac{b_0}{16})V_{in}$