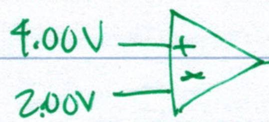
EEC 18

Sept. 28

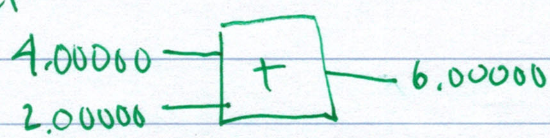
Adder, Ex: 2+4

Analog

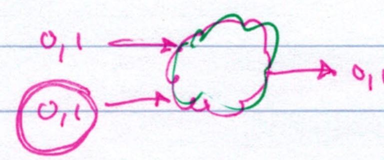


6.00V ± noise = f(voltage supply, temp., manufacturing variations, ...)

Digital



- arbitrary precision



Roth book

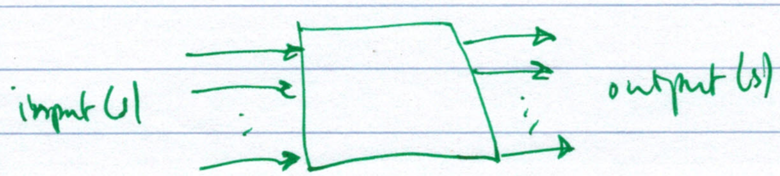
1) System design (180, 170)
* 2) Logic design (18)
3) Circuit design (118, 116)

A) Combinational Logic

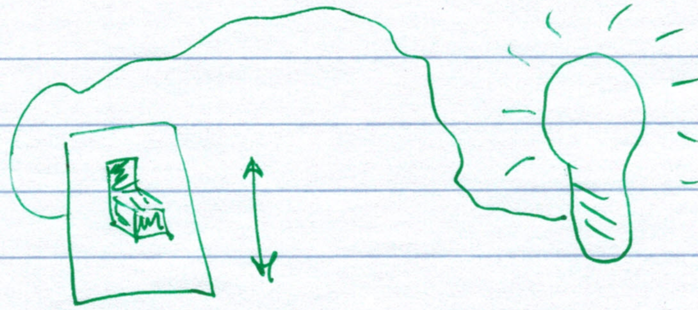
B) Sequential Circuits (comb. + memory)

A) Combinational Logic

Def: Block whose outputs depend on only the present inputs



Ex:

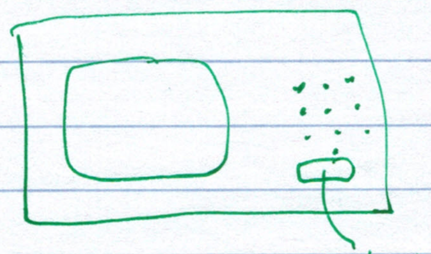


B) Sequential Circuits

Def: Block whose outputs depend on present and past inputs

Require memory

Ex: Microwave oven



Digital Systems are made of:

1) Memory - store data
2) Datapath - processes data (+, -, ×, ÷, compare, ...)
3) Control
4) Misc supporting circuits

Number Systems

Binary
- base 2
- Unsigned

$$\boxed{1}\ \boxed{0}\ \boxed{1}\ \boxed{1}\ .\ \boxed{0}\ \boxed{1} = 8+2+1+\tfrac{1}{4} = 11.25_{10}$$

$$2^3\quad 2^2\quad 2^1\quad 2^0\ .\ 2^{-1}\quad 2^{-2}$$

$$8\quad 4\quad 2\quad 1\ .\ \tfrac{1}{2}\quad \tfrac{1}{4}$$

Hexadecimal
- base 16
- digits : 0 - 9, A - F

Bin / Hex

$$\underbrace{1011}\underbrace{0101}_2$$

$$= \quad B \quad 5_{16}$$

Ex: Dec → Bin

42.25_{10}

1	0	1	0	1	0	.	0	1
32	16	8	4	2	1		$\frac{1}{2}$	$\frac{1}{4}$

$[0, 63\frac{3}{4}]$

10.25

2.25

Addition

$\boxed{1}\boxed{0}\boxed{0}\boxed{0}$

Ex:

$$\begin{array}{rcl} 1100_2 & = & 12_{10} \\ +\ 0110_2 & = & 6_{10} \\ \hline 10010 & = & 18_{10}\ \checkmark \end{array}$$

$2_{10} = 10_2$

$3_{10} = 11_2$

Subtraction

1) Book: similar to decimal subtraction ×

2) $a - b = a + (-b)$

- done in HW
- must use "signed" numbers

Ex: $1 - 2 = \underline{\underline{-1}}$

Multiplication

$$
\begin{array}{rrrrrrl}
 & & & 1 & 1 & 1_2 & = 7_{10} \\
\times & & & 1 & 0 & 1_2 & = 5_{10} \\
\hline
 & & & 1 & 1 & 1 & \\
 & & 0 & 0 & 0 & & \\
+ & 1 & 1 & 1 & & & \\
\hline
1 & 0 & 0 & 0 & 1 & 1_2 & = 35_{10} \checkmark \\
32 & 16 & 8 & 4 & 2 & 1 &
\end{array}
$$

Signed Number Formats

① Signed Magnitude

Sign	Magnitude
□	□□ . . . □
0 = pos 1 = neg	std. unsigned binary

- not so good for HW for +/−
+ great for mult.
- two zeros

  0 0000 = +0

  1 0000 = −0

② Two's Complement

Def.: Same as unsigned except the positional weight of the MSB is negative

MSB					LSB
$\square$	$\square$	$\square$	$\square$.	$\square$	$\square$
-2^3	2^2	2^1	2^0	2^{-1}	2^{-2}
-8	4	2	1 .	$\frac{1}{2}$	$\frac{1}{4}$

$[-8, +7\frac{3}{4}]$

1000,00   0111,11

_ _ _ _ _ _ . _ _

-32 16 8 4 2 1

$[-32, +31\frac{3}{4}]$

-4 $\underline{1}\ \underline{1}\ \underline{0}\ \underline{0}\ .\ \underline{0}\ \underline{0} = -4$

$-$ $+$

$-8 + ? = -4$

4

$-4 = \underline{1}\ \underline{0}\ \underline{0}\ .\ \underline{0}\ \underline{0}$

$-4\ \ 2\ \ 1$

Book: n-bit number N, $\rightarrow$ $-N = 2^n - N$

Invert 2's ~~compl~~ complement number:
"Flip bits and add 1"

$+3$ 0011

1100 flip bits

1 add 1

1101 $= -8 + 4 + 1 = -3$ ✓

- MSB is a sign bit 1 = negative
  0 = positive or zero

+ one zero 00000

- All 1's $= -1_{10}$ 1111 $= -1$
  11111 $= -1$

- We can always sign extend MSB bit by replicating it

005

00005

Binary - Coded Decimal (BCD)

Every 4 bits → 1 decimal digit

Ex: 129_{10}

	1				2				9				
$\boxed{S}$	0	0	0	1	0	0	1	0	1	0	0	1	BCD
	800	400	200	100	80	40	20	10	8	4	2	1	