Lecture 36

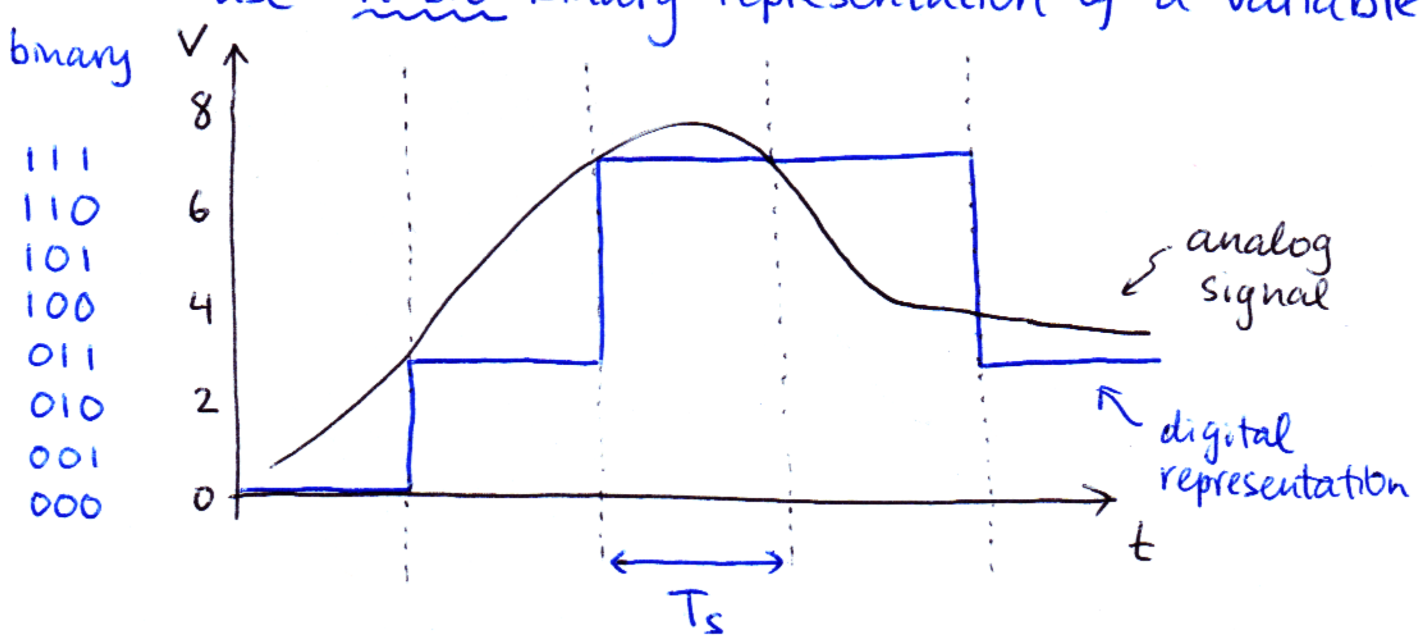
A/D and D/A converters

- most physical variables are analog
- humans respond most efficiently to data represented in analog form

⇒ must perform A/D & D/A conversion to utilize computers & digital circuitry

Digital representation of info (time varying)

- sampling time $T_s = \frac{1}{f_s}$
- use n-bit binary representation of a variable



- both sampling time and # of bits affect fidelity of representation

1) # bits – precision (smallest variation that can be still represented)

E.g. 10V p-p signal, $n = 10$ bits

$$\boxed{\Delta V_{min} = \frac{V_{range}}{2^n - 1}} \simeq 10\,mV$$

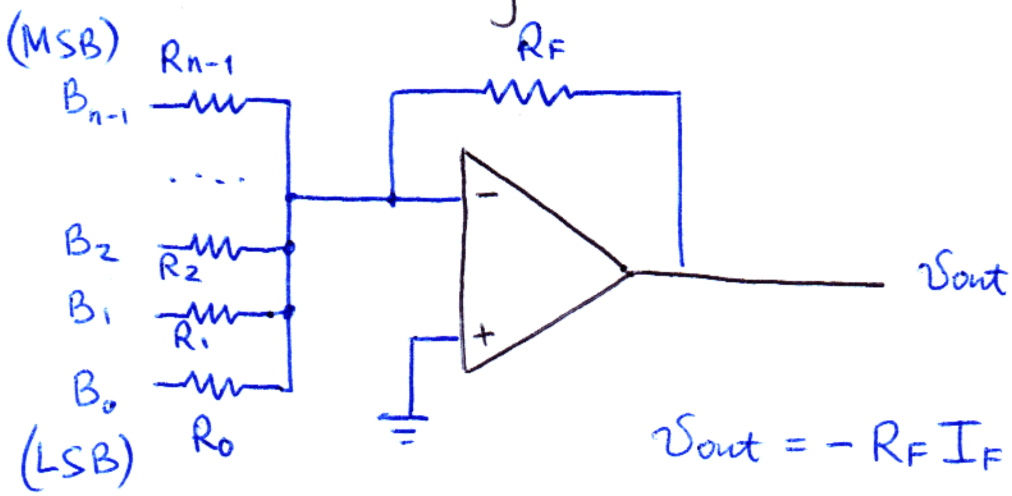
(if using the full range of D/A or A/D converter)

2) sampling rate $f_s = \frac{1}{T_s}$ determines the highest freq. content (actually $f_s/2$) ← sampling theorem

D/A conversion

$$\text{VALUE} = 2^{n-1} B_{n-1} + \ldots + 2^0 B_0$$

recall summing circuit



$$v_{out} = -R_F I_F$$

logic volt. levels (0–5V)

$$= -\left(\frac{R_F}{R_{n-1}} B_{n-1} + \ldots + \frac{R_F}{R_0} B_0\right)$$

Assume $R_0 = R$, $R_1 = \frac{R}{2}$, ...

$$v_{out} = -\frac{R_F}{R_0}\left(2^{n-1} B_{n-1} + \ldots + 2^0 B_0\right)$$

Problems

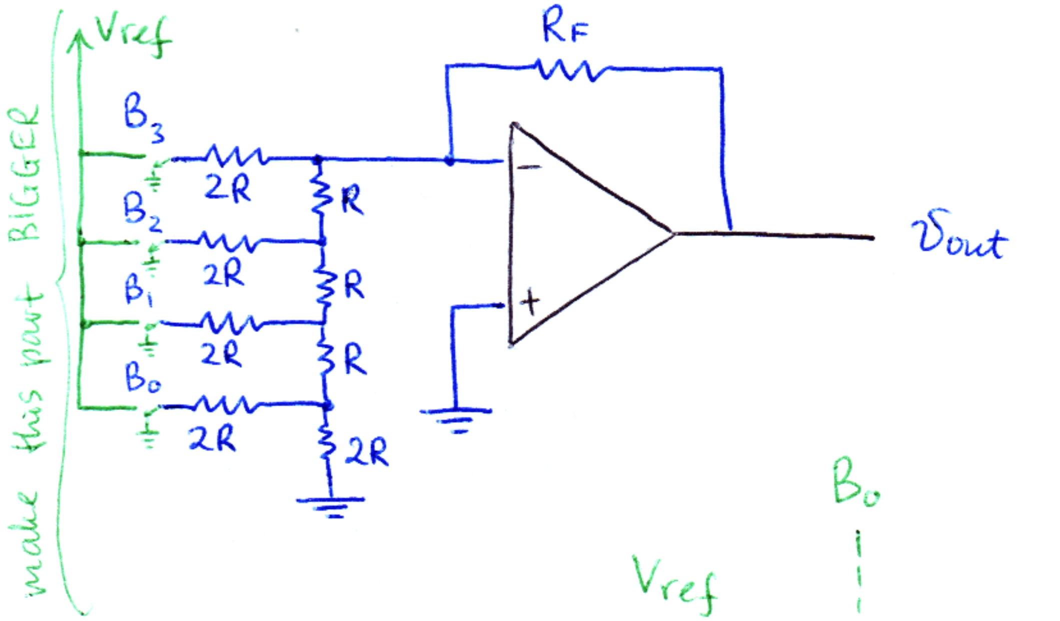
1) R's must be very accurate

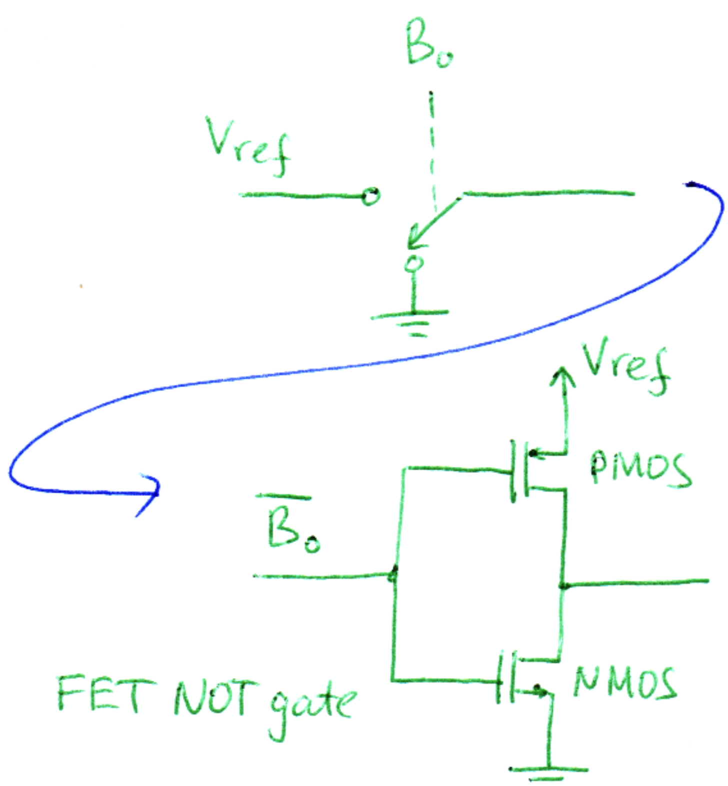
e.g. 16-bit ~ $\pm 0.0015\% \left(\frac{R_F}{R_{n-1}}\right)$ accuracy

2) large range of R's

3) $B_{n-1}, \ldots, B_0$ must be just as accurate

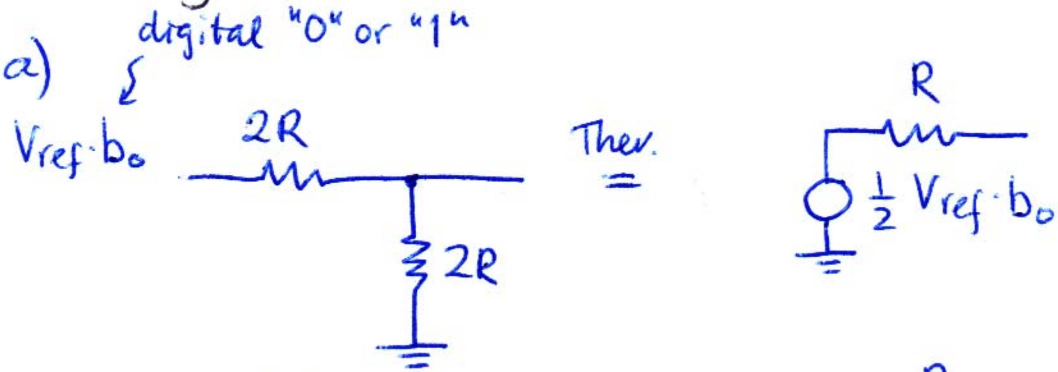
R-2R ladder D/A converter (DAC)



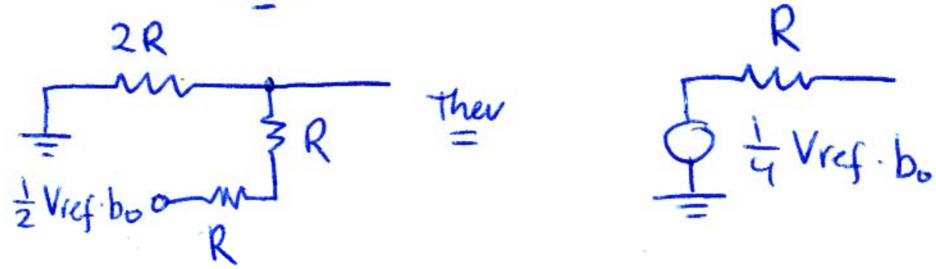


starting from LSB

a)



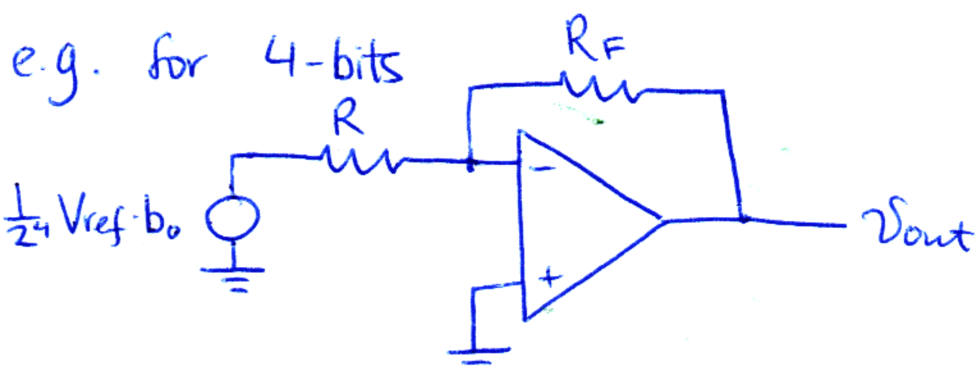
b)



c) etc. : Thev. resistance is always R

Thev. voltage ⇒ $\frac{1}{2}$ for each stage

e.g. for 4-bits



"Activate" each bit by superposition to get

$$v_{out} = -\frac{R_F}{2^n R} V_{ref} \left(2^{n-1} b_{n-1} + \ldots + 2^0 b_0\right)$$

n-bit DAC

- widely used
- (another widely used type Σ Δ modulator, next week)