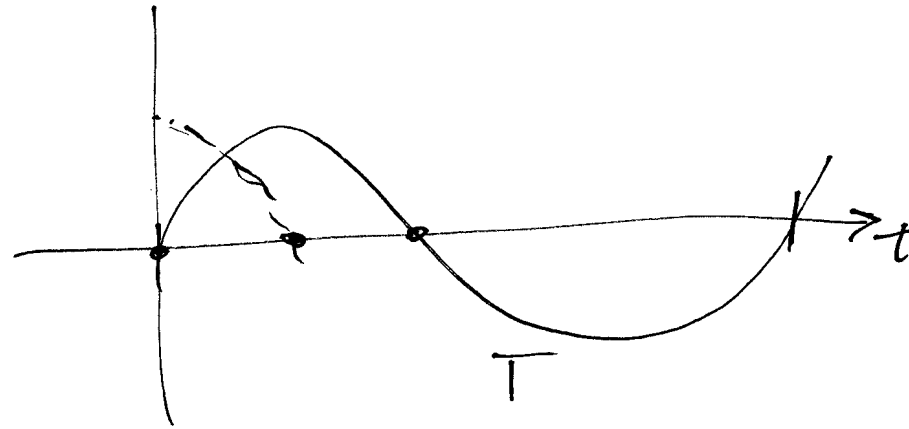
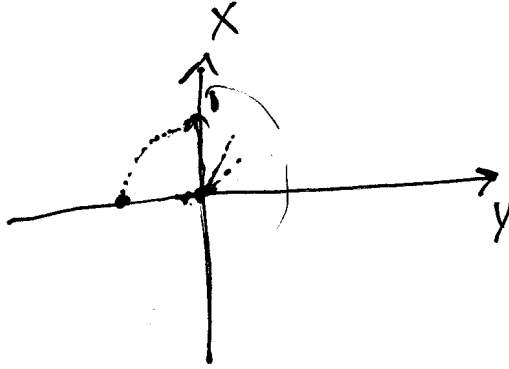


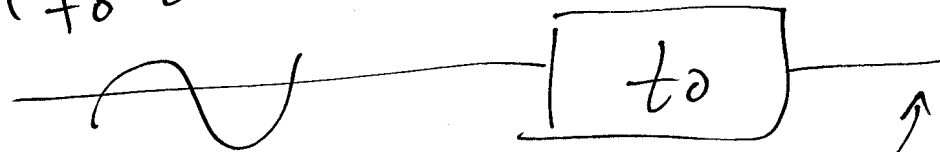
Lecture 2 ECE 615 mixed-signal 1-26-09



$\sin \rightarrow 190$

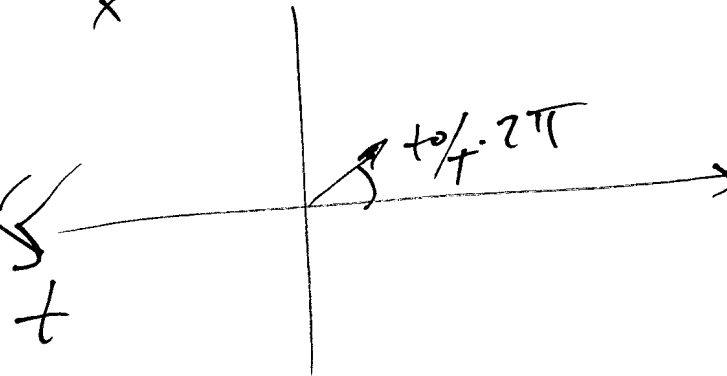
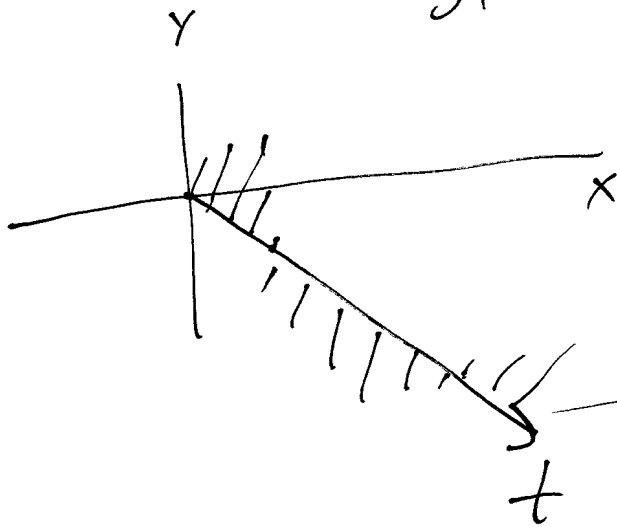
$\cos \rightarrow 180$

$\sin 2\pi f_0 \cdot t$



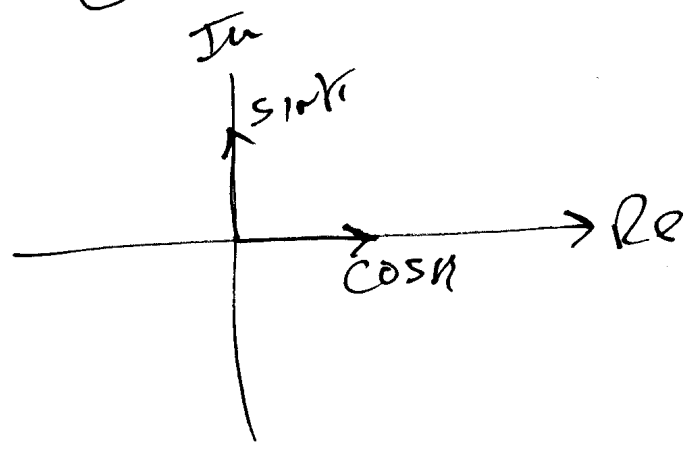
$\sin 2\pi \left( 2\pi f_0 t - \frac{t_0}{T_0} \cdot 2\pi \right)$

$\frac{1}{T_0} = f_0$

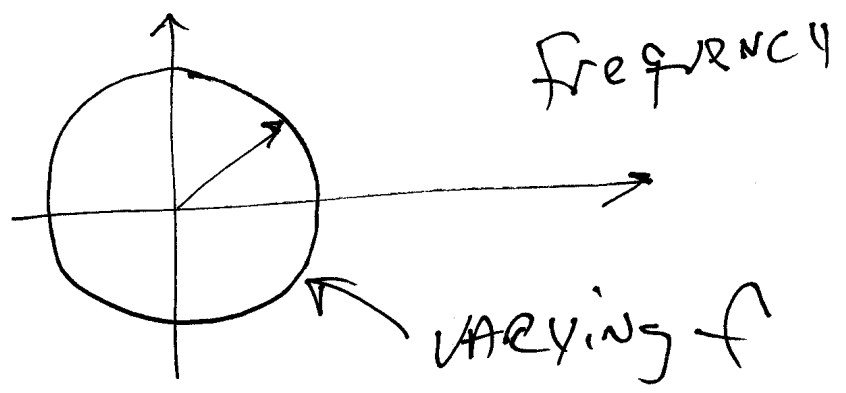


11

$$e^{j \cdot K} = \cos K + j \sin K$$



$$e^{j 2\pi f t_0}$$



$$e^{-j 2\pi f \cdot t_0}$$

e

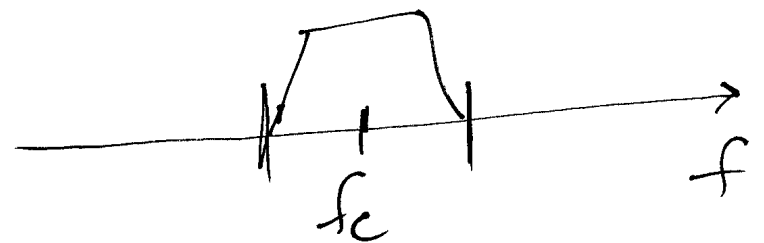
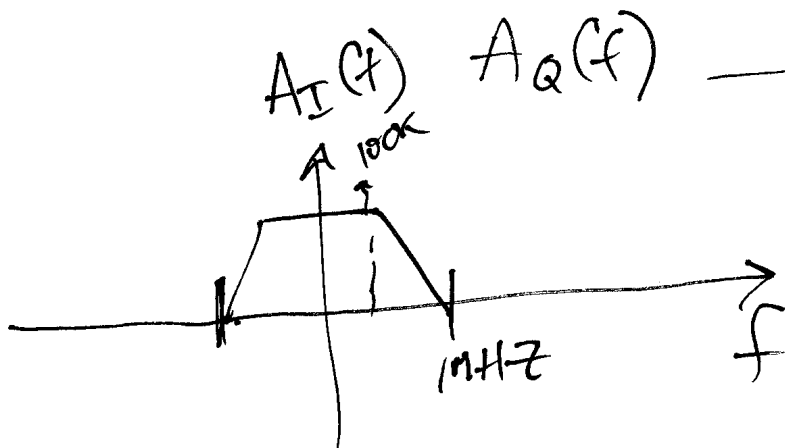
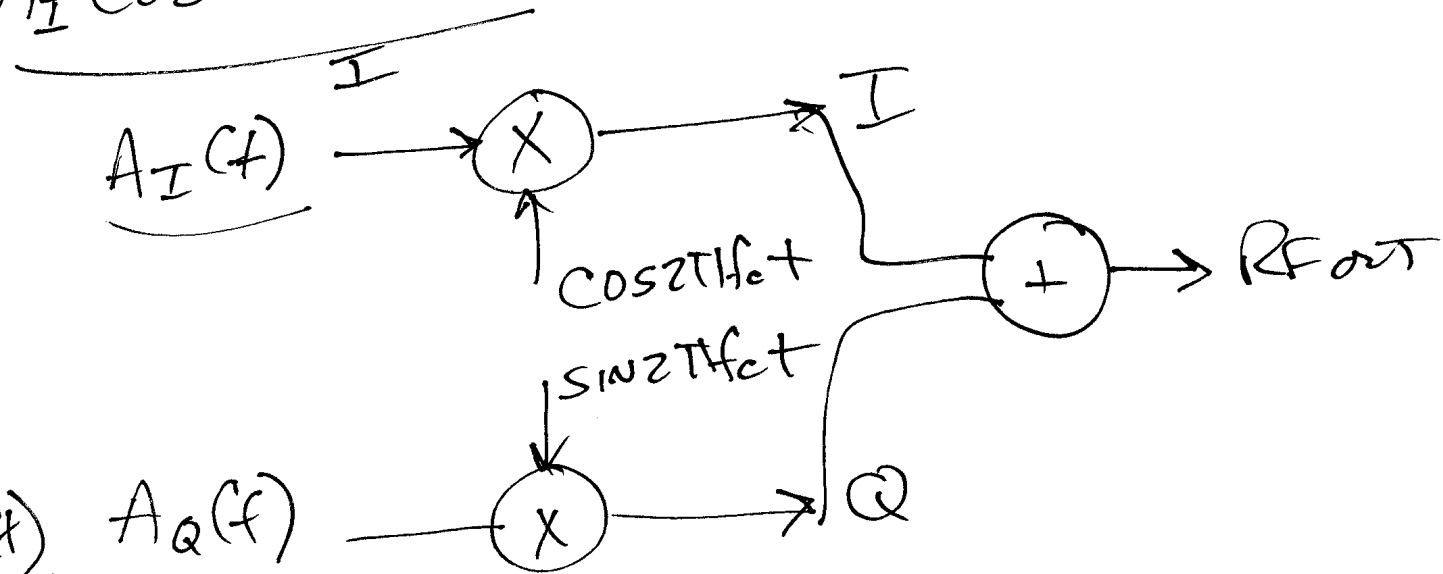


2)

# Quadrature Amplitude Modulation QAM

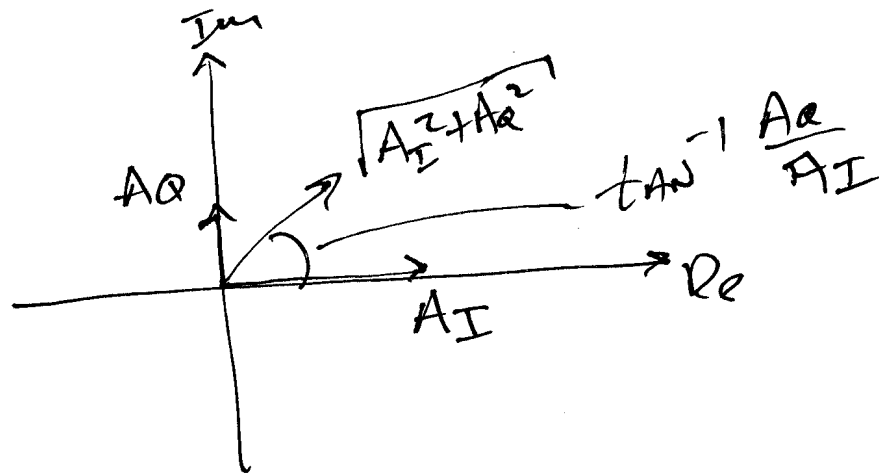
## Constellation Diagram

$$A_I \cos 2\pi f_c \cdot t + j A_Q \sin 2\pi f_c \cdot t$$



(3)

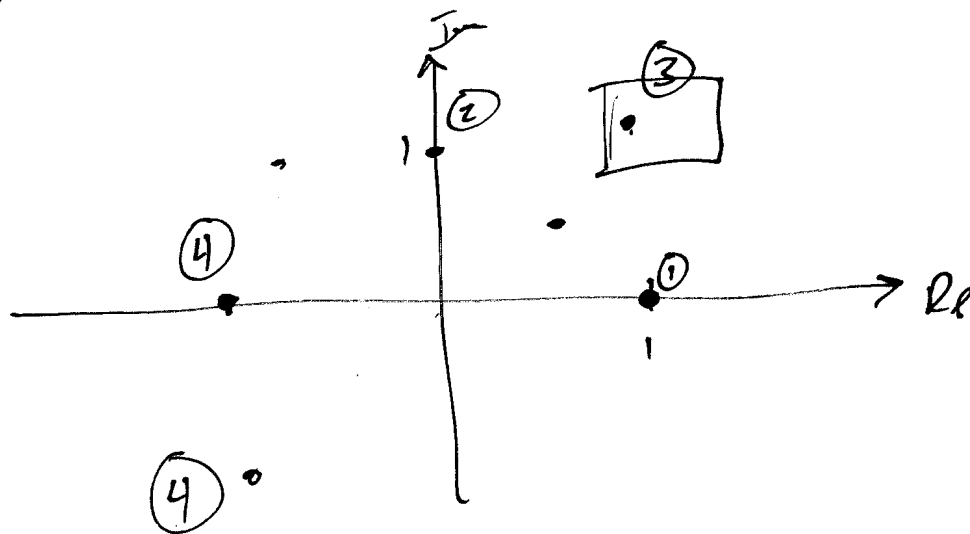
$$A_I \cdot \cos 2\pi f_c \cdot t + j A_Q \cdot \sin 2\pi f_c \cdot t$$



16-level QAM

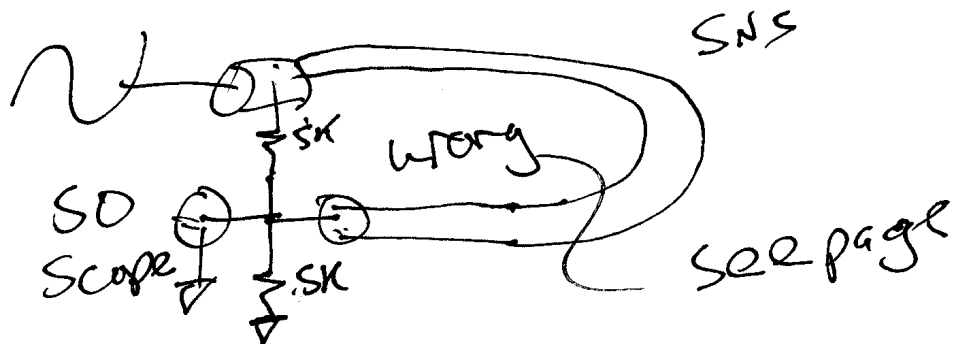
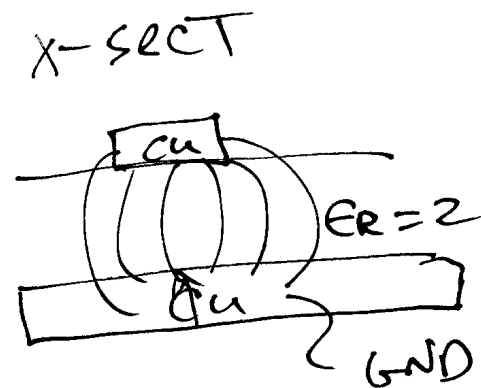
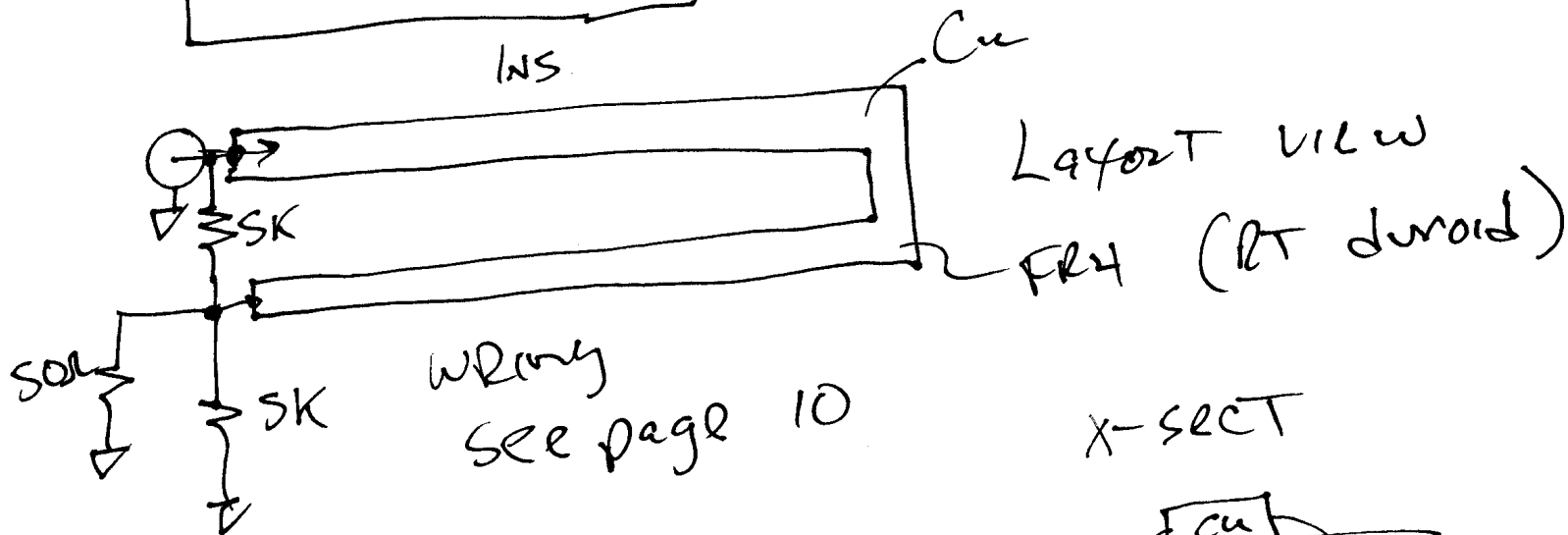
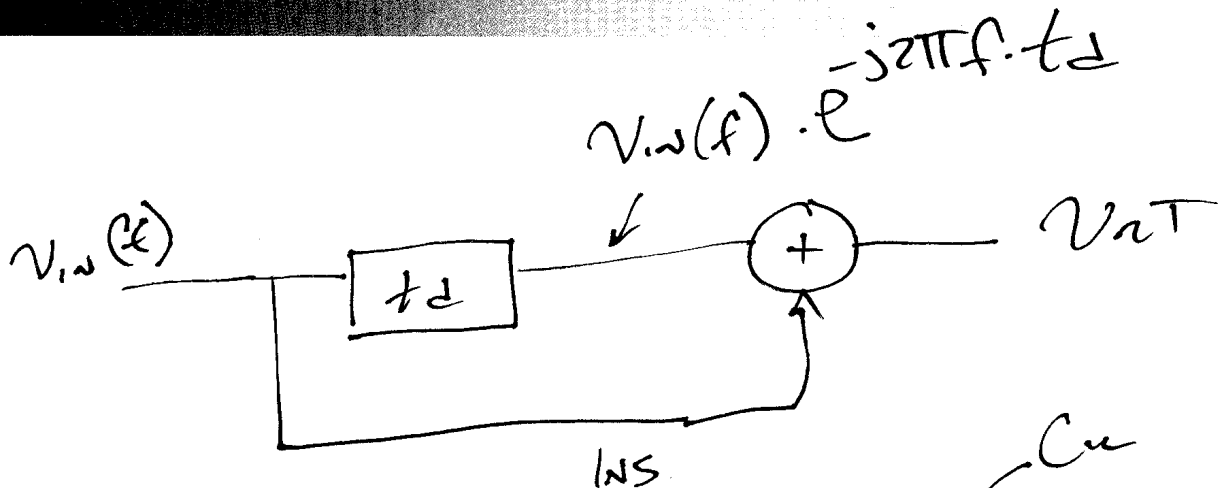
QUAD I

$$P_{\text{out}} = \sqrt{A_I^2 + A_Q^2} \cdot \cos\left(2\pi f_c \cdot t + \tan^{-1} \frac{A_Q}{A_I}\right)$$

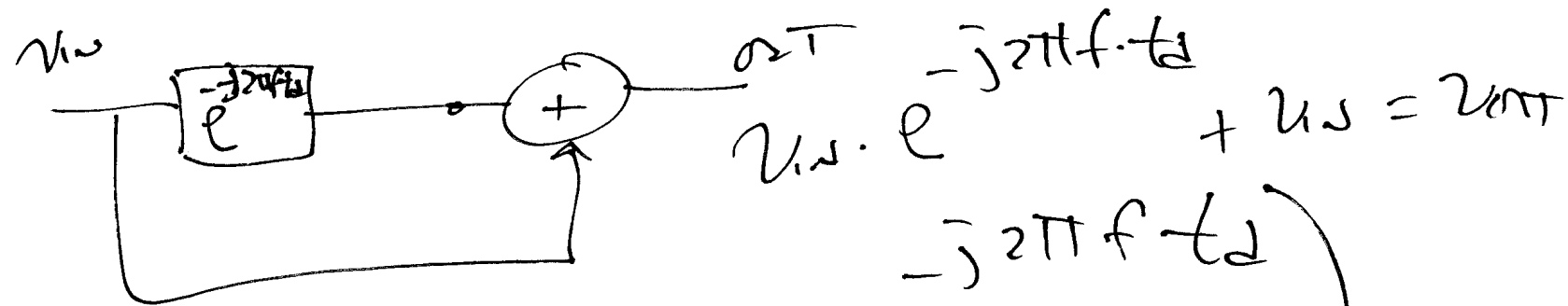


- ①  $A_I = 1, A_Q = 0$
- ②  $A_I = 0, A_Q = 1$
- ③  $A_I = 1, A_Q = 1$
- ④  $A_I = -1, A_Q = 0$
- ⑤  $A_I = -1, A_Q = -1$

4)



5)



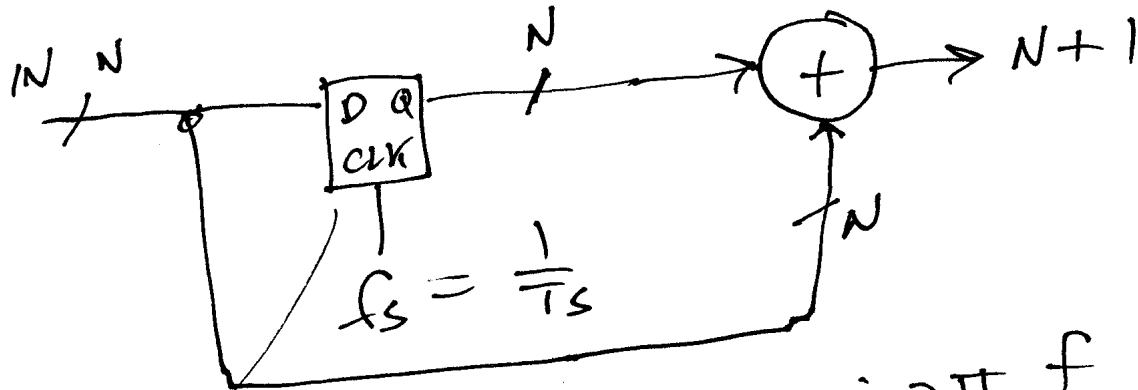
$$v_{out} = v_{in} (1 + e^{-j2\pi f t_d})$$

$$\frac{v_{out}}{v_{in}} = \underbrace{1 + \cos 2\pi f \cdot t_d}_{\text{real}} + j \sin 2\pi f \cdot t_d$$

$$\left| \frac{v_{out}}{v_{in}} \right| = \sqrt{(1 + \cos 2\pi f \cdot t_d)^2 + (-\sin 2\pi f \cdot t_d)^2}$$

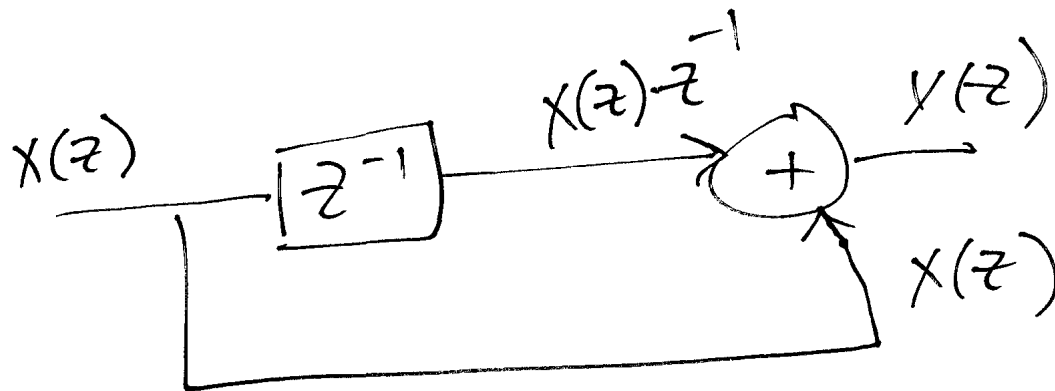
$$= |\cos \pi f \cdot t_d|$$

b)



$$e^{-j2\pi f \cdot T_s} = e^{-j2\pi \frac{f}{f_s} T_s} = z^{-1}$$

$$z = e^{j2\pi \frac{f}{f_s} T_s}$$



$$z = x + jy$$

$$Y(z) = X(z) \cdot (1 + z^{-1})$$

$$\frac{Y(z)}{X(z)} = \left( \frac{1}{1 + z^{-1}} \right)^{-1} = \frac{z + 1}{z}$$

7)

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1+z}{z} = z^{-1} + 1$$

$(a + jd)(c + jd)$   
 $\tan^{-1} \frac{b}{a} + \tan^{-1} \frac{d}{c}$

$$z^{-1}(1+z) = e^{-j2\pi \frac{f}{f_s}} \left( 1 + \cos 2\pi \frac{f}{f_s} + j \sin 2\pi \frac{f}{f_s} \right)$$

$$\angle = -2\pi \frac{f}{f_s}$$

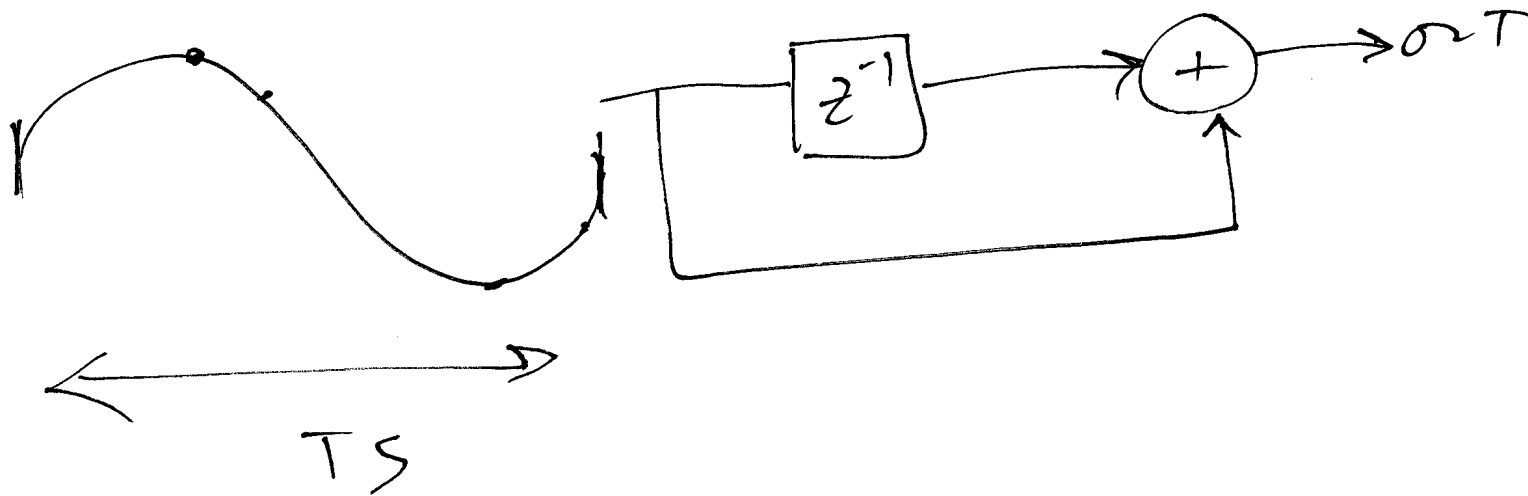
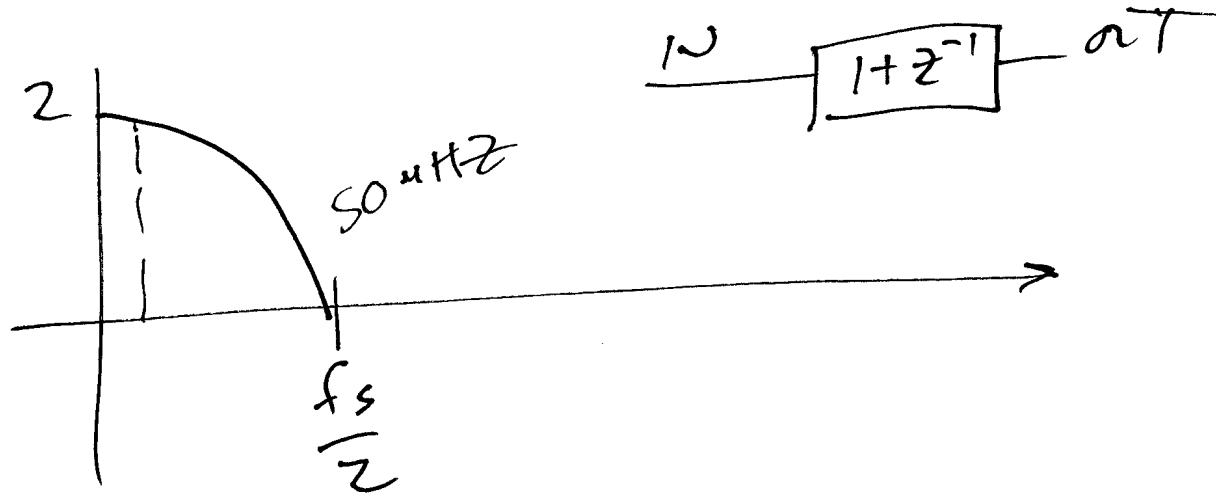
$$= 2\pi \frac{T_s}{T} + \tan^{-1} \frac{\sin 2\pi \frac{f}{f_s}}{1 + \cos 2\pi \frac{f}{f_s}}$$

$$| \cdot | = 1 \cdot \sqrt{\left( 1 + \cos 2\pi \frac{f}{f_s} \right)^2 + \sin^2 2\pi \frac{f}{f_s}}$$

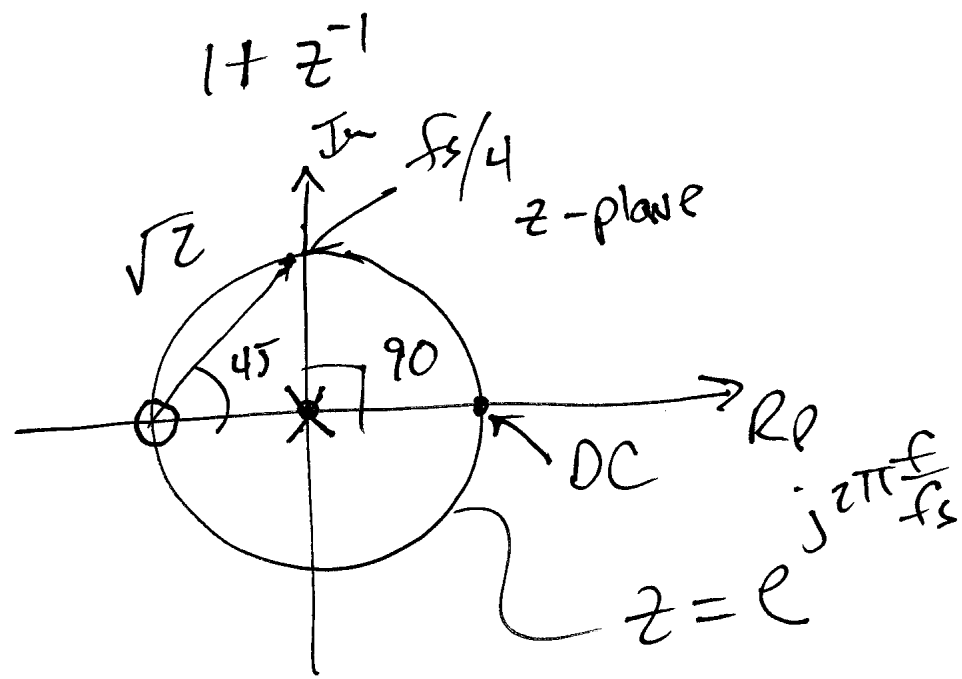
$$= 2 \left| \cos \pi \frac{f}{f_s} \right|$$

8)

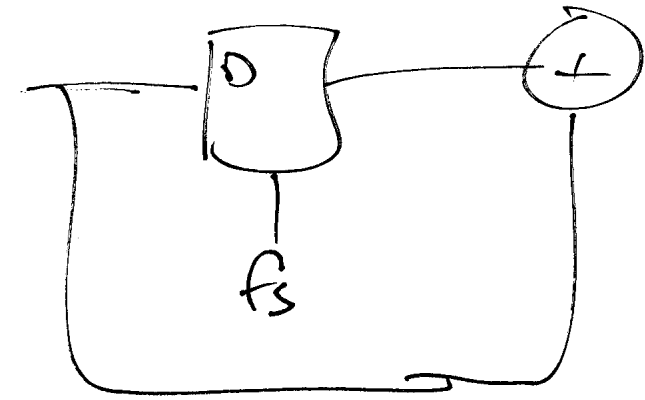
# Averager



9)

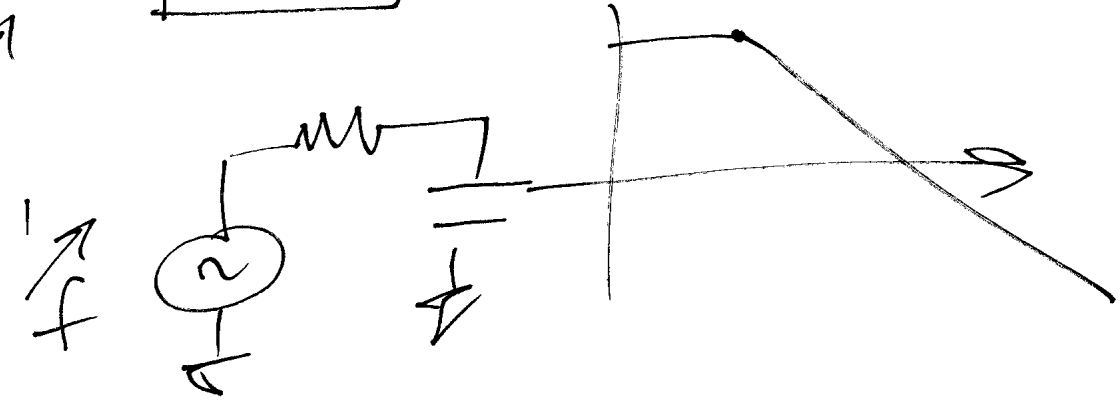
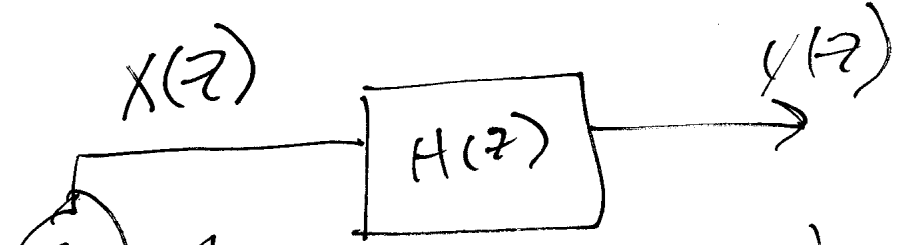


$z^{1/K}$



$\frac{z+1}{z+0} \rightarrow \frac{z}{1}$

$45 - 90 = -45$



(10)