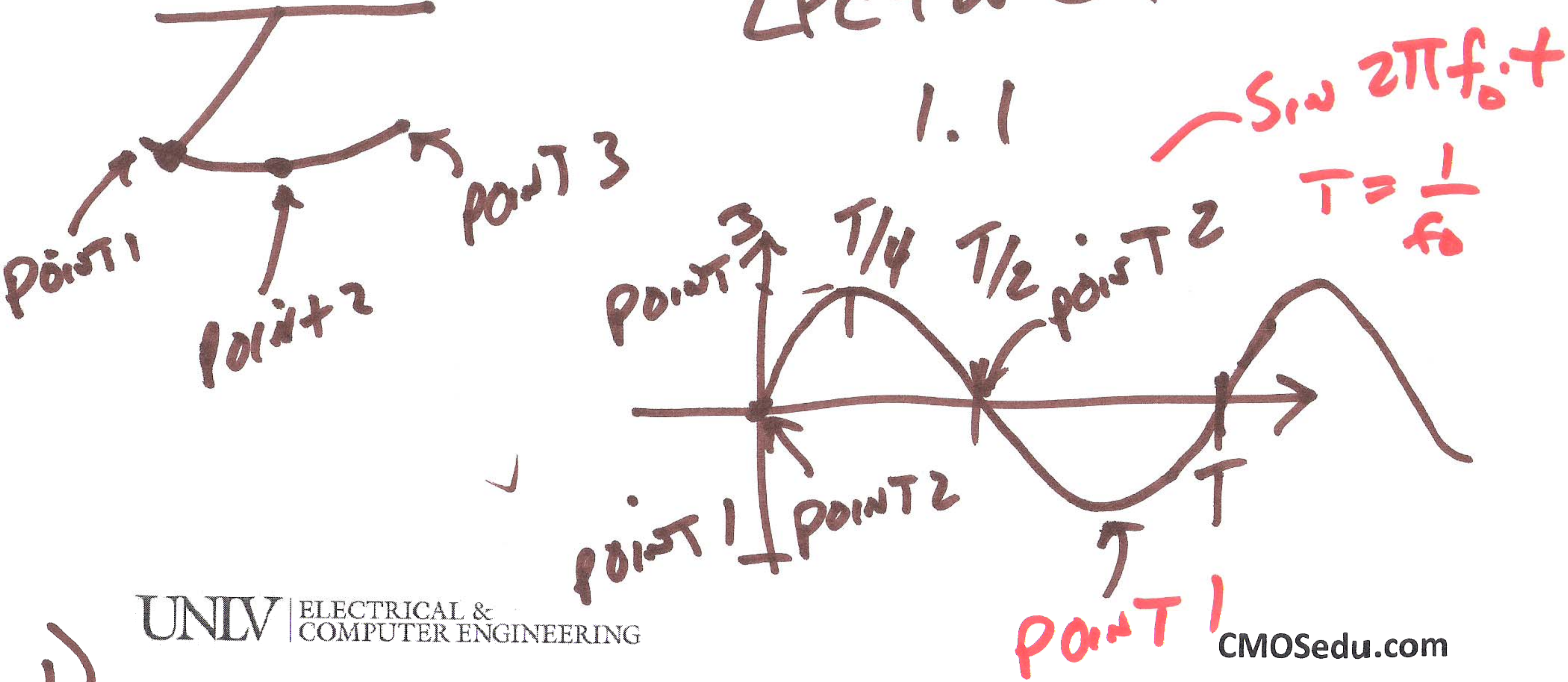
EE 722

CMOS Mixed-Signal design

Aug. 25, 2014

Lecture 1

1.1



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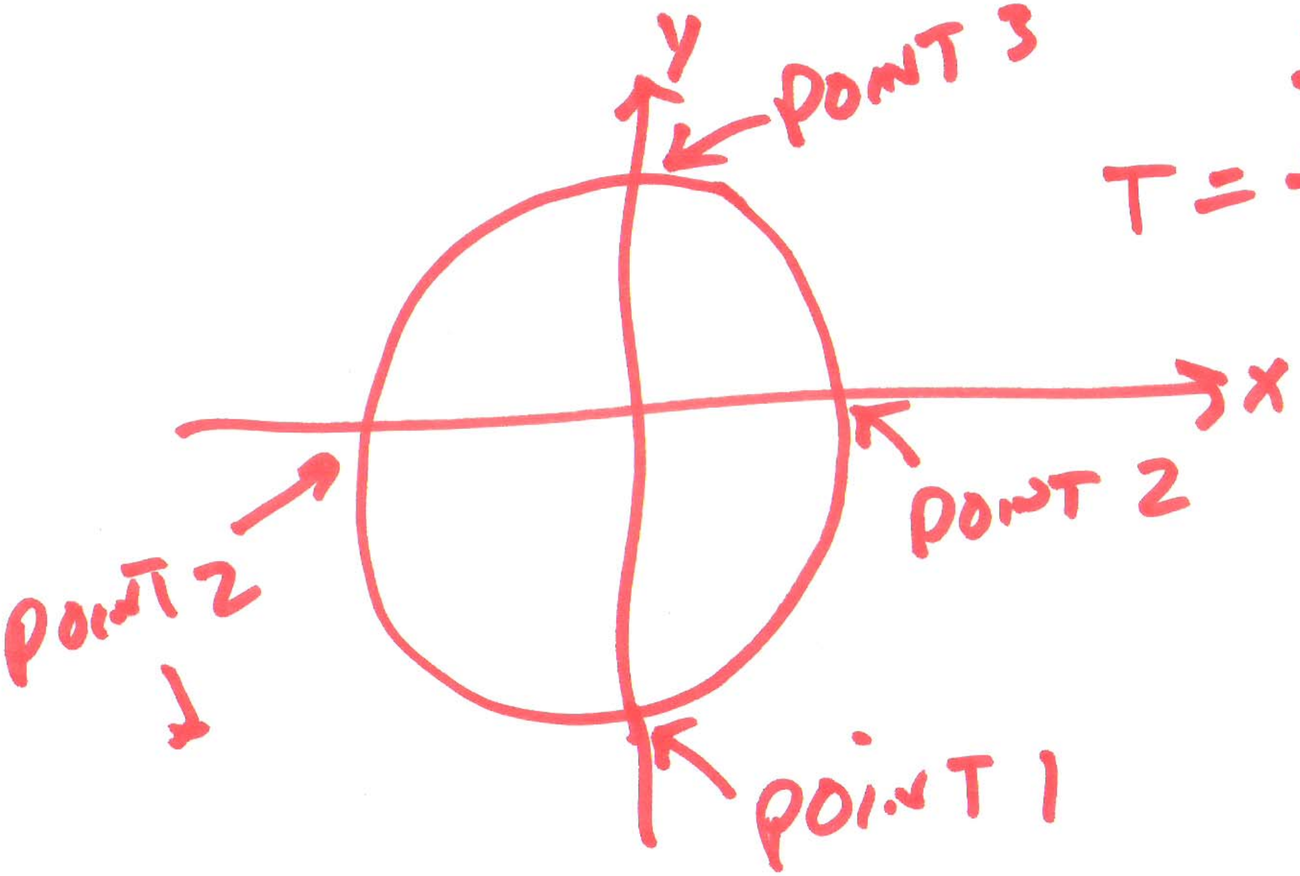
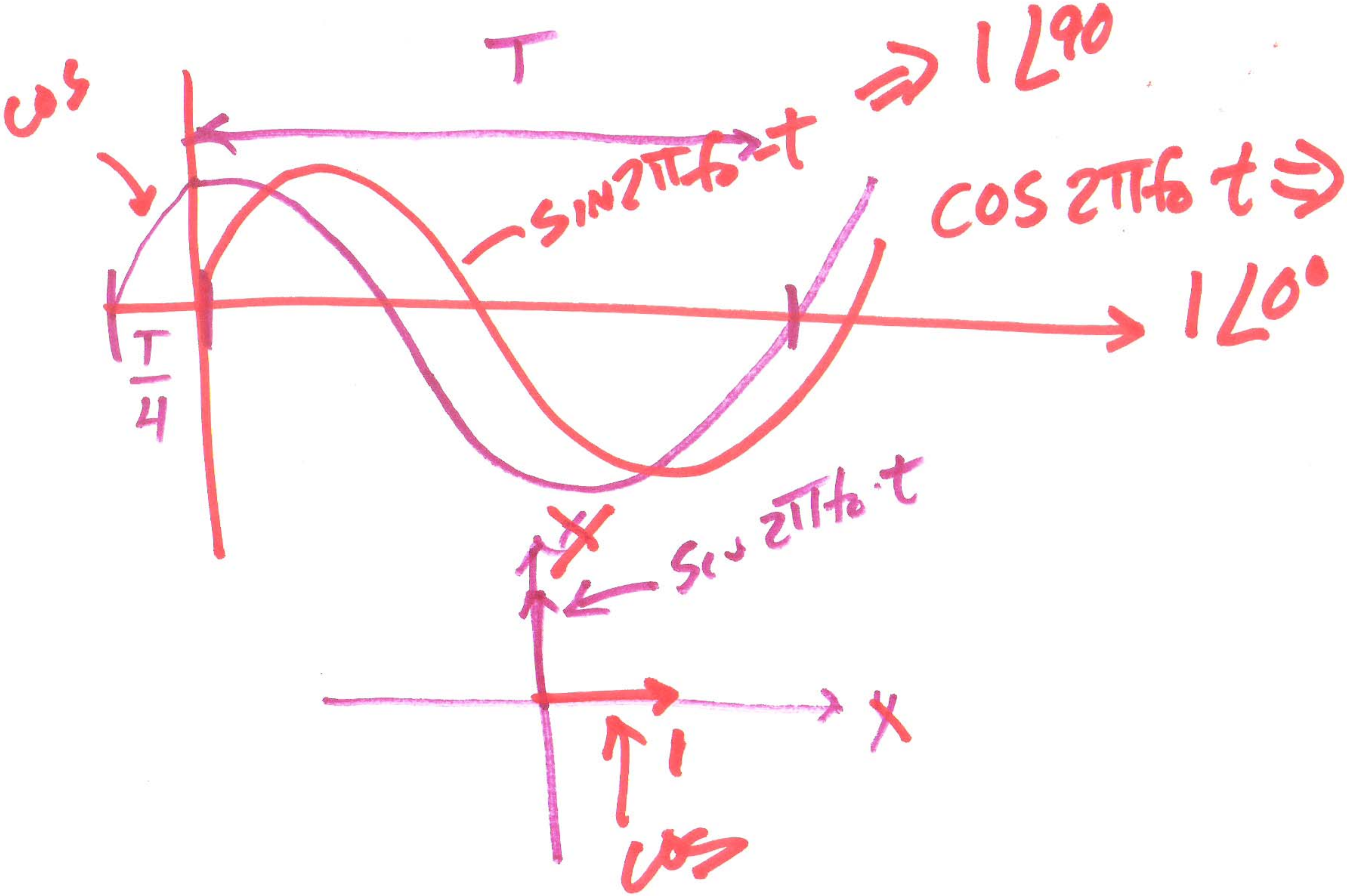
X - Y plane

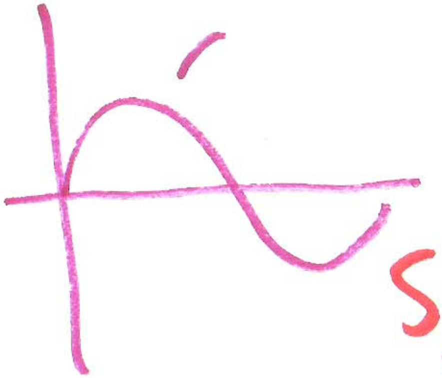


$T = \frac{1}{f}$

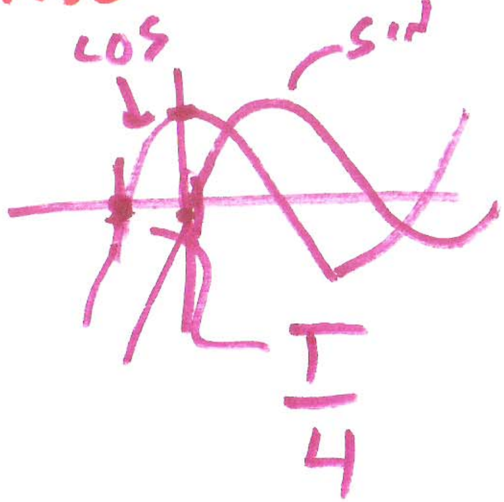
$\sin 2\pi f_0 \cdot t \Rightarrow 1\angle 90^\circ \Rightarrow \begin{matrix} x=1 \\ y=0 \end{matrix}$

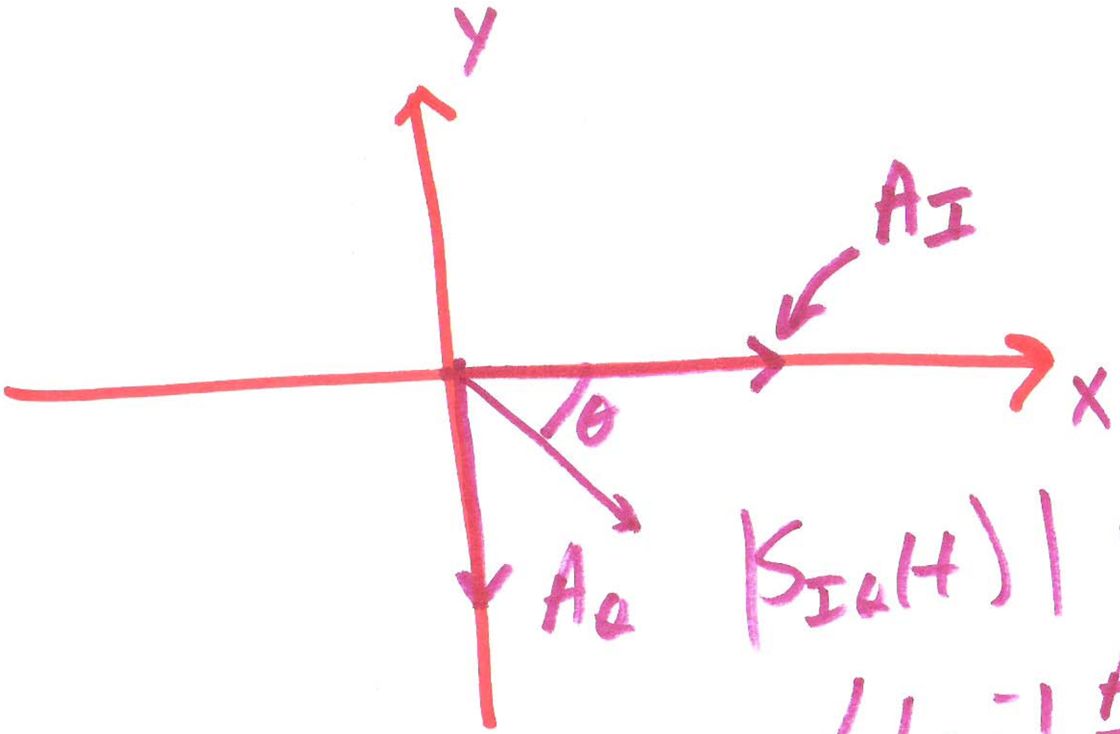


IQ Signals



$$s_{IQ}(t) = A_I \cos 2\pi f_0 \cdot t + A_Q \cdot \sin 2\pi f_0 \cdot t$$





$$|s_{IQ}(t)| = \sqrt{A_I^2 + A_Q^2}$$

$$\angle \tan^{-1} \frac{A_Q}{A_I}$$

z-plane (complex plane)

$$e^{k} = 1 + k + \frac{k^2}{2!} + \frac{k^3}{3!} + \dots$$

$$\cos k = 1 - \frac{k^2}{2!} + \frac{k^4}{4!} - \frac{k^6}{6!} + \dots$$

$$\sin k = k - \frac{k^3}{3!} + \frac{k^5}{5!} - \frac{k^7}{7!}$$

$$e^{jk} = \cos k + j\sin k = 1 + jk - \frac{k^2}{2!} - j\frac{k^3}{3!} + \frac{k^4}{4!}$$

$\uparrow$ Add

$j = \sqrt{-1}$

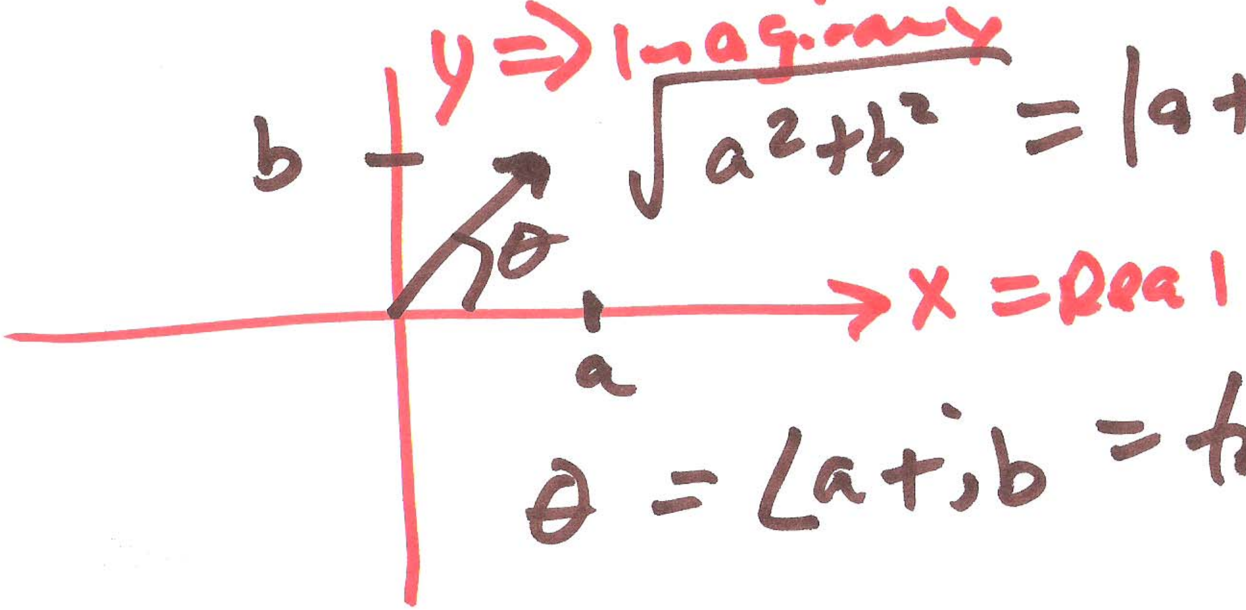
$$e^{jx} = 1 + jk - \frac{k^2}{2!} - j\frac{k^3}{3!} + \frac{k^4}{4!}$$

$$= \cos k \quad + j \sin k$$

Real

Imaginary

$a + jb$



$$\sqrt{a^2+b^2} = |a+jb|$$

$$\theta = \angle a+jb = \tan^{-1}\frac{b}{a}$$

$$\frac{1}{a+jb}\cdot\frac{a-jb}{a-jb} \Rightarrow \underbrace{\frac{a}{a^2+b^2}}_{x} + j\,\underbrace{\frac{-b}{a^2+b^2}}_{y}$$

$$\left|\frac{1}{a+jb}\right| = \sqrt{\left(\frac{a}{a^2+b^2}\right)^2+\left(\frac{-b}{a^2+b^2}\right)^2}$$

$$= \sqrt{\frac{\cancel{a^2+b^2}}{(a^2+b^2)^{\cancel{2}}}} = \frac{1}{\sqrt{a^2+b^2}}$$

$$\angle\frac{1}{a+jb} = \tan^{-1}\frac{-b}{a} = -\tan^{-1}\frac{b}{a}$$

Euler's formula

$$e^{jk} = \cos k + j \sin k$$

$$\tan^{-1} \frac{\sin 2\pi f_0 t}{\cos 2\pi f_0 t}$$

$$\cos k = \frac{e^{jk} + e^{-jk}}{2}$$

$$\theta = 2\pi f_0 \cdot t$$

$$\sin k = \frac{e^{jk} - e^{-jk}}{2j}$$

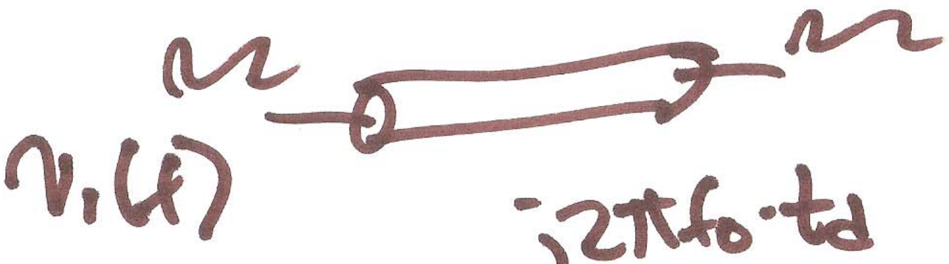
1.1 plot $e^{j2\pi f_0 \cdot t}$ in the complex plane

$$\left|e^{j2\pi f_0 \cdot t}\right| = \left|\cos 2\pi f_0 t + j \cdot \sin 2\pi f_0 t\right|$$

$$= \sqrt{\cos^2(\,) + \sin^2(\,)} = 1$$

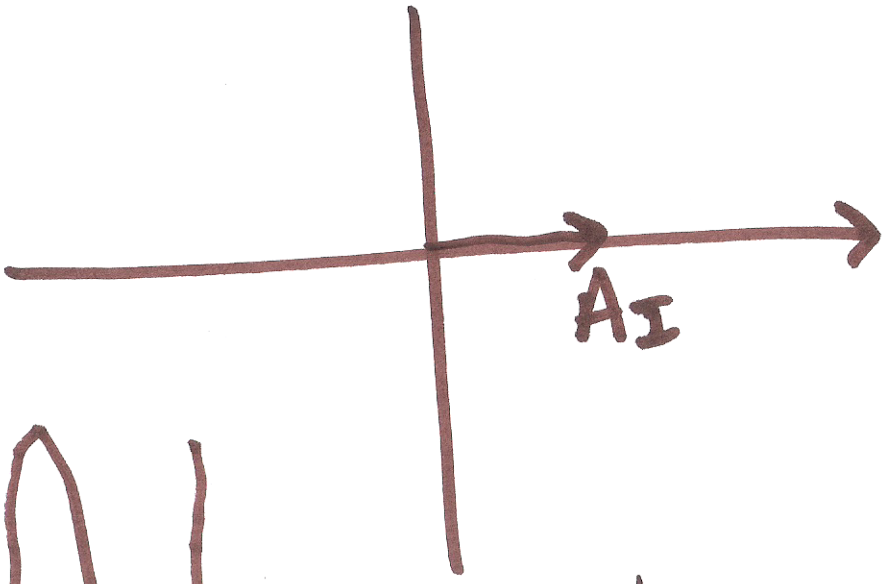
$$\left| e^{j2\pi f_0 \cdot t_d} \right| = 1$$

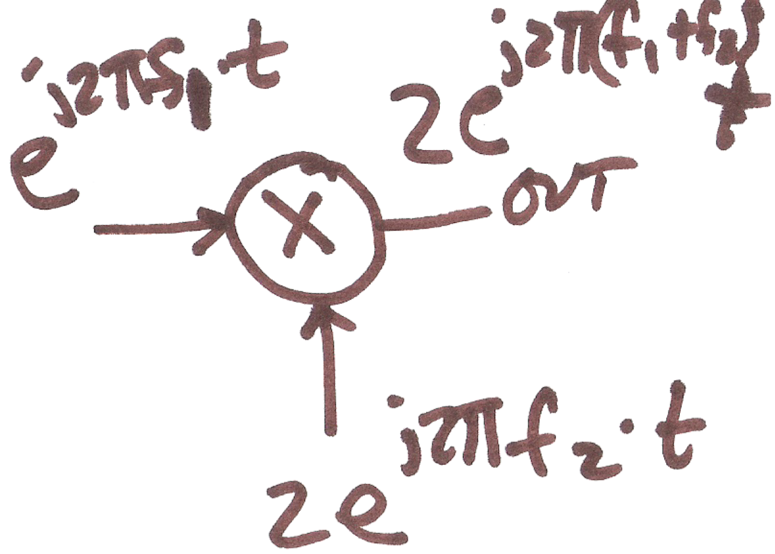
$$\angle 2\pi f_0 \cdot t_d = \text{CONST}$$

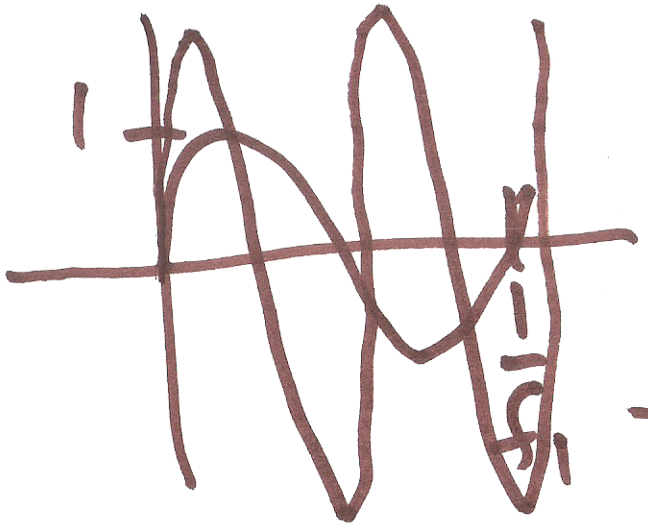


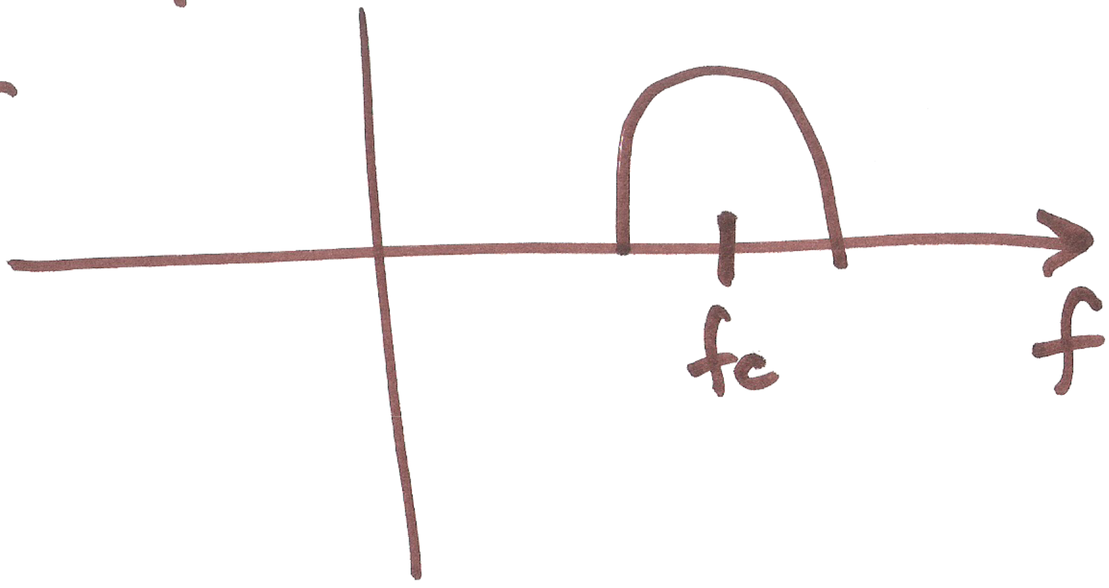
$$v_2(f) = v_1(f) \cdot e^{j2\pi f_0 \cdot t_d}$$

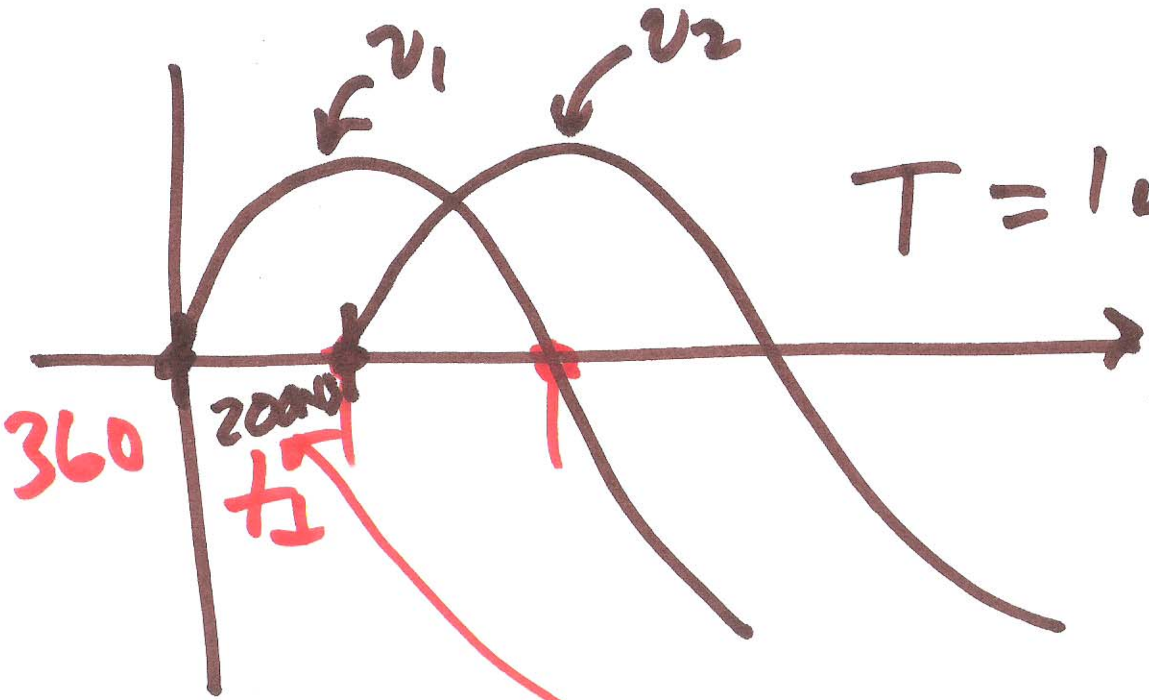
$$\cos 2\pi f_1 \cdot t \rightarrow \mathrm{Re}\left\{ e^{j2\pi f_1 \cdot t} \right\}$$


A_I


$e^{j2\pi f_1 \cdot t}$
$2e^{j2\pi(f_1+f_2)t}$
OUT
$2e^{j2\pi f_2 \cdot t}$


1
$\frac{1}{f_1}$


f_c
f



$T = 1\mu s$

$T = \frac{1}{f}$

$t_d \cdot f \cdot 360$

v_1 leads v_2

$$\theta = \frac{t_d}{T} \cdot 360$$

$$= \frac{200n}{1\mu} \cdot 360$$

$$72°$$

$$\angle \frac{v_1}{v_2} = +72°$$

$$\angle \frac{v_2}{v_1} = -72°$$