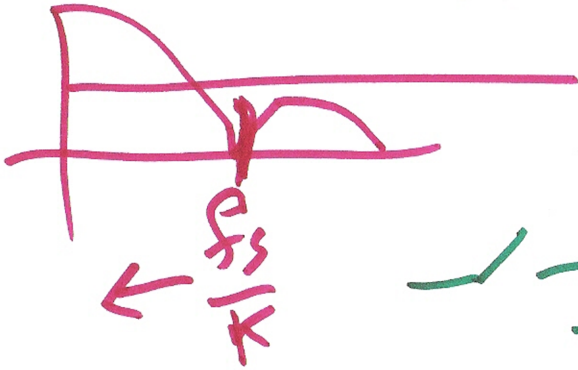
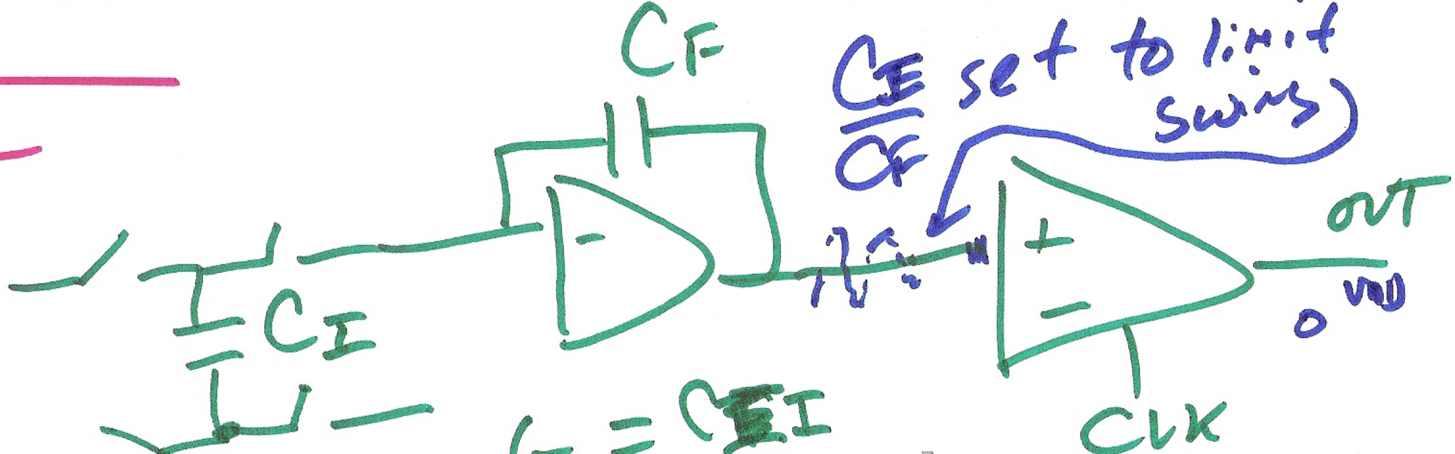
ECE 615 CMOS Mixed-Signal Circuit Design

Lecture 24 NOV. 15, 2010





$G = \frac{C_I}{C_F}$

select C_I based upon thermal noise considerations

$V_N = \sqrt{\frac{KT}{C_I}}$

$V_N^2 = \frac{KT}{C_I}$ ← K: Boltzmann's constant.

eff noise $= \frac{V_N^2}{K}$ ← K: OSR

1)

~~Second~~ First-order noise-shaping

1st-order

$$\lim_{t_0 \to 0} \frac{x(t) - x(t - t_0)}{t_0}$$

$$V_{OUT} = V_{IN} \cdot z^{-1} + V_{QE} (1 - z^{-1})$$

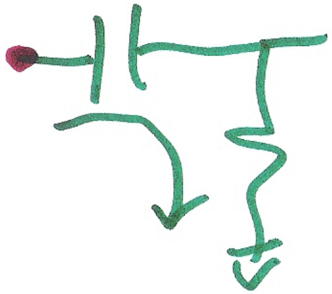
$f < f_s$

$\frac{1}{j\omega C}$

$f \ll \frac{1}{2\pi RC}$ $v_{OUT} \approx$

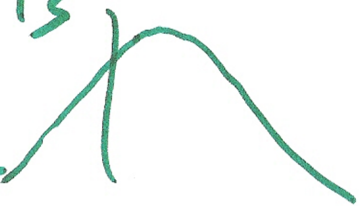
$v_{OUT} = i \cdot R$

v_{IN}



$$i = C \frac{dv}{dt} = C \frac{d(v_{IN} - v_{OUT})}{dt}$$

$$z = e^{j\omega \cdot T_s} = e^{j\frac{f}{f_s} \cdot 2\pi}$$



$$z \approx 1 + j 2\pi \frac{f}{f_s}$$

$f \ll f_s$

$$v_{OUT} = v_{IN} \cdot \frac{R}{R + \frac{1}{j\omega C}}$$

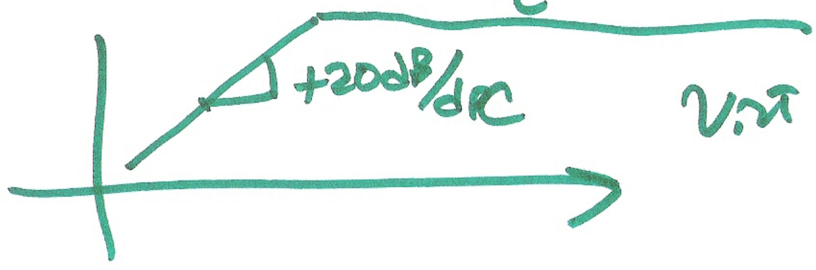
$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots$$

$$\frac{v_{OUT}}{v_{IN}} = \frac{j\omega RC}{1 + j\omega RC}$$

$$1 - z^{-1} = \frac{z - 1}{z} = j 2\pi \frac{f}{f_s}$$

$f \ll \frac{1}{2\pi RC}$

$\approx j\omega RC$

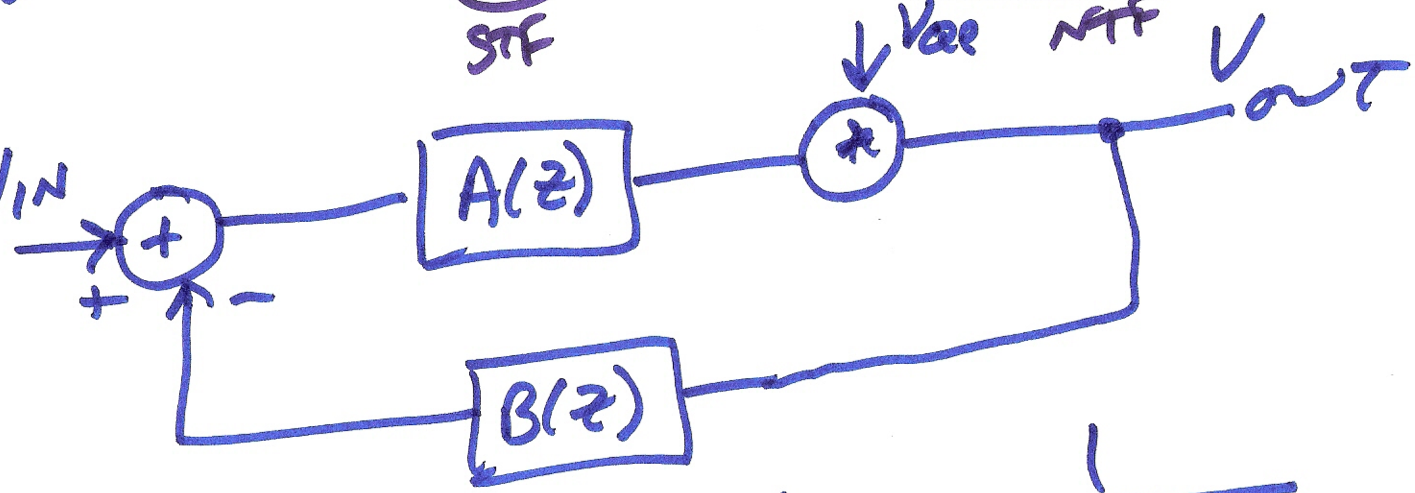


$$v_{OUT} = j\omega RC \cdot v_{IN}$$

2)

second-order noise-shaping

$$V_{OUT} = \underbrace{V_{IN} \cdot z^{-1}}_{STF} + \underbrace{V_{QE}\,(1 - z^{-1})^2}_{NTF}$$



$$V_{OUT} = V_{IN} \cdot \frac{A}{1+AB} + V_{QE} \cdot \frac{1}{1+AB}$$

STF → 1, A → ∞

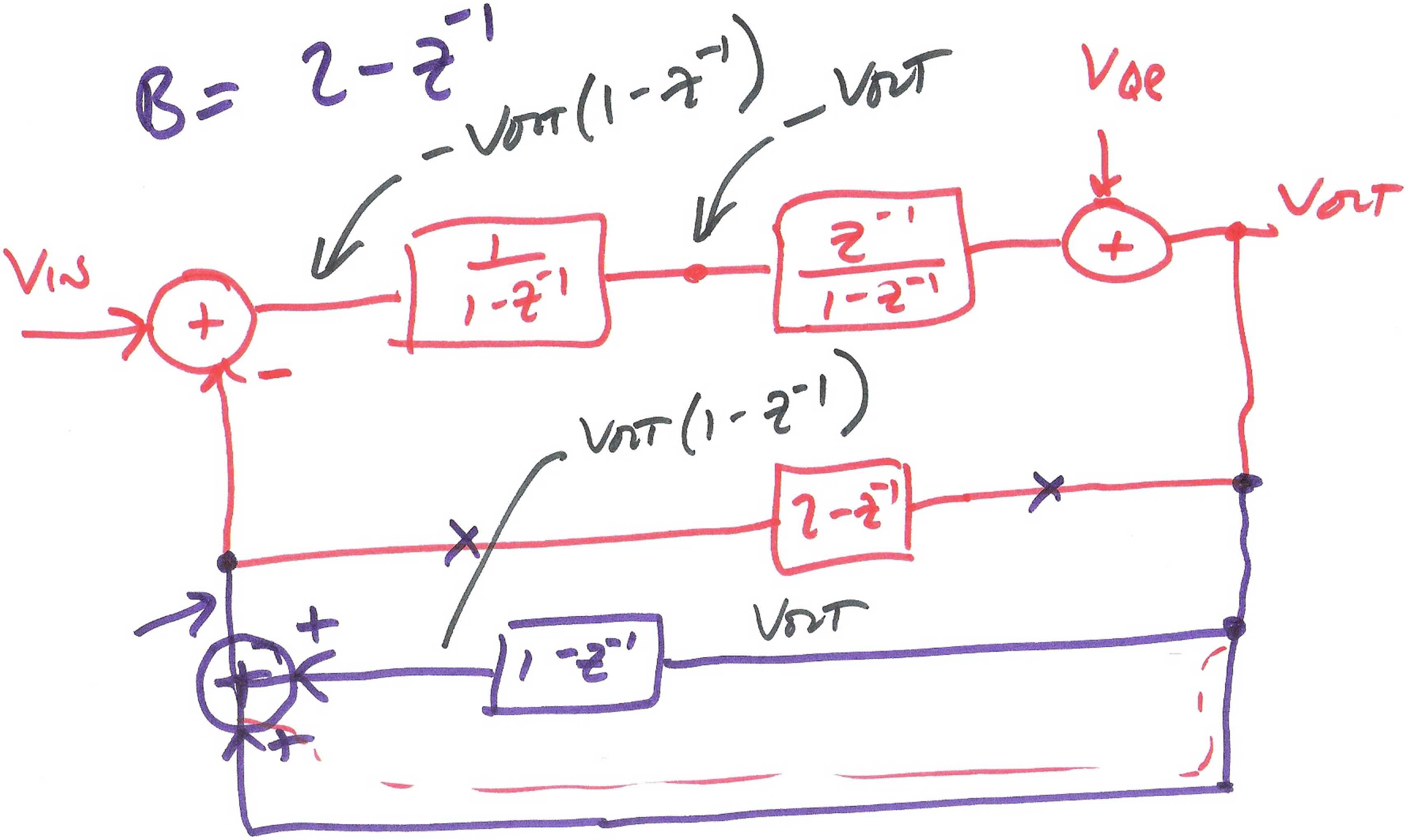
NTF → 0, A → ∞

$$z^{-1} = \frac{A}{1+AB} \qquad (1 - z^{-1})^2 = \frac{1}{1+AB}$$

3)

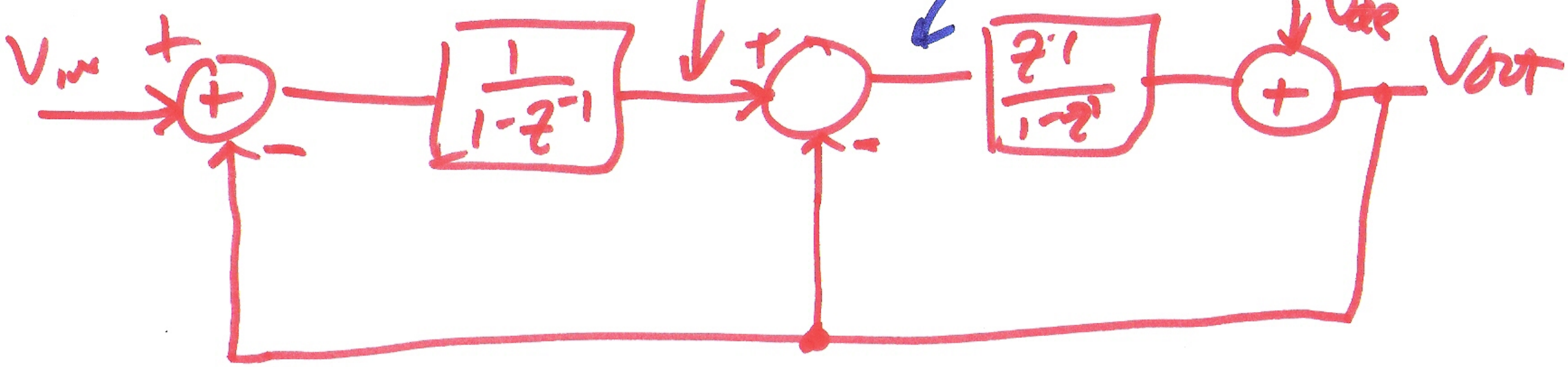
$$A = \frac{z^{-1}}{(1-z^{-1})^2} = \frac{1}{1-z^{-1}} \; \frac{z^{-1}}{1-z^{-1}}$$

$$B = 2 - z^{-1}$$



4)

$$(V_{IN} - V_{OUT})\left(\frac{1}{1-z^{-1}}\right) - V_{OUT}$$



$$(1-z^{-1})\left(\frac{(V_{IN}-V_{OUT})z^{-1}}{(1-z^{-1})^2} - \frac{V_{OUT}z^{-1}}{1-z^{-1}}\right)\frac{z^{-1}}{1-z^{-1}} + V_{QE} = V_{OUT}$$

$$z^{-1}V_{IN}(1-z^{-1}) - V_{OUT}z^{-1}(1-z^{-1}) - V_{OUT}z^{-1}(1-z^{-1})$$

$$+ V_{QE}(1-z^{-1})^2$$

$$= V_{OUT}(1-z^{-1})^2$$

5)

$$z^{-1}\cdot V_{IN} - V_{OUT}\cdot z^{-1} - V_{OUT}\, z^{-1}(1-z^{-1}) + V_{QE}(1-z^{-1})^2 = V_{OUT}\,(1-z^{-1})^2$$

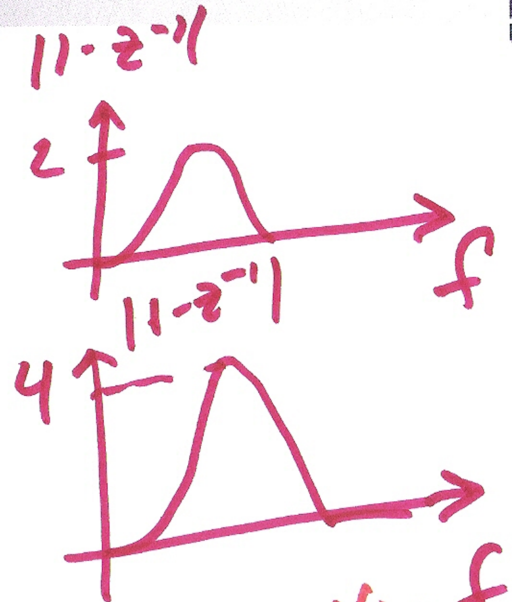
$$z^{-1}V_{IN} - V_{OUT}\, z^{-1} - V_{OUT}\, z^{-1} + V_{OUT}\, z^{-2} + V_{QE}(1-z^{-1})^2 = V_{OUT} - 2z^{-1}V_{OUT} + V_{OUT}\, z^{-2}$$

$$\boxed{V_{OUT} = V_{IN}\cdot z^{-1} + V_{QE}(1-z^{-1})^2}$$

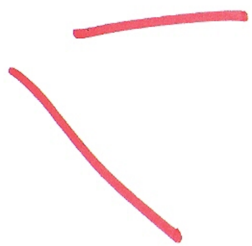
for every doubling in OSR (=K) we get 2.5 bits ↑ in N_{eff}

$\boxed{15\,dB}$

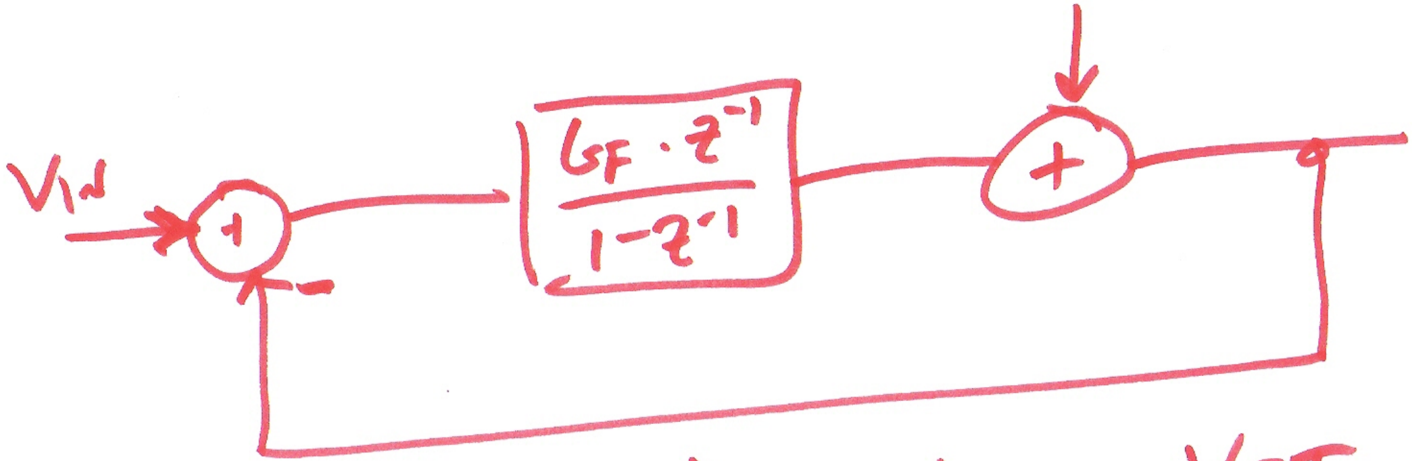
$(1-z^{-1})V_{QE} \rightarrow$



$(1-z^{-1})^2 V_{QE}$



Stability in first-order



$$\frac{G_F \cdot z^{-1}}{1-z^{-1}}(V_{IN}-V_{OUT}) + V_{QE} = V_{OUT}$$

$$G_F \cdot z^{-1} V_{IN} - V_{OUT} G_F z^{-1} + V_{QE}(1-z^{-1}) = V_{OUT}(1-z^{-1})$$

$$G_F z^{-1} V_{IN} + V_{QE}(1 - z^{-1})$$

$$= V_{OUT}(1 - z^{-1} + G_F z^{-1})$$

$$V_{OUT} = \frac{G_F z^{-1} V_{IN}}{1 - z^{-1}(1 - G_F)} + \frac{V_{QE}(1 - z^{-1})}{1 - z^{-1}(1 - G_F)}$$

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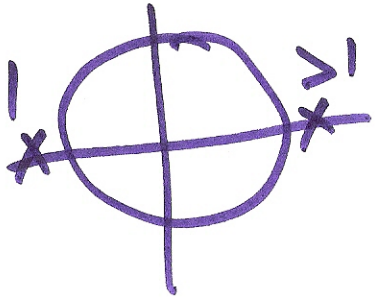
Fig. 4.37



$$z_{p1,2} = 1 - G_F \begin{matrix} > 1 \\ < -1 \end{matrix}$$

$$STF = \frac{V_{OUT}}{V_{IN}} = \frac{G_F}{z - (1 - G_F)}$$

$$NTF = \frac{V_{OUT}}{V_{QE}} = \frac{z - 1}{z - (1 - G_F)}$$

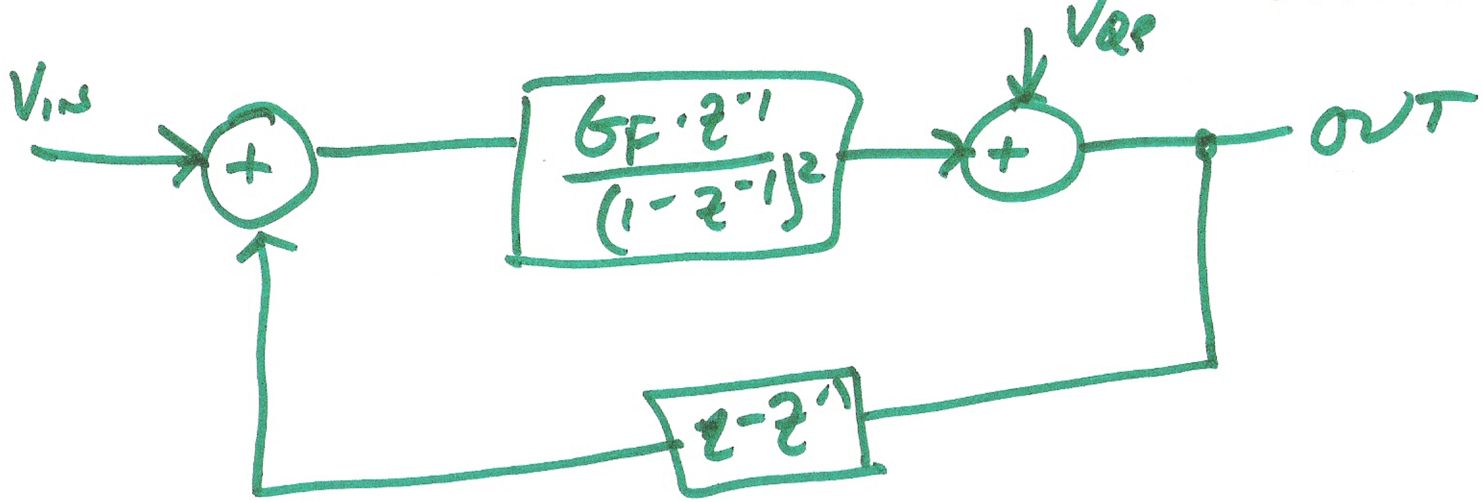
$G_F > 2$

$G_F < 0$

$$\boxed{0 < G_F < 2}$$

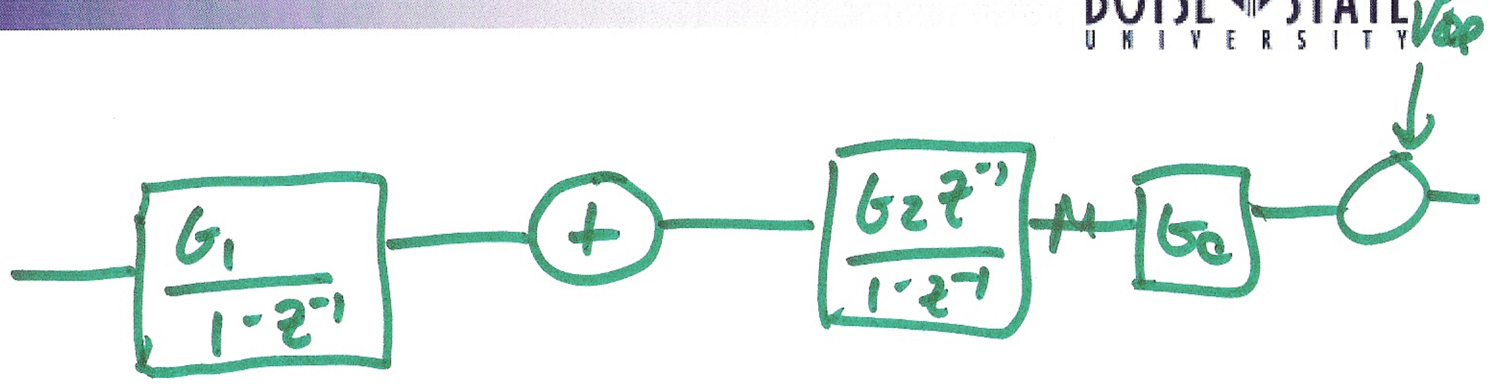
8)

Second-order Modulator



$$z^2 + z\left(2 \cdot (G_F - 1)\right) + (1 - G_F)$$

$$0 \leq G_F \leq 1.33$$



10)