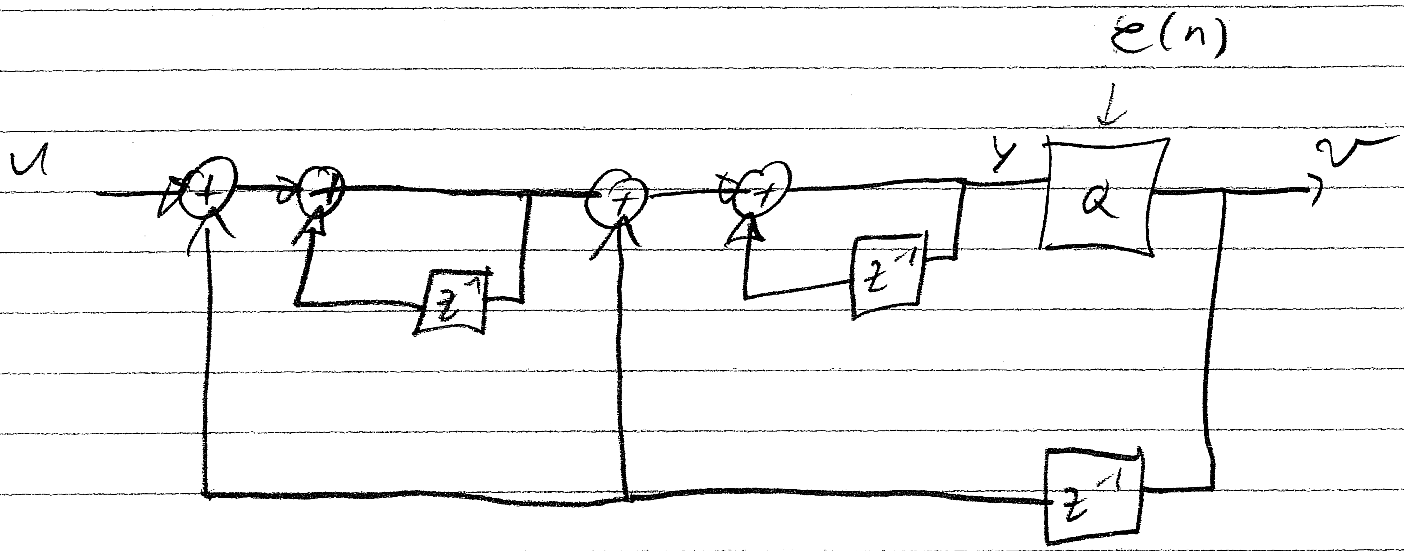
CHAP 3 MOD 2 SECOND-ORDER MODULATOR.



$$V(z) = STF(z)\,U(z) + NTF(z)\,E(z)$$

$$V(z) = U(z) + (1 - z^{-1})^2 E(z)$$

CAN SHOW

$$SQNR = \frac{15 M^2 (OSR)^5}{2\pi^4}$$

SIMULATION WITH -6dBFS SINE WAVE SHOWS

GOOD AGREEMENT WITH THEORY WHEN k = 0.63
FOR QUANTIZER GAIN (WHICH IS WHAT IS SIMULATED)

ALSO SEE SOME HARMONICS DUE TO NON-LINEAR "K" FACTOR IN QUANTIZER. K DEPENDS ON INPUT SIGNAL AMPLITUDE

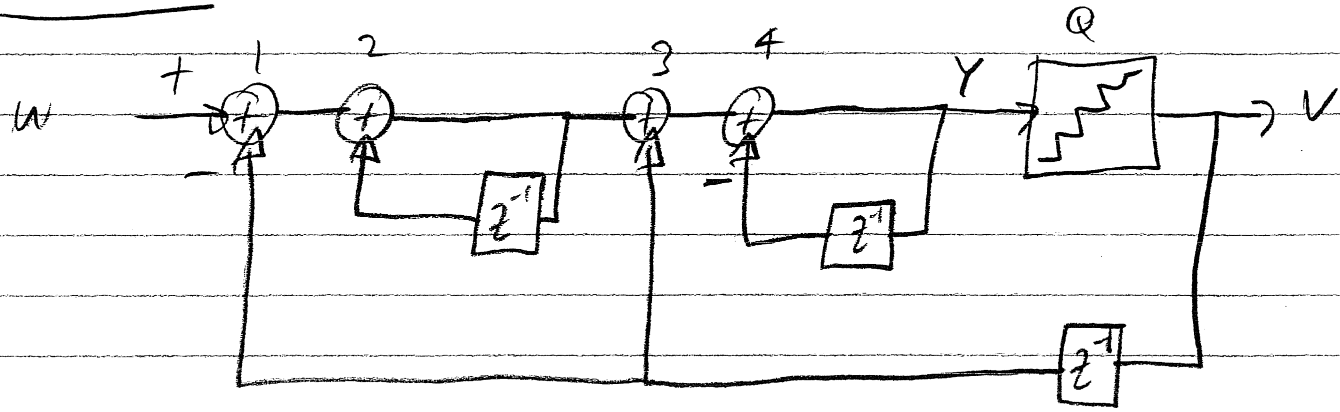
STABILITY SHOWS IT TO BE MORE UNSTABLE THAN MOD 1.
NORMALLY NEED $|u| < 0.8$ FOR ± 1 FEEDBACK

DEAD BAND NOT MUCH OF AN ISSUE BECAUSE NOW RELATED TO $\frac{1}{A^2}$

NOISE FILL-IN STILL SAME AS BEFORE

3.4 ALTERNATIVE 2ND ORDER MODULATORS.

ORIGINAL

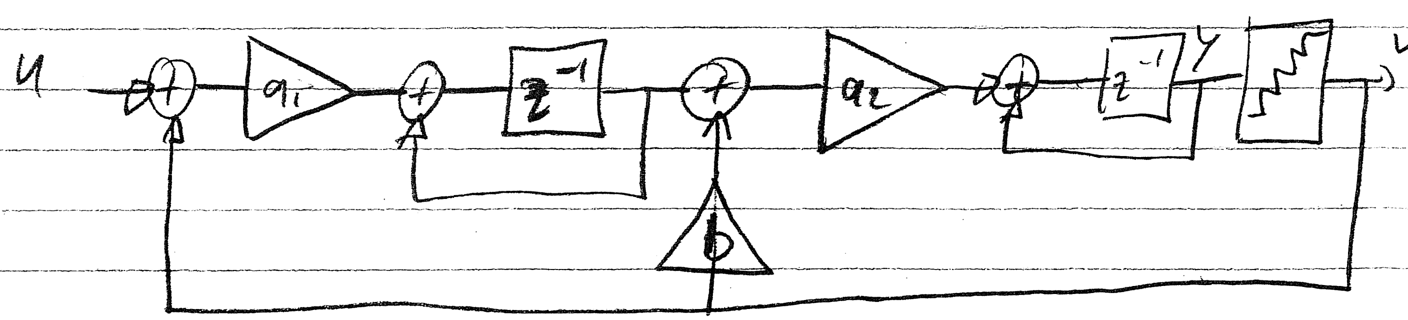


NOTE

DIGITAL IF Q IS ONE BIT

$\approx$ 2 ADDERS IN HARWARE COMPLEXITY
SINCE ADDERS 1 & 3 ADD ± 1.000000
(NO NEED TO ADD LSBs)

BOSER - WOOLEY MOD.



ALLOWS INTEGRATORS TO SETTLE INDEPENTLY SO
FASTER SETTLING TIME (2 DELAYING INTEGRATORS)

$$STF = \frac{a_1 a_2 z^{-2}}{D(z)} \qquad NTF = \frac{(1-z^{-1})^2}{D(z)}$$

WHERE $D(z) = (1-z^{-1})^2 + a_2 b z^{-1}(1-z^{-1}) + a_1 a_2 z^{-2}$

$= 1 + (a_2 b - 2) z^{-1} + (a_1 a_2 + 1 - a_2 b) z^{-2}$

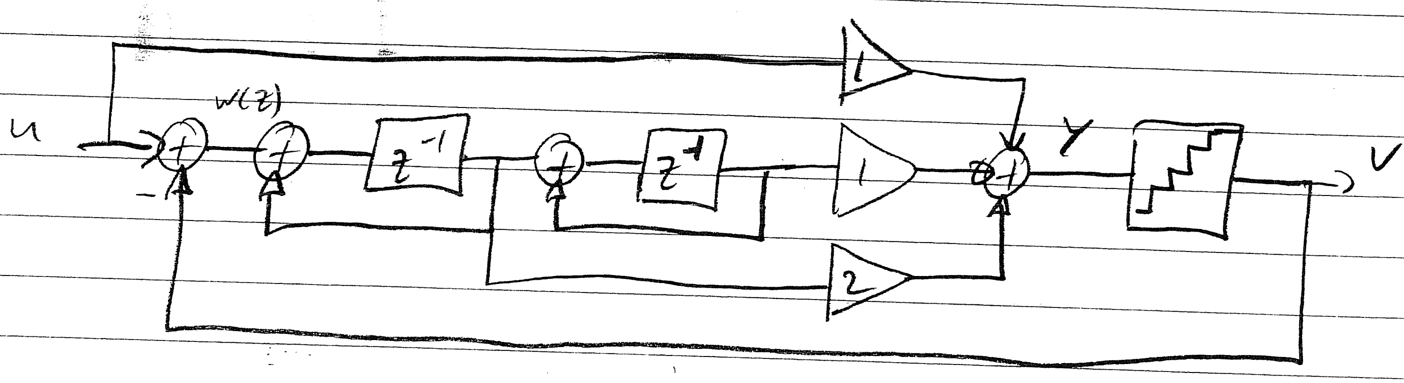
FOR $D(z) = 1 \Rightarrow a_1 a_2 = 1$ & $a_2 b = 2$

MULTIPLE SOLUTIONS $\Rightarrow$ DYNAMIC RANGE SCALING TO SET FINAL SOLUTION.

POSSIBLE SOLUTIONS

$a_1 = a_2 = 1 \quad b_2 = 2$ OR $a_1 = 0.5 \quad a_2 = 2 \quad b = 1$

SILVA-STEENSGAARD STRUCTURE

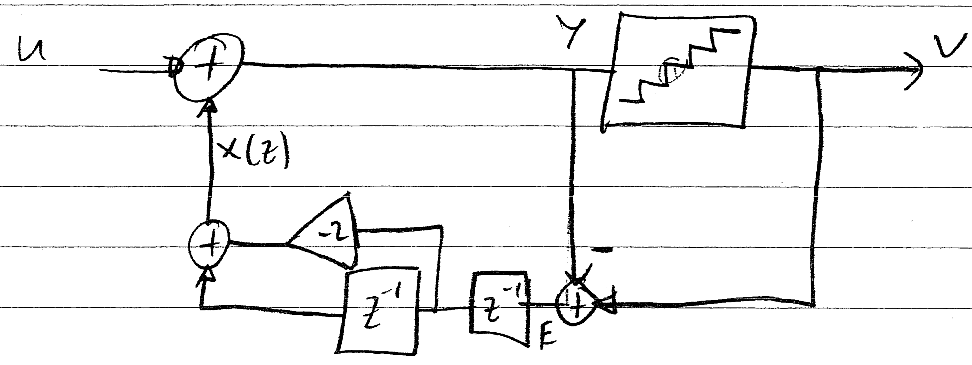


$V(z) = U(z) + (1-z^{-1})^2 E(z)$

$W(z) \equiv U(z) - V(z) = -(1-z^{-1})^2 E(z)$ ONLY QUANTIZATION NOISE

REQUIREMENTS ON INTEGRATORS ARE REDUCED & LESS SIGNAL LEVELS.

ERROR FEEDBACK STRUCTURE



$$H_f(z) \equiv \frac{X(z)}{E(z)} = -2z^{-1} + z^{-2}$$

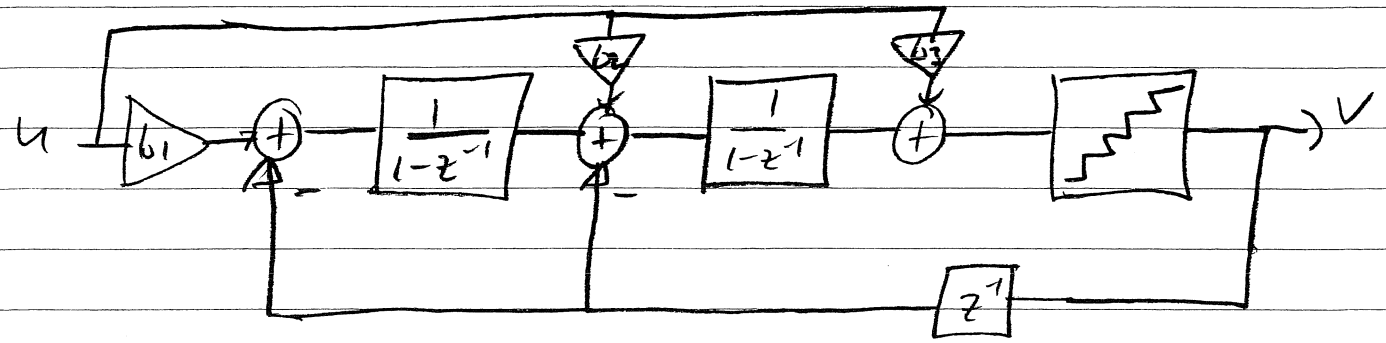
$$V(z) = Y(z) + E(z) = U(z) + H_f(z)E(z) + E(z)$$

$$NTF(z) \equiv 1 + H_f(z) = 1 - 2z^{-1} + z^{-2} = (1-z^{-1})^2$$

NOT PRACTICAL FOR ANALOG IMPLEMENTATIONS SINCE <u>VERY</u> SENSITIVE

OKAY FOR DIGITAL MODULATORS.

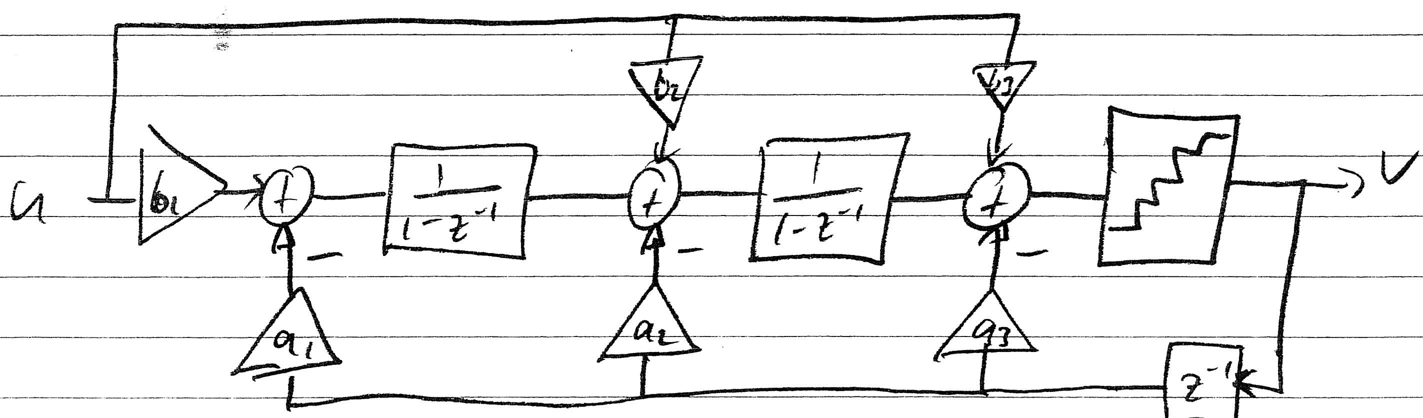
GENERALIZED 2ND ORDER STRUCTURES



$NTF = (1-z^{-1})^2$ UNCHANGED SINCE FEEDBACK UNCHANGED

$$STF = b_1 + b_2(1-z^{-1}) + b_3(1-z^{-1})^2$$

2 ZEROS & ALSO 2 POLES AT $z=0$



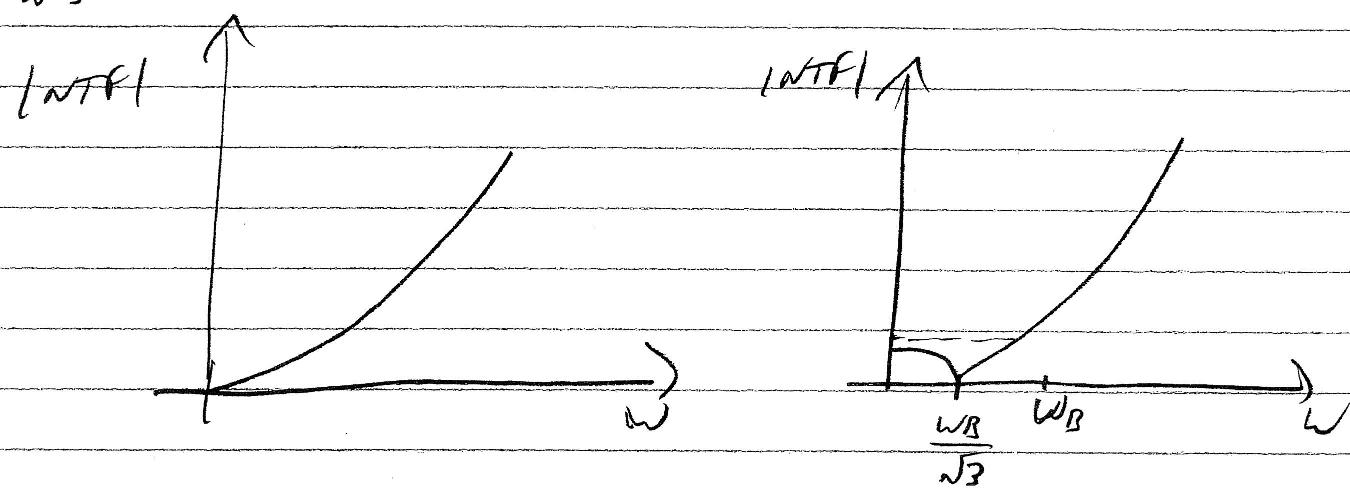
$STF = \frac{B(z)}{A(z)}$ & $NTF = \frac{(1-z^{-1})^2}{A(z)}$

WHERE $B(z) = b_1 + b_2(1-z^{-1}) + b_3(1-z^{-1})^2$

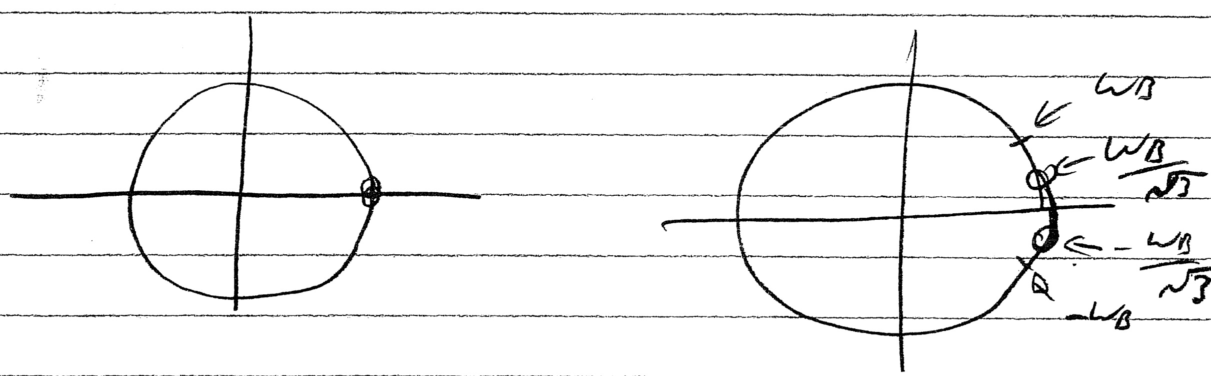
$$A(z) = 1 + (a_1+a_2+a_3-2)z^{-1} + (1-a_2-2a_3)z^{-2} + a_3 z^{-3}$$

NORMALLY $a_3 = 0$ SINCE IT DOES NOT INCREASE # OF ZEROS AT $z=1$

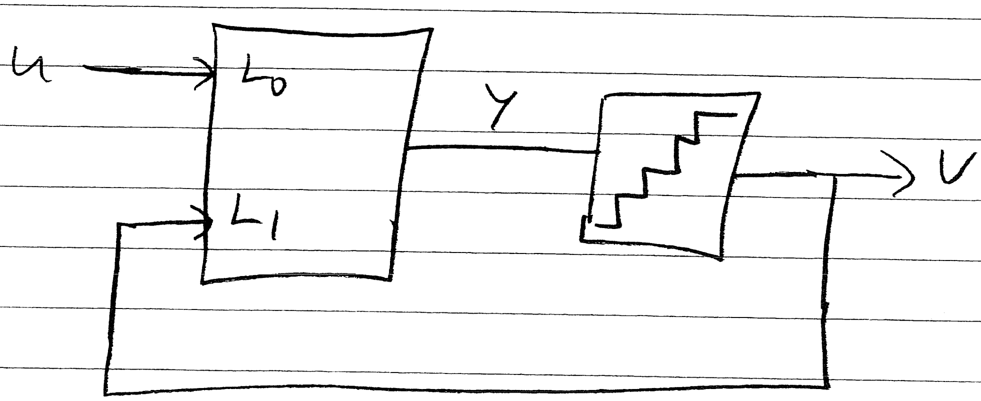
IF OSR IS GIVEN THEN MORE NOISE REDUCTION BY PLACING NTF ZEROS AT $\frac{\omega_B}{\sqrt{3}}$ RATHER THAN DC



IMPROVEMENT $\approx$ 3.5 dB



CHAPTER 4 HIGHER ORDER MODULATION



$$Y(z) = L_0(z)\,U(z) + L_1(z)\,V(z)$$

$$V(z) = STF(z)\,U(z) + NTF(z)\,E(z)$$

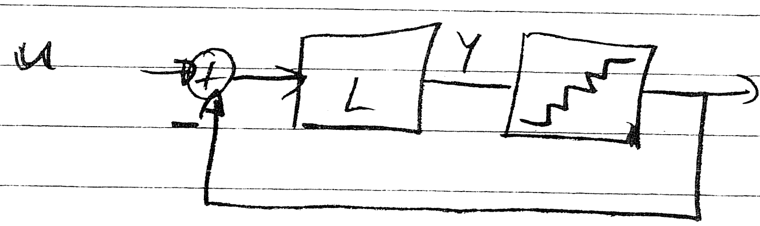
$$NTF(z) = \frac{1}{1 - L_1(z)} \qquad STF(z) = \frac{L_0(z)}{1 - L_1(z)}$$

OR $\quad L_0(z) = \dfrac{STF(z)}{NTF(z)}$ & $L_1(z) = 1 - \dfrac{1}{NTF(z)}$

SAME POLES FOR BOTH NTF & STF (ZEROS CAN BE DIFFERENT)

BOTH L_0 & L_1 SHOULD BE LARGE IN BAND $0 \to \omega_B$

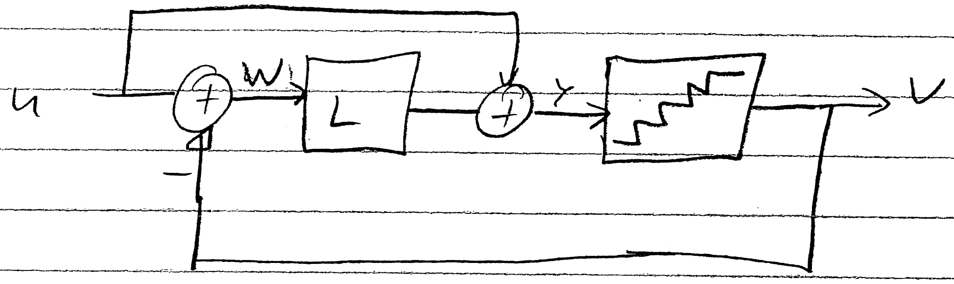
SPECIAL CASE: $L_0 = L$ & $L_1 = -L$



$$NTF(z) = \frac{1}{1 + L(z)}$$

$$STF(z) = \frac{L(z)}{1 + L(z)}$$

SINGLE FEEDBACK (NO FEED FORWARD)



$$L_1 = -L \qquad L_0 = L+1 \Rightarrow STF(z) = \frac{L(z)+1}{1+L(z)} = 1$$

$$NTF(z) = \frac{1}{1+L(z)}$$

$$W(z) = U(z) - V(z) = U - \left[(STF \cdot U) + NTF \cdot E \right] = -\frac{E}{1+L}$$

W(z) HAS NO SIGNAL COMPONENT SO LINEARITY OF L NEED NOT BE HIGH.

REALIZABILITY CANNOT HAVE A DELAY FREE LOOP

SO THERE MUST BE 1 DELAY IN L_1
(ELSE V DEPENDS ON Y + Y DEPENDS ON V ....)

SO FIRST SAMPLE OF IMPULSE RESPONSE OF L_1 IS ZERO
$\Rightarrow L_1(\infty) = 0$

$$NTF(\infty) = \frac{1}{1 - L_1(\infty)} = 1 \quad \text{SO} \quad NTF(\infty) = 1$$

DEFINING $H(z) \equiv NTF(z) \Rightarrow H(\infty) = 1$ + $h(0) = 1$

$$H(z) \equiv \frac{b_n z^n + b_{n-1} z^{n-1} + \ldots + b_1 z + b_0}{a_n z^n + a_{n-1} z^{n-1} + \ldots + a_1 z + a_0}$$

$H(\infty) = 1 \Rightarrow$
$+ \; b_n = a_n$

4.2 STABILITY

4.2.1 SINGLE-BIT MODULATORS

A BINARY $\Delta\Sigma$ MODULATOR WITH NTF $= H(z)$ IS LIKELY STABLE IF $\max_{w} |H(e^{jw})| < 1.5$

PLACE POLE CLOSER TO ZEROS TO MAKE MORE STABLE $\Rightarrow$ WILL RESULT IN HIGHER IN BAND NOISE

4.2.2 MULT-BIT MODULATORS

CONSIDER MODULATOR WITH M-STEP (M+1 LEVEL) QUANTIZER. INITIAL INPUT $y(0)$ IS IN NO OVERLOAD RANGE, THEN MODULATOR GUARANTEED NOT TO EXPERIENCE OVERLOAD FOR ANY INPUT $u(n)$ SUCH THAT $\max_{n} |u(n)| \leq M + 2 - \|h\|_1$

WHERE $\|h\|_1 = \sum_{n=0}^{\infty} |h(n)|$ $h(n)$ IS IMPULSE RESPONSE OF $H(z)$ (OR NTF)

EXAMPLE $M = 16$ NTF $= (1 - z^{-1})^3 \Rightarrow \|h\|_1 = 8$

\# LEVELS = 17

THEN STABLE WITH $|u(n)| < 10$

MAX FEEDBACK $= \pm 16$ BUT $|u| < 10$ SO 62.5% OF FULL-SCALE 16.