7.2 Second-order Noise-Shaping

first-order →

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

second-order

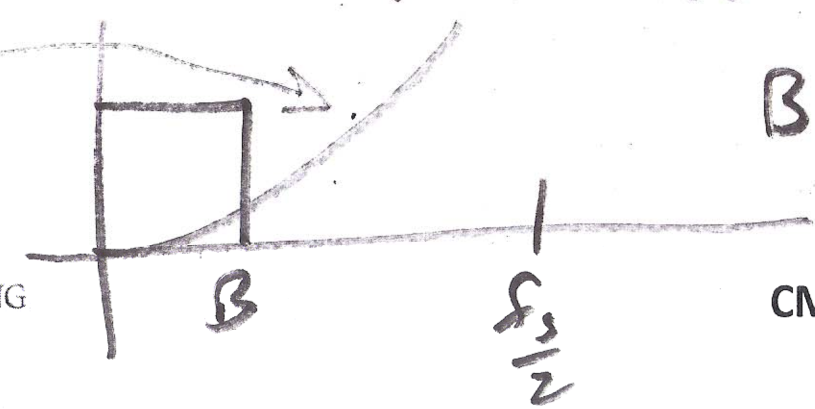
$$V_{OUT}(z) = V_{IN}(z)\cdot z^{-1} + V_{Qe}(z)(1-z^{-1})^2$$

$$\int_0^B |NTF(f)|^2\cdot|V_{Qe}(f)|^2\,df = \int_0^B \frac{V_{LSB}^2}{12 f_s}\cdot 16\sin^4\pi\frac{f}{f_s}\,df$$

Modulation

$$V_{Qe,rms} \approx \frac{V_{LSB}}{\sqrt{12}}\cdot\frac{\pi^2}{\sqrt{5}}\cdot\frac{1}{K^{5/2}}$$

$$B = \frac{f_s}{2K}$$



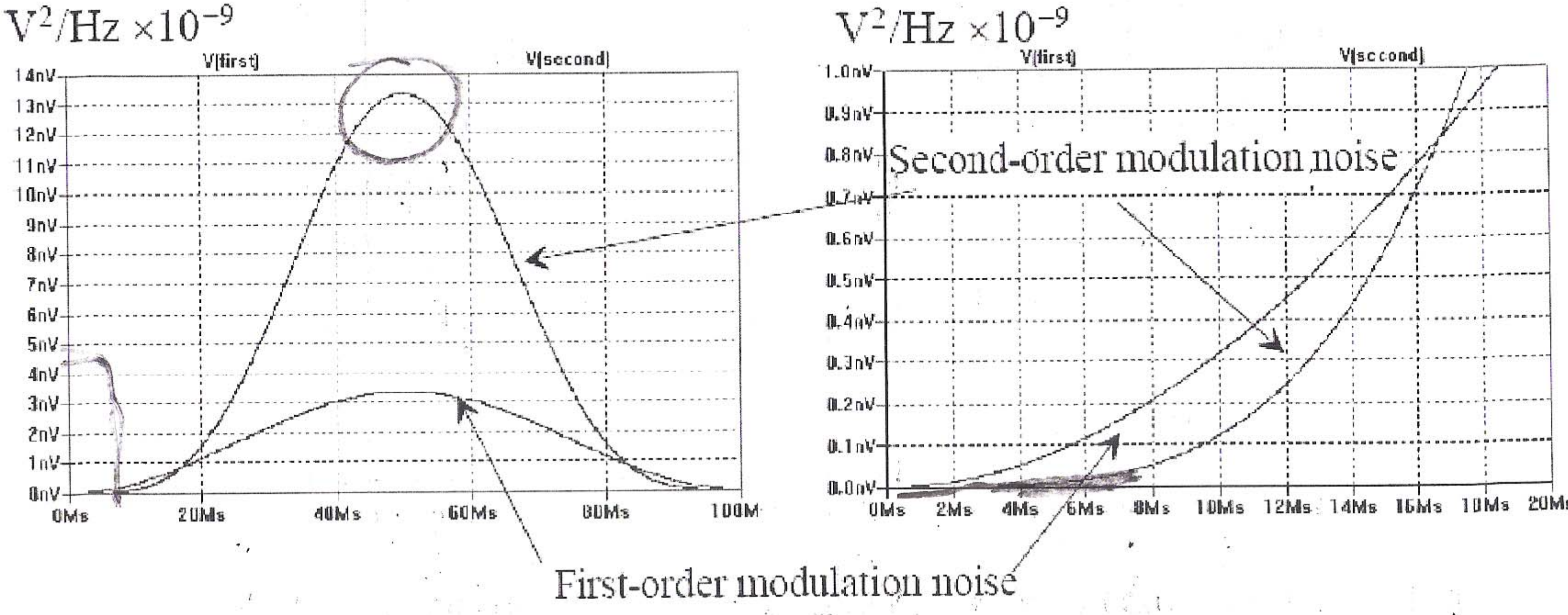


Figure 7.23 Comparing first- and second-order NS modulator's modulation noise.

$SNR_{ideal} = 6.02N + 1.76 - 12.9 + 50\log K$

for every doubling in K you get 15 dB improvement in SNR

N ↗ 2.5 bits

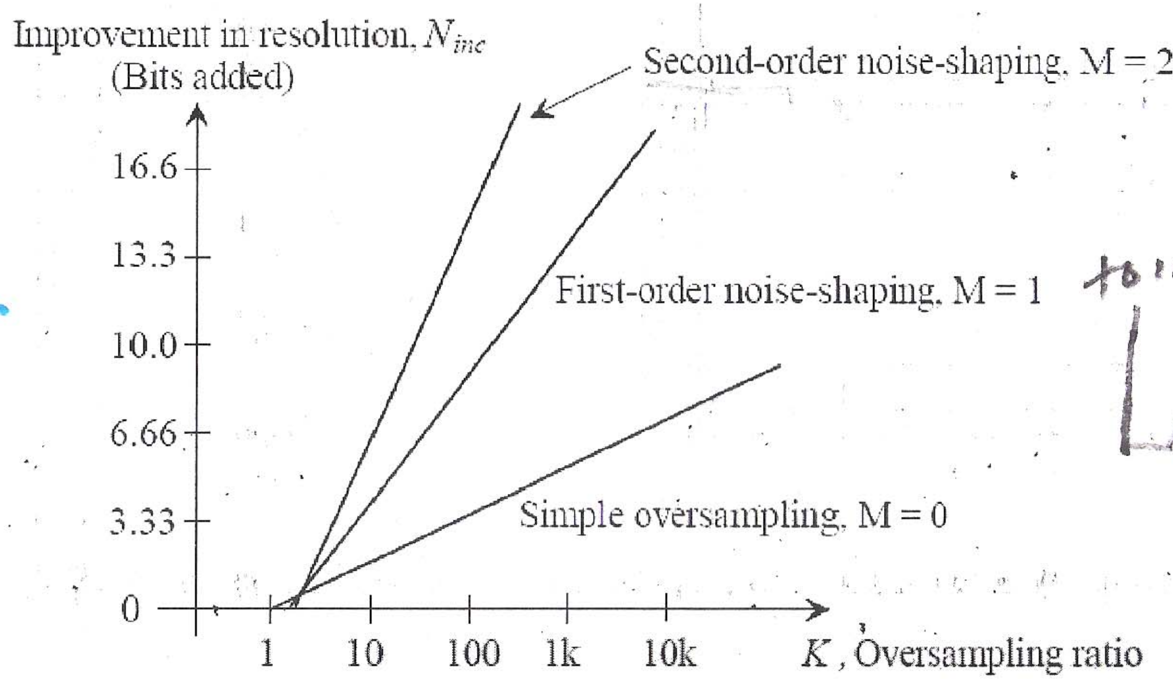
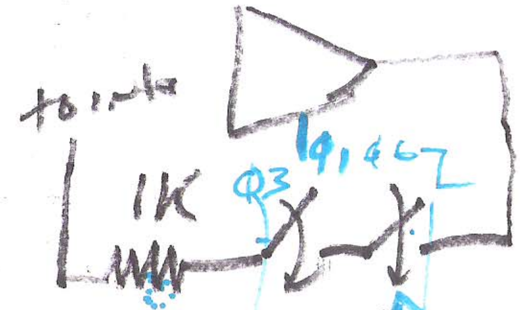
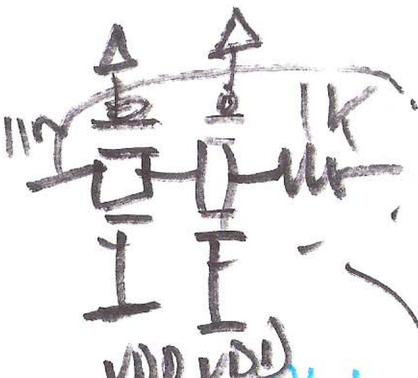
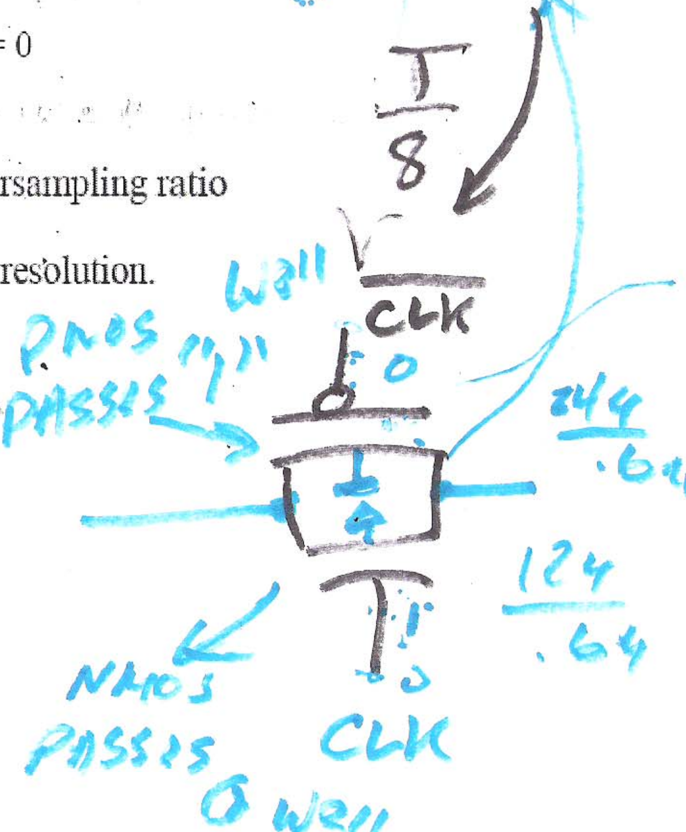
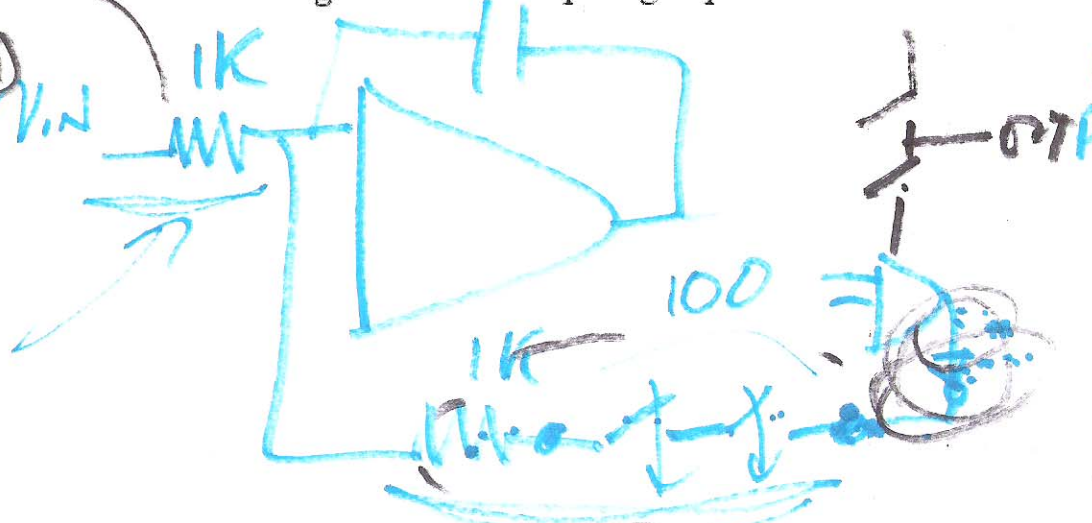


Figure 7.24 Comparing improvement in modulator resolution.









$$V_{OUT}(z) = \frac{A(z)}{1+A(z)\cdot B(z)} \cdot V_{in}(z) + V_{Qe}(z) \cdot \frac{1}{1+A(z)B(z)}$$

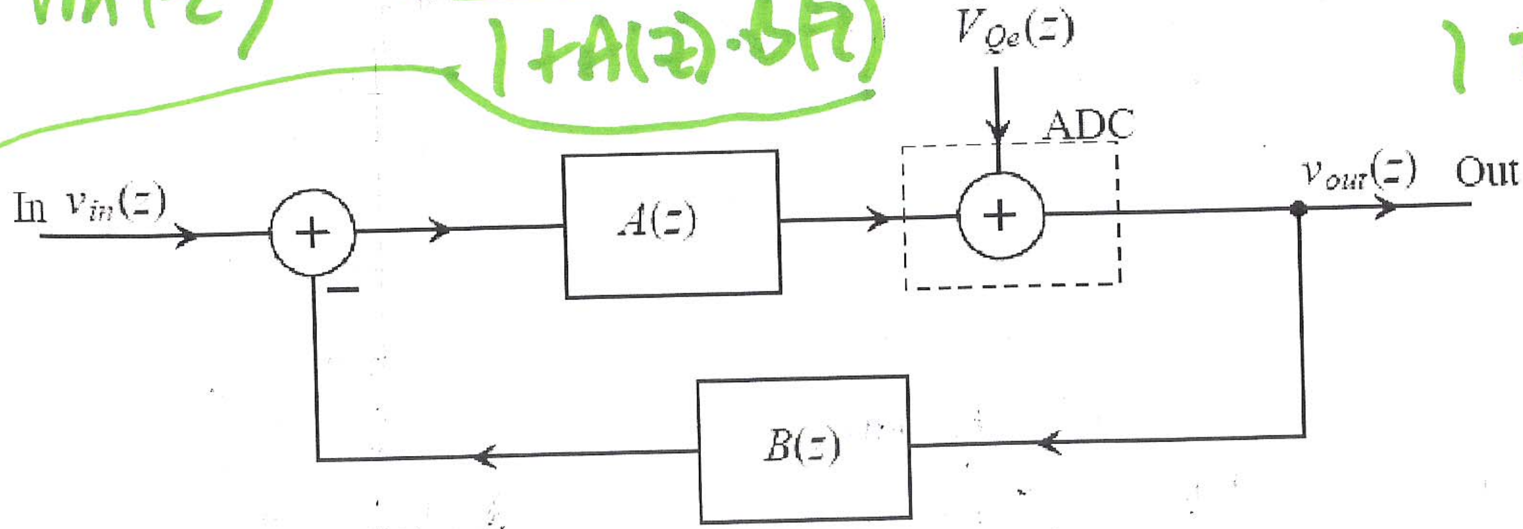
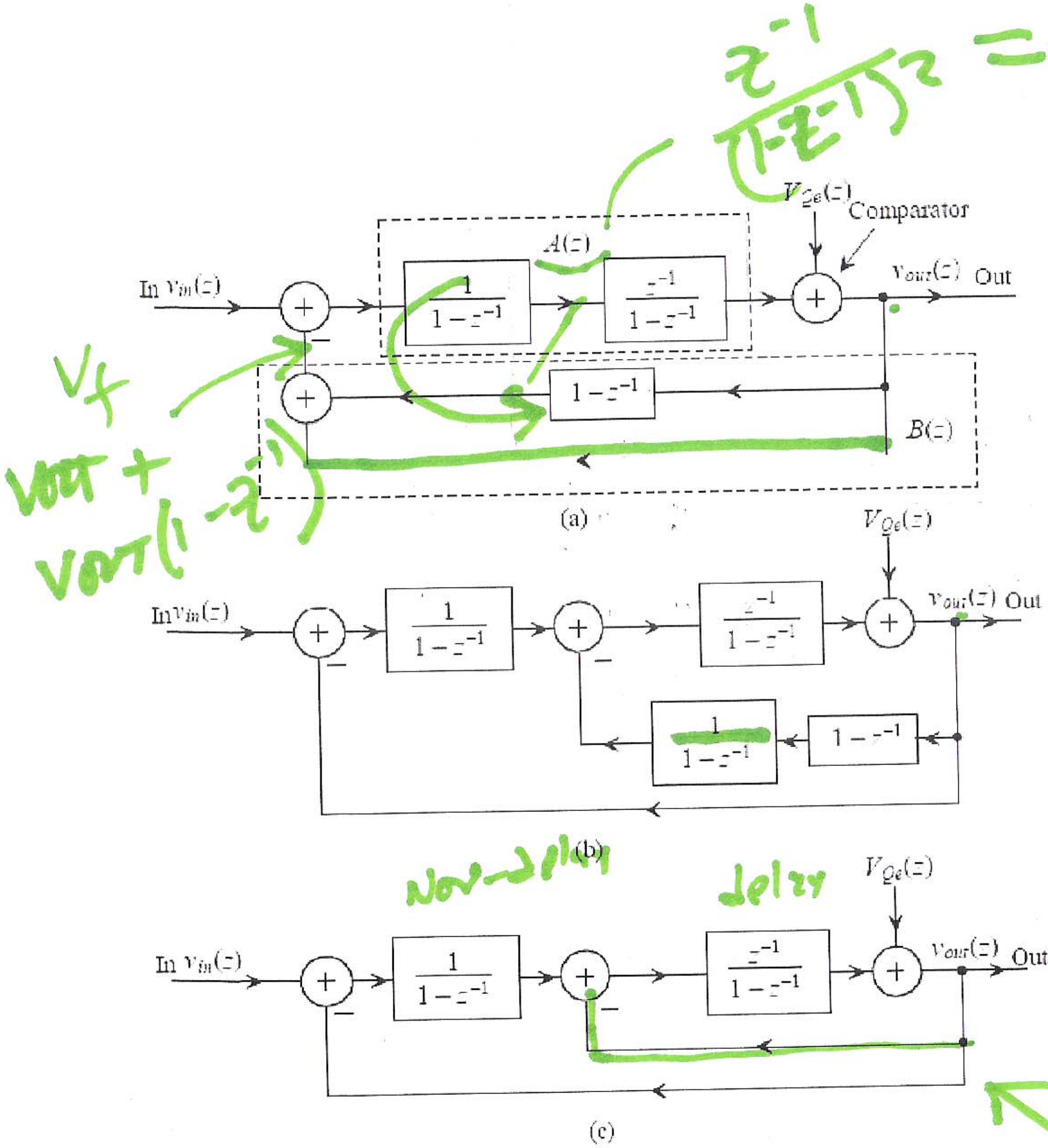


Figure 7.25 Block diagram of a feedback modulator.

$$z^{-1} = \frac{A(z)}{1+A(z)\cdot B(z)}$$

$$(1-z^{-1})^2 = \frac{1}{1+A(z)\,B(z)}$$



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

$v_f = v_{out}(2 - z^{-1})$

$B(z) = \frac{v_f}{v_{out}} = 2 - z^{-1}$

← topology for second-order noise-shaping.

Figure 7.26 Block diagrams of second-order modulators.

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5)

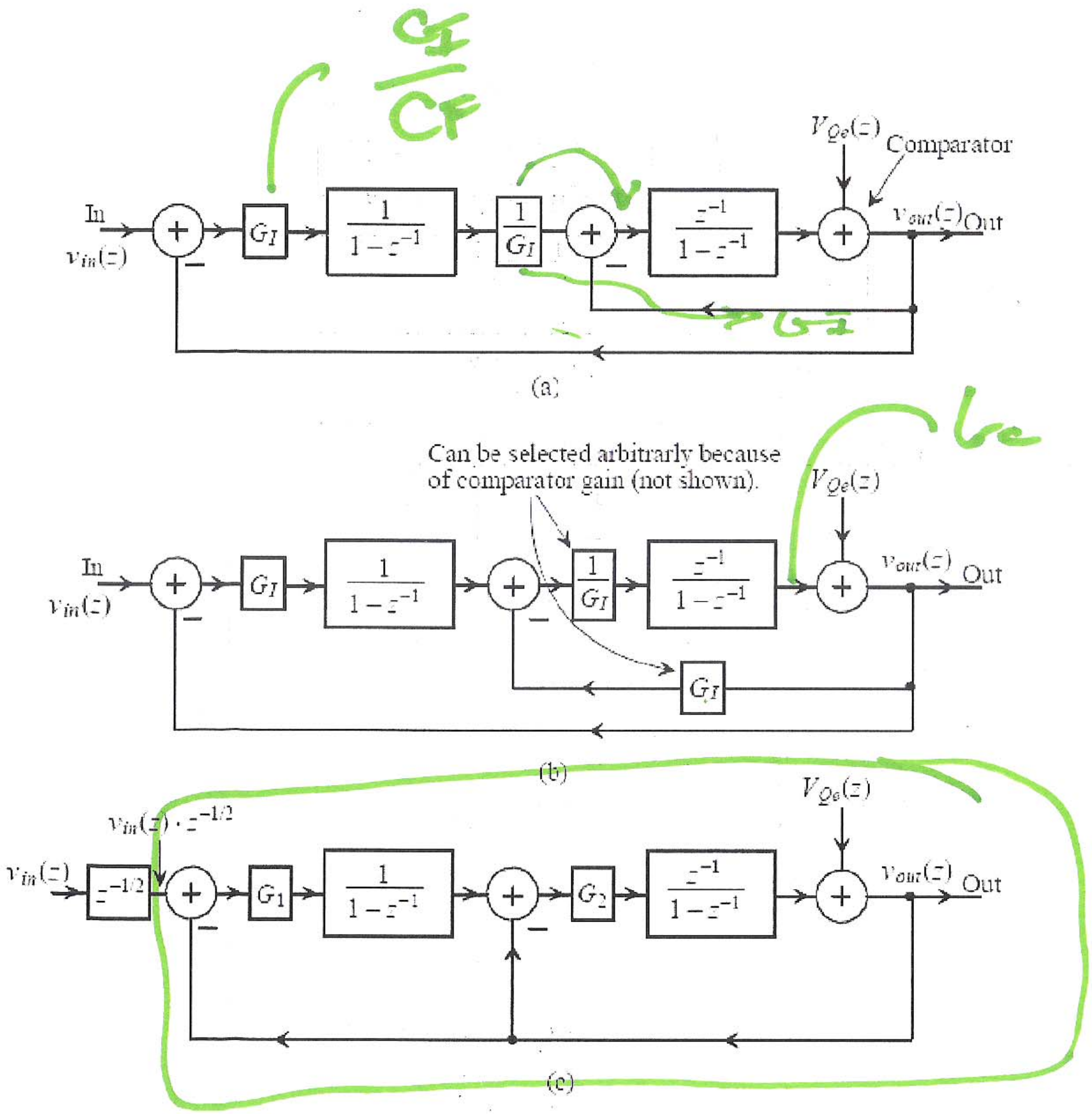
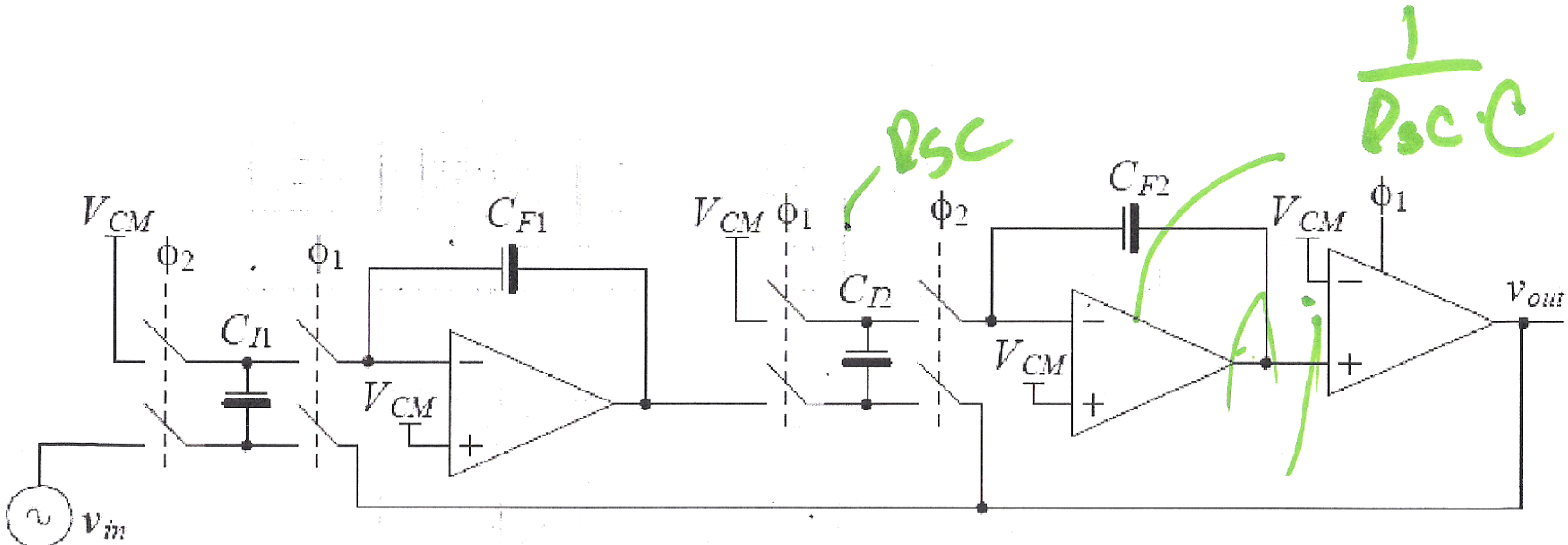
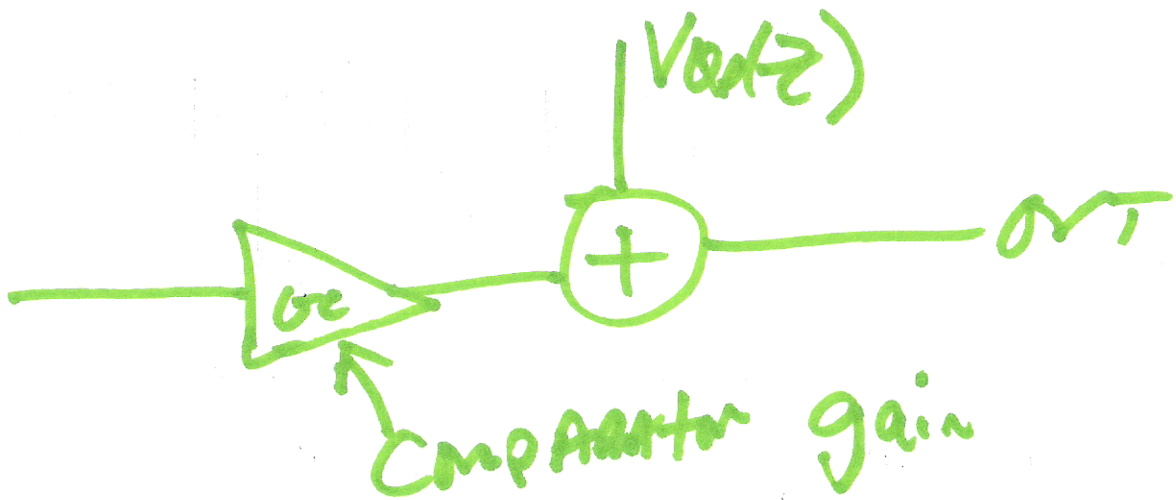


Figure 7.27 Block diagrams of second-order modulator introducing integrator gains.



$$G_1 = \frac{C_{I1}}{C_{F1}} \qquad G_2 = \frac{C_{I2}}{C_{F2}}$$

Figure 7.28 Implementation of the second-order modulator of Fig. 7.27c.



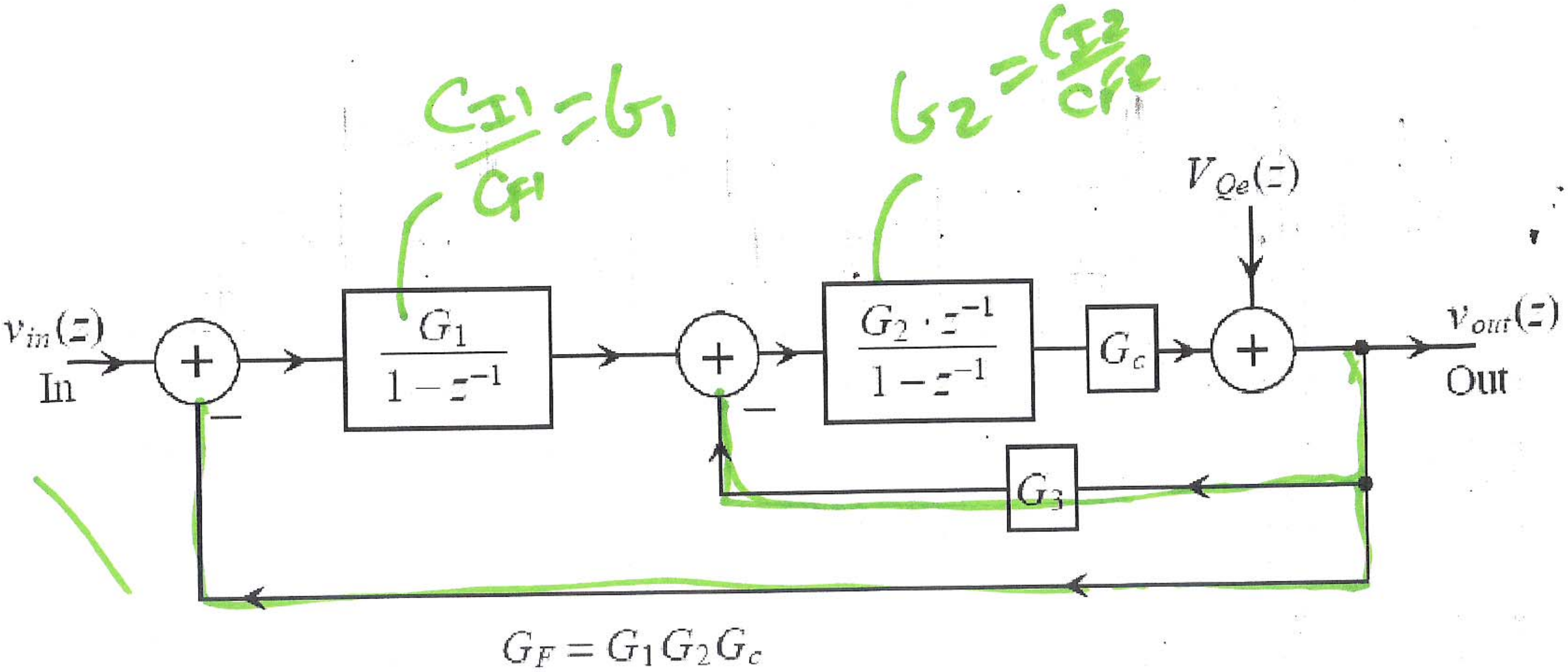
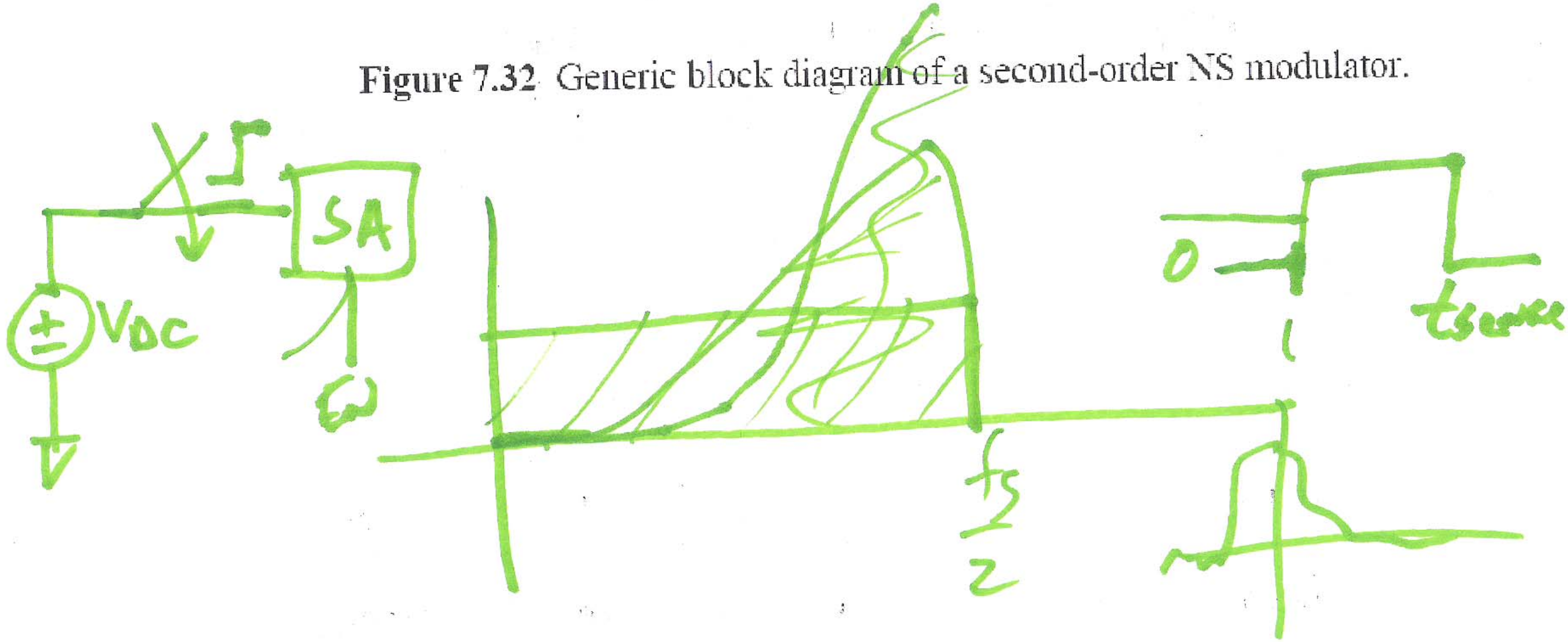


Figure 7.32 Generic block diagram of a second-order NS modulator.



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