1) a) T b) F c) T

2) a) See next

b) The output rails to 1 and holds there

The integrator continues to rise without bound, linearly increasing over time.

c) See next. Noise shaping evident in the upward slope of noise vs frequency.

d)

3) Thermometer MSB - 6bits $\sigma_u = 3\%$
Binary LSB - 6bits $\sigma_u = 4\%$

$\sigma^2_{BIN} = (2^B - 1)\sigma_u^2 = 0.1008$ $\sigma_{BIN} = 0.3175$ LSB

$\sigma_{THERM} = \sigma_u = 0.03$

$\sigma_{DAC} = \sqrt{\sigma_{THERM}^2 + \sigma_{BIN}^2} = 0.3175$ LSB

4) DAC designed for cable TV applications where you need to send a channel without disrupting adjacent channels through harmonic distortion

5) a) $B = 12$ bits

INL < 0.5 LSB DNL < 0.5 LSB 95.0% Yield $\rightarrow C = 2$

$A_{decode} = 2^{B_t} \cdot 2000\mu m^2$ $A_{tot} = 2^B \cdot A_{unit} + A_{decode}$

$K_u = 6.0\%\mu m$ $\sigma_u = \frac{K_u}{\sqrt{A_{unit}}}$

A_{unit} = area for DNL of thermometer = 0.5LSB

$$\sigma_u = \frac{K_u}{\sqrt{A_{unit}}} \Rightarrow A_{unit} = \left(\frac{K_u}{\sigma_u}\right)^2$$

$$Yield_{unit} = Yield_{chip}^{1/2B_t}$$

$$C = \sqrt{2} \cdot erfinv(Yield_{unit})$$

$$DNL_t = C \cdot \sigma_{unit} \qquad \sigma_{unit} = \frac{DNL_t}{C} = \frac{0.5}{C}$$

$$A_{unit} = \left(\frac{6.0\% um}{\sigma_{unit}}\right)^2$$

$B = B_t + B_b$

$$INL = \frac{1}{2}\sigma_u\sqrt{2^B} = \frac{k_u\sqrt{2^B}}{2\sqrt{A_{unit}}} \qquad \cancel{A_{INL} = \left(\frac{K_u\sqrt{2^B}}{2 \cdot INL}\right)^2}$$

$$INL = \frac{1}{2}\sqrt{2^B}\,\sigma_u = 32\sigma_u \qquad Area(INL = 0.5) = 2$$

$$A_{unit} = \frac{1}{\sigma_u^2} \qquad 0.5 = 32 \cdot \sigma_{INL} \qquad \frac{1}{64} = \sigma_{INL}$$

$$A_{INL} = \frac{A_{unit}}{\left(\frac{1}{64}\right)^2} = 4096 \cdot A_{unit}$$

$$DNL_{Binary} = \sigma_u\sqrt{2^B - 1} = \sigma_{DNL_{Bin}} 64 \qquad 0.5 = 64\,\sigma_{DNL_{Bin}} \qquad \frac{1}{128} = \sigma_{DNL_{Bin}}$$

$$A_{DNL_{BIN}} = \frac{A_{unit}}{\left(\frac{1}{128}\right)^2} = 16384 \cdot A_{unit}$$

$$DNL_{seg} \simeq \sigma_{seg}\sqrt{2^{B_b+1}} \qquad \frac{0.5}{\sqrt{2^{B_b+1}}} = \sigma_{seg} \qquad A_{DNL_{seg}} = \frac{A_{unit}}{\left(\frac{0.5}{\sqrt{2^{B_b+1}}}\right)^2}$$

5) a)

Segmented

$$\sigma_{DNL} = \sigma_\mu \sqrt{2^{B_b+1} - 1} \qquad \sigma_{INL} = \frac{1}{2}\sigma_u \sqrt{2^B}$$

$$\sigma_{u_{DNL}} = \frac{\sigma_{DNL}}{\sqrt{2^{B_b+1} - 1}} \qquad A_{unit} = \left(\frac{k_u}{\sigma_u}\right)^2$$

$$\sigma_{u_{INL}} = \frac{2\sigma_{INL}}{\sqrt{2^B}} \qquad C = \sqrt{2} \cdot \mathrm{erfinv}\left(\mathrm{yield}^{\left(\frac{1}{2^{B_t}}\right)}\right)$$

$$\sigma_u = \min(\sigma_{u_{DNL}}, \sigma_{u_{INL}})/C$$

i) Minimized at $B_t = 3$, $A_{unit} = 109.6\,\mu m^2$ Total Area $= 0.465\,mm^2$

ii) Paper optimum at $B_t = 9$, $A_{unit} = 223.1\,\mu m^2$ Total Area $= 1.938\,mm^2$

b) See next page