Problem 5.22

Sampling rate = 64 kHz
Voice signal bandwidth = W = 3.1 kHz
Maximum signal amplitude $A_{\max}$ = 10 volts

(a) To avoid slope overload, we must satisfy the following requirement (see Problem 5.21)

$$A_{\max} < \frac{\Delta}{2\pi W T_s}$$

Solving for the step size Δ, we write

$$\Delta > \frac{1}{2\pi W T_s A_{\max}} = \frac{f_s}{2\pi W A_{\max}} \qquad (1)$$

Substituting the given values into Eq. (1) yields

$$\Delta > \frac{64}{2\pi \times 3.1 \times 10}$$

or

$$\Delta > 0.33 \quad \text{volts}$$

Effectively, provided that the step size Δ is 0.33 volt, then slope-overload distortion is avoided.

(b) Let $\in(t)$ denote the granular noise, viewed as a function of time t. The average power of granular noise (analogous to quantization noise in PCM), is defined by

$$\begin{aligned} P_g &= \frac{2}{\Delta} \int_{-\Delta/2}^{\Delta/2} \in^2 d\in \\ &= \frac{2}{\Delta}\left[\frac{\in^3}{3}\right]_{\in=-\Delta/2}^{\Delta/2} \\ &= \frac{\Delta^2}{3} \end{aligned}$$

With Δ set at 0.33 volt, the average power of granular noise is therefore 0.03 watts (assuming that the power is calculated for a load of 1 ohm).

(c) The minimum channel bandwidth needed to transmit the DM encoded signal is the inverse of the sampling rate, that is, 64 kHz.