Biomedical Instrumentation and Measurement

- Integrated average

$$\overline{X} = \frac{1}{T}\int_{t1}^{t2} X dt$$

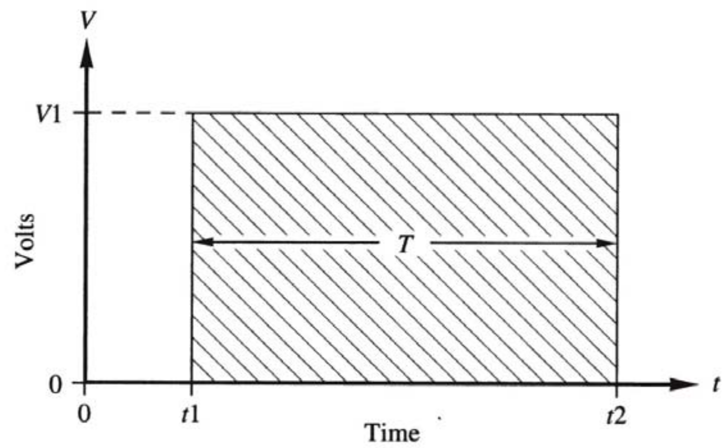
- Root-mean-square (rms)

$$V_{rms} = \sqrt{\frac{1}{T}\int_{t1}^{t2} [V(t)]^2 dt}$$

- Root-sum-squares (rss)

$$V_{rss} = \sqrt{\sum_{i=1}^{n} (V_{n_i})^2}$$

$$V_{rss} = \sqrt{(V_{n_1})^2 + (V_{n_2})^2 + (V_{n_3})^2 \ldots + (V_{n_n})^2}$$



$$V_{ave} = \frac{(V1 - 0)\,T}{t2 - t1}$$

Figure 3-3
Integrated average. Source: EEIM.

Biomedical Instrumentation and Measurement

- Root-mean-square (rms)

$$V_{rms} = \sqrt{\frac{1}{T}\int_{t1}^{t2}[V(t)]^2\,dt}$$

$$= \sqrt{\frac{1}{2\pi}\int_{0}^{2\pi}[V_p \sin(\theta)]^2\,d\theta}$$

$$= \sqrt{\frac{1}{2\pi}V_p^{\,2}\int_{0}^{2\pi}\sin^2(\theta)\,d\theta}$$

$$= \sqrt{\frac{1}{2\pi}V_p^{\,2}\int_{0}^{2\pi}[\frac{1}{2}-\frac{\cos 2\theta}{2}]\,d\theta}$$

$$= \sqrt{\frac{1}{2\pi}V_p^{\,2}\,\frac{1}{2}[2\pi-0]} = \frac{V_p}{\sqrt{2}}$$

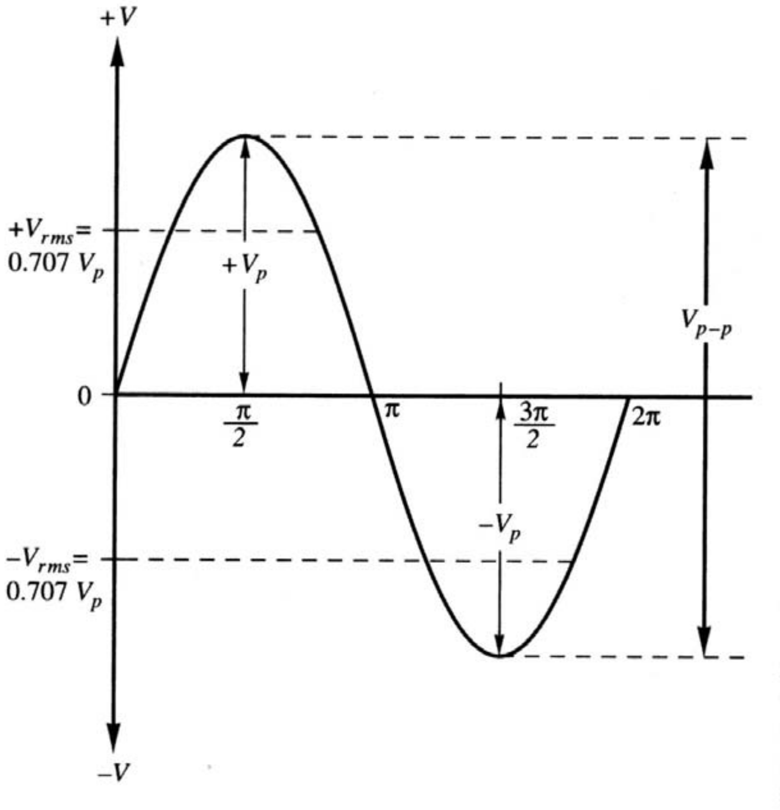


Figure 3-4
Peak value of a sine wave voltage. Source: EEIM.

Biomedical Instrumentation and Measurement

- Example 3-1
  - An electronic amplifier circuit contains five independent noise sources that produce the following decorrelated noise signal voltage levels Vn_1=25nV, Vn_2=56nV, Vn_3=-33nV, Vn_4=-10nV, Vn_5=62nV. What is the rss value of a composite(混合) noise signal?

Ans:

$$V_{rss} = \sqrt{(V_{n_1})^2 + (V_{n_2})^2 + (V_{n_3})^2 + (V_{n_4})^2 + (V_{n_5})^2}$$
$$= \sqrt{(25)^2 + (56)^2 + (-33)^2 + (-10)^2 + (62)^2}$$
$$= \sqrt{8794} = 93.8nV$$

Biomedical Instrumentation and Measurement

- Logarithmic representation of signal levels
  - Decibel notation(dB)-The decibel measurement originated in the telephone industry and was named after telephone inventor Alexander Graham Bell(亞歷山大・葛拉罕・比爾)1880年

- The gain can expressed for voltage and current

$$dB = 20\log(\frac{V_o}{V_i}) \qquad dB = 20\log(\frac{I_o}{I_i})$$

- The gain can expressed for power

$$dB = 10\log(\frac{P_o}{P_i})$$

Biomedical Instrumentation and Measurement

Logarithmic representation of signal levels

- Adding it all up

$$A = A_1 \cdot A_2 \cdot A_3 \cdot A_4 = (\frac{V_1}{V_i}) \cdot (\frac{V_2}{V_1}) \cdot (\frac{V_3}{V_2}) \cdot (\frac{V_4}{V_3})$$

$$20\log A = 20\log[(\frac{V_1}{V_i}) \cdot (\frac{V_2}{V_1}) \cdot (\frac{V_3}{V_2}) \cdot (\frac{V_4}{V_3})]$$

$$= 20\log(\frac{V_1}{V_i}) + 20\log(\frac{V_2}{V_1}) + 20\log(\frac{V_3}{V_2}) + 20\log(\frac{V_4}{V_3})$$

$$\underline{dB = dB_1 + dB_2 + dB_3 + dB_4}$$

$$A_1 = (\frac{V_1}{V_i}) \qquad A_2 = (\frac{V_2}{V_1}) \qquad A_3 = (\frac{V_3}{V_2}) \qquad A_4 = (\frac{V_4}{V_3})$$

$$dB_1 = 20\log(\frac{V_1}{V_i}) \qquad dB_2 = 20\log(\frac{V_2}{V_1}) \qquad dB_3 = 20\log(\frac{V_3}{V_2}) \qquad dB_4 = 20\log(\frac{V_4}{V_3})$$

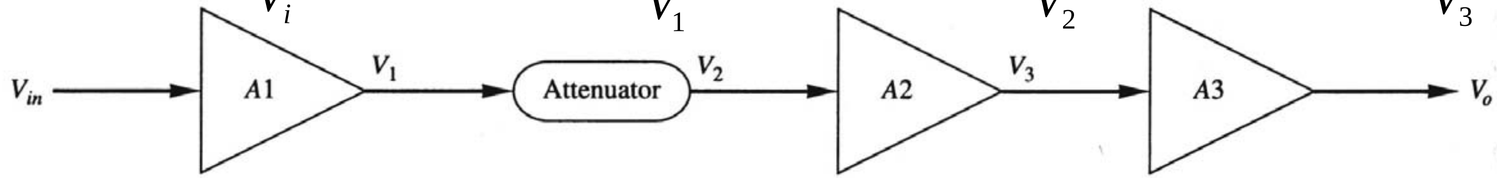


Figure 3-6
Three-stage amplifier with attenuator pad. Source: EEIM.