Biomedical Instrumentation and Measurement

- Three basic equations for calculating decibels

TABLE 3-8 COMMON GAINS AND LOSSES EXPRESSED IN DECIBELS

Ratio (out/in)	Voltage gain (dB)	Power gain (dB)
1/1000	−60	−30
1/100	−40	−20
1/10	−20	−10
1/2	−6.02	−3.01
1	0	0
2	+6.02	+3.01
5	+14	+7
10	+20	+10
100	+40	+20
1,000	+60	+30
10,000	+80	+40
100,000	+100	+50
1,000,000	+120	+60

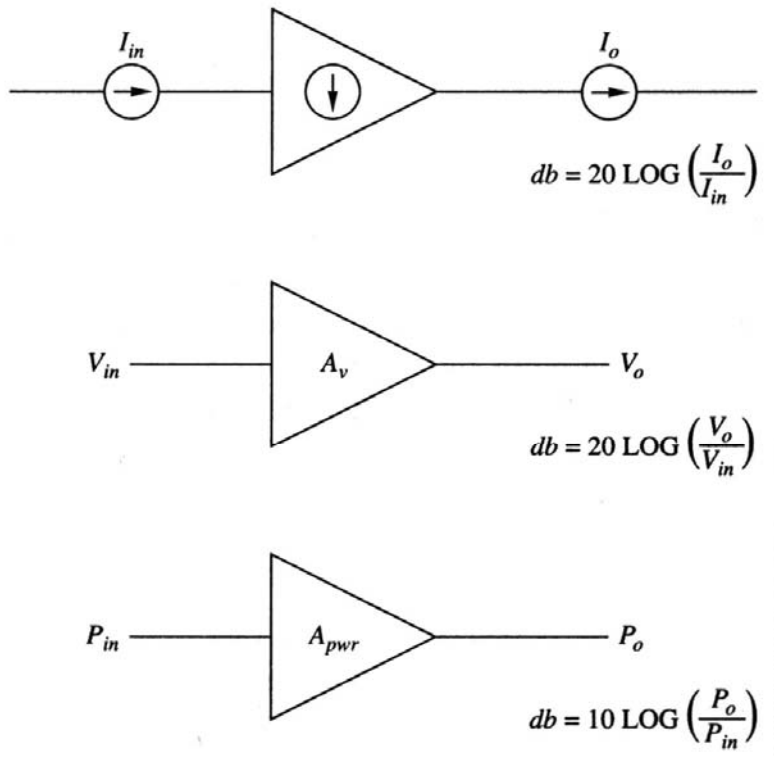

Figure 3-5
Three basic equations for calculating decibels.
Source: EEIM.

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- Example: When Vin=1mV, find V_o=?

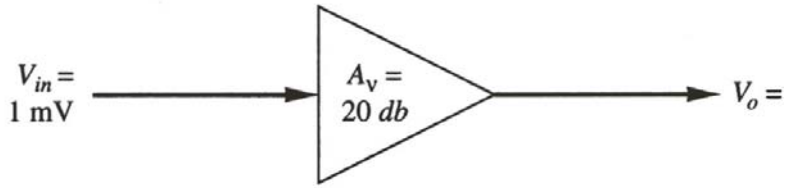

Figure 3-7
20-dB amplifier with 1-mV input signal.
Source: EEIM.

Ans: $$A_v = 20dB = 20\log(\frac{V_0}{V_{in}})$$

$$=> 1 = \log(\frac{V_0}{V_{in}}) => 10^1 = \frac{V_0}{V_{in}}$$

$$V_0 = 10 \cdot V_{in} = 10 \cdot 0.001 = 0.01$$

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- Special decibel scales
  - dBm –Used in reference frequency(RF) measurement, 0 dBm is defined as 1 mW

$$dBm = 10\log(\frac{P}{1mW})$$

  - VU(volume units) –The VU scale is used in audio work and defines 0VU as 1 mW of 1000Hz audio signal dissipated in a 600 –ohm resistive load
  - dB(telephone) –The dB scale defined 0dB as 6 mW of 1000Hz audio signal dissipated in a 500–ohm resistive load
  - dBmV –Used in television antenna coaxial cable system with 75-ohm resistive impedance, the dBmV system uses 1000uV across a 75-ohm resistive load as the 0dBmV reference point

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- Example: What is the signal level 9mW as expressed in dBm?

Ans:

$$dBm = 10\log(\frac{P}{1mW})$$

$$=> 10\log(\frac{9mW}{1mW})$$

$$= 9.54dBm$$

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- Measurement standards
  - The science of measurement, requires a rule to which things are compared
  - The rule is called a standard
  - Hierarchy of standards

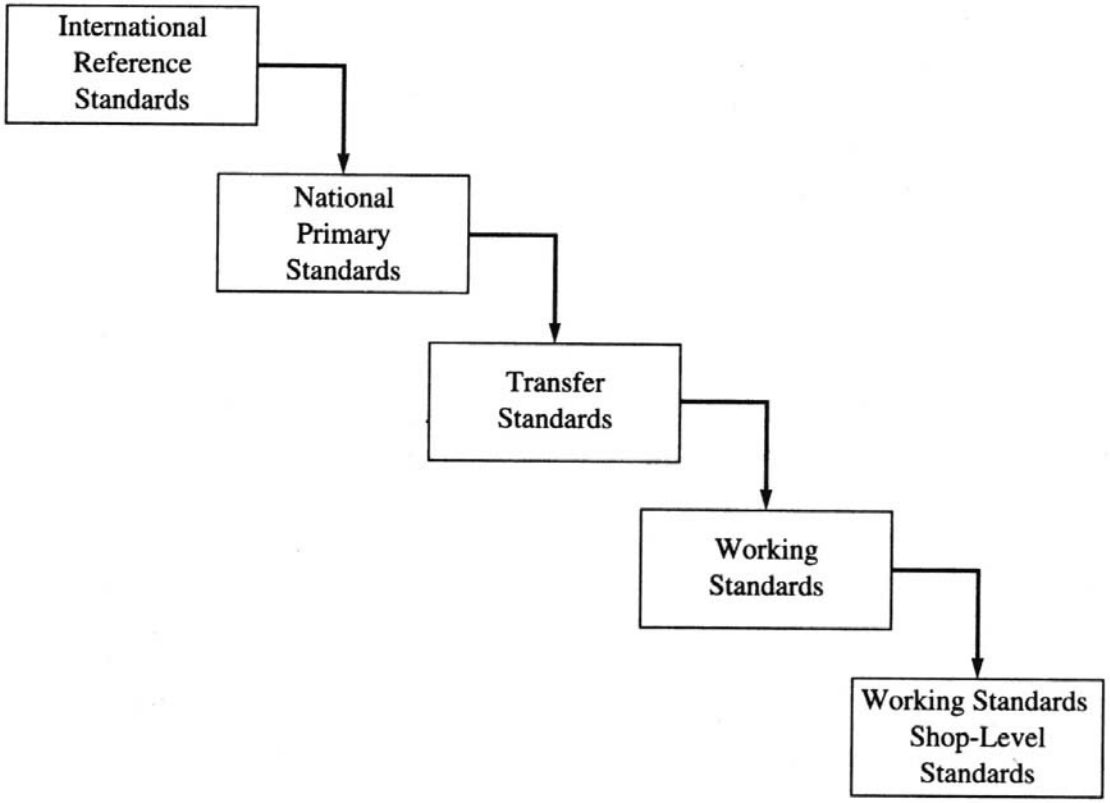

Figure 3-9
Hierarchy of standards.

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- Standard deviation(標準差)

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N}}$$

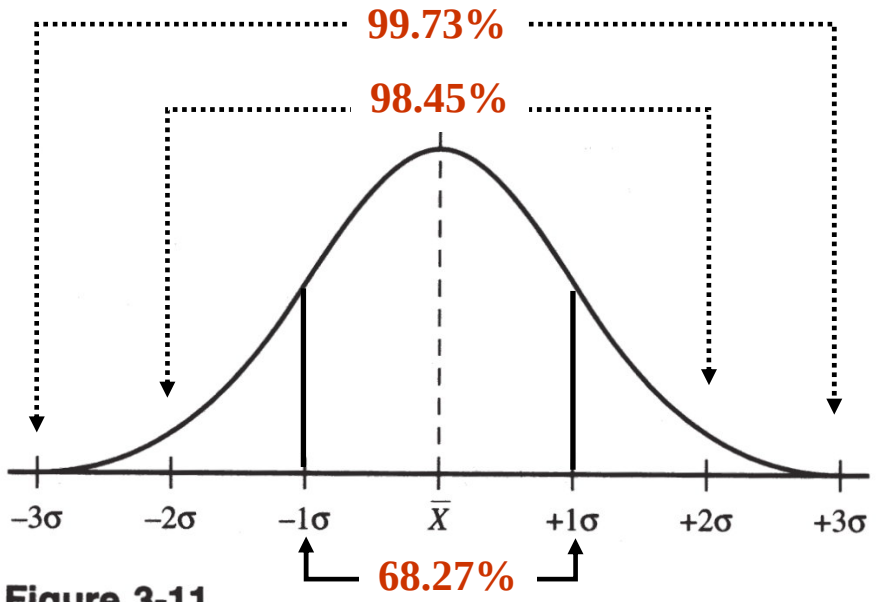

Figure 3-11
Standard deviation. Source: EEIM.

- Variance(變異數)

$$\sigma^2 = \frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N}$$

Biomedical Instrumentation and Measurement

- For small sample taken
  - Standard deviation(標準差)

$$S = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N-1}}$$

  - Variance(變異數)

$$S^2 = \frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N-1}$$