

CHAPTER 2
Experimental Data and Errors

2.1) Accuracy of a measurement specifies the difference between the measured and the true value of the quantity. Precision specifies the repeatability of a set of readings, each made independently with the same instrument. P. 33-34

2.2) The three classes of measurement errors are Human, System, and Random. Fig. 2.4, P. 38

2.3) Several examples are given in Fig. 2.4, P. 38

2.4) Error for voltmeter:
 $\pm 2\% \times 50\text{V} = \pm 1\text{V}$

$$\text{Percent error} = \frac{\text{Measured Value} - \text{True Value}}{\text{True Value}} \times 100\%$$

$$\text{Percent error for 15 V measurement} = \frac{(15 \pm 1) - 15}{15} \times 100\% = \pm 6.67\%$$

$$\text{Percent error for 42 V measurement} = \frac{(42 \pm 1) - 42}{42} \times 100\% = \pm 2.4\%$$

2.5) Error for ammeter
 $0.5\% \times 50 \text{ mA} = 0.25 \text{ mA}$ (The error on most analog meters is usually based on full scale.

$$\begin{aligned} \text{Possible error } & 13 \text{ mA} \pm 0.25 \text{ mA} \\ \text{Limits } & 12.75 \text{ mA} \rightarrow 13.25 \text{ mA} \end{aligned}$$

- 2.6) a) $0.35 \text{ A} \left(\frac{1000 \text{ mA}}{1 \text{ A}} \right) = 350 \text{ mA}$
 $0.35 \text{ A} \left(\frac{1 \times 10^6 \mu\text{A}}{1 \text{ A}} \right) = 3.5 \times 10^5 \mu\text{A}$
- b) $0.041 \text{ mV} \left(\frac{10^3 \mu\text{V}}{1 \text{ mV}} \right) = 41 \mu\text{V}$
- c) $400,000 \Omega \left(\frac{1 \text{ M}\Omega}{10^6 \Omega} \right) = 0.4 \text{ M}\Omega$

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d) $67 \mu\text{V} \left(\frac{1 \text{ mV}}{10^3 \mu\text{V}} \right) = 0.067 \text{ mV}$

2.7) a) 2 b) 6 c) 3 d) 3 e) 2

f) 6 Note: non-technical writers commonly consider zeros to the left of the decimal point as non-significant.

2.8) For series resistance

$$R_{\text{EQ}} = R_1 + R_2 + \dots + R_n$$

$$\begin{array}{r} 14.5 \pm 0.1 \\ 5.36 \pm 0.01 \\ 64.2 \pm 0.1 \\ 4.37 \pm 0.01 \\ \hline R_{\text{EQ}} = 88.43 \pm 0.22 \Omega \end{array}$$

2.9) 635 ± 4 %Error = $\frac{8}{339} \times 100\%$

$$\frac{-296 \pm 4}{339 \pm 8} \qquad \qquad \qquad \text{\%Error} = 2.36\%$$

2.10) a)

$$\text{AVG} = \frac{50.2 + 50.6 + 49.7 + 51.1 + 50.3 + 49.9 + 50.4 + 49.6 + 50.3 + 51.0}{10} = 50.31$$

b) Standard Deviation $\sigma = \sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + \dots + d_n^2}{n-1}}$

d = Deviation from the average value

$$\sigma = 0.474$$

c) Probable error = $0.675 \sigma = \pm 0.31995 \text{ mA}$

2.11) a) 21.107 V b) $\sigma = 0.927$ Probable Error = $0.675 \sigma = \pm 0.6257$

c) The deviation from the average value $d_4 = 2.04$ is $< 3\sigma$, so the value 19.07 should be retained.

2.12) Decibel Power Gain

$$A_p = 10 \log_{10} \left(\frac{P_{\text{out}}}{P_{\text{in}}} \right) \text{ dB}$$

a) $A_p = 10 \log_{10} \left(\frac{45 \times 10^{-3} \text{ W}}{7.4 \times 10^{-3} \text{ W}} \right) = 2.23 \text{ dB}$

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$$b) A_p = 10 \log_{10} \left(\frac{52 \times 10^{-6} \text{ W}}{14 \times 10^{-6} \text{ W}} \right) = 1.23 \text{ dB}$$

$$c) A_p = 10 \log_{10} \left(\frac{32 \times 10^{-3} \text{ W}}{16 \times 10^{-3} \text{ W}} \right) = 3.01 \text{ dB}$$

$$d) A_p = 20 \log_{10} \left(\frac{1.414 \text{ V}}{2 \text{ V}} \right) = -3.01 \text{ dB}$$

2.13) Magnitude Power Gain

$$\frac{P_{\text{out}}}{P_{\text{in}}} = \log_{10}^{-1} \left(\frac{A_p}{10} \right) = 10^{A_p/10}$$

$$\frac{P_{\text{out}}}{P_{\text{in}}} = \log_{10}^{-1} \left(\frac{82}{10} \right) = 10^{8.2/10} = 158 \times 10^6$$

$$2.14) \frac{P_{\text{out}}}{P_{\text{in}}} = \log_{10}^{-1} \left(\frac{-40}{10} \right) = 10^{-40/10} = 1 \times 10^{-4}$$

2.15) a) Power gain in dB

$$A_p = 10 \log_{10} \left(\frac{P_{\text{out}}}{P_{\text{in}}} \right) = 10 \log_{10} \left(\frac{150 \text{ W}}{300 \text{ W}} \right) = -3.01 \text{ dB}$$

b) Power gain in dB

$$A_p = 10 \log_{10} \left(\frac{P_{\text{out}}}{P_{\text{in}}} \right) = 10 \log_{10} \left(\frac{V_o^2 / R_o}{V_{\text{in}}^2 / R_{\text{in}}} \right) = 20 \log_{10} \left(\frac{V_o}{V_{\text{in}}} \sqrt{\frac{R_{\text{in}}}{R_o}} \right)$$

$$A_v = 20 \log_{10} \left(\frac{V_o}{V_{\text{in}}} \right) \text{ if } R_o = R_{\text{in}}$$

$$\text{Voltage Out} = V_o = \sqrt{P_o \times R_o} = \sqrt{150 \text{ W} \times 8 \Omega} = 34.6 \text{ V}$$

$$\text{Voltage In} = V_{\text{in}} = 12 \text{ V}$$

$$A_{v \text{ dB}} = 20 \log_{10} \left(\frac{34.6 \text{ V}}{12 \text{ V}} \right) = 9.20 \text{ dB}$$

$$c) R_o = 8 \Omega \qquad R_{\text{in}} = \left(\frac{V_{\text{in}}^2}{P_{\text{in}}} \right) = \left(\frac{12^2}{300} \right) = 0.48 \Omega$$

$A_p = A_v$ only if $R_o = R_{\text{in}}$, but in this case $R_o \neq R_{\text{in}}$

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$$\begin{aligned} 2.16) \quad a) \quad A_p &= 10 \log_{10} \left(\frac{P_o}{P_{in}} \right) \\ \therefore P_{in} &= \frac{P_o}{\log^{-1} \left(\frac{A_p}{10} \right)} = \frac{30 \text{ W}}{\log^{-1} \left(\frac{42 \text{ dB}}{10} \right)} = 1.89 \text{ mW} \\ b) \quad V_o &= \sqrt{P_o \times R_o} = \sqrt{30 \text{ W} \times 10 \Omega} = 17.32 \text{ V} \\ A_v &= 60 \text{ dB} = 20 \log_{10} \left(\frac{17.32}{V_{in}} \right) \\ \therefore V_{in} &= \frac{17.32}{10^{60/20}} = 17.32 \text{ mV} \end{aligned}$$