

43.1 Measurement loading, amplifier gain and detector response

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS dead time • input impedance

Objective

Calculate measurement loading from finite meter and source impedances; Determine simple amplifier gain and first-order filter response; Interpret detector efficiency, resolution, dead time and calibration bias. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

A meter forms a divider with the source: $\text{reading} = V_{th} \cdot R_m / (R_m + R_{th}) \leq V_{th}$. Quote both resistances.

Non-inverting gain is $1 + R_2/R_1$. A first-order low-pass has $f_c = 1/(2\pi RC)$, amplitude $1/\sqrt{1 + (f/f_c)^2}$, and passes $1/\sqrt{2}$ at f_c .

Efficiency, FWHM/E resolution and dead time $m = n/(1 + n\tau)$ are separate properties; invert to $n = m/(1 - m\tau)$ with $m\tau < 1$.

Calibration removes constant offset or scale error, not noise or nonlinearity; report resolution and efficiency separately.

■ Worked method

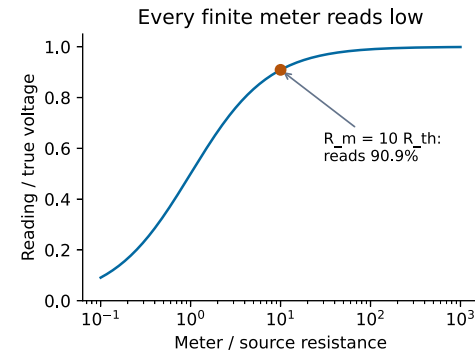
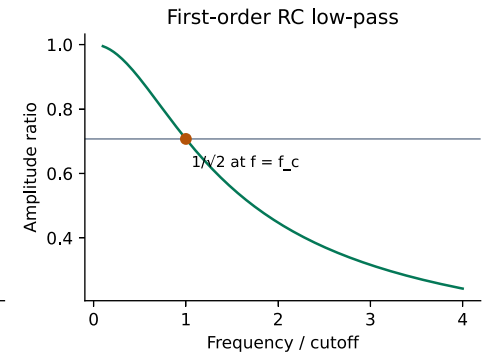
A voltmeter of finite input resistance forms a divider with the source resistance.

$$V_m = V_{th} \frac{R_m}{R_m + R_{th}} = (12 \text{ V}) \frac{1.0 \text{ M}\Omega}{1.0 \text{ M}\Omega + 0.20 \text{ M}\Omega} = 10.0 \text{ V}.$$

For a nonparalysable detector with observed rate m and dead time τ ,

$$n = m / (1 - m\tau), \quad m\tau < 1.$$

Efficiency, dead time and spectral resolution are different corrections; one cannot replace the others.



2 Practice

2.1 Choose one answer. A 12 V source with internal resistance 200 k Ω is measured by a voltmeter with input resistance 1 M Ω . The meter reads: [1]

- A 12.0 V
- B 10.0 V
- C 9.6 V
- D 2.0 V
- E 11.0 V

2.2 Choose one answer. A first-order RC low-pass driven exactly at its cutoff frequency passes an amplitude fraction of: [1]

- A $1/2$
- B $1/\sqrt{2}$
- C $1/e$
- D $9/10$
- E 1

2.3 An ideal non-inverting op-amp stage with $R_1 = 1 \text{ k}\Omega$ and $R_2 = 9 \text{ k}\Omega$ has gain _____. Show your relation and units. [2]

[2]

[4]

Solutions

2.1 B Divider: $12 \times (1.0/1.2) = 10.0$ V; the finite meter loads the source.

Compare the rejected options: 12.0 V; 9.6 V; 2.0 V; 11.0 V. Use the stated model and conditions.

2.2 B $1/\sqrt{1+(f/f_c)^2} = 1/\sqrt{2}$ at $f=f_c$, the -3 dB point.

Compare the rejected options: $1/2$; $1/e$; $9/10$; 1. Use the stated model and conditions.

2.3 10. $1+R_2/R_1 = 1+9 = 10$.

2.4 False. Dead time removes events: $m=n/(1+n\tau)$ falls as τ grows.

3.1 Let resistance r be in megohms. The first reading gives $V_{th} = 6(1+r)$. The second gives $V_{th} = 9(3+r)/3 = 9+3r$. Equating yields $r = 1$, hence $R_{th} = 1$ megohm and $V_{th} = 12$ V. Both readings are below the unloaded voltage. Award two divider equations, resistance and voltage/check.