

## ECE 209: *Circuits and Electronics Laboratory*

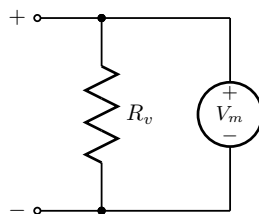
### Lab 2: Meters, Measurements, and Errors Quiz (100 points)

**Description.** *This quiz tests your comprehension of the introductory lab material over meters and measurements. This quiz is **closed book** and **closed notes**.*

#### Problem Q2-1: Non-Ideal DC Voltmeter (40 points)

1. Draw the equivalent circuit of a non-ideal DC voltmeter. Make sure the internal resistance is drawn clearly. **(20 points)**

SOLUTION



The internal resistance is  $R_v$ .  
Measured voltage is  $V_m$ .

2. What do we assume about the internal resistance of an ideal DC voltmeter? (hint: what is the current into an ideal voltmeter?) **(20 points)**

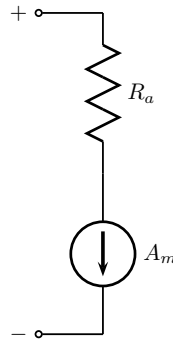
SOLUTION

The voltmeter is placed in parallel with a component under test, and we assume that it draws no additional current from the circuit. So it should have **nearly infinite resistance** or **very large resistance relative to the circuit under test**. Otherwise, the additional current drawn into the voltmeter will cause a significant voltage drop across the rest of the circuit, and the voltage across the component under test will change when the voltmeter is removed. In other words, **the voltmeter should look like an open circuit**.

## Problem Q2-2: Non-Ideal DC Ammeter (40 points)

3. Draw the equivalent circuit of a non-ideal DC ammeter. Make sure the internal resistance is drawn clearly. (20 points)

SOLUTION



The internal resistance is  $R_a$ .  
Measured current is  $A_m$ .

4. What do we assume about the internal resistance of an ideal DC ammeter? (hint: what is the voltage drop across an ideal ammeter?) (20 points)

SOLUTION

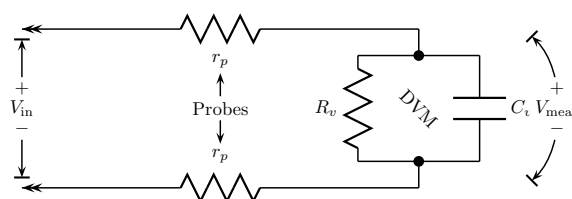
Because the ammeter is in series with the circuit under test, we assume that its internal resistance is **negligible** (i.e., **nearly zero** or at least **relatively small compared to the circuit under test**). Otherwise, the current in the circuit will change when we remove the ammeter. In other words, **the ammeter should look like a short circuit**.

## Problem Q2-3: Measuring High-frequency Voltage (20 points)

5. When considering measuring voltages at all frequencies, what kind of linear-time-invariant (LTI) system does an AC voltmeter look like? (20 points)

SOLUTION

The **simplest** AC voltmeter looks like a **low-pass filter**. The parallel capacitance of the voltmeter draws a large displacement current for high-frequency signals (i.e., the signal changes too quickly for the capacitor to “fully” charge, and so current always flows). This extra current causes a voltage drop across the probes and circuit we’re testing, and the high-frequency amplitude at the voltmeter appears to be much smaller than it should be. So very high-frequency signals will be severely attenuated, and the voltmeter will draw more current from the circuit at these frequencies than at DC.



$$\begin{aligned} \frac{V_{\text{meas}}}{V_{\text{in}}} &= \frac{(R_v \parallel 1/(sC_v))}{(R_v \parallel 1/(sC_v)) + 2r_p} \\ &= \frac{\frac{R_v/(sC_v)}{R_v + 1/(sC_v)}}{\frac{R_v/(sC_v)}{R_v + 1/(sC_v)} + 2r_p} \\ &= \frac{R_v}{1 + sC_v(R_v \parallel 2r_p)} \quad (\text{an LPF}) \end{aligned}$$

**Real** DVM's *do* act like severe low-pass filters, but it is for much more complicated reasons, and they do not draw much more current until *very* high frequencies. High-precision DVMs have *internal* filters by **design** that are necessary for proper function. For details, take more ECE classes (e.g., [ECE 600](#)).