Electronics I. laboratory measurement guide

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1. Measurement: Basic measurements

Please refer to the instrument guide for detailed instructions of the lab instruments!

Homework

As homework (before coming to laboratory session), using calculations methods learned in electricity theory, calculate the voltages and currents for the exercises with resistors. Fill out the "Calculated values with nominal R" columns in the tables where you find them.

1. Measuring the internal resistance of the milliampermeter

The value of the internal resistance of the milliampermeter is important for exercise 4. As it is not given in the multimeter's manual, we are going to measure it.

The milliampermeter has a different resistance in each measurement range, we are going to measure all of them. We'll need both multimeters for this. Set up one of them as mA meter, the other as Ω meter. Connect the COM to COM; mA to Ω .

The ohmmeter is actually a current generator, as such, its measuring current will be shown on the milliampmeter, note this number as well in the following table.

Use the best resolution available for the measurements.

| Range: | L1 | L2 | L3 | L4 | L5 | L6 |
|--------------------------------------|----|----|----|----|-----|-----|
| | | | | | | |
| mA meter | | | | | N/A | N/A |
| R _{internal} : | | | | | | |
| Measuring current of ohmmeter: | | | | | | |

2. Learn to measure voltage and current



1. Measuring the voltage divider circuit

Parameters: $V_{supply}=6V$, $R_1=1k\Omega$, $R_2=2.2k\Omega$

Before creating the circuit, set up approx. 20mA current limit on the power supply. Keep this limit for the rest of the laboratory session! (On the Twintex supply, make sure the current limit is not above the arrow stickers.)

The rest of the measurements need the **breadboard** that is introduced in the instrument guide (see on the web page).

We don't always have enough number of multimeters, so we will have to measure voltages one at a time. This is indicated by the dashed lines. The voltmeter's internal resistance is very large, thus we don't make a measurable error either way.

The ampermeter (milliampermeter) does have a non-negligible internal resistance (we have measured it previously!), so removing it during the measurement could be a problem. Therefore the milliampermeter should stay connected throughout the measurement, and be in the same range (as its internal resistance depends on the range). Also, the V₀ voltage is measured on the two resistors, and not on the power supply, in order to avoid the voltage falling on the ampermeter.

For these reasons, the power supply and the ampermeter should be connected to the circuit first, as they are not removed, and the voltmeter last, so it can be removed and moved to another points without affecting the rest of the circuitry. Follow this rule in later measurements as well.

On the image (figure 1) we have indicated the instruments' banana sockets' labels (COM, mA ill. V) for easier connection. This is only for learning, it will not be done in real life. (Actually the meters themselves will not be shown most times on the schematics. Learn how to connect them.)

2.1 Homework (calculate before coming to lab!):

Calculate the I current and V1, V2 voltages, supposing V0=Vsupply. (In homework, just as in exam, follow the form: quantity=equation with parameters (formula)= substitution=result in SI prefix format.

2.2. Measurement exercise:

Measure resistances R_1 and R_2 as precisely as possible. (Before building the circuit...). In the future, do this for all other exercises in electronics. (Obviously write the measured values...)

2.3. Measurement exercise:

Measure V_0 , V_1 and V_2 voltages and I current. Use the best resolution mA range. Use the V range with 3 fractional digits.

2.4. Lab report exercise:

Calculate again I, V_1 and V_2 using the measured values of V_0 , R_1 and R_2 .

Compare these with the measured I, V_1 and V_2 values and check the validity of Ohm and Kirchhoff laws.

In all later exercises in electronics, always measure the power supply voltage, even if the exercise doesn't mention it! It is generally impossible to set up exactly the same voltage on the supply as is in the original calculation. So in order to compare calculation with measurement, we will re-calculate the homework with the measured V0 (Vsupply in later measurements) value.

These instructions will not always appear in later measurements. You will have to remember them (ie. what to do in lab report, how to exactly measure etc.)

3. Series resistor network:

In the next exercise a simple, four resistor voltage divider is used. We shall learn about voltages and node potentials.

The + and – symbols on the schematics indicate the V and COM inputs of the multimeter. Make sure the polarities are correct. Again we will measure the voltages sequentially (ie. after each other).



Figure 2. Series network

3.1 Measure the precise resistance of the four resistors.

| R ₁ = | R ₂ = | R ₃ = | R ₄ = |
|------------------|------------------|------------------|------------------|
|------------------|------------------|------------------|------------------|

3.2 After setting up the current limit, setup 12V output voltage on the power supply.

Connect the four resistors in series as shown in figure 2. One voltmeter will be enough for this measurement.

| | Calculated values with nominal R (homework) | Calculated values with measured R | Measured values |
|----------------|---|-----------------------------------|-----------------|
| V ₁ | | | |
| V ₂ | | | |
| V ₃ | | | |
| V ₄ | | | |

Fill the first column with calculated voltages using the nominal R values, the second column with calculations using the R values you already measured. The sum of the four voltages (in each column) should be equal to V_0 .

3.3 Using the same circuit, now connect the COM input of the voltage meter to the reference point of the circuit indicated by a 0 (the negative pole of the power supply) as in figure 3.



Figure 3. Potentials

Leaving the COM input in place, use the V input on the four nodes (A to D) to measure four node potentials.

| (V _A =V ₀) | Calculated (homework) | Calculated using measured R values | Measured |
|-----------------------------------|--------------------------|------------------------------------|----------|
| VA | 12V | | |
| V _B | | | |
| Vc | | | |
| VD | | | |

Similarly to the previous exercise, fill the first column using nominal, the second column using measured R values (and V_A =measured supply voltage).

In the lab report, include all calculations and check the validity of Kirchoff laws (eg. $V_C\!=\!V_3\!+\!V_4$ etc).

4. Parallel resistor network

We'll do the measurement in four steps, using only one milliampermeter. In each step, connect the current meter in series with one of the resistors, while leaving its space in short circuit in the other branches. (You can expect that this will cause measurements errors.)

Please note that the resistor values here are changed from the previous exercise!



Figure 5. Mixed circuit

Parameters: V₀=1V

 $R_1 = 2,2k\Omega \pm 1\%$

 $R_2 = 1k\Omega \pm 1\%$

 $R_3=620\Omega~\pm1\%$

$$R_4 = 1k\Omega \pm 1\%$$

4.1 Measure the precise resistance of the four resistors.

| R ₁ = | R ₂ = | R ₃ = | R ₄ = |
|------------------|------------------|------------------|------------------|
| | | | |

| | Calculated value | Calculated value |
|----------------|------------------|----------------------------|
| | (homework) | (using measured resistors) |
| I ₁ | | |
| I 2 | | |
| I ₃ | | |
| I 4 | | |

Fill the first column using the nominal resistor values, the second column using the measured resistor values. Check if the sum $I_1+I_2+I_3$ is equal to I_4 .

4.3 Now measure the four currents in **all measurement ranges**. Compare the measured values to the calculated ones, and compare the sum of the first three current to the fourth. Are there differences? What could be the reason?

| range ► | L1 | L2 | L3 | L4 |
|---|----|----|----|----|
| I ₁ | | | | |
| I ₂ | | | | |
| I ₃ | | | | |
| I ₄ | | | | |
| I ₁ + I ₂ + I ₃ | | | | |

5. AC measurement



Figure 6. RC network as low pass filter

Parameters:

 $R_1=2,2k\Omega, C_1=100nF$

V_{in}=10Vpp

Generate the input sine wave signal with the function generator.

5.1 Homework

Calculate the breakpoint frequency of the filter: $f_0 = \frac{1}{2\pi RC}$

Calculate the time constant: $\tau = R \cdot C$

5.2 Measurement

Measure the frequency plot (Bode plot) of the filter (amplitude only). Use the oscilloscope's automatic Vpp measurement function to measure the peak-to-peak voltages. (Voltmeters could be used in AC settings to measure RMS value, but they have limited upper frequency, so only use them if you know their limit is above the needed frequency range!)

From the measured values, find $A_V = V_{out}/V_{in}$

In the lab report, draw a linear graph of A_v versus frequency!

Bonus exercise: draw lin-log or log-log scale graph as well.

| f (Hz) | Vin (V) | Vout (V) | Av |
|------------------|---------|----------|----|
| 100 | | | |
| 300 | | | |
| 500 | | | |
| 600 | | | |
| f ₀ = | | | |
| 800 | | | |
| 900 | | | |
| 1000 | | | |
| 1200 | | | |
| 1500 | | | |
| 1800 | | | |
| 2000 | | | |

5.3. Measurement

Show the input signal on channel 1 of oscilloscope (use a T-junction!) and output signal on channel 2.

Set up f=100Hz. Amplitude is the same as previously.

Set the function generator to square wave output with zero offset.

On the oscilloscope, zoom into the signal so we can see the rising edge of the input and the output signal properly. Draw the waveforms in the lab report. Measure the time constant on the output signal.

Reminder: in 1 τ time, the output rises to 63.2% of maximum. Use the *cursor* mode of the oscilloscope to find the times and voltages for this.

6 Test questions:

- 1. Describe the internal resistances of the ideal and real voltage meters!
- 2. Describe the internal resistances of the ideal and real current meters!

3. What does measurement range mean and how do you set it up when measuring an unknown quantity?

- 4. How do you connect a voltage and current meter to the measured two-pole (include drawing)?
- 5. How do you set up the current limit on a laboratory power supply?
- 6. Draw and describe the characteristic curve of a laboratory power supply!

7. Give a voltage divider formula for calculating the voltage of one of the resistors out of three connected in series!

- 8. Draw its symbol and explain what is a potentiometer.
- 9. Give the current divider formula for calculating the current of one of the resistors out of two connected in parallel!
- 10. Describe and draw the Thevenin model and a possible way of measuring the internal resistance!
- 11. Draw and describe a sinusoidal time-voltage function!
- 12. Define effective voltage (RMS voltage)!
- 13. Give a formula for a sinusoidal function with offset! Define the offset.