Experiment M

Metrology

Before you start to perform an experiment you are obliged to have mastered the following theoretical subjects:

1. DC and AC currents. Voltage, current intensity and electric resistance. [1], [2].
2. Principle of electrical measurements. [3], [4].
3. Four-terminal network. [1], [2].
4. Principle of oscilloscope operation. [5].

Experimental procedure

1. Make the resistance measurements of a reference resistor using all possible ranges of DMM **ohmmeter**. Start the measurements from the higher range. Follow instructions from DMM user manual and Appendix A8. Write down the required equations and calculate the measuring errors of all ohmmeter ranges. Determine which resistance measurements are most accurate.
2. Make the serial connection of DMM **ammeter** and load resistor (resistor with the radiator). Connect this circuit to the output sockets of the power supply MASTER section (black and red banana sockets). Draw the schematic diagram of tested circuit. Select 200mA DC range of DMM ammeter. Turn round the current limit knob of power supply (CURRENT) to the half of adjustment range (if you need don't hesitate ask the supervisor). Turn round the voltage adjustment knob (VOLTAGE) to the extremely left position. Switch on the power supply and use the voltage adjustment knob to set 28V (read the value from the power supply build-in voltmeter). Use the current limit knob to reduce step by step the current intensity flowing through the load resistor (read the value from the DMM ammeter and notice the moment when the voltage starts to decrease). Set the current limit to about 150mA (it may be not easy to set precisely because of low quality of the power supply potentiometers). Write down both the current limit setting value and the related voltage value. Repeat the measurement for the current limit value about 100mA. Switch off the power supply and disconnect the tested circuit. Use the DMM ohmmeter to determine the load resistance value. Compare the measured voltage values (related to the two current limits) with the theoretical voltage values calculated for tested circuit using the Ohm's law for the known current flowing through the load resistor. Give explanation why the power supply voltage adjustment is disabled when the current adjustment knob is turned round to the extremely left position.
3. Connect DMM DC **voltmeters** to the power supply outputs. Select the optimal ranges of voltmeters. Make the measurements for the three different operating modes of the MASTER and SLAVE sections. Set up the independent mode and adjust the following voltages: 5V (MASTER) and 10V (SLAVE). Set up the serial mode and adjust the symmetrical voltage to ±15V with "zero to the ground". Set up the parallel mode and adjust the voltage to 18V. Follow instructions from DMM user manual and Appendix A8 to calculate the measuring errors of registered voltages.
4. Make the serial connection of the first DMM voltmeter and reference resistor (make use of I_1 and I_2 terminals of resistor). Connect this circuit to the output connectors of the power supply MASTER section. Select 20V DC range of DMM voltmeter. Switch on the power supply and use the voltage adjustment knob to set 10V. Use the second DMM voltmeter to measure the voltage across U_1 and U_2 terminals of the reference resistor. Draw the schematic diagram of tested circuit. Follow schematic diagram to derive a formula for an input impedance of the first DMM voltmeter. Use the derived formula to calculate DMM voltmeter input impedance. Derive a formula for an input impedance error and calculate this one.
5. Connect the function generator to the CH1 input (8) of oscilloscope. Select the DC position of the input switch (10). Adjust the level of generated signal amplitude to U_m = 3V. Check if the shape and frequency of generated signal have an effect on the amplitude of curve observed on the oscilloscope display. Change the frequency from 1Hz to 2MHz. Notice the minimum and maximum frequency (independently for sine and rectangular signal) when the amplitude is constant.
6. Connect the function generator to the CH1 input (8) of oscilloscope. Set up the shape of signal to sine, the amplitude level to 8V and the frequency to 1kHz. Check how the amplitude level of generated signal depends on the output attenuator of function generator. Make the measurements for the following attenuations: 0dB, 20dB, 40dB and 60dB. Draw four oscillograms with strongly marked attenuation values and oscilloscope settings. Compare measured results with theory – see Appendix A3.

7. Connect the function generator to the CH2 input (20) of oscilloscope. Set up the shape of signal to rectangular, the amplitude level to U_m = 2V, the frequency to ν = 1kHz, the pulse-duty factor to $W_{\%}$ = 50% (see Appendix A4) and the DC offset level to U_{DC} = 1V (see Appendix A1). Adjust the clear and stable image on the oscilloscope display. Change the oscilloscope settings to get the maximum size of displayed image. Draw the adequate oscillogram with strongly marked oscilloscope settings and the following values: peak-to-peak voltage, amplitude level, period, reference level and DC offset level.
8. Connect the function generator to the CH2 input (20) of oscilloscope. Set up the shape of signal to triangular, the amplitude level to U_m = 0.2V, the frequency to ν = 5kHz and the DC offset level to U_{DC} = 0V. Adjust the clear and stable image on the oscilloscope display. Change the oscilloscope settings to get the maximum size of displayed image. Draw the adequate oscillogram with strongly marked oscilloscope settings and the following values: peak-to-peak voltage, amplitude level and period.
9. Connect the function generator to the CH2 input (20) of oscilloscope. Set up the shape of signal to sine and the frequency to 50Hz. Select the LINE position of the oscilloscope switch (23). Fine-tune the frequency of function generator to get the stable and immovable image (with minimal image drift to the left or right). Read the frequency value from the generator display and estimate the frequency error. Make an assumption the power-line frequency (50Hz) is the reference frequency standard.
10. Connect the function generator to the oscilloscope. Set up the shape of signal to sine, the amplitude level to 6V and the frequency to 5kHz. Adjust the clear and stable image on the oscilloscope display. Turn round the horizontal shift knob (32) to shift the displayed image to the right (left edge is visible). Use the knob (28) LEVEL to adjust the trigger level and notice the changes of displayed image. Use the switch (26) SLOPE to change the trigger slope and compare the registered images related to the rising (+) and falling (–) slopes. Draw the proper four oscillograms with strongly marked oscilloscope settings for the following cases: the rising slope for two trigger levels +3V, –3V and the falling slope for two trigger levels +3V, –3V.
11. Connect the function generator to the both oscilloscope and DMM AC voltmeter (use T junction to divide signal from the output of function generator). Use DMM to measure rms voltages of sine and rectangular signals for the following five fixed frequencies: 50Hz, 500Hz, 5kHz, 50kHz and 500kHz. Draw the proper ten oscillograms with strongly marked oscilloscope settings. Follow oscillograms to calculate rms voltages (see Eq. 1 and Appendix A2) and compare them with the related rms values registered by DMM. Calculate measuring errors for both DMM and oscilloscope measurements. Follow instructions from DMM user manual and below Eq. 1 to make critical analysis of registered results. Read DMM user manual to find out information about the kind of signals and the frequency range where the rms voltage measurements are acceptable.
12. Connect the function generator to the both oscilloscope and four-terminal network (ask technician about the required four-terminal network). Use DMM and/or oscilloscope to measure voltages U_A, U_B, U_C and U_D (see Figs. 6 to 9). Next use DMM to measure the values of R_L and R_S. Make an assumption the r_g value is equal to 50Ω. Use Eqs. (13) and (23) to make proper calculations and estimate the input and output impedances of tested four-terminal network.
13. Connect the function generator to the both X and Y (8)/(20) inputs of oscilloscope (use T junction to divide signal from the output of function generator). Set up the shape of signal to sine and the frequency to 1kHz. Select the X-Y mode of oscilloscope – switch (29). Adjust the gain of X and Y input amplifiers to get the 45° angle of inclination for the observed line segment. Regulate the frequency of generated signal and notice the changes of displayed oscilloscope image. Find out the threshold frequency related to the undesirable phase shift which transforms the observed line segment to an ellipse.

Report elaboration

Report has to be composed of:

1. Front page (by using a pattern).
2. Description of experiment purposes.
3. Short introduction (basic definitions, formulas, description of used marks and symbols).
4. Schematic diagrams of tested circuits.
5. List of used instruments and devices (id/stock number, type, setting and range values).
6. Measuring results, calculations, analysis and sub-conclusions related to the first point of “Experimental procedure”.
7. Measuring results (including oscillograms and tables), calculations, analysis, interpretation and sub-conclusions related to the next points of “Experimental procedure”.
8. Remarks and final conclusions.

References

[1] F. Przezdziecki, A. Opolski, *Elektrotechnika i elektronika*, PWN, Warszawa, 1986.
[2] M. Krakowski, *Elektrotechnika teoretyczna*, PWN, Warszawa, 1983.
[3] B. B. Oliver, J. M. Cage, *Pomiary i przyrządy elektroniczne,* WKŁ, Warszawa, 1978.
[4] B. Żółtowski, *Wprowadzenie do zajęć laboratoryjnych z fizyki*, Skrypt PŁ, Łódź, 2001.
[5] J. Rydzewski, *Pomiary oscyloskopowe*, WNT, Warszawa, 1994.
[6] User manuals of the oscilloscope, power supply, function generator and DMMs.