Experiment 1.1

Objective

The objective of this experiment is to use a multimeter for measuring the resistance, current and voltage. In this exercise we should learn how a resistor influences a circuit and what its purpose is; mainly effects the voltage and the current outputs, and the other way around. Also, we should understand how to read the color codes of resistors and how to combine them in parallel and in series.

Results and procedure

To find out what resistance a resistor has we looked at its colour coding, and calculated the resistance from there (brown, green, orange, gold = $15k\Omega$ with 5% tolerance) After identifying the resistor, it is smart to check if it actually works or not. This can be done by measuring the resistance with a multimeter.

- Measurement on a $15k\Omega$ resistor shows: $14.98k\Omega$

Conclusion. Looking at the colour coding we could see that the resistor has a tolerance of 5%. Hence, the measured value is perfectly acceptable. In order to see how the resistor influences the current we set the voltage to 5V. To measure the voltage in the circuit, the multimeter was connected in parallel. To measure the current, we put the multimeter in series. On the side, we made calculations to later be able to compare our measurement to the datasheet. The representation of the measurements and the calculations can be seen in "Table 1." and "Table 2." respectively.

"Step 2" was repeated, but this time for 11 different voltages, ranging from -15 to 15V:

Attempt	1	2	3	4	5	6	7	8	9	10	11
Voltage (V)	-15.01	-9.97	-7.02	-3.96	0	5.02	7.04	8.98	12.1	13.05	15.03
Current (mA)	-0.99	-0.63	-0.44	-0.23	0.00	0.37	0.47	0.63	0.81	0.90	1.03
Resistor (kΩ)	14.98										

Table 1: Current (I) Measurement

Attempt	1	2	3	4	5	6	7	8	9	10	11
Voltage (V)	-15	-10	-7	-4	0	5	7	9	12	13	15
Current (mA)	-1.00	-0.67	-0.47	-0.27	0.00	0.33	0.47	0.60	0.80	0.87	1.00
Resistor (kΩ)	14.98										

Table 2: Current (I) Datasheet

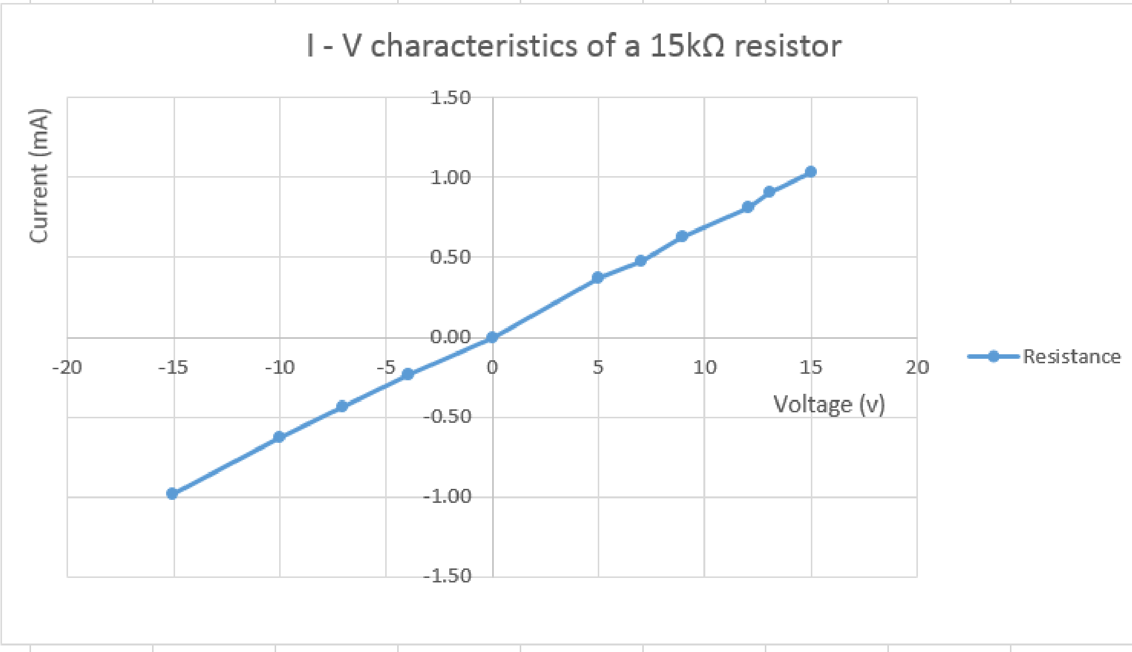

Figure 1: I-V Characteristics of a 15k resistor

Conclusion

In conclusion we can say that our measurements are on one line, taking the tolerance level (our margin of error) into consideration. The function is linear. We proved the Omh's Law that resistance is dependant on voltage and current.

Experiment 1.2

Objective
The objective of this experiment is to learn how to build small circuits with resistors and to get familiar with analysing circuits using "device" and "connection" equations.

Results
Following resistors are given by:

$$R_1 = 15k\Omega \quad R_2 = 22k\Omega \quad R_3 = 33k\Omega \quad R_4 = 10k\Omega$$

The equivalent resistance is calculated in the equations below. The measurements are presented after each equation:

a) $R = R_1 + R_2 + R_3 = 15 + 22 + 33 = 70k\Omega$
$R_{measured} = 69.96k\Omega$

b) $R = R_1 \parallel R_2 + R_3 = \frac{R_1R_2+R_3(R_1+R_2)}{R_1+R_2} = \frac{330+33\times37}{37} = \frac{330+1221}{37} \cong 41.92k\Omega$
$R_{measured} = 41.90k\Omega$

c) $R = (R_1 \parallel R_2) + R_3 = \frac{R_1(R_2+R_3)}{R_1+R_2+R_3} = \frac{15(22+33)}{15+22+33} = \frac{165}{14} \cong 11.8k\Omega$
$R_{measured} = 11,81k\Omega$

d) $R = R_1 \parallel R_2 + R_3 \parallel R_4 = \frac{R_1R_2}{R_1+R_2} + \frac{R_3R_4}{R_3+R_4} = \frac{330}{37} + \frac{330}{43} \cong 8.92 + 7.67 \cong 16.59k\Omega$
$R_{measured} = 16.60k\Omega$

e) $R = (R_1 + R_2) \parallel (R_3 + R_4) = \frac{(R_1+R_2)(R_3+R_4)}{R_1+R_2+R_3+R_4} = \frac{37\times43}{80} \cong 19.89k\Omega$
$R_{measured} = 19,86k\Omega$

Conclusion
All of our resistors that were used for the measurements had 5% tolerance. Hence, our calculations and measurements were slightly different, but definitely within the tolerance level.

Experiment 1.3

Objective
The objective of this experiment is to get more familiar with KVL and KCL and superposition.

Results and procedure
Following values are given:

$$V_a = 5V \quad V_b = 10V \quad R_1 = 22k\Omega \quad R_2 = 33k\Omega \quad R_3 = 10k\Omega$$

KVL and KCL imply:

$$\begin{aligned} V_2 + V_1 &= V_A \\ V_2 + V_3 &= V_B \\ i_1 + i_3 &= i_2 \end{aligned}$$

Using superposition:

$$\begin{aligned} i_1 &= \frac{5 \times 33 \times 10^3 + 5 \times 10^3 - 10 \times 10^3}{22 \times 10^6 \times 33 + 33 \times 10 \times 10^6 + 22 \times 10 \times 10^6} = \frac{-115}{1276 \times 10^3} \cong -0.09mA \\ i_{1measured} &= -0.15mA \\ i_2 &= \frac{(5 \times 10 + 10 \times 22) \times 10^3}{1276 \times 10^6} \cong 0.2mA \\ i_{2measured} &= 0,18mA \\ i_3 &= \frac{(10 \times +10 \times 22 - 5 \times 33) \times 10^3}{1276 \times 10^6} = \frac{385}{1276 \times 10^3} \cong 0.3mA \\ i_{3measured} &= 0.34mA \end{aligned}$$

Using KVL following voltages were determined:

$$\begin{aligned} V_1 &= i_1 \times r_1 = -0.09 \times 22 = -1.98V \\ V_{1measured} &= -3.25V \\ V_2 &= 0.2 \times 33 = 6.6V \\ V_{2measured} &= 5.94V \\ V_3 &= 0.3 \times 10 = 3V \\ V_{3measured} &= 3.44V \end{aligned}$$

Conclusion
In conclusion our measurements and the calculations are in average within the level of tolerance of 20

Experiment 1.4

Objective
The objective of this experiment is to use use superposition to analyse the circuit.

Results
Following values are given:

$$V = 5V(With\, max\, current\, 60mA) \quad I = 60mA(With\, max\, voltage\, 3V) \tag{1}$$

$$R_1 = 180\Omega \quad R_2 = 18\Omega \quad R_3 = 270\Omega \tag{2}$$

The voltage that falls on R_3 is calculated using superposition. Firs the voltage is set to 0; the circuit simplification process allows us to derive the following equations:

$$R_{12} = \frac{R_1 R_2}{R_1 + R_2} = \frac{180 \times 18}{180 + 18} = 16.36\Omega$$
$$R_5 = R_{12} + R_2 = 16.36 + 18 = 34.36\Omega$$
$$R_P = \frac{R_5 R_3}{R_5 + R_3} = \frac{34.36 \times 270}{34.36 + 270} = 30.48\Omega$$

Next, from the equation: $I = \frac{V_a}{V_b}$ the voltage V_a can be calculated:

$$V_a = I \times R_P = 0,06 \times 30.48 = 1.83V$$

Conclusion

Experiment 2.1

Objective

The objective of this experiment is to get familiar with Thermometers and see how their resistance changes with temperature.

Results and procedure

The table below shows our measurement of the resistance of the NTC sensor for room temperature and temperature of the hand. The table also shows the datasheet values for the corresponding temperatures (22 C and 33 C). Table

Open circuit voltage (V_{oc}) is calculated for both cases using the equation: Thus,

$$V_{oc} = V_a - V_b = V(\frac{R_3}{R_1 + R_3} - \frac{R_4}{R_2 - R_4})$$

$$\begin{aligned} V_{oc,room} &= 1.45(\frac{4.7}{8.6+4.7} - \frac{1.8}{10+1.8}) \\ &= 1.45 \times 0.2 \\ &= 0.29V \end{aligned} \quad \text{and} \quad \begin{aligned} V_{oc,hand} &= 1.45(\frac{4.7}{6.1+4.7} - \frac{1.8}{10+1.8}) \\ &= 1.45 \times 0.29 \\ &= 0.42V \end{aligned}$$

The measured voltages "V_{oc}":

$$V_{oc,room} = 0.3V \qquad V_{oc,hand} = 0.45V$$

Conclusion

In conclusion we achieved the goal of understanding how a thermometer work. Our measurements and calculations for voltage have a differance smaller than 0.05V. In regards to the resistance we learned that although we set the temperature to 22 and 35, looking at the datasheet, we could see that our measurement values of R_{room} and R_{hand} corresponded to 28 and 36 respectively.

Experiment 2.2

Objective
The objective of this experiment is to use Thevenin and Norton Theories and find their equivelents, by experimend and also by calculating.

Results and procedure
Following values are given by :

$$V = 20V \qquad R_1 = 1k\Omega \qquad R_2 = 100k\Omega \qquad R_3 = 4.7k\Omega \qquad R_4 = 1.8k\Omega$$

The Thevenin Equivalent is measured to: $R_{th} = 3k\Omega$. Resistance (R_{th}) is calculated by:

$$R_{th} = (R_1 \parallel R_3) + (R_2 \parallel R_4) = \frac{R_1R_3}{R_1 + R_3} + \frac{R_2R_4}{R_2 + R_4} = \frac{1 \times 4.7}{1 + 4.7} + \frac{100 \times 1.8}{100 + 1.8}$$
$$= 2.59 \cong 2.6k\Omega$$

Voltage (V_{th}) is calculated by:

$$V_{th} = V(\frac{R_3}{R_1 + R_3} - \frac{R_4}{R_2 - R_4}) \quad = 20(\frac{4.7}{1 + 4.7} - \frac{1.8}{100 + 1.8}) = 20 \times 0.8 = 16.1V$$

Norton equivalent current(I_n) is measured to: $I_n = 5.98mA$. Resistance (R_{th}) is calculated by:

$$I_n = \frac{V_{th}}{R_{th}} = \frac{16.1}{2.6} = 6.2mA$$

Conclusion

Experiment 2.3

Objective

Results and procedure

Using the Thevenin equivalent we find the smallest possible resistor for the output part, such that the current in the resistor remains less than 1mA, by:

$$R = \frac{V}{I} = \frac{16.1V}{1mA} = 16.1k\Omega$$

Now from the formula for power (P) we can derive that:

$$P = \frac{V^2}{R} \quad \text{for} \qquad R \to 0$$

power (P) will be higher. The table that shows the power consumption for different resistances can be seen below.

Resistance (kΩ)	1	1.2	1.5	1.8	2.2	2.7	3.3	3.9	4.7	5.6	6.8
Voltage (V)	4.38	5	5.67	6.5	7.3	8	8.9	9.94	10	10.8	12
Power (mW)	19.18	20.83	21.43	23.47	24.22	23.70	24.00	25.33	21.28	20.83	21.18
Voltage (V^2)	19.1844	25	32.1489	42.25	53.29	64	79.21	98.8036	100	116.64	144

Table 3: Power consumption for different resistances

Plot for the table(3) is drawn:

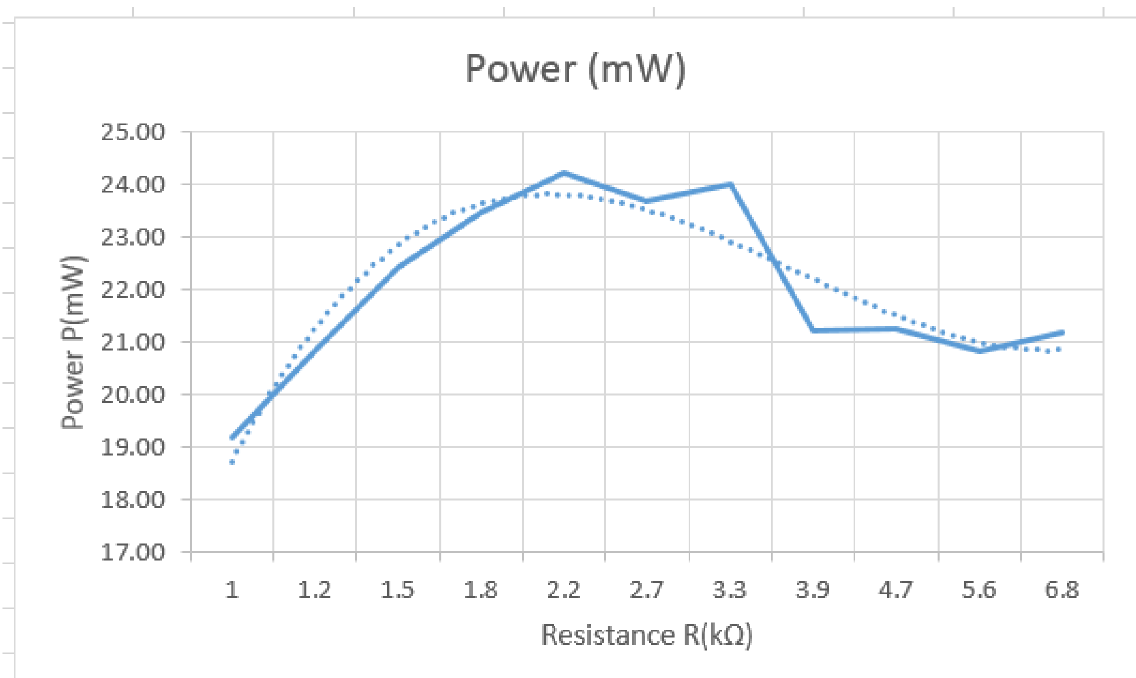

Figure 2: Power consumption

Conclusion

We found out that the maximum power consumption is obtained when the resistance of the load matches the R_{th}, and falls when we increase the resistance of the load.

Experiment 3.1

Objective

Results and procedure

Following values are given by:

$$R = 1k\Omega \qquad D = 1N4001 \qquad E = 2v\ (i_{max} = 350mA)$$

Measurements of the diode and resistor voltage and current for different resistors can be seen in the table below:

Try	1	2	3	4
R (Ω)	60	38.8	20.8	11.2
V_D (V)	0.7	0.72	0.74	0.76
V_R (V)	1.27	1.24	1.11	0.9
I_D (mA)	20	30	50	80

Table 4: Measurements for diode and resistor

I-V characteristics of the diode can be seen below:

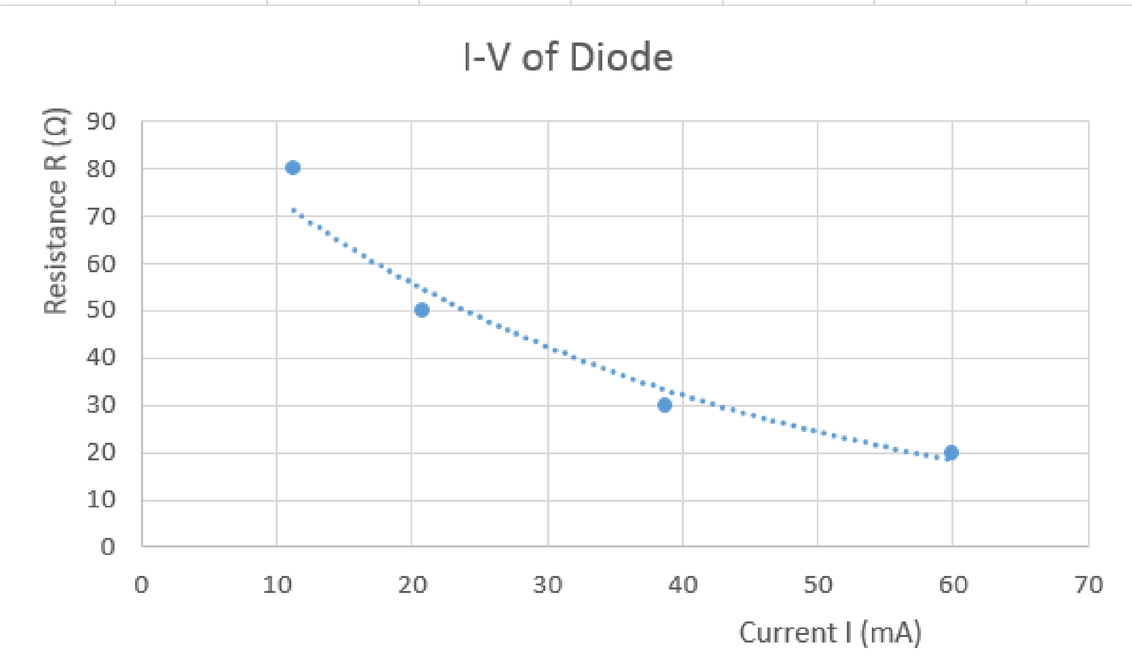

Figure 3: I-V characteristics for the diode

I-V characteristics of the resistor can be seen below:

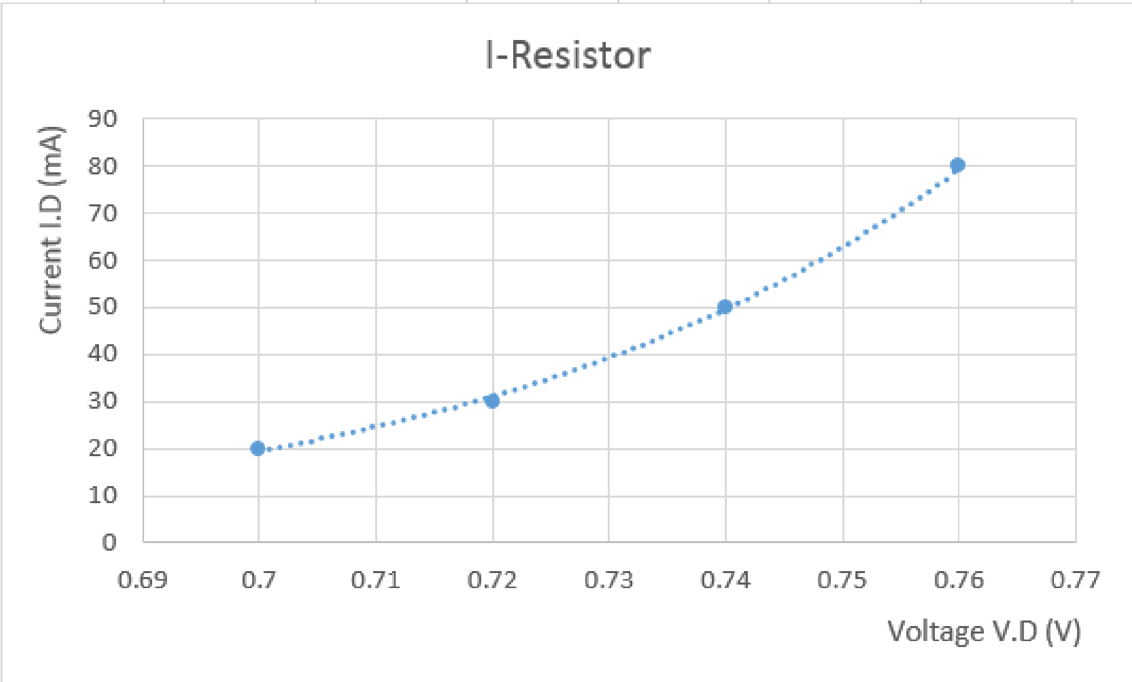

Figure 4: I-V characteristics for the resistor

Conclusion

Experiment 3.2

Objective
Aim of this experiment is to analyze a full wave recififer with an oscilloscope.

Results and procedure
Following values are given by:

$$R = 1k\Omega \qquad D = 1N4001 \qquad V_i = 20sin(100\pi t)$$

Following measurements were made using bot multimeter and oscilloscope:

$$V_i = 13.87V \quad \text{(AC)}$$
$$i = 1.41mA \quad \text{(AC)}$$
$$V_{RL} = 11.85V \quad \text{(DC)}$$

Conclusion

Experiment 3.3

Objective
Aim of this experiment is to measure an inverting amplifier with an oscilloscope.

Results and procedure
Following values are given:

$$V_{in} = 1.5V \qquad V_{cc} = 12V \qquad I_{out} \leqslant 10mA$$

We measured the output voltage to be: $V_{in} = 1.5V \Rightarrow V_{out} = 3.15V$

Our calculations of what the output voltage should be:

$$-A_v = \frac{V_{out}}{V_{in}} \quad \text{,thus:} \qquad V_{out} = V_{in} \times A_v = 1.5 \times 2 = 3V$$

We use $V_{i2} = 20sin(100\pi t)$ and measure the output voltage using oscilloscope. The results follow as:

$$V_{out2} = -0786V \qquad (AC)$$
$$V_{out2} = 1.59V \qquad (DC)$$

Conclusion
The picture in the oscilloscope was a perfect sine wave.

Experiment 4.1

Objective

Results and procedure

Conclusion

Experiment 4.2

Objective

Results and procedure

Conclusion

Experiment 4.3

Objective

Results and procedure

Conclusion