DG220 – INTRODUCING ELECTRONICS

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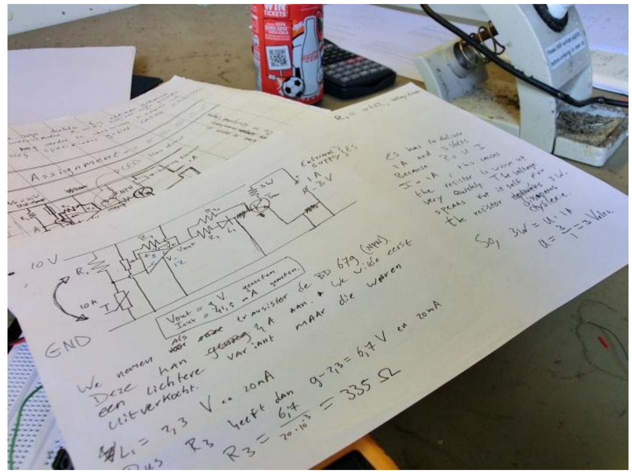
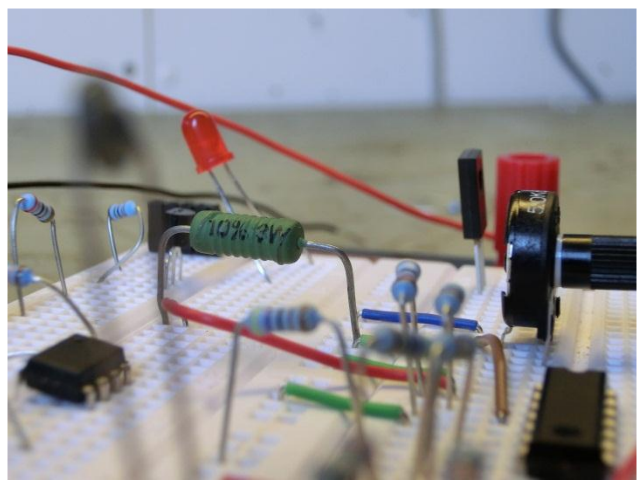
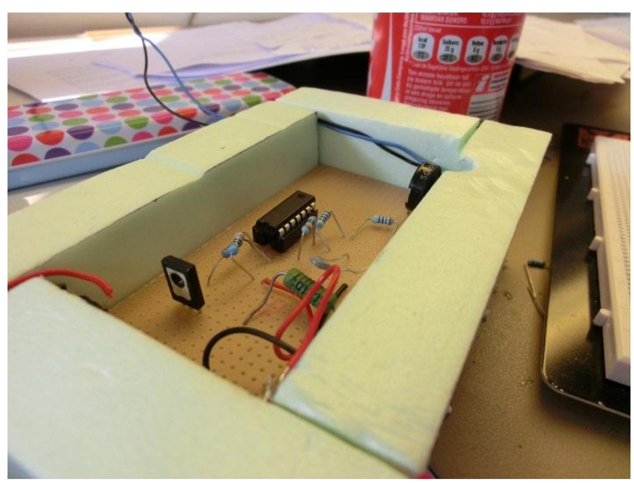






Content //

2.1

How long can we use the MP3 player with a new set of batteries?

In series:

The current remains the same in series. Here it is the voltage that doubles. So, in this way the MP3 player will last for 6 hours.

I = 300 mAh $\frac{300}{50} = 6h$

In parallel:

In a parallel circuit the current is doubled because every battery delivers 300 mAh. So, in this way the MP3 player will last for 6 hours.

I = 600 mAh $\frac{600}{50} = 12h$

2.2

Which graph depicts an ideal power source an which graph depicts a non-ideal realistic power source?

B depicts an ideal power source, because you prefer that the voltage stays constant regardless the current.
C depicts a non-ideal but realistic power source, because the voltage drops before the load current is fully drained from the battery.

2.3

Which graph depicts an ideal power source and which graph depicts a non-ideal power source?

C depicts an ideal power source, because the voltage remains constant over time.
B depicts a non-ideal power source, because the voltage drops as the battery is drained over time.

2.4

Is the supply sufficient for this amplifier? Explain!

The answer is no, because:

$P = U * I = 50 * 2 = 100\ Watt$

The efficiency is: $E = \frac{P_{out}}{P_{source}} * 100\% = 35\%$

$35\% = \frac{50W}{P_{source}} * 100\%$ => $P_{source} = \frac{50}{0{,}35} * 1 = 143\ W$

The desired P is bigger than the actual P, this means that the supply is not sufficient.

2.5

At what frequency does this bulb flicker?

The lamp turns on twice during a period of $\frac{1}{50}$ second.

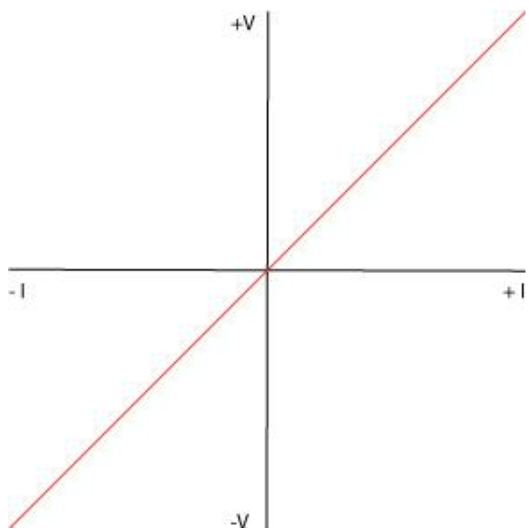
So, $T = \frac{1}{100}$

$$f_{lamp} = \frac{1}{\frac{1}{100}} = 100\ Hz$$

3.1

Draw the graph of V = f(I) with R = constant.

$$V = f(I) = R \cdot I$$



3.2

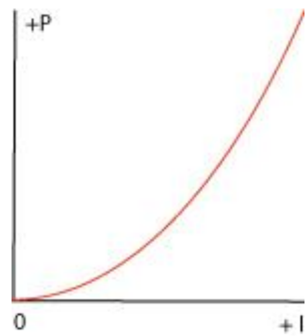
Determine the current flowing through and the power dissipated in the resistor.

1. Current flowing: $I = \frac{U}{R} = \frac{10}{100} = 0{,}01\ A = 10\ mA$
2. Power dissipated: $P = U * I = 10 * 0{,}01 = 0{,}1\ W$

3.3

Draw the graph of P = f (I) with R = constant.

$$P = I^2 \cdot R$$



3.4

Which type of resistors do you think can handle the largest power, resistor types having a physical large size or small ones? Explain!

The larger resistor can handle more power, as it takes more energy to warm up the resistor.

3.5

Show by calculation that is it not possible to let R dissipate more than the maximum amount of power that R can handle.

$$Pmax = 0{,}25\ W$$
$$U = 19\ V$$
$$R = 1{,}5\ k\Omega$$
$$I = \frac{U}{R} = \frac{19{,}0}{1500} = 12{,}6\ mA$$

$P\ is\ constant\ and\ will\ be\ the\ same\ regardless\ the\ connection.$

$$P = U \cdot I = 12{,}6 \cdot 103 \cdot 19 = 0{,}24\ W$$

$0{,}24 < 0{,}25 \qquad thus\ the\ power\ will\ always\ be\ less.$

3.6

Find two resistor from the E12 series and connect them in such a way that R_{re} satisfies the demands for the resistance value, tolerance and the amount of power to handle.

For a parallel circuit applies in this case: $Rtot = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}$

$If\ R_1 = R_2\ than\ is\ R_{tot} = \frac{R_1}{2} \qquad gives: R_1 = 500 * 2 = 1000\ \Omega$

This will give two resistors with the following coloring: Brown-Black-Black-Brown-Brown (1kΩ)

3.7

Find two resistors in the E12 series which realize the voltage divider shown in Figure 3.5 as accurate as possible.

The most suitable resistors are the resistors of R_1 = 4,7kΩ and R_2 = 3,9kΩ.

4.1

A capacitor of 100 pF is coupled to a DC-source of 12 V.

1. **What is the total amount of charge stored on it?**

$$C = \frac{Q}{V}, Q = C \cdot V = (0{,}1 \cdot 10^{-9}) * 12 = 1{,}2 \cdot 10^{-9}\ Coulomb$$

2. **What is the total amount of electrical energy is stored in it?**

$$V = 12\ Volt$$
$$C = 100 \cdot 10^{-12}\ Farad$$
$$E = \frac{1}{2}CV^2 = \frac{1}{2} \cdot (100 \cdot 10^{-12}) * 12^2 = 7{,}2 \cdot 10^{-9}\ Joule$$

3. **When we charge this capacitor (don't think about the voltage of the source) with a steady current of 50 mA. How long does it take to charge this capacitor to a voltage of 90 V?(Note: Ampere is Coulomb per second!)**

$$I = C \cdot \frac{\Delta V}{\Delta t} \rightarrow \Delta t = \frac{C \cdot \Delta V}{I} = \frac{0{,}1 \cdot 10^{-9} * 90}{50 \cdot 10^{-3}} = 1{,}8 \cdot 10^{-7} Coulumb/second$$

4.2

What will happen with the impedance X_c if:

1. **Frequency *f* increases?**

X_c decreases.

2. **The frequency *f* decreases?**

X_c increases.

4.3

Derive that holds:

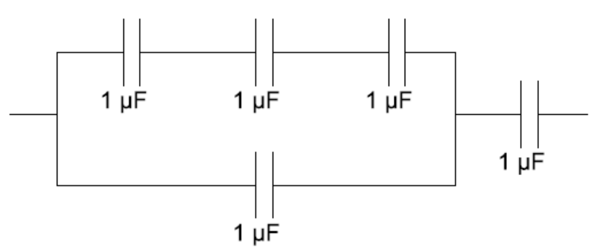
$$\boldsymbol{C_{re}} = \sum_{i=1}^{N} C_i$$

Use the fact that the potential difference across each capacitor is the same, use Equation 4.1 and take the same steps as in the derivation of Equation 4.6 .

$$C = \frac{Q}{V} \rightarrow V = \frac{Q}{C}$$
$$V = \frac{Q_1}{C_1} = \frac{Q_2}{C_2} = \frac{Q_3}{C_3} = \frac{1}{C_{re}} \cdot (Q_1 + Q_2 + Q_3)$$
$$(C_1 \cdot V + C_2 \cdot V + C_3 \cdot V) \cdot \frac{1}{C_{re}} = V$$
$$C_{re} = C_1 + C_2 + C_3$$
$$C_{re} = \sum_{i=1}^{N} C_i$$

4.4

What is the equivalent capacitance of the circuit shown below?



$$S_1 = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{3}\ \mu F$$
$$P_1 = S_1 + 1\mu F = 1\frac{1}{3}\ \mu F$$
$$S_2 = \frac{1}{1\frac{1}{3} + \frac{1}{1}} = \frac{4}{7}\ \mu F$$
$$C_{re} = \frac{4}{7}\mu F\ \approx 0{,}57\ \mu F = 570\ nF$$

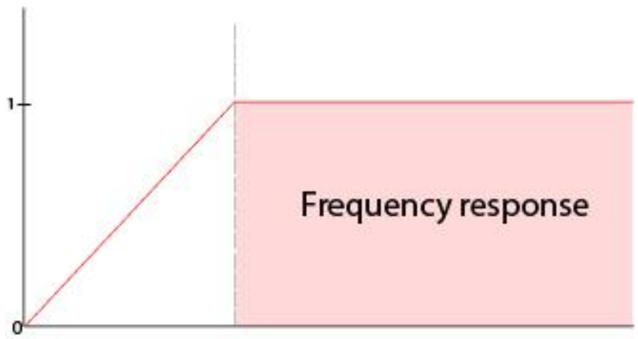
4.5

Equation 4.8 shows the transfer function of a RC low-pass filter. Rework this function in such a way that it describes the transfer function of a RC high-pass filter and draw its (amplitude) transfer-function.

$$V_{out}(\omega) = \frac{R}{\sqrt{R^2 + X_C^2}}$$

Because V_{out} is based on V over the resistor instead of over the capacitor.

$$H = \left|\frac{V_{in}}{V_{out}}\right| \uparrow$$



$$f \rightarrow$$

4.6

Show by calculation that for both types of RC-filters at the cut-off point holds: Vout /Vin = 0.707

$$V_{out} = \frac{V_{in}}{\sqrt{2}}$$
$$V_{out} \cdot \sqrt{2} = V_{in}$$
$$\frac{V_{in}}{V_{out}} = \sqrt{2}$$
$$\frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{2}} \approx 0{,}707$$

4.7

Determine the current flowing through and the power dissipated in the resistor.

1. $V_c(t) = V_{in}\left(1 - e^{-\frac{t}{RC}}\right)$
   $t = (15 \cdot 10^3) \cdot (100 \cdot 10^{-9}) \cdot \ln(2) \approx 1{,}04ms$

2. $I_{charge} = C\frac{dV_c}{dt}$ is a differential equation derived from $V_c = f(t)$. Solving it results in a logarithmic function with e. This means it's non-linear.

5.1

When a current flows through an inductor and the current is suddenly cut off, this can damage your circuit. Explain why this can happen.

When the current is cut off, the magnet will discharge. This will result in a voltage peak, which can damage vulnerable components in a circuit.

5.2

A current source provides a current of 100 mA which flows through an 1 mH inductor. How many energy is stored in the inductor?

$$I = 100mA$$
$$L = 1mH$$
$$E_{magnetic} = \frac{1}{2}LI^2 = \frac{1}{2}\cdot(1\cdot 10^{-3})\cdot(100\cdot 10^{-3})^2 = 5{,}0\cdot 10^{-6}\,J$$

5.3

What will happen with the impedance Zl if:

1. **The frequency f increases?**

Z_l will increase

2. **The frequency f decreases?**

Z_l will decrease

5.4

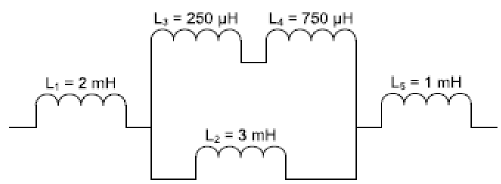
If you consider the parallel connection of three inductors with L1 = 0.33 mH, L2 = 68 µH and L3 = 12 mH. What can you tell, without calculating it, about the replacement inductance Lre? So, which of the three answers is correct and why is it correct ?

1. **Lre > 12 mH**
2. **Lre < 68 µH**
3. **68 µH < Lre < 0.33 mH**

L_{re} < 68 µH. Because one divided by a very small number gives a big answer. 3 big answers together give a much bigger answer. If you divide 1 by this answer, the outcome will be very small, and thus smaller than 68 µH.

5.5

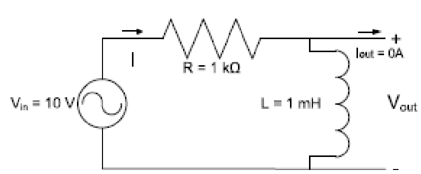
What is the equivalent inductance Lre of the circuit shown below?



$$L_{s_1} = L_2 + L_4 = 1000\mu H = 1mH$$
$$L_p = \frac{1}{\frac{1}{L_{s_1}} + \frac{1}{L_3}} = \frac{1}{\frac{1}{1} + \frac{1}{3}} = 0{,}75\ mH$$
$$L_{s_2} = L_1 + L_p + L_5 = 2 + 0{,}75 + 1 = 3{,}75\ mH$$

5.6

Is the filter drawn in Figure 5.6 a high-pass or a low-pass filter?



High-pass, since an inductor works the opposite way compared to a capacitor.

5.7

1. **What do you get by interchanging the position of L and R in Figure 5.6: a high-pass or a low-pass filter?**

A low-pass filter.

2. **Mathematically derive the equation which describes the input-output relation (like Equation 5.8) of this newfound filter.**

$$\frac{V_{out}}{V_{in}} = \frac{R}{Z_{re}}$$
$$V_{out} = \frac{R}{Z_{re}} \cdot Vin$$
$$V_{out} = \frac{R}{\sqrt{R^2 * \omega^2 * l^2}} \cdot V_{in}$$

5.8

Calculate the current I in the circuit drawn in Figure 5.6 at 3 different Vin frequencies:

1. **100 kHz**

$$f = 100kHz$$
$$X_l = 2\pi \cdot (100 \cdot 10^3) \cdot (1 \cdot 10^{-3}) = 200\pi\Omega$$
$$I = \frac{U}{R_{tot}} = \frac{10}{\sqrt{R^2 + X_l{}^2}} = \frac{10}{\sqrt{1000^2 + 200\pi^2}} = 99{,}9\ mA$$

2. **0 Hz**

$$f = 0\ Hz \ \rightarrow X_l = 0$$
$$I = \frac{U}{R} = \frac{10}{1000} = 10\ mA$$

3. **approaching infinity**

$$f = 1 \cdot 10^{99}\ Hz$$
$$X_l = 2\pi \cdot (1 \cdot 10^{99}) \cdot 10^{-3} = 2\pi \cdot 10^{96}$$
$$I = \frac{10}{2\pi \cdot 10^{96} + 1000} = 1{,}6 \cdot 10^{-96} A \ \rightarrow I > 0\ A$$

5.8

Verify that for an ideal transformer it holds that Pprimary = Psecondary.

In a non-ideal transformer there always is some energy loss, because the transformer generates a little bit of heat. This indicates that an ideal transformer does not generate any heat.

6.1

Find the potential for node b in the schematic below, use KCL.

$$I_{tot} = \frac{12}{690} = 17{,}4\ mA$$

$$Node\ B = I_1 - I_2 = 0$$

$$I_1 = \frac{V_a - V_b}{R_1} = \frac{12 - V_b}{400} \qquad\qquad I_2 = \frac{V_b}{R_2} = \frac{V_b}{290}$$

$$I_1 - I_2 = \frac{12 - V_b}{400} - \frac{V_b}{290} = 0$$

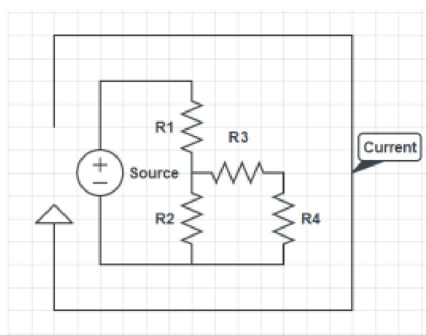
$$400V_b = 290(12 - V_b)$$

$$V_b = \frac{3480}{690} = 5{,}043 = 5{,}0\ V$$

6.2

Can you think of another closed loop in the circuit shown in Figure 6.2?

The loop fo R_1, R_3 and R_4; the outer loop.



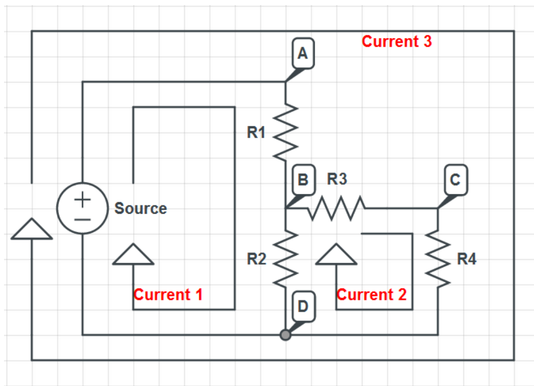
6.3

Write out the KVL for all closed loops of the circuit shown in Figure 6.2.

$$Current\ 1 = V_{AB} + V_{BD} - V_S = 0$$

$$Current\ 2 = V_{BC} + V_{CD} - V_{BD} = 0$$

$$Current\ 3 = V_{AB} + V_{BC} + V_{BD} + V_{CD} - V_{DB} - V_S = 0$$



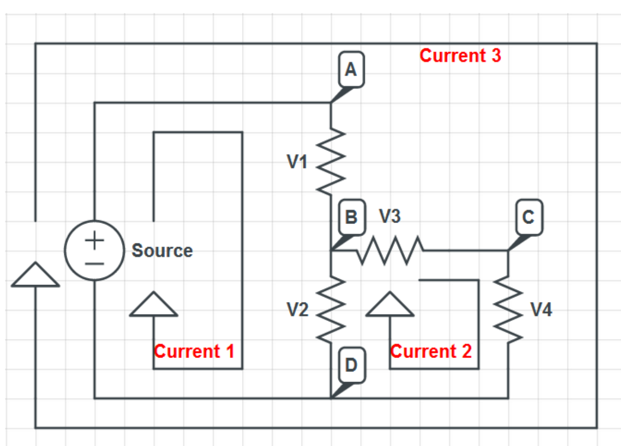
6.4

1. **Apply the KVL to all Loops in the circuit.**

$$Current\ 1 = V_{AB} + V_{BD} - V_S = 0$$

$$Current\ 2 = V_{BC} + V_{CD} - V_{BD} = 0$$

$$Current\ 3 = V_{AB} + V_{BC} + V_{CD} - V_S = 0$$



2. **What is the value of V_2?**

$$V_S = 9\,V \ \ and\ V_1 = 3{,}7\,V.$$

$$V_1 + V_2 - V_S = 0$$

$$V_2 = 9 - 3{,}7 = 5{,}3\,V$$

3. **Take V_4 = 1.3V. What is the value of V_3?**

$$V_3 + V_4 - V_2 = 0$$

$$V_3 = 5{,}3 - 1{,}3 = 4{,}0\,V$$

4. **With all voltage drops, check the KVL for all loops.**

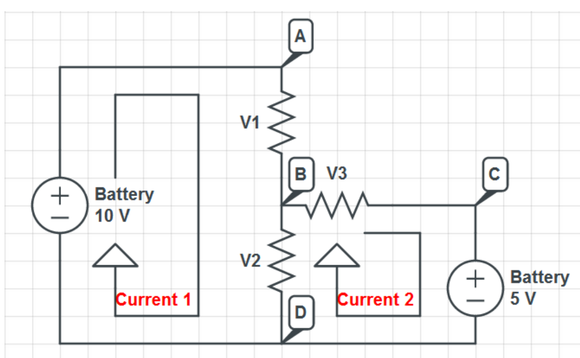
$$Current\ 1 = V_1 + V_2 - V_S = 3{,}7 + 5{,}3 - 9{,}0 = 0$$

$$Current\ 2 = V_3 + V_4 - V_2 = 4{,}0 + 1{,}3 - 5{,}3 = 0$$

$$Current\ 3 = V_1 + V_3 + V_4 - V_S = 3{,}7 + 4{,}0 + 1{,}3 - 9{,}0 = 0$$

6.5

1. **Apply KCL to determine the voltage at the nodes of the circuit below.**



$$I_{R_1} = \frac{V_S - V_B}{R_1} = \frac{10 - V_B}{2000}$$

$$I_{R_2} = \frac{V_B - V_D}{R_2} = \frac{V_B - 0}{500}$$

$$I_{R_3} = \frac{V_B + V_C}{R_3} = \frac{V_B + 5}{2000}$$

$$I_{R_1} - I_{R_2} - I_{R_3} = 0$$

$$\frac{10 - V_B}{2000} - \frac{V_B}{500} - \frac{V_B + 5}{2000} = 0$$

$$\frac{15 - 2_{VB}}{2000} - \frac{V_B}{500} = 0$$

$$500(15 - 2V_B) = 2000V_B$$

$$V_B = 2{,}5\ V$$

2. **Apply KVL to determine the voltage at the nodes of the circuit below**

$$Loop\ 1 = a \rightarrow b \rightarrow d \rightarrow a$$

$$Loop\ 1 = R_1 \cdot I_1 + R_2 \cdot (I_1 + I_2) - V_{Battery1} = 2000 \cdot I_1 + 500(I_1 + I_2) - 10 = 0$$

$$Loop\ 2 = c \rightarrow b \rightarrow d \rightarrow c$$

$$Loop\ 2 = R_3 \cdot I_2 + 500(I_1 + I_2) - V_{Battery2} = 2000 \cdot I_2 + 500(I_1 + I_2) - 5 = 0$$

Solving these equations gives $I_1 = 3{,}75\ mA\ and\ I_2 = 1{,}25\ mA$
With these values we are able to calculate the voltage drops over each resistance:

$$V_B = R_2 \cdot (I_1 + I_2) = 500 \cdot (3{,}75 + 1{,}25) = 2{,}5\ V$$

3. **Verify the both yield the same solution!**

As you can see, both methods give the same solution. $V_B$is in both cases 2,5 V.

7.1

1. **Calculate the open circuit voltage V_{oc}.**

$$V_{OC} = \frac{R_2}{R_1 + R_2} \cdot V_{in}$$

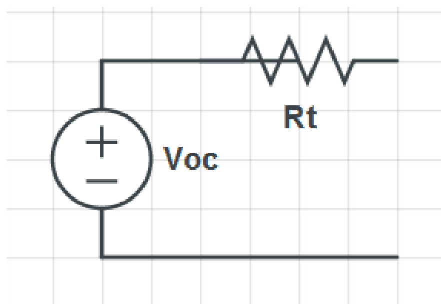
2. **Calculate the short circuit current I_{sc}.**

$$I_{SC} = \frac{V_{in}}{R_1}$$

3. **Calculate the equivalent resistance $\frac{R_T}{R_N}$ by applying Equitation 7.1.**

$$\frac{R_T}{R_n} = \frac{V_{oc}}{I_{SC}} = \frac{\frac{R_2}{R_1 + R_2} \cdot V_{in}}{\frac{V_{in}}{R_1}} = \frac{R_1}{V_{in}} \cdot \frac{R_2}{R_1 + R_2} \cdot V_{in} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

4. **Draw the equivalent Thevenin circuit and indicate the values for V_{oc} and R_T.**

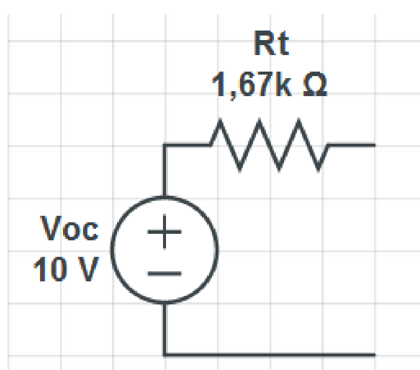


7.2

Determine the Thevenin equilevant circuit paramaters of this circuit.

$$V_{OC} = \frac{R_3}{R_1 + R_2 + R_3} \cdot V_{in} = \frac{1}{3} \cdot 10 = 3{,}33\ V$$

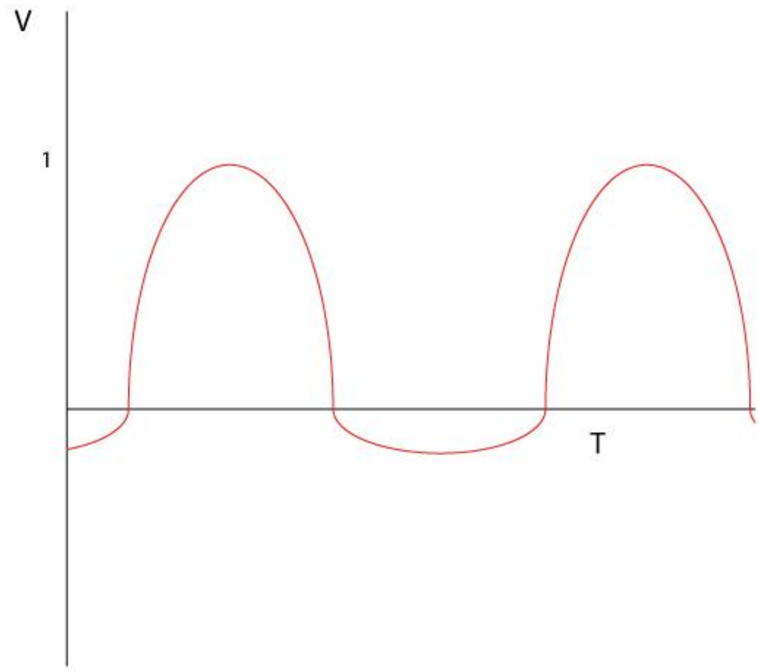
$$R_T = \frac{V_{oc}}{I_{SC}} = \frac{\frac{10}{3}}{\frac{10}{\frac{2500}{2}}} = \frac{3{,}33}{2 \cdot 10^{-3}} = \frac{5}{3} = 1{,}67\ k\Omega$$



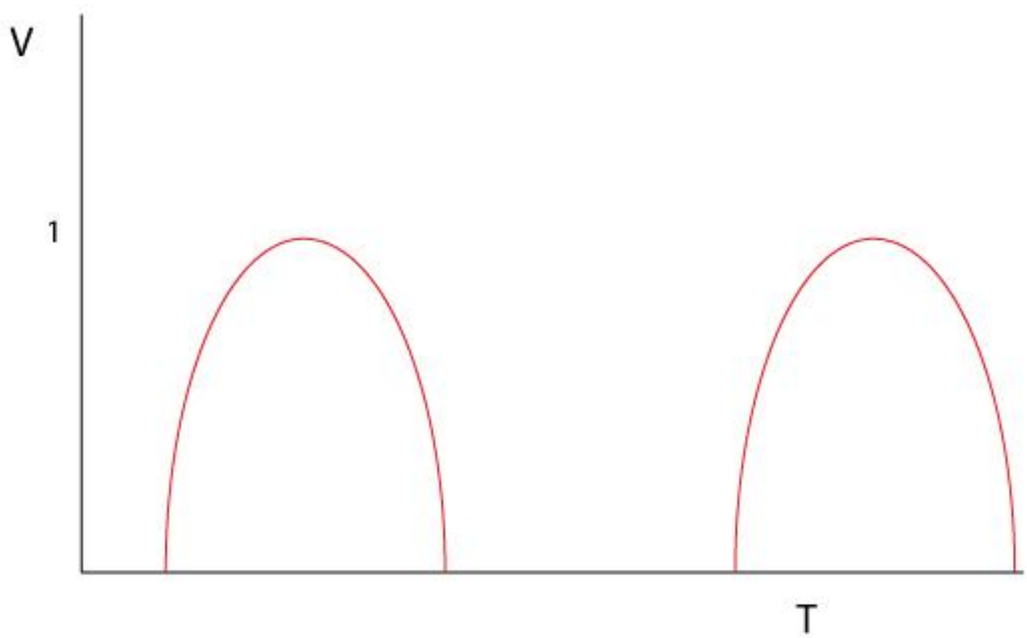
8.1

The signal of the AC-source is a sine wave. Sketch the course of the output for both situations. Assume V_{in} to be 2 $V_{top\text{-}top}$. Now indicate the top values of V_{out} in both situations.

V_{out} for situations A



V_{out} for situation B



8.2

Assume that the voltage across the LED is 2 V and that we want to have a current of 15 mA. What will be a good E-12 based value for R?

$$R = \frac{U_R}{I} = \frac{9-2}{15 \cdot 10^{-3}} = 467\Omega$$

If we look to the E-12 resistor series. We see that 470 Ω is the most suitable resistor for this job.

9.1

What should the ouput voltage level of subcircuit X be if we want to switch the lamp on? Explain why!

A PNP transistor is applied, which means that the transistor switches when there is no voltage. So, the output voltage level of subcircuit X should be 0 V to turn the lamp on.

9.2

1. **Argue that suddenly interrupting even a small current will lead to a huge potential difference over the inductor.**

$$V = L \cdot \frac{dI}{dT} = 1 \cdot 10^{-3} \cdot \frac{100 \cdot 10^{-3}}{1 \cdot 10^{-6}} = 100\ V$$
$$V = L \cdot \frac{dI}{dT} = 1 \cdot 10^{-3} \cdot \frac{100 \cdot 10^{-3}}{1} = 0{,}1\ mV$$

So, when your transistor switches many times in a second. You've to watch out for the voltage peak. Because, how more switches per second how higher the voltage peak will be when the current stops.

2. **Suppose no bleeding diode is available. Which of the three transistors can switch the above mentioned load condition without being damaged.**

Transistor Name	Max Voltage in Voltage	Status
BC 550	45	Will be damaged, cannot resist voltage peak
2N3439	450	Stays in intact, resist voltage peak
BC618	80	Will be damaged, cannot resist voltage peak

9.3

Give an approximation of the darlington's base-emitter potential difference that is needed to make it conduct.

This potential difference should be two times larger. Because the transistors are connected in serie.

9.4

Which of the four transistors will fulfill the requirements when switched into saturation? Calculate the resistance value of R_b needed for the saturation condition.

BC 550 is not suitable, because I_{max} is too small. BC 550 can resist a current of 0.1 A, the lamp needs 0.2A. So, the transistor will be damaged.

2N3773 is not suitable either, because β is too small. Now I_b has to be bigger than 0,4 mA to get a current of 200 mA at I_c. $I_b = 10 \cdot \frac{I_c}{\beta} = \frac{0{,}2}{60} \cdot 10 = 33mA$ this is far more current then subcircuit x delivers.

BD 139 is also not suitable, because: $I_b = 10 \cdot \frac{I_c}{\beta} = \frac{0{,}2}{250} \cdot 10 = 8mA$

BC 618 is suitable, because $I_b = 10 \cdot \frac{0{,}2}{50000} = 0{,}04mA$

10.1

Determine (the same way as we did for the inverting amplifier) that for the transfer of the non-inverting amplifier, drawn in Figure 10.4, holds:

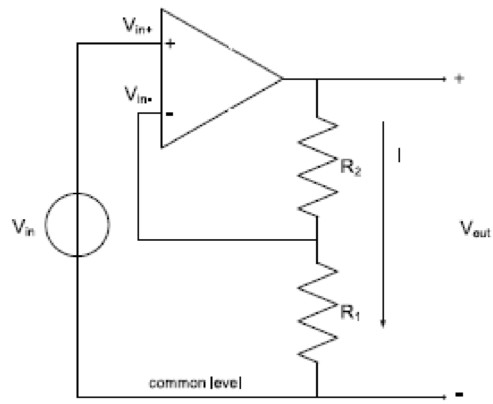
$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

If $V_{in,+} = V_{in,-}$ gives that over point A V = V_{in} , then:

$$V_{in} = I_1 \cdot R_1$$
$$V_{out} = I_1(R_1 + R_2)$$

Thus

$$\frac{V_{out}}{V_{in}} = \frac{I_1(R_1 + R_2)}{I_1 \cdot R_1} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$



10.2

Why are resistance values for the feedback resistors chosen in KΩ and not in Ω? (e.g. See figure 10.4: R1 = 10 Ω and R2 = 100 Ω or R1 = 1KΩ and R2 = 10KΩ will both result in a gain of11)

If you use a 10Ω resistor, you will probably damage your circuit due to a massive current, as $I = \frac{U}{R}$.
By using a resistor with a higher value, like a 10kΩ resistor, the circuit will be protected against a high current.

10.3

Suppose an opamp is powered by a symmetrical power supply.

- What will happen with the output of the non-inverting amplifier if the input voltage Vin is higher than the supply voltage?

The opamp needs power to amplify. That means if V_{in} is higher than the voltage over the opamp, nothing will change in the amplified signal. This is due to the fact that the opamp needs more power to create the amplified signal for the new V_{in}, otherwise the output will be clipped.

- Same question but now for the inverting amplifier?

The same occurs for the inverting opamp. Nothing will change in the amplified signal.

12.1

Give the truth table for an 'XNOR'-gate.

Input 1	Input 2	Output
0	0	1
1	0	0
0	1	0
1	1	1

Assignment 1 (Chapter 3)

Calculate $R_{retotaal}$, I_1, I_2, I_3, I_4, and V_{out}.

$$R_{retotaal} = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4 + R_5}} + R_6 = 2{,}2 + \frac{1}{\frac{1}{10} + \frac{1}{4{,}7} + \frac{1}{2{,}2 + 3{,}3}} + 3{,}3 = 7{,}5\ k\Omega$$

$$R_{replace} = \frac{1}{\frac{1}{10} + \frac{1}{4{,}7} + \frac{1}{3{,}3 + 2{,}2}} = 2{,}02\ k\Omega$$

$$I_{tot} = \frac{10}{7500} = 1{,}33\ mA$$

$$I_1 = I_6 = I_{tot}$$

$$V_1 = I_1 \cdot R_1 = 1{,}3 \cdot 2{,}2 = 2{,}93\ V$$

$$V_3 = I_6 \cdot R_6 = 1{,}3 \cdot 3{,}3 = 4{,}4\ V$$

$$V_2 = V_{tot} - V_1 - V_3 = 10 - 2{,}93 - 4{,}4 = 2{,}67\ V$$

$$I_2 = \frac{V_2}{R_2} = \frac{2{,}67}{10000} = 0{,}267\ mA = 0{,}27 mA$$

$$I_3 = \frac{V_2}{R_3} = \frac{2{,}67}{4700} = 0{,}568\ mA = 0{,}57\ mA$$

$$I_4 = \frac{V_2}{R_{4,5}} = \frac{2{,}67}{5500} = 0{,}485\ mA = 0{,}49\ mA$$

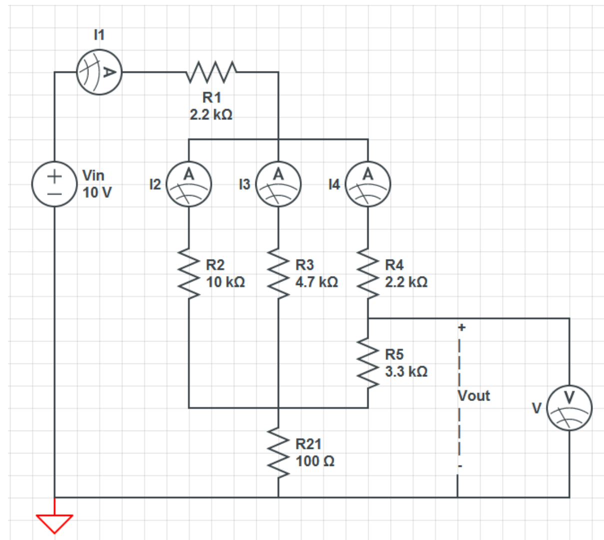
$$V_{out} = I_4 \cdot R_5 + I_1 \cdot R_6 = 0{,}49 \cdot 3{,}3 + 1{,}3 \cdot 3{,}3 = 5{,}907\ V = 5{,}9\ V$$

Measure to see if you calculation are right

	Measured	**Calculated**
I_1	1,32 mA	1,33 mA
I_2	0,268 mA	0,267 mA
I_3	0,568 mA	0,568 mA
I_4	0,486 mA	0,485 mA
R_{tot}	7,47 kΩ	7,52 kΩ
V_{out}	6,03 V	5,9 V

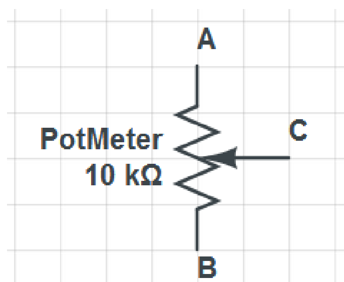
How did we measured?

This is a picture of how we did our measurements for knowing the current and voltage. The resistance we measured by disconnecting the power source and placing the multimeter on V+ and V- of V_{in}.



Take a potmeter of 10 kΩ and replace resistance R_4 and R_5. What are you conclusions?

A potmeter works the same as two resistors, only with the potmeter you devide a resistor in half. So if you take a 10 kΩ potmeter the pins A and B will scale from 0 Ω to 10 kΩ and the pins B and C will scale from 10 kΩ to 0 Ω.



$$If\ V_{out} = 5\,V\ \ than, R_4 = 7{,}82\ k\Omega\ and\ R_5 = 3{,}07\ k\Omega$$

Calculation:

$$R_{tot} = 2{,}2 + \frac{1}{\frac{1}{10} + \frac{1}{4{,}7} + \frac{1}{7{,}82 + 3{,}07}} = 7{,}79\ k\Omega$$

$$I_1 = \frac{10}{7970} = 1{,}25\ mA$$

$$V_1 = 1{,}25 \cdot 2{,}2 = 2{,}75\ V$$

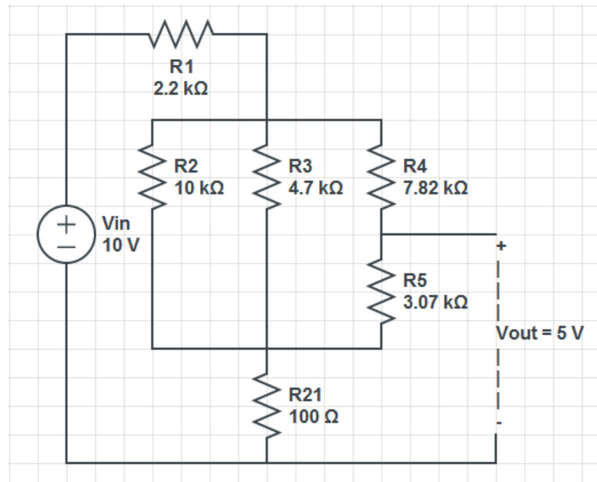
$$V_3 = 3{,}3 \cdot 1{,}25 = 4{,}125V$$

$$V_2 = V_{tot} - V_1 - V_3 = 10 - 2{,}75 - 4{,}125 = 3{,}125\ V$$

$$I_4 = \frac{V_2}{R_4 + R_5} = \frac{3{,}125}{7820 + 3070} = 0{,}287\ mA$$

$$V_{out} = R_6 \cdot I_1 + R_5 \cdot I_4 = 3{,}3 \cdot 1{,}25 + 3{,}07 \cdot 0{,}287 = 5{,}00\ V$$

By using a potmeter you can easily influence the output of your voltage divider. In this way you can easily dim a light bulb or control the loudness of you stereo. This is possible because a potmeter works like two different resistors which you both changes by turning the knob. When turning, the resistance will become higher on one side and lower at the other side.



Assignment (Chapter 4)

Build the circuits and measure V_{out} at 100 Hz, 1 kHz and 100 kHZ.

Because we are working with a sinus wave, we got V+ and V- which means we work with V_{rms}. Unfortunately our multimeter measure V_{rms}. So, we did a calculation instead. And because the voltage on 100 Hz, 1kHz and 100 kHz is the same, because only the frequencies changes and not the amplitudes which causes the voltage.

$$V_{rms} = 0{,}7 \cdot 1{,}0 = 0{,}7\ V$$

Build circuit B, calculate the amplitude for 100 Hz, 1 kHz and 100 kHz and measure if you are right.

We work with a high-pass filter. Thus the higher the frequencies, the bigger the amplitude and the voltage.

$$f = 100Hz$$
$$V_{out} = \frac{R}{\sqrt{R^2 + X_l^2}} \cdot V_{in} = 125\ mV$$

$$f = 1kHz$$
$$V_{out} = 1{,}06\ V$$

$$f = 100\ kHz$$
$$V_{out} = 2{,}0\ V$$

Build circuit C, calculate the amplitude for 100 Hz, 1 kHz and 100 kHz and measure if you are right.

We work with a low-pass filter. Thus the lower the frequencies, the bigger the amplitude and the voltage.

$$f = 100\ Hz$$
$$V_{out} = \frac{X_c}{\sqrt{R^2 + X_c^2}} * V_{in} = 2{,}0\ V$$

$$f = 1\ kHz$$
$$V_{out} = 1{,}7\ V$$

$$f = 100\ kHz$$
$$V_{out} = 30\ mV$$

Calculate the cut-off frequency f_c of the last filter. Verify your result by measuring V_{out} at this frequency with the oscilloscope.

At $f = \frac{1}{2\pi \cdot RC} = \frac{1}{2\pi \cdot 10^3 \cdot (100 \cdot 10^{-9})} = 1591\ Hz\ \approx 1{,}6\ kHz$

We could clearly see this at the screen of the oscilloscope. It started slowly, but at 1,6 kHz the voltage dropped very fast and at 1.8 kHz their almost was no amplitude anymore.

What for a kind of filter is this?

This is a low-pass filter, because the higher the frequency, the lower the voltage. This can be seen in de calculations from above.

Frequency	Calculated value	Measured value
100 Hz	100 mV	0,1 V
1 kHz	1,06 V	1 V
100 kHz	2,00 V	2 V
100 Hz	2,00 V	2,01 V
1 kHz	1,7 V	1,69 V
100 kHz	30 mV	50 mV

Our measurements, this were our readings from the oscilloscope.

Conlusion

By interchanging the capacitor and the resistor, the high-pass filter becomes a low-pass filter. This means taking the voltage over the resistor as V_{out} will result in a low-pass filter, whereas taking the voltage over the capacitor as V_{out} will result in a high-pass filter.

Assignment (Chapter 6)

Calculate the voltage drops across the resistors and the currents through them. Use KVL and indicate the loops you've chosen. Take node 'e' as reference.

$$Loop1 = I_1 \cdot R_1 + R_2(I_1 + I_2) - V_S = 2670 \cdot I_1 + 470 \cdot I_2 - 10 = 0$$

$$Loop2 = I_2 \cdot R_3 + R_2(I_1 + I_2) + I_2 \cdot R_4 - V_A = 8270 \cdot I_2 + 470 \cdot I_1 - 5 = 0$$

Deducing this will give us the following equation:

$$21860000 \cdot I_1 - 85050 = 0$$

$$I_1 = \frac{85050}{21860000} = 3{,}89\ mA$$

$$I_2 = \frac{5 - 470 \cdot 3{,}89 \cdot 10^{-3}}{8270} = 3{,}84 \cdot 10^{-4}\ A = 0{,}38\ mA$$

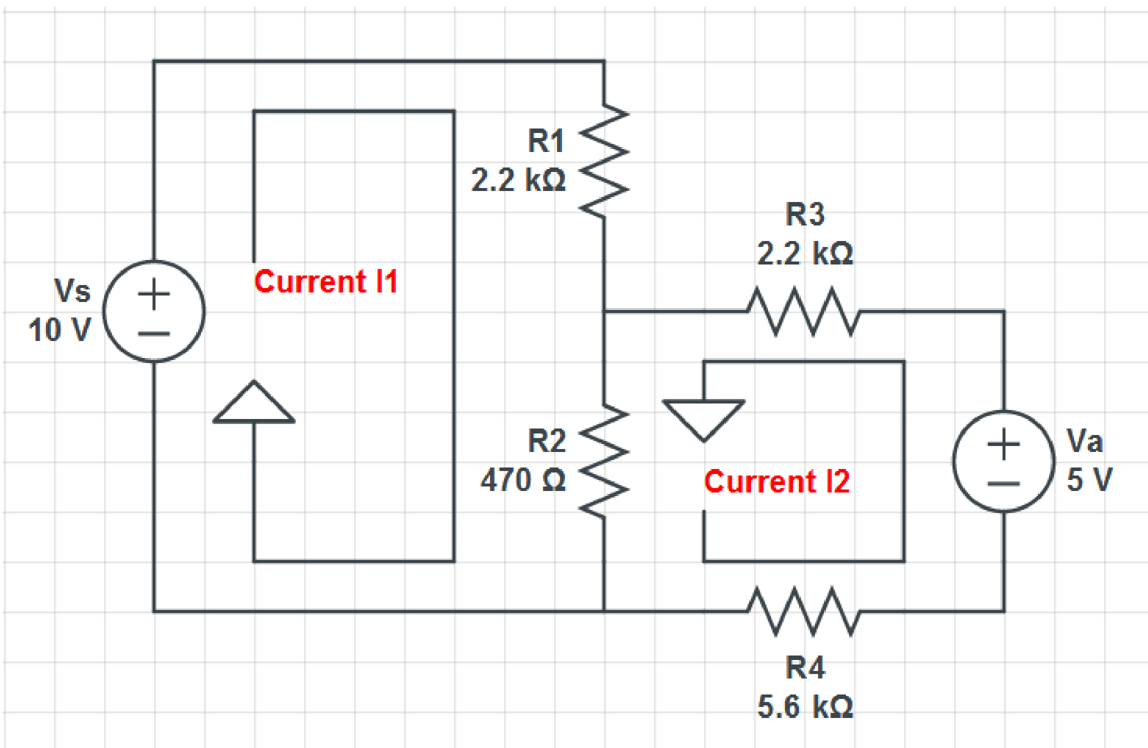
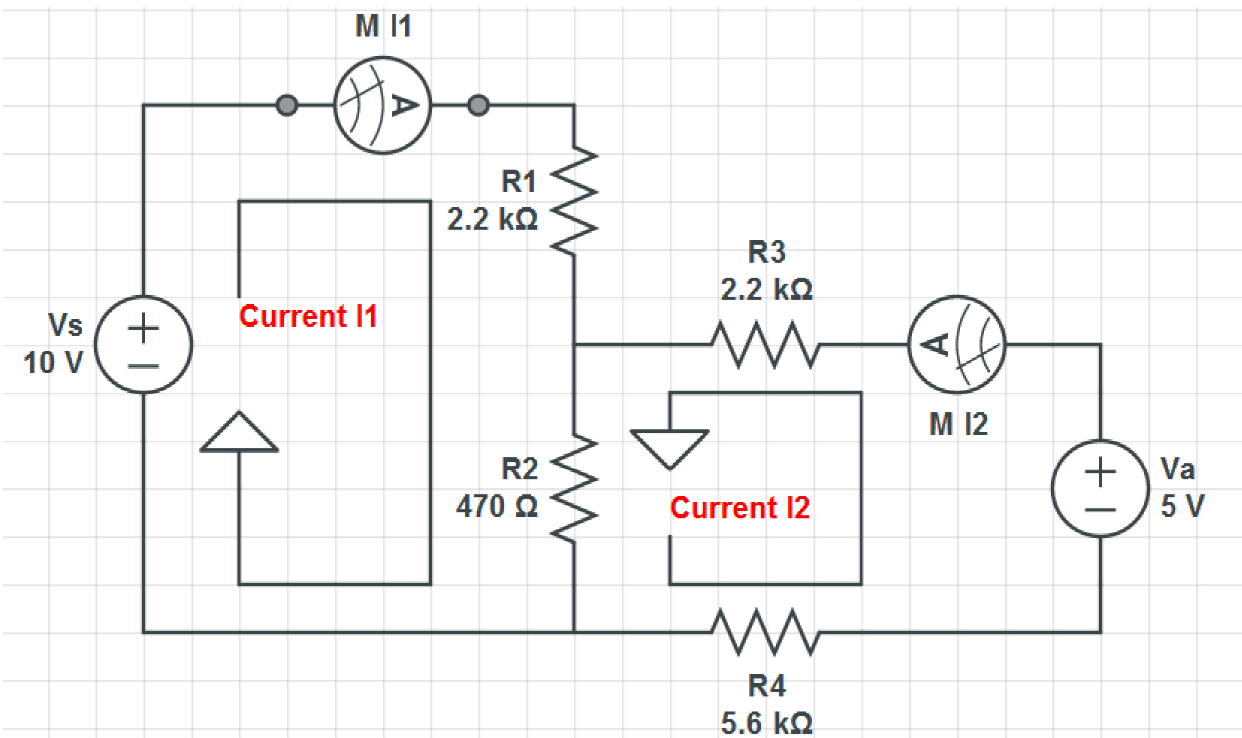


Image: Current I1 and Current I2 symbolize the current in this circuit, were in Current I1 is Loop 1 and Current I2 is Loop 2.

Build the circuit and verify your calculations

	Measurements	Calculations
I_1	3,71 mA	3,89 mA
I_2	0,38 mA	0,38 mA

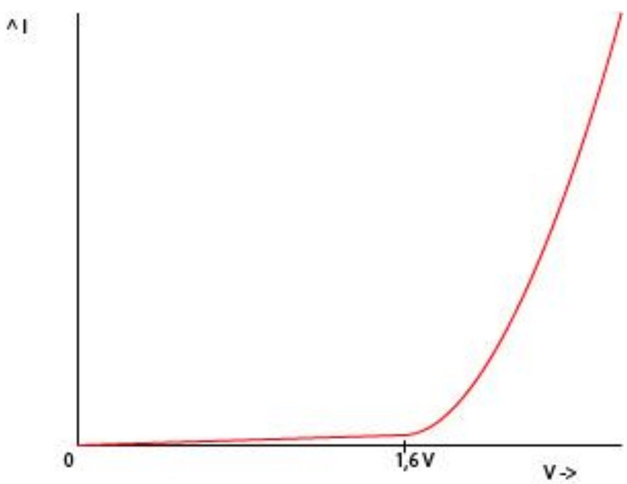
Our measurements almost confirm our calculations, but we cannot find the reason why I_1 is so different from the calculation. Here is an image of how we measured.



Assignment (Chapter 8)

Take a red LED and determine the relationship between Id and Vd. Start at Vd = 0 V and increment Vd with steps of 0.1 V until just above the 'knee' voltage.
Before you start, you must limit the current of the power supply to 500 mA.
- Show the results of your measurements in a table.
- Present a graph which shows the relation between I_d and V_d .
- Finally tell how you detect the 'knee' voltage.

Measurement	1	2	3	4	5	6	7	8	9	10
V	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4	2,5
mA	1,1	2,4	5,7	10,1	15,0	19,5	24,3	30,4	35,5	40,0



We detected the knee voltage by observing the LED, as from a certain value it started emitting light. The knee voltage is around 1,6 V.

Assignment (Chapter 9)

	100 kΩ	10 kΩ	4,7 kΩ	2,2 kΩ	1 kΩ	470
I_c	-	0,105	0,16	0,19	0,23	0,27
V_{ce}	6,02	4,83	3,82	2,85	1,49	0,30
V_{be}	0,32	0,66	0,68	0,74	0,83	0,91

When reaching saturation V_{ce} much lower and V_{be} is becomes slowly higher. This is totally as we expected. Because when more voltage can go through the transistor from I_b, which depends on how low the resistor R_b is, the transistor will breakdown the diode which will open I_{ce}.
When the transistor opens a current will flow and most of the voltage will be used by the lamp, which is some kind of resistor. This will cause V_{ce} to drop and I_c to rise. Because the lamp needs more current, 50 mA to be precisely.
Also V_{be} will rise, because when using a resistor with less resistance, more voltage will go over the transistor instead of the resistor. This means that V_{be} will rise when a resistor with lesser resistance is used.

Assignment (Chapter 10)

Notice:

We used different resistors for R_1 and R_2, as the 10kΩ resistors were out of stock at the E-lab. For each 10kΩ resistor we used two 4,7kΩ in series, having values of 9,4kΩ. So, $R_1 = R_2 = 9{,}4 \cdot 10^3\ \Omega$.

Build the circuit by using a datasheet on the internet and Calculate the two transition levels and verify them.

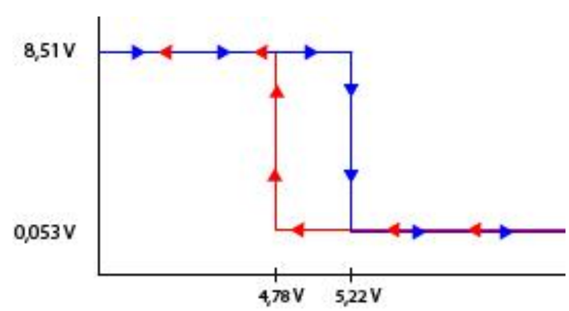
$$V_x = 10\ V$$

$$V_x = I_1(R_1 + R_2)$$
$$V_{in} = -I_1 \cdot R_2$$
$$V_{out} = 10\ V$$
$$V_{in} = \frac{R_2}{R_2 + \frac{R_1 \cdot R_3}{R_1 + R_3}}$$
$$V_{out} = 10\ V \ \rightarrow V_{in} = \frac{R_2}{R_2 + \frac{R_1 \cdot R_3}{R_1 + R_3}} \cdot V_x = 5{,}22\ V$$

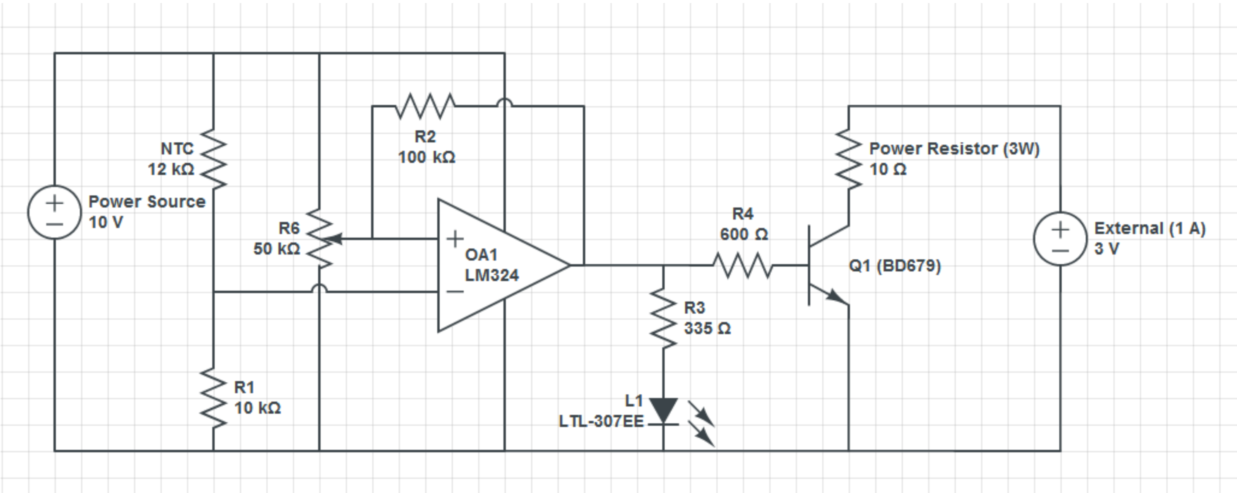
$$V_{out} = 0\ V \ \rightarrow V_{in} = \frac{\frac{R_2 \cdot R_3}{R_2 + R_3}}{R_1 + \frac{R_1 \cdot R_3}{R_2 + R_3}} \cdot V_x = 4{,}78\ V$$

Draw the hysteresis graph and indicate the measured values (see Figure 10.7).

$$V_{max} = 8{,}51\ V\ ; V_{min} = 0{,}053\ V$$



Final Assignment



V_x = 10 V ; T_{low} = 20 °C ; T_{high} = 40 °C ;

The datasheet of the 10k NTC read the following values for T_{min} and T_{max}:

T (°C)	R_T/R_{25}	R_T ($\cdot 10^3$ Ω)
20 °C (T_{min})	1,2683	12,603
40 °C (T_{max})	0,5074	5,074

We took R1 = 10 kΩ, as it is a value in between T_{min} and T_{max}.

$R_{6,max}$ = 50 kΩ (potentiometer). Here we can adjust the value rather accurately.

The transistor we took is BD679 (NPN). It can handle 4 A. This is a bit overkill, but a lighter version was out of stock.

L_1 = 2,3 V ; 20 mA

R_3 (protecting the LED) has to take up to 9 – 2,3 = 6,7 V as well as 20 mA (in series).

This means $R_3 = \frac{6{,}7}{20\cdot 10^{-3}} = 335\ \Omega$

The heater is a power resistor, namely 10 Ω ; 3 W.

The external power source (External), has to deliver 3W of power which the power resistor dissipates. This means we chose for 3V and 1A, since P = U · I = 3 W. I = 1 A. This causes the resistor to warm up quickly. The voltage then goes without saying as P = 3 W and I = 1 A, which means $U = \frac{P}{I} = \frac{3}{1} = 3\ V$

$Q_1 \rightarrow \beta = 750$; So $I_B = 10 \cdot \frac{1}{750} \approx 0{,}013\ A \approx 1{,}3\ mA$

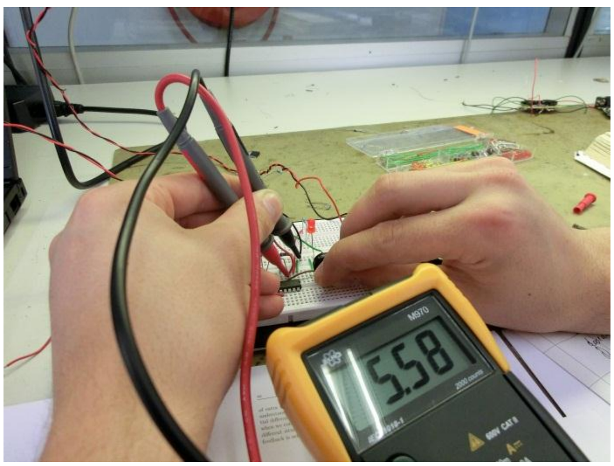
Through testing, we found out that the knee voltage of Q_1 is around V = 1,2 V.

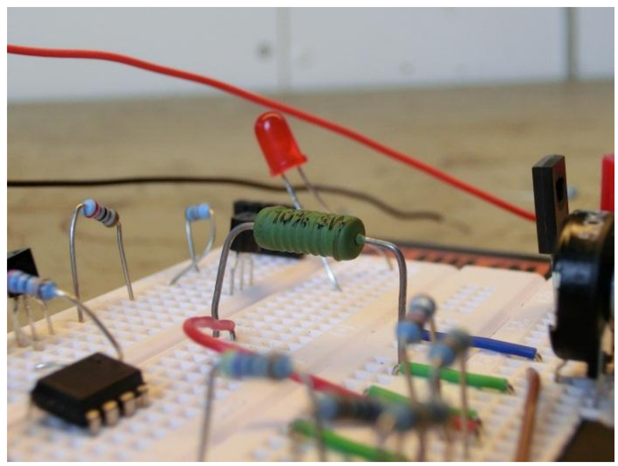
$V_x = 9\ V, I_B = 13\ mA, V_{BE,sat} = 1{,}2\ V$, so $R_4 = \frac{U}{I} = \frac{9-1{,}2}{(1{,}3 \cdot 10^{-3})} = \frac{7{,}8}{1{,}3 \cdot 10^{-3}} = 600\Omega$

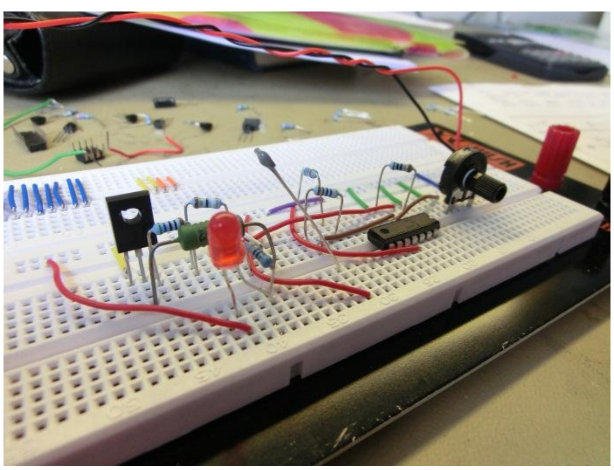
R_6 and R_2 determine the bandwidth of the transition. For R_2 we took a constant resistor, and for R_6 a potentiometer in order to tune to the right bandwidth.

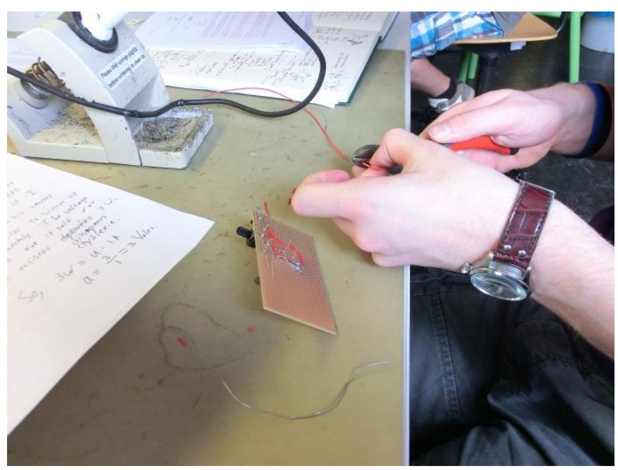
R_2 = 100 kΩ

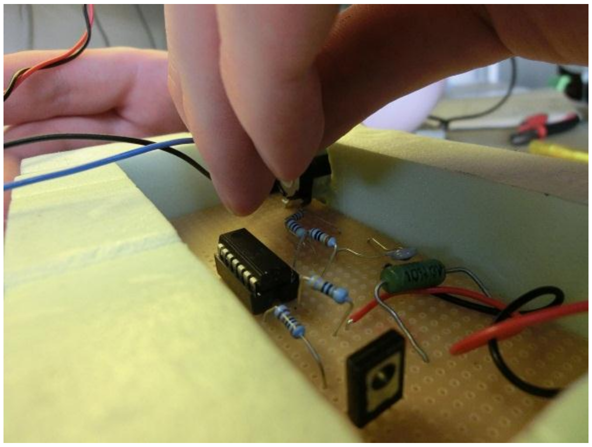
R_6 is tuned to 5 kΩ, since the R_{NTC} is close to 5 kΩ when T = 40 °C. To get the difference to zero at that level, R_6 = 5 kΩ.



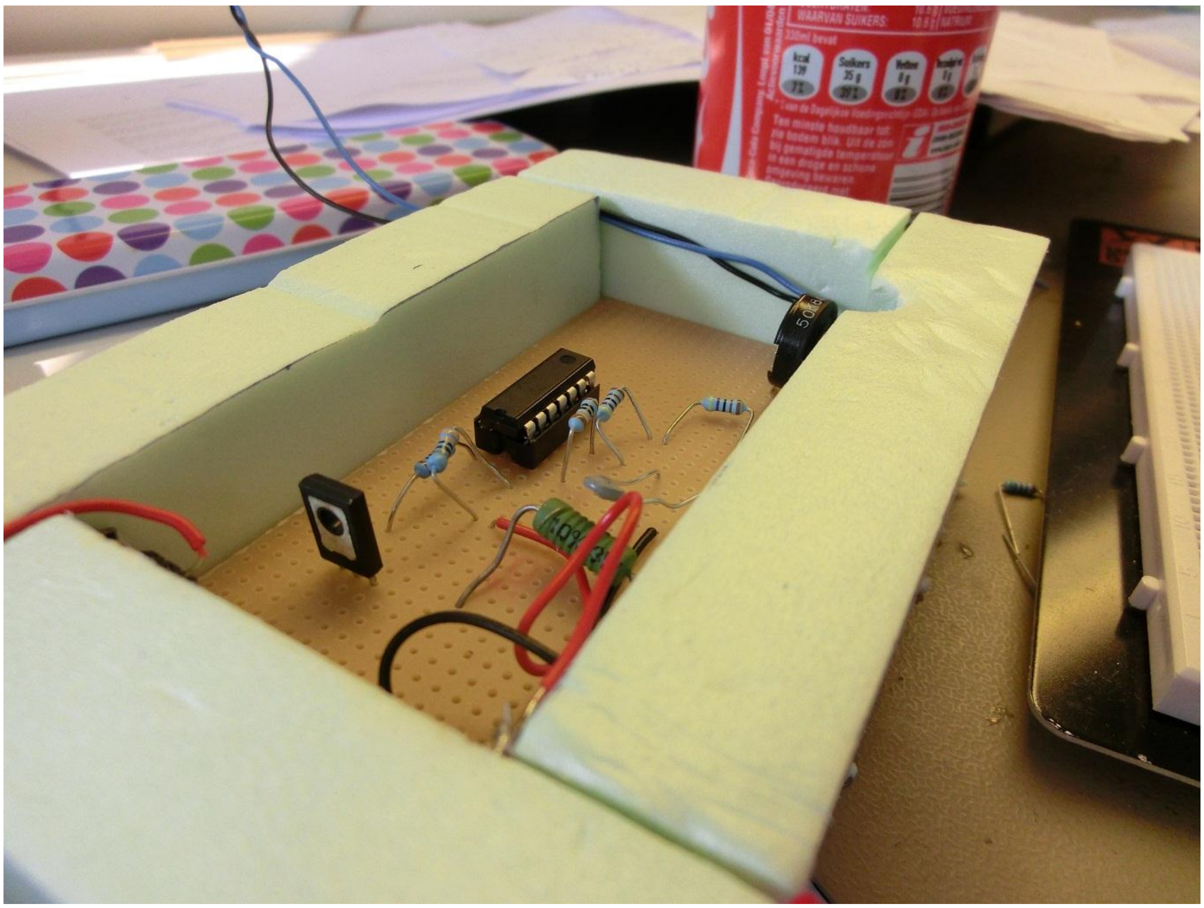









Coke



Reflection Jeroen Rood

The goal for me of the assignment was to get some more grips on dealing with electronics. Besides, I wanted to develop myself in the competency area ‘Integrating Technology’. Since I did not do anything with electronics last semester, I would like to implement it this semester. To be honest, the assignment was better than expected. The work was not just theoretical, but also practical. I think this helped me a lot. Making the exercises was great to practice some theory as well as practicing doing some calculations, but if it were just these exercises, I would have missed a great deal of insight. Besides, I would also never get grips on dealing with electronics if there were not any practical assignments.

But thanks to the assignment I now feel like I can handle electronics, and it is not magic anymore. I now also know how to choose components and what these components do. It is great to look up how other people make the circuit, but it is even better to understand how it is done.

I can say this assignment was a challenge for me. The exercises were harder than I expected, but thanks to the physics classes not so long ago on secondary school most of the theory was pretty understandable. But one thing I was struggling to understand was how transistors and opamps work. In the end, I found out by means of the practical assignments.

To put it in a few words, the assignment has been pretty helpful to me. I learned a great deal of how to work with electronics, and even got some more confidence on actually working with them.

Reflection Floris Voorhoeve

Besides the electronic lessons I got at high school, which were more theoretical than practical, I never worked with electronics before. Also last semester I did not much with electronics and that is why I really wanted to participate in this assignment. First of all, to understand electronics and how to deal with it and secondly to develop more skill in the competence of 'Integrating Technology'.

I first thought that the assignment would be a more theoretical, but it also had a good practical side. This really helped me to understand what I was doing when I was working with electronics. If I only had to deal with theory, I would never understand how some components would work. Besides this, the theory side was sometimes hard to grasp and after an assignment I got more insight in these difficult parts. One example is the assignment about opamps and transistors. The theory was pretty difficult to grasp for both subjects. But during the practical assignments I started to understand those components better by just trying out some things and seeing what happened.

The nice thing about this assignment is that I learned how easy it can be to create a something without using an Arduino. I find it awesome that we were able to create a heat controller without using an Arduino or something like that.

So in short, this was a helpful and very learning full assignment for me. I learned about things I never would have thought about before and learned how I can create a simple circuit without using an Arduino. I developed the competency 'Integrating Technology' and could use everything I learned to create my final prototype without an Arduino.