FINAL REPORT
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CREATIVE ELECTRONICS

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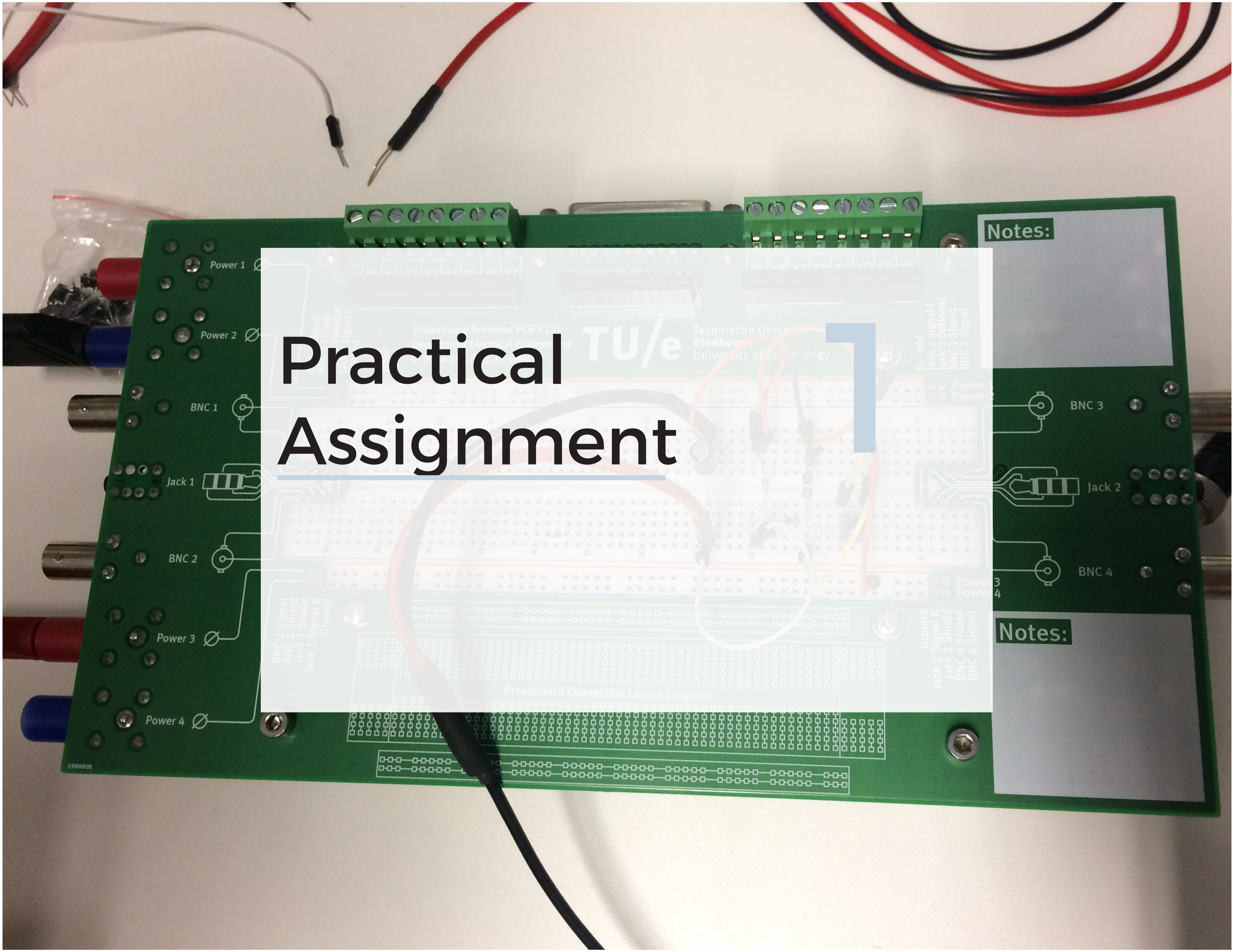
Contents

Practical Assignment 1



Pre-analysis

We will have to calculate Rretotal, I1, I2, I3, I4, and Vout. After doing this, we will have to measure Rretotal, I1, I2, I3, I4, and Vout to confirm our calculations. We, then, take the potmeter to measure the resistance between pins a and b, and between pins b and c. While we are doing this, we also turn the knob.
We replace R4 and R5 by the potmeter R7 and measure the voltage on pin b. We adjust the knob until we get an output voltage of 5V.
Then, we measure the resistance between pins a and b, and between b and c after we have taken away the potmeter.
Finally, we verify our measurement results by calculations.

Necessities:
Power supply with 10V
Breadboard
Resistor 2.2kΩ
Resistor 10kΩ
Resistor 4.7kΩ
Resistor 1.8kΩ
Resistor 8.2kΩ
Resistor 3.3kΩ
Potmeter with resistance value of 10kΩ

Modeling

We made three loops.

Loop 1:

$$10V - R1 * I1 - R2 * I2 - R6 * I1 = 0$$
$$10V = R1 * I1 + R2 * I2 + R6 * I1$$
$$10V = 2.2k\Omega * I1 + 10k\Omega * I2 + 3.3k\Omega * I1$$
$$10V = 5.5k\Omega * I1 + 10k\Omega * I2$$

Loop 2:

$$R2 * I2 - R3 * I3 = 0$$
$$R2 * I2 = R3 * I3$$
$$10k\Omega * I2 = 4.7k\Omega * I3$$
$$I2 = \frac{4.7k\Omega}{10k\Omega} * I3$$

Loop 3:

$$R3 * I3 - R4 * I4 - R5 * I4 = 0$$
$$4.7k\Omega * I3 - 1.8k\Omega * I4 - 8.2k\Omega * I4 = 0$$
$$4.7k\Omega * I3 = 10k\Omega * I4$$
$$I4 = \frac{4.7k\Omega}{10k\Omega} * I3$$

This means we can conclude that I2=I4
Additionally I1=I2+I3+I4
If we insert this formula in loop 1, we get:

$$10V = 5.5k\Omega * I2 + 5.5k\Omega * I3 + 5.5k\Omega * I2 + 10k$$
$$10V = 5.5k\Omega * I3 + 21k\Omega * \frac{4.7k\Omega}{10k\Omega} * I3$$
$$10V = 15.37k\Omega * I3$$
$$I3 = 0.65mA$$

We insert this in the formula for loop 2:

$$I2 = \frac{4.7k\Omega}{10k\Omega} * 0.65mA$$
$$I2 = 0.31mA = I4$$

We now add these values for I1:

$$I1 = 0.31mA + 0.65mA + 0.31mA$$
$$I1 = 1.26mA$$

We now calculate Rtot.
R2, R3 and (R4+R5) are in paraller. R1 and R6 are in series, just like R4 and R5.

$$\frac{1}{R2345} = \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4 + R5}$$
$$\frac{1}{R2345} = \frac{1}{10k\Omega} + \frac{1}{4.7k\Omega} + \frac{1}{1.8k\Omega + 8.2k\Omega}$$
$$R2345 = 2.42k\Omega$$
$$Rtot = R1 + R6 + R2345$$
$$Rtot = 2.2k\Omega + 3.3k\Omega + 2.42k\Omega$$
$$Rtot = 7.92k\Omega$$

We continue by calculating Vout.

$$Vout = Vin - R1 * I1 - R4 * I4$$
$$Vout = 10V - 2.2k\Omega * 1.26mA - 1.8k\Omega * 0.31mA$$
$$Vout = 6.67V$$

Now, we calculate Rab and Rbc.
Vin is the sum of all voltages in serie, so:

$$Vout = Vin - V1 - Vab = Vin - (R1 * I1) - (Rab * I4)$$
$$Rab = \frac{Vin - Vout - R1 * I1}{I4}$$
$$Rab = \frac{10V - 5V - 2.2k\Omega * 1.26k\Omega}{0.31mA}$$
$$Rab = 7.19k\Omega$$
$$Rpot = Rab + Rbc$$
$$Rbc = 10k\Omega - 7.19k\Omega$$
$$Rbc = 2.81k\Omega$$

Measurements

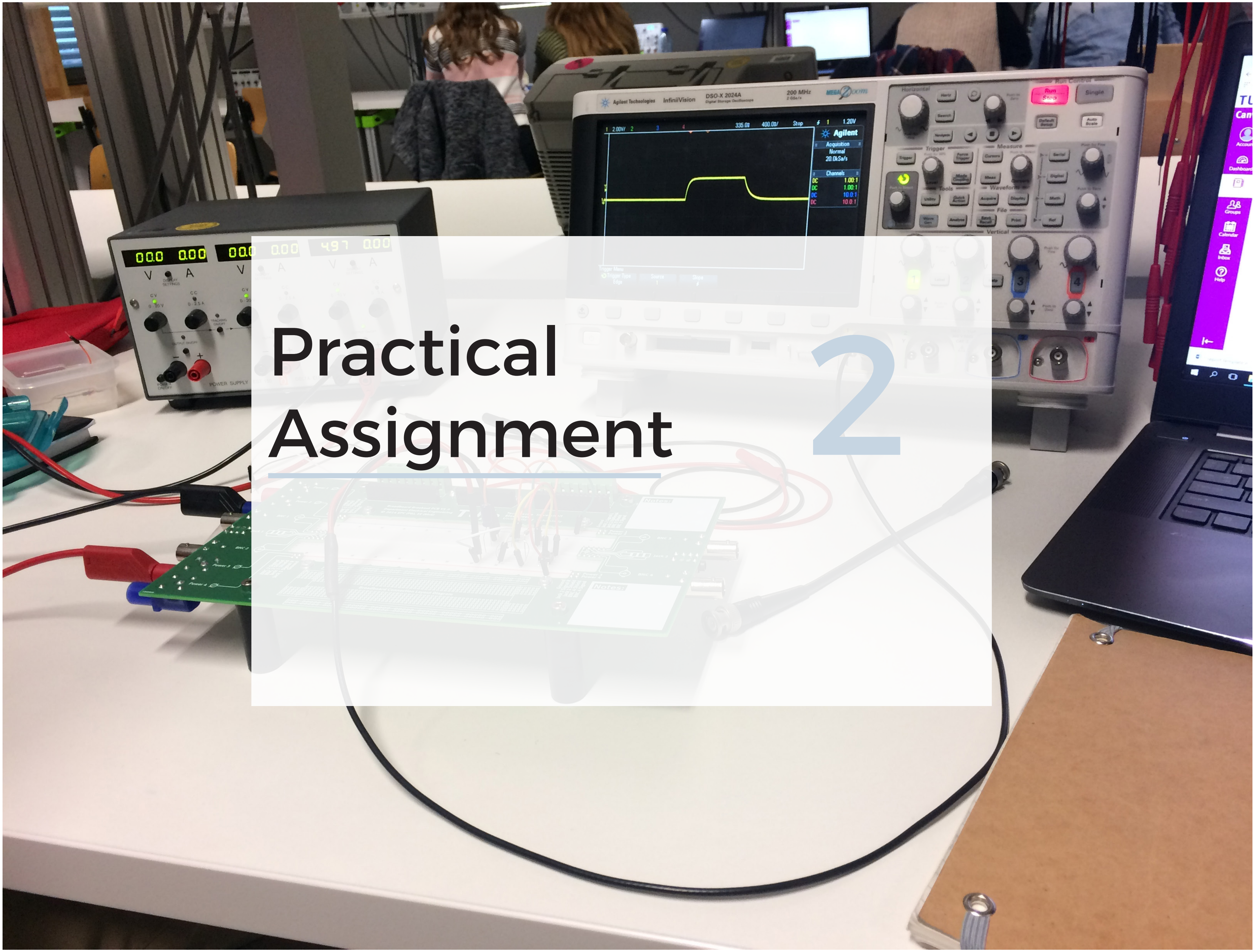
The measurements were conducted using a voltmeter for voltage measurements, and an ammeter for current measurements. To measure voltages, we attached the probes of the meter to the two points between which we wanted to measure the difference in potential. For current measurements, the ammeter was integrated in the circuit at the point we needed to know the current flow for. Below, the measured values are compared to those calculated before.

Results

Calculated	Measured
$I1 = 1.26mA$	$I1 = 1.26mA$
$I2 = 0.31mA$	$I2 = 0.30mA$
$I3 = 0.65mA$	$I3 = 0.64mA$
$I4 = 0.31mA$	$I4 = 0.30mA$
$Rtot = 7.92k\Omega$	$Rtot = 7.93k\Omega$
$Vout = 6.67V$	$Vout = 6.68V$
$Rab = 7.19k\Omega$	$Rab = 7.37k\Omega$
$Rbc = 2.81k\Omega$	$Rbc = 2.82k\Omega$

Conclusion

When comparing our calculations to our measurements, we can verify that they are correct. All answers lie within a 2% difference of each other. We can conclude that our answers are correct.



Practical Assignment 2

Pre-analysis

We build the circuit and connect the power supply, oscilloscope, and multimeter. We check whether the capacitor is positioned correctly. We set the multimeter to DC voltage, the oscilloscope to 2V/division, 400ms/division and the power supply to 5V, 100mA. We push and release the button a few times and capture the waveform of the capacitor charging when pushing the button. We measure the time constant for charging and discharging. We, then, calculate both time constants of the circuit.

We disconnect the power supply and connect the function generator. We set it to generate square waves, 5V, 1Hz. We check the DC offset of the function generator to get a square wave alternating between 0V and 5V. We use a second channel to display the output voltage.

Necessities:
Breadboard
Power supply, 5v, 100mA
Oscilloscope, 2V/division, 400ms/division
Multimeter, DC voltage
Function generator
Capacitor 10μF
Resistor 10kΩ (2x)
Resistor 1MΩ

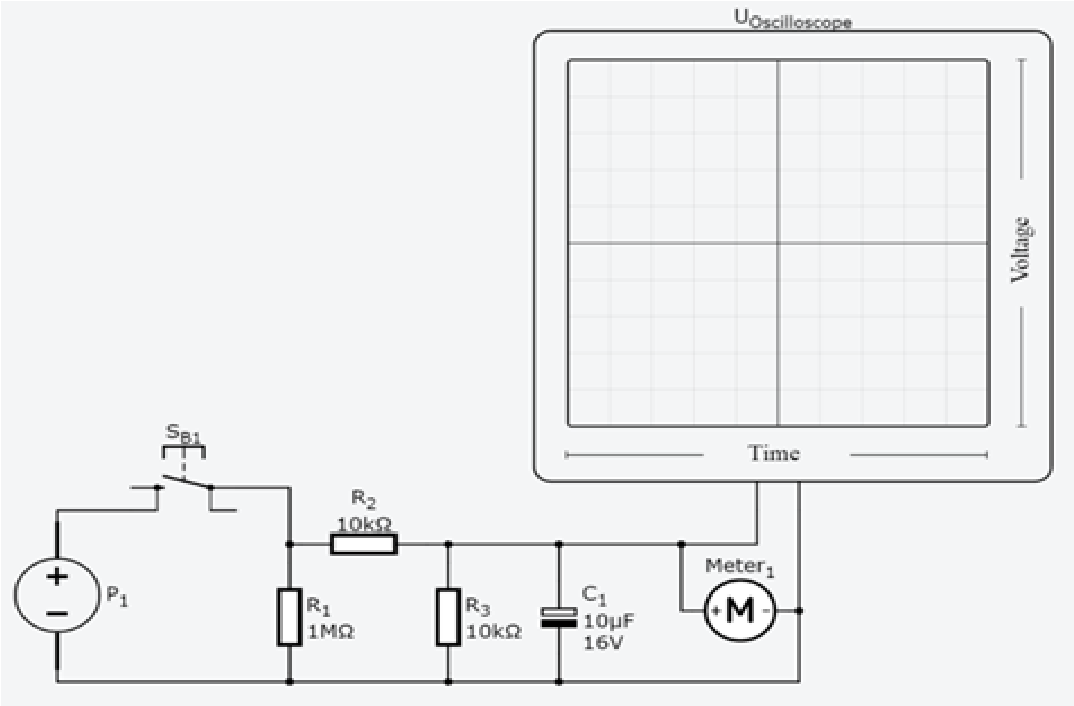
Modeling

We start by calculating the RC when charging

$$\tau, charging = R * C$$
$$\tau, charging = 5k\Omega * 10\mu F$$
$$\tau, charging = 0.05s = 50ms$$

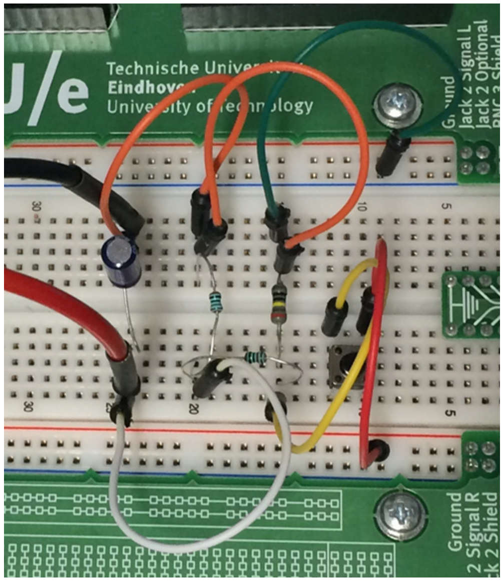
We now calculate the RC when discharging

$$\frac{1}{R} = \frac{1}{R1 + R3} + \frac{1}{R2}$$
$$\frac{1}{R} = \frac{1}{1M\Omega + 10k\Omega} + \frac{1}{10k\Omega}$$
$$R = 9.9k\Omega$$
$$\tau, discharging = 9.9k\Omega * 10\mu F$$
$$\tau, discharging = 0.099s = 99ms$$

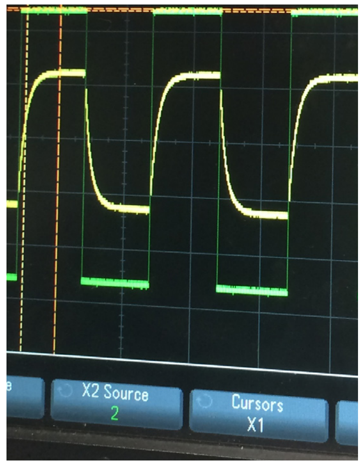


Measurements

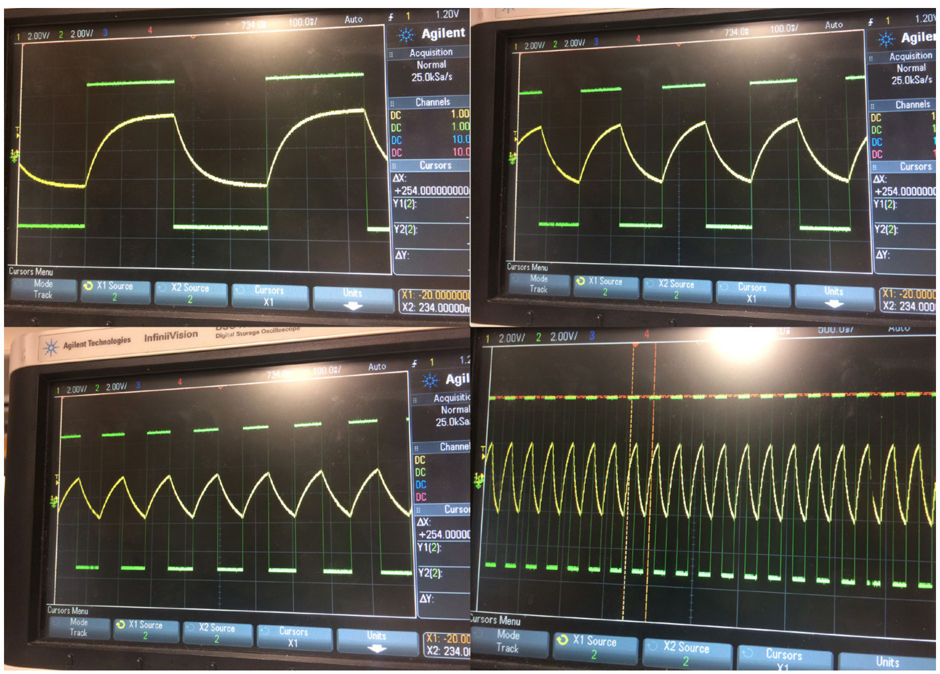
The circuit:



Measuring the time constant for charging and discharging the capacitor using an oscilloscope.



Attached to waveform generator, displaying generated waveform (green) and circuit voltage (yellow)

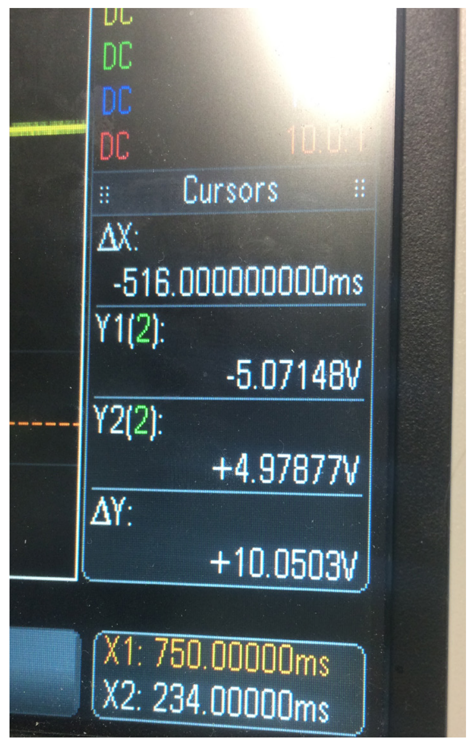


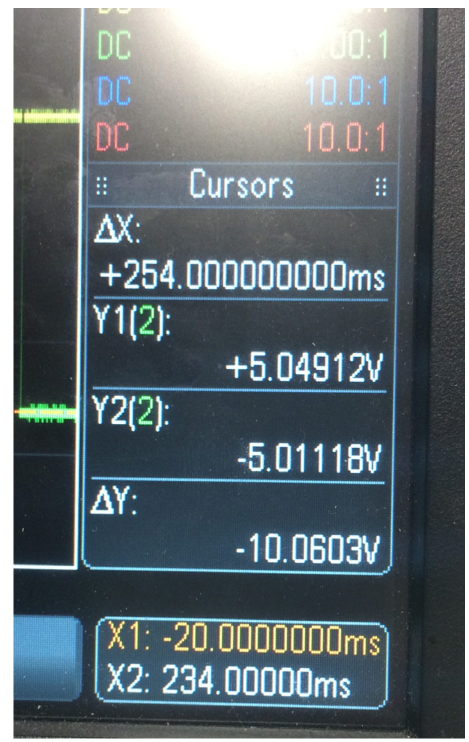
Results

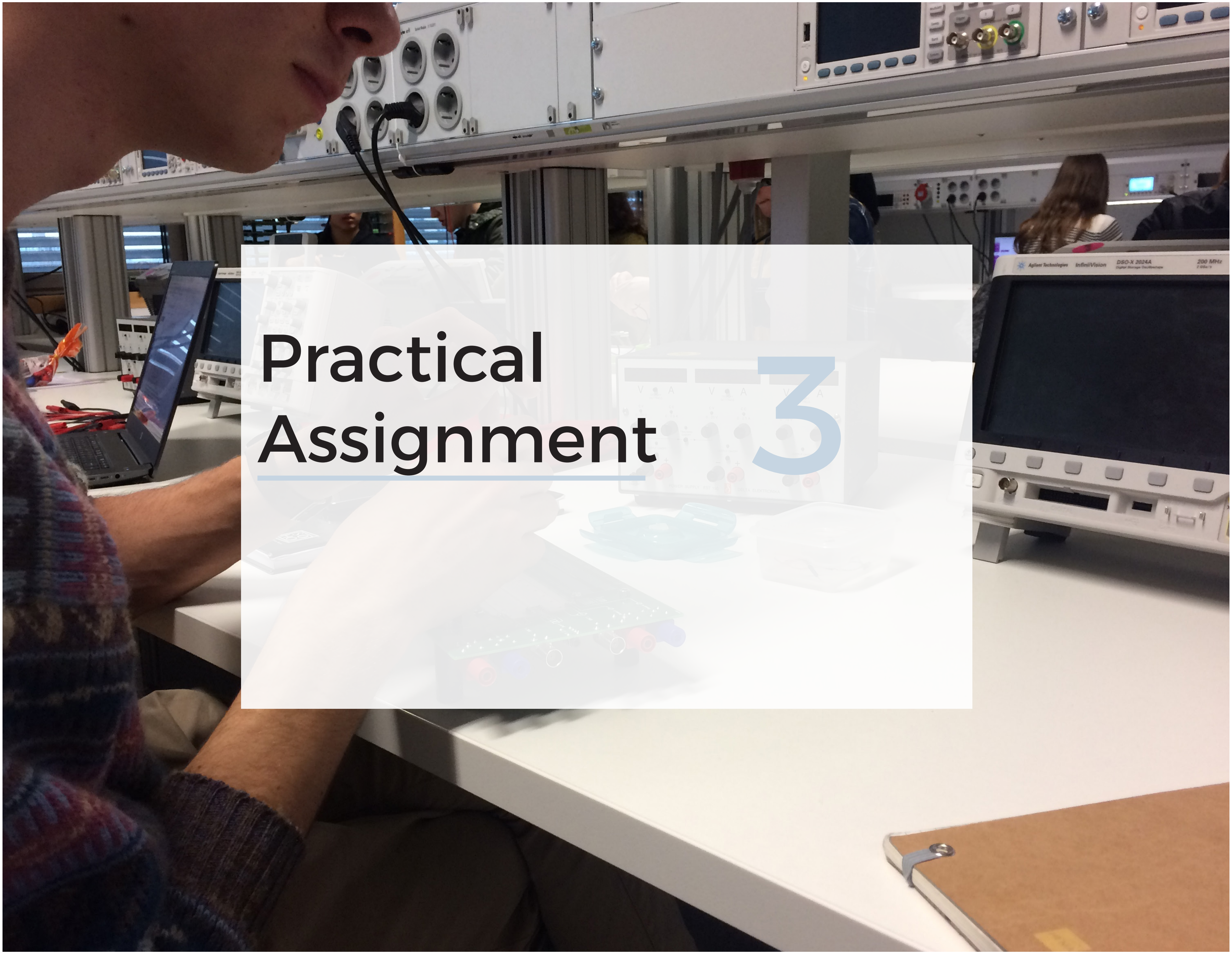
Calculations	Measurements
τ,charging=0.05s=50ms	τ,charging=59ms
τ,discharging=0.099s=99ms	τ,discharging=103ms

Conclusion

From our results we can conclude that our measurements and calculations correspond. We found a slight difference in τ,charging. We can assume that the reason for the fact that we were unable to read the time accurately is because it was unclear when it was done charging.







Practical Assignment 3

Pre-analysis

Part 1:
For every Rb, we will measure Ic, Vce and Vbe. We calculate Ib in mA given the transistor(BC550) is in saturation and Rb is 10kΩ.

Necessities:
- Power supply with 6V
- Breadboard
- Lamp 6V/50mA
- Resistor 100kΩ
- Resistor 47kΩ
- Resistor 10kΩ

Part 2:
We build the new circuit with the LM324 type opamp. We use a combination of a LED with relevant series resistor as indicator on the output of the comparator. We calculate the two transition levels and verify them by measurements. Finally, we draw the hysteresis graph and indicate the measured values.

Necessities:
- Breadboard
- Resistor 10kΩ (2x)
- Resistor 100kΩ
- Transistor (LM324)
- Resistor 1kΩ

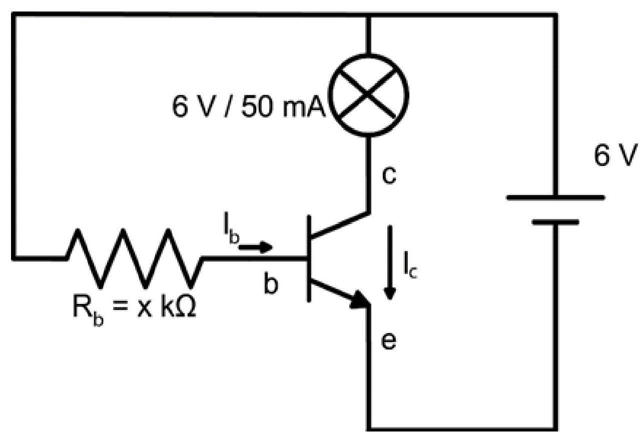
Modeling

Part 1:
We calculate Ib given the transistor(BC550) is in saturation and Rb is 10kΩ.

$$Ib, saturation = \frac{Vx - Vbe}{Rb} * 10$$

$$Ib, saturation = \frac{6V - 0.7V}{10k\Omega} * 10$$

$$Ib, saturation = 5.3mA$$



Part 2:
First, we calculate Vout if the output changes from 0V to 10V. R2 and R3 have the same voltage drop and are connected to the same node (parallel).

$$Vout: Vin = \frac{\frac{R2 * R3}{R2 + R3}}{R1 + \frac{R2 * R3}{R2 + R3}} * Vx$$

$$Vout: Vin = \frac{\frac{10k\Omega * 100k\Omega}{10k\Omega + 100k\Omega}}{10k\Omega + \frac{10k\Omega * 100k\Omega}{10k\Omega + 100k\Omega}} * 10V$$

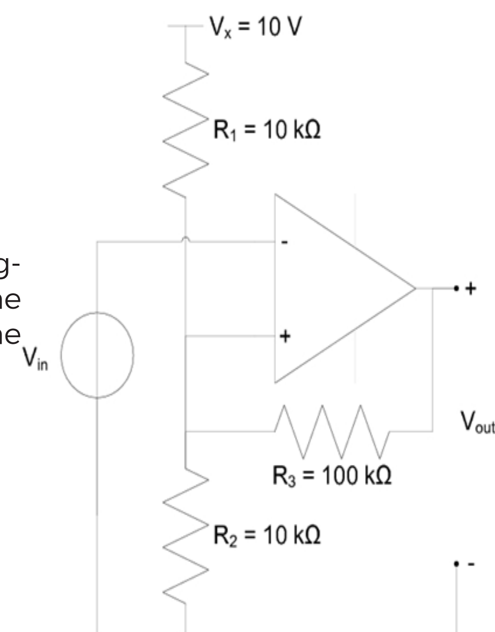
$$Vout: Vin = 4.76V$$

We, then, calculate Vout if the output changes from 10V to 0V. R1 and R3 now have the same voltage drop and are connected to the same node (parallel).

$$Vout: Vin = \frac{R2}{R2 + \frac{R1 * R3}{R1 + R3}} * Vx$$

$$Vout: Vin = \frac{10k\Omega}{10k\Omega + \frac{10k\Omega * 100k\Omega}{10k\Omega + 100k\Omega}} * 10V$$

$$Vout: Vin = 5.24V$$

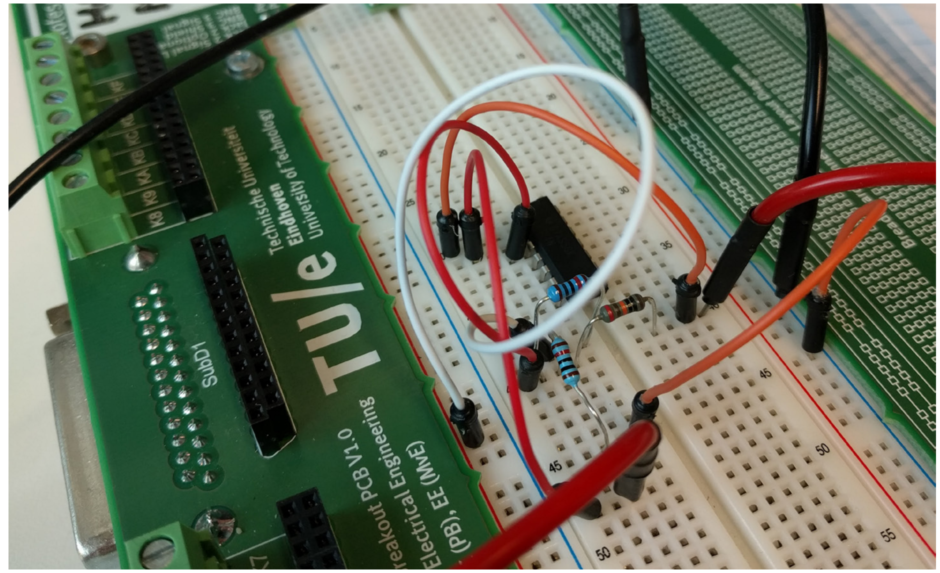


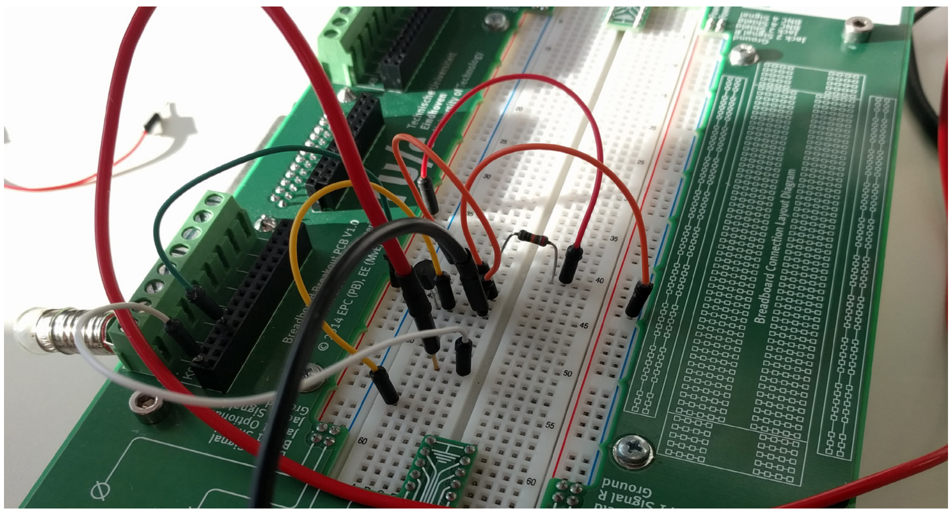
Measurements

Part 1:

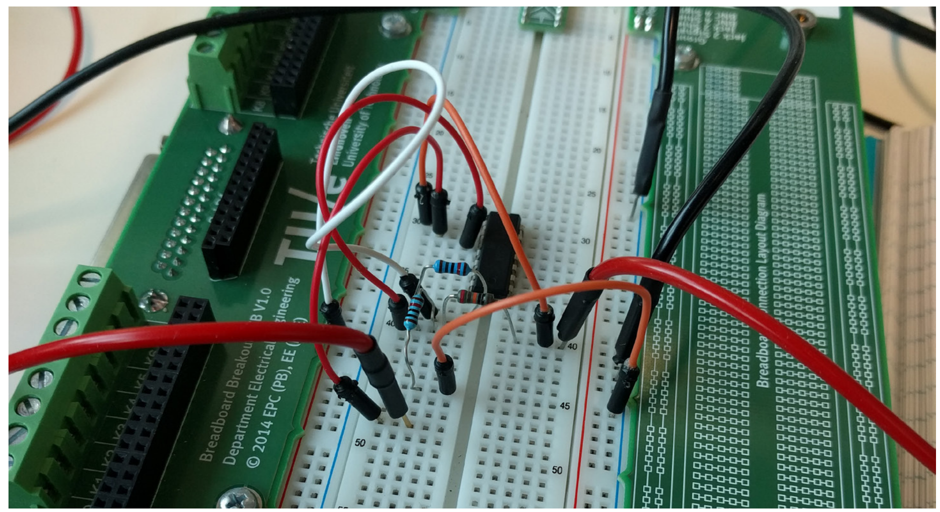
We measured Ic, Vce and Vbe for 4 different values of Rb.

Rb	Ic	Vce	Vbe
1kΩ	55.12mA	0.109V	0.856V
10kΩ	49.1mA	1.22V	0.793V
47kΩ	36.0mA	3.20V	0.730V
100kΩ	28.4mA	4.10V	0.700V





Circuit for assignment part 1 (notice the lightbulb on the left)



Circuit for assignment part 2. We left out the LED and replaced it with probes for a voltmeter, for more accurate measurements.

Results

Calculated	Measured
Vout:Vin (0v-10V)=4.76V	Vout:Vin (0v-10V)=4.7V
Vout:Vin (10v-0V)=5.24V	Vout:Vin (10v-0V)=5.1V

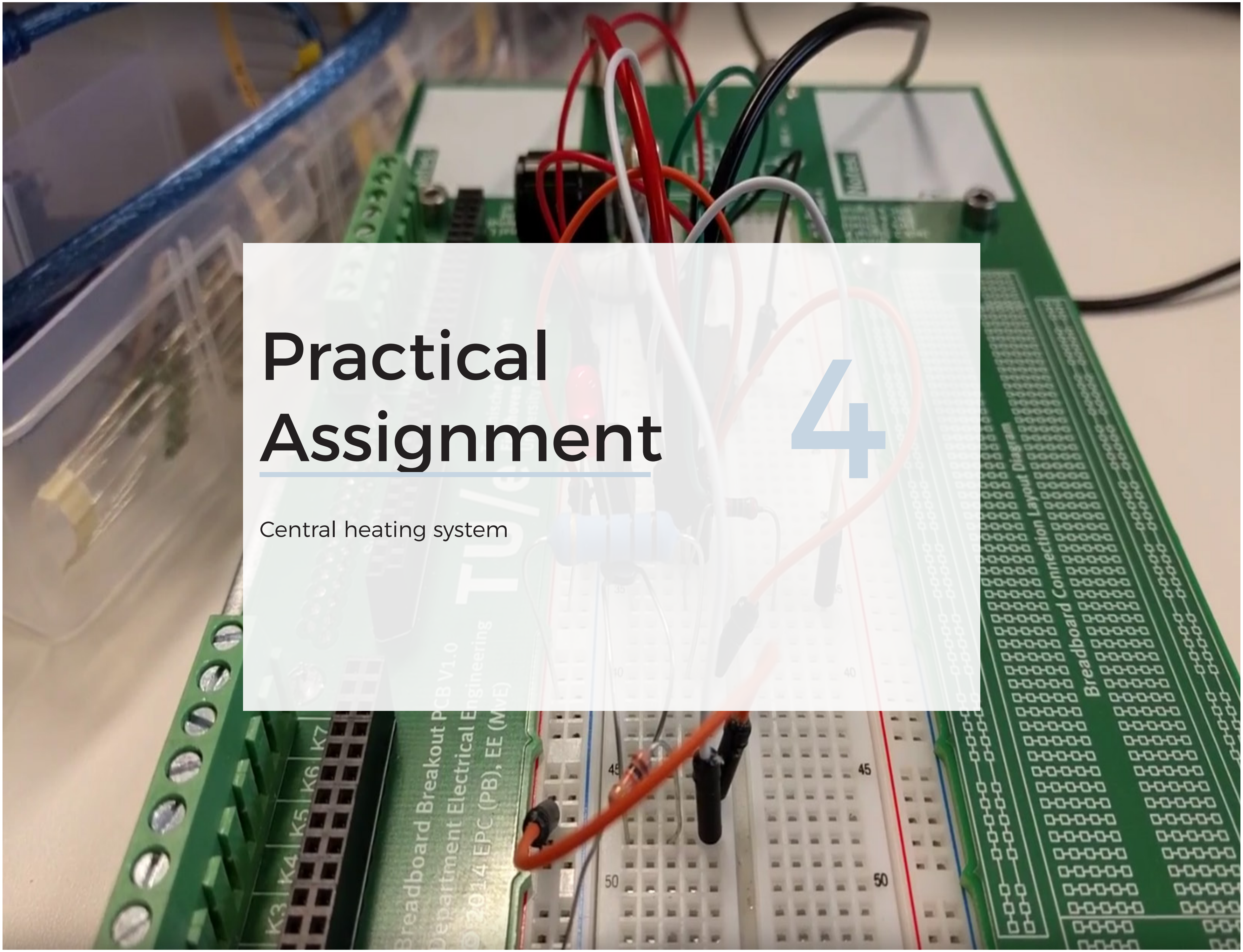
Conclusion

When comparing our calculations to our measurements, we can verify that they are correct. All answers lie within a 3% difference of each other. We can conclude that our answers are correct.

Practical Assignment

4

Central heating system



Pre-analysis

Analyze your actuator: what power source do you need to heat it up to its maximum?

Actuator: 10Ω resistor with power rating of 3 Watt. The power source should be able to supply 3 Watt to heat up the actuator to its maximum.

P=U*I=3W

What is the maximum supply voltage for the resistor?

Maximum supply voltage:

U_max=P/I=3W/I

The limiting element voltage (LEV) for the resistor is 150V (appendix). The applied voltage should never exceed this.

What is the maximum current through the resistor?

I_max=P/U=3W/U

This is for any given voltage.

Is the N-FET able to handle that?

The gate threshold voltage for the N-FET is between 2V and 4V. The current thus should be between 0.75A and 1.5A (see calculation below)

I=3W/U=3W/4V=0.75A

I=3W/U=3W/2V=1.5A

According to the datasheet of the N-FET, the continuous drain current at a temperature of 25˚C is 11A. This is plenty for our application.

How can you use a potmeter to generate an appropriate voltage usable as setting?

By using a voltage divider we can get the potmeter to generate an appropriate voltage to reference the comparator to.

Analyze your sensor: find the R value vs T graph of your NTC.

To the right, a table containing T-values with corresponding R's is displayed. For our NTC, R25=10kΩ

How can you convert the NTC resistance value to a voltage?

V=I*R

Modeling

R/T No.	2904	
T (°C)	$B_{25/100}$ = 4300 K	
	R_T/R_{25}	α (%/K)
−55.0	121.46	7.4
−50.0	84.439	7.2
−45.0	59.243	7.1
−40.0	41.938	6.9
−35.0	29.947	6.7
−30.0	21.567	6.6
−25.0	15.641	6.3
−20.0	11.466	6.2
−15.0	8.451	6.0
−10.0	6.2927	5.9
−5.0	4.7077	5.7
0.0	3.5563	5.5
5.0	2.7119	5.3
10.0	2.086	5.1
15.0	1.6204	5.0
20.0	1.2683	4.8
25.0	1.0000	4.7
30.0	0.7942	4.6
35.0	0.63268	4.5
40.0	0.5074	4.3
45.0	0.41026	4.2
50.0	0.33363	4.1
55.0	0.27243	4.0
60.0	0.2237	3.9
65.0	0.18459	3.8
70.0	0.15305	3.7
75.0	0.12755	3.6
80.0	0.10677	3.5
85.0	0.089928	3.4
90.0	0.076068	3.3
95.0	0.064524	3.3
100.0	0.054941	3.2
105.0	0.047003	3.1
110.0	0.040358	3.0
115.0	0.034743	3.0
120.0	0.030007	2.9
125.0	0.026006	2.8
130.0	0.022609	2.8
135.0	0.01972	2.7
140.0	0.017251	2.6
145.0	0.015139	2.6
150.0	0.013321	2.5
155.0	0.011754	2.5

How do you connect the inputs to your comparator?

See schematic below

How do you connect the N-FET to the comparator?

See schematic below

How are you going to supply power to the comparator?

See schematic below

How do you connect the LED and its series resistor? What is the value for the resistor?

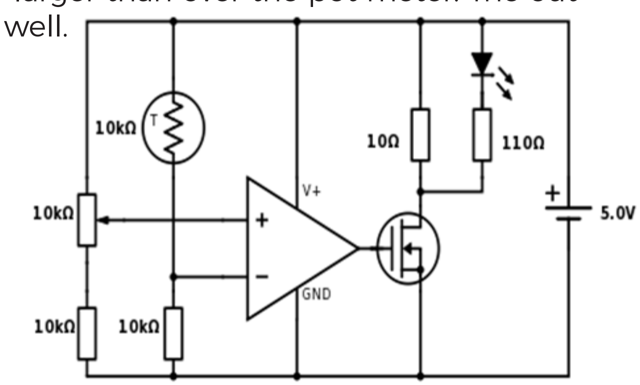
See schematic below

Once your design is ready, check if you understand its behavior. What is the effect on the NTC if the temperature rises to 40 degrees? What is the effect on the input of the comparator? What happens at the output?

When the temperature rises to 40 degrees, the NTC's resistance will decrease This increases the voltage difference between the voltage divider

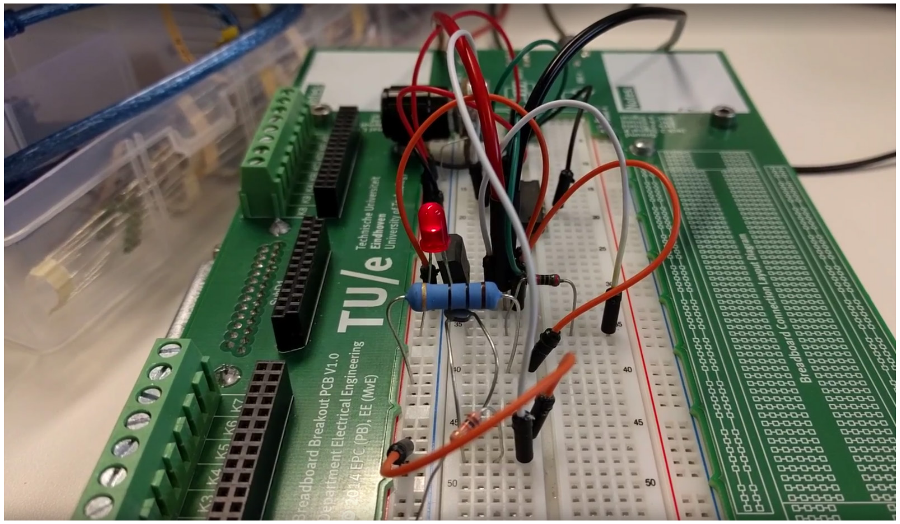
and ground (because $V_{out} = \frac{R_2}{R_1+R_2} * V_{in}$).

This has the effect that the comparator switches off, as the voltage over the NTC is now larger than over the pot meter. The output now switches off as well.



Measurements

We measured the resistance of the potmeter in the circuit to be 5.27 kΩ. This means that the temperature of the 10Ω resistor is kept around a constant 40˚C (see R/T table above).
The measured current through the circuit at 5V is 0.47A



Conclusion

Once the temperature rises above a certain number, the device stops heating and once the temperature drops below a certain number, the device starts heating again. From our measurements and observations we can conclude that our central heating system works and is correct.

Reflection Tjeu

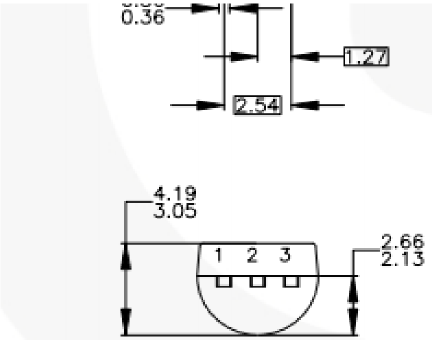
From this course I learned how to make interactive electronics without using microcontrollers and programming to achieve my goal. I didn't anticipate on this being such a useful skill for me, but it turns out it is. Being able to design circuits without microcontrollers makes you have a deeper understanding of the electronics you are using, since you have to preform calculations to obtain certain values to use. We are continuing this challenge in the mini project, making a plant watering system without the use of microcontrollers.
For me, the change in teams after the first week worked out great. My new teammate and I were a good duo, we both had a slightly deeper understanding of certain parts of the theory than the other, so we complemented each other well. Something to keep in mind in the future, is to think about reporting earlier in the process. Right now, we missed some pictures and forgot to draw the final version of the circuit that we used and that worked. When processing results weeks after the experiment, you tend to forget the little things you dealt with and can't implement them in the report anymore.

Reflection Sophie

Before doing the course 'Creative electronics' I had little practical knowledge about electronics. I knew how to work with the mathematical side after Physics though. The course taught me how to create circuits and make electronics, I believe that this will definitely be beneficial in the future for making prototypes and understanding products better. We will create a system which can water plants for our mini project. During this project we will be able to apply our new knowledge in practice.
In my opinion, Tjeu and I are a great team. We both know when to work hard and both had some prior knowledge regarding electronics. This atmosphere made working together nice. When looking back at the past few weeks, I noticed that it would have been better to write about each practical assignment right after we had done it. This would have made it easier to remember what exactly we had done and we would have noticed things like missing information sooner.
Over all, I think 'creative electronics' is a crucial course for understanding interactive electronics.

Appendices

Measurements Practical assignment 3.



NOTES: UNLESS OTHERWISE SPECIFIED

A) DRAWING WITH REFERENCE TO JEDEC TO−92 RECOMMENDATIONS.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DRAWING CONFORMS TO ASME Y14.5M−1994.
D) TO−92 (92,94,96,97,98) PIN CONFIGURATION:

PIN	92			94			96			97			98		
	P	F	M	P	F	M	B	F	M	P	F	M	P	F	M
1	E	S	S	E	S	S	B	D	G	C	G	D	C	G	D
2	B	D	G	C	G	D	E	S	S	B	D	G	E	S	S
3	C	G	D	B	D	G	C	G	D	E	S	S	B	D	G

LEGEND:
P − BIPOLAR E − EMITTER D − DRAIN
F − JFET B − BASE S − SOURCE
M − DMOS C − COLLECTOR G − GATE

E) FOR PACKAGE 92, 94, 96, 97 AND 98: PIN CONFIGURATION DRAIN "D" AND SOURCE "S" ARE INTERCHANGEAGLE AT JFET "F" OPTION.
F) DRAWING FILENAME: MKT−ZA03DREV3.

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Operational Amplifiers

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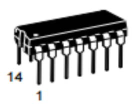
The LM324 series are low−cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one−fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

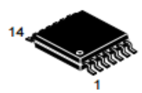
Features

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant



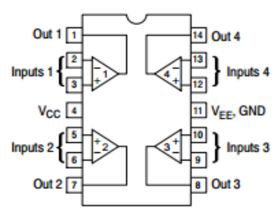
PDIP−14 N SUFFIX CASE 646

SOIC−14 D SUFFIX CASE 751A



TSSOP−14 DTB SUFFIX CASE 948G

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

DEVICE MARKING INFORMATION

See general marking information in the device marking

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Measurements Practical assignment 4.

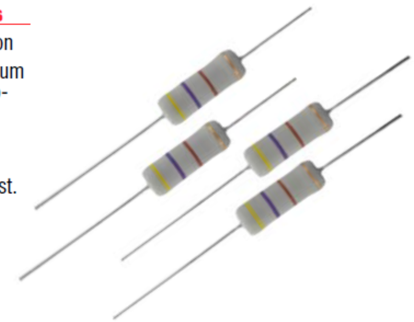
50 Series

Economical Silicone Coated Wirewound

Automated winding, in-line color banding, and testing allow for an economically priced, industrial grade wirewound power resistor. These resistors feature an all welded construction with a high purity alumina ceramic core and high quality RoHS grade tinned copper wire instead of copper weld which produces better thermal characteristics. The 50 series accompanies Ohmite's wide range of axial leaded products.

FEATURES

- Rugged construction
- Optimized for Medium to High volume production
- Custom resistance values can also be produced on request.



SERIES SPECIFICATIONS

Series	Power at 25°C	Resistance	Limiting Element Voltage
53J	3W	0R1 to 10K	150
55J	5W	0R1 to 20K	200

CHARACTERISTICS

Temp. Coefficient of Resistance	±90 ppm/°C for below 1.0 Ω ±50 for 1.0 Ω to 99 Ω ±30 for 100 Ω and above	
Short Term Overload	53J	5X for 5 seconds
	55J	10X for 5 seconds
Leads	Tin Coated Copper	

Test	Condition	Maximum ΔR
Short term overload	5X Rated power for 5 seconds (3W); 10X Rated power for 5 seconds (5W)	<2% + 0R05
Load life at rated power	1000 hours (1.5 Hrs ON, 0.5 Hrs OFF cycle)	<5% + 0R05
Robustness of termination	As per BS-CECC 40201-002	<1% + 0R05

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