Preview Research project

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Contents

1 Abstract

This report briefly summarizes the research project and its results. A deeper insight as well as the interpretation of the results will take place in the actual report of the research project.

2 Introduction

The research project was carried out in cooperation with the company KSD Köthener Spezialdichtungen GmbH. The company deals with the production and trade of seals for valve and plant construction. The cooperation arose because the faulty pumps were examined and the grease used had turned dark. One assumption is that water and other dirt particles (metal abrasion or dirt from outside) are deposited in the grease and thus influence the functionality of the seal. This gave rise to the topic of the research project: "Moisture detection in grease".
There were two basic ideas to investigate the problem of moisture. On the one hand, the observation in the infrared spectrum or the capacitive observation in an analog or digital variant.

3 Methods

3.1 Analog

The measurement with the analog variant was done via an AC bridge. The circuit was designed and built by Mr. Adler. The first measurements seemed to be successful, however, a problem turned out quickly: The DC voltage at the output of the measuring circuit became an oscillating AC voltage signal. This meant that the DC signal fluctuated or oscillated by 500mV. Since a possible explanation for this was not found, it was decided to create a digital version.

3.2 Digital

In the digital version, the charging time of the capacitor was measured by means of ESP32. This microcontroller was taken because it has a very high clock frequency and thus the timers can also resolve very high. The measurement setup can be seen in the figure 3.1 and 3.2. Due to development reasons the circuit was designed to measure two capacitances. For the purposes of this project only one measurement of a capacitance was taken. The charging time of this circuit is very low because the measured capacitance is very small (in range of pF). To slow down the charging time a resistor with $R = 1\text{M}\Omega$ was used. Then a comparator (LM358) compared the voltage of the capacitor with 0.63 of the total voltage. Furthermore the ESP32 measured the analog voltage of the capacitor to ensure it resets its value back to 0V after the interrupt has been thrown. When the threshold value was reached, the output of the comparator was set to HIGH and the ESP32 reacted with an interrupt on pin G25 and calculated the corresponding capacitance. For output purposes the ESP32 sends a PWM-signal from its pin G16 to a low-pass-filter which smoothed out the signal and pass it directly to an op-amp to get the DC output value from 0V to 10V. This has not been tested yet due to the limited time. The capacitor was a plate capacitor with a plastic tube containing the grease mixture [3.3]. The graphical evaluation of the measurement results can be seen in the figures [3.4] - [3.7]. The grease is the grease provided by Mr. Adler. The grease-water mixture contains 6.66% water. The measurements were always performed with the same water and the same grease-water mixture, since the dielectric constant is frequency-dependent. A striking feature is the measurement at a very low frequency (f=2Hz), where the measured capacitance of the water is lower than that of the grease, for which there is still no explanation. In this case, the measurements at higher frequencies show an expected result, where the grease-water mixture has a higher capacitance than the grease. The differences between the two capacitance became larger the higher the frequency of the

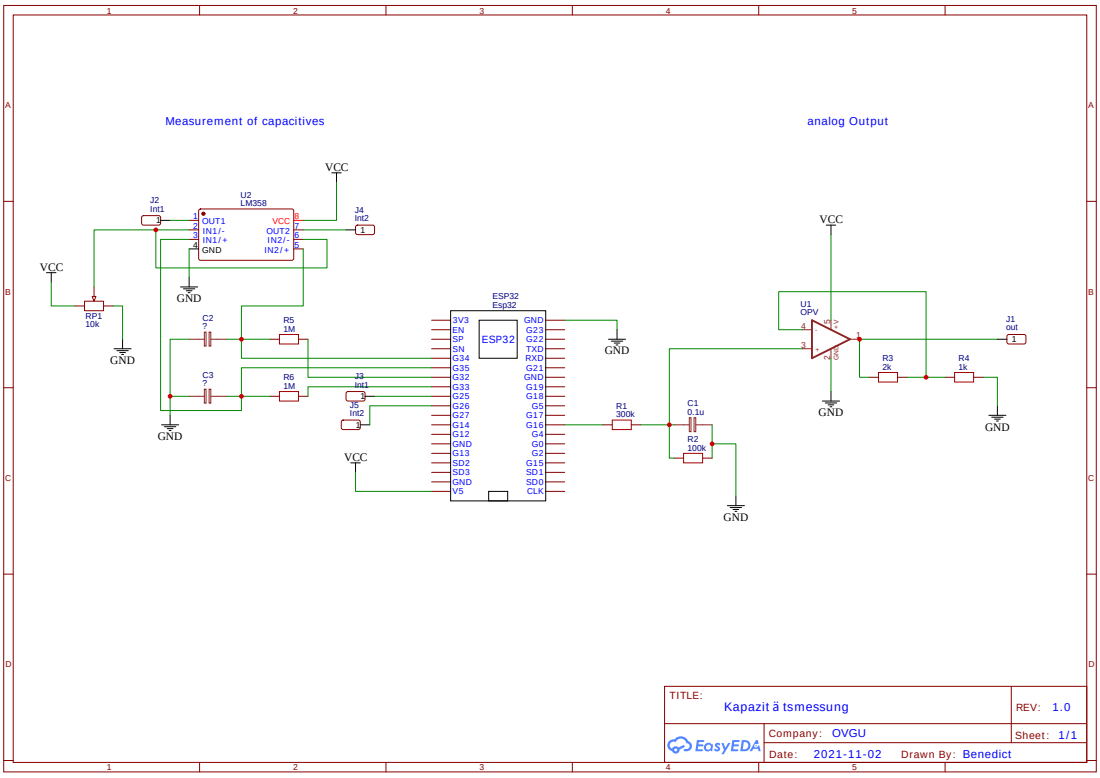

Figure 3.1: Overall design of the circuit

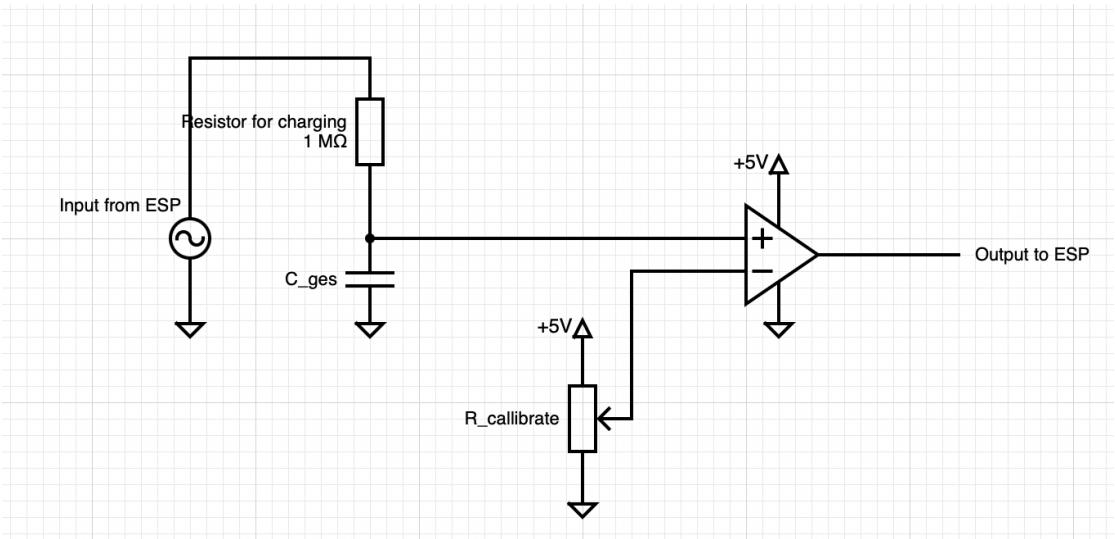

Figure 3.2: Simplified structure of the circuit

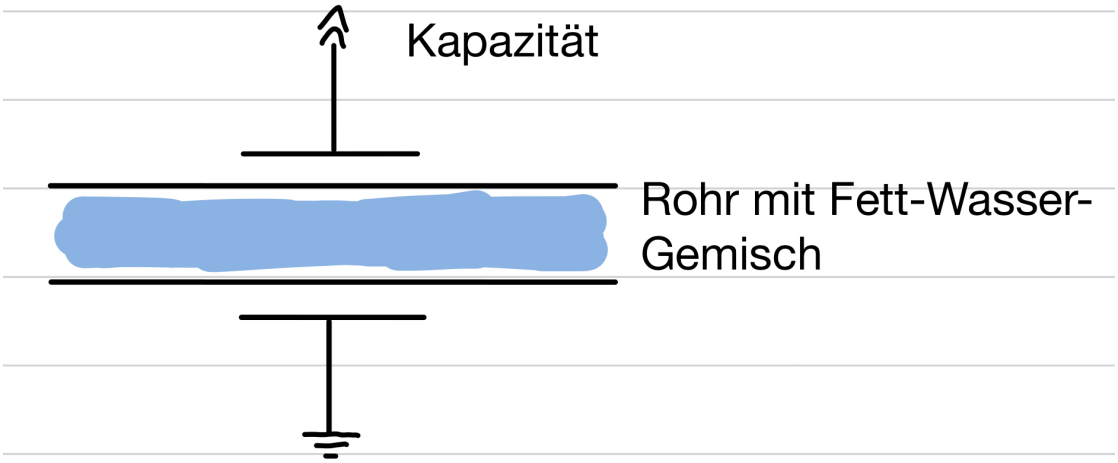

Figure 3.3: Schematic structure of the circuit. This shows the capacitance (Kapazität) and the tube with the grease-water-mixture (Rohr mit Fett-Wasser-Gemisch).

measurement became.
With f=2Hz:

$$C_{\text{grease}} = 64.30890242334323\text{pF} \tag{3.1}$$
$$C_{\text{grease-water}} = 64.16628618199802\text{pF} \tag{3.2}$$
$$\Delta C = 0.05090726447917859\text{pF} \tag{3.3}$$

With f=20Hz:

$$C_{\text{grease}} = 65.54378418879908\text{pF} \tag{3.4}$$
$$C_{\text{grease-water}} = 65.59469145327826\text{pF} \tag{3.5}$$
$$\Delta C = 0.05090726447917859\text{pF} \tag{3.6}$$

With f=200Hz:

$$C_{\text{grease}} = 63.32508218439551\text{pF} \tag{3.7}$$
$$C_{\text{grease-water}} = 63.39419065185354\text{pF} \tag{3.8}$$
$$\Delta C = 0.06910846745802957\text{pF} \tag{3.9}$$

With f=568Hz:

$$C_{\text{grease}} = 63.30306145021645\text{pF} \tag{3.10}$$
$$C_{\text{grease-water}} = 63.40192108738288\text{pF} \tag{3.11}$$
$$\Delta C = 0.09885963716643431\text{pF} \tag{3.12}$$

Those calculated values can also be seen in the following graphs. Figure 3.4 shows the calculation of the capacitance over 2000 samples with a measurement-frequency of 2Hz. The ESP charged the capacitance 1000 times for each mixture. The blue graph represents the calculated capacitance of the pure grease. The mean value is 64.30890242334323pF. The maximum and minimum value different about 0.5pF which is related to the inconsistent measurement of the timer value (noise). The green graph represents the calculated capacitance of the grease-water-mixture. The mean value is 64.16628618199802pF. It also has a difference about 0.5pF from the lowest value to the highest value. As mentioned earlier the strange behavior of this measurement is that the calculated capacitance of the mixture is lower than the value of the pure grease which is not what to expect from this measurement because the dielectric constant of the water is higher than the dielectric constant of the grease. This must be discussed later on.

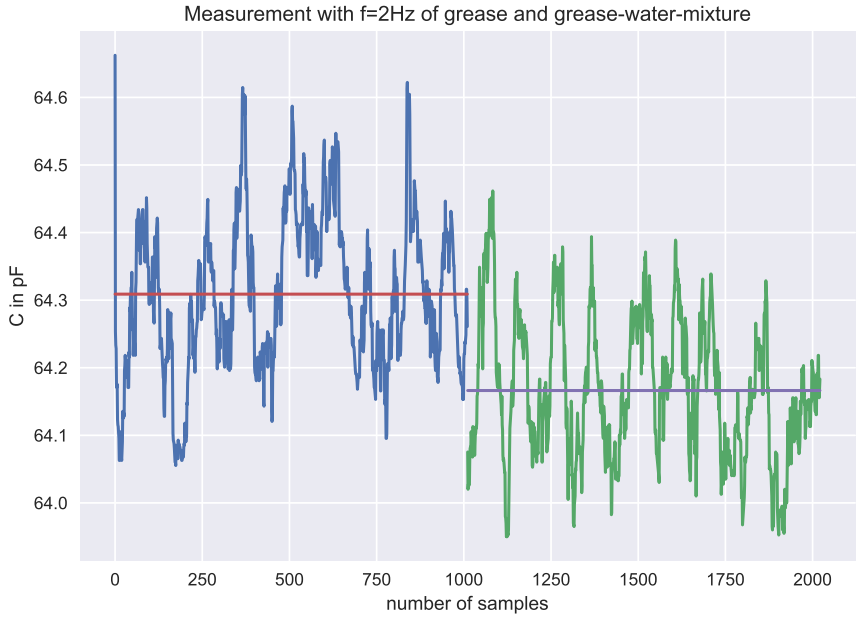

Figure 3.4: graphical representation of the grease (blue) and water (green) with the calculated mean values of the grease (red) and water (purple)

Figure 3.5 shows the calculation of the capacitance over 7000 samples with a measurement-frequency of 20Hz. The ESP charged the capacitance 3500 times for each mixture. The blue graph represents the calculated capacitance of the pure grease. The mean value is 65.54378418879908pF. In comparison to figure 3.4 the noise of the measurement has decreased a lot. It only shows a difference of the maximum and a minimum value of by 0.3pF. The green graph represents the calculated capacitance of the grease-water-mixture. The mean value is 65.59469145327826pF. Its noise also decreased to a difference of 0.3pF. The results of the measurement are the ones expected from theory. The

capacitance value of the mixture is greater than the pure grease mixture due to the water in the mixture. A difference of 0.05090726447917859pF can be calculated from both values which is not much but can be increased with higher frequencies.

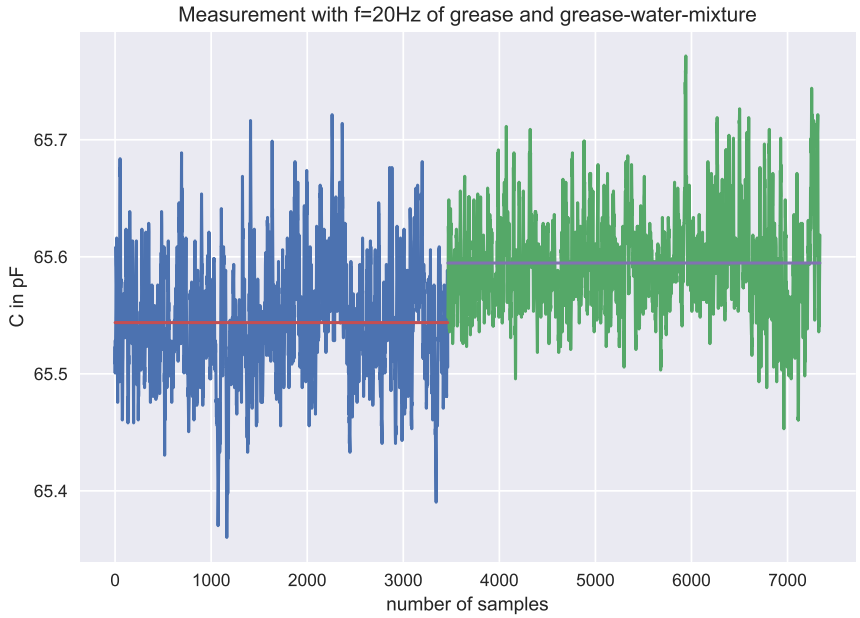

Figure 3.5: graphical representation of the grease (blue) and water (green) with the calculated mean values of the grease (red) and water (purple)

Figure 3.6 shows the calculation of the capacitance over 35000 samples with a measurement-frequency of 200Hz. The ESP charged the capacitance 17500 times for each mixture. The blue graph represents the calculated capacitance of the pure grease. The mean value is 63.32508218439551pF. In comparison to figure 3.5 the noise of the measurement has not decreased further but due to the faster measurements the timer value was more likely to be off the correct value. This results in those high peaks shown in the picture. The green graph represents the calculated capacitance of the grease-water-mixture. The mean value is 63.39419065185354pF. The difference of the both values is even greater with a value of 0.06910846745802957pF. It shows that faster measurement seems likely to increase the different of both mixtures due to the strong frequency-dependency-dielectric-constant of water.

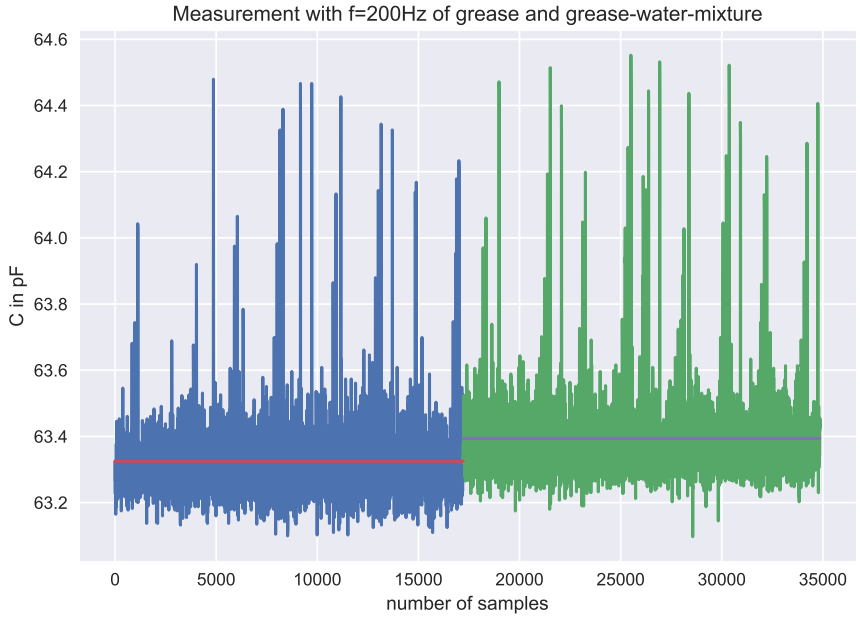

Figure 3.6: graphical representation of the grease (blue) and water (green) with the calculated mean values of the grease (red) and water (purple)

Figure 3.7 shows the calculation of the capacitance over 25000 samples with a measurement-frequency of 568Hz which is the maximum frequency of the GPIO. The ESP charged the capacitance 12500 times for each mixture. The blue graph represents the calculated capacitance of the pure grease. The mean value is 63.30306145021645pF. In comparison to figure 3.6 the noise of the measurement has not decreased further and also due to the fast measurement the timer value has been read incorrectly. This also results in those high peaks shown in the picture. The green graph represents the calculated capacitance of the grease-water-mixture. The mean value is 63.40192108738288pF. The difference of the both values is even greater with a value of 0.09885963716643431pF.

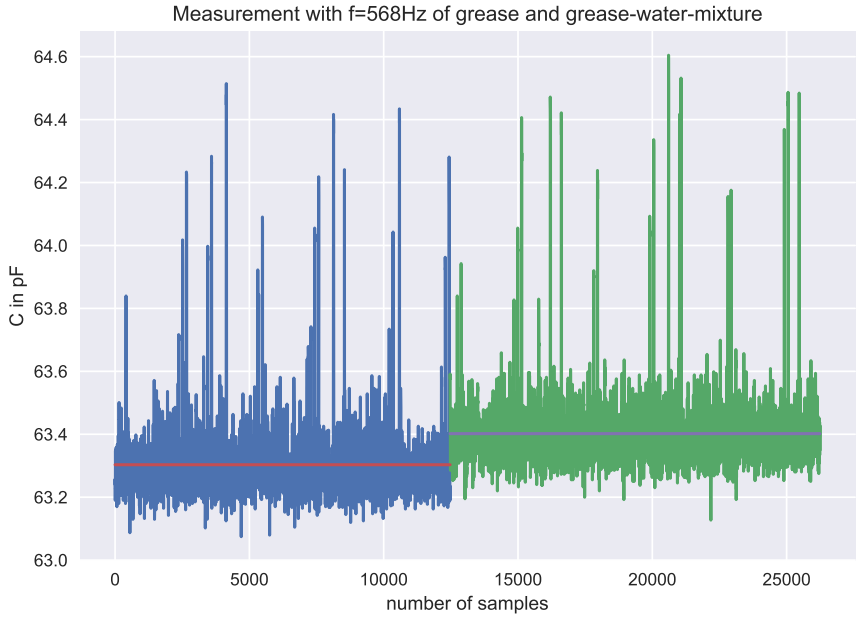

Figure 3.7: graphical representation of the grease (blue) and water (green) with the calculated mean values of the grease (red) and water (purple)

The last figure 3.8 shows a more precise look at the figure 3.7. It shows more details about the actual calculated values of the measurement. There is still a difference of 0.2pF from the maximum to the minimum value but it also shows a clear difference between the two mixtures.

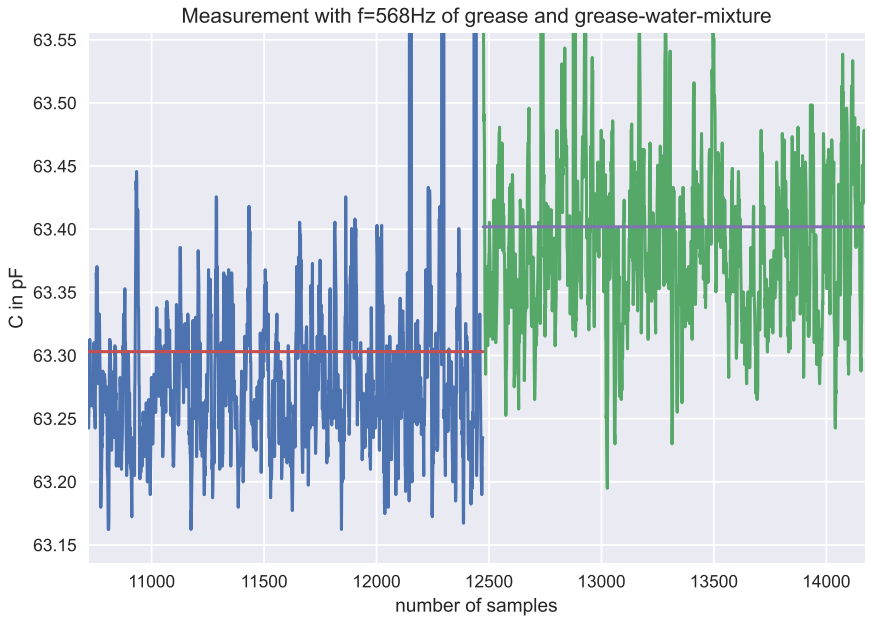

Figure 3.8: graphical representation of the grease (blue) and water (green) with the calculated mean values of the grease (red) and water (purple)

4 Conclusion

With the developed method it is possible to detect even small amounts of water (6.6%) in grease. The results can even be improved by using a PWM-Signal instead of toggling the GPIO on and off, changing the microcontroller to a faster or more timer-value precise one and improve the algorithm for calculation and measurement. Overall the setup is relativly simply and cheap and can produce valid result.