Laboratory Electronics 2

Task 6: Digital-to-Analog Converter

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Learning Objectives

The objective of the sixth lab task is the conversion between digital and analog signals. We will use the R/2R network to setup a digital-to-analog converter (DAC). After this, the setup will be used to set up an analog-to-digital converter (ADC).
The protocol for this experiment must be uploaded during the lab time in the Moodle course. This makes it necessary for the protocol to be prepared to such an extent that only the measurement results need to be inserted. During the last hour of the lab there is an opportunity to finalize the protocol. Finally there will be a discussion where feedback can be given.

- Learning how to convert an analog to a digital signal and vice versa
- Understanding of the R-2R-DAC
- Preparation of a lab task with an instant report submission
- Lessons learned and feedback discussion

Lab Devices

You will find the following devices in the lab. Please make sure that you have the manuals ready. We also provide a breadboard with all required components and wires to setup your electrical circuit.

- **Digital Multimeter** Fluke 8808A
- **Oscilloscope** Tektronix MDO3034
- **Frequency Generator** Rohde & Schwarz HMF2550
- **DC Power Supply** Toellner TOE 8735

1 Digital-to-Analog Converter

To convert a digital word into an analog signal, an R-2R network can be used. This circuit can be used to analyze a certain amount of switch states. The base circuit of the R-2R network is shown in figure 1.

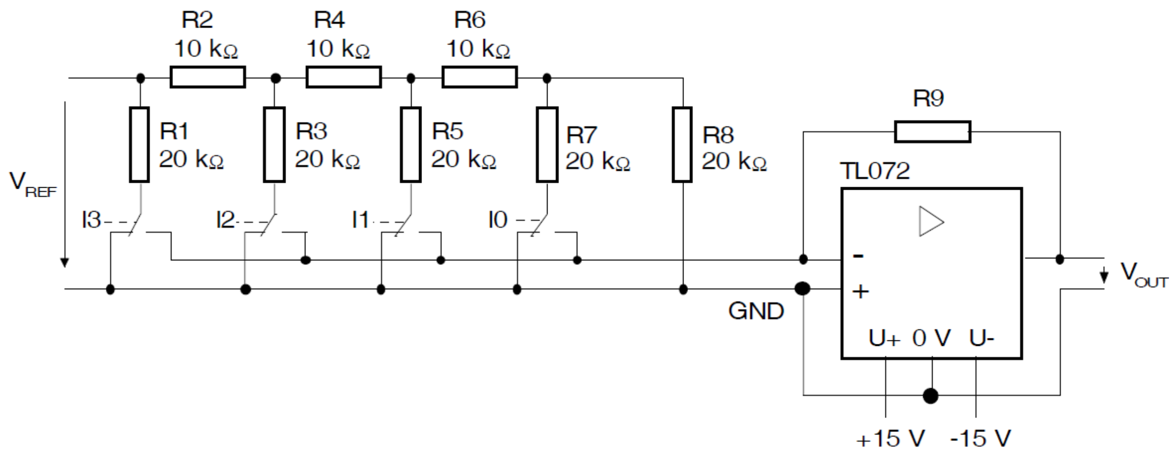

Figure 1: R-2R Network Base Circuit [1]

In this circuit, the switch positions represent the digital value. This means that a 4-bit conversion is possible with this circuit. There are circuit boards containing the basic circuit available in the laboratory. This circuit board can be seen in picture 2.

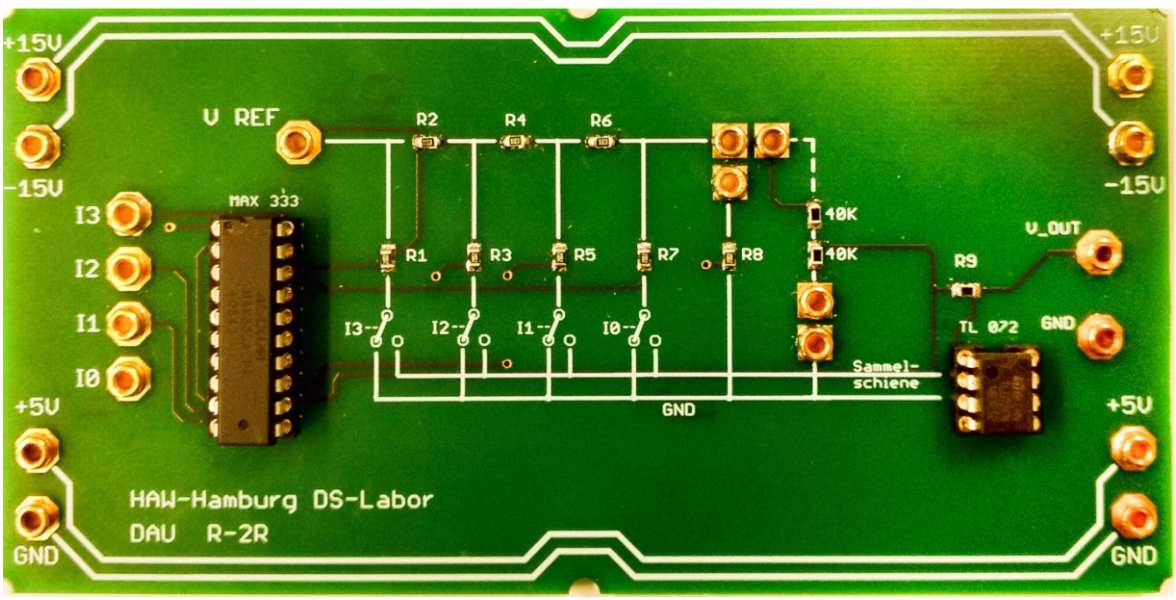

Figure 2: R-2R Network Circuit Board [1]

As can be seen on the circuit board, the resistor R_8 can be connected using a jumper. Alternatively, the resistor R_8 can be set to a value of $80\,\mathrm{k\Omega}$. This value causes a constant offset of half a bit at the output of the DAC. The MAX333 IC contains analog switches that can be switched using digital signals at inputs I0 to I3.

- Calculate the correct value of R_9 for a reference voltage of $V_{\mathrm{REF}} = 5\,\mathrm{V}$ and a full-scale output voltage of $V_{\mathrm{OUT}} = -4\,\mathrm{V}$.
- Find $V_{\mathrm{OUT}} = f(d)$. The value d represents the digital input value.
- Prepare a table with all input signal variations and the corresponding calculated output voltages. Add the measurements to this table, calculate the differences between calculated and measured output voltages and explain the reason for the differences.
- Now add a binary counter to the circuit so that the input signal counts up automatically. The IC 74HCT93 should be used for this. A clock signal from the frequency generator is used as the input signal. This IC is also available on a separate printed circuit board. The board is shown in figure 5. Measure the output signal V_{OUT} and explain the term ”quantization error” with the help of the output signal. Find the quantization error of your circuit.

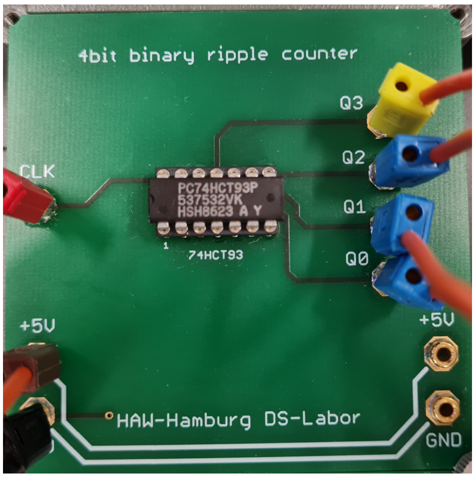

Figure 3: ADC Circuit Board [1]

- Analyze the change of the output signal between the different input signals. There could occur glitches. Explain the reason for them.

2 Sensor Value Conversion

The DAC from task 1 is now used to convert a sensor value. The goal is to convert the output value of a sensor circuit into a digital word using an analog-to-digital converter (ADC). The input circuit consists of any sensor circuit that has an output voltage range of 0 V to 4 V. At the output of the ADC this should correspond to a range from 0x0 to 0xF. The circuit with which this can be realized is shown in figure 4.

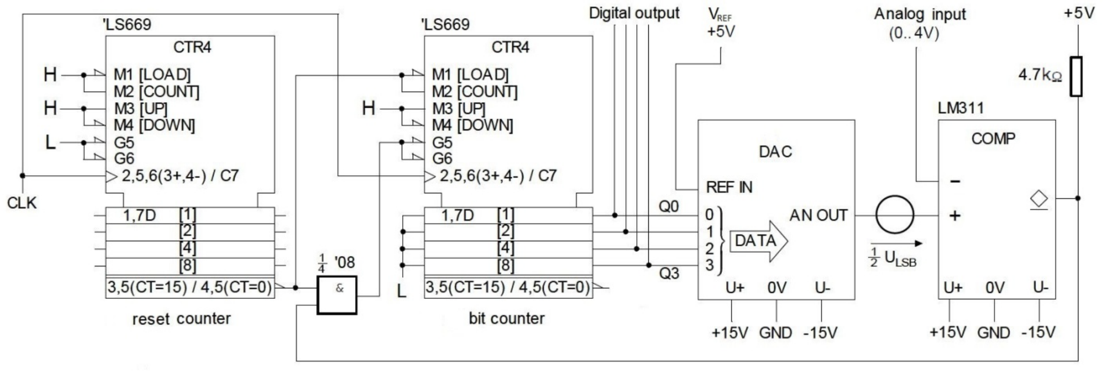

Figure 4: ADC Circuit [1]

To setup this circuit the printed circuit boards in figure 2 and 5 can be used.

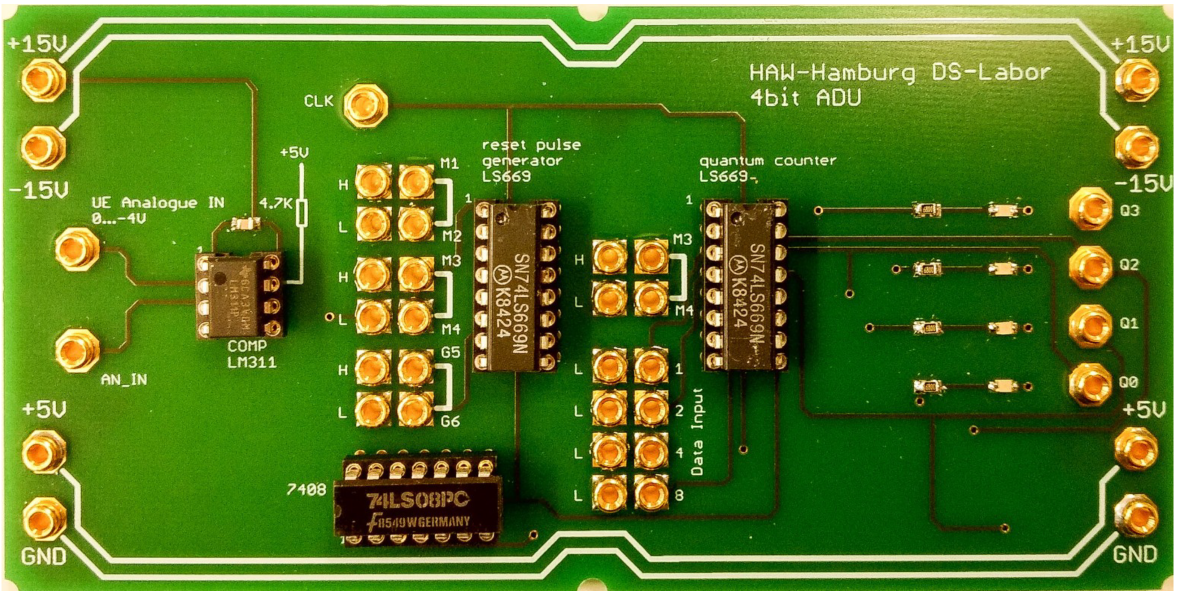

Figure 5: ADC Circuit [1]

- Define the input and the output of the circuit.
- A sensor voltage of 2.8V is assumed. Describe the function of the circuit, starting with the input and ending with the output. Find the state which will arise.
- All the necessary components are contained on the two printed circuit boards shown in figures 2 and 5. Plan the setup using the two printed circuit boards. Find the correct setting for the control pins of all integrated circuits.
- Find the output values of the circuit for the input voltages 0V, 2.8V and 4V. Build the circuit and verify the calculation.
- Find the sample rate and resolution of this ADC. Rate these values as good or bad.

3 Report and Feedback

- Prepare your report in a way that you can insert your measurement results during the lab session. You must upload the completed report during the lab session. You will get approximately 40 minutes to finish and upload the report.
- Add a section "Lessons learned" to your report and answer the following questions:
  - What was the biggest learning we had during the lab?
  - What should we do better in the coming labs?
  - How can we increase the efficiency of preparation / lab work / protocol?
- Prepare a feedback for a short (20 minutes) discussion in the end.

References

[1] P. D. H. Kölzer, *Dau und adu mit r-2r-netzwerk - laboraufgabe elektronik 3.*