AARHUS
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GFV

Experiment

Build a scale
and determine how good it is

Purpose

The main purpose of these experiments is to understand the principles of A/D conversion and signal conditioning and to use the knowledge about measurement theory to examine the precision, sensitivity, non-linearity and sensitivity to disturbances of a real physical system.

You will implement a digital scale using a load cell, an instrumentation amplifier and the PSoC.
You will then specify how good the scale is, in terms of sensitivity, non-linearity, precision and sensitivity to disturbances.

The experiments should end up with a journal and a PSoC creator project.

Literature

- Data sheets
- PSoC Manuals.
- Course material on Blackboard.

The relevant documents can be downloaded from BlackBoard.

General guidelines

Document the experiments in a journal.

Describe the experiment objective(s), results and reflect upon the results.

Document the test setup with photos and diagrams.

Note which components you use.

Document the electrical wiring and create oscilloscope/logic analyzer dumps, where you find it appropriate.

Include relevant parts of datasheets or other documentation. The relevant parts are often diagrams and illustrations.

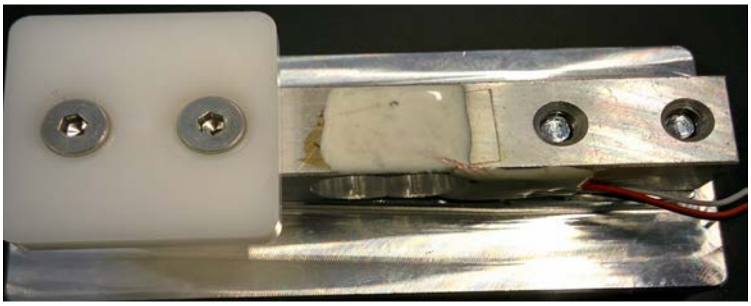
Keep a good structure in the code and document the code.

Perform the experiments in a structured manner: Think -> Do -> Document -> Reflect. And possibly iterate.

Conclude upon the results:

- What worked?
- What didn't work?
- Did anything surprise you?
- What caused the most problems?

1 kg load cell



Figur 1 Load cell

The load cell is based on a strain gauge and has a range from 0 to 1 kg. A few 3 kg variants are also available.

Even without a provided load, the load cell may output a positive signal, so you will need to consider that, when you calculate the weight.

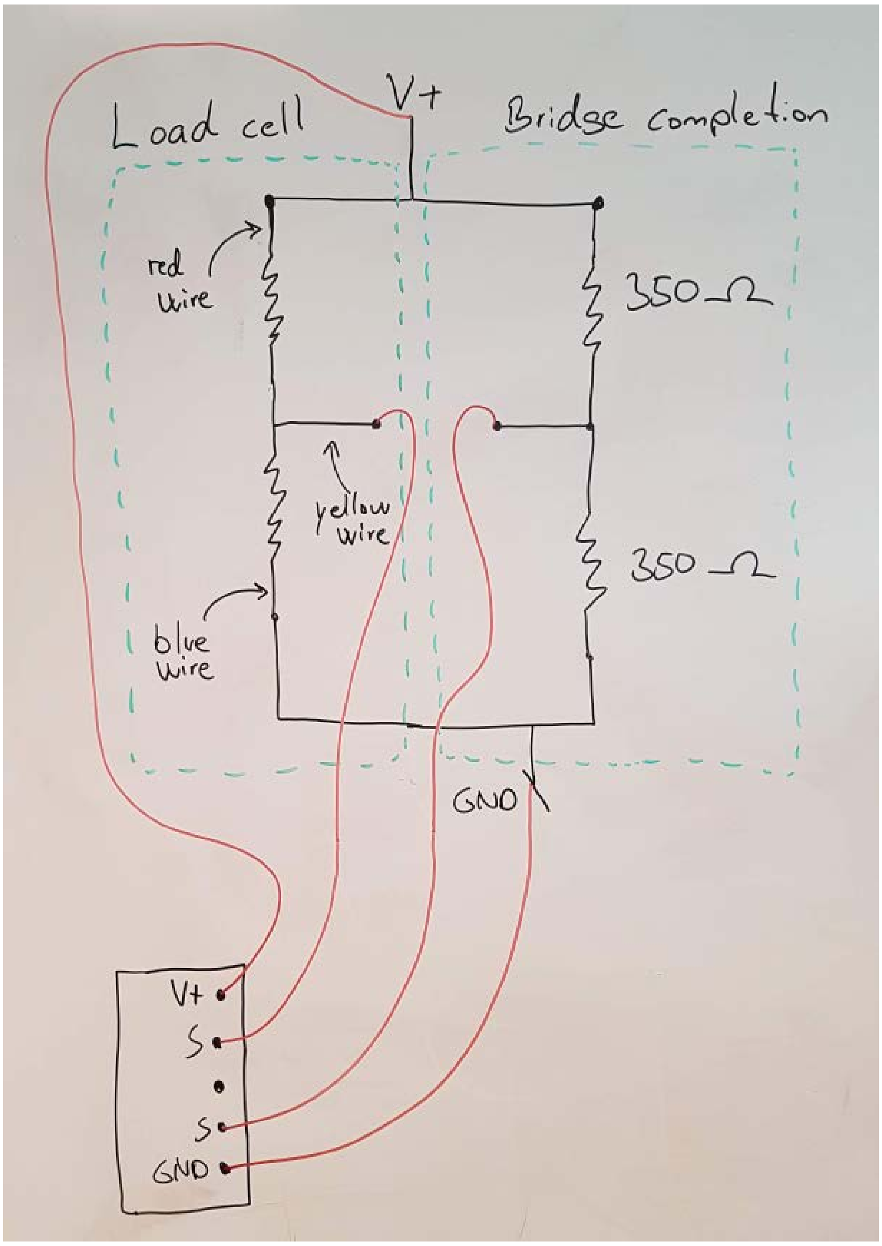
The output of the load cell may be non-linear with very small loads, so you may have to ‘pre-load’ it with some weight to enter its linear range.

10 kg load cell

The 10 kg load cell is only a half-bridge strain gauge, so you have to provide the bridge completion circuit. Bridge completion is built using two resistors of equal value, e.g. 350 ohms.

The output from the load cell and from the bridge completion circuit shall be connected to the input on the Load Cell Amplifier PCB. Figure 2 shows a schematic of the bridge completion and connections.

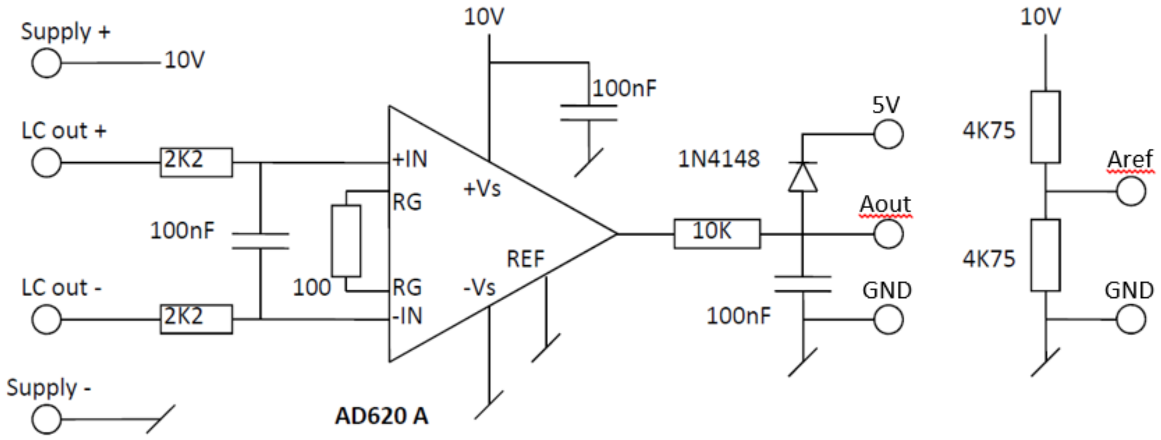
The load cell amplifier only works with positive inputs, so try swapping the two input wires, if you have no output from the amplifier. The 10 kg load cell may also have non-zero output without a load and have initial non-linearity.



Figur 2 - Connecting the 10 kg load cell to the amplifier PCB.

Conversion circuit

The following circuit is used in the experiment for signal conditioning and to interface between the strain gauge and the A/D converter in the PSoC.



Figur 3 AD620 diagram

The circuit is available on a PCB.

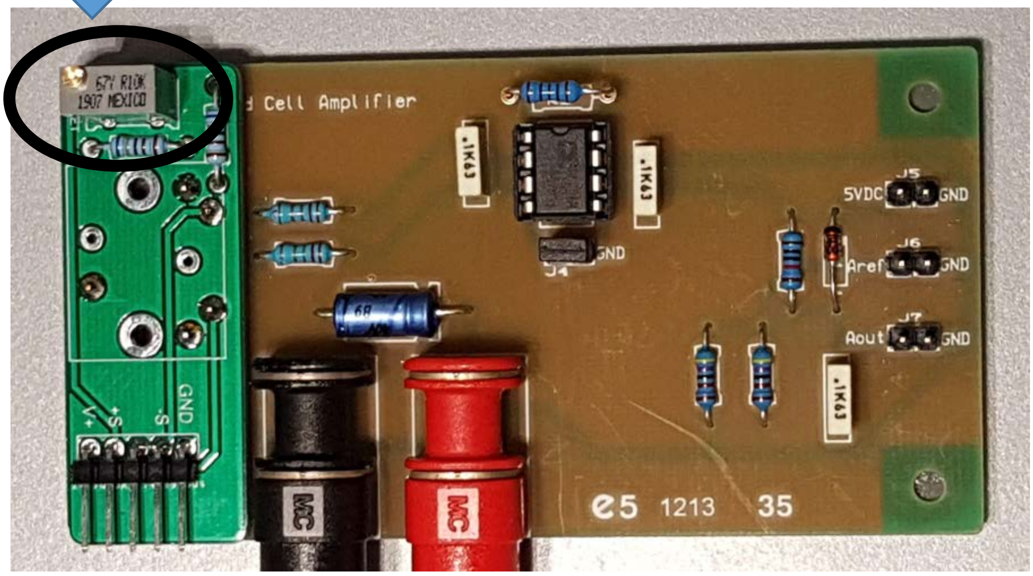
NOTE! Remember to include all your raw measurements (in a text file or as a spreadsheet) in the handin. Keeping the data is also necessary, if you have to go back and re-evaluate some of your conclusions.

NOTE! Remember to note the load cell number. They are all different, so the conversion formula from ADC value to kg, will also be different for all load cells.

Circuit adjustment before the experiment

Before you begin the experiment, you shall perform the following adjustment to the circuit:

1. Connect the load cell to the amplifier circuit.
2. Connect power to the amplifier.
3. Connect an oscilloscope (or your Analog Discovery) to the Aout and GND pins on the amplifier.
4. Perform offset adjustment by turning the adjustment screw on the amplifier board.
    a. Find the point, where you see a change in the output on Aout, when you apply light pressure to the load cell.
    b. Be careful not to increase the offset more than you have to (increasing it too much will cause you to get a lower quality scale).



Experiment 1: Implement a digital scale

Implement a scale based on the load cell, the instrumentation amplifier and the PSoC.

The PSoC contains both a Sigma-Delta ADC and a SAR ADC. You shall use the SAR ADC for this experiment.

Connect the ADC input to Aout and the ADC reference to Aref.

Connect the 5V pin on the PCB to a 5V pin on the PSoC. This is to protect the input pin on the PSoC.

A project to start from is available on Blackboard. It has the SAR ADC configured and ready to use.

The provided PSoC project will output the value from the ADC to the console. This value is proportional to the voltage at the **Aout** pin.

Examine the scale.

Is it linear?

Is there an off-set and if so, how large is it?

Do you need to pre-load the load cell to enter its linear area?

Write a program to calculate the weight in kg at least once per second and output the measured weight to a console, connected to the UART on the PSoC. Note that you **can not** use the ADC_CountsTo_Volts() method, because the ADC has an external reference (you don't need the method anyway.. just work with the raw ADC values).

The scale should output 0 kg, when there is no load on the scale (except for the preload if one is needed) and output the correct weight when loads are placed on it. Make sure to work in the load cells linear area. There are a lot of steel nuts available and a kitchen scale in the lab, so you can weigh off the amount you want. **Bring your own container e.g. some plastic cups or something else to hold the steel nuts.**

Make the scale as good as you can. In reality, you will probably have to accept, that your scale will be worse than the kitchen scale in lab.

If you use the 10 kg load cell, you can use the 100g, 500g, 1000g, 2000g and 5000g loads.

Experiment 2: Non-linearity and sensitivity

Determine the non-linearity and sensitivity of the scale.

a) Preparation

Describe a measuring procedure (e.g. 10 measurements), which can be used to determine the non-linearity and sensitivity of the scale.

b) Preparation

Describe how the non-linearity and sensitivity can be determined based on the measurements (hint: use a trend-line in excel).

c) Measurements

Perform the measurements.

d) Calculations

Calculate the non-linearity and sensitivity of the scale.

Experiment 3: Precision

Determine the precision of the scale with 95% confidence, based on 10 measurements.

a) Preparation

Describe the measuring procedure needed to determine the precision of the scale.

b) Preparation

Specify the parameters, which has to be calculated.

c) Measurements

Perform the measurements.

d) Calculations

Calculate the precision of the scale. (You may want to defer this to after experiment 4, in order to have more time to perform measurements).

Experiment 4: Sensitivity to disturbances.

In this experiment, the disturbance is the time passed since the measurements in experiment 2 was performed.

The sensitivity to this disturbance shall be found by determining the zero-drift and sensitivity-drift of the scale.

a) Preparation

Describe the measuring procedure needed to determine the zero-drift and sensitivity-drift of the scale.

b) Measurements

Perform the measurements.

c) Calculations

Describe whether or not the scale has experienced drift and if so, specify how much the zero-point and sensitivity has changed since experiment 2.

Experiment 5: (Optional)

Experiment with different external reference voltages for the A/D converter, while you change the supply voltage to the load cell. What happens?

If the ADC reference voltage is a constant voltage, e.g. 5V from the PSoC or an internal reference, the measurement is absolute. If the reference voltage is proportional to the load cell supply voltage, the measurement is ratiometric (this is when the ADC reference is connected to Aref shown on figure 2).

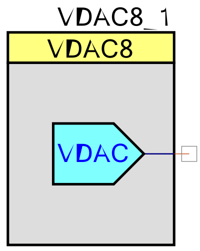
What benefits does the ratiometric measurement give? And why?

Software challenge:

Add 'Tara' functionality to the program, so the scale is reset, when a command is sent to the PSoC via the UART.

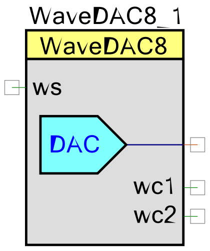
Experiment 6: DAC (optional)

Experiment with the VDAC8 and WaveDAC8 components in the PSoC.



Figur 4 VDAC8 komponent

Start by generating a steady output from the VDAC8 (e.g. max, max/2, min) and verify the output with an oscilloscope.
Add functionality to generate a variable output, e.g. based on input to the ADC.



Figur 5 WaveDAC8 komponent

Experiment with the WaveDAC8. It can be used to generate arbitrary waveforms, so basically, you can implement a function generator with the PSoC. Verify the output with an oscilloscope.