INF5470, exercise 3: Building an Adaptive Photo Cell

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Abstract

This exercise is to build an adaptive optical sensor, that shares some properties with the retinal cells in our eye.

1 Tools

- **Oscilloscope HP54622D**
  A manual can be found in the lab. *DO NOT REMOVE IT!* Only consult it in the lab. Traces can be loaded to the computer via the GPIB interface or using floppy disks. The GPIB bus interface can be handled by matlab functions. You must tell matlab where to find those functions first by setting the search paths correctly. Remember to turn it on first.

  Example session:

```
>> %Add the GPIB tools to the matlab path:
>> addpath(genpath('~mes/src/matlab/gpib/linux'))
>> % Get traces from the oscilloscope:
>> [time,chan] = HP54622_GetData2;
>> % Plot the results:
>> plot(time,chan(1,:),'g',time,chan(2,:),'r');
>> xlabel('Time [s]'); ylabel('Voltage [V]');
```

  This should plot the trace from channel 1 in green and channel 2 in red. *Please note* that both channels on the oscilloscope must be turned on for this script to work. You may use the Run/Stop and Single buttons to find a suitable trace for dumping.)
  Also note that there is a bug in the `HP54622_GetData2` script, in order to not get weird results, you need to make sure that none of the two plots

on the oscilloscope cross eachother's paths. There will be an offset in the plotted graph in matlab, but this can easily be corrected in matlab afterwards.

- **Voltage sources**
  Use the 'Agilent E3631A' triple output voltage source. It has two independent voltage outputs. Use the one labeled with +6V for the one bias voltage that is needed and the +25V for the power supply.

- **Agilent 34401A multi-meter**
  The 34401A is a multi-meter that you can use to verify that constant voltage are where they are supposed to be.

- **An Agilent 33250A wave form generator**
  Its use is quite intuitive. When you have set a waveform type, a frequency, offset, and amplitude, you also need to activate the 'output'.

- **A bread board**
  The board into which you plug the discrete electronic components to make your circuit. Pins are connected if they are pushed into the same column on the board.

- **A light sensor diode (BPW 34)**
  A data sheet is available from the courses homepage. The pole with the marking bar on the top side is the side you should tie to ground.

- **A red light emitting diode (LED)**
  Note that it has a built in serial resistor. Make sure to use a red LED: the light sensor is actually reacting optimally to infra red light.

- **Schottky diodes**
  Or normal bipolar diodes.

- **CMOS transistors**
  The Motorola chip MC14007UB contains 6 transistors, 3 NFETs and 3 PFETs. A data sheet can be found on the course's web site. It shows which pins are to be used as bulk, source, drain, and gate. Note that not all terminals are independently usable on all transistors: some are connected to others on-chip.

- **Capacitor**
  Be very careful with tantal capacitors! They can only used with the right polarity. A huge negative voltage over a tantal capacitor can even burst the capacitor physically and endanger eyes and skin of people nearby. If you need to have both negative and positive voltages across a capacitor, another type of capacitor must be used. (The capacitors provided in the course's cmponent box are not tantal.)

Always clean up the lab after your time slot, such that the next group can use the equipment! You may however keep the bread board with your setup from lab day to lab day. Only, please, do not forget to clean it up and put all components back to where they belong after the lab is finished!

2 Task

2.1 Build a photo cell with logarithmic voltage output

Use the discrete components on the bread board to build an simple photo cell according to the left hand schematic in figure 7.9 in the lecture script. Set Vdd at 5V. Use a voltage around 4V as the bias voltage on the NFET.

Try to make the room as dark as possible and use the red LED over the photo sensor as a controlled stimulus. *Note that the photodiode is sensitive to noise from the light sources, especially 50Hz from the lightbulbs AC supply.* LEDs emit light of an intensity proportional to the current that flows through them (just like light diode sensors produce current proportional to light intensity). Since this LED contains a built in resistor, the current flow should be roughly proportional to the voltage across the diode. But one can expect a little offset, i.e. current will only start to flow at a certain voltage across the LED and increase almost perfectly linearly thereafter. Can you say why?

Draw a graph, voltage across LED versus output voltage of your photo sensor circuit. Does the curve correspond with your expectations?

2.2 Build an adaptive photo cell

This task is to build an adaptive photo cell according to figure 7.15 in the script. Unfortunately the properties of the discrete building blocks that are available for this exercise are quite different from the ones in integrated circuits: the photo diode supplies a rather big current and the transistors seem to have little gain. And its somewhat impractical to implement the non-linear element with a pFET. Thus, the circuit needs to be adapted:

- To get a good amplification, replace the common source amplifier with an operational amplifier (the package ICL7621). Think about how to connect the operational amplifier appropriately.
- Use diodes to build a non-linear element (NLE) that has similar properties as the NLE discussed in the lecture script.

Draw your schematic in the report. Indicate what capacitor sizes you used. Put the LED directly on the sensor and supplyi a square wave to the LED from the waveform generator. You should be able to see some of the effects of the adaptive photo cell. What are those? Document your observations with traces from the scope.