INF5470, exercise 1: Building an Integrate-and-Fire Neuron

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Abstract

This first exercise is meant to introduce the students to work with electronic equipment in circuit testing and to the somewhat unusual use of analog electronics for neuromorphic designs.

1 Tools

- **MATLAB**
  We will be using MATLAB for all excersises and you should bring a working knowledge to this course. If you have none, get a crash course from a fellow student who has used it! It is a powerful mathematics tool with a command line interface. One useful function is 'help'. 'help <command_name>' will display an explanation on how to use '<command_name>'. Another help function that helps you find functions that you do not know the exact name of is 'lookfor'. Type 'help lookfor' to learn more.

- **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. The GPIB bus interface can be handled by matlab functions. To make matlab work with the GPIB interface you must first follow the steps on the following webpage:
  `http://nano.wiki.ifi.uio.no/GPIB`

  You must tell matlab where to find those functions first by setting the search paths correctly. Remember to turn it on first.

  Example session (Lines beginning with '%' are comments and are ignored by MATLAB):

```
>> %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.

Sometimes the GPIB system fails. If this happens you may have to restart
MATLAB and switch off and on the Lab equipment before continuing.
More help for the lab equipment is available from the course pages for
INF3410/4410.

- **Voltage sources**
  There are two kinds, the 'Agilent E3631' and the 'Keithley 236'. The
  second is actually quite a bit more than just a voltage source and probably
  a bit more complicated to handle, but it will not be needed in this exercise.
  If you still wish to use it, make sure it is set to 'source V/ measure I' mode.
  A tri-pole cable from its back delivers the voltage between the red and the
  black clamp. You can ignore the green clamp. After you set the voltage
  you also have to hit the 'operate' button and the 'trigger' in order for it
  to be active.

  You may use the E3631 as both a power supply and to set a constant
  input voltage. It is preferable to use the +25V Channel to set the power
  supply voltage, and the 6V channel to set an input voltage beacause it
  has a finer resolution.

  Example session to initialize GPIB interface to HPE3631 and set its output
  voltage through MATLAB:

  ```
  >> HPE3631_Init;
  >> HPE3631_SetILimit(1,0.1);
  >> HPE3631_SetVolt(1,1);
  >> HPE3631_Operate;
  ```

  This should set the HPE3631 6V channel to 1 Volts. The `HPE3631_SetILimit()`
  command sets a current limit of 0.1 Ampere.

- **Multimeters**
  Keithley 6512/617 and Agilent 34401A are a multi-meters that you can
  use to verify that constant voltages are where they are supposed to be.
  Remember to turn off the zero check on the Keithley before use.

- **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.

- **CMOS transistors**
  The IC that contains a set of individual transistors is labeled 'MC14007UBCP'. A data sheet will be available in the lab or through the course pages that shows which pins are to be used as bulk, source, drain, and gate.

- **CMOS inverters**
  The IC is labelled '74HC04N'. Again a data sheet will tell you more about the pinout.

- **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.

- **Potentiometer operated as tweakable voltage source**
  If the Keithley or the HP is to cumbersome to use as a voltage source you may also just use potentiometers as resistive voltage dividers between Vdd and Gnd.

Always clean up the lab after your time slot, such that the next group can use the equipment!

2   Task

You are required to execute the following tasks and to submit a report on your work. Supply the report with drawings of the circuits (including the values of the components you use, e.g. the capacitors, currents) and measurement setups, and show your measurements in graphs!

2.1   Build an Integrate-and-Fire neuron

Use the discrete components on the bread board to build an integrate-and-fire neuron according to figure 4.8 in the lecture script. Use an additional transistor with a fixed gate voltage (provided by either the E3631, Keithley or a potentiometer) as a current source. (Question: Why might it not be a good idea to use an unlimited 'ideal' current source?) Show traces of the working neuron's membrane potential and output.

If you would like to use this device to encode the input current in the output frequency, how are you limited with respect to DC input currents? Illustrate your answers with traces from the oscilloscope. How would you be limited with
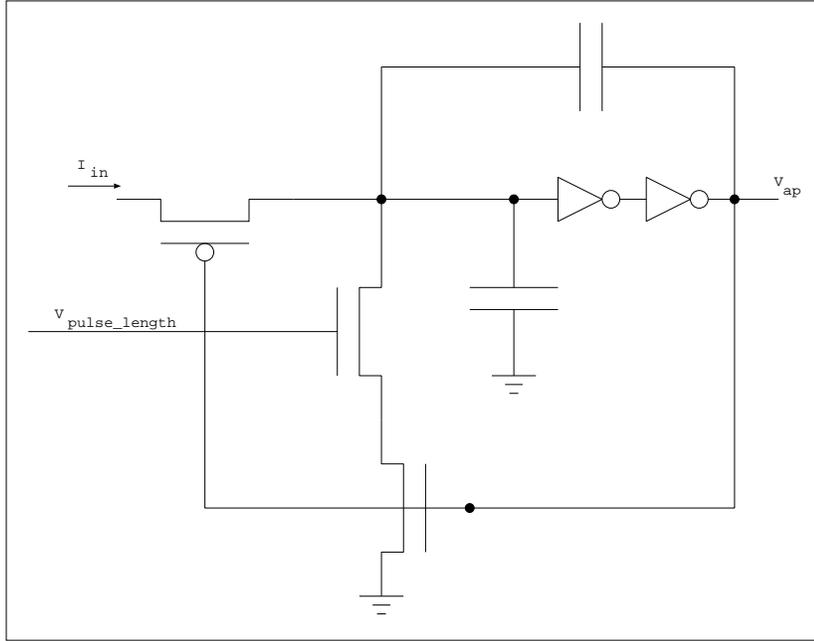
Figure 1: Integrate-and-fire neuron from the lecture notes

respect to AC inputs (i.e. if you have a changing positive current)? You do not have to show this last question experimentally, since we do not have a good AC current source available. Just try to reason it out.

Write a report that answers the raised questions and illustrate your conclusions!

2.2 I&F neuron with refractory period

Biological neurons have a so called refractory period. This is a period after an output pulse during which the neuron is unable to fire, irrespective of how big the input current is during that time. This is one way to set an upper limit to the pulse frequency of a neuron.

Try to extend the I&F neuron such that it has a refractory period. You do not need to implement it on the bread board, just draw the schematics and explain how it works. Keep it as simple as possible. (Maybe you can briefly veryfy with a simulation, that it really does work.) We will discuss the different solutions in class.