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BME/ELC 4372
Bioinstrumentation Laboratories

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Contents

1	Raspberry Pi	3
1.1	GIT	3
1.2	Das Blinken LED	4
1.3	Das Blinken LED II	6
1.4	Das Blinken LED III	6
2	One Wire Thermometer	9
2.1	Add One Wire Support	9
2.2	Test It	9
2.3	Code It	9
3	Op Amps	11
3.1	MCP 3008	11
3.2	Follower	12
3.3	Inverting Amplifier	12
4	Electro-X-Gram	13
4.1	Setting up the Raspberry Pi	13
4.1.1	Adding the Arduberry	13
4.1.2	Olimex EKG/EMG Shield	13

Lab 1

Raspberry Pi

Over the course of this semester we will be building a variety of medical and biological sensors. We will be using the Raspberry Pi as our microcomputer to control them, because of its ease of use, large number of IO pins, and tons of example code to build on. In this lab we will be introducing the Raspberry Pi and how to use it. I am going to try to do most things in Python, due to its simplicity and extensibility, but I can't guarantee we won't have to do a little programming in another language.

One thing I really want to bring to your attention is the use of **git**. Git is a version control system (VCS), that was designed by Linus Torvalds to handle the development of Linux. I will be maintaining a git repo at github, which means you will be able to clone it and do a pull any time you want to update it. You do not have to use git, it just saves time and is a good skill to know for industry.

1.1 GIT

```
mkdir code
```

```
cd code
```

```
git clone https://github.com/BaylorBMEELC4372BioInstrumentation/labs.git
```

```
cd labs
```

```
ls
```

To update from the main repository, just do a pull

```
git pull
```

More sample code can be found by:

```
cd /code
```

```
git clone http://github.com/adafruit/Adafruit-Raspberry-Pi-Python-Code.git
```

```
cd Adafruit-Raspberry-Pi-Python-Code
```

1.2 Das Blinken LED

- Raspberry Pi (with keyboard, mouse, monitor, cobbler, and breadboard)
- 220 Ω - 330 Ω Resistor
- LED

First you need to assemble the circuit. Hook up a wire from a gpio pin to the anode (long leg) of the diode, then connect the resistor to ground. The resistor limits the current flow. The Pi will output 3.3V and the diode will cause about a .7V drop resulting in a 2.6V drop left over. The remaining 2.6V flowing through around 220 Ω to 330 Ω will result in around 10mV, which is enough to light the LED but not cause problems sinking or sourcing the current for the Pi. Generally be careful with more than 20mV - 30mV for an IC.

Boot the Pi by plugging it in. When the desktop appears, launch a terminal either from the menu or the terminal button. Type the following line to edit the code to turn on and off with a timer.

```
sudo nano das_blinken_light.py
```

Note that nano is a small editor, hence the cute name. You are welcome to use any editor you like. You should see something that looks like Code 1.1. The only thing you have to edit is the gpio pin number to match the one you used, see Figure 1.1.

Listing 1.1: Blink the Light.

```
# das_blinken_light.py

import RPi.GPIO as GPIO
import time

ledPin = 23

GPIO.setwarnings(False)
GPIO.setmode(GPIO.BCM)
GPIO.setup(ledPin, GPIO.OUT)
GPIO.output(ledPin, GPIO.LOW)





















try:
    while True:
        GPIO.output(ledPin, GPIO.HIGH)
        time.sleep(1)
        GPIO.output(ledPin, GPIO.LOW)
        time.sleep(1)
except KeyboardInterrupt:
    GPIO.cleanup()
```

To run the code you need to type the following in the terminal window.

```
sudo python das_blinken_light.py
```

You need sudo to give enough permission to access the gpio pins. The LED should blink on for a sec and off for a sec.

Figure 1.1: Raspberry Pi 2 General Purpose Input Output (GPIO) pinout.

Raspberry Pi2 GPIO Header				
Pin#	NAME		NAME	Pin#
01	3.3v DC Power		DC Power 5v	02
03	GPIO02 (SDA1 , I ² C)		DC Power 5v	04
05	GPIO03 (SCL1 , I ² C)		Ground	06
07	GPIO04 (GPIO_GCLK)		(TXD0) GPIO14	08
09	Ground		(RXD0) GPIO15	10
11	GPIO17 (GPIO_GEN0)		(GPIO_GEN1) GPIO18	12
13	GPIO27 (GPIO_GEN2)		Ground	14
15	GPIO22 (GPIO_GEN3)		(GPIO_GEN4) GPIO23	16
17	3.3v DC Power		(GPIO_GEN5) GPIO24	18
19	GPIO10 (SPI_MOSI)		Ground	20
21	GPIO09 (SPI_MISO)		(GPIO_GEN6) GPIO25	22
23	GPIO11 (SPI_CLK)		(SPI_CE0_N) GPIO08	24
25	Ground		(SPI_CE1_N) GPIO07	26
27	ID_SD (I ² C ID EEPROM)		(I ² C ID EEPROM) ID_SC	28
29	GPIO05		Ground	30
31	GPIO06		GPIO12	32
33	GPIO13		Ground	34
35	GPIO19		GPIO16	36
37	GPIO26		GPIO20	38
39	Ground		GPIO21	40

Rev. 1
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<http://www.element14.com>

1.3 Das Blinken LED II

- all the previous parts
- switch

Hook up with switch or button to ground. The Broadcom chip that runs the gpio for the Pi has the ability to connect a pullup or pulldown resistor to an input. We will thus use a pullup resistor, and the button will pull it down to ground when pressed.

We will now write code to read input and blink led if the button isn't pressed. Type in:

```
sudo nano das_blinken_light_II.py
```

You can also refer to the GitHub repository, if need be.

Listing 1.2: Blink the Light while the button is not pressed.

```
# das_blinken_light_II.py

import RPi.GPIO as GPIO
import time

ledPin = 4
butPin = 22

GPIO.setwarnings(False)
GPIO.setmode(GPIO.BCM)
GPIO.setup(ledPin, GPIO.OUT)
GPIO.setup(butPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.output(ledPin, GPIO.LOW)

try:
    while True:
        GPIO.output(ledPin, GPIO.input(butPin))
        time.sleep(.1)
        GPIO.output(ledPin, GPIO.LOW)
        time.sleep(.1)
except KeyboardInterrupt:
    GPIO.cleanup()
```

```
sudo python das_blinken_light_II.py
```

1.4 Das Blinken LED III

One last thing for today is to dim the led. The Raspberry Pi does not have an A/D converter, so we will just deal with two levels based on the button. We also only have one pulse width modulated output on Broadcom (BCM) pin 18, which is Board pin 12. Lack of A/D converters is one of several reasons it is not a replacement for a micro-controller, the main one being it doesn't have a real time operating system (RTOS) and lacks the necessary timers, like watchdog timers, to build one. If you ever need a micro-controller then use an Arduino, MSP430, or similar. The Pi has a bunch of advantages too in standard tools, quad core, and so on. We care more about the later for labs and testing. If you ever build patient used tools, get a micro-controller as you need the RTOS.

Getting back to the point, we want to have the LED on all the time now, and we will dim it when the button is pushed. To handle the diming, we will use a pulse width modulator. We will set the frequency to 50Hz, which is a reasonable refresh rate, and will use the duty cycle (percent of the wave that is high) to control the brightness. This is a simple and standard way to handle this. Type in:

```
sudo nano das_blinken_light_III.py
```

You can also refer to the GitHub repository, if need be.

Listing 1.3: Dim the Light while the button is pressed.

```
# das_blinken_light_III.py

import RPi.GPIO as GPIO
import time

ledPin = 18
butPin = 22

GPIO.setwarnings(False)
GPIO.setmode(GPIO.BCM)
GPIO.setup(ledPin, GPIO.OUT)
GPIO.setup(butPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)
pwm = GPIO.PWM(ledPin, 50)
pwm.start(100)

try:
    while True:
        if GPIO.input(butPin):
            pwm.ChangeDutyCycle(100)
        else:
            pwm.ChangeDutyCycle(25)
except KeyboardInterrupt:
    pwm.stop()
    GPIO.cleanup()
```

```
sudo python das_blinken_light_III.py
```


Lab 2

One Wire Thermometer

2.1 Add One Wire Support

First you need to edit the boot configuration file to add one wire support.

```
sudo nano /boot/config.txt
```

Scroll to the bottom (use the down arrow), then type **dtoverlay=w1-gpio**. Save by typing **ctrl-o** then exit with **ctrl-x**.

Now reboot to make your changes active.

```
sudo reboot
```

2.2 Test It

```
sudo modprobe w1-gpio
```

```
sudo modprobe w1-therm
```

```
cd /sys/bus/w1/devices
```

```
ls
```

Note that the next directory has a really long name, and incorporates the device number so it is not constant on all systems. This allows multiple to be connected.

```
cd 28*
```

```
cat w1_slave
```

2.3 Code It

Listing 2.1: Read from a One Wire Thermometer.

```
import os
import glob
import time

os.system('modprobe w1-gpio')
os.system('modprobe w1-therm')

device_folder=glob.glob('/sys/bus/w1/devices/28*')[0]
device_file=device_folder+'w1_slave'

def read_w1_file():
    f=open(device_file, 'r')
    lines=f.readlines()
    f.close()
    return lines

def read_temp():
    lines=read_w1_file()
    while lines[0].strip()[-3:] != 'YES':
        time.sleep(0.2)
        lines=read_w1_file()
    temp_loc=lines[1].find('t=')
    if temp_loc != -1:
        temp_string=lines[1][temp_loc+2:]
        temp_c=float(temp_string)/1000.0
        temp_f=temp_c*9.0/5.0+32.0
        return temp_c, temp_f

while True:
    print(read_temp())
    time.sleep(1)
```

Lab 3

Op Amps

3.1 MCP 3008

The MCP 3008 is an 8 channel, 10 bit A/D converter that is bus addressable. Communication is through a SPI bus. Our Raspberry Pi has hardware support¹. There are four code sequences I have provided:

1. mcp3008bitbang.py - slow software SPI bus. Don't use, this is only for reference if you don't have a system with hardware support.
2. mcp3008hw.py - fast hardware SPI bus. outputs values on command line to 3 decimal places. Good for getting precise values, but bad for lots of values.
3. mcp3008plot.py - hardware SPI bus that plots the results on a graph. Tends to be slow because it has to sample and plot.
4. mcp3008plot-thread.py - multi-threaded hardware SPI bus that plots the result on a graph. Yes I was having fun... This has three threads, one that reads, one that outputs a square wave, and one that plots. Syntax for the plot commands follows MatLab standards. Fast and oh so much fun.

These of course require library support so we have written an install shell script. You will need to navigate to where it is located, change its permissions so it is executable, then run it. From a terminal window type:

```
cd /code/labs/labs

chmod 755 install_python_libs.sh

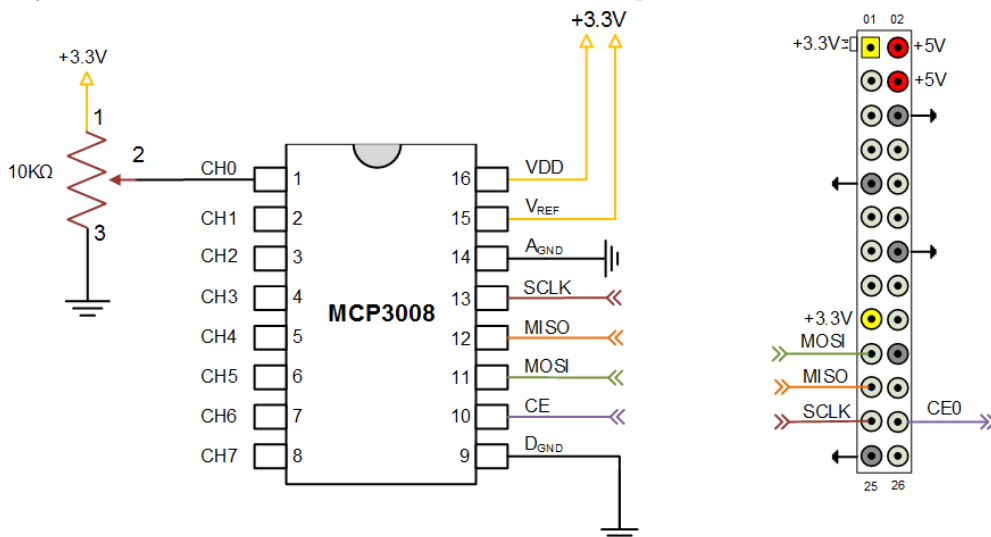
./install_python_libs.sh
```

The mcp3008 has an analog power reference(Vref) and ground and a digital power (Vdd) and ground. Vdd must always be connected to 3v3 (3.3V) and its ground (pin 9) to ground. Vref and analog ground define the voltage range to compare. Often this is the same, but it doesn't have to be. For instance connecting to 5v gives a bigger swing. Remember that the chip only has 10 bits of precision (just over 1000 divisions) and thus the precision is:

$$\frac{V_{ref} - A_{gnd}}{2^{10}}$$

¹If you had a controller that didn't have hardware support you would have to implement it in software, which is very slow and called bit banging. I have included a bit banging code for your reference in the code part of lab 3.

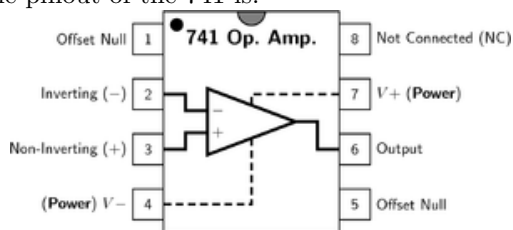
Thus the larger the reference swing, the less precise the measurement. If you want to measure something small, you should have a small reference! The basic hookup is thus



Note the voltage divider on the left is only for testing and does not need to be done each time. You will build the divider the first time to test your code and setup. The 8 pins on the left are now available for measuring your circuit.

3.2 Follower

We will be using a general purpose 741 Op Amp. We will connect the positive rail to 3v3 and the negative rail to ground. Hook the output to the negative input and the signal to follow goes on the positive input. The pinout of the 741 is:



3.3 Inverting Amplifier

Note we thus can't get negative voltages, but we have no choice since we don't have a negative voltage. We can make a new reference ground by a voltage divider between 5v and ground with identical resistors (say around 1k each) or a potentiometer around a few k², so the center will be 2v5. Hook this to the positive input, and the rails should be connected to 5v and ground. Hook the Vref on the MCP3008 to 5v. Now make another potentiometer voltage divider, this time running from the op amp's output to gpio 4, with the central tap going to the op amp's negative (inverting) input.

²hook 5v to one outer pin and ground to the other, the center tap is the reference

Lab 4

Electro-X-Gram

4.1 Setting up the Raspberry Pi

4.1.1 Adding the Arduberry

The Arduberry is a shield that allows Raspberry Pi's to use Arduino shields.

Open a web browser and go to <http://www.dexterindustries.com/Arduberry/getting-started/> and follow the instructions. You will download and install the drivers and run a simple test script that verifies everything is working.

4.1.2 Olimex EKG/EMG Shield

You should not have to perform any installs for this.