Lab 2: External Actuators for Arduino with CircuitPython

A. Trahan, P.E.

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Introduction

This lab provides an overview of using external actuators (output devices) on Arduino with Circuit Python. While there are many built-in actuators on the CPX, there may be additional actuators (like servos) that need to be attached for a given project. In addition, most other Arduino devices don't have as many built-in actuators, so all actuators for a project must be attached externally.

The CPX has a variety of "pins" for inputs and outputs. Instead of traditional pins, the CPX uses alligator clip mounts around the edge of the device. Since these are mapped to pins on the SAMD21 chip on the CPX (the "brain"), and they're actually pins on some Arduino devices, so references will often call them pins. The clip mounts on this device are generally called pads, so we will use that nomenclature. Some pin definitions from the SAMD21 are connected to on-board sensors and actuators, but this lab will focus on the externally accessible pads.

External sensors (inputs) and actuators (outputs) are driven directly by controlling the voltages applied to these pads. This is the only way to interface with custom elements, but for many common elements (e.g. servos), there are libraries that make it eaiser to write code using their functionality.

In this lab we will:

1. Connect directly to CPX pads/pins
2. Add libraries to Circuit Python on the CPX

3. Use external actuators to respond to sensors on the CPX

Required materials (per group):

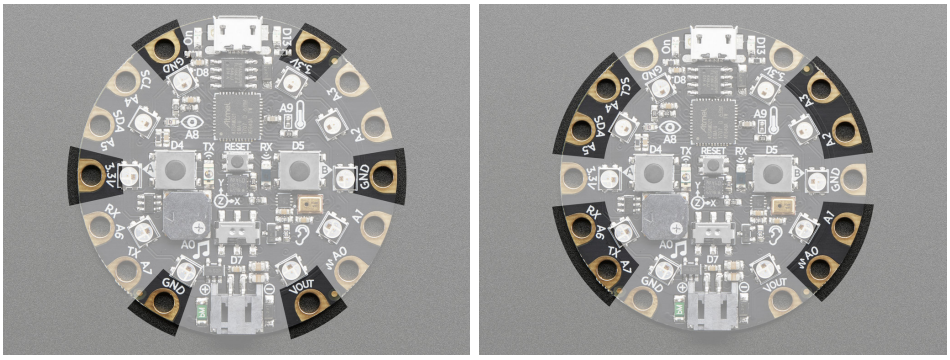
- (1) Circuit Playground Express (CPX)
- (1) Micro USB cable
- (1) Breadboard
- (1) LED (any color)
- (1) Piezometric buzzer
- (1) Servo (SG90)
- (1) Resistor [1 $k\Omega$]
- (1) Resistor [100 Ω]
- Assorted jumpers and alligator clips

1 Connecting to Pads/Pins on the CPX

The CPX has fourteen pads along the edge - six power pads for power/ground and eight I/O pads for signals (Figure 1). A full definition of the pads can be found at the Adafruit website, but a few to note:

1. **GND** - There are three ground pads
2. **3.3V** - There are two 3.3V power pads
3. **Vout** - This pad carries the (higher of) battery or USB voltage, with a 1 Amp fuse
4. **A0** - This is a true analog pin, so it can carry real waves (inc. audio)
5. **A1-A7** - There are three digital I/O pads, many with pulse-width modulation (PWM) and capcitive touch options

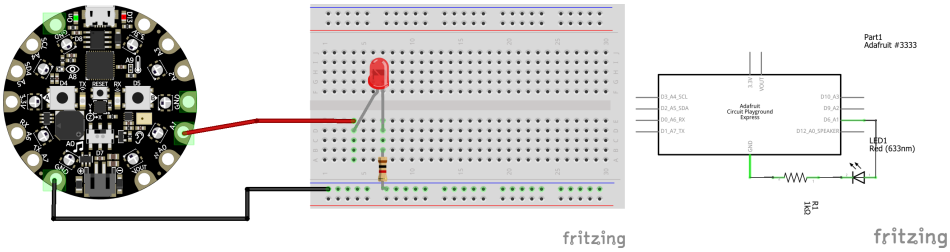
As an example, try connecting an LED to pad A1:



(a) Power Pads (b) I/O Pads

Figure 1: Pads on the CPX for connecting to external sensors and actuators

1. Follow the circuit diagram in 2 to connect an LED to pad **A1**
   (a) Use an alligator clip jumper to connect **A1** to a breadboard row
   (b) Use an alligator clip jumper to connect **GND** to the breadboard ground column
   (c) Connect an LED to the breadboard with positive (long) lead in the same row as the **A1** jumper
   (d) Connect a 10k ohm resistor to the breadboard ground column and the row with the LED negative (short) lead



(a) Breadboard layout (b) Circuit diagram

Figure 2: Diagrams for attaching external LED to CPX

2. Enter the code below in Mu, and save to the CPX as `code.py`. A few things to note:

(a) We import `board` to map python commands to pins/pads

(b) We import `digitalio` to control signals being passed through the pins/pads

(c) To access the pin/pad, create a `DigitalInOut` object connected to it, then assign it a direction (in/out)

(d) This example is available online: Adafruit Digital Outputs Tutorial

3. This can also be controlled live via the REPL console by entering the Serial console and hitting Ctrl-C (**C**ancel). Try entering the command: `led.value = not led.value`

```
#-- ExternalLedBlink.py - CircuitPython code for CPX --#

# Import Section
import board
import digitalio
from time import sleep

# Setup Section
led = digitalio.DigitalInOut(board.A1)
led.direction = digitalio.Direction.OUTPUT

# Loop Section
while True:
   led.value = True
   sleep(0.5)
   led.value = False
   sleep(0.5)
```

2 Adding Libraries for External Actuators

Directly modifying pins provides the most granular control for the CPX, but many actuators and sensors have packages mapping pin control to functionality. For example, in Lab 1, set neopixel brightness with a single command,

even though there are actually several pins involved. Actuator and sensor libraries allow us to focus on coding for functionality and often make code faster to write and easier to read.

As an example, we will install the Circuit Python Library Bundle. Then we will walk through an example using an external buzzer via direct pin control vs. via an I/O library. The following examples were developed using the Adafruit Piezo Buzzer Tutorial.

2.1 Installing the Circuit Python Library Bundle

1. Each version of Circuit Python requires a different bundle. Begin by checking your Circuit Python version

   (a) Open Mu and connect the CPX

   (b) Enter the REPL console by opening the Serial console and hitting Crtl-C

   (c) This will automatically print the current version above the first input line. Note the major version number. As an example, the CPX in Figure 3 is running CircuitPython version 3.

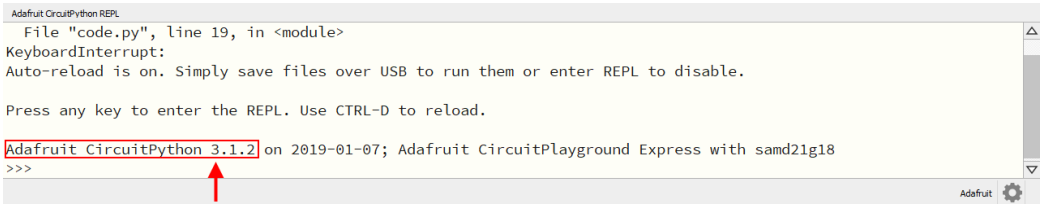


Figure 3: Finding the CircuitPython version with Mu

2. Download the latest version of the bundle for your version from `https://circuitpython.org/libraries` and unzip the bundle.

3. To add a library to the CPX, copy it from the `lib` directory in the bundle into the `lib` directory on the CPX (create one if it does not exist)

4. For the buzzer exercise, we will be using `SimpleIO.mpy`, so copy that into the CPX `lib` directory

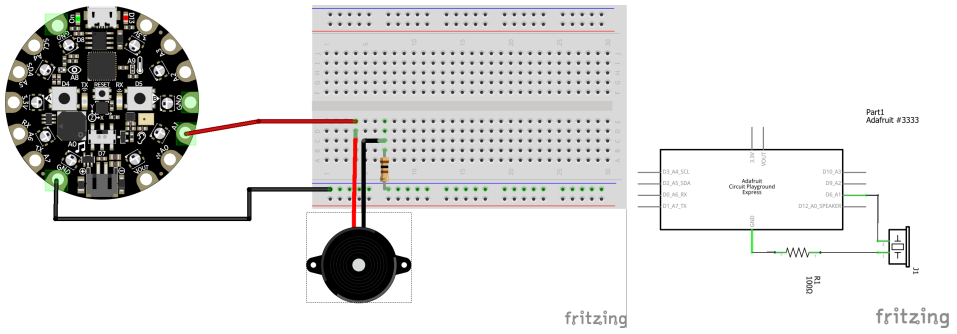
2.2 Using a Buzzer via Direct Pin Control

As a first example, we will run the buzzer using direct pin control. A piezoelectric buzzer has an element that deforms when subjected to a voltage. By turning that voltage on and off, the element oscillates at a chosen frequency, generating a sound. This can be done with a true analog signal (e.g. a sine wave), but most of the pins on an Arduino are digital - they can be on or off. To get around this, many some pins are attached to an oscillator on the device and provide "pulse width modification" (PWM), which turns them on and off at a chosen frequency, emulating an analog signal. The `pulsio` package allows us to control PWM signals over pins.

You can learn more about PWM in the Adafruit PWM Outputs Tutorial.

Try connecting and using a buzzer as an example of PWM control:

1. Connect the buzzer to the CPX. Wiring is very similar to the LED example above, simply change the actuator and the resistor. Lower resistance gives higher volume, so try a 100 ohm resistor. See Figure 4.



(a) Breadboard layout (b) Circuit diagram

Figure 4: Diagrams for attaching external Buzzer to CPX

2. Enter the code below in Mu, and save to the CPX as `code.py`, and note the following:

   (a) We import `pulseio` to control PWM signals being passed through the pins/pads

   (b) To access the pin/pad, create a `PWMOut` object with variable frequency connected to it

(c) The buzzer `frequency` determines the tone it will create

(d) The buzzer `duty_cycle` determines what percent of time power will be on and off. Setting this to 50% maximizes the on/off flipping, which is what drives the buzzer. The `duty_cycle` variable is a 16-bit integer, so half power is approximately 2^{15}.

```
#-- ExternalBuzzerDirect.py - CircuitPython code for CPX --#

# Import Section
import board
import pulseio
from time import sleep

# Setup Section
buzzer = pulseio.PWMOut(board.A1, variable_frequency=True)
buzzer.frequency = 440  # This is an A3
OFF = 0
ON = 2**15

# Loop Section
while True:
   buzzer.duty_cycle = ON
   sleep(1.0)
   buzzer.duty_cycle = OFF
   sleep(2.0)
```

2.3 Using a Buzzer via SimpleIO

The same can be achieved in fewer lines of code using an external library. This is a relatively simple example, so using the library doesn't change much, but for more complicated actuators external libraries can save a lot of time and greatly improve the readability of your code. To drive the buzzer with the `simpleio` library:

1. Be sure the library is installed. The file `SimpleIO.mpy` should be in the CPX `lib` directory, as described above.

2. Use the same connections as the previous example (Figure 4)

3. Enter the code below in Mu, and save to the CPX as `code.py`, and note the following:

   (a) We import `simpleio` to access the library

   (b) `simpleio` has a `tone` function that plays a given frequency through a given pin/pad for a given duration

```
#-- ExternalBuzzerLibrary.py - CircuitPython code for CPX --#

# Import Section
import board
import simpleio
from time import sleep

# Setup Section
freq = 440  # This is an A3

# Loop Section
while True:
   simpleio.tone(board.A1, frequency=freq, duration=1.0)
   sleep(2.0)
```

3 Responding to Sensors on the CPX

Previous examples have run external actuators on schedules set in the code, but often systems will need to respond to sensors. As an example, we will use a servo as a needle gauge to show how bright a room is, as read by the CPX's on-board light detector (Figure 5).

Steps for this example:

1. Install the `adafruit_motor` library by copying it from the bundle to the CPX `lib` directory. Note that this is a directory, not just a single file.

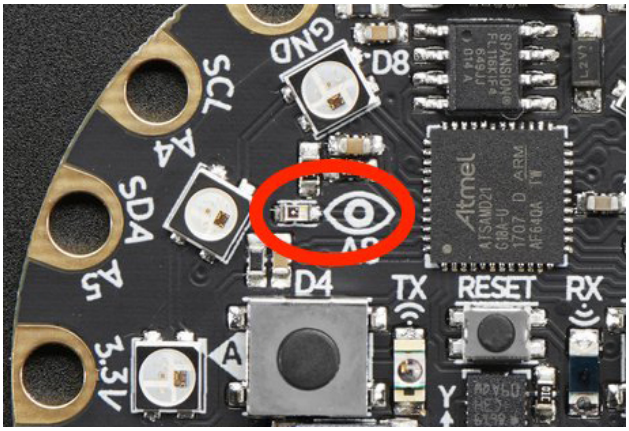
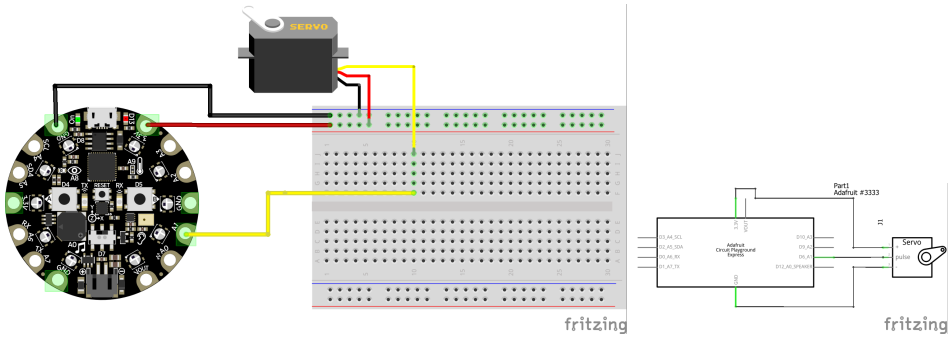


Figure 5: Light sensor on the CPX

2. Connect the servo to the CPX as shown in Figure 6. With so few parts, this can even be done without a breadboard.



(a) Breadboard layout (b) Circuit diagram

Figure 6: Diagrams for attaching external Servo to CPX

3. Enter the code below in Mu, and save to the CPX as `code.py`, and note the following:

   (a) We first need to define a PWM pin with the correct frequency to control the servo (as given in specs).

   (b) We can then attach a `servo` object to that pin. The min and max pulse arguments define the range of the device and may vary

depending on your servo (especially for inexpensive models). If the range of motion seems incorrect, try adjusting these.

(c) There's a new Section, the Function Section, in which we define the conversion between light sensor reading (0 to 320) and the servo position (0 to 180 degrees).

(d) To set the servo position, we read the light sensor (`cpx.light`), map that to a servo position via the function, then set the angle parameter of the servo object.

```
#-- ServoLightGauge.py - CircuitPython code for CPX --#

# Import Section
import board
import pulseio
from adafruit_circuitplayground.express import cpx
import adafruit_motor.servo
from time import sleep

# Setup Section
pwm = pulseio.PWMOut(board.A1, frequency=50)
servo = adafruit_motor.servo.Servo(pwm, min_pulse=750, max_pulse=2600)

# Function Section
def light_to_servo_pos(light):
    light_max = 320
    return 180 - ((light/light_max) * 180)

# Loop Section
while True:
    servo.angle = light_to_servo_pos(cpx.light)
    print(servo.angle)
    sleep(0.5)
```

Additional ideas and questions:

1. How would you change the direction of the gauge? Try programming it such that the needle swings the other direction for light.

2. After the last lab, you're quite familiar with the neopixels. Try programming the neopixels to light up (number or brightness) as the light in the room increases - this is like the automatic brightness response on a cell phone.

3. Extreme brightness can be harmful to the eyes. Try adding a buzzer that chirps when the surroundings are too bright.

4. The CPX has many more sensors (sound, accelleration, etc.). Pick one and make your actuators respond to it instead of the light sensor. Remember the API for the `cpx` module can be found here: Circuit Python cpx Module API.