ENGR 21:
Computer Engineering Fundamentals

Lecture 3
Tuesday, September 09, 2025

Counter Variables (for HW 1)

- For Conway's game of life

```
# Define a counter
x = 0

if (condition1):
    x = x + 1
elif (condition2):
    # don't do anything
elif (condition3):
    x = x + 1
```

Base systems

Decimal, binary and hexadecimal

Base Systems

The decimal system

Digits run from 0 to 9

'Base ten'

The smallest three-digit number is

$10^{3-1} = 100$

The binary system

Digits run from 0 to 1

'Base two'

The smallest three-digit number is

~~$2^{4-1} = 8$~~ $2^{3-1} = 4$

The hexadecimal system

Digits run from 0 to 15. 'Base sixteen'

Invented new 'digits' [0,1,2,...,9,A,B,C,D,E,F] new symbols for 10, 11, 12, 13, 14, 15

The smallest three-digit number is

$16^{3-1} = 256$

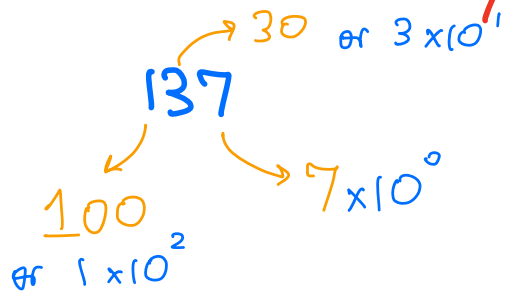
Reminder: How do (decimal) numbers work?

ten

$n^0 = 1$

Number : 137

one hundred and thirty-seven



powers of 10	2	1	0
value :	1	3	7

– we have 3 digits in 137

7×10^0 – how many powers of 10?

3×10^1 +

1×10^2 +

1 → 10 → 100 → 1000

137

place your number

How binary numbers work

Let's write down a 3-digit binary number.

101

powers of 2	2	1	0
value :	1	0	1

$1 \times 2^0 = 1$

$0 \times 2^1 = 0$

$1 \times 2^2 = 4$

$1 + 0 + 4 = 5$ number: five

0b101

convention for binary

6 + 10 = 16

How hexadecimal numbers work

Let's write a 2-digit hexadecimal number

"2D"

powers of 16	2	1	0
value :	0	2	D

$16^0 \times$ "D" : thirteen

$16^1 \times 2$: thirty-two

= forty-five

0	0
1	1
2	2
3	3
⋮	⋮
9	9
A	10
B	11
C	12
D	13
E	14
F	15

45 interpreted hexadecimally mean?

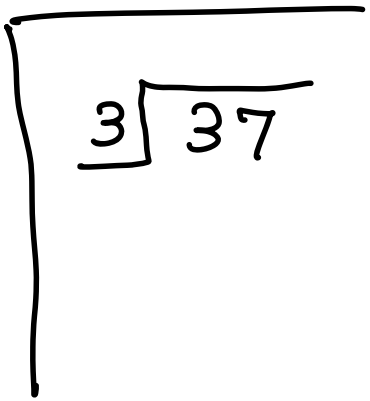
$16^1 \times 4 + 16^0 \times 5 = 69$

0x2D

convention for reminding you it's hexadecimal.

Converting between decimal, binary, and hexadecimal numbers

- Convert 13 from decimal to binary.



- look for closest power of 2.
  - 13 lies between 2^3 and 2^4 : four digits
- successively divide by 2 [integer division]

Division → quotient

quotient remaind. → remainder

Python : "//"

13 ÷ 2 :	1	: least significant bit
6 ÷ 2 :	0	
3 ÷ 2 :	1	
1 ÷ 2 :	1	: most significant bit

1101

Analog vs. Digital data

What does ‘digital’ actually mean?

“ 0’s and 1’s”

Dictionary

Definitions from Oxford Languages · Learn more

dig·i·tal

/ˈdijədl/

adjective

adjective: **digital**

1. (of signals or data) expressed as series of the digits 0 and 1, typically represented by values of a physical quantity such as voltage or magnetic polarization.
   - relating to, using, or storing data or information in the form of digital signals.
     "digital TV"
   - involving or relating to the use of computer technology.
     "the digital revolution"
2. (of a clock or watch) showing the time by means of displayed digits rather than hands or a pointer.
3. relating to a finger or fingers.

Origin

LATIN digitus — finger, toe

LATIN digitalis → digital — late 15th century

late 15th century: from Latin *digitalis*, from *digitus* ‘finger, toe’.

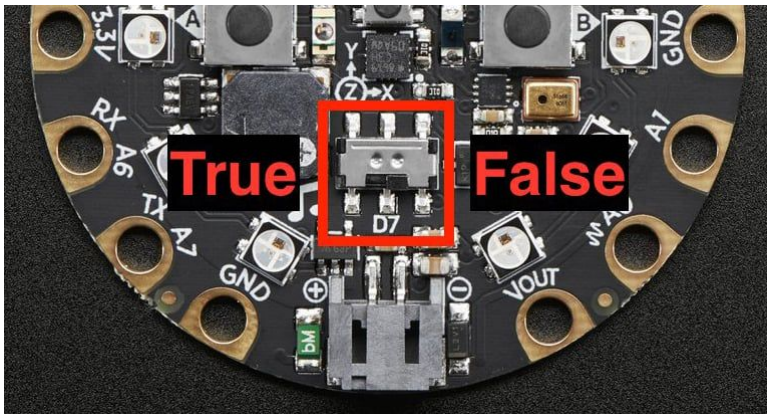
Use over time for: digital

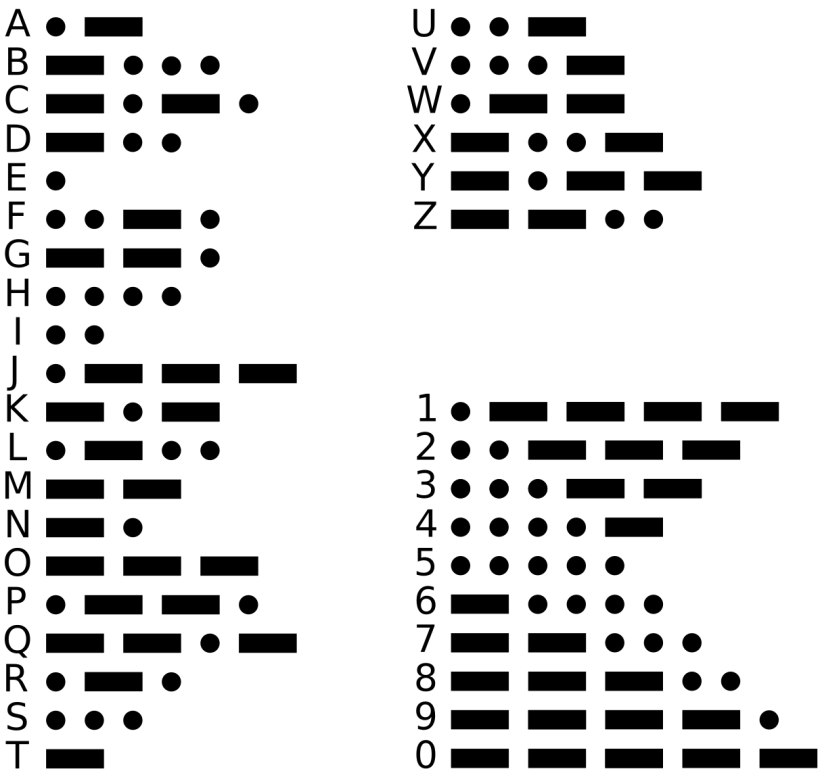
Examples of digital signals

https://morsecode.world/international/translator.html

International Morse Code

1. The length of a dot is one unit.
2. A dash is three units.
3. The space between parts of the same letter is one unit.
4. The space between letters is three units.
5. The space between words is seven units.





What does ‘analog’ mean?

“ anything that’s not 0’s and 1’s “

Dictionary

Definitions from Oxford Languages · Learn more

an·a·log

/ˈanlˌôg,ˈanlˌäg/

adjective

adjective: **analogue**; adjective: **analog**

relating to or using signals or information represented by a continuously variable physical quantity such as spatial position, voltage, etc.
"analog signals"

- (of a clock or watch) showing the time by means of hands rather than displayed digits.
- not involving or relating to the use of computer technology, as a contrast to a digital counterpart.
  "old-school analog paper map skills"

noun

noun: **analogue**; plural noun: **analogues**; noun: **analog**; plural noun: **analogs**

a person or thing seen as comparable to another.
"an interior analogue of the exterior world"

- **CHEMISTRY**
  a compound with a molecular structure closely similar to that of another.
  "thioacids are sulfur analogues of oxyacids"

Origin

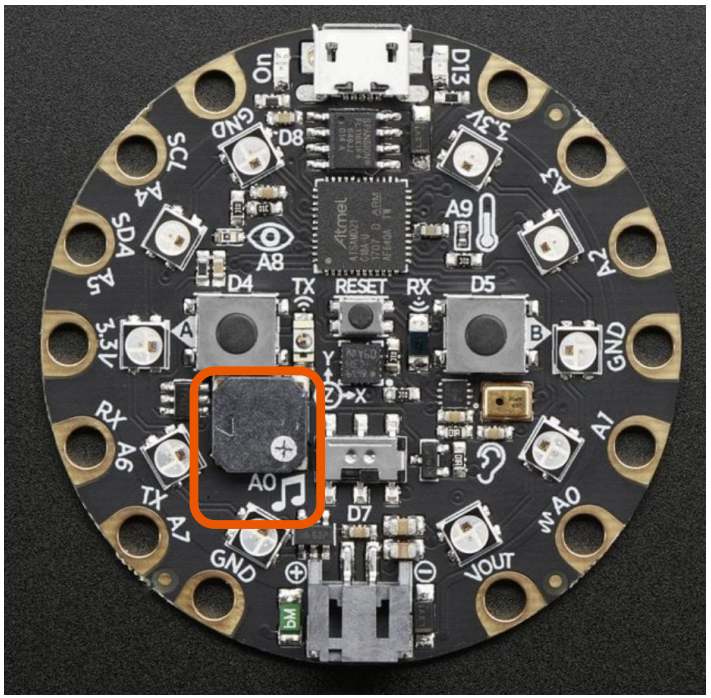
GREEK analogos → GREEK analogon → FRENCH analog (*early 19th century*)

proportionate

early 19th century (as noun): from French, from Greek *analogon*, neuter of *analogos* ‘proportionate’.

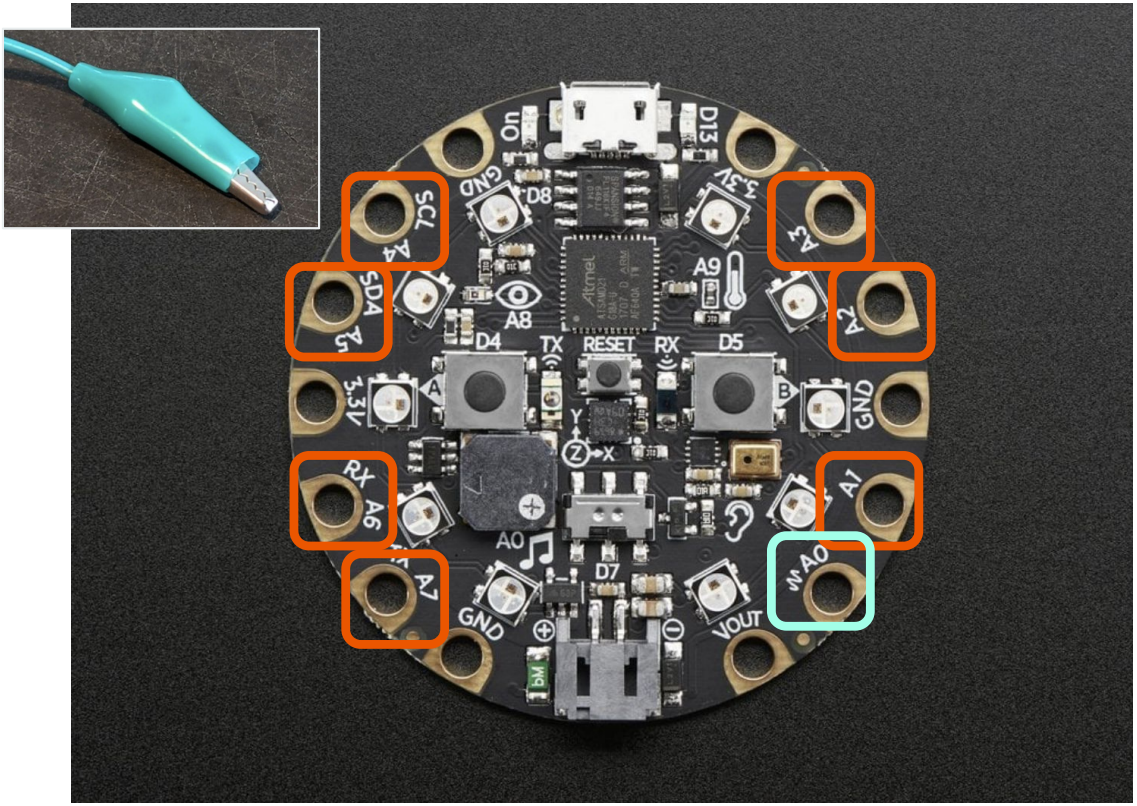
Use over time for: analog

Examples of analog signals



Analog & digital signals in Circuit Playground ~~Express~~ Bluefruit

- Most pins can serve as:
  - Digital input
  - Digital output
  - Analog input
- Special: pin A0
  - Above + Analog output



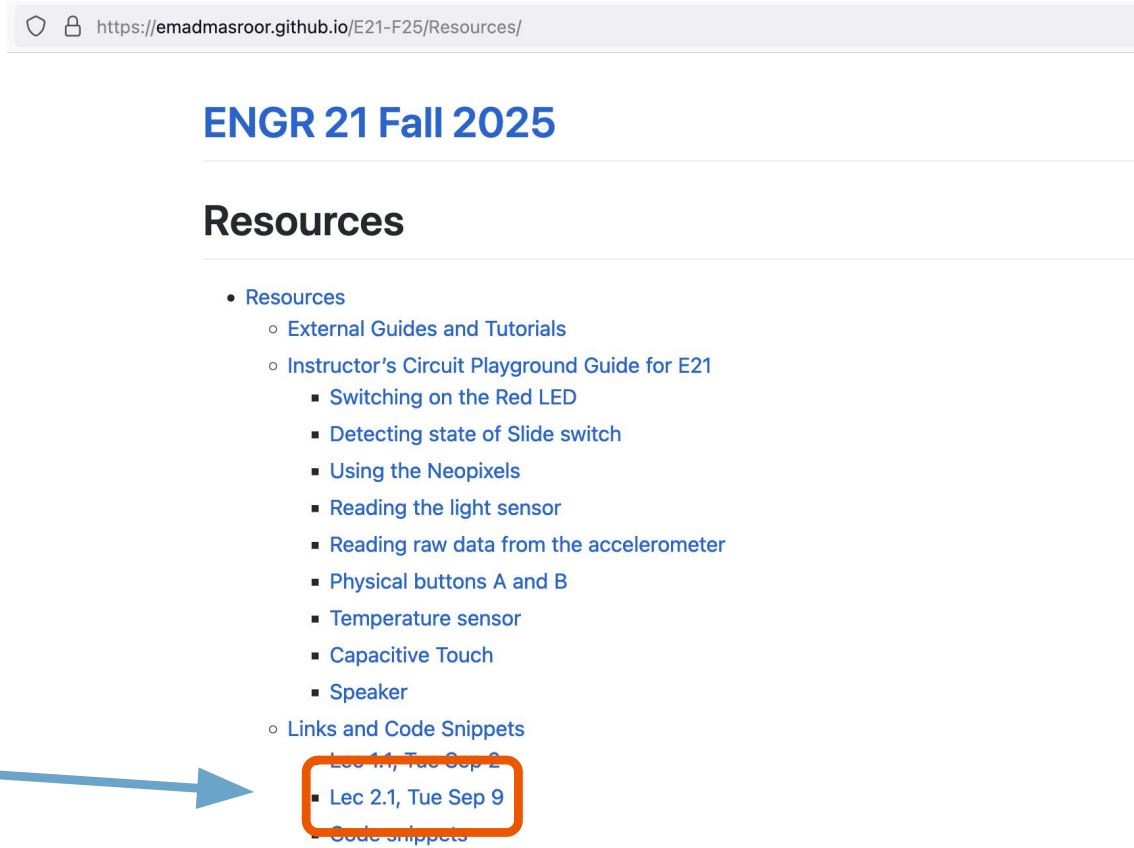
Closer look at digital vs analog

Download files

Zip file containing three * . py files:

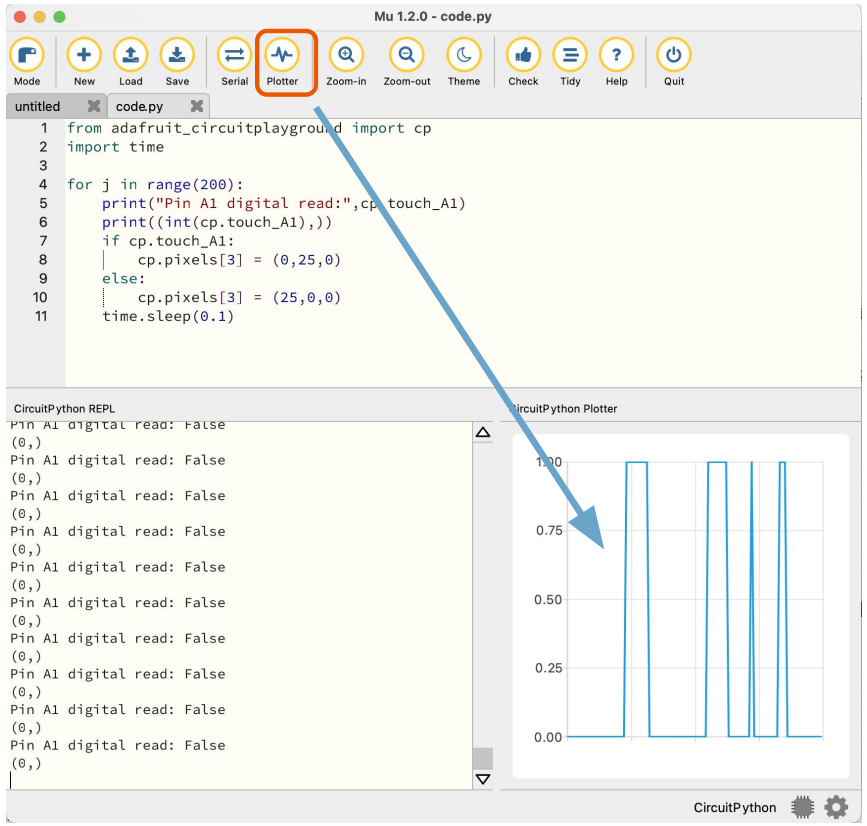
- `read_pinA1_as_analog_input.py`
- `read_pinA1_as_analog_input_v2.py`
- `read_pinA1_as_digital_input.py`

Start with this one



Read pin A1 as digital input

- Copy into your board's code . py file.
- Save; automatically runs
- Touch pin A1 !



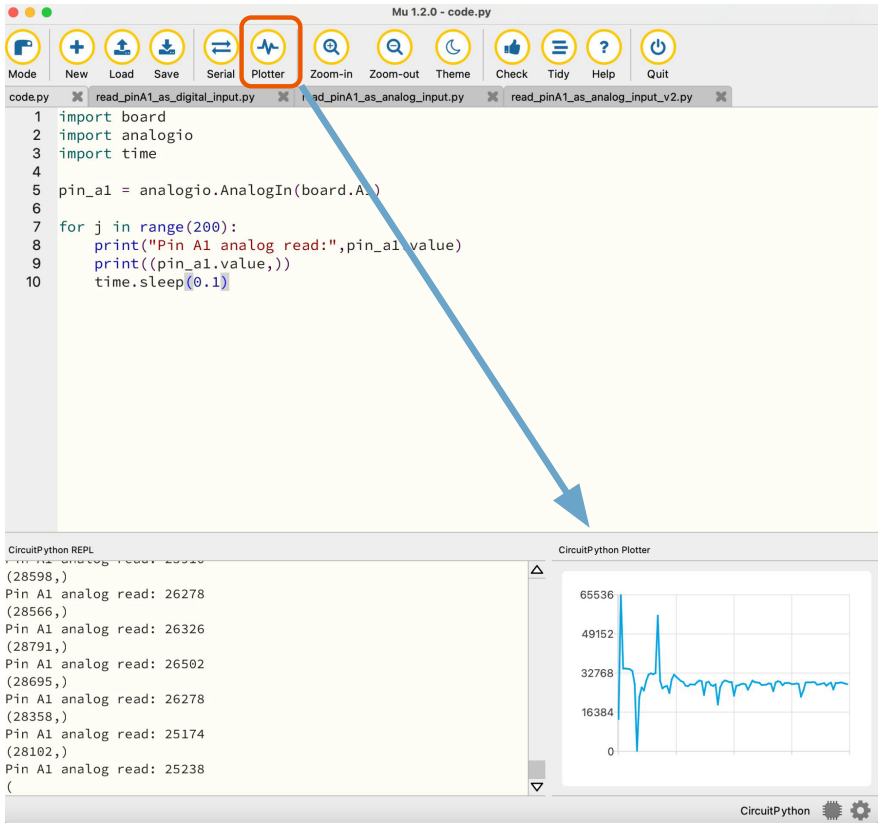

```
from adafruit_circuitplayground import cp
import time

for j in range(200):
    print("Pin A1 digital read:",cp.touch_A1)
    print((int(cp.touch_A1),))
    if cp.touch_A1:
        cp.pixels[3] = (0,25,0)
    else:
        cp.pixels[3] = (25,0,0)
    time.sleep(0.1)
```

indent

file: read_pinA1_as_digital_input.py

Read pin A1 as analog input

- Copy into your board's code . py file.
- Save; automatically runs
- Touch pin A1 !




```
import board
import analogio
import time

pin_a1 = analogio.AnalogIn(board.A1)

for j in range(500):
      print("Pin A1 analog read:",pin_a1.value)
      print((pin_a1.value,))
      time.sleep(0.1)
```

file:
read_pinA1_as_analog_input.py

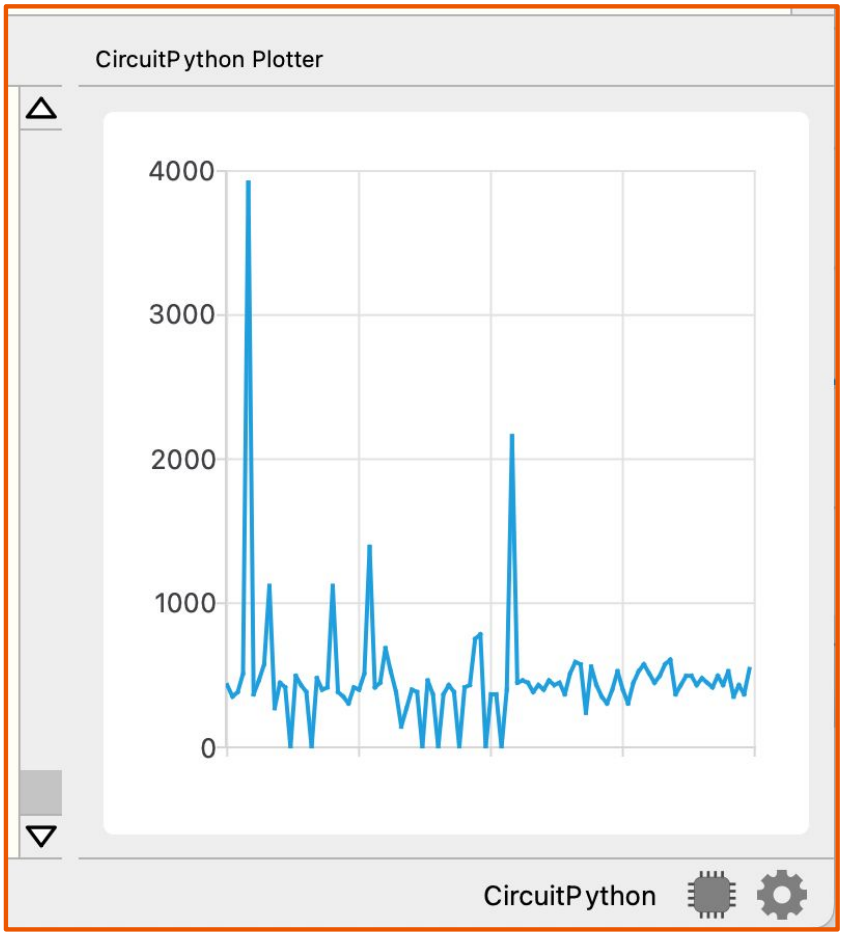
Two different ways to use pins e.g. A1

The same underlying information can be used to create an analog or digital signal!

- Packages:
  - `import board`
  - `import analogio`
- Low-level
- Access to “raw” reading
- Analog

- Packages:
  - `from adafruit_circuitplayground import cp`
- High-level
- No access to “raw” reading
- Digital

Thresholds for analog-to-digital conversion



Read pin A1 as analog input and map to LED

```
# Write your code here :-)
import board
import analogio
import time
import neopixel

pin_a1 = analogio.AnalogIn(board.A1)
pixels = neopixel.NeoPixel(board.NEOPIXEL, 10,
auto_write=False)

for j in range(200):
     print("Pin A1 analog read:",pin_a1.value)
     print((pin_a1.value,))
     mapped_brightness = 150
     pixels[3] = (0,mapped_brightness,0)
     pixels.show()
     time.sleep(0.1)
```

file: read_pinA1_as_analog_input_v2.py