

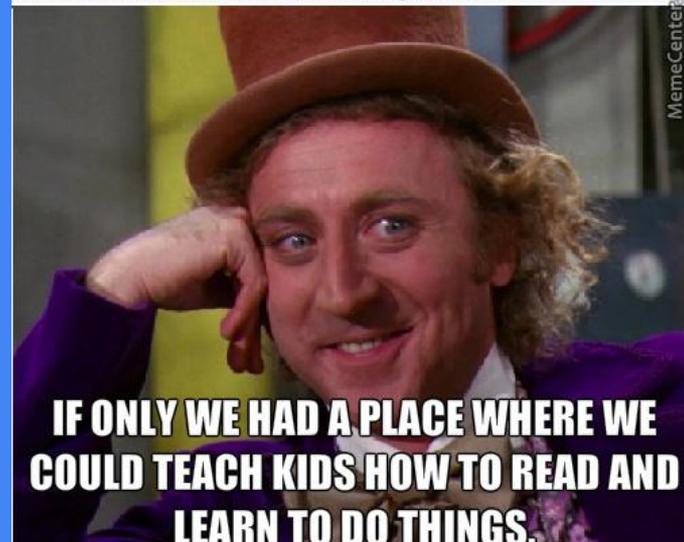
Lab 2: Analog to Digital Circuit Interfaces

EECS 16B Spring 2024

Slides: links.eecs16b.org/lab2-slides



Schools Are Removing Analogue Clocks Because Kids Can't Read Them
As our age becomes more technological, we've become more dependant on the our screens. And this has had a very drama...



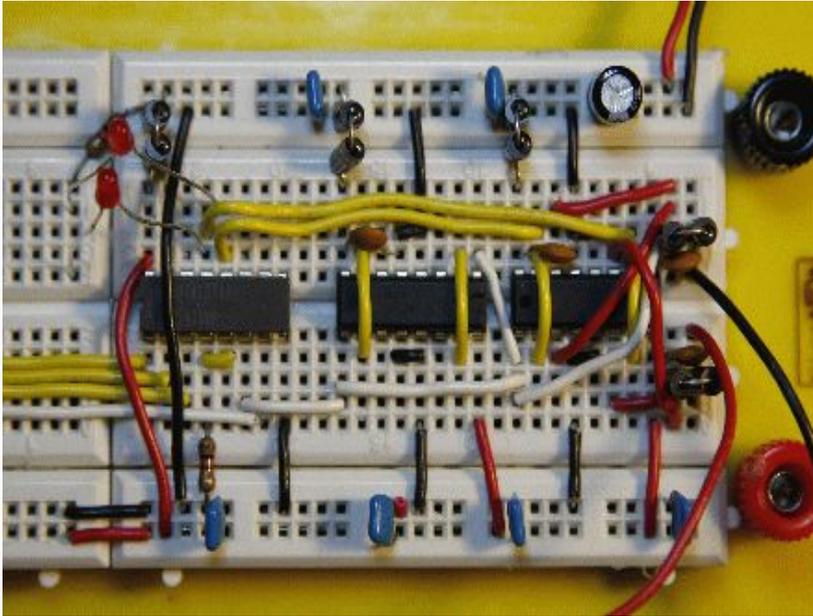
**IF ONLY WE HAD A PLACE WHERE WE
COULD TEACH KIDS HOW TO READ AND
LEARN TO DO THINGS.**

Logistics: Groups

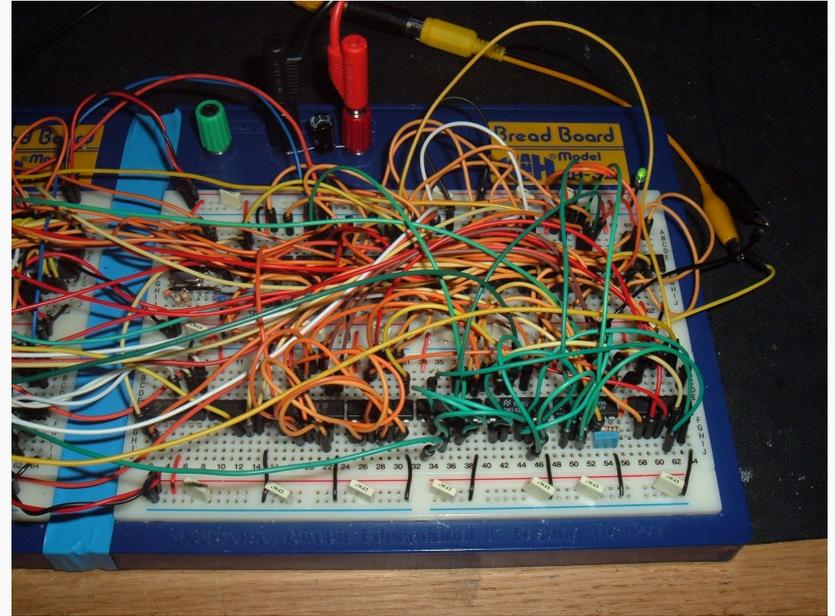
- **Fill out the Lab Group Form** (necessary to receive an Arduino):
<https://eecs16b.org/lab-groups>

Planar Circuits

Planar

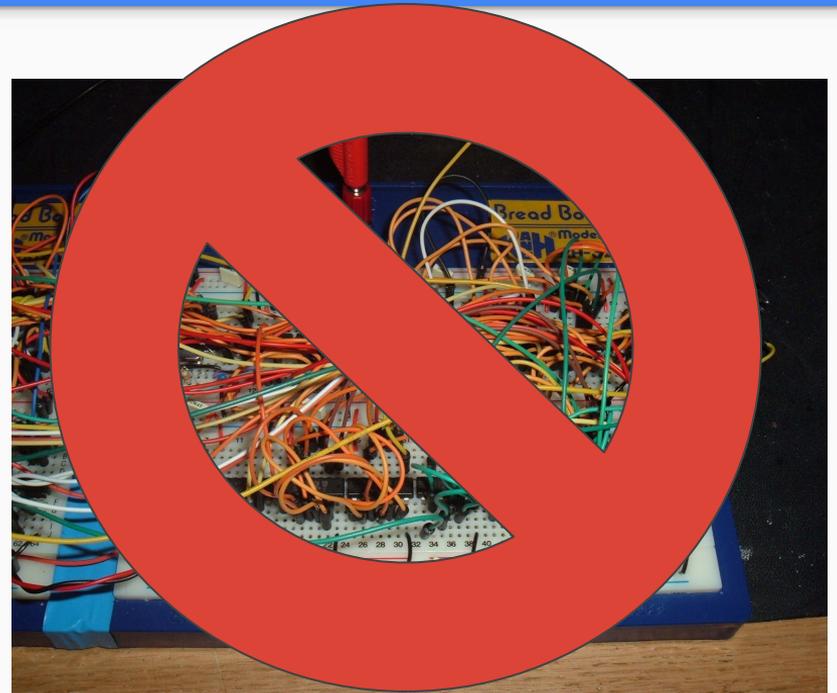
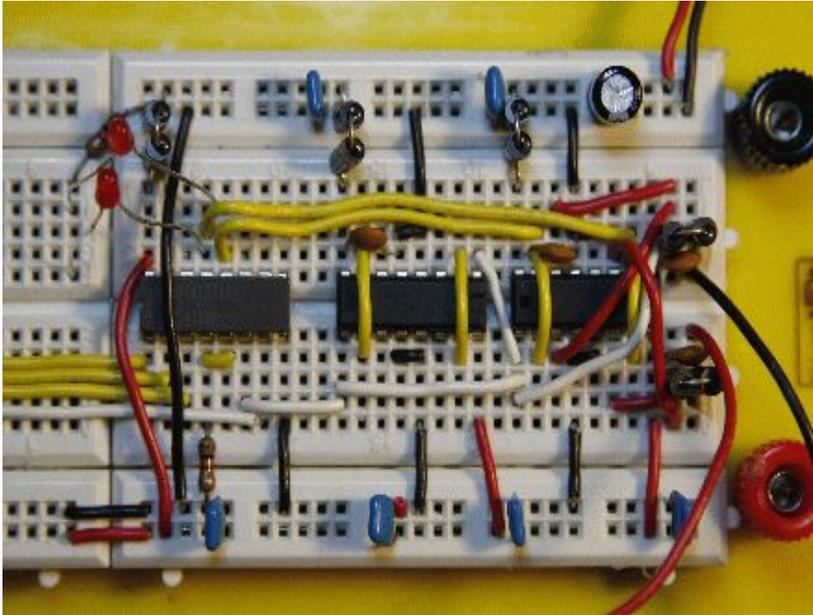


Non-planar



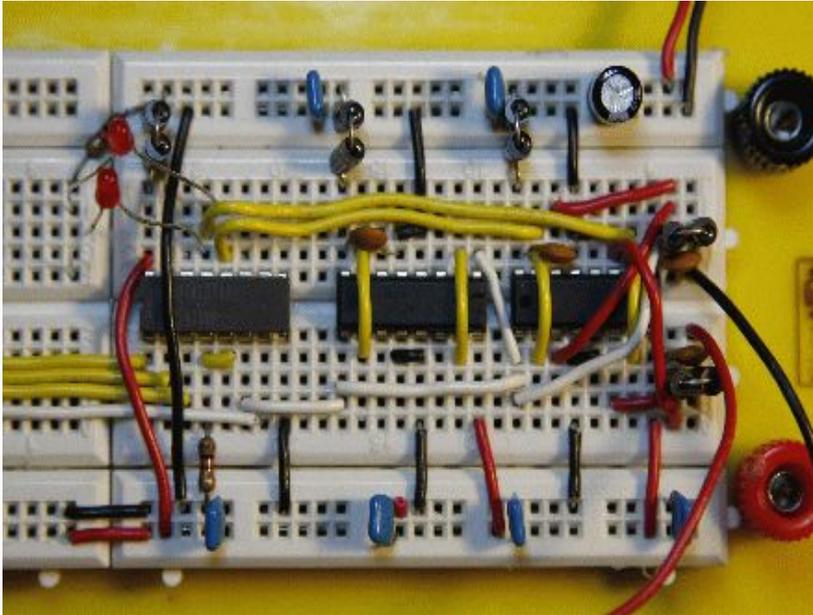
Planar Circuits

Planar



Planar Circuits

Planar



- Planar Circuits are now a **requirement** to:
 - Get help from staff
 - Get checked off
- Tips to create planar circuits:
 - Plan your circuit ahead of time
 - Trim wires to length
 - Cut components to length

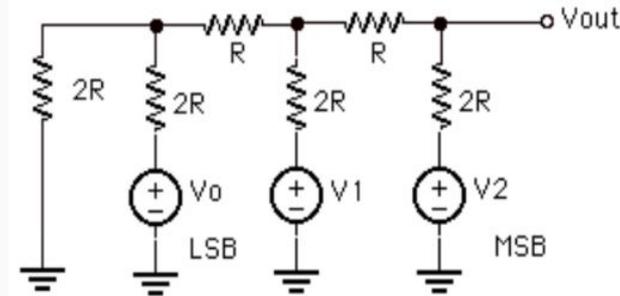
We will ask you to redo your circuit if it is nonplanar

Lab 2 Overview: DAC and ADC

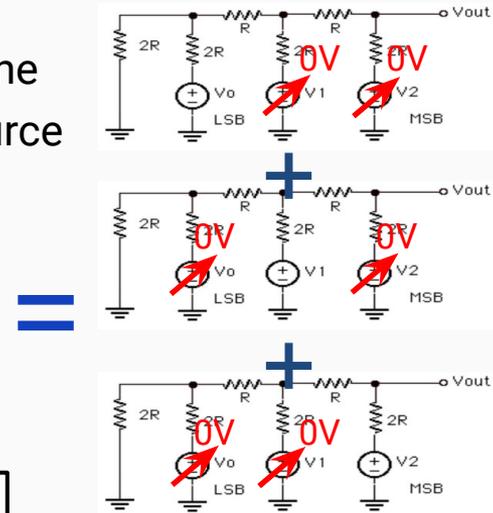
- DAC = Digital to Analog Converter
- ADC = Analog to Digital Converter
- Real world is continuous, but computers need to store data digitally
 - Need to find a way to convert between analog and digital for signals
 - EE 123 discusses consequences of digitally sampling analog signals, EE 140 discusses the design of DACs/ADCs
- DAC/ADC in your life:
 - DAC for MP3 players, analog TVs, video on cell phones
 - ADC for sound/video recording
 - VoIP (voice over IP) uses both!

DAC Review: Superposition

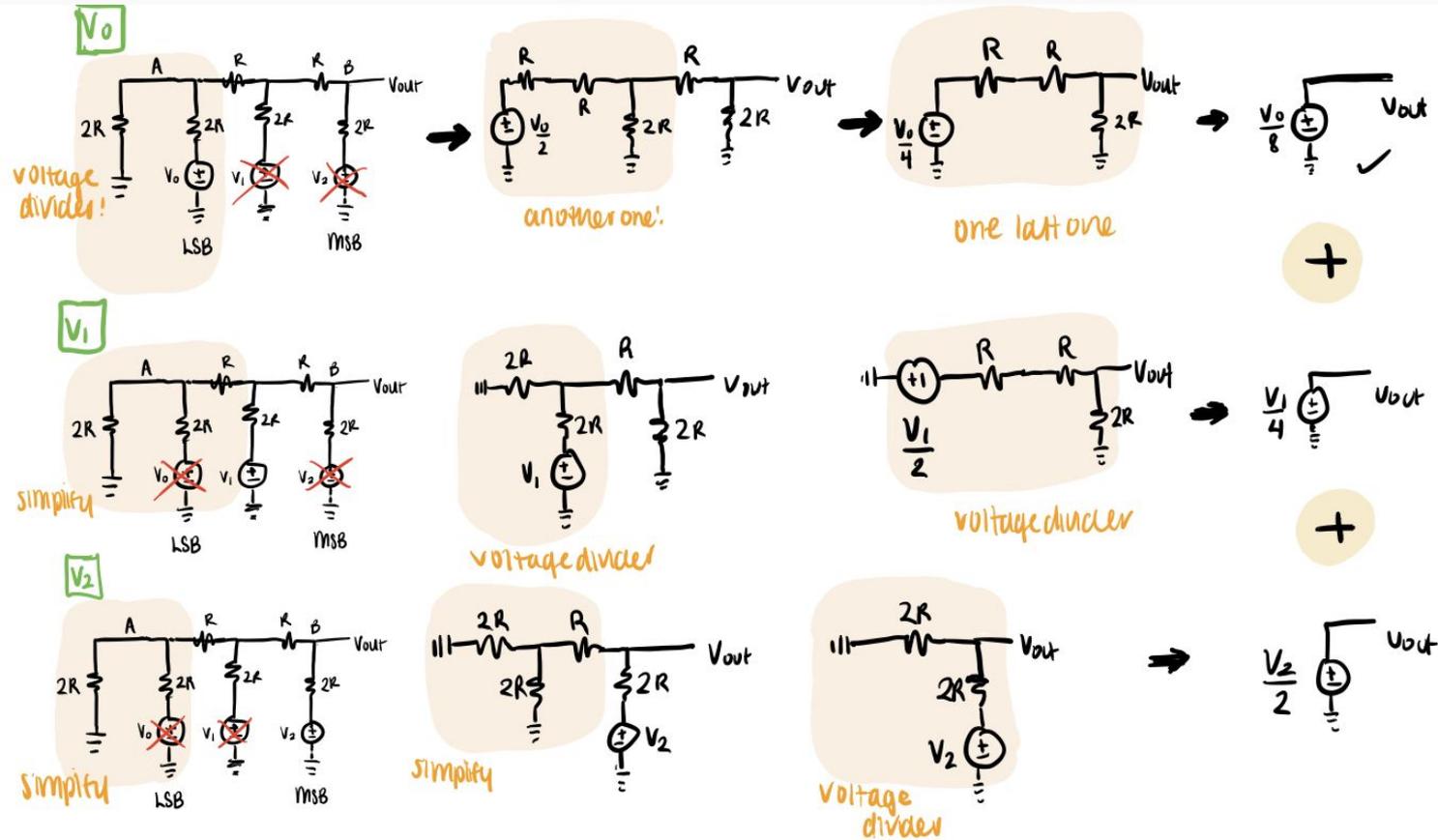
- Since resistive circuits are linear, we can apply the principle of superposition:
 - Treat each source independently – zero out all but one
 - The total effect is the sum of the effects of each source
- Example:



$$V_{out} = V_{out_1} + V_{out_2} + V_{out_3}$$

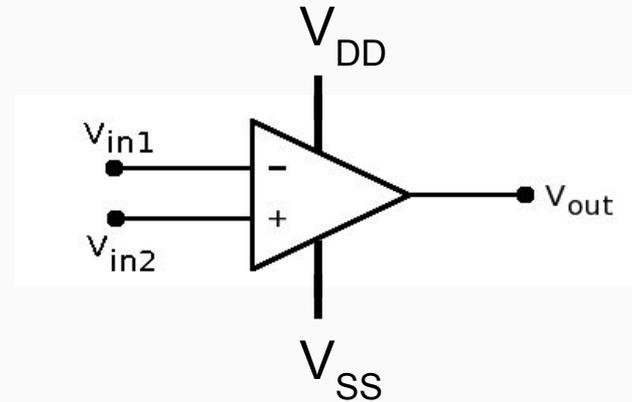


DAC Review: Superposition Example



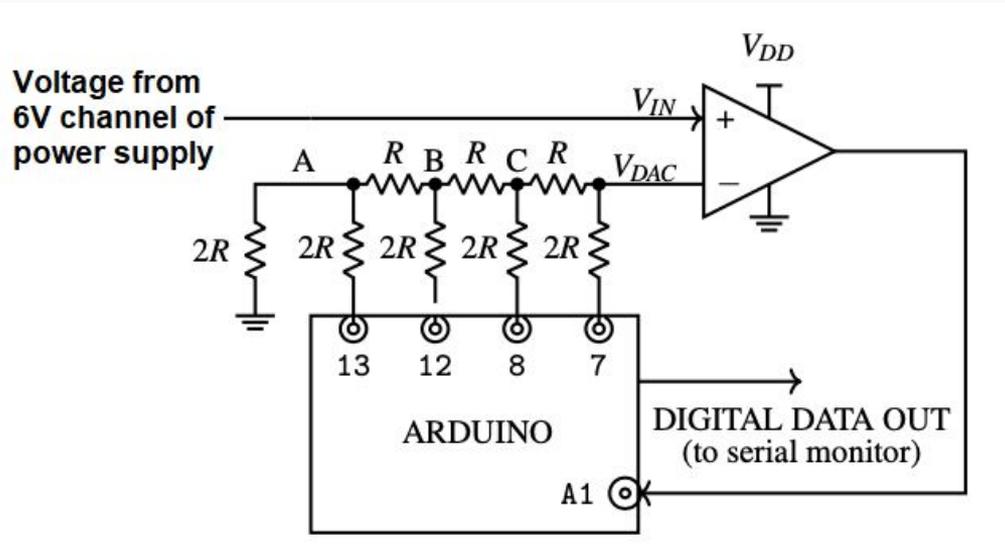
ADC Review: Comparators

- A device that compares two voltages (or currents) and outputs a digital signal to indicate which is larger
- Op-amp Implementation:
 - If $V_{in2} > V_{in1}$, V_{out} goes to VDD
 - If $V_{in1} > V_{in2}$, V_{out} goes to VSS
 - (think: if V_{out} is connected to V^- , its value will bring V^- closer to V^+)
- NOTE: Arduinos use 5V pin logic
 - VDD = 5 V
 - VSS = 0 V



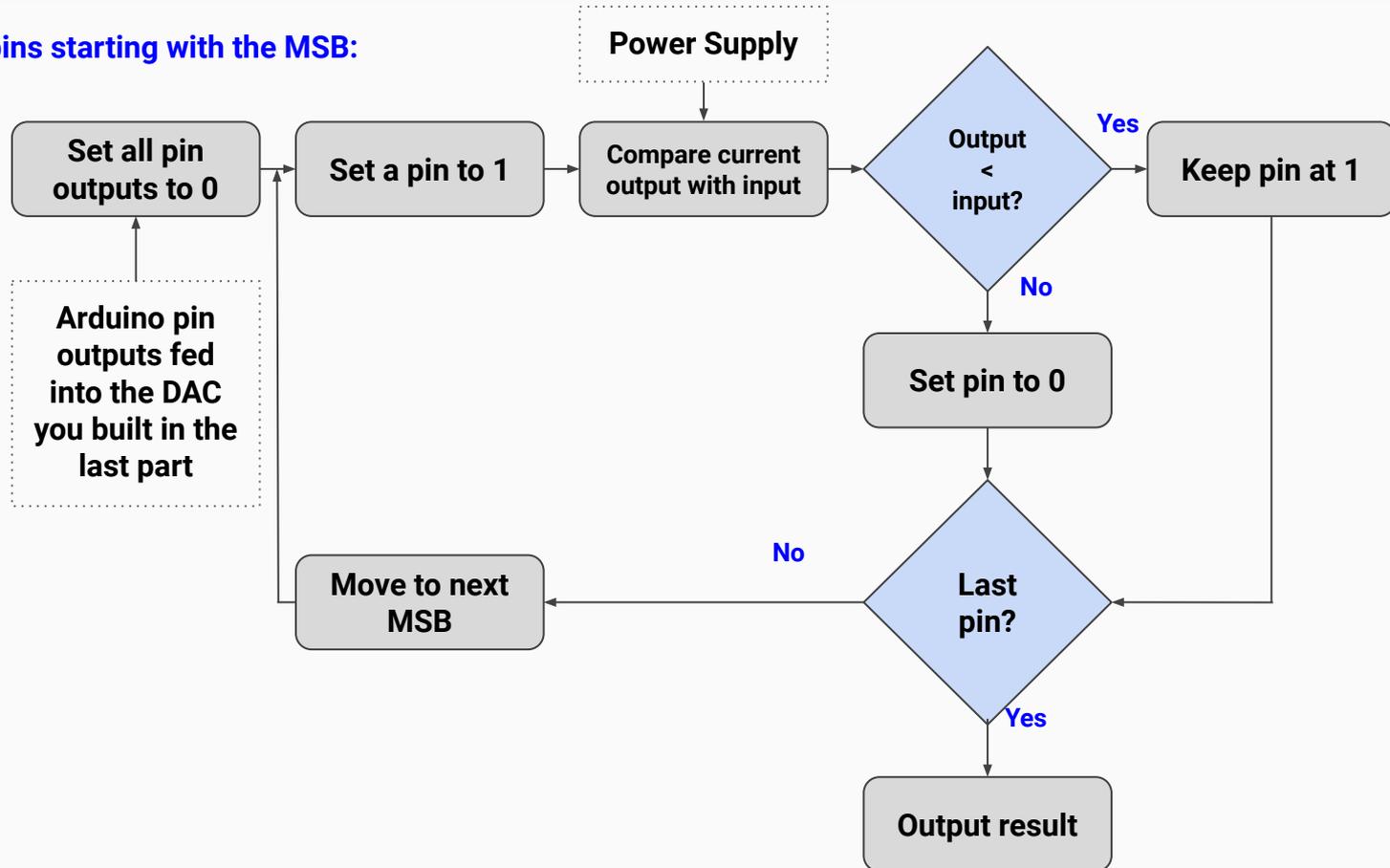
Review: ADC

- ADC - The Arduino uses binary search when turning on MSB (most significant bit) to LSB (least significant bit) and comparing the resulting V_{DAC} with V_{in}



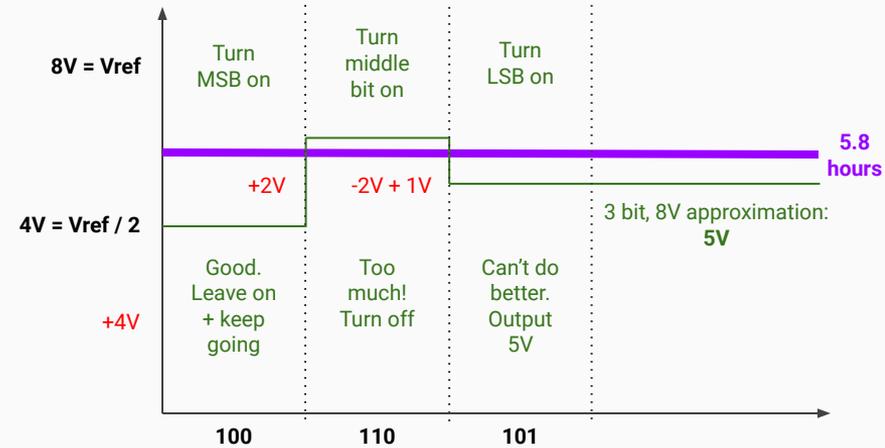
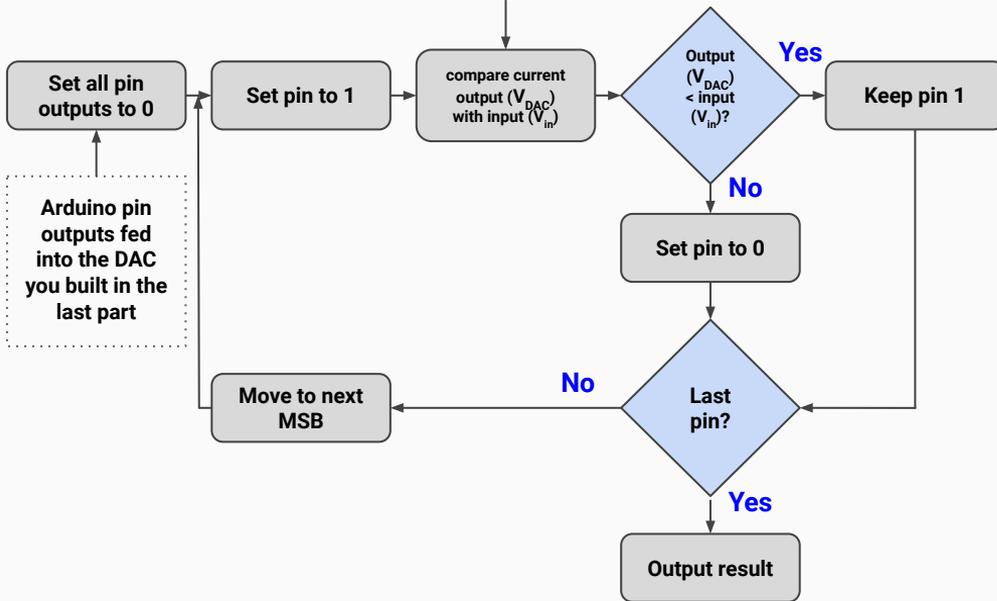
Successive Approx. Register ADC

Loop over all pins starting with the MSB:



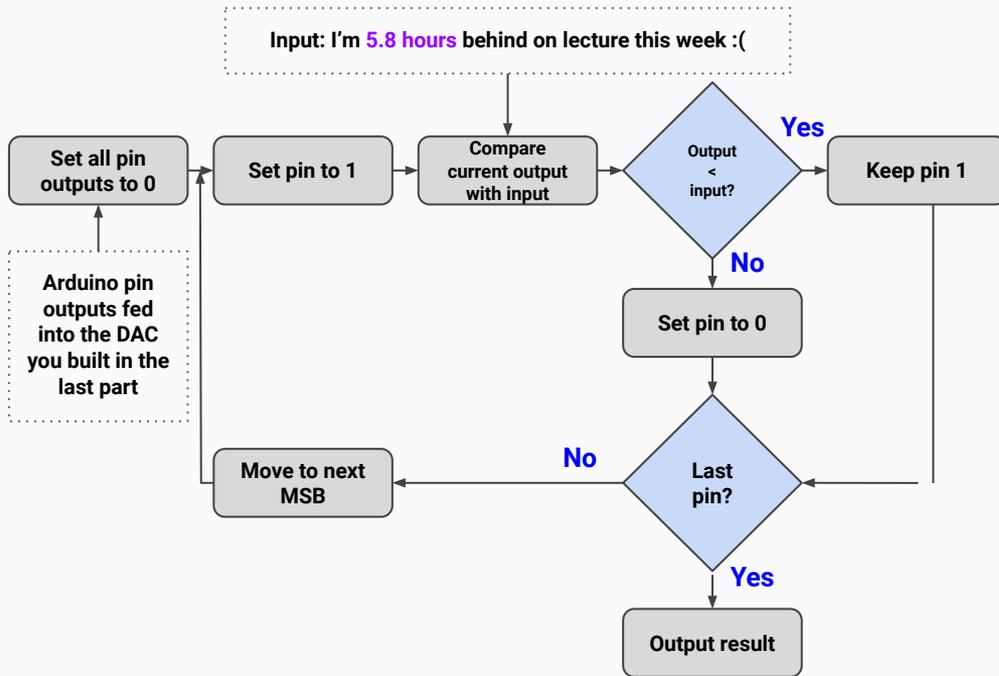
Successive Approx. Register ADC

Input: I'm 5.8 hours behind on lecture this week :(



Result: We forget to account for the last 0.8 hour of lecture because our 3 bits cannot represent it. :(

Successive Approx. Register ADC

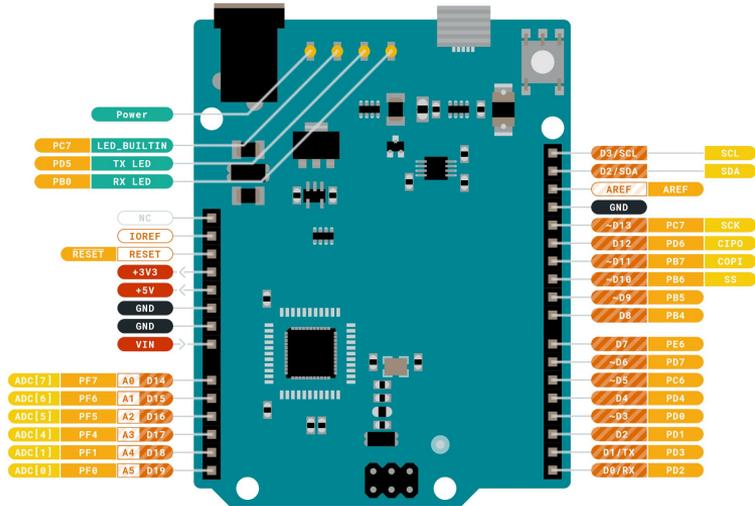


We're trying to match our 5.8V input:

- $V_{ref} = 8V$, we have 3 bits
- 1. Turn on MSB: **1 0 0**
 $4V < 5.8V$, keep going, keep bit on
- 1. We can do better: **1 1 0**
 $(4V + 2V) > 5.8V$, too much, turn off
- 1. Try the next pin (LSB): **1 0 1**
 $(4V + 1V) < 5.8V$
- 1. That's all folks, we're out of bits
Output: 5V

Result: We forget to account for the last 0.8 hour of lecture because our 3 bits cannot represent it. :(

Introduction to Arduinos



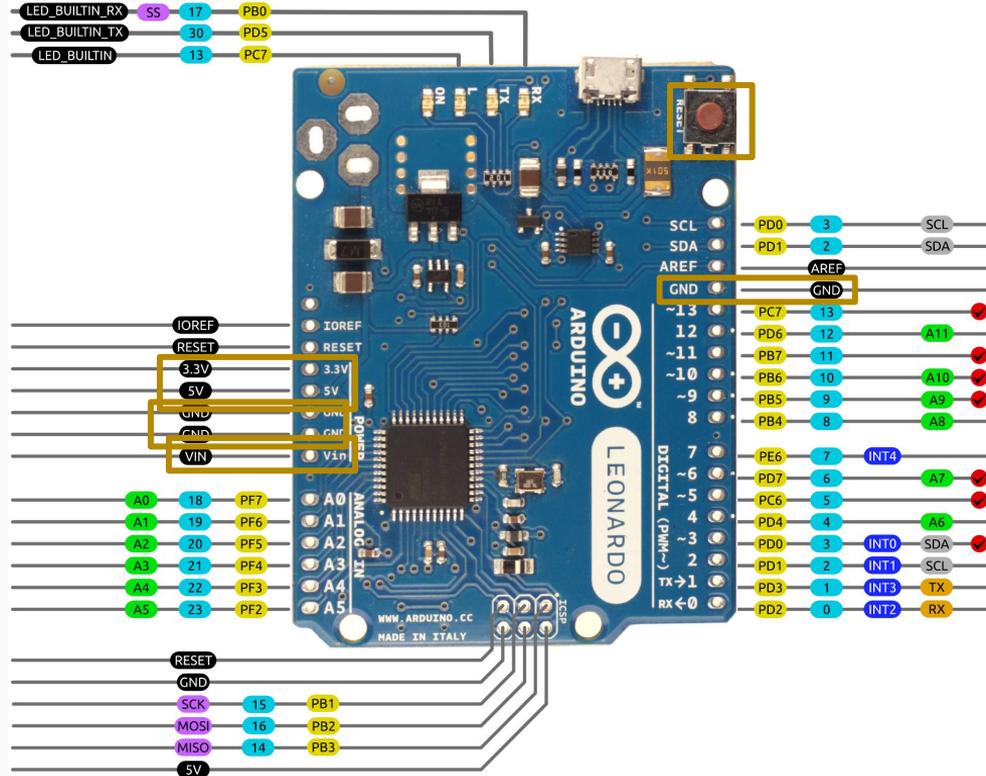
- There are 4 main “Pin Modes”
- Digital: High (5V) or Low (0V) [1s and 0s]
 1. Digital Output
 2. Digital Input
- Analog: range from 0-5V [numerical values]
 1. Analog Output: mapped from 0 - 255
 2. Analog Input: mapped to 0 - 1023

■ Ground	■ Internal Pin	■ Digital Pin	■ Microcontroller's Port
■ Power	■ SWD Pin	■ Analog Pin	
■ LED	■ Other Pin	■ Default	

ARDUINO.CC

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Arduino Leonardo Pinout

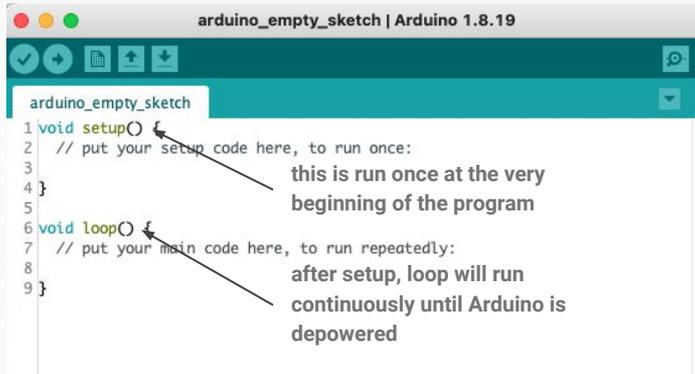


AVR DIGITAL ANALOG POWER SERIAL SPI I2C PWM INTERRUPT



2014 by Bouni, 2016 bperrybap
Photo by Arduino.cc

Introduction to Arduinos



```
arduino_empty_sketch | Arduino 1.8.19
arduino_empty_sketch
1 void setup() {
2   // put your setup code here, to run once:
3
4 }
5
6 void loop() {
7   // put your main code here, to run repeatedly:
8
9 }
```

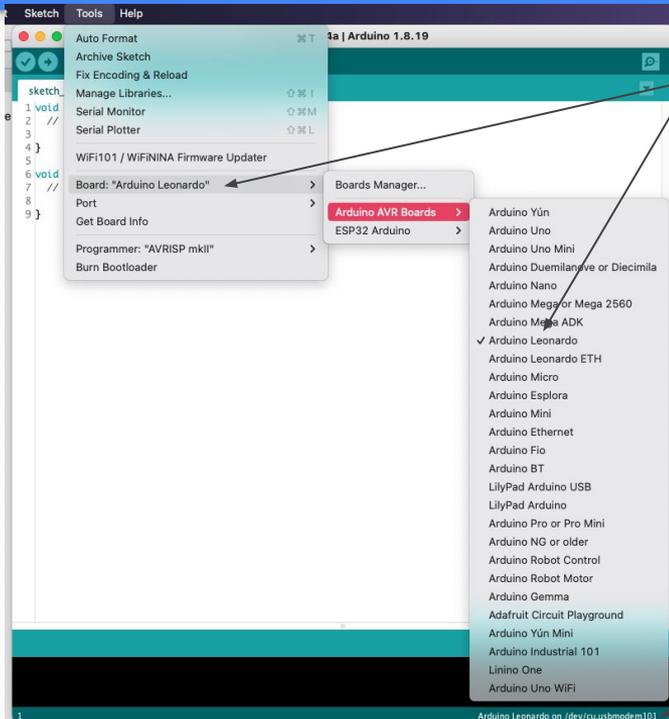
Annotations in the image:

- An arrow points from the text "this is run once at the very beginning of the program" to the `void setup()` function.
- An arrow points from the text "after setup, loop will run continuously until Arduino is depowered" to the `void loop()` function.

Note: Arduino is programmed in C via the [Arduino IDE](#) (pre-installed on lab computers)

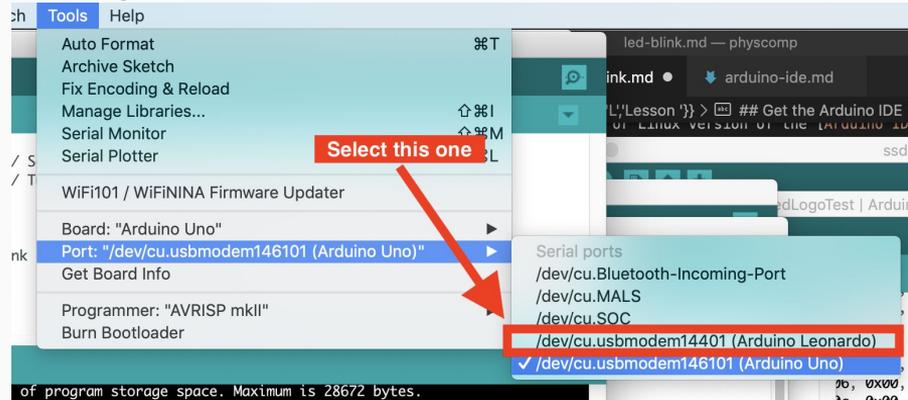
- Code uploaded from computer to Arduino via micro-USB port
- If powered, code is ALWAYS running
 - RST -> restart
 - Unpowering and powering Arduino -> begins re-running whatever was last uploaded
- If you find this to be an issue, the easiest solution is to upload a blank program

Uploading Code to Arduino



Ensure this says *Arduino Leonardo*, otherwise select it

- PORT selection
- Upload button



Arduino *should* auto-detect your port

(works 100% of the time 25% of the time)

Arduino Logistics (pt2)

- Arduinos will be passed out during lab today
- **Arduinos are property of 16B and have to be returned to us by the end of the semester**
- Fill out <https://eecs16b.org/lab-groups> to receive your Arduino

General Reminders/Habits

- Return resistors to the brown RETURN RESISTORS HERE box.
- Connect all grounds together, including the Arduino GND pin (any works)
- In general, avoid having voltage/currents going into your Arduino if your Arduino isn't already powered
- Check that your probes are working by probing a known voltage value
 - i.e. 5V/3.3V/GND from power supply
- PLEASE CLEAN UP AFTER YOURSELF!! Put probes back, pack up kits, throw away stripped wires etc.
- Don't unplug computers
- Work on the lab report :), the deadline will creep up on you

Important Forms/Links

- Help request form: <https://eecs16b.org/lab-help>
- Checkoff request form: <https://eecs16b.org/lab-checkoff>
- Slides: <links.eecs16b.org/lab2-slides>
- Lab Groups: <https://eecs16b.org/lab-groups>
- Anon Feedback: <https://eecs16b.org/lab-anon-feedback>