PHY405-L06

Analog Meets Digital: Arduinos

Logistics

- Reading week next week
- No lecture, no scheduled lab
- Lab 4 due date extended to Feb 21/24
- I'll probably be in the department next week.
- If you need to get into the lab, email me **ahead of time**...

Lab 4 - Op Amps

Students should upload their lab submission here.

The lab instructions are available at https://www.physics.utoronto.ca,

Please contact the course Instructor if you have any questions.

Points 10 Submitting a file upload

Due	For				
Feb 21 at 11:59a.m.	1 Section				
Feb 24 at 11:59a.m.	1 Section				
+ Rubric					

Analog and digital signals

- Analog signals: signals that have a continuous range of values within some specified limits and can be associated with continuous physical phenomena
- Digital signals: signals that can take only a finite number of values and are appropriate for any phenomena that involve counting or integer numbers



https://www.guru99.com/analog-vsdigital.html

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Analog vs digital











Analog Computer

Vs.



Digital Computer

https://en.wikipedia.org/wiki/Analog _computer

Analog vs digital: pros and cons

- Analog:
 - High data density, faster processing, doesn't require high bandwidth
 - Distortion due to noise, transmission quality can be challenging
- Digital:
 - Less subject to noise distortion, easy to edit, easy to store
 - Lower data density, needs higher bandwidth, requires conversion from physical measurements, processing can be challenging



https://www.predig.co m/whitepaper/reducing -signal-noise-practice



1.57 = 0f3FF91EB851EB851F

Analog-to-Digital Converters (ADC)

- An ADC converts an analog input voltage or current into a digital output signal.
- The number of bits that an ADC has determines its precision.
 - e.g. an 8-bit ADC can output numbers between
 0 and 2! 1 = 255, so if it has an input range of
 10 V, the correspondence between digital output
 and analog input is
 - $\circ \quad 0 \to 0 \ V$
 - $\circ \quad 1 \rightarrow 39 \text{ mV,}$
 - $\circ \quad 2 \rightarrow 78 \text{ mV,}$
 - o ...,
 - $\circ~~254 \rightarrow 9.961$ V, and
 - \circ 255 \rightarrow 10 V



Analog-to-Digital Converters (ADC)

- An ADC converts an analog input voltage or current into a digital output signal.
- For best accuracy, always check the linearity and calibration of an ADC
- WARNING: You can fry an ADC if you input a voltage outside its measurement range.



ADC vs DAC



http://www.cmm.gov.mo/eng/exhibit ion/secondfloor/MoreInfo/ADConver ter.html

Lab 5: mini-project to build a system to automatically measure temperature

- First make measurements with subcircuit components:
 - <u>Thermistor</u>
 - <u>Arduino</u> micro-controllers
 - Analog-to-Digital Converter (ADC)
 - Op-amp Follower
 - potentiometers (variable resistors)
 - Communicating with the Arduino via Python.
- Then put together and read out with Python

"Temperature" vs "Time"

From Arduino Serial Plot



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Microcontrollers

- Micro controllers are small special purpose computers on a single chip or board with input and output capabilities that allow them to control or otherwise interact with external apparatus.
 - a microprocessor (single chip CPU) & memory
 - digital input/output
 - e.g. serial or parallel or USB or ...
 - often have dedicated
 - ADC & DAC
 - timers, <u>interrupts</u>, <u>counters</u>
 - pulse-width-modulation
- They are ubiquitous in modern "smart" devices. A modern car might have 10².



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Arduinos

Common inexpensive microcontrollers that come in several models. We use the Arduino Uno.







Arduino LilyPad 00^[48] (rev 2007) (No USB)



Arduino Robot^[49]



Arduino Esplora^[50]



Arduino Ethernet^[51] (AVR + W5100)



Arduino Yún^[52] (AVR + AR9331)



Arduino Due^[53] (ARM Cortex-M3 core)

Arduino Data Sheet

Top view



Board topology

Ref. Description		Ref.	Description
X1	Power jack 2.1x5.5mm	U1	SPX1117M3-L-5 Regulator
X2	USB B Connector	U3 ATMEGA16U2 Module Capacitor U5 LMV358LIST-A.9 IC	
PC1	EEE-1EA470WP 25V SMD Capacitor		
PC2	EEE-1EA470WP 25V SMD Capacitor	F1	Chip Capacitor, High Density
D1	CGRA4007-G Rectifier	ICSP	Pin header connector (through hole 6)
J-ZU4	ATMEGA328P Module	ICSP1	Pin header connector (through hole 6)
Y1	ECS-160-20-4X-DU Oscillator		



Arduino Simulator

TinkerCad Blinking LED Example

https://www.tinkercad.com/things/4Pqq9BwlvHG

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	Simulate							

Arduino Uno

- The Arduino Uno has:
 - 6 ANALOG IN input pins (A0-A5) with 10-bit ADC that digitize 0 5 V.
 - 13 DIGITAL pins that can receive or transmit digital signals, where 0 V is OFF and 5 V is ON.
 - pins 3, 5, 6, 9, 10, 11 can be used as <u>Pulse Width Modulation</u> (PWM) outputs to control suitable motors and other devices.
 - 5 POWER pins that can output power to external circuits or devices.
- <u>Fancier microcontrollers</u> can have faster processors, higher resolution ADCs, analog outputs, <u>Time-to-Digital Converters</u>, ...
- There is a very wide range small specialized circuit boards ("<u>Arduino Shields</u>") that can be attached directly to an Arduino 16

Arduino Sketches

- Start with the Arduino IDE
 - Arduino programs are called "sketches"
- Try out the "<u>blink</u>" example with the built-in LED first





Arduino Temperature Sketch

- You want to print temperature out on the serial port.
- Outline to get you started: <u>arduino_thermistor.ino</u>
- Read the code first...

Measuring a thermistor's output

• A thermistor is a resistor whose resistance (R_t) depends on temperature.



 R₂₅ is nominal resistance at 25° C



Potentiometers

- A potentiometer is a small 3-wire variable resistor used as a potential divider.
 - "trimpot" is a small "trimming" potentiometer
 - If a voltage is is applied across the outer two wires, the middle wire provides an output voltage that can be adjusted by rotating the slot on top with your little screwdriver.
- When only two terminals of a variable resistor are used, it is called as a rheostat.





Breadboard Organization

- Makes it easier to build correctly and debug when things go wrong
- Use consistent colour wires. For example:
 - Black wires \rightarrow Common.
 - Yellow wires \rightarrow DC Power Supply Output 1.
 - Green wires→DC Power Supply Output 2 (V+supply)
 - Blue wires→DC Power Supply Output 3 (V-supply).
 - \circ White or Orange wires—internal connections.
 - Red wires are Input or Output
 - Use power rails columns for V+supply and V-supply.
 - Create Common rows or columns to provide easy access
 - In general best to only have a single Common connection for any circuit.
- Some short white wires hold Arduino on the board.



Arduino Python Communications

- Can interact with Arduinos using Python.
 - Often via serial communication
- Useful examples
 - Open up <u>arduino_LED_user.py</u> in your preferred python environment
 - Replace: port = '/dev/cu.usbmodem143301'
 - run <u>port_check.py</u> to list computer's serial ports.
 - Control Arduino LED (same as Blink sketch)
- Read from Arduino
 - Run sketch: Examples --> Basics --> AnalogReadSerial
 - Open up <u>arduino_Serial_reader.py</u>.
 - Read the instructions at the beginning of the python file.
 - Read Serial port output into your computer and make quick plot.

Final project

- The final two weeks of the semester are dedicated to a project that will be marked on the basis of originality, execution, testing, and the quality of the final report.
 - Project topics are up to you, but can be discussed with the instructor.
- See the project guidelines for more information.
- Lab 5 provides the basis for many possible projects.
- Suggest thinking about final project during reading week
 - Can start discussing with the instructor when coming back

Questions?

Clean up after you are done

Yea, this is still here

