

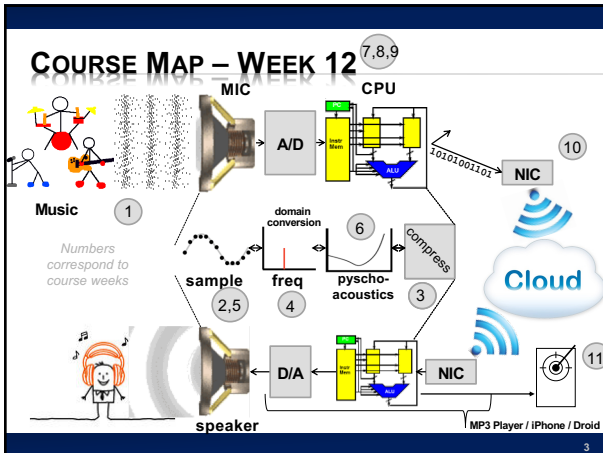
Lecture #21 – Actuation

**ESE 150 –  
DIGITAL AUDIO BASICS**

Based on slides © 2021 DeHon

### LECTURE TOPICS

- × Where are we on course map?
- × Review Sound
- × Sensing
- × Actuation
  - + Motor
  - + Servo
  - + Control
  - + PWM



### REVIEW

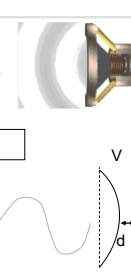
### WEEK 1: PRESSURE TO VOLTAGE

- × Microphones convert pressure to voltage
  - + (speakers/headphones voltage to pressure)
  - + Physical position to voltage
- × Reason as parallel plate capacitor
  - + ESE 112 or PHYS 151

$$C = \frac{\epsilon A}{d}$$


$$Q = CV \quad V = \frac{Q}{C}$$

Voltage is a function of distance (pressure)



### SPEAKERS/MICROPHONES

- × Can sense the world
  - + Physical effect (position)
  - + Convert to voltage ... to bits
- × Can manipulate the world
  - + Bits → voltage
  - + Voltage causes physical movement

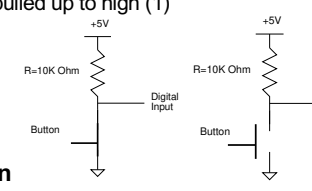


# SENSING

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## SWITCH

- × Can easily give a high or low input
  - + Connected short to ground (0)
  - + Unconnected, weakly pulled up to high (1)

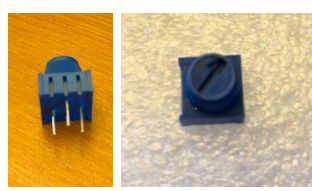
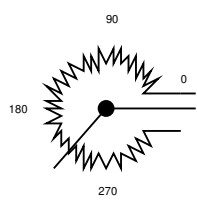


- × Read on input pin
- × Use to sense position
  - + Did something make content to actuate switch?

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## POTENTIOMETER

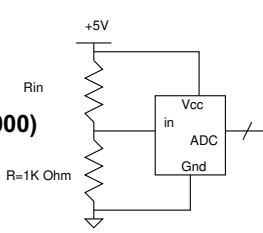
- × Variable Resistance
  - + Based on position, different amount of resistance across
  - +  $R = R_0 * \text{length}$
  - +  $R \sim R_0 * 2\pi r * (\text{degrees}/360)$

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## PRECLASS 1

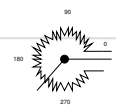
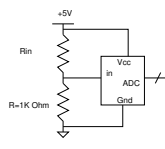
- × Voltage at ADC Input
  - + Rin=10 Ohm ?
  - + Rin=10K Ohm ?
- ×  $V_{\text{divide}} = 1000 / (R_{\text{in}} + 1000)$



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## SENSE POSITION

- × Variable Resistance
  - + Based on position, different amount of resistance across
- × Voltage Divider
  - + Output voltage depends on potentiometer position/resistance
- × Get analog voltage out
- × Feed to A2D

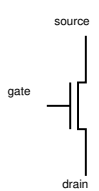
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# ACTUATION

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### ON-OFF SWITCH

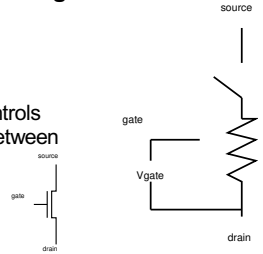
- × **Logic produces a 0/1**
- × **Can control flow of much larger current**
  - + Stop flow – off
  - + Enable flow – on
- × **Transistors**
  - + Voltage on input (gate) controls current flow (resistance) between source and drain



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### ON-OFF SWITCH

- × **Easy to produce 0/1**
- × **Can control flow of much larger current**
  - + Stop flow – off
  - + Enable flow – on
- × **Transistors**
  - + Voltage on input (gate) controls current flow (resistance) between source and drain
  - + Simplified model
    - ×  $V_{gate} > V_{ref} \rightarrow R = R_{trans}$
    - ×  $V_{gate} < V_{ref} \rightarrow R = \infty$



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### ON-OFF SWITCH

- × **Easy to produce 0/1**
- × **Can control flow of much larger current**
  - + Stop flow – off
  - + Enable flow – on
- × **Relay**
  - + Similar model
    - × Input voltage controls switch
  - + Mechanical switching
  - + Lower resistance
  - + Different (usually larger) voltage range, current

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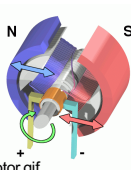
### ON-OFF POWERFUL

- × **Many things can control just by turning on or off**
  - + How often on or off
  - + When turn on or off
- × **Examples**
  - + Temperature – when turn on heater (cooler)
  - + Position – turning on or off motor

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### MOTOR – ABSTRACT VIEW

- × **Applying a Voltage (providing current) across a motor causes it to spin**
  - + Magnitude of current determines how fast
- × **Direction of current controls direction**

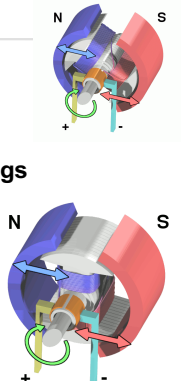


Pictures from:  
[https://en.wikipedia.org/wiki/Electric\\_motor#/media/File:Electric\\_motor.gif](https://en.wikipedia.org/wiki/Electric_motor#/media/File:Electric_motor.gif)  
[https://commons.wikimedia.org/wiki/File:Electric\\_motor\\_cycle\\_2.png](https://commons.wikimedia.org/wiki/File:Electric_motor_cycle_2.png)

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### MOTOR

- × **Exploits magnetic attraction/repulsion and electro-magnetic fields**
- × **Run current through wire windings**
  - + Induces electromagnet
  - + Motor turn to line up with external magnets
- × **Switch current direction**
  - + Turns again to realign magnet
- × **Continue to switch to cause continuous rotation**



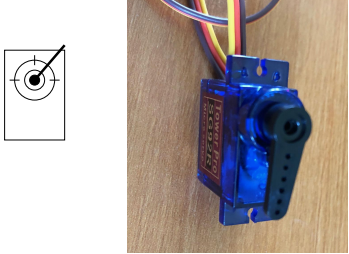
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## SERVO – BASIC FUNCTION

- × Can specify a position (0 to 180 degrees)
- × Will rotate shaft to position

× **Applications**


- + Steering
- + Positioning
- + Pan/tilt



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## SERVO – HOW WORK

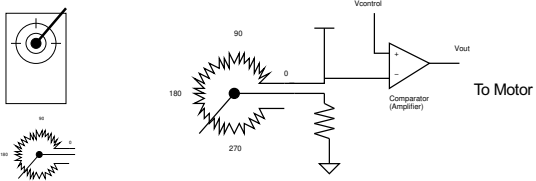
- × **Motor + sensor + control**
- × **Sense if motor in position**
  - + If not, turn on motor in appropriate direction to move closer to position



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## SERVO - CONTROL

- × Provide analog input
- × Sense with potentiometer
- × Is voltage above or below control target?



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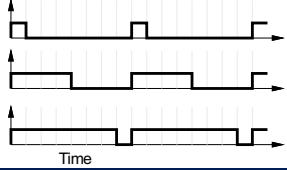
## MOTIVATE DIGITAL INPUT

- × Could provide Analog output from microcontroller with D2A
- × ...but, D2A is somewhat expensive
- × **Communicate position using single digital output**
  - + Look at output over time period
  - + How much of the time period is high/low?
  - + Use to communicate more than 1 bit of data

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## PWM – PULSE WIDTH MODULATION

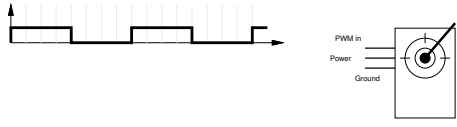
- × Provide pulses at some fixed frequency (490Hz)
- × Vary how long the pulse is high
  - + Vary the *width* of the high pulse
- × Use that to communicate value (position)



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## SERVO

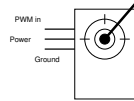
- × Puts some control smarts in servo package
- × Takes PWM input to specify position
- × Senses shaft rotation and engages motor to move to specified position



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## SERVO SMARTS

- × **Could just do all this control from processor**
  - + Sense position, drive motor
- × **Often cheaper to offload that little control from processor**
  - + Including saves pins on (wires to) processor



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## PWM ENCODING WITH DIGITAL LOGIC

- × **How convert digital number to PWM?**
- × **always @ (posedge PWM\_CLK)**
  - + cnt<=cnt+1;
  - + PWM<=(cnt<=digital\_value)

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## PWM DECODING WITH DIGITAL LOGIC

- × **How convert PWM input to digital number?**
- × **always @ (posedge PWM\_CLK)**
  - + pwm\_pos<=pwm\_pos+1
  - + If (PWM) cnt<=cnt+1
  - + If (pwm\_pos==max)
    - digital\_out<=cnt;
    - cnt<=0;
    - pwm\_pos<=0;

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## BIG IDEAS

- × **Information world can interact with physical world**
  - + Sense – read state of physical world into bits for computation
  - + Actuate – have bits control physical world
    - Turn on/off, move, position
- × **Connect sensing and actuation to control**
  - + Even with noisy actuators and external disturbances

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## LEARN MORE @ PENN

- × **Courses**
  - + ESE350 – Embedded Systems
  - + ESE421 – Control for Autonomous Robots

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## REMEMBER

- × **Feedback**
- × **Lab 10 due today**
- × **Monday (4/12) Engagement Day**
  - + No class
- × **Actuation Lab will be following Monday (4/19)**

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