


EEL 4744

Menu


- What Next?
- Use uPs and uCs to change the world!
 - > Sensors
 - > Actuators
- Where to go with this knowledge?
 - > IoT (smart everything!), e.g., smart clothes, body-embedded uP's
 - Over the last dozen years:
 - Medical devices (pacemakers, brain stimulation, human augmentation)
 - mmWave sensors (radar)
 - Door locks, bike locks and trackers, WiFi lighting, sprinkler system
 - Shoes (auto tying laces, adjusts between strides, lighted)
 - Sports equipment (in balls), helmets, shoulder pads
 - Thermostats, Amazon Echo, Google Home, Apple HomePod, ...



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Sensors and Feedback

- One of the primary uses for microcontrollers is interfacing with sensors and giving feedback
- Sensors are used to supply information to a system
 - > Washer Machine, Cars
 - > TVs, Robots
 - > Pretty much **EVERYTHING!**
- Sensors tell these systems when something has happened
- Feedback devices supply data to other devices or for external view
 - > Monitors, TVs, watches, speakers, lights, vibration devices

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Our Sensors and Feedback

- We have already seen a few sensors and talked about others
 - > Switches, IMU (accelerometers and gyroscopes)
 - > IR Receiver (that we discussed w.r.t. timers/Input Capture)
- And a few feedback devices
 - > LED, LCD Panel, Speaker, Motor (DC motor in lab kit)
- In future 4744: Microphones

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How to talk to sensors?

- Discrete On/Off Signals
 - > Simply reading True/False from pins/ports
- Analog Signals
 - > Signal wire attached to ADC channels and read as a quantized discrete value
- Asynchronous Serial (UART/EIA232=RS232)
 - > Signals sent between two UART type devices via RX and TX communication lines
 - > Devices vary in rate, setup, voltage, etc.

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EEL 4744 How to talk to sensors?

- Asynchronous serial communication (SCI)
- Synchronous serial communication (SPI) :
 - > 3-wire (4-wire) Synchronous serial communication between master and student devices chosen by a select line
- I2C (I²C) [pronounced eye-squared-C]
 - > 2-wire Multi Master serial single ended communication with devices specified by address (in our XMEGA)
- CAN (Controller Area Network) used in cars
- Wireless (WiFi, Bluetooth, ZigBee [XBee])
- Pulse-Width Modulation (PWM)
 - > Send a pulse chain of digital data to an analog device
- Input Capture
 - > Receive changes in the sensor output signal

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Touch Sensors

- Sensors that are used as simple tactile response, bump or force gauges (accelerometers)
- Used for
 - > Acknowledging a desired input
 - Volume, keypads
 - Yes/No responses
 - > Acknowledge once a limit has been met
 - Mechanical moving systems
 - > Alert if something is happening that is not desired
 - Bump sensors

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Switches


- Simple sensor
- Extremely cheap
- Easy implementation
 - > Simple digital logic circuits
- Used as
 - > Input for devices
 - > Bump sensors
 - > Limit switches
- **Connection to μ P:**
 - > Discrete data through GPIO ports



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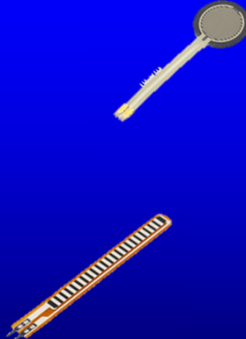


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Pressure/Force

- Measure pressure or force by varying resistance of a flat sensor
- Circuit or flat sensing area
- Precision varies based on device
- Used in
 - > Force feedback to device
 - > Grippers
 - > Weight measurement
- **Connection to μ P:**
 - > Analog data through ADC channels



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Proximity Sensor

- No touching allowed!
- Determine that something is nearby
- Can use sound, heat (infrared), light (visible or not), ...



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IR Rangefinder

- IR Transmitter/Receiver combo to detecting distance to objects
- Varies due to lighting
 - >Sunlight saturates signal
- May be built or made
- Used in
 - >Vending Machines
 - >Trip Sensors
 - >Distance Sensor
- **Connection to μ P:**
 - >Analog data through ADC channels
 - >Discrete data through ports (usually for near range \rightarrow binary)



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Motion Sensors

- Passive infrared sensors
- Detects “moving” heat
- Used in
 - > Vending machines
 - > Motion lights
 - > Security systems
- **Connection to μP :**
 - > Analog data through ADC channels
 - > Discrete data through ports (usually for near range → binary)



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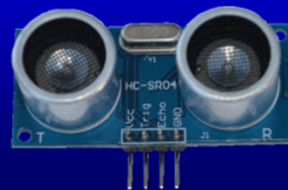
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Sonar (Ultrasonic) Rangefinders


- Use sound to detect distance to objects
- Varies in Beam Width and Distance
- Noise caused by surface and environmental factors
- Used in
 - > Car Backup Systems
 - > Distance Sensors
- 5 years ago ~\$28, now about \$1
- **Connection to μP :**
 - > Analog Data through ADC channels
 - > Serial Communication through UART
 - > PWM (timer)



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CdS Cell

- Measure light intensity
- Used in simple to complex designs
 - > Braitenburg vehicles
- Very cheap
- Used in
 - > Night Headlight Sensors
 - > Automatic room lighting
 - > Behavior Sensors for robots
- **Connection to μP :**
 - > Analog data through ADC channels



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Photodiode/ Phototransistor

- Similar usage to the CdS Cell
- May be tuned to specific wavelengths of light
- Faster response than CdS cells
- Requires additional (more advanced) circuitry to be accurate
- Used in
 - > Automatic room lighting
 - > Isolated communication when paired with emitter
 - > Consumer electronics (smoke detectors, light meters, remote controls)
- **Connection to μP :**
 - > Isolated communication when paired with emitter
 - > Analog data through ADC channels





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Vision Sensors

- Sensors that supply a device with info about the visual environment
- Information may be in the form of
 - >Color
 - >Shape
 - >Distance
 - >Brightness/Intensity
- Data is typically collected and compared to expected values (thresholds)



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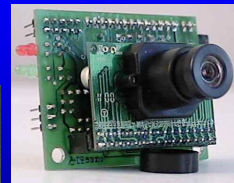
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Smart Camera System (e.g., CMU Camera, Arduino Camera)

- Vision tracking of color or movement
- May have limited capability, but small learning curve
- All processing of vision done onboard
- Used in
 - >Visual tracking system
 - >Visual servoing
 - >Motion detection with pictures
- **Connection to μ P:**
 - >Serial communication through UART



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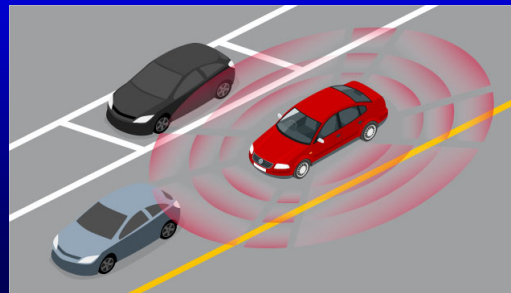
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Radar

- Common in cars (especially more expensive ones)
- Works by bouncing RF signals off of objects (a little like sonar devices)
- TI mmWave radar cost < \$100!

>Interface options

- ADC
- SPI
- UART
- I2C
- CAN bus
- GPIO



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Sound Sensors - Microphones

- Sensors that supply a device with the auditory information from the environment
- Various types of microphones
- Requires amplification, filtering, digitization
- Normally omnidirectional
- Used in
 - >Auditory acknowledgement
 - >Digital Signal Processing to manipulate sound

• **Connection to μ P:**

- >Analog data through ADC channels



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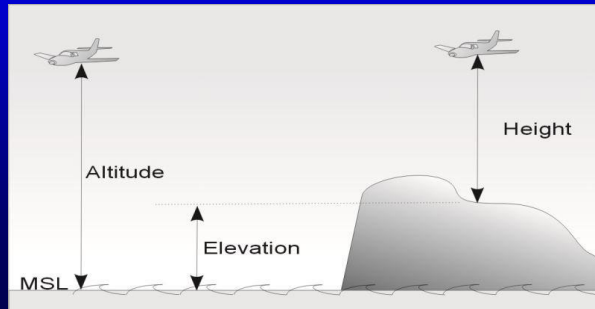
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Position Sensors

- Sensors that supply a device with attitude or position
- Position may be precise or an estimate
- Attitude may include all degrees of motion
 - >Roll, Pitch, Yaw
 - >Altitude
 - >Depth



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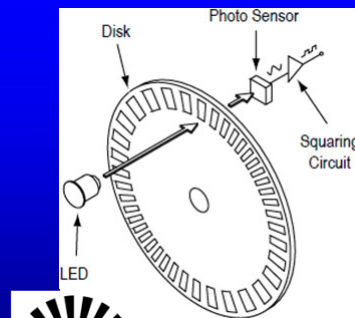
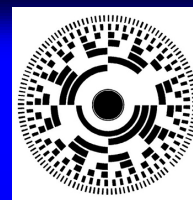
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Encoders

- Count the angle or RPMs a rotary device has moved
- Typically a discrete sensor
 - >Not digital as it is continuous time
- Used for general positioning
 - >Dead reckoning
- Used in
 - >CNC Mills/Rapid Proto-type machine
 - >Mechanical movement system
 - >Robot wheels
- **Connection to μP :**
 - >Input Capture system through ports and timers



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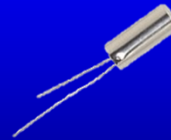
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Tilt Switch

- Simple to use
- Metal or mercury
- Typically used in groups for more accuracy
- Used in
 - > Tilt sensor in pinball machines
 - > Tilt sensor in robots
- **Connection to μP :**
 - > Discrete data through ports



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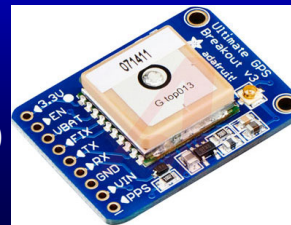
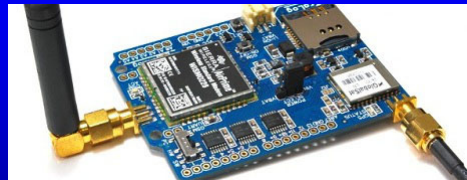
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GPS

- Semi accurate position of device
- Useful for waypoint movement or position data
- Used in
 - > Cars
 - > Phones
 - > Robot Position
- **Connection to μP :**
 - > Serial communication through UART
 - > I²C communication
- **Inside** “GPS” now available ~\$500



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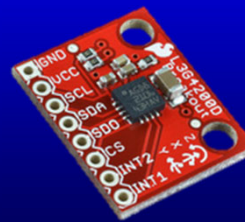
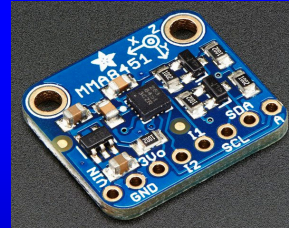
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Gyro

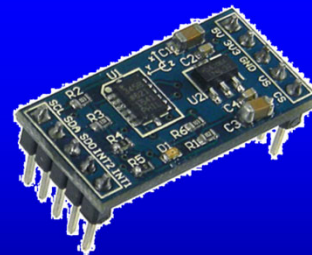
- Position, tilt, roll information
- 2-3 Axis
- Used in
 - > Orientation Sensor
 - > Tilt Sensor
- **Connection to μP :**
 - > Serial communication through UART
 - > I²C communication
 - > SPI communication



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Accelerometer

- Measure acceleration in various directions
- Up to 3 Axis
- Used in
 - > Speed calculation
 - > Directional feedback
 - > Dead reckoning sensor
- **Connection to μP :**
 - > Serial communication through UART
 - > I²C communication
 - > SPI communication

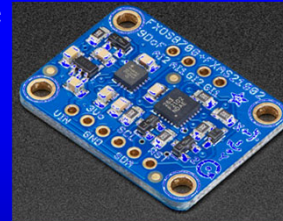




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Magnetometer/Compass

- Measure magnetic poles to calculate compass values (heading)
- Strong affected by magnetic sources
- Used in
 - >Cars
 - >Phones
 - >Robot Heading
- **Connection to μP:**
 - >Serial communication through UART
 - >I²C communication
 - >SPI communication



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Environmental Sensors

- Sensors that supply a device with information of the environment
- Ability to sense various sources
 - >Heat
 - >Magnetic
 - >Moisture

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Thermistor or other Temperature Sensors

- Measure temperature sources (heat, cold)
- Typical range of 0 to 100 degrees Celsius
- Easy to implement
- Used in
 - > Thermometers
 - > Phones
 - > Air conditioning
- **Connection to μP :**
 - > Analog data through ADC channels



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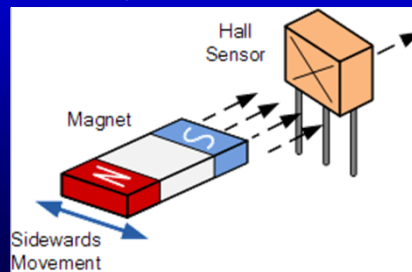
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Hall Effect

- Measure current of magnetic sources
- Useful for detecting magnetic objects
- Used in
 - > Magnetic switches
 - > Metal detectors
- **Connection to μP :**
 - > Analog data through ADC channels



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Communication Devices

- Various communication systems may be used to talk between devices
 - > XBee RF (common ZigBee device)
 - > Bluetooth – BlueSMiRF
 - > WiFi
 - > RFID
- **Connection to μ P:**
 - > Serial communication through UART








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Other Sensors

- Pyro-electric
- Pressure/Barometer
- Chemical Sensors

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Sites for Sensors, Etc.

- www.sparkfun.com
- www.digikey.com
- www.amazon.com
- www.pololu.com
- www.adafruit.com
- www.trossenrobotics.com
- www.robotshop.com
- www.mcmaster.com
- www.hobbyking.com

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What about motors?

- Another use for microcontrollers is to control motors/servos
- You have already learned about motors/servos
 - > Controlled by modifying PWM/PCM signal with various settings to change direction of motor

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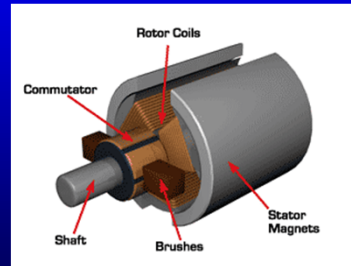
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DC Motors

- A DC motor can be driven, although generally driven with PWM, can be driven with a DC voltage, i.e., +V and GND
- Increasing/decreasing +V increases/decreases the motor's speed
- Flipping +V and GND reverses the motor's direction
- To control this dynamically, i.e., under μ P control, motor drivers are used



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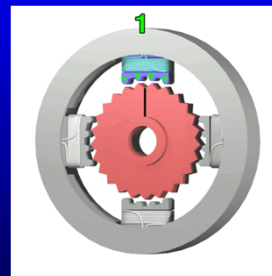
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Stepper Motors

- Brushless DC motor that drives a motor with equal steps
- Position can be accurately controlled without position sensors or feedback



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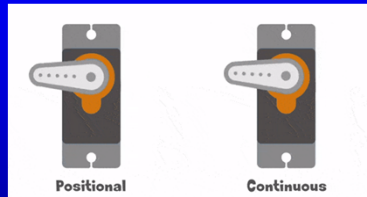
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Servo Motors

- **Servomotor:** A rotary (or linear) actuator that allows for precise angular (or linear) positioning
- Consists of a motor, a position sensor, and a control circuit



- **Linear actuators** creates straight-line motion, usually with a screw, rack and pinion, or gears



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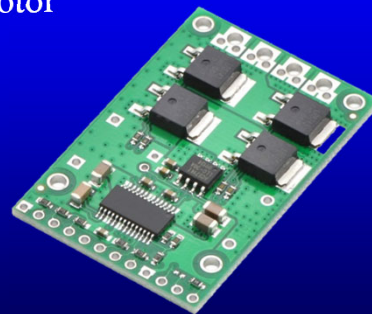
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Motors Drivers


- H-Bridge Control system
 - >MOSFETs
- May control more than one motor per board
- Controls speed and direction of motor
- Used in
 - >Motor control system
 - >Vending Machines
 - >Robots
- **Connection to μ P:**
 - >PWM output



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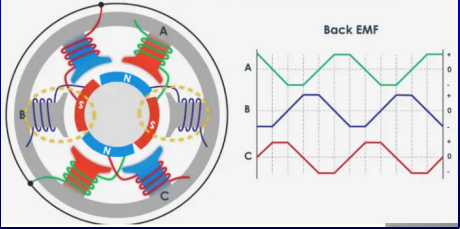
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Electronic Speed Controllers

- ESCs are electronic circuit made to control brushless motors
- Provides electrically-generated 3-phase electric power to low voltage motors
- Used in
 - >Cars
 - >Rotor Vehicles (drones, copters)
 - >Robots
- **Connection to μP :**
 - >PWM output

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Where to go with this Knowledge?

- **4744** teaches how to use a μP /microcontroller
- You learned how to communicate with various devices
- You can build
 - >Advanced sensors
 - >Electro/mechanical systems
 - Robots, Toys, Cool Stuff!
 - >**Just about anything!**

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