

Sensors and Cellphones



What is a sensor?

- *A converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument ...*
- What are some sensors we use every day?
 - Thermometers
 - Radar guns, red light cameras
 - Automatic door openers
 - Cameras
 - GPS

Why are we talking about sensors?

- Sensors have been used in cellphones since they were invented ...
 - *Microphone, number keys*
- What made smartphones smart?
 - *Touchscreens, accelerometers, gyroscopes, GPS, cameras, etc ...*
 - Allowed cellphones explode into different markets
 - R.I.P. Garmin, Tomtom, Kodak Intel?
 - Instead of carrying around 10 separate devices, now you just need 1

Types of Sensors

Distance & Range

- Infrared Sensors



- Contain an infrared emitter, and an infrared detector
- Works by emitting a certain amount of infrared light, and seeing how much it gets back
- Why infrared?
 - There are not many other infrared sources in everyday life that would interfere with this sensor
 - If visible light were used, light bulbs, computer screens, cellphone screens, etc, would all interfere with the depth reading

Types of Sensors

Distance & Range

- Great at measuring shorter distances (2" – 30")
- Where do you see these?
 - Touchless Switches (toilets, faucets, etc)
 - Roomba vacuums
 - Kinect
- Related: Passive Infrared (PIR) Sensors
 - No IR emitter, just detects ambient IR.
 - Detects some normal state (like a wall's IR emissions) and when something moves in front, it detects a change
 - Great for detecting motion (motion sensors for security systems)



KINECT
for XBOX 360



Types of Sensors

Distance & Range

- Related: Speed detectors (police radar guns)
 - Microwave radars use the Doppler effect (the return echo from a moving object will be frequency shifted).
 - The greater the target speed, the greater the frequency (Doppler) shift
 - IR/Laser radars send pulses of light, and determine the difference in reflection time between consecutive pulses to determine speed

Types of Sensors

Distance & Range

- Related: Ultrasonic Sensors

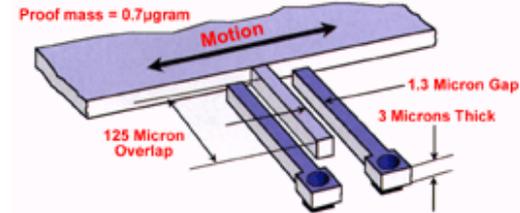


- Contain a high frequency speaker , and a microphone
- Works just like a sonar, emitting a sound, and listening for the echo to determine range
- Why is it called ultrasonic?
 - Very high frequency sound, it is barely at the edge of what humans can hear.
 - This is nice since it is not as annoying to use
- Pros: More accurate than IR sensors at slightly longer distance (typically up to several feet)
- Cons: Almost twice the price

Types of Sensors

Accelerometers/Gyroscopes

- Accelerometers:



- Measures change in velocity in axial dimensions (typically 2 or 3 axes)
- How does it work?
 - The “proof mass” shown above is allowed to move in a plane.
 - The attached fingers form a capacitor with the two plates around it.
 - The rate of change of the capacitance is measured and translated into an acceleration

Types of Sensors

Accelerometers/Gyroscopes

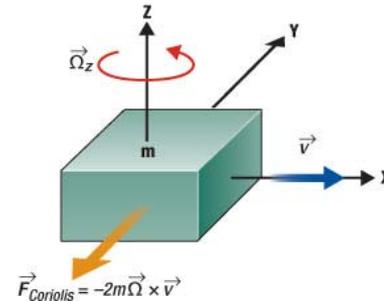
- Gyroscopes:

- Measures orientation

- How does it work?

- If an object is moving along one axis, and it is rotated about another, it will feel a Coriolis force in the third axial direction
 - A gyroscope will have a mass oscillating back and forth along the first axis, and plates on either side of the mass in the third direction (direction of the Coriolis force)
 - When a rotation is detected around the second direction, the capacitance changes

- Paired with an accelerometer, and you have a full 6-degree of freedom sensor (called an IMU)



Types of Sensors

Accelerometers/Gyroscopes

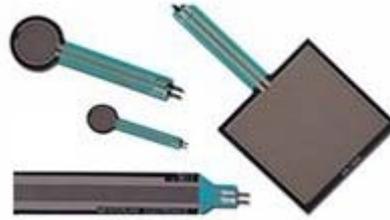
- Where do you see these?
 - Wii Nunchuks
 - Orientation sensing in smartphones
 - Image Stabilization in cameras
 - Collision detection in cars
 - Pedometers
 - Monitoring equipment for failure (vibrations in ball bearings, etc)



Types of Sensors

Force Sensors

- Force Sensing Resistor



- Determines when pressure is being applied
- How does it work?
 - Made of a material called Polymer Thick Film (PTF)
 - When pressure is applied to a PTF, its resistance decreases, which can be easily measured (strain gauge)
- What is it used for?
 - Robot end-effectors, load and compression sensing, contact sensing (buttons), Joysticks



Types of Sensors

Touchscreens



- 3 types: resistive, capacitive, and surface acoustic wave
- Resistive:
 - Consists of 2 layers (1 conductive, 1 resistive) held apart by spacers
 - An electric current is constantly sent through the layers
 - When something touches the screen, it causes the two layers to touch, changing the electric current
 - This change can be measured and based on how much it changes, the location of touch can be computed
- Pro: very cheap, doesn't require the input to be a finger or some other conductive input
- Con: Since two layers are required, only about 75% of the screen light can get through



Types of Sensors

Touchscreens



- Capacitive:
 - Consists of a single capacitive layer
 - This layer stores a constant charge
 - When something conductive touches the screen, the charge on the screen decreases
 - This change can be measured and based on how much it changes, the location of touch can be computed
- Pro: Since only 1 layer is required, about 90% of the screen light can get through
- Con: More expensive than a resistive system. Requires a conductive input device.



Types of Sensors

Touchscreens



- Surface Acoustic Wave:
 - Consists of no metallic layers
 - Uses a transducer placed along the edge of the glass that sends an ultrasonic wave across the glass
 - A receiver on the other end receives the waves
 - When something touches the screen, it disturbs the waves and the position of the disturbance can be computed
- Pro: 100% of the screen light can get through, making it the right choice for graphics applications
- Con: Very expensive, and can be messed up if there is dirt or something on the screen

Types of Sensors

Localization (GPS) Sensors

- Used to figure out where you are
- How do they work?
 - Handheld GPS receivers are passive devices, they don't transmit anything back to the satellites
 - 24 operational GPS satellites at all times, operated by USAF, synchronized using atomic clocks
 - At specific synchronous intervals, they each emit a signal containing their current position and the time of the emission



Types of Sensors

Localization (GPS) Sensors

- A receiver will receive multiple signals from different satellites at different times, depending on the distance to each satellite
- When it receives a transmission, based on the time it takes to get the packet it can determine how far it is from the satellite
- It must be on a sphere centered at where the satellite is, with a radius of the distance it just computed
- Once you have several spheres, the receiver lies at the intersection of those spheres
- 3 spheres are necessary in 2D, 4 in 3D

Types of Sensors

Cameras

- Helps capture the world around us
- Won't cover details – a whole class coming up on cameras and computer vision
- Compared to other sensors, collects orders of magnitude more data (a whole image instead of a just a single change in voltage)
- One of the most impactful sensors, especially when coupled with the cellphone (just look at facebook, instagram, etc)



Types of Sensors

Everything Else (just a taste)

- Switches
 - Contact switches, power switches, etc
- RFIDs
 - Cheap identification (not so secure)
- Bluetooth/WiFi/WiDi (communications)
 - Not really a sensor in the traditional sense, but often related, particularly when talking about cellphones
- Environment sensors: moisture, humidity, temp
- <http://www.pivotmylife.com/products/parts.html>
- <http://www.sensorland.com/>



A Good Sensor



- Sensitive to only the measured property
 - Biggest worry here is temperature
- The sensor itself doesn't influence the measured property
 - Think about dropping a mercury thermometer into a glass of hot water
- The output should be linearly proportional to the measured value or a simple function of the measured value
- Sensitivity = ratio of output signal to measured property



A Bad Sensor



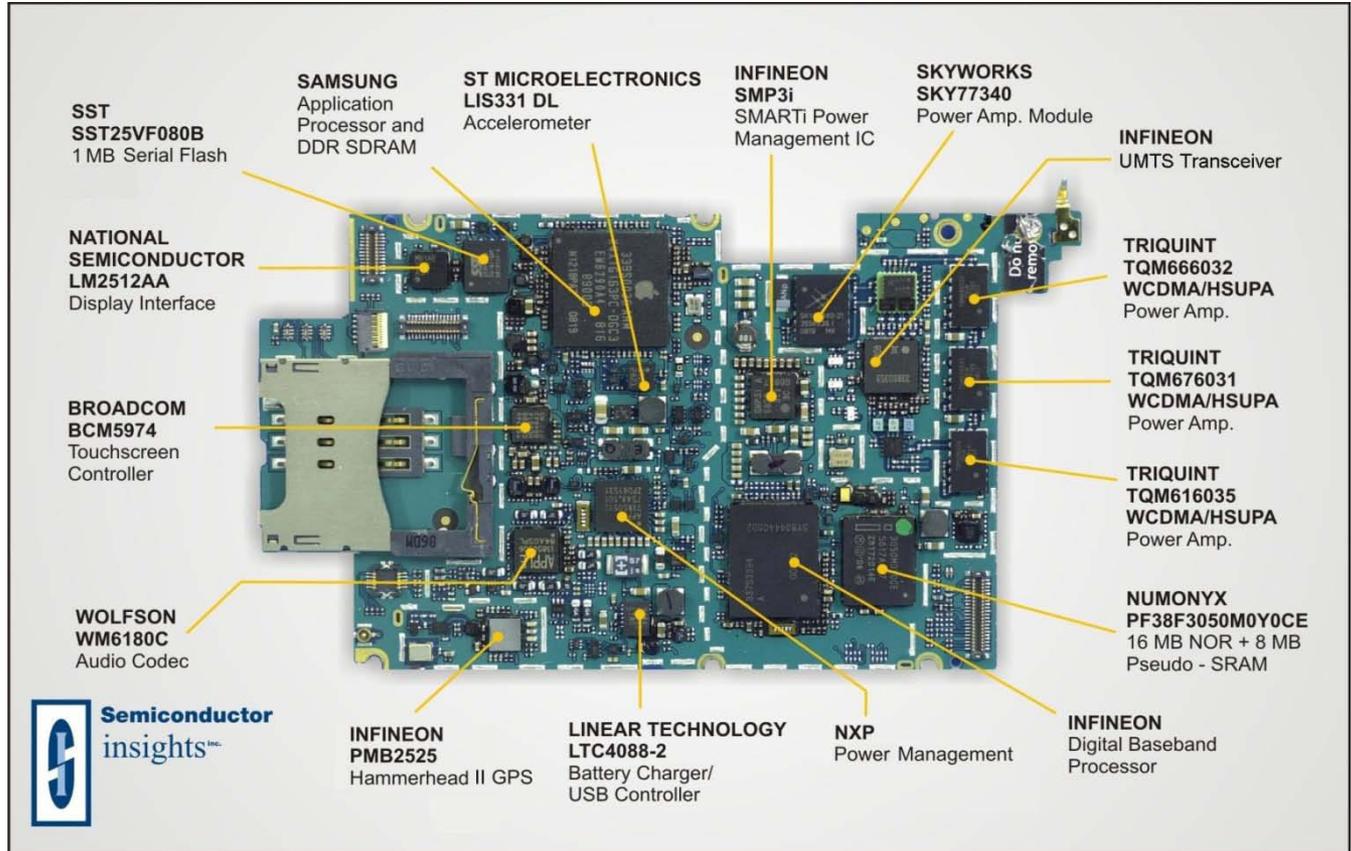
- Drift
 - If the output signal changes independent of the measured property
- Noise
 - Random deviation of the signal over time
- Systematic errors (drift) can often be corrected via calibration.
- Random errors (noise) can be filtered out using signal processing techniques, but these are slow
- Particularly in the context of mobile devices
 - Anything that consumes a lot of power
 - Costs a lot to produce
 - (small == less material != cheaper)

Sensors – Before



Let's Go Digital

Sensors – After



What changed?

- Smaller
 - Process technology is much better
- Faster
 - Multi-core chips can now process a lot more sensor data simultaneously
- Better
 - Sensors are more accurate (e.g. better cameras in smaller spaces)
- Cheaper
 - Thanks China

Lots of Hardware, so what?

- Now that you can collect all this data, how do you use it?
- Application Programming Interfaces (APIs) expose a cellphone's sensors and sensor data to the cellphone programmer
- The Android Accessory Development Kit (ADK) even provides the ability to add external sensors in a standard way

Sensors on Android Phones

- Access to the sensors on an Android phone are available through the ***SensorManager*** class in the ***hardware*** package of the android SDK
- <http://developer.android.com/sdk/> 
- Supports: Accelerometer, Ambient Temperature, Gravity, Gyroscope, Light, Linear Acceleration, Magnetic Field, Orientation, Pressure, Proximity, Relative Humidity, Rotation Vector
- Not all sensors are present in all phones
- **SensorManager.getSensorList()** returns all the ones in your phone

Sensors on Android Phones

```
public class SensorActivity extends Activity, implements SensorEventListener {
    private final SensorManager mSensorManager;
    private final Sensor mAccelerometer;

    public SensorActivity() {
        mSensorManager = (SensorManager) getSystemService(SENSOR_SERVICE);
        mAccelerometer = mSensorManager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
    }

    protected void onResume() {
        super.onResume();
        mSensorManager.registerListener(this, mAccelerometer, SensorManager.SENSOR_DELAY_NORMAL);
    }

    protected void onPause() {
        super.onPause();
        mSensorManager.unregisterListener(this);
    }

    public void onAccuracyChanged(Sensor sensor, int accuracy) {
    }

    public void onSensorChanged(SensorEvent event) {
    }
}
```

One thing to note, make sure to disable sensors when you don't need them (such as onPause above), otherwise you will drain your battery fast.

External Sensors on Android

- Use Android Accessory Development Kit (ADK)
- <http://developer.android.com/guide/topics/usb/adk.html>
- ADK is for hardware development as the SDK is to software development (sets standards)
- Built on top of Arduino



Arduino



- <http://www.arduino.cc>
- Some pins to connect to a sensor
- A microcontroller you can program to interpret the data from the sensor
- Some memory to hold your program
- A USB port to send it somewhere useful
- The key is the pins it uses to connect to sensors.
Sensor manufacturers recognize these pin standards, so you don't have to deal with all sorts of different communication protocols with interfacing with a sensor