SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Lecture 3
Computer hardware (cont'd). Software.
Extending the computer system – intro to sensors.

IAT 267 Introduction to Technological Systems

Instructor: Helmine Serban

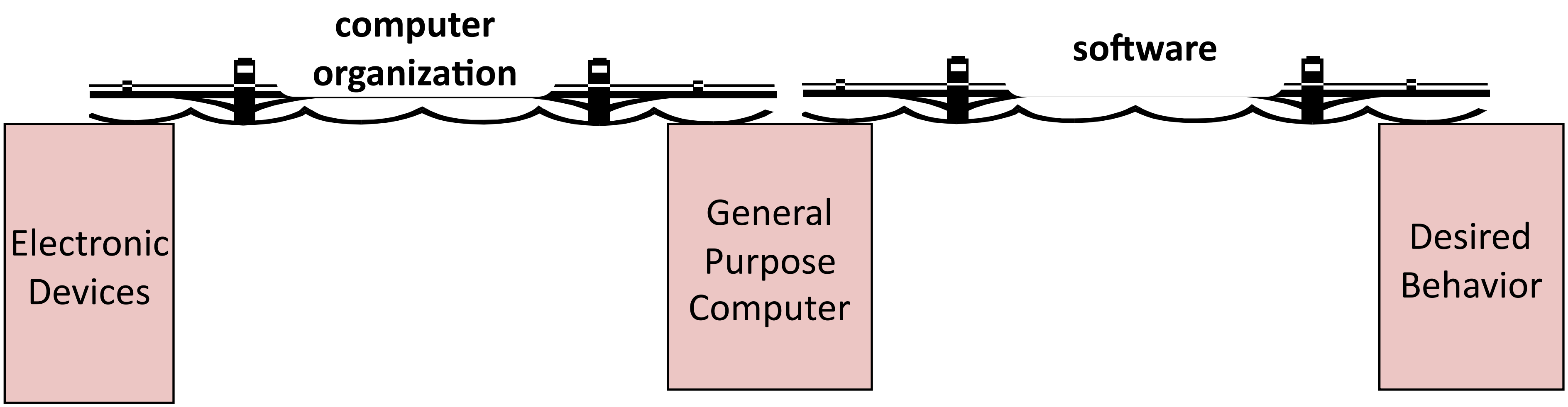
Organizational Items

- Assignment 1 posted on webct – due Oct. 5
- Online quiz (Week 3) will become available on webct on Friday September 23
  - Due Wednesday September 28

Topics

- Computer hardware – the von Neumann architecture (cont'd from lecture 2)
- Software: system software and application software
- Extending the computer system – intro to sensors
  - What are sensors
  - Role
  - Sensor technology

Role of General Purpose Computers

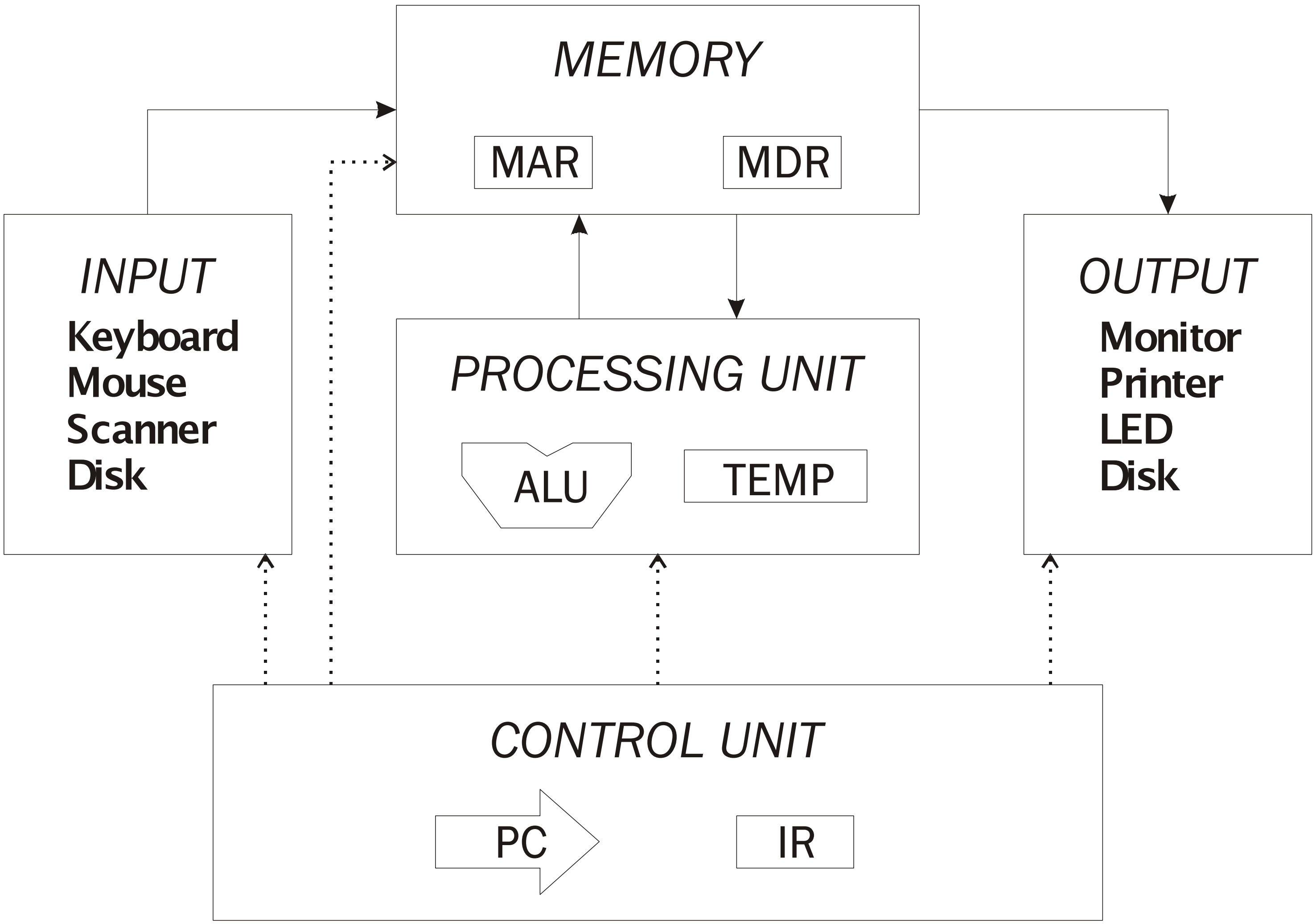


A general purpose computer is like an island that helps span the gap between the desired behavior (application) and the basic building blocks (electronic devices).

SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Von Neumann Model

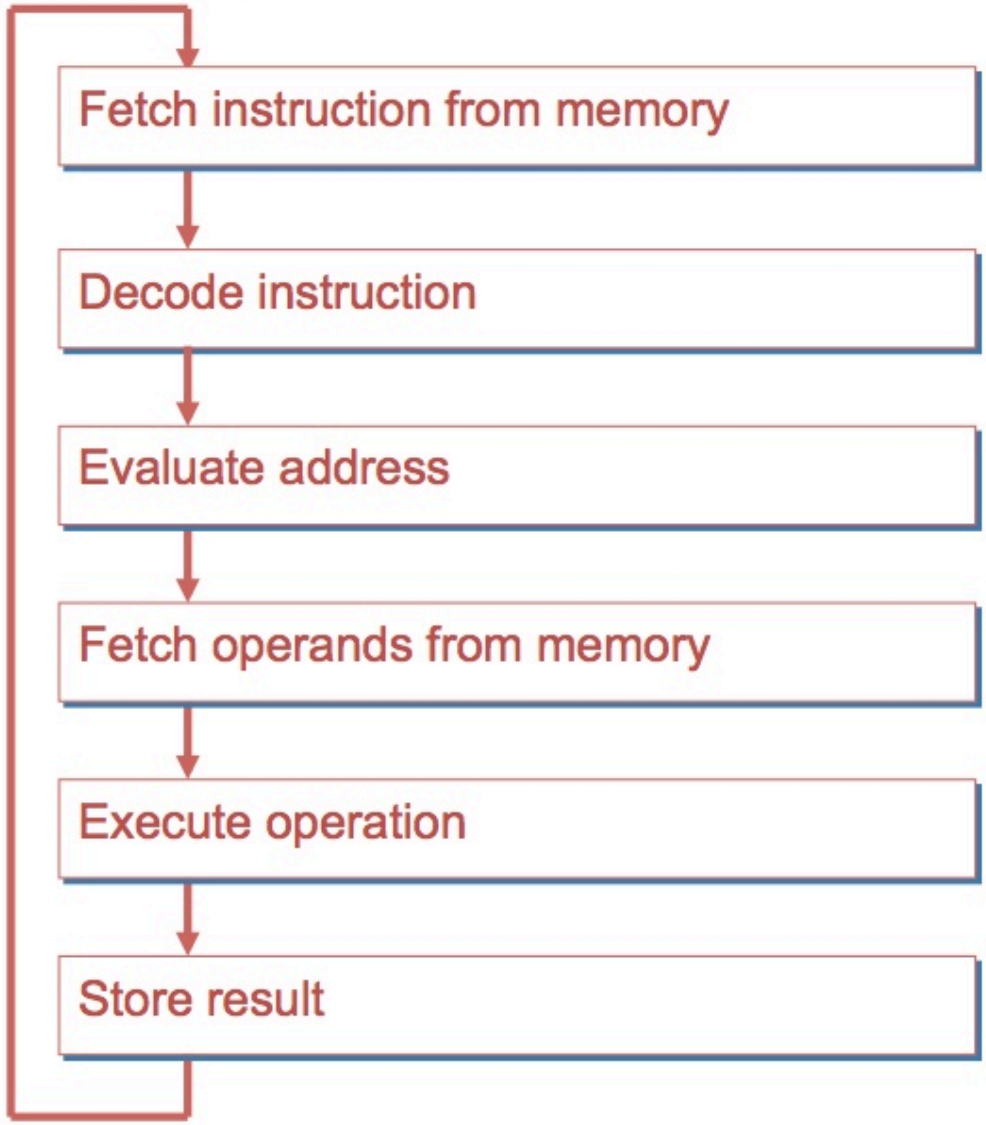


- **Memory**: holds both data and instructions
- **Processing Unit**: carries out the instructions
- **Control Unit**: sequences and interprets instructions
- **Input**: external information into the memory
- **Output**: produces results for the user

Instruction Processing

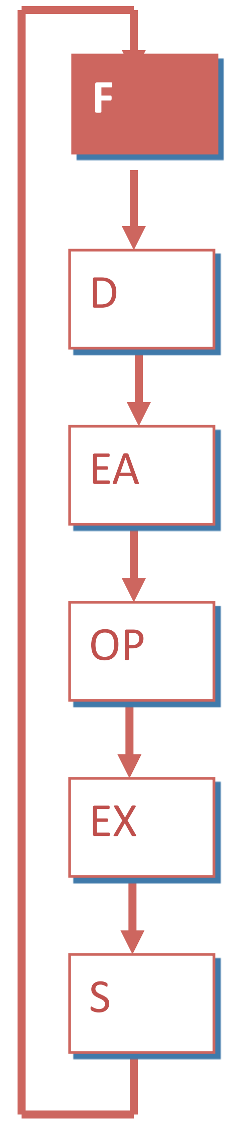
- Central ideas in the von Neumann model:
  - Program and data are both stored as sequences of bits in the computer's memory
  - The program is executed one instruction at a time under the direction of the control unit

Instruction Processing



Instruction Processing: FETCH

- Load next instruction (at address stored in PC) from memory into Instruction Register (IR).
  - Copy contents of PC into MAR.
  - Send "read" signal to memory.
  - Copy contents of MDR into IR.
- Then increment PC, so that it points to the next instruction in sequence.
  - PC becomes PC+1.

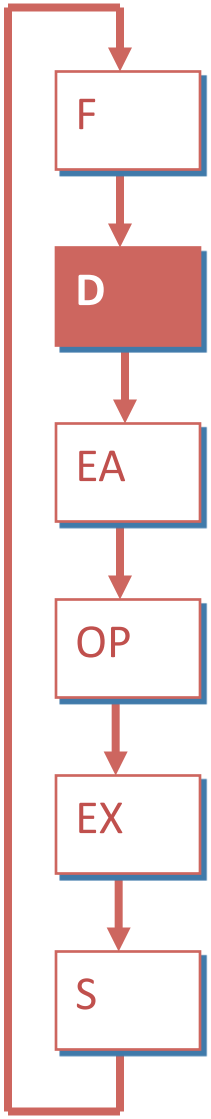


SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Instruction Processing: DECODE

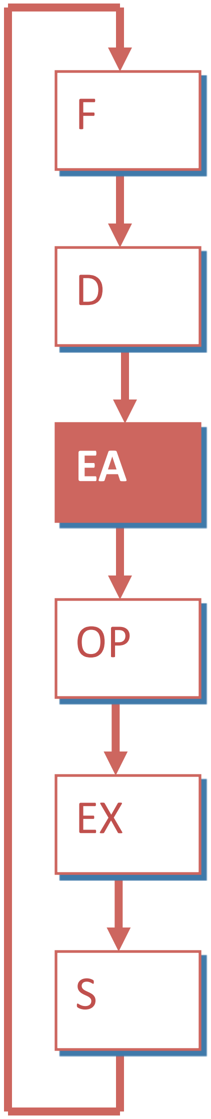
- First identify the opcode.
  - A 4-to-16 decoder asserts a control line corresponding to the desired opcode.
- Depending on opcode, identify other operands from the remaining bits.



Instruction Processing: EVALUATE ADDRESS

- For instructions that require memory access,
  compute address used for access.

- Examples:
  - add offset to base register (as in LDR)
  - add offset to PC
  - add offset to zero



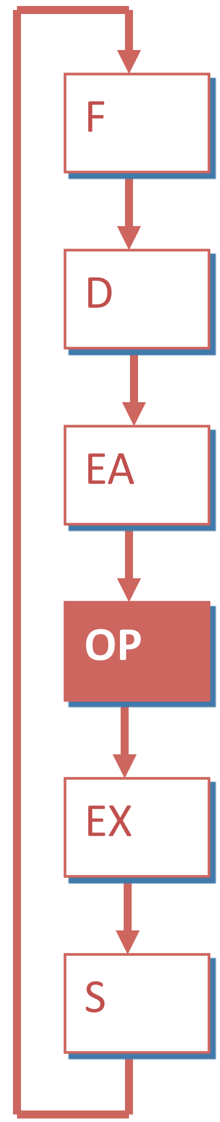
SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Instruction Processing: FETCH OPERANDS

- Obtain source operands needed to perform operation.

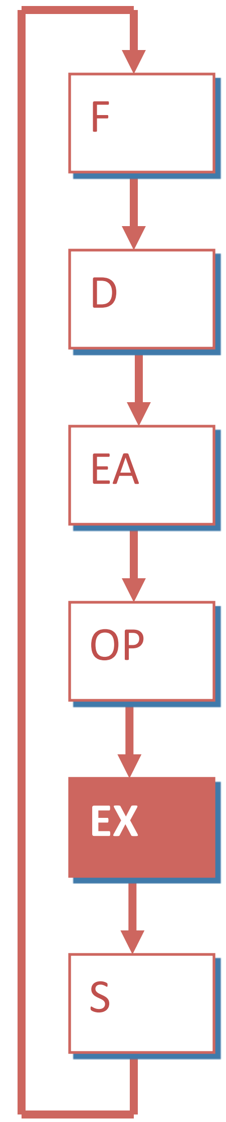
- Examples:
  - – load data from memory (LDR)
  - – read data from register file (ADD)



Instruction Processing: EXECUTE

- Perform the operation,
  using the source operands.

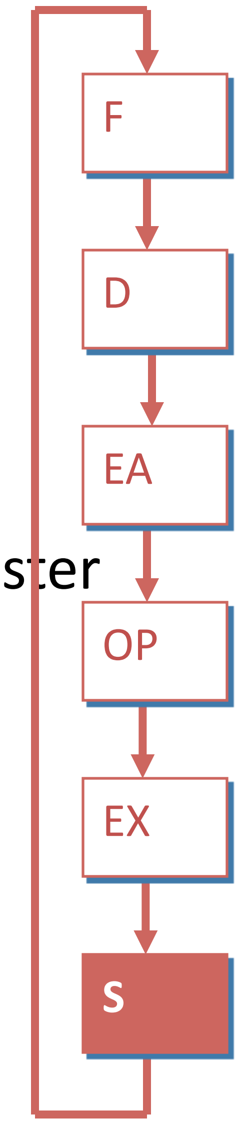
- Examples:
  - send operands to ALU and assert ADD signal
  - do nothing (e.g., for loads and stores)



Instruction Processing: STORE RESULT

- Write results to destination.
  (register or memory)

- Examples:
  - result of ADD is placed in destination register
  - result of memory load is placed in destination register
  - for store instruction, data is stored to memory
    - write address to MAR, data to MDR
    - assert WRITE signal to memory



Changing the Sequence of Instructions

- In the FETCH phase, we increment the Program Counter by 1.

- What if we don't want to always execute the instruction
that follows this one?
  - examples: loop, if-then, function call

- Need special instructions that change the contents of the PC.

- These are called *control instructions*.
  - jumps are unconditional -- they always change the PC
  - branches are conditional -- they change the PC only if some condition is true (e.g., the result of an ADD is zero)

Instruction Processing Summary

- Instructions look just like data -- it's all interpretation.

- Three basic kinds of instructions:
  - computational instructions
  - data movement instructions
  - control instructions

- Six basic phases of instruction processing:
- F → D → EA → OP → EX → S
  - not all phases are needed by every instruction
  - phases may take variable number of machine cycles

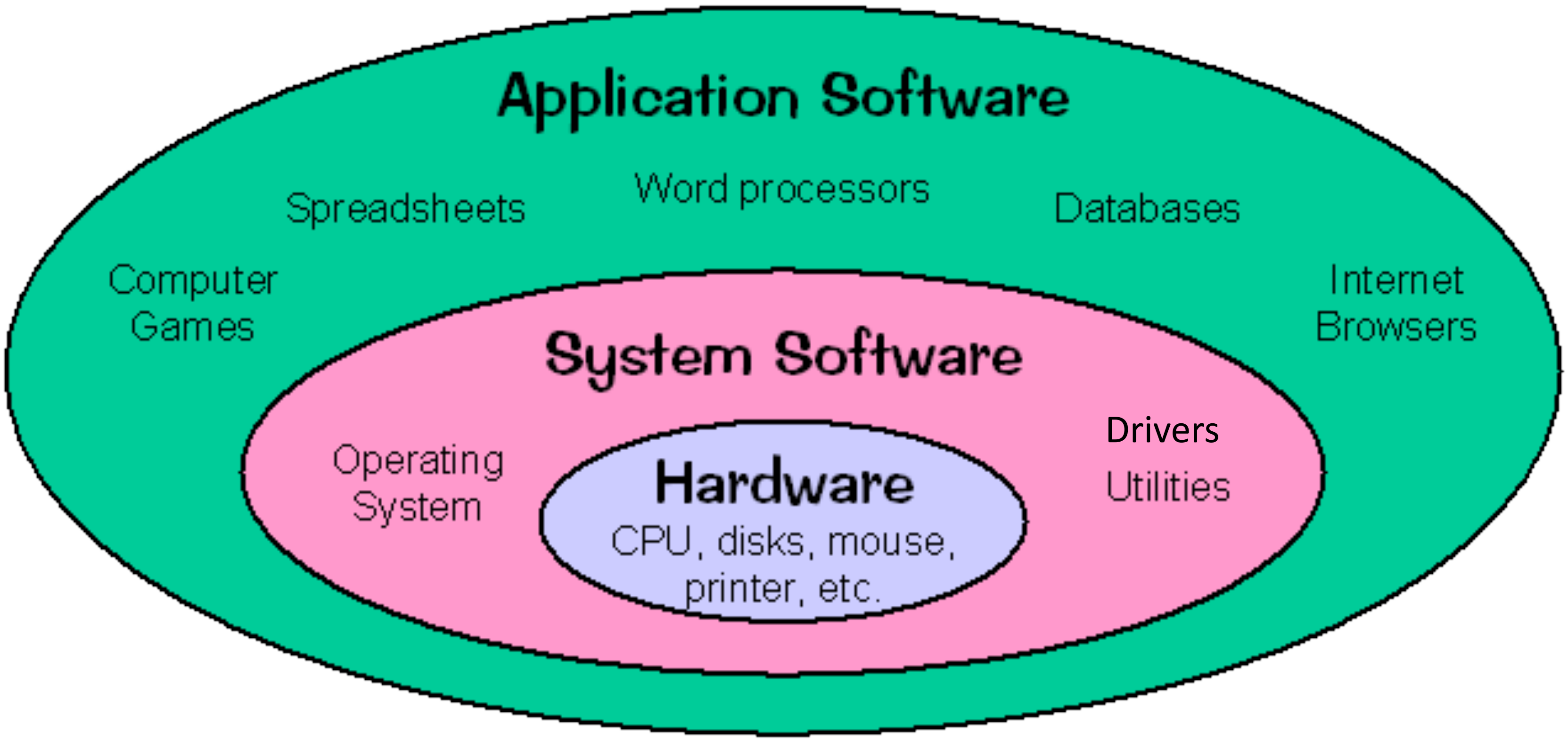
SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Software

- Classification of software
- System Software: The Power behind the Power
- The Operating System: it's role
- Other System Software: Device Drivers & Utilities

Classification of Software



- **Application Software**
  - Software developed to solve a particular problem for users
    - Either performs useful work on a specific task
    - Or provides entertainment
  - We interact mainly with this software
- **System Software**
  - Enables application software to interact with the computer
  - Helps the computer to manage its own internal and external resources

System Software: The Power behind the Power

- System Software has 3 basic components:

1. Operating System (OS)

- The principal component of system software
- Low-level, master system of programs to manage basic computer operations

2. Device Drivers

- Help the computer control peripheral devices

3. Utility Programs

- Used to support, enhance, or expand existing programs in the compute

Examples – utility programs

- Practical Utility programs perform the following tasks:
  - Virus protection
  - Data compression
  - File defragmentation
  - Disk scanner & disk cleanup
  - Backup
  - Data recovery

Operating System

Do all computers need an OS?

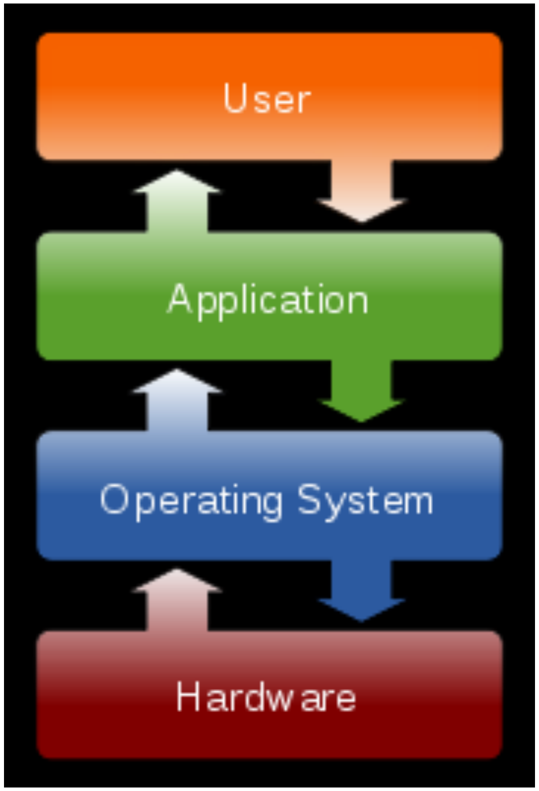
- No

- E.g.: computers / microcontrollers controlling appliances do not have an operating system
  - Not necessary
    - It would drive up the manufacturing costs
    - Add complexity when not required

The Operating System – it's role

- **User/ programmer convenience:**
  simple, consistent way for applications to interact with the hardware.

- **Greater resource utilization:**
  manages the hardware and software resources of the computer system, often invisibly.



Benefit for application developers

- **Don't have to manage hardware complexity**: Application developers can design software for an OS and it will run on all machines that support that OS → abstraction

- The OS hides and manages the hardware complexity and provides an Application Programmer Interface (API).

API

- Application Programming Interface

- Set of functions, procedures, methods, classes or protocols that an OS provides to support requests from computer programs

SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Core Tasks of an OS

1. Processor management
2. Memory management
3. Device management
4. Storage management
5. Application Interface
6. User Interface

Processor Management

- Various programs compete for the attention of the microprocessor.
- The OS makes sure that each application gets the necessary attention required for its proper execution.
- It tries to optimally manage the limited processing capacity of the microprocessor to the greatest good of all the users & apps.

Memory Management

- Straight forward for a single-user, single tasking
- The OS ensures that:
  - each application has enough private memory
  - applications do not run into other application's private memory.
- The OS is responsible for efficient utilization of hierarchical system memory (e.g. RAM, cache, etc.).

Device Management

- Applications talk to devices through the OS and OS talks to and manages devices through device drivers

- Example:

  When we print to a laser printer, we do not need to know its details. All we do is to tell the printer device driver about what needs to be printed and it takes care of the details.

Storage Management

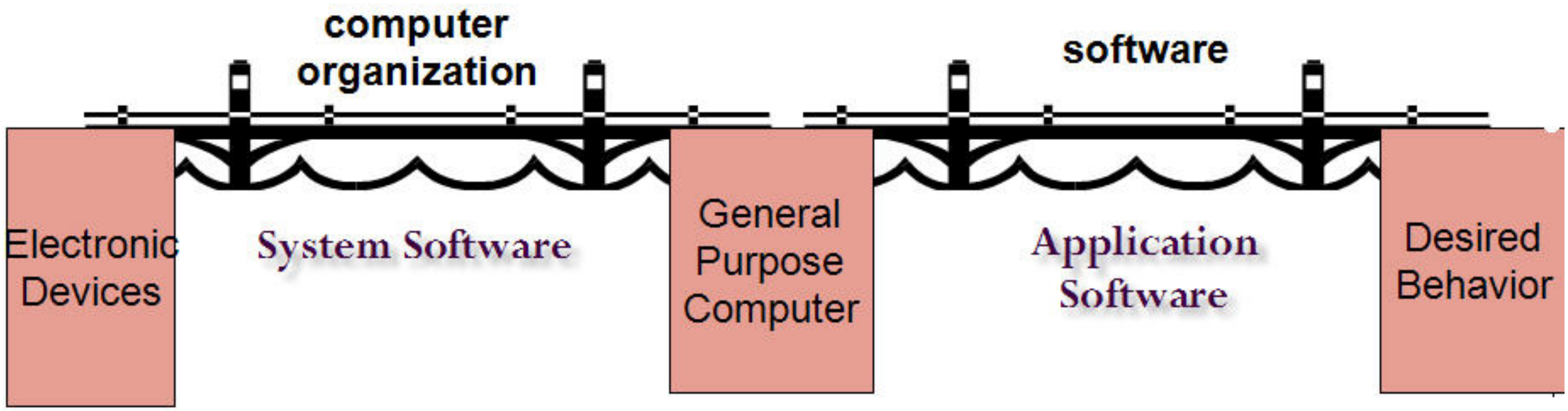
- A file system is a collection of directories, subdirectories, and files organized in a logical order
- The OS is responsible for maintaining the file system through indexing of filenames and their disk location.
- The OS can find any file in a logical and timely fashion

SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Major Benefits of an OS

- **Convenience:** facilitates the use of hardware
- **Efficiency:** ensures that resources are used efficiently
- **Security:** ensures that resources are not misused
- **Communication:** enables access to other computers
- **Real-Time Support:** enables real-time constraints to be met


computer organization
software
Electronic Devices
System Software
General Purpose Computer
Application Software
Desired Behavior

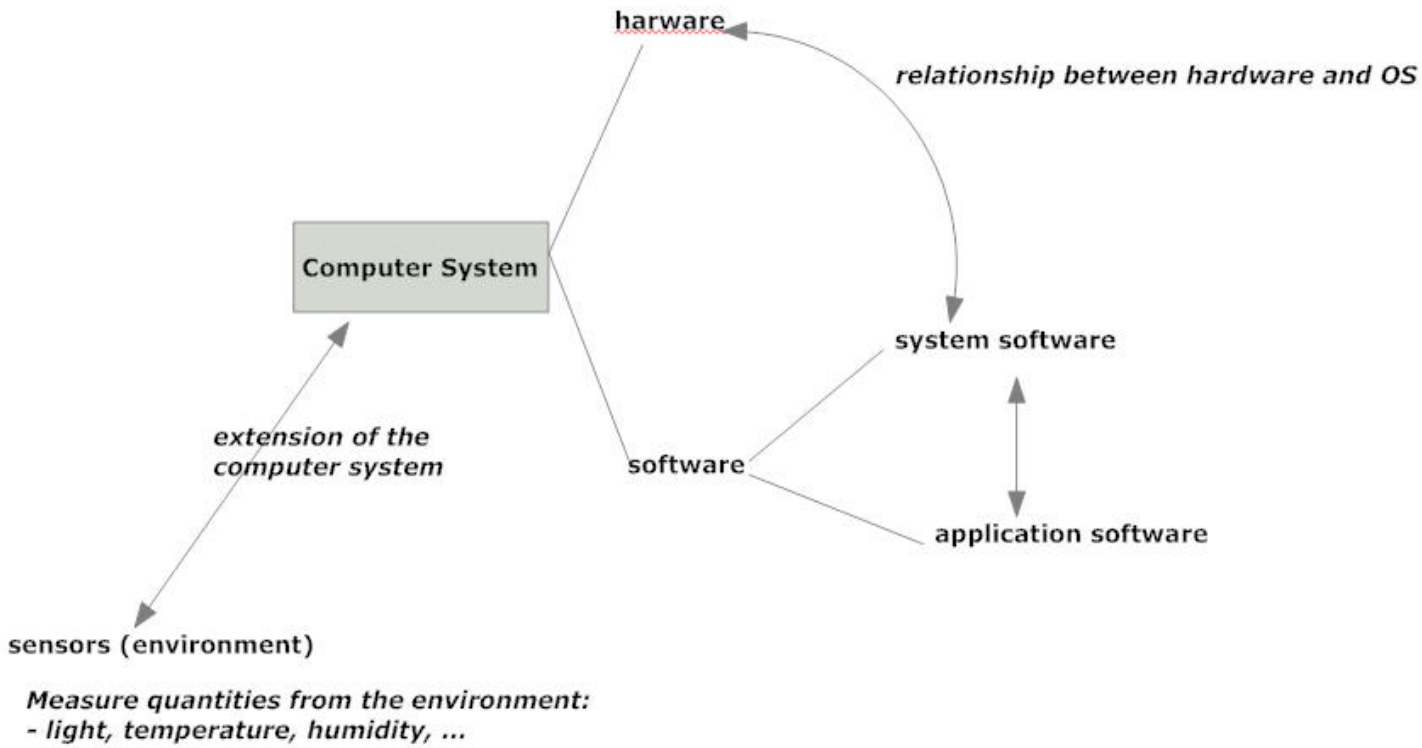
SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Application Software

- Examples:
  - Word processing
  - Spreadsheet
  - Database
  - Specialty software
  - Etc…

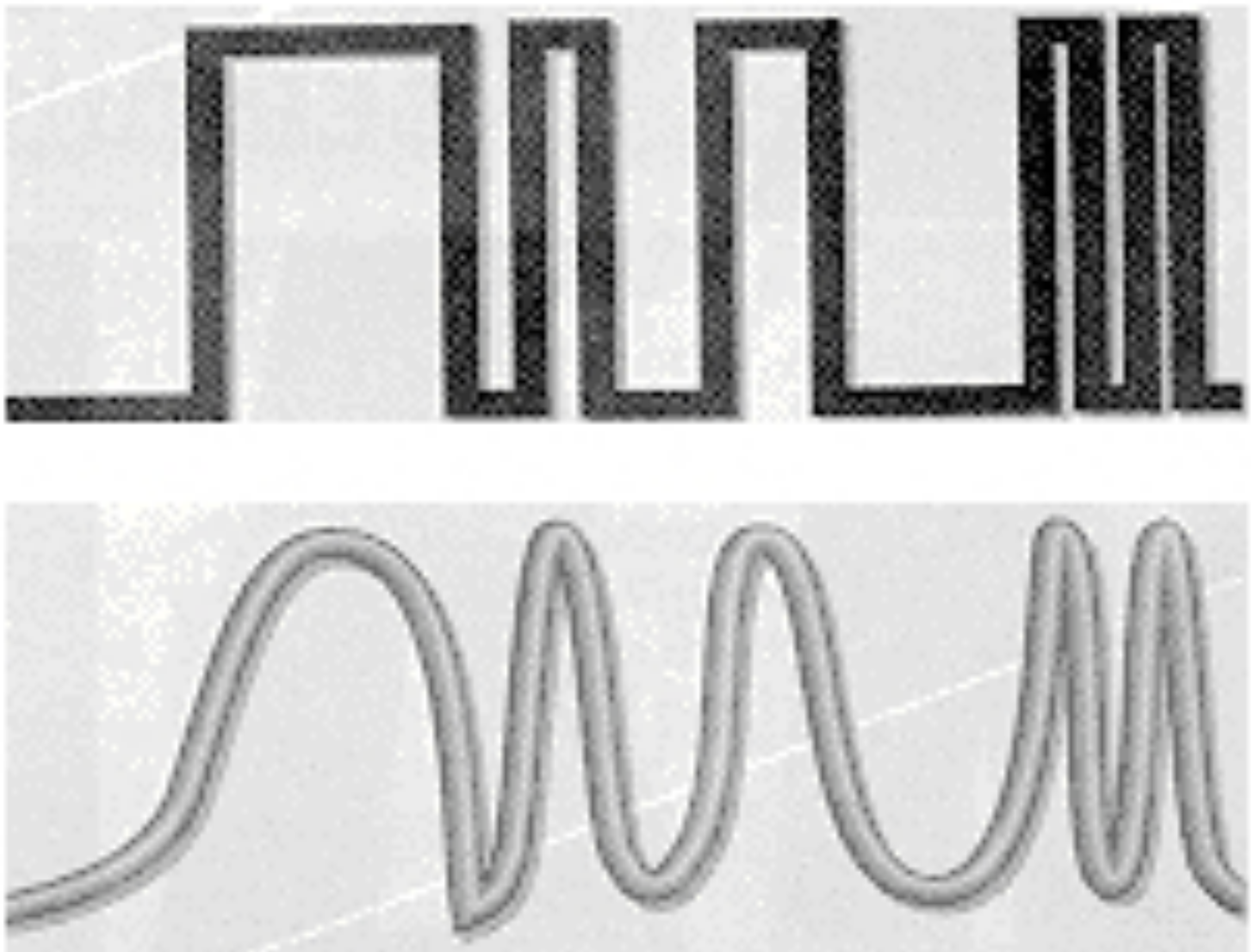
Extending the computer system



Applications using sensors
Networking

Analog data

- Examples of analog data / signals:
  - The temperature of outside
  - The speed at which an object is travelling.
  - The amount of light in a room.
  - The amount of oxygen in a river.
  - The level of noise being made by aircraft flying over a town.



digital

analog

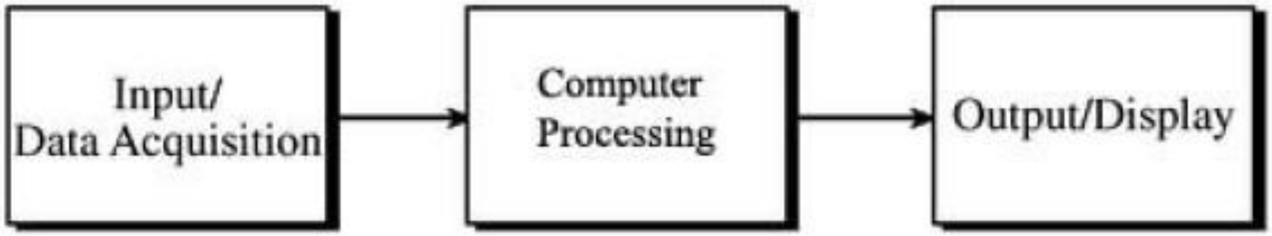
Processing analog data using a computer system

- What is needed:
  - **Sensors** to measure the physical quantities (e.g. temperature) of interest.
  - An interface is used to connect the sensors to the computer.
  - Some software to store and display the information on the computer.


Sensor
Analogue Voltage
Interface
Digital Signal
Computer

Connecting the Sensors to the Computer

- The sensors that are used are not plugged directly into the computer. This is because :
  - Some of the sensors produce analogue voltages which can not be understood by the computer. These voltages need to be changed into digital signals (0s and 1s) before the computer can understand them.
  - The computer could be damaged if the voltages that the sensors sent to it became too large.



- Data / input acquisition: the data may be temperature, light, humidity, displacement, or other physical parameter.

- The output signal from most sensors is not suitable for immediate display. Rather, some form of signal processing/amplification is usually needed.

- Finally, for the data to be utilized as useful information, there must be a display, data storage or control function.

What are sensors?

- A sensor is a device which converts a physical phenomena into an electrical signal.

- Sensors represent part of the interface between the physical world and the world of electrical devices, such as computers.

- (the other part of this interface is represented by **actuators,** which convert electrical signals into physical phenomena).


Accelerometer
Gyro
Pendulum Resistive Tilt Sensors
Piezo Bend Sensor
Metal Detector
Gas Sensor
Gieger-Muller Radiation Sensor
Pyroelectric Detector
UV Detector
Digital Infrared Ranging
CDS Cell Resistive Light Sensor
FlexiForce
Resistive Bend Sensors
Limit Switch
Mechanical Tilt Sensors
Touch Switch
Pressure Switch
Miniature Polaroid Sensor
IR Pin Diode
Side view of Lens
IR Sensor w/lens
Thyristor
Magnetic Sensor
Hall Effect Magnetic Field Sensors
Polaroid Sensor Board
IR Reflection Sensor
IR Amplifier Sensor
IRDA Transceiver
Magnetic Reed Switch
Lite-On IR Remote Receiver
Radio Shack Remote Receiver
IR Modulator Receiver
Solar Cell
Compass
Compass
Piezo Ultrasonic Transducers

Choosing the right sensor

- Decide first what parameters of the external environment are important for our application (e.g.: temperature, humidity, pressure, light, etc).

- Determine what kind of sensor is optimal for measuring that parameter.

Types of sensors

- Sensors can be categorized in many ways:
  - by the underlying physics of their operation
  - by the particular phenomenon they measure
  - by a particular application

Types of sensors

- **Analog:** output is continuous, output is function of input. Requires ADC for interfacing to computer

- **Digital:** the output is in form of digital signal

- **Active:** need separate power source to obtain the output

- **Passive:** these are self-generating, produce electrical signal when subjected to sensed quantity (piezoelectric, thermoelectric, radioactive, etc).

Digital Sensors

- A digital sensor's output can only be in one of two possible states.
- It is either ON (1), often +5V or OFF (0), 0V. Most digital sensors work with a threshold.
- If the incoming measurement is below the threshold, the sensor will output one state, if it is above the threshold, the sensor will output the other state.

Analog Sensors

- In contrast to a digital sensor, an analog sensor's output can assume any possible value in a given range.
- Very often the output of an analog sensor is a variable resistance that can be used to control a voltage.
- Rather than only being able to toggle between two states, the analog sensor can output an almost infinite range of values.

SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Analog sensors used in class

Rotation Sensor

- This sensor rotates 300 degrees.
- Type: Resistive 3-Pin
- Formula:
  Fully clockwise: min res
  Fully counter clockwise

Slider Sensor

- This device is a variable resistor similar to a potentiometer.

- Type: Resistive 3-Pin
- Formula:
  When the slider is at one side: 0
  When the slider is at the other end: the maximum resistance of the slider is 10kΩ

Temperature Sensor

- This sensor measures ambient temperature from –40 to +125 degrees Celsius. This device is a precision temperature to voltage converter that outputs a voltage that is directly proportional to temperature.

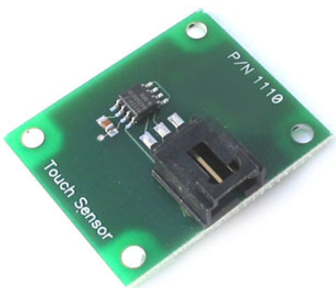
- Formula:

  Temperature (in degrees Celsius) = (SensorValue – 200) / 4

- Sensor: Microchip TC1047A

Touch Sensor

- This sensor changes value from max to 0 when it is touched.
- More specifically, this sensor is actually a capacitive change sensor.
  When the capacitance changes the sensor goes to zero.
- It will work through ¼ inch of glass

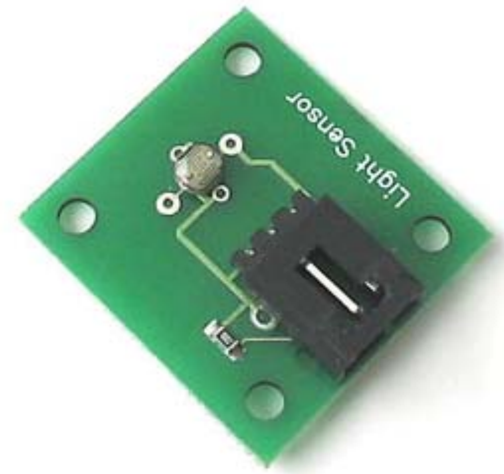


Force Sensor

- With no force applied this sensor will read zero. As force increases on the circular button the value increases. It is not accurate enough to be used as a weight measurement device.

- The sensor is not designed to have force applied constantly over time.

Light Sensor



- Resistive 2-Pin
- Formula: With no light the resistance of this sensor is 500 k ohm. At 10 lux the resistance falls to between 10 k and 5 k ohm. This resistance is in a voltage divider with a 7.5 k ohm resistor.
- Sensor: A standard CdS (Cadmium Sulfide) photoresistor

Sensor technology – underlying physical principles

- Overview of physical principles by which sensor operate
- One physical principle can be used to measure many different phenomena
- One phenomenon can be measured by many physical principles

Piezoelectric sensors

- The Piezoelectric effect is an effect in which energy is converted between mechanical and electrical forms.
- Discovered in the 1880's by the Curie brothers.
- When a pressure (piezo means pressure in Greek) is applied to a polarized crystal, the resulting mechanical deformation results in an electrical charge.

Piezoelectric effect

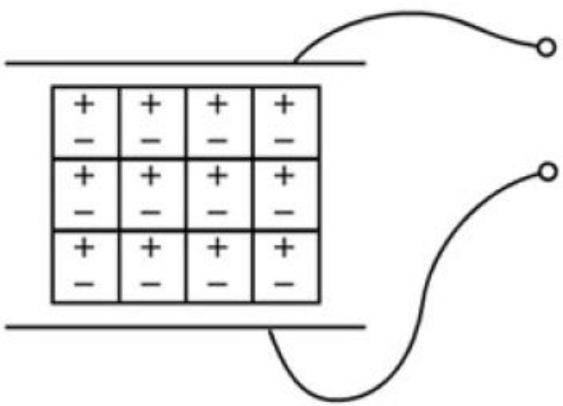
- Crystals have permanent electrical polarization.
- Each cell of the crystal has an electric dipole, and the cells are oriented such that the electric dipoles are aligned.
- This results in excess surface charge which attracts free charges from the surrounding atmosphere making the crystal electrically neutral.

Piezoelectric effect

- If a sufficient force is applied to the piezoelectric crystal, a deformation will take place.
- The deformation disrupts the orientation of the electrical dipoles and creates a situation in which the charge is not completely cancelled. This results in a temporary excess of surface charge, which subsequently is manifested as a voltage which is developed across the crystal.
- In order to utilize this physical principle to make a sensor to measure force, we must be able to measure the surface charge on the crystal.

Sensor based on the piezoelectric effect

- A common method of using a piezoelectric crystal to make a **force** sensor: two metal plates are used to sandwich the crystal making a capacitor.



- An external force causing a deformation of the crystal results in a charge which is a function of the applied force.

- In its operating region, a greater force will result in more surface charge.

- Resulting voltage will be proportional with the applied force

Use of the piezoelectric effect

- The piezoelectric effect can measure force, flexure, acceleration, heat, and acoustic vibrations.

- Piezoelectric transducers find use both as speakers (voltage to mechanical) and microphones (mechanical to electrical).

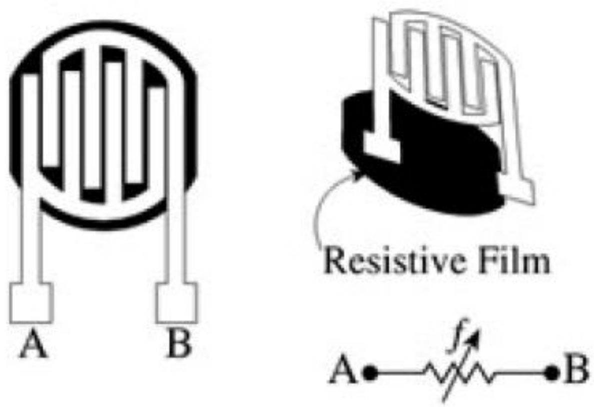
Force sensing resistors

- Force sensing resistors use the electrical property of resistance to measure the force (or pressure) applied to a sensor.

- A force sensing resistor is made up of two parts:
  - The first is a resistive material applied to a film.
  - The second is a set of digitizing contacts applied to another film.

Force sensing resistors

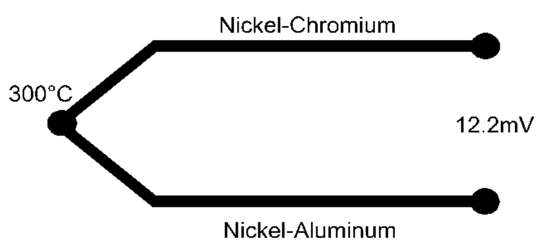
- Diagram of a force sensing resistor:



- The resistive material serves to make an electrical path between the two sets of conductors on the other film.
- When a force is applied to this sensor, a better connection is made between the contacts, hence the conductivity is increased.

Temperature sensing

- Several different sensors are commonly used to measure temperature:
  - thermal resistors (RTDs and thermistors)
  - thermocouples



Thermal Resistors

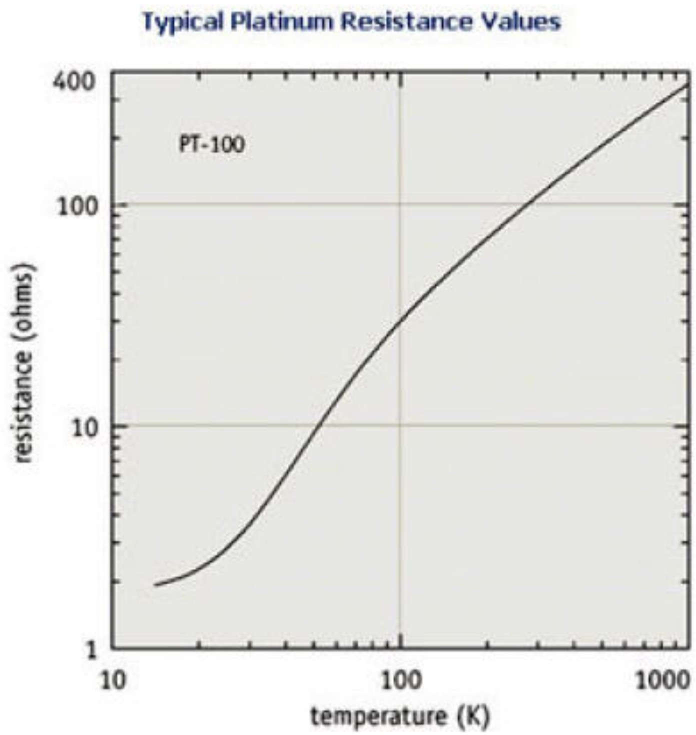
- Electrically conductive elements that are designed to change electrical resistance in a predictable manner with changes in applied temperature.

- **Resistance temperature devices (RTDs)** - based on the tendency of materials (naturally occurring materials) to change physical dimensions with changes in temperature.

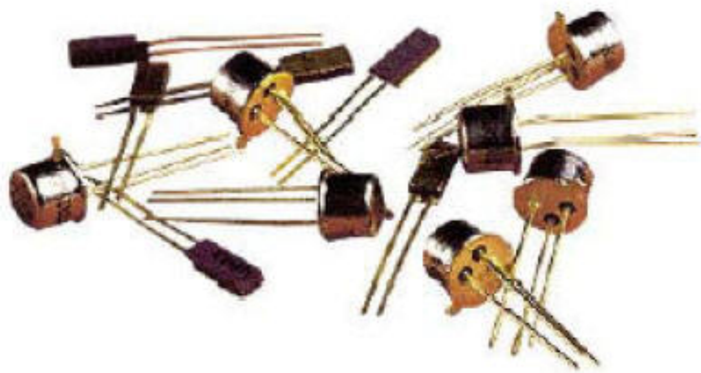
- **Thermistors** – made from a human-made substance, called semiconductor. Have a negative temperature coefficient (semiconductor's resistance decreases with an increase in temperature).

RTD example

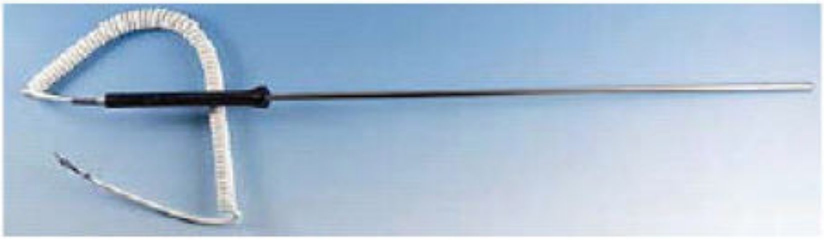
Platinum RTD - Lake Shore Cryotronics, Inc



Thermistor examples



Omega Engineering, Inc.



thermistor probes

SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

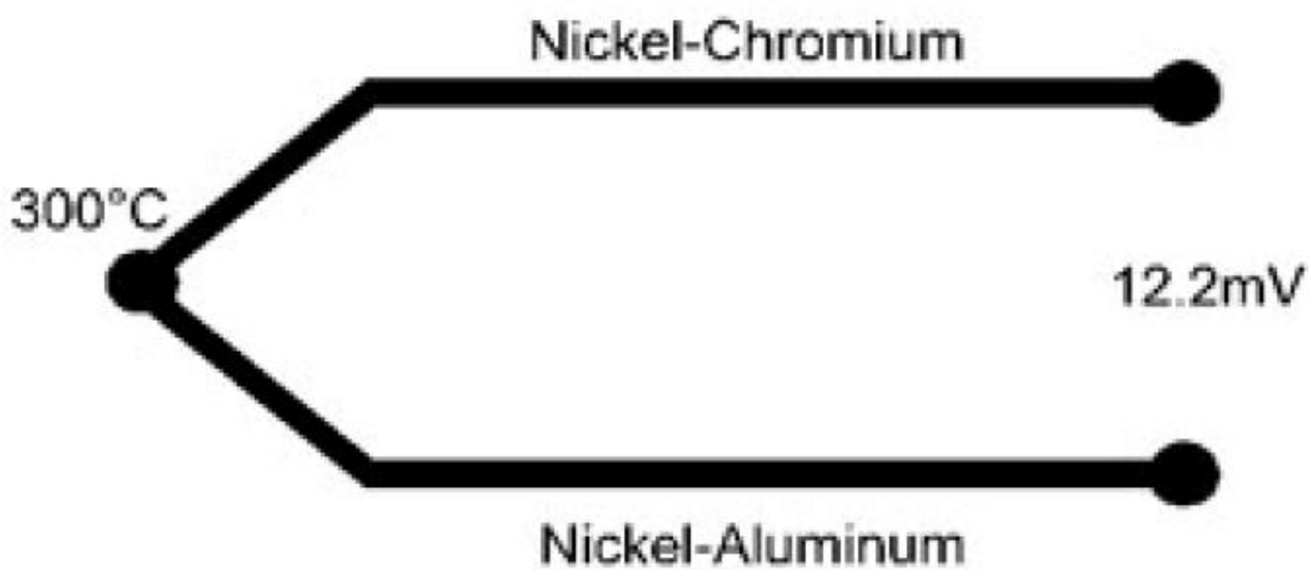
Thermocouples

- Most popular temperature sensors
- In 1822, an Estonian physician named Thomas Seebeck discovered that the junction between two metals generates a voltage which is a function of temperature. Thermocouples rely on this **Seebeck effect.**
- Although almost any two types of metal can be used to make a thermocouple, a number of standard types are used because they possess predictable output voltages and large temperature gradients.

Thermocouples - example

Standard tables show the voltage produced by thermocouples at any given temperature.

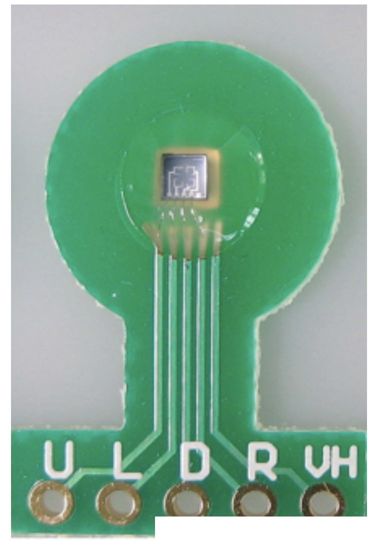
Example of K-type thermocouple (most popular):



Force and pressure sensors

- Force and pressure are related concepts
- Force F: vector quantity (it has both magnitude and direction of application).
- Basic methods to sense force:
  - **Acceleration methods:** measure the acceleration of a known mass on which the unknown force operates.
  - **Gravity-balance methods**: compare the unknown force with the action of the gravitational force on a known mass
  - **Pressure-sensing methods**: convert the force to a fluid pressure, which is measured using a pressure transducer

Force and Pressure Sensors



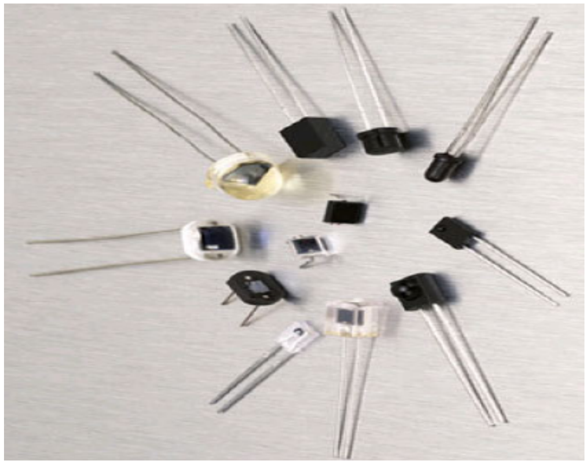
Light sensing

- Light = a form of electromagnetic radiation

- Light detectors essentially may be broken into two categories:
  - **Quantum detectors** - convert incoming radiation directly into an electron in a semiconductor device, and process the resulting current with electronic circuitry.
  - **Thermal detectors** - simply absorb the energy and operate by measuring the change in temperature with a thermometer.

Light sensing: quantum detectors

- Offer the best performance for detection of optical radiation.
- The photon is absorbed and an electron is liberated in the structure with the energy of the photon.
- Example of device: photodiode (PerkinElmer)



Light sensing: thermal detectors

- Thermal detectors operate by absorbing the infrared radiation and measuring the temperature rise of the detector with a thermometer.

- Generally, the performance of thermal detectors is limited by the availability of sensitive and small heat capacity thermometers.

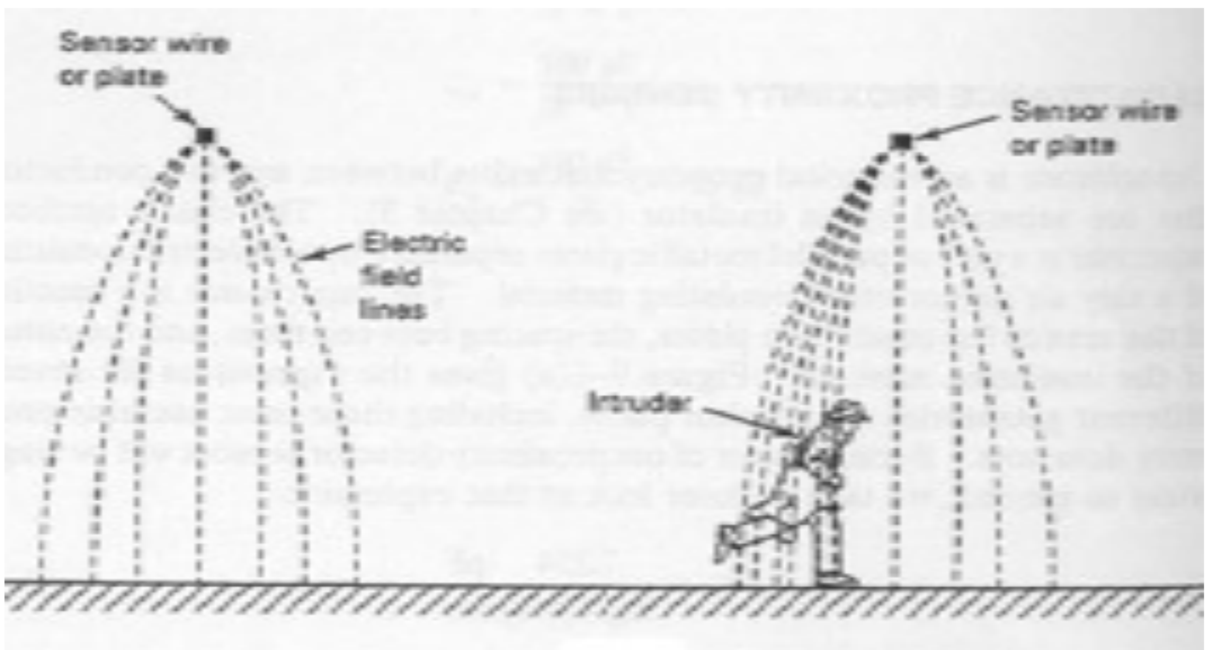
- If the conditions allow use of a quantum detector, such a detector will outperform a thermal detector by several orders of magnitude. Thermal detectors come into their own in situations which simply don't allow quantum detectors.

SFU

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Proximity and Presence Sensors

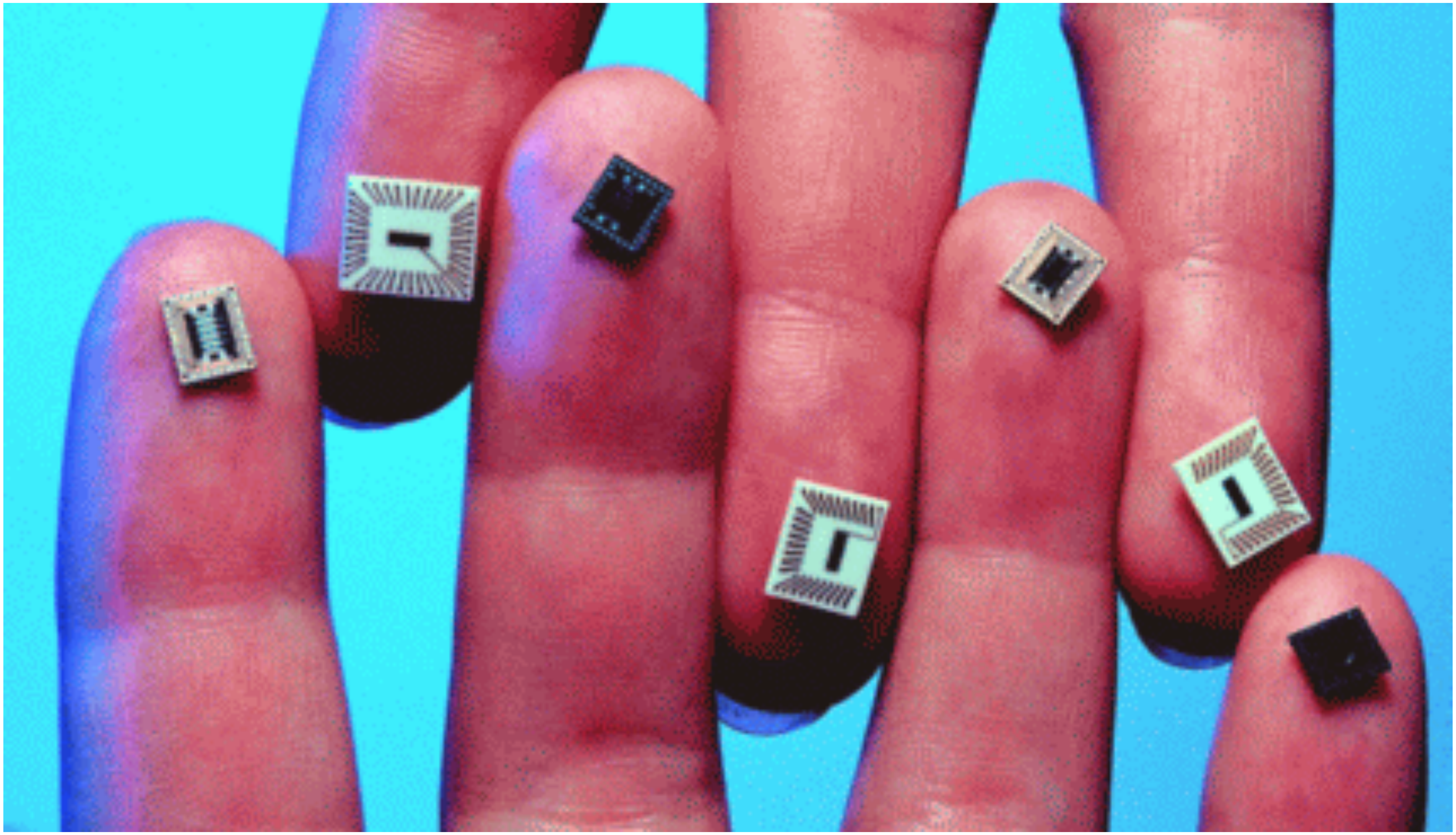
- Proximity sensors are used for sensing the closeness of objects.
- Their range varies with the type of sensor, its sensitivity and the material being sensed.
- There are three basic types of proximity sensors: inductive, capacitive and ultrasonic.



Proximity and presence sensors

The future of sensors: smaller

- Less space for installation.
- Decreased installation space means that sensors are installed in inaccessible places.
- Miniature sensors are specially designed for precision sensing in small areas previously accessible only to remote sensors and fiber optic cable.



The future of sensors: smarter

- Monitor parameters such as voltage, radiation, temperature and humidity, and process this information within the sensor itself.

- Identify threshold limits, process and manipulate data, and activate alarms.

- The sensor works off an electrical bus, which eliminates the need for large wiring harnesses.

Thank you

Questions?