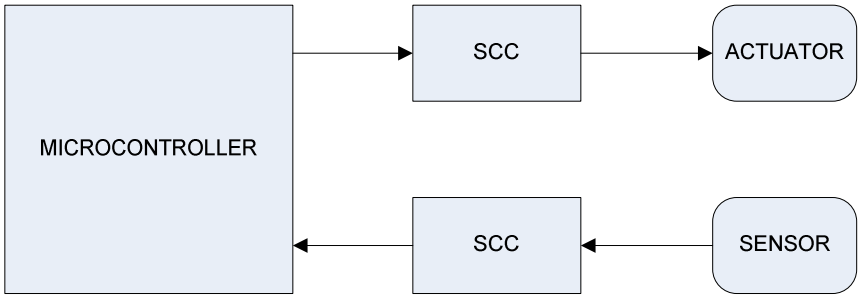
Embedded systems are product sub-systems controlled by a special-purpose computer.

- Embedded systems control one system task or a small number of system tasks.
- Embedded systems can be categorized into application domains such as transportation, appliances, building systems, audiovisual, gaming, and medical.
- Embedded systems have design constraints that are different from personal computers. For example, embedded systems must often fit in a small footprint, tolerate high vibrations, hit a low cost-point, and be a low-power device.

Real-time embedded systems must respond to event as they occur.

- Hard real-time systems ***must*** meet system response time constraints.
- Soft real-time systems ***should*** meet system response time constraints.
- Not all embedded systems have real-time constraints.
- Interrupts and timers are hardware features used to implement real-time responses.

Basic embedded system modeling describes the system inputs, outputs, and design constraints.



- A basic model can be used to start the design for all embedded systems.
- The model names the key parts of the embedded system.
- Model refinement occurs as the design constraints are solved.

Transducers convert energy from one form to another.

- Embedded systems use electromechanical transducers.
- **Sensors** are transducers that convert physical energy to electrical energy. For example, the microphone converts sound to voltage. Similarly, a photo-receiver converts photons to voltage or current. Other examples are accelerometers, thermometers, buttons, switches, flowmeters, and load cells for pressure.
- **Actuators** are transducers that convert electrical energy to physical energy. For example, the LED converts current to photons. Similarly, motors convert voltage to rotations motion. Other examples are solenoids, speakers, valves, and relays.

Signal conditioning circuits protect the computer from inappropriate signal voltage or current levels.

- **Isolation** prevents unwanted electrical energy from reaching the embedded computer. For example, unwanted electrical frequencies can be filtered out by signal-conditioning circuits. Similarly, large spikes in voltage and current can be leveled out by signal-conditioning circuits.
- **Ranging** ensures that sensor and actuator voltages fall within the correct mathematical range. For example, analog signals are often very weak with only millivolts of energy. This energy is not sufficient for computer sampling. Thus, signal conditioning circuits strengthen, or amplify, the energy in the signal into the volts range.

Microcontrollers and **microprocessors** can both serve as the embedded system "brain."

- Microprocessors are single-chip processors. Memory chips and I/O devices must be added on the motherboard of a microprocessor-based embedded system. This increases the space and cost constraints. However, microprocessors are often used when speed or advanced numeric calculations are required.
- Microcontrollers are single-chip computers. Memory and I/O devices are implemented on chip. This reduces the space and cost constraints. Microcontrollers are preferred if high-speed and advanced numeric calculations are not required.

Microcontroller I/O devices facilitate interfacing to sensors and actuators.

- **Software-controlled port pins** provide attachment points for sensor and actuator signals.
- **Analog-to-digital converters** sample analog sensor signals into binary bytes for software use.
- **Communications devices** send data using SCI, SPI, I^2C, USB, CAN, PS2, Ethernet or ZigBee.
- **Timers** provide high-precision timing of real-time constrained input and output waveforms.
- **Interrupt controllers** provide immediate response to real-time system events.
- **EEPROM memories** provide non-volatile storage for event or data logging.

Microcontrollers dominate the embedded systems market.

- The 4-bit microcontroller is widely used in lower-cost products. Some examples are watches, razors, toothbrushes, and toys.
- The 8-bit microcontroller is the most commonly used microcontroller in the embedded systems market with billions of them powering automotive systems, elevators, appliances, and many other products!
- The 16-bit and 32-bit microcontrollers are used in products such as PC peripherals, digital cameras, advanced instrumentation panels, and military systems.
- **Remember** that ***any*** product can be designed around ***any*** microcontroller!

Microcontrollers and **microcontroller families** come from many manufacturers. Some examples are:

	EXAMPLE CHIPS OR CHIP FAMILIES		
Company	**8-bit**	**16-bit**	**32-bit**
AMCC			PowerPC
Atmel	ATmega16, ATmega32, Atmega64		AT91SAM
Freescale	MC68HC05, MC68HC08, MC68HC11	MC68HC12, MC68HC16	MC68332
Intel	8048, 8051	8096, 80186	
Microchip	PIC10, PIC12, PIC14, PIC16, PIC18	PIC24	PIC32
MIPS			MIPS32 cores
Rabbit	R2000, R3000, R4000		
Texas Instruments	TMS370	MSP430	C2000, TMS470
Zilog	Z8	Z16	Zatara