Microcontrollers

Microcontroller

A **microcontroller** (or **MCU**) is a **computer-on-a-chip** used to control electronic devices. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (the kind used in a PC). A typical microcontroller contains all the memory and interfaces needed for a simple application, whereas a general purpose microprocessor requires additional chips to provide these functions. A microcontroller is a single integrated circuit with the following key features:

- central processing unit (CPU) - ranging from small and simple 8-bit processors to sophisticated 32- or 64-bit processors
- input/output interfaces such as serial ports
- peripherals such as timers and **watchdog circuits**
- RAM for data storage
- ROM, EEPROM or Flash memory for program storage
- **clock generator** - often an oscillator for a quartz timing crystal, **resonator** or RC circuit

This integration drastically reduces the number of chips and the amount of wiring and PCB space that would be needed to produce equivalent systems using separate chips.

Microcontrollers are inside many kinds of electronic equipment .

A PIC 18F8720 microcontroller in an 80-pin TQFP package.

In addition to the key features listed above, most microcontrollers today take further advantage of not needing external **pins** for **memory buses**. They can afford to use a Harvard architecture: separate memory buses for instructions and data, allowing accesses to take place concurrently. Microcontrollers also usually have a variety of input/output interfaces. Serial I/O (UARTs) are very common, and many include analog-to-digital converters, timers, or specialized serial communications interfaces like I²C, Serial Peripheral Interface and Controller Area Network. Originally, microcontrollers were only programmed in assembly language, or later in C code. Recent microcontrollers integrated with on-chip **debug circuitry** accessed by

In-circuit emulator via JTAG enables a programmer to debug the software of an embedded system with a **debugger**.

Some microcontrollers have begun to include a built-in high-level programming language interpreter for greater ease of use. The Intel 8052 and Zilog Z8 were available with BASIC very early on, and BASIC is more recently used in the popular BASIC Stamp MCUs.

Controller

It is a device that controls the transfer of data from a computer to a peripheral device and vice versa. For example, disk drives, display screens, keyboards, and printers all require controllers.

In personal computers, the controllers are often single chips. When you purchase a computer, it comes with all the necessary controllers for standard components, such as the display screen, keyboard, and disk drives. If you attach additional devices, however, you may need to insert new controllers that come on expansion boards.

Controllers must be designed to communicate with the computer's **expansion bus**. There are three standard bus architectures for PCs -- the AT bus, PCI (Peripheral Component Interconnect), and SCSI. When you purchase a controller, therefore, you must ensure that it conforms to the bus architecture that your computer uses.

Basic principles

A **controller** can monitor and affect the operational conditions of a system. The operational conditions are typically referred to as output variables of the system which can be affected by adjusting certain input variables. For example, the heating system of a house can be equipped with a thermostat (controller) for sensing air temperature (output variable) which can turn on or off a furnace or heater when the air temperature becomes too low or too high. In this example, the thermostat is the controller and directs the activities of the heater. The heater is the processor that warms the air inside the house to the desired temperature (setpoint). The air temperature reading inside the house is the feedback. And finally, the house is the environment in which the heating system operates. The notion of controllers can be extended to more complex systems. In the natural world, individual organisms also appear to be equipped with controllers that assure the homeostasis necessary for survival of each individual. Both human-made and natural systems exhibit collective behaviors amongst individuals in which the controllers seek some form of **equilibrium.**

Types of control

In control theory there are **two basic types of control**. These are **feedforward** (**feed-forward** is a term describing a kind of system which reacts to changes in its environment, usually to maintain some desired state of the system. A system which exhibits feed-forward behavior responds to a measured disturbance in a pre-defined way) and **feedback (feedback** is the signal that is looped back to control a system within itself. This loop is called the feedback loop. A control system usually has input and output to the system; when the output of the system is fed back into the system as part of its input) . The input to a feedback controller is the same as what it is trying to control - the controlled variable is "fed back" into the controller.

In electronic engineering

The processing and control of feedback is engineered into many electronic devices and may also be embedded in other technologies.

The most common general-purpose controller is a **proportional-integral-derivative (PID) controller**. Each term of the PID controller copes with time. The proportional term handles the present state of the system, the integral term handles its past, and the derivative or slope term tries to predict and handle the future.

If the signal is inverted on its way round the **control loop**, the system is said to have **negative feedback**; otherwise, the feedback is said to be positive. Negative feedback is often deliberately introduced to increase the stability and accuracy of a system, as in the **feedback amplifier** .

In mechanical engineering

In ancient times, the float valve was used to regulate the flow of water in Greek and Roman water clocks; similar **float valves** are used to regulate fuel in a **carburettor** and also used to regulate **tank water level** in the **flush toilet**. **Internal combustion** engines of the late 20th century employed mechanical feedback mechanisms such as vacuum advance but mechanical feedback was replaced by electronic engine management systems once small, robust and powerful single-chip microcontrollers became affordable.

Types of controllers

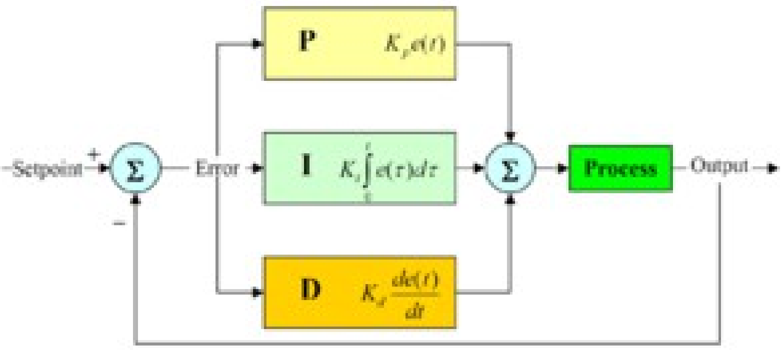
Most control systems in the past were implemented using mechanical systems or **solid state electronics**. Pneumatics were often utilized to transmit information and control using pressure. However, most modern control systems in industrial settings now rely on computers for the controller. Obviously it is much easier to implement complex control algorithms on a computer than using a mechanical system. For a) feedback controllers there are a few simple types. The most simple is like the thermostat that just turns the heat on if the temperature falls below a certain value and off it exceeds a certain value (on-off control). Another simple type of controller is a proportional controller. With this type of controller, the controller output (control action) is proportional to the error in the measured variable. The error is defined as the difference between the current value (measured) and the desired value (**setpoint**). If the error is large, then the control action is large.

Open-loop control can be used in systems sufficiently well-characterized as to predict what outputs will necessarily achieve the desired states. For example, the rotational velocity of an electric motor may be well enough characterized for the supplied voltage to make feedback unnecessary. **Drawbacks** of open-loop control is that it requires perfect knowledge of the system (i.e. one knows exactly what inputs to give in order to get the desired output), and it assumes there are no disturbances to the system.

In personal computers, the controllers are often single chips. When you purchase a computer, it comes with all the necessary controllers for standard components, such as the display screen, keyboard, and disk drives. If you attach additional devices, however, you may need to insert new controllers that come on expansion boards.

Controllers must be designed to communicate with the computer's expansion bus. There are three standard bus architectures for PCs -- the AT bus, PCI (Peripheral Component Interconnect), and SCSI. When you purchase a controller, therefore, you must ensure that it conforms to the bus architecture that your computer uses.

PID controller



A traditional PID controller

A **proportional-integral-derivative controller (PID controller)** is a common feedback loop component in industrial control systems .

The controller takes a measured value from a process or other **apparatus** and compares it with a reference setpoint value. The difference (or "error" signal) is then used to adjust some input to the process in order to bring the process' measured value back to its desired setpoint. Unlike simpler controllers, the PID can adjust process outputs based on the history and rate of change of the error signal, which gives more accurate and stable control. PID controllers do not require advanced mathematics to design and can be easily adjusted (or **"tuned"**) to the desired application, unlike more complicated control algorithms based on optimal control theory.

Control loop basics

Intuitively, the PID loop tries to automate what an intelligent operator with a **gauge** and a **control knob** would do. The operator would read a gauge showing the output measurement of a process, and use the knob to adjust the input of the process (the "action") until the process's output measurement stabilizes at the desired value on the gauge.

A control loop consists of three parts:

1. Measurement by a sensor connected to the process
2. Decision in a controller element,
3. Action through an output device ("actuator") such as a **control valve**.

As the controller reads a sensor, it subtracts this measurement from the "**setpoint"** to determine the "error". It then uses the error to calculate a correction to the process's input variable (the "action") so that this correction will remove the error from the process's output measurement.

In a PID loop, correction is calculated from the error in three ways: cancel out the current error directly (Proportional), the amount of time the error has continued uncorrected (Integral), and anticipate the future error from the rate of change of the error over time (Derivative).

For example: suppose a water tank is used to supply water for use in several parts of a plant, and it is necessary to keep the water level constant. A sensor would measure the height of water in the tank, producing the "measurement", and continuously feed this data to the controller. The controller would have a "setpoint" of (for example) 75% full. The controller would have its output (the "action") connected to a proportionally-controlled characterized control valve controlling the make-up water feed. Opening the valve would increase the rate of water entering the tank, closing the valve would decrease it. The controller would use the measurement of how the level is changing over time to calculate how to manipulate the control valve to maintain a constant level at the "setpoint".

A PID controller can be used to control any **measurable variable** which can be affected by manipulating some other process variable. For example, it can be used to control temperature, pressure, flow rate, chemical composition, speed, or other variables. Automobile cruise control is an example of a process outside of industry which utilizes crude PID control.

Some control systems arrange PID controllers in **cascades** or networks. That is, a "**master" control** produces signals used by "slave" controllers. One common situation is motor controls: one often wants the motor to have a controlled speed, with the "slave" controller (often built into a variable frequency drive) directly managing the speed based on a proportional input. This "slave" input is fed by the "master" controllers' output, which is controlling based upon a related variable.

Coupled and cascaded controls are common in chemical process control, heating, ventilation, and air conditioning systems, and other systems where many parts cooperate.