Work-Ready Electronics

Synchronizing Curriculum to the Rapidly Changing Workplace

Module: Micro & Embedded Controllers

Part 1: Microcontroller Technology Update

WORKREADY ELECTRONICS

Microcomputers and Microprocessors

A microcomputer is digital computer made up of a microprocessor with added memory and input/output (I/O) circuits. A personal computer or laptop is the common example of a microcomputer.

The term microprocessor means a single integrated circuit containing the main circuits of a computer which we call the central processing unit (CPU). The CPU is made up of the arithmetic logic unit (ALU) and the control unit plus a variety of registers and buses. The term microprocessing unit (MPU) is also widely used to describe a microprocessor.

The most well known microprocessors are the Intel Pentium and the AMD Opteron in their many forms. They are used in most personal computers and laptops.

Microcontroller/Embedded Controller

A microcomputer can also be a microprocessor, memory, and I/O circuits all integrated on a single chip of silicon. Such a microcomputer is also called a microcontroller because it is most commonly used to monitor and control virtually all functions in other electronics products.

Another term for microcontroller is embedded controller. It is embedded or built into almost every electronic product. Its function is dedicated to the product or application.

The Importance of Microcontrollers

Literally all electronic products, large or small, simple or complex, contain at least one microcontroller. It truly is difficult to name a product that does NOT contain an embedded controller. TV sets, cell phones, printers, fax machines, DVD/CD players, keyboard synthesizers, toys, automotive subsystems, home appliances, and many others contain one or more embedded controllers that organize, manage, and operate all the other circuits in a product.

Micro Training in Electronics

Most electronic technology degree curricula contain at least one course on microcontrollers. In such a course, you learn the stored program concept and computer fundamentals, computer architecture and operation, interfacing, and programming. Such courses focus on a single commercial microcontroller because of the short time available for learning. The missing ingredient is information on all the other types of microcontrollers, their specifications and applications. Such courses also omit one key topic, digital signal processing (DSP). Digital signal processors are a special type of embedded controller used in analog signal processing. This module and the companion Part 2 module supply this missing information and perspective.

Prerequisites

To complete this module successfully, you should have knowledge and background in digital logic fundamentals. You should also have knowledge of stored program concept and the operation and programming of one popular microcontroller.

You should have completed a one semester course on microcontrollers or its equivalent. It is also assumed that memory and I/O interfaces were covered adequately in the course or elsewhere.

This module makes an ideal supplement to a one semester micro course. It can be completed during or near the end of the course.

What Technicians Need to Know

- Definitions of microprocessors, microcomputers, embedded controllers, and cores
- Importance and pervasiveness of microcontrollers
- How micro & embedded controllers are categorized and specified
- Important new architectures and features
- Popular buses and I/O interfaces

How Micros Are Used

Micro Definitions

The term “micro” as used in this module is an abbreviation for the more official and definitive expression “embedded controller”.

Remember the definition given earlier: a micro or embedded controller is a complete digital computer on a single chip containing a CPU, memory, and I/O interface circuits. It is completely self contained.

You will also see the term microcontroller unit (MCU) used to describe an embedded controller.

A micro must be programmed to do what you want. The program defines the application. And in most cases, the micro is dedicated to the application and its use cannot be changed.

Core

Another term you will hear often is core. A core is a microprocessor or an embedded controller that is part of and made on the same chip as some larger more complex large scale integrated circuit. Circuits this big are commonly referred to as systems on a chip (SoC).

Many large scale ICs contain cores along with other special circuitry that is designed for a specific application. Cell phones contain chips that typically contain two or more cores.

The newest Intel and AMD processors for PCs now have two cores, that is two processors on the same chip or die. The computing tasks are divided between the two microprocessors to speed up operations by carrying out parallel processing.

Micro Applications

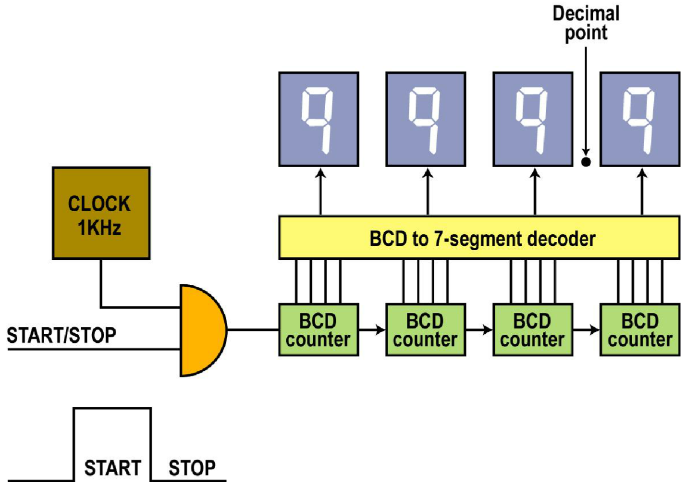
Micros have three basic functions. First, they implement general digital logic operations. The second function is to provide monitor and control functions for electronic products. Finally, they replace analog signal processing in some applications. These three functions are illustrated in the following slides.

General Digital Logic Operations

General digital logic operations include logic functions (AND, OR, NOR, NAND, XOR, etc.) and counting, simple math, and basic input/output operations.

Such basic operations were previously implemented with logic ICs made with TTL or CMOS circuits. These small scale and medium scale circuits are still available but it takes many of them to perform the desired operations. Instead of using dozens of ICs on a large PC board with high power consumption, a micro can do all of these operations in a single IC. Instead of wiring the circuit to perform the operation, the micro is programmed to do it.

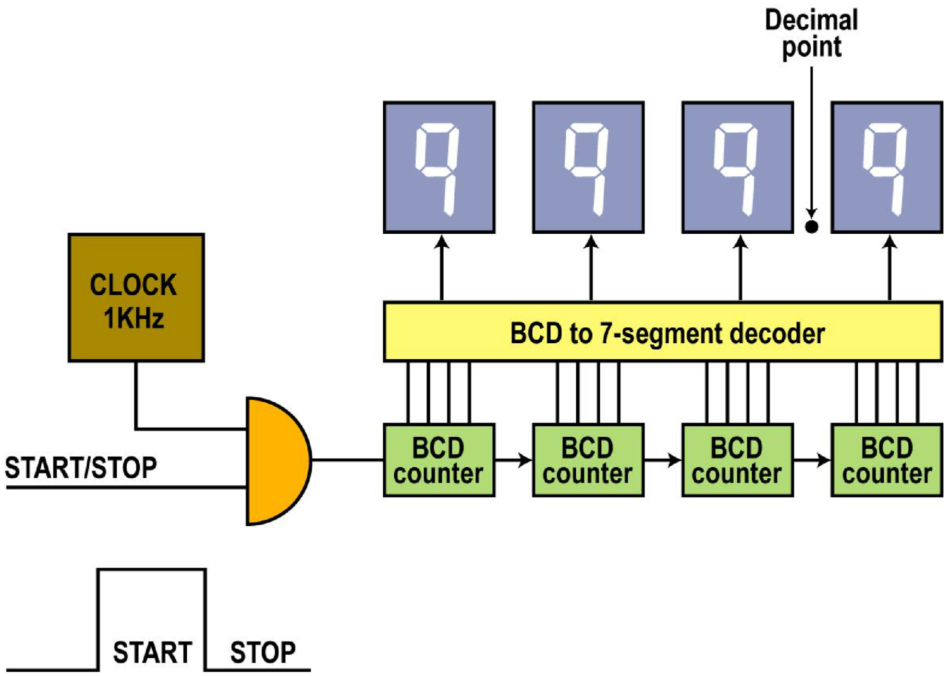
Programmed Logic Example



An example of this is shown by using the circuit implemented with TTL logic circuits shown here. The objective is to replace a counter/timer circuit with a microcontroller.

An accurate time clock with 1 mS pulses (1 kHz) is used to time an operation. A start/stop pulse is used to gate the clock to the counter. The counter is a set of cascaded BCD counters to display time up to 9.999 seconds. The counter outputs would be decoded and sent to a 7-segment display.

Programmed Logic Example: Reset



The counter is first reset to zero with a clear logic pulse. When the start/stop line goes high (binary 1), the counter begins accumulating the pulses. When the start/stop line goes low, the count is held in the counter and the time is displayed on the 7-segment displays.

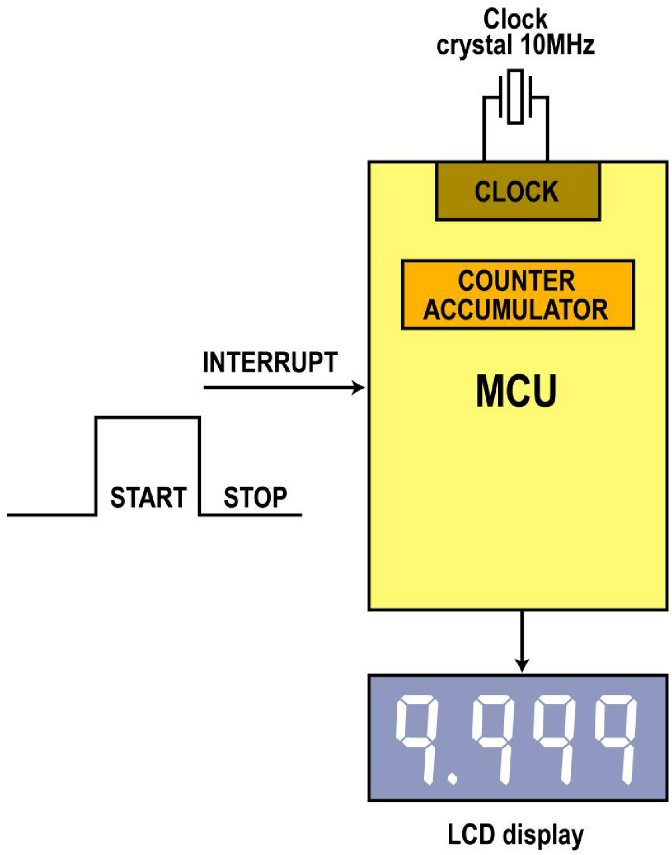
Replacing the Timer with a MCU

In this figure, an accumulator in the MCU register is designated as the counter.

The start/stop pulse is applied to one of the interrupt lines.

When the start/stop line goes high, an interrupt is recognized and the MCU jumps to a counter subroutine.

The counter subroutine increments the accumulator in a loop until the interrupt disappears.



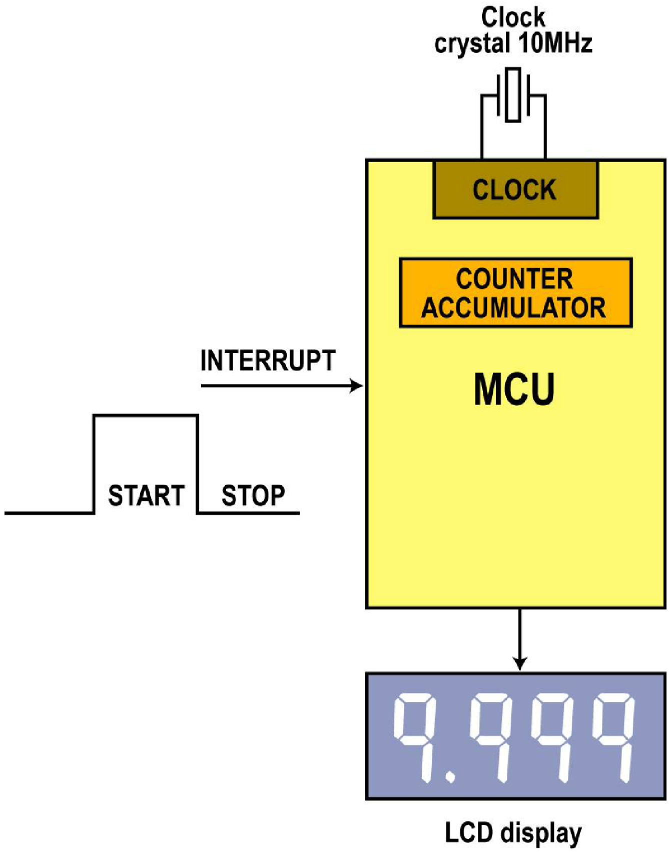
Clock Rate

The clock rate is a function of the MCU clock frequency (crystal) and the speed of execution of the increment and jump instructions.

The count value in the counter is then multiplied by the clock rate to get the actual time.

The time value is then converted to a BCD format by a binary to BCD conversion subroutine.

The BCD value is displayed on an external liquid crystal display (LCD).



Generic Timer Coding

The generic timer coding would be as follows:

- On interrupt, jump to counter subroutine.
- Clear accumulator A.
- Increment accumulator A.
- Start pulse still present. Loop back and increment again.
- When start pulse goes low, multiply clock rate by count value.
- Jump to binary to BCD conversion subroutine.
- Jump to I/O subroutine for LCD display code.

Monitor and Control Functions

Today, all electronic products must be monitored or controlled in some way.

Monitoring refers to the process of looking at various input signals from switches, keyboards, and sensors for temperature, light, position, pressure, etc. Most inputs come from front panel switches, buttons, and controls.

Control refers to some operation that must be performed based on the inputs. The circuit looks at the inputs and then makes decisions based on the defined operation as to what electronic signals to generate and send to other circuits or components.

One common control output is a display such as LED indicator lights or an LCD alphanumeric display. Turning a motor or relay off or on is another type of output.

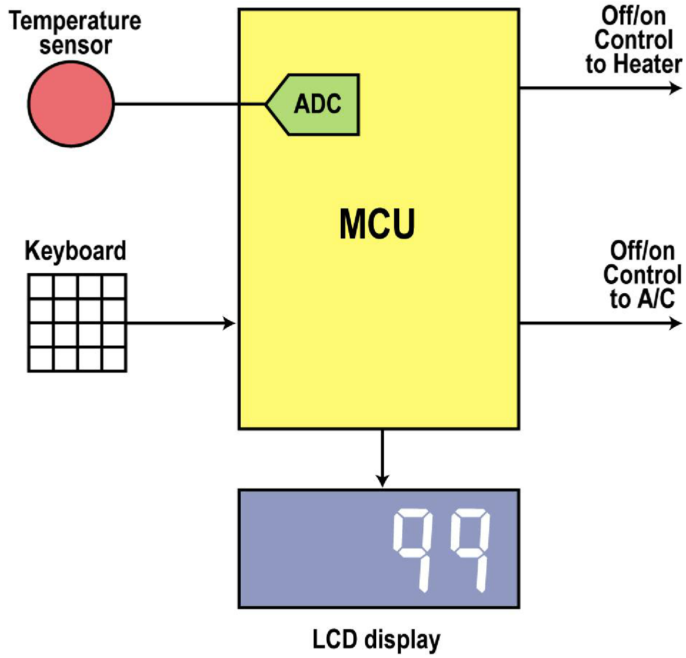
Monitor and Control Example

One example of monitor and control is shown in the home thermostat figure shown here.

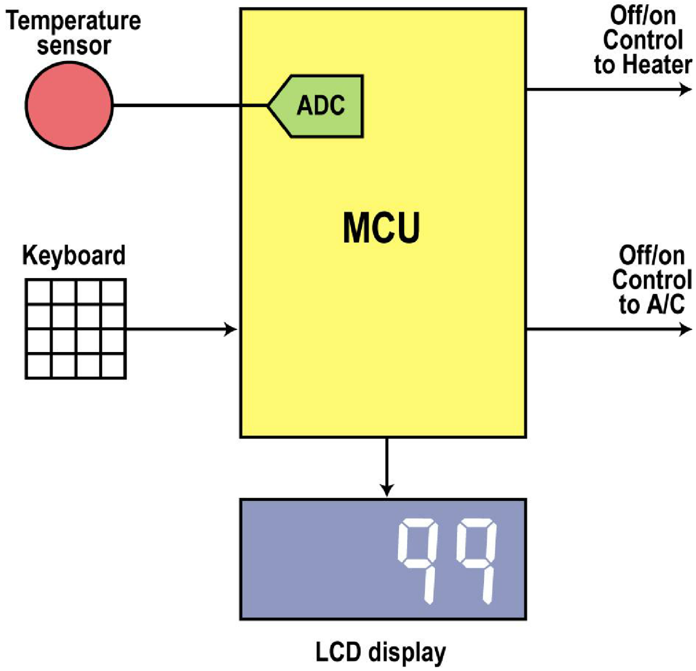
A keyboard is used to enter a desired temperature called the set point.

The temperature sensor provides an accurate value to the MCU.

The program code compares the set point to actual temperature.



Adjustment



During heating, the heater is turned on if the actual temperature is less than the set point. Otherwise, the heater is kept off.

If cooling, the A/C is turned on if the actual temperature is greater than the set point. Otherwise, the A/C is kept off.

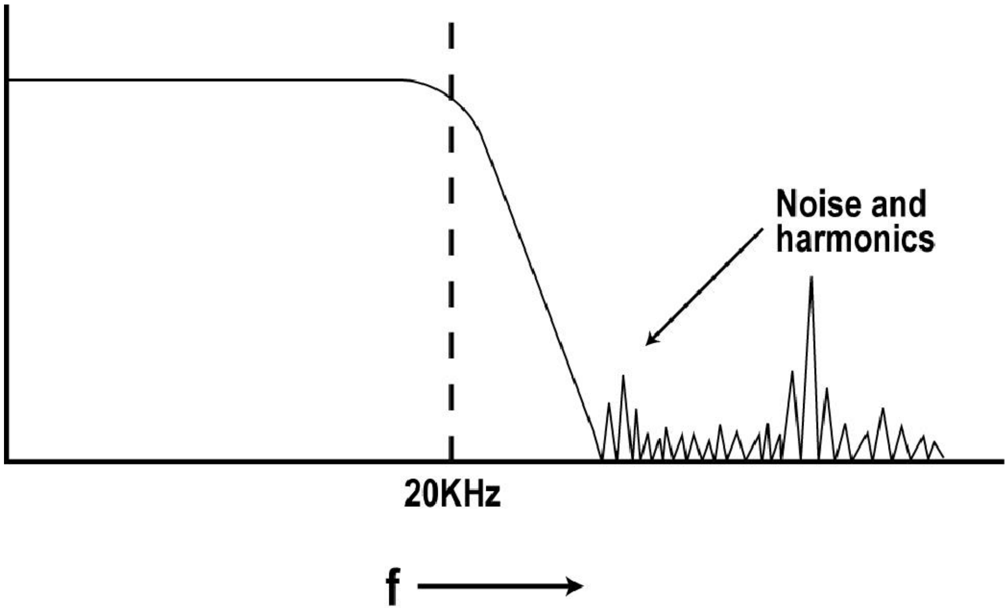
Replace Analog Signal Processing

Most electronic applications still require some form of analog signal processing operations such as amplification, filtering, mixing, modulation/demodulation, or other operations.

Many analog circuits are still used in equipment even though more and more of these signal processing operations are performed digitally.

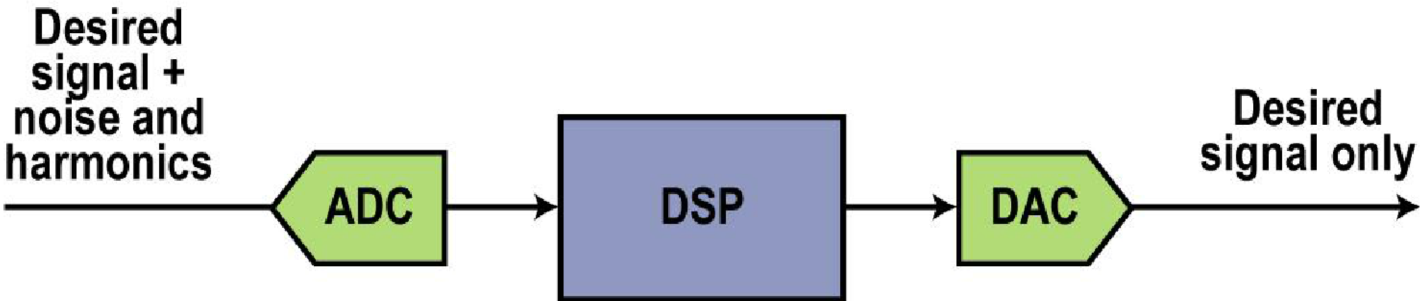
Digital signal processing (DSP) is the process of converting the analog signals to binary data then performing the analog processing through the use of an algorithm that can be programmed on a special embedded controller. This process is covered in more detail in part two of this module.

Signal Processing Example



An example of how signal processing can be used is shown in this figure. The objective is to create a filter that will eliminate signals such as noise and harmonic distortion above 20 kHz.

Signal Processing Output



The ADC converts the input signal to digital. Digital samples are processed by the DSP.

The DSP is programmed with an algorithm that emulates a low pass filter with a cut-off frequency of 20 kHz.

The output of the DSP is converted back to analog by the DAC. Signals below 20 kHz are passed as desired.

Test your knowledge

Micro & Embedded Controllers
Part 1: Microcontroller Technology Update
Knowledge Probe 1
How Micros Are Used

Click on Course Materials at the top of the page.

Then choose **Knowledge Probe 1**.