

# WHAT IS A MICROCONTROLLER?\*

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## Abstract

This module aims to define what a microcontroller is in terms of power, cost, speed and other specifications.

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Consider the following set of words: microprocessor, microcontroller, processor, digital signal processor, mixed signal processor. In one sense, they are all the same thing - an **ASIC** that fetches and executes instructions based on input from some user program. These devices do not have a fixed function, but rather are controlled by software. Each of them share certain architectural features that have been developed since Intel<sup>1</sup> created the first "microprocessor" in 1971.

NOTE: Intel's web site contains an interesting history<sup>2</sup> of the microprocessor.

In the three decades since the invention of the first microprocessor, there has been tremendous development and innovation in this field of engineering. Each of the terms used at the start of this section are correct names for a microprocessor, but they all have different application spaces and features. This still leaves us with the question, "What is a microcontroller?"

In truth, this is a bit difficult to pin down, due to the ever-evolving nature of the semiconductor industry. Consider that what we would call today's average microcontroller is orders of magnitude more powerful than the computer used in the Apollo Lunar Module<sup>3</sup>. We can make some generalizations, however, that can help us characterize a microcontroller. Typically, these devices reside at what is the "low-end" of computing. This does not, however, mean that microcontrollers are useless. For **embedded systems** design, microcontrollers are usually an ideal choice. The following list shows some qualities that define all microprocessors, along with how they specifically define microcontrollers.

### Some Common Processor Characteristics

- **Cost:** The cost of the part. Microcontrollers are usually very cheap, sometimes even less than \$1 each.
- **Speed:** The frequency (speed) of the system clock, often stated in **megahertz** (MHz) or **gigahertz** (GHz). Microcontrollers are typically slow, less than 20MHz.
- **Power:** The power dissipation of a system, measured in **Watts**. Microcontrollers are almost always "low-power."

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<sup>1</sup><http://www.intel.com>

<sup>2</sup>[http://www.intel.com/museum/online/hist\\_micro/hof/index.htm](http://www.intel.com/museum/online/hist_micro/hof/index.htm)

<sup>3</sup><http://www.abc.net.au/science/moon/computer.htm>

- **Bits:** This usually means the number of bits that can be processed at one time by each instruction (e.g. 8-bit, 16-bit, 32-bit, etc...). Microcontrollers are almost always 8-bit or maybe 16-bit devices.
- **Memory:** Most processors have some amount of storage on the device for data and program instructions. In computing systems, memory is often hierarchical, so on-chip memory can serve different purposes. Microcontrollers typically have a limited amount of memory, less than 1MByte total.
- **Input/Output (I/O):** All processors have some means of getting data in and out of the chip. In the physical sense, this relates to metal pins on the part package which are used to connect to other circuitry in the system. Microcontrollers usually have just a few I/O pins, as few as 8 or as many as 100. Larger processors, such as the ones found in a typical PC, will typically have hundreds of pins.

NOTE: Some of the characteristics listed above are interdependent. For example, the greater number of pins a particular part has, the more complicated the packaging will need to be, which will probably cost more.

The figure below shows a photo of a modern microcontroller that meets all of these criteria.

**Texas Instruments MSP430F169 16-bit Microcontroller**



**Figure 1:** The TI MSP430F169 meets the criteria we listed above and is a good example of a modern microcontroller.

As a last exercise, it is useful to compare different types of processors to see the tremendous amount of variety available. The following table shows a selection of modern processors and some numbers related to the features listed above. It is clear that there are tradeoffs to be made in choosing the right part for the design at hand, and part of being a good engineer is being able to do this well.

**Comparisson of Modern Processors**

Processor	Manufacturer	Cost	Speed	Power	Bits	On-Chip Memory	Off-Chip Memory	Package Pins
<i>continued on next page</i>								

MSP430F169	Texas Instruments	\$1 - \$10	8 MHz	~5 mW	16-bit	1 - 62 KByte	N/A	20-100
Pentium II	Intel	~\$65	333 MHz	~25 W	32-bit	548 KByte	4 GByte	615
TMS320C6416	Texas Instruments	~\$300	700 MHz	~1.5 W	16/32-bit	1 MByte	1.28 GByte	532
PowerPC 970	IBM	N/A	1.8 GHz	~42 W	64-bit	608 KByte	8 GByte	576

Table 1

## Glossary

### Definition 1: ASIC

Application Specific Integrated Circuit

### Definition 2: embedded system

A self contained electronic control system, generally with limited user input/output.

NOTE: A traffic light control system is a good example of an embedded system. The system is self-contained and controls the flow of vehicles at an intersection. Users (pedestrians, bicyclists and car drivers) interact with the system in a limited manner. There may be sensors that detect the presence of vehicles and buttons for pedestrians to push when they want to cross the intersection. The traffic lights output the "state" of the system and inform the users of the actions they must take.

NOTE: The best designed embedded systems are those that are unobtrusive to the user. That is, they require little user interaction and, for the most part, are "invisible."

### Definition 3: Hertz

A unit of measurement for frequency, abbreviated Hz, denoting the number of cycles per second. 1 Hz = 1 cycle/second. For a more detailed explanation of frequency, see the following module<sup>4</sup>.

#### Example

1 megahertz (MHz) = 1,000,000 cycles/second.

#### Example

1 gigahertz (GHz) = 1,000,000,000 cycles/second.

### Definition 4: Watt

A unit of measurement for power, abbreviated W, denoting the amount of energy (in joules) per second. 1 W = 1 joule/second.

<sup>4</sup>"Frequency definitions and periodicity" <<http://cnx.org/content/m11477/latest/>>