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General-Purpose Microcontrollers

Introduction

Embedded systems, which are computing systems that are incorporated into a physical device, are essential to everyday life - more than 99% of the computers in use today are embedded systems, and a typical household contains over fifty embedded devices [1]. At the core of many embedded systems is a microcontroller (MCU), a computer that is contained in a single integrated circuit and does not run a dedicated operating system. This paper surveys the market for general-purpose microcontrollers and briefly explains how microcontrollers are implemented in embedded system designs.

Commercial Applications

Given their low-cost and low-power characteristics, microcontrollers are utilized across a range of industries, including consumer electronics, medical devices, industrial equipment, and military systems [1]. The microcontroller is capable of executing many computing tasks within an embedded system, such as reading analog signals from a sensor, performing calculations, printing information to an LCD, and communicating with a server through a serial link. The increasing R&D costs of microcontrollers and other advanced semiconductor devices has led to the consolidation of many semiconductor companies since 2015 [2]. Thus, the microcontroller market is dominated by a few well-known companies and their portfolios.

One of the market leaders for microcontrollers is Texas Instruments (TI). TI markets its MSP430 family of microcontrollers for a variety of applications. For example, the MSP430F5252 can be implemented in “smart” consumer devices that require minimal energy usage; one microcontroller unit costs $0.00205. Another version, the MSP430F6779, costs $0.00676 and has seven Sigma-Delta ADCs that make this unit appropriate for “smart” utility metering [3].

Another significant company in the microcontroller market is Microchip, which produces the AVR family of MCUs. One particular microcontroller, the ATmega328P, is famous for its incorporation into the Arduino Uno prototyping board. This 8-bit MCU, which has a price of $0.00188, is valued by hobbyists for the free development tools available for it [4].

Underlying Technology

All the components that make up a microcontroller are contained on a single die, which allows for optimized performance and lower cost. These components, at the most basic electronic level, are

composed of transistors; a microcontroller IC can thus contain hundreds of thousands of transistors. Transistor count roughly translates to MCU performance, often in terms of CPU speed. But many other microcontroller specifications are important measures, and may be valued above CPU speed depending upon the application. Given that many microcontrollers are implemented in low-power systems, power consumption is of particular interest to many embedded developers. The MSP430F5252 can run on a few μA when active, and reduce that amount to a few tenths of a μA when set in low-power (idle) mode. Other performance metrics include the amount of RAM and non-volatile memory, the number of pins for GPIO and other purposes such as UART, and the resolution of the internal ADCs. For reference, the MSP430F5252 contains 16 KB of RAM, 128 KB of non-volitive memory, 53 GPIO pins, and 10-bit ADCs [5].

Because microcontrollers have limited computational resources, they are often programmed in a low-level language such as C. MCU programs are first written on a PC and then compiled to machine-level code by a cross compiler; this code can then be flashed onto a microcontroller. Some microcontrollers are meant to be flashed only once; others may be re-flashed as many times as the memory will allow.

Implementation of Microcontrollers

A typical general-purpose MCU consists of a CPU, memory, one or several ADCs, GPIO pins, timers, etc. However, a microcontroller often requires external components in order to function properly. For example, a microcontroller needs an external power supply, as well as capacitors and diodes to guarantee stable operation. Microcontrollers also ought to be connected to other chips and components in order to increase their utility. Sensors, wireless boards, motors, and LEDs are just a few common parts found in embedded systems. Many microcontroller development boards, such as the Arduino Uno, include these external components and “breakout” the microcontroller’s pins to allow for rapid prototyping.

In terms of software, microcontrollers tend to require proprietary developer tools that are exclusive to the manufacturer’s product line, which makes developing for different platforms cost-prohibitive. Many IDEs provide features that are particularly useful for embedded development. For example, TI’s Code Composer Studio (CCS) IDE has debugging tools that enable inspection of a microcontroller’s registers while the microcontroller is running [6].

References

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