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Microcontrollers in Embedded Systems

Introduction

An embedded system is any electronic device that has a computer in its design, using a combination of hardware and software to run. The main connection between the software and the hardware in is the microcontroller. Microcontrollers allow devices, such as a simple IR remote control to complex cell phones, to perform tasks based off of the data input they receive. This paper reviews the applications of microcontrollers in industry and for hobbyists, and how microcontrollers work.

Microcontrollers on the Market

A basic microcontroller is a small, inexpensive, computer processing unit (CPU) with flash memory and serial ports and is programmed to perform one dedicated task. It differs from a microprocessor, the two terms being used interchangeably in common vernacular, because a microprocessor is simply a CPU and replies on "external memory to provide program and data storage [1]." Microcontrollers may differ from one another in clock speed, power, number of digital I/O pins, power voltage, amount of flash memory, programming environment and other specifications. A vast number of companies are in the microcontroller market such as Texas Instruments (TI), Atmel, STMicroelectronics, NXP Semiconductors and Intel.

Consumer and Commercial Products

The Internet of Things is used to describe a network of "**sensors and actuators embedded in physical objects are linked through wired and wireless networks** [2]" allowing components to send and receive data. Microcontrollers are important in these "smart" devices, allowing common household items or industrial machinery to communicate over Wi-Fi or Bluetooth with a user's cell phone, tablet, or computer.

TI offers the MSP432P401R microcontroller series for used in IoT products. These microcontrollers have up to 256 KB of Flash memory, have a supply voltage ranging from 1.62V – 3.7V and cost $6.26 – $8.29 [3]. Another company, Atmel, offers the SAM4S Arm Cortex-M4 microcontroller series for IoT products. These microcontrollers have up to 2MB of Flash memory, have a supply voltage ranging from 1.62V – 3.6V and cost $5.30 - $8.69 [4]. Lastly, Intel offers the Quark D100 with that has up to 32KB of Flash memory, has a supply voltage range from 1.6V-3.6V and costs in bulk $2.58

(minimum order being 3000 units [5].) All of these microcontrollers and many similar ones advertised for the IoT market are similar as they are advertised as "low power, high-performance," the latest trend for microcontroller development.

Microcontrollers for Prototyping

Arduino is a company known for designing microcontrollers to be used by hobbyists and students to create interactive projects. The Arduino Uno Rev 3 is the microcontroller advertised for beginners and rapid prototyping and has 32KB of Flash memory, a supply voltage of 5V and costs $24.95 [6]. The Arduino MEGA 2560 is designed for more complicate projects, with more digital I/O pins, 256 KB of Flash memory and costs $45.95 [7]. Arduino's microcontrollers come with their own software IDE and Arduino language which is based off of C/C++. These Arduinos are much larger than the microcontrollers mentioned previously, allowing large scale prototyping before buying and committing small parts to be soldered.

Building Blocks of Implementing a Microcontroller

Similar to software development, microcontrollers can be worked at "work at a higher level where things are easier, more abstracted into human language" or can be worked at "a lower level where things are more difficult because they are more in a computer language [8]." The process of implementing a microcontroller starts with identifying the task that needs to be performed and what additional parts will be needed. General good programming practices, such as commenting code and optimizing loops, apply whether programming the task in higher-level languages such as C/C++ or low-level languages such as ARM Assembly. Addition parts and sensors are attached to the microcontroller either in a breadboard or are soldered on a circuit board.

The compiler converts the source code and the program is loaded onto the microcontroller. Once the microcontroller has power, the control logic unit disables all other units except the quartz crystal oscillator that will be the clock speed of the system. The program counter is set to zero and the first instruction from that address is sent to the address decoder where it is executed. After the instruction is finished, the program counter increments by 1 and the process repeats over and over, allowing the microcontroller to perform it task [9].

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[3] Texas Instruments, “MSP432P401R, MSP432P401M Mixed-Signal Microcontrollers (Rev. E),” MSP432P401R datasheet, March 2015 [Revised July 2016].

[4] Atmel, “SAM4S Series,” SAM4S datasheet, June 2015.

[5] Intel, “Intel® Quark™ microcontroller D1000,” Intel® Quark™ microcontroller D1000 datasheet, Sept. 2015.

[6] Arduino, "Arduino MEGA 2560," Arduino, 2017. [Online]. Available: https://www.arduino.cc/en/Main/ArduinoBoardMega2560. [Accessed 4th March 2017].

[7] Arduino, "Arduino UNO," Arduino, 2017. [Online]. Available: https://www.arduino.cc/en/Main/ArduinoBoardUno. [Accessed 4th March 2017].

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