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The Current State of Single-Board Prototyping Microcontrollers

Introduction

A single-board prototyping microcontroller (also known as a microcontroller development board) is a computing system built on a small, integrated circuit that provides useful development and testing tools such as I/O circuits and pinouts, RAM, internal program memory, and clock generators (with some variation between brands and models). Such microcontrollers are used widely in both practical education and development testing due to their inexpensiveness and ease-of-use; Timothy L. Warner emphasizes this in his book *Hacking Raspberry Pi*: "Any interested individual can learn not only how to program computer software, but also to work directly with electronics and computer hardware. If an experiment goes wrong… then the [user] is only out $35 as opposed to hundreds or thousands [1]". For use on a mobile autonomous robot, the prototyping microcontroller must have enough pinouts (ports) to accommodate all motors, sensors, and other hardware used in the robot while fast enough to maintain "RTOS" status.

Existing Products and Commercial Applications

Currently the most popular manufacturers of single-board prototyping microcontrollers are NXP (owned by Philips, produces MBED systems) [2], the BeagleBoard.org Foundation (mainly Texas Instruments produces BeagleBoard systems) [3], and Arduino [4]. This section will compare various products produced by each company based on clock speed, memory, types of I/O ports, and peripherals.

NXP produces the MBED LPC1768 (US$50) and the LPCXpresso54628 (US$65). The LPC1768 is "packaged as a small 40-pin DIP, 0.1-inch pitch form-factor making it convenient for prototyping with solderless breadboard." It features a high-performance ARM Cortex-M3 core running at 96 MHz, has 512KB FLASH memory and 32KB RAM [5]. The LPC1768 runs binaries compiled through ARM's online MBED C/C++ compiler (exported to the board through Micro USB) and can also be programmed directly in Assembly. In comparison, the LPCXpresso54628 is more powerful than the LPC1768, with its "DSP capabilities [enabling it] to support complex algorithms in data-intensive applications." It features a power-efficient ARM Cortex-M4 core running at up to 220 MHz, has 512 KB FLASH memory and 200 KB SRAM [6]. Like the LPC1768, the LPCXpresso54628 can be programmed by transferring binaries compiled on ARM's online C/C++ compiler to the board via Micro USB. Additionally, the

LPCXpresso54628 features a color LCD with capacitive touch screen, full-size SD card slot, accelerometer, and expansion options for integration with Arduino UNO [6].

BeagleBoard.org offers the BeagleBone Blue (US$80) for robotics projects. The BeagleBone Blue is an "all-in-one Linux-based computer for robotics." It features an ARM Cortex-A8 processor (ARM Cortex-M3 available) running at 1 GHz, has 4GB FLASH memory and 512 MB RAM. The Blue is accessed (via USB) through basic Linux terminal commands and can run both Python and C programs. Additionally, it has 802.11 b/g/n Wi-Fi and Bluetooth 4.1 capabilities, 4 motor control with H-Bridges, and a 9-axis IMU [7].

Arduino's latest development board is the Arduino UNO Rev3 (US$22). It features an ATmega328P microcontroller running at 16 MHz, has 32 KB FLASH memory and 2 KB SRAM. The UNO Rev3 has 14 Digital I/O pins (6 of which are PWM) and 6 Analog Input pins [8]. It is programmed (via USB) through the online Arduino Software IDE, similar to ARM's.

Underlying Technologies/Standards

The following standards pertain to development languages: the C++ programming language is standardized by the C++ Standards Committee ISOCPP (JTC1/SC22/WG21). The latest existing draft is 14882:2017 [9]. Python is based on the PEP 8 standard, though additions have been made [10].

The following standards pertain to development board peripherals: Micro USB conforms to IEC International Standard 62680-2-2 Revision 1.01 [11]. The BeagleBoard Blue's Wi-Fi conforms to IEEE 802.11 b/g/n standard. This only supports the 2.4 GHz band; however, it supports a bandwidth of up to 54 Mbps and is backwards compatible with 802.11b while being faster and having better signal range [12]. All Bluetooth devices must meet standards set by the Bluetooth Special Interest Group (previously standardized by IEEE 802.15.1) [13].

Implementation

Single-board prototyping microcontrollers are dual hardware/software testing devices. The hardware can include any number of physical pins (usually between 20-30) which implement Digital and Analog In/Out, Pulse Width Modulation, and communications protocols (I2C, SPI, Serial, etc.). They are low-power devices, operating on average at 5 V [5][8]. On an autonomous robot, they would have to run off an external battery-pack. If any external devices hooked up to the development board require pull-ups/-downs, they can be done in software via special libraries [5]. As mentioned earlier, programming is done in C/C++ (additionally in Python for BeagleBoard Blue) through online IDEs (or through direct Linux commands for BeagleBoard Blue) and compiled into binaries run by the microprocessors.

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