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Instructing Mechanical Engineers in Mechatronics and Microcontrollers

MOHAMMED PARVEZ, SHAIKH NOOR, MD MUTTE KHAN

Abstract

A program is offered to improve the education of mechanical engineering students at the University of South Carolina in the areas of mechatronics and microcontrollers. To begin, the current trends and developments in the field of Mechatronics education are presented and addressed. Then we will go on to discuss the Mechatronics programs offered by the University of South Carolina's Mechanical Engineering Department. After that, the study looks at the tools and resources that are part of micro-controller and mechatronics courses. The MC68HC11 microcontroller and its associated evaluation boards for (a) code development and (b) embedded applications are shown as examples. Next, the software that is crucial to microcontroller and mechatronics training is discussed. An overview of the powerful THRSim11 simulation and interface program is provided. At last, the study delves into how a microcontroller communicates with the many electromechanical sensing and actuation components included in a mechatronics system. Instructional modules are presented that may be used to educate mechanical engineering students about interface. Results and suggestions for further research are presented at the end of the publication.

Keywords: Evaluation boards; Embedded applications; Simulation; Interfacing software; Mechatronics; Teaching with Microcontrollers; MC68HC11 Electrical, Detection, Action, and Operation, and Logic Blocks

1. Introduction

Reason Number One for Pursuing Mechatronics Education

The rapid expansion of the electronics, computer, and information technology (IT) sectors has created a skills gap between what is taught in conventional non-Electrical Engineering school (e.g., mechanical, civil, chemical, etc.) and what is needed by employers. Computers, sensors, microcontrollers, and actuators have become ubiquitous in modern life. Every element of our lives relies on gadgets and appliances powered by microcontrollers.

Asst. Professor[1,2,3]
Department of Mech
mohammedparvez124@gmail.com, Shaiknoor@gmail.com, mdmak.khan98@gmail.com
ISL Engineering College.
International Airport Road, Bandlaguda, Chandrayangutta Hyderabad - 500005 Telangana, India.

The automotive sector, which has traditionally been a bastion of mechanical engineering, is already using tens of microcontrollers in a single vehicle and has ambitious intentions to expand this number many times over when new technologies are implemented. BMW factory representatives recently visited our school, revealing that hybrid propulsion, a 42-volt wiring bus, "steer-by-wire," "brake-by-wire," collision avoidance, autopilot, etc. are all under development, and vehicles with these features will soon be available on the market.

The State of Mechatronics Education in the United States and Abroad 1.1

But students get less training in electrical engineering, electronics, and IT in the conventional engineering curriculum. Non-EE education falls well short of the mark in terms of the "high-tech" components that are in great demand. As a result of this discrepancy, non-EE engineering graduates who are entering the labor market are at a significant disadvantage. Some students in mechanical engineering aim to enroll in upper-division electrical engineering classes in order to obtain marketable high-tech abilities. Inadequate preparation in prerequisite courses will have a detrimental impact on their grades and course loads. As a result of this need, the field of mechatronics engineering has developed, which incorporates concepts from mechanical engineering, electronics, embedded microcontrollers/digital signal processing, controls, and information technology. Over twenty colleges in the United States and elsewhere have made concerted attempts to include mechatronics instruction into non-EE curricula [2-7,10,11,13-16,18-20].

Reason Number One for Pursuing Mechatronics Education

Non-electrical engineering students at the University of South Carolina have a pressing need for instruction in the multidisciplinary subject of mechatronics/microcontrollers.

Economically, South Carolina is undergoing a period of rapid growth with an emphasis on high-tech enterprises and industries. With this work, we want to close the technology gap that has left South Carolina well behind the rest of the country in terms of its high-tech sector. The success of this statewide initiative depends on the development of a sufficient number of highly skilled workers who can "hit the ground running" in the expanding high-tech labor market. Parallel to other ongoing initiatives of a comparable kind

taking place elsewhere (like Southern California), this will provide a "critical mass of talent from which local enterprises may draw." [1].

Education in microcontrollers and mechatronics at the mechanical engineering level 1.1

The University of South Carolina's Department of Mechanical Engineering (DME-USC) is well situated to aid in the spread and growth of this burgeoning area of engineering study. EMCH 367, found online at http://www.me.sc.edu/courses/emch367 , is a course developed by the Department of Mechanical Engineering at the University of Southern California to educate students in mechanical engineering on the use of microcontrollers. There are four primary *parts to this course: (a) lecture, (b) homework, (c) lab, and (d) a final project. Classes are designed to teach students the fundamentals of microcontroller operation and programming. Students work individually using simulation software in a computer lab as part of the classroom curriculum. The homework is designed to help students learn on their own and retain the material; it includes both modeled examples and hands-on tasks that students are expected to complete and submit via email to their TAs for feedback. Students will learn how to use the microcontroller's many features, from its parallel ports and serial connection to its event timing (detection and generation), DC motor tachometer, stepper motor control, and analog-to-digital conversion, over the course of five lab sessions. The culminating assignment for the course is a microcontroller-based project that students work on in pairs for a month to conceptualize, design, code, construct, and demonstrate. There will be a final report, presentation, and practical demonstration at the end of the project. Examples of previous work may be seen on the course webpage at http://www.me.sc.edu/courses/emch367 .*

Support is needed to increase and improve mechatronics/microcontroller education for the 22% of female and 30% minority engineering students at the University of South Carolina. The project presently underway at the University of South Carolina with NSF funding will provide engineering students with the theoretical grounding and practical experience necessary to thrive in today's technologically competitive economy and market environment.

2. Hardware for mechatronics/microcontroller education

The hardware problem is complicated by the many different kinds of microcontrollers on the market. One of our goals in creating this curriculum has been to identify a microcontroller that is widely used in professional settings. Another factor we used to make our choice was whether or not the microcontroller had the necessary features to teach the pupils. Thirdly, we looked for a microcontroller that didn't break the bank. These days, you may find a wide variety of microcontrollers on the market. In contrast, the 68HC11 microcontroller is second to none.

for the setting of a schoolroom The computer architecture and instruction set of many OTP microcontrollers may be superior in a specific application, but they are not suited for use in a classroom setting as a whole. The 68HC11 has been around for almost ten years because it has a strong and easily memorized instruction set. Once you have mastered the 68HC11 microcontroller, you will have no trouble moving on to the HC12 family or additional microcontrollers. In addition, there is a plethora of useful apps available for free download online. Therefore, the Motorola MC68HC11 micro-controller was selected.

2.1. The microcontroller evaluation board (EVB)

Single-chip microcontrollers are often utilized in embedded systems. The microcontroller's software is "burned" into the ROM memory before it is used in an embedded application. After setting up the microcontroller in its designated spot, the user need merely plug it in and run the software. The microcontroller will thereafter function autonomously. The manufacturing process also includes writing the software into ROM storage.

The microcontroller requires a host personal computer (PC) and/or terminal for *programming tasks. The developer may work on the code on the host computer and then transfer it to the microcontroller for testing. The terminal interface also allows the programmer to develop the code directly on the microcontroller. All of the necessary electrical components and integrated circuit chips for this procedure are mounted on an evaluation board (EVB). The EVB includes ICs for memory expansion, a port replacement unit, and connection maintenance with a host device and/or a terminal. Because it enables the developer to create and test the microcontroller application software, the EVB is crucial to the programming process. After the application software for the microcontroller has been written and validated, it will be "burned" into the ROM of the microcontrollers to be used in the manufacturing process. To create programs for either single-chip mode or extended mode microcontroller applications, the user may utilize the EVB expanded system with an MC68HC24 and a PC. There are a number of commercially available microcontroller assessment boards. The spectrum of their complexity is wide. We have chosen to use two distinct types in our lab: the EVBplus2 microcontroller evaluation board from http://www.evbplus.com/ for code development, and the Adapt11C24DX microcontroller evaluation board from Technological Arts, Inc. (http://www.technologicalarts.com/myfiles/t1.html#EVBU) for embedded applications.*

Microcontroller evaluation board EVBplus2

The EVBplus2 microcontroller evaluation board, available at http://www.evbplus.com/, is a versatile device that includes not only the standard EVB functions but also numerous more (Fig. 1). It contains a number of parts including a microcontroller, a port replacement device, and extra memory. These supplemental materials are given to make EVB more usable in educational settings, for the creation of projects, and in the design of finished goods. The EVBplus2 has a convex section, as seen in

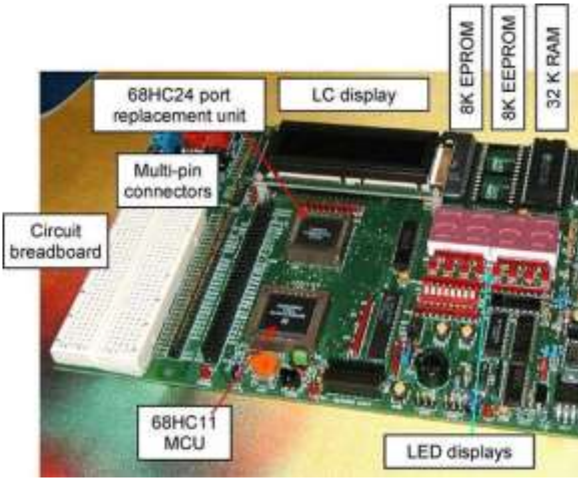


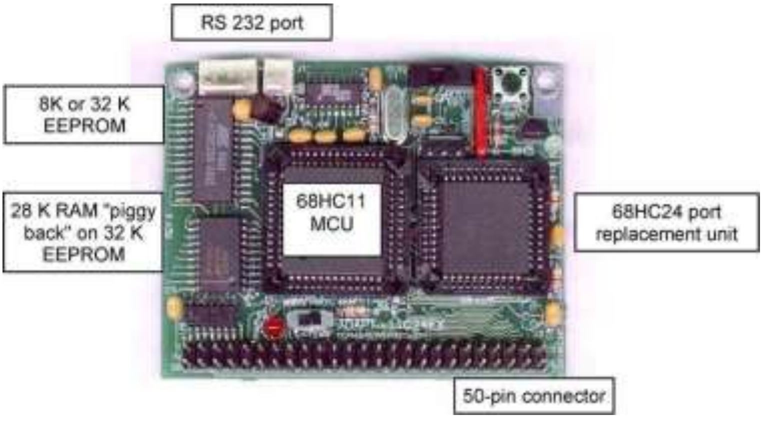
Fig.1 Fig. 1. EVBplus2 evaluation board for MC68HC11 microcontroller (http://www.evbplus.com/).

incorporates a liquid crystal display, multiple port interfaces, a liquid crystal display, a four-digit seven-LED display, a row of eight LEDs for monitoring port B, and a bread board for impromptu circuit construction.

2.2. Adapt11C24DX microcontroller evaluation board

The Adapt11C24DX microcontroller evaluation board by Technological Arts, Inc. is renowned for its compact design (Fig. 2). The microcontroller (MCU), port replacement unit, up to 32 kilobytes (kb) of EEPROM, and up to 28 kilobytes (kb) of RAM "piggy back" on the 32 kb of EEPROM all fit on this tiny EVB's 2.1 by 2.8-inch PCB. As a result, it has a 50-pin port for connecting all your electronic devices.

Fig. 2. Adapt11C24DX microcontroller evaluation board from Technological Arts, Inc. http://www.technologicalarts.com/myfiles/t1.html#EVBU.



ports for microcontrollers It is suggested for embedded systems that need more memory or a port replacement device due to its small size.

3. Software for mechatronics/microcontroller education

Since education in script programming is not provided to mechanical engineering students until the micro-controller semester, this presents a significant challenge in terms of the software. Visual languages like MathCad and LabView, for which the College holds site licensing, are now widely used for teaching programming to mechanical engineering students. Therefore, instructing students in a script language like Assembly or C++ to program the microcontroller should begin with the fundamentals. The usage of microcontroller simulation software has been shown to significantly improve students' capacity to scale this challenging pedagogical wall. We decided to use THRSim11 by Harry Broeders, available at http://www.hc11.demon.nl/thrsim11/thrsim11.htm, a cheap assembly-language-based microcontroller simulator. This program was included in the DrDobbs Journal special edition on simulation and emulation from March 1999.
Programming for the 68HC11 microcontroller may be edited, assembled, simulated, and debugged on a Windows computer using the THRSim11 application. Debugging the code on the intended EVM or EVB compatible board is also possible using THRSim11. The central processing unit, read-only memory, random-access memory, and any I/O ports connected to memory are all shown visually inside the simulator (Fig. 3). On-board features like the audio and video jacks, USB ports, and even the Ethernet port are all simulated

I/O pins, serial port, parallel port, analog-to-digital converter, parallel port (with handshake), and timer (including analog and interrupt pins).
While debugging, the graphical user interface allows access to all of the registers (including CPU registers and I/O registers), memory locations (data, program, and stack), and pins of the emulated microcontroller. In spite of the fact that the software is already active. You may pause the simulation whenever you want. Exit when RxD goes low, RAM address $003F contains $BD, or I/O register TCNT is higher than $3456.
During debugging, the pins of the emulated 68HC11 may be linked to a variety of external components. Just to provide one illustration:

Indicator lights, pushbuttons, analog potentiometers, a serial transmitter and receiver, and much more... (check out http://www.hc11.demon.nl/thrsim11/comp.htm).

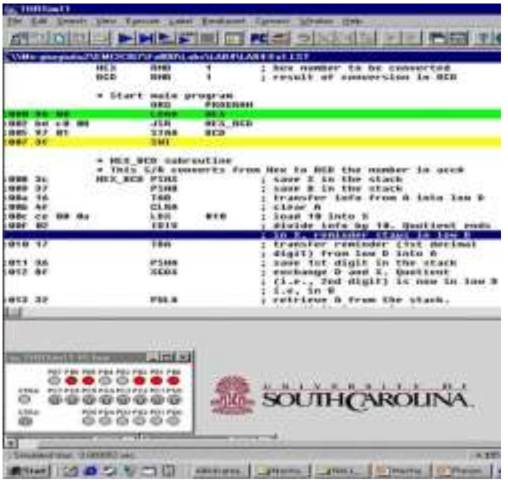


Fig. 3. Screen capture of the THRSim11 simulation and emulation software for MC68HC11 microcontroller. A site license was purchased for the University of South Carolina from http://www.hc11.demon.nl/thrsim11/thrsim11.htm. The site license includes the university logo.

The 68HC11's address space is also configured to accommodate a 4 • 20 LCD character display.

With the BUFFALO monitor software installed, THRSim11 can talk to any board, including the Motorola EVM and EVB boards. The monitoring software is available for free download from Motorola's website. You may see and modify every register (CPU registers and I/O registers) and memory location (data, program, and stack) of the actual microcontroller through the graphical user interface after loading your assembly program into the target board. Any point in execution may be halted so that the registers and memory can be inspected or modified.

The coupling of microcontroller and mechatronics tasks

Last but not least, we're talking about how to connect a microcontroller to the many electromechanical sensors and actuators of a mechatronics system. This is crucial information for students who are not majoring in electrical and electronics engineering and have little to no background in connecting electronics with mechanical engineering devices. Several functional modules were used to address this concern. These practical modules are used to provide students real-world experience with the interfacing of mechanical, electrical, and electronic parts of a mechatron- ics system.

In order to feel comfortable with electrical and electronics principles, especially during the execution phase of a mechatronics project, students who aren't majoring in electrical engineering require practical experience. We've begun working on a set of useful educational courses to fill this gap. These functional modules are designed to be used as pluggable components, complete with documented inputs, outputs, and a description of how they work. Functional modules are intended to be used by students as a means of instruction. After students have learned their purpose, they will be asked to recreate the circuitry on their own bread boards so it may be used in their mechatronics class

projects and other practical assignments. All of these modules have been created thus far:
Op-Amp Signal Amplifier (ii) Opto-Electronic Sensor (iii) Voltage Divider

(iv) on/off (field-effect MOSFET) power amplifier; (v) linear power amplifier; (vi) pulse-width modulation (PWM) dc motor drive unit; (vii) stepper motor drive unit; (viii) AC/DC converter; (ix) temperature sensor; and (x) humidity sensor.

H-bridge (relay and transistor) for DC motor, dimmer circuit, open collector buffer, voltage comparator, limit switch, wireless transmitter and receiver, ultrasonic sensor, and so on.

Detailed reports including electrical and component diagrams, relevant equations, and a complete set of experimental findings from calibration testing accompany the functional modules. These reports are crucial in teaching functional modules. These reports were written for each functional module at the time it was originally constructed by a team of students comprised of both graduate and undergraduate students. These reports aim to achieve these aims by describing the circuits of functional modules in sufficient detail for the reader to comprehend them and to make it easier to recreate the functional modules. Following the circuit layout and viewing the functional module's physical reality in the functional module box, students are given a bag of components and instructed to recreate the circuit. This method allows students to get both theoretical knowledge from the report and practical knowledge from constructing the actual functioning module. See Fig. 4 for an illustration of how the op-amp functional module looks. In the functional module report, the inverting op-amp and non-inverting op-amp circuit diagrams are shown in Figures 5 and 6, respectively. These functional modules were described in further depth by Giurgiutiu and Mouzon [9] and Giurgiutiu and Liu [8].

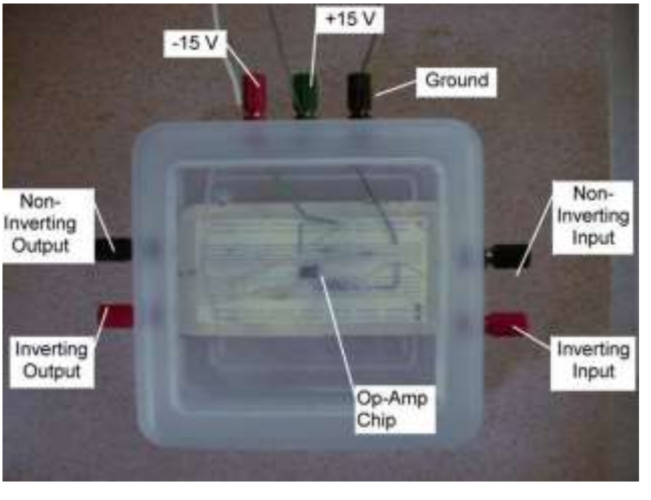


Fig. 4. Op-amp functional module displaying inputs and outputs for the inverting and non-inverting circuits.

V_{in}

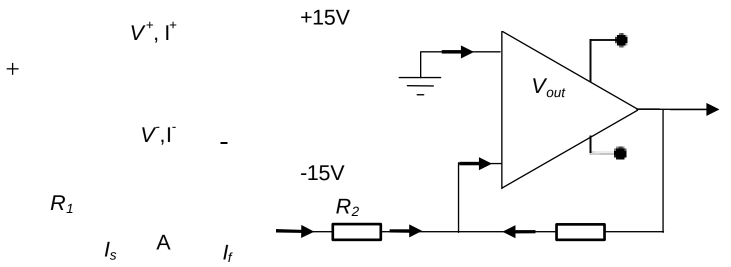


Fig. 5. Inverting op-amp circuit.

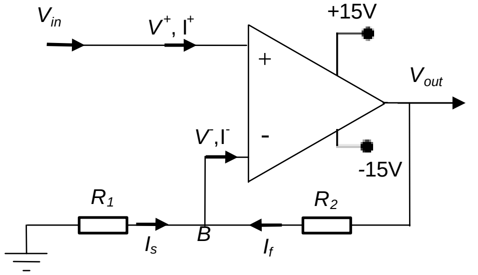


Fig. 6. Non-inverting op-amp circuit.

4. Conclusions

Mechatronics courses are now available at many institutions at both the undergraduate and graduate levels. Undergraduates, post-graduates, and even professors may all benefit from interdisciplinary courses that bring together theory, practical experimentation, and technological applications. They push the curriculum forward into the cutting edge of engineering education and provide concrete solutions to the pressing issues of 21st century training and education.

The University of South Carolina's Mechanical Engineering Department has begun an initiative to better prepare students in fields other than electrical engineering for careers in mechatronics. The NSF is providing the primary funding for this endeavor, with contributions from the Mechanical Engineering Department and the College of Engineering and Information Technology. The students' knowledge of micro-controllers, from both an analytical and practical perspective, will grow with the implementation of our method. Instead of teaching the inner workings of the microcontroller, we have concentrated on its practical applications. Students in mechanical engineering, as well as those in related fields that don't focus on electricity, may find this most useful.

The team is still working on this. When new information becomes available, it will be reported in books and journals.

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