Framework of Multi-Microcontroller Evaluation Tool for a use of Academic Environment

S. Raja Saravana Kumar, Kamarul Hawari Ghazali, Nik Mohd Kamil Nik Yusoff, & Hazizulden Abdul Aziz

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***Abstract*— This paper presents a framework for developing applications based on a three type of microcontroller (µC), Freescale HC11, MCS51 and Microchip PIC18. This project consists of the hardware and software implementation that supports the development and transfer process of the program code from a personal computer to the microcontroller, which led to the evaluation of educational based training kit systems. The first part of the paper focuses on hardware design, which is based on a modular approach, i.e. recomposed for the design of each application, in order to ensure maximum adaptability. The Multiple Microcontroller Evaluation Tool (MicroEVAT) thus consists of a programmer tool, a main board including adapters for a variety of chip packages, and plug-in modules. These are presented in the second part of the paper describing the software part of the framework, which besides programming tools also discusses the code development tools. The stress is given to the use of assembly code and high-level tools, where the algorithms are described in the form of different graphical notations, i.e. block diagrams. Throughout the paper, a special attention is given to the use of framework in the electronics engineering education process.**

1. Introduction

Research and education activities at Faculty of Electrical & Electronics Engineering, Universiti Malaysia Pahang involve embedded systems design and development [1]. Every year, there are Embedded Control Technology course available for third year diploma and degree and also for students from our faculty who taking final year projects. All these activities require different microcontroller types, each with its own development board, but structure of such boards is very similar, only microcontroller and its associated circuitry being different.

However, users' feedbacks indicate that they have difficulties not only in developing an application system due to limited expendability but also in understanding the hardware structure and configuration of the microcontroller-based application to be developed [2]. Most of the development boards come with limited expandability of the system that prevents the user to develop and to integrate their own application development systems.

Therefore, a flexible and versatile prototype system of MicroEVAT has been developed. This system can be used extensively in experiment or project for diploma, undergraduate and short courses. This MicroEVAT has been also be boosted with a simple application board that is suitable for the students to test their capabilities and to improve their knowledge in this course. In addition, a monitor program has been developed to integrate the basic software such as communication software, text editor, cross assembler, and compiler. Needless to say, it will tremendously create a user friendly environment. The first major step in developing a multiple microcontroller hardware platform is the design of microcontrollers‟ system for the central controlling unit (CCU) itself. The work presented in this paper is to develop a hardware and software design and implementation of these three types of microcontroller families, which are Freescale HC11, MCS51, and Microchip PIC 18.

2. Implementation of Embedded Systems

Due to dramatically increasing complexity of development tool over the past decades, developers are facing ever-increasing challenges for their products to stay market competitive [3]. In this context the utilization of systematic design methods is essential in order to aggregate rather than trade-off the technical, cost, and time-to-market feasibility factors [4-10].

As depicted in Figure 1, the general progression of the design steps in time is indicated from left to right. Hence the horizontal axis of the diagram can be thought of as time, but since the design is often an iterative process, the actual development rather cycles between left and right leg of the diagram than proceeds linearly through the steps. The vertical axis represents the level of system components‟ abstraction, with the top steps representing high-level system view and the bottom steps representing very low-level processes.

S. Raja Saravana Kumar, Kamarul Hawari Ghazali, Nik Mohd Kamil Nik Yusoff, and Hazizulden Abdul Aziz are with Faculty of Electrical & Electronics Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
(email: inderjit-1791@yahoo.com(✉), kamarulh@ump.edu.my, mik@ump.edu.my, haazizulden@ump.edu.my)

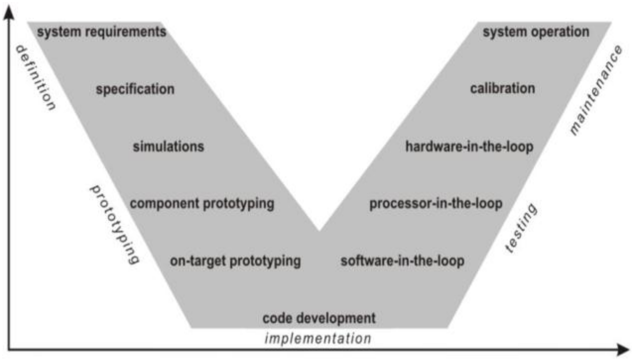

Fig. 1. V-diagram of development tool design flow.

The implementation of MicroEVAT which is presented in this paper aids narrowing the development tool design V-diagram by providing a common set of tools that are used through the prototyping implementation and testing stages. In prototyping stage first a simulation model is designed that behaves according to the requirements. Then for the validation of feasibility, the design components are prototyped on general prototyping hardware. The timing characteristics are not modelled in this step, and may change in the actual design. Once the components behave appropriately, the on-target prototyping is employed on the envisaged processing device, in our case a microcontroller.

3. MicroEVAT Implementation

This section briefly discusses the overall project design including the workflow of activities, device design and program development. Initial construction of circuit is done on a project board by module section for easier testing and modification. Then it is transferred to a donut board after all the module sections circuits are found to be working. Software development includes the programming of the microcontrollers, which interfaces to all the hardware part. A set of instruction code is written to indicate the microcontroller performs the function required. In the interfacing stage, hardware and software work together as a complete system as shown in Figure 2.

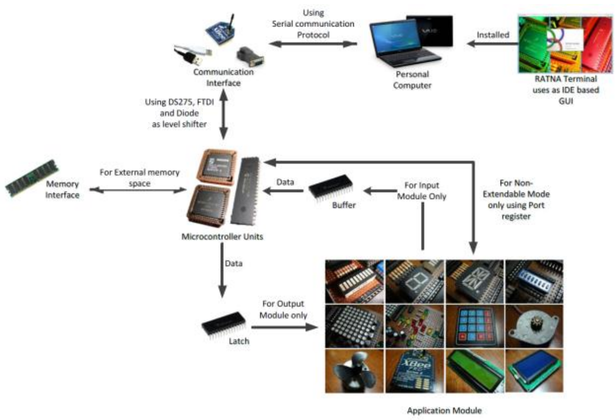

Fig. 2. Block diagram of the MicroEVAT system

A. *System Bard of MicroEVAT*

The system board consists of microcontrollers of Freescale HC11, MCS51 and Microchip PIC, power units, and communication interfacing units. The power units refer to supply voltage of direct current (DC) from voltage regulators while the communication interfacing units refer to serial communication consist of RS232, USB and ZigBee protocol. Then interfacing to I/O port requires the use of data bus and address bus of designated of microcontroller. Although the systems have separate power supply for each microcontroller, the communication interface of each microcontroller will be uniting into one serial communication link to the personal computer. In other words, the user does not require to plug out the serial or USB cable whenever the user uses the different microcontroller from the current one or vice versa. Figure 3 shows the structure diagram of the MicroEVAT system board with power and communication interface.

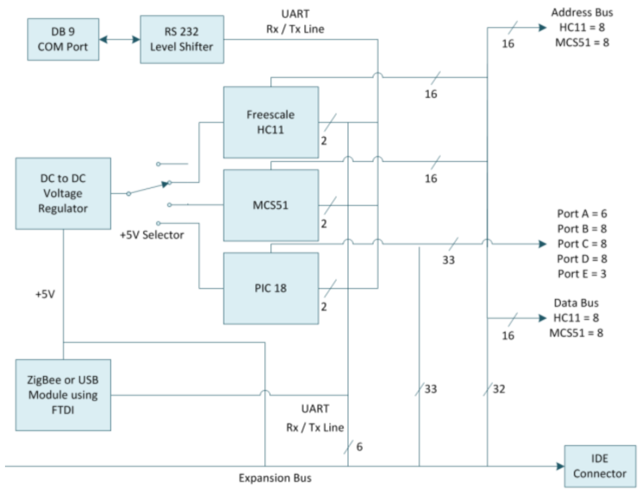

Fig. 3. The structure diagram of the MicroEVAT system board with power and communication interface

B. *Memory Board of MicroEVAT*

The main purpose of the implementation of external memory storage is to create a microcontroller expended capability beyond the on-chip resource to avoid a potential design bottleneck. If any resources must be expanded memory or I/O, then the capability must exist. The memory storage unit consists of RAM and ROM. As usual, RAM is used as a temporary storage for system board. In other words, RAM is volatile memory that requires power supply to keep the system operate. ROM, on the other hand, is used as a permanent storage for monitor program. The type of ROM that being used in the system is Electrically Erasable Programmable Read Only Memory (EEPROM). This type of memory could erase its content by supplying appropriate voltage.

In order to have external memory storage for MicroEVAT system, an addressing module has to be designed to enable the microcontroller devices to access the memory content at designated address. This is depends on what microcontroller is used. Only Freescale HC11 and MCS51 have been implemented in this system. Six address decoder are used in order to create the addresses for memory storage and as well as the application module. Based on Figure 4, the structure diagram of the MicroEVAT memory board is shown.

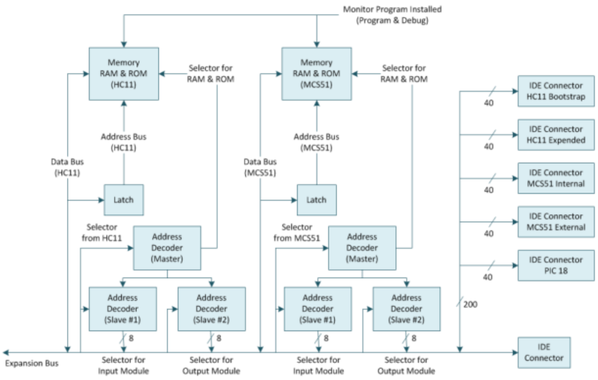

Fig. 4. The structure diagram of the MicroEVAT memory board

C. Application Board of MicroEVAT

Figure 5 is a structure diagram with its application modules in MicroEVAT prototype system. The former include input modules such as Temperature Sensor, 8-ways DIP switches, and Keypad and the latter consists of output modules such as LED, Bar Graph, 7-Segment Display, 16-Segment Display, Dot Matrix, Traffic Light, LCD, GLCD, DC motor, and Stepper Motor. Some of the modules are directly connected to the I/O port of microcontroller for bootstrap mode. These include LED, Bar Graph, 7-Segment Display, LCD, GLCD, DC motor, and Stepper Motor. Due to the limited ports that available in the microcontroller, as mention above, six address decoders is used to select another ten I/O devices by using latch and buffer. These include LED module, Bar Graph module, 7 and 16 Segment Display module, Traffic Light Module, Dot Matrix module, Keypad module and 8-ways DIP switches module. The latch is an eight-bit edge-triggered register coupled to eight tri-state outputs for enabling the devices. Buffer, on the other hand, is an eight tri-state buffers or line drivers to enabling two input modules. However, the Microchip PIC does not consist of using latch and buffer since the connection only through the port register, like using bootstrap mode for Freescale HC11 and MCS51 microcontroller.

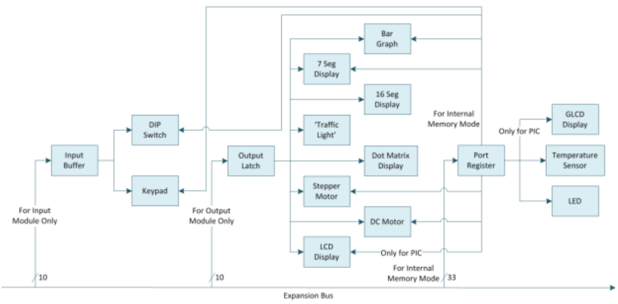

Fig. 5. The structure diagram of MicroEVAT application board

D. Source Code of MicroEVAT

In order to implement the source code in microcontroller system, a basic assembler or compiler is required to convert the following source code into binary file or most commonly known as the machine code. These machine codes that the processor understands will be programmed into the memory storage. Several steps have to be done in converting the assembly language or the high level language into binary file or the machine code. Figure 6 shows the flow chart of the source code implementation in application module.

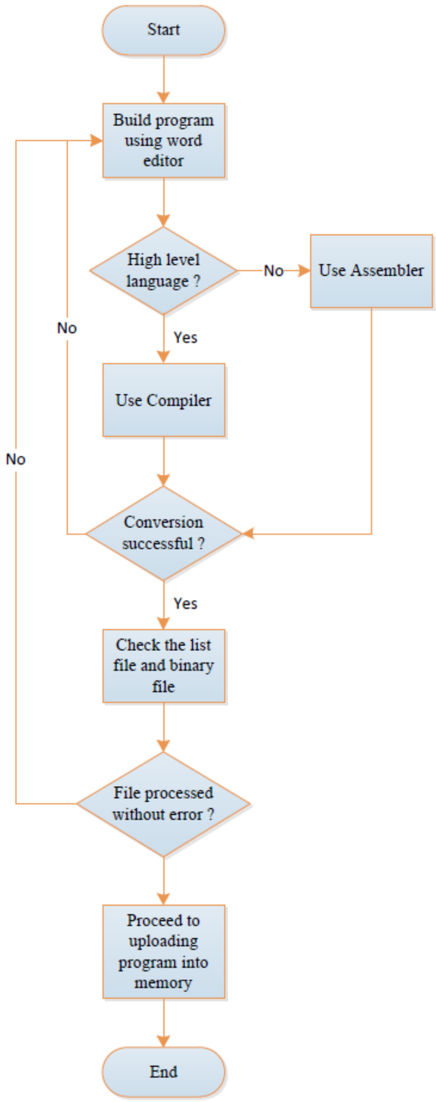

Fig. 6. The flow chart of the source code implementation

E. RATNA Terminal of MicroEVAT

RATNA Terminal is the developed software for MicroEVAT system where, the user can communicate these systems using the proposed serial communication interfaces and used for uploading and execute the desired program code with the provided application module or any other user-designed application interface. This system has been developed by using Microsoft Visual Studio 2010 (VS2010) as the platform for the entire recent developed GUI using

Windows Presentation Foundation (WPF) or known as the Microsoft Silverlight. The reason of creating the RATNA Terminal using VS2010 platform is because the previous version of Visual Studio does not have the latest version of .Net Framework. The use of the current version of .Net Framework 4 (.NF4) helps to improve support for parallel computing, which target multi-core or distributed systems, which will be used in current computer system like Intel Core system processor. If the RATNA Terminal integrates with the current version of windows OS, these supports of .NF4 must be implemented in order to install the RATNA Terminal. Figure 7 shows the main screen of RATNA Terminal software.

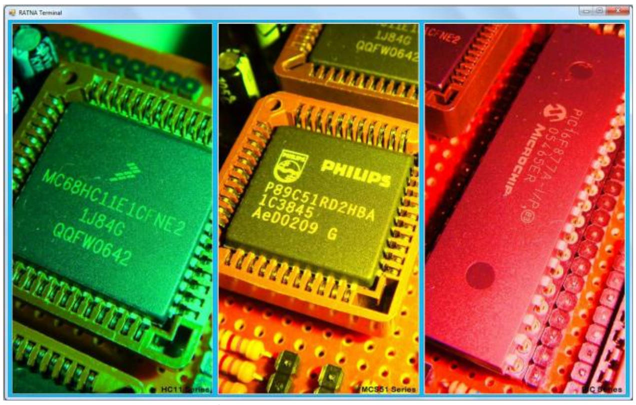

Fig. 7. The screen shot of RATNA Terminal main screen

4. Result and Testing

Various tests are conducted in this project. The results of the testing reveal the system have achieved of substantial goal. Since the system consists of development board and application module, each part is tested independently. Finally, the modules are integrated and tested for its functionality. The MicroEVAT system has integrated with three independent microcontroller devices that connected into one serial interface for communication purposes. As shown in Figure 8, the MicroEVAT system has been setup with the communication interface with the PC using all the available links for experimental purpose which will be used for reveal the testing results.

Fig. 8. The experimental setup for MicroEVAT prototype system

A. Preliminary Testing

Before the actual MicroEVAT system tests were performed on the RATNA Terminal, several preliminary tests had been conducted to ensure the stability of the MicroEVAT system board that will operate as desired during the test. One of the tests is power supply tests. This test had been done to ensure the stability and the durability of power scheme module for MicroEVAT. There are two types of parameter need to consider for building a power supply module, the current load and the heat temperature. For typical LM 7805 voltage regulator devices, the current load must be not exceed above 1.0 A at 5VDC. If the system or the application module uses more current load than the specified load will resulting increase of heat temperature of the voltage regulator.

Based on Table 1, the MicroEVAT system can operate multiple microcontroller system in one main board since the current and the thermal load does not exceeds the specified value at the range of 259 mA in 52˚C. However, the application module can operates more than 4 modules in one board executed at the same period of time, which will give the value of 912 mA of current but the heat temperature rises until 90˚C, and will give the application board a heat transfusion to the application devices. Although it is safe to have more than 4 modules in one application board, but is this system produce in a large scale, it is considered as a risk for the user when handling this development board and may get burns from the heat produced by the board.

B. Subsequent Testing

After the preliminary testing has been conducted to ensure the stability of MicroEVAT system board, the subsequent test will be conducted in terms of the software and the application module integrations. This testing procedure is to ensure the connected application devices works well with the designed GUI based IDE approach software for MicroEVAT system. Since the application board consists of extensive devices, each of them must be tested individually to ensure its functionality. The result of the testing reveals that application board is ready for interface purpose. Figure 9 shows some of the example in application module testing.

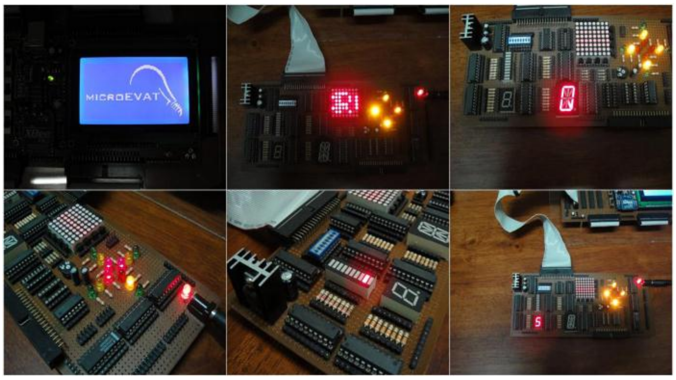

Fig. 9. The example of testing result for some application module

Table 1: The testing results for current and thermal load for MicroEVAT system

Board	No of module	Current Load, mA	Temperature, °C*
System	Power Supply	17	34
	One microcontroller	68	37
	2 microcontrollers	117	46
	3 microcontrollers	259	52
Application**	One module	98	38
	2 modules	169	49
	3 modules	257	56
	4 modules	419	66
	More than 4 modules***	557 - 912	74 - 90

* Measured at LM7805 Heatsink with the room temperature of 28˚C.

** Application module consists of random devices excluding of LED and Bar Graph devices.

*** Not include High Power Application devices.

5. Conclusion

In this paper the framework consisting of the Multiple Microcontroller Evaluation Tool (microEVAT) and the supporting software tools were presented together with some proposals for its use in educational courses. Destined to three types of microcontroller application design, the microEVAT is designed as open as possible, so that anyone can fabricate it on his/her own and use it with freely available basic accompanying software. Its design is sufficiently general to be used as a whole or as a component in another system. It is not focused on a particular microcontroller device, but it enables to select the most appropriate device for each application design. When using as a whole, the microEVAT represents a very robust system, where even an incorrect use does not harm any of the system's components. The development and improvement of the system is still in progress and additional plug-in modules (e.g. keypad, Multi-segment display, stepper motor module, ZigBee communication module, etc.) are being designed. As such the system is particularly appropriate for educational purposes, trying to support those entering to the world of microcontrollers.

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References

[1] Abdul Aziz, H., Nik Yusoff, N.M.K. and Sapien, M.Z.B.M. 2010. MINI11: Microcontroller Development Board for SCL Approach. *Proceedings of 2010 IEEE Student Conferences on Research and Development*, pp. 178-182

[2] Ling, L.C. 2008. *The MC68HC11 Development Board with Integrated Development Environment (IDE)*. B.Eng. Thesis. Universiti Malaysia Pahang, Malaysia

[3] Mosterman, P.J. 2006. Automatic Code Generation: Facilitating New Teaching Opportunities in Engineering Education. *36th ASEE/IEEE Frontier in Education Conference*, pp. 165-171

[4] Al-Dhaher, A.H.G. 2001. Integrating Hardware and Software for the Development of Microcontroller Based Systems. *Elsevier Journal of Microprocessors and Microsystems*. **25**(7): 317-328

[5] Databeans. 2009. Microcontroller Market Share, Electronics.ca Publications, Mar 2010. http://www.electronics.ca/publications/products/2009-Microcontrollers-Market-Share.html (2 August 2010)

[6] Ferreira, L.F., Matos, E.L., Menendez, L.M. and Mandado, E. 2005. MILES: A microcontroller Learning System combining Hardware and Software Tools. *35th ASEE / IEEE Frontiers in Education Conferences*, pp. 77-81

[7] Nikolaidis, S., Kavvadias, N., Laopoulos, T., Bisdounis, L. and Blionas, S. 2005. Instruction Level Energy Modeling for Pipelined Processors. *Elsevier Journal on Embedded Computing*. **1**(3): 317–324

[8] Smolnikar, M. and Mohorcic, M. 2008. A Framework for Developing a Microchip PIC Microcontroller Based Applications. WSEAS Transactions on Advances in Engineering Education. **5**(2): 83-91

[9] Stoltz, T. 2003. *The Development of Microcontroller Hardware Platform with MC68HC11E2*. M.Eng. Thesis. University of Detroit Mercy, USA

[10] Striegel, A. and Rover, D. 2002. Enhanced Student Learning in an Introductory Embedded System Laboratory. *32nd ASEE / IEEE Frontiers in Education Conferences*, pp. 138-143

Raja Saravana Kumar Selvakumar received the B.E Engineering degree in Electronics in 2009 from Universiti Malaysia Pahang, Kuantan, Pahang, where he is currently working towards the M.E Engineering in Electronics. He has published a small number of papers in conferences proceedings. His main field of research is on the techniques for microprocessor and microcontroller design implementation as well as the development of the good operating condition of digital embedded control system. He is familiar with the developing of evaluation tool that combine the use of a personal computer along with the use of microprocessor and microcontroller system equipment connected to it.

Kamarul Hawari Ghazali received his B.E.E. and M.E.E. from Universiti Teknologi Malaysia and Ph.D. from Universiti Kebangsaan Malaysia in 2009. He is currently the Deputy Dean of Research and Postgraduate studies at Faculty of Electrical & Electronics Engineering in Universiti Malaysia Pahang. He serves as a Lecturer of numerous short courses to industry as his expertise in industrial control technology. His current research interests include the application of digital and image signal processing in instrumentation and measurement, the application of vision control, automation and intelligent system, and renewable and alternative energy.

Nik Mohd Kamil Nik Yusoff received the B.E. Engineering degree from Arizona State University, USA in 1987 and M.E.E from Universiti Teknologi Malaysia in 1991, Skudai, Johor. He is currently a Senior Lecturer with Faculty of Electrical and Electronics Engineering, Universiti Malaysia Pahang. He is also involved in several research projects funded by local universities and private sectors and the author and co-author more than 50 papers in international scientific journals and conferences proceeding. He won several awards in local and international exhibitions and involved as a consultant in many fields. His research interest including the design of embedded processor architecture, telephone system and network such as switching and broadband communications, wireless system and home automation.

Hazizulden Abdul Aziz received his MSc and BSc in Electrical Engineering from Universiti Teknologi MARA, Malaysia and University of Colorado, USA, respectively. Currently, he is a faculty member of the Electrical & Electronics Engineering Faculty at Universiti Malaysia Pahang. His current research interests include embedded system, digital signal processing and neural network application in instrumentation and industrial electronics. He is a Corporate Member of Institute of Engineers Malaysia (IEM).