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EDUCATIONAL MODELS FOR LESSONS OF MICROCONTROLLER PROGRAMMING

Jan Dolinay
Tomas Bata University, Faculty of Applied Informatics
Nad stranemi 4511, Zlin
Czech Republic

Petr Dostalek
Tomas Bata University, Faculty of Applied Informatics
Nad stranemi 4511, Zlin
Czech Republic

Vladimir Vasek
Tomas Bata University, Faculty of Applied Informatics
Nad stranemi 4511, Zlin
Czech Republic

ABSTRACT
This paper describes new educational models developed at our department for lessons of microcontroller programming. These models are intended to make the lessons more attractive for students by allowing them to see interaction of the microcontroller with a real world application. The models are in a form of unified modules which attach to development kit which is used in the lessons. The following modules are described: simple heating plant, DC motor controller.
Keywords: microcontroller, education, modules

1. INTRODUCTION
Microcontrollers invaded to virtually all areas of our life. Nowadays there is wide choice of micro-computer systems which can be utilized for various tasks including controlling complicated technological processes but also providing basic logic for simple devices, such as microwaves, TVs, MP3 players etc. Despite their relatively low computing power and limited memory microcontrollers are useful for wide choice of applications and thanks to their low cost they successfully replace designs made of discrete parts in even the simplest circuits.
As well as in the devices itself, progress can also be seen in programming languages and tools. Programming languages used in industry can be divided to several levels, the lowest being assembler language, followed by higher programming languages, such as C, with the top level represented by visual design tools which automatically generate the code.
Even though higher programming languages are generally preferred today, sometimes it is useful or necessary to program in assembler, especially with microcontrollers. At our university, we chose to start the lessons of microcontroller programming with assembler, followed by C later on. The reason for use of assembler is that this language, being very close to the processor code, provides good idea of the basic principles on which microcontroller works. We feel that this is more useful to students than mastering one specific high-level development environment.
To make the lessons more attractive we decided to develop several modules which will allow the students to see a real application of microcontroller-operated device, make a program for such device

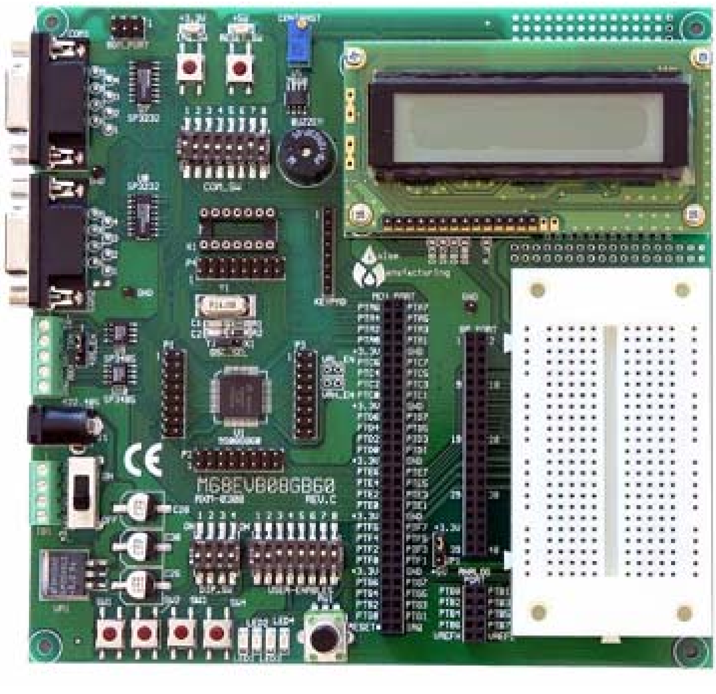
and see how it works. Of course, there are many possible modules which could be used this way but in first stage four modules were proposed and created in the course of diploma theses at our faculty: model of simple heating plant, DC motor control, keyboard-display module and a servo control module.

2. THE HC-08 MICROCONTROLLER AND ITS PROGRAMMING

For the lessons of microcontroller programming we use HC-08 microcontroller made by Freescale, division of Motorola. For our purpose the microcontroller itself without any peripherals would not be practical, so we use an evaluation kit, which is equipped with serial port connectors, LED diodes, switches, small display, buzzer etc. With this kit it is possible to create an application which can interact with the outside world, e.g. respond to a button press with turning on a LED, or displaying value set by potentiometer on the display. The kit is described in more details further in this text. It utilizes the M9S08GB60 derivative from the HC-08 production line, which is microcontroller with 4 KB of RAM and 60 KB of Flash memory and up to 20MHz clock. It offers 56 input/output lines in 7 ports, 2 independent timer modules, 8 channel, 10 bit A/D converter etc. [1]

2.1. Evaluation board M68EVB908GB60

The evaluation board which we use in lessons is marked as M68EVB908GB60. Because our students learn the basics of microcontroller programming using this kit, we decided that the modules should be connected to this kit as a kind of extension board, instead of being equipped with their own microcontroller. This makes the design of the modules extremely simple and at the same time does not require that the students learn to operate another device before being able to see the module at work. Operating the module is basically the same as operating any peripheral of the evaluation kit, such as LED or push button. The kit itself is depicted in figure 1. [2]



PTA6/KBD6	1	2	PTA7/KBD7
PTA4/KBD4	3	4	PTA5/KBD5
PTA2/KBD2	5	6	PTA3/KBD3
PTA0/KBD0	7	8	PTA1/KBD1
3.3V	9	10	GND
PTC6	11	12	PTC7
PTC4/CLKOUT	13	14	PTC5
PTC2/SDA	15	16	PTC3/SCL
PTC0/TXD2	17	18	PTC1/RXD2
3.3V	19	20	GND
PTD6/TPM2CH3	21	22	PTD7/TPM2CH4
PTD4/TPM2CH1	23	24	PTD5/TPM2CH2
PTD2/TPM1CH2	25	26	PTD3/TPM2CH0
PTD0/TPM1CH0	27	28	PTD1/TPM1CH1
3.3V	29	30	GND
PTE6	31	32	PTE7
PTE4/MOSI	33	34	PTE5/SPSCK
PTE2/SS*	35	36	PTE3/MISO
PTE0/TXD1	37	38	PTE1/RXD1
3.3V	39	40	GND
PTF6	41	42	PTF7
PTF4	43	44	PTF5
PTF2	45	46	PTF3
PTF0	47	48	PTF1
3.3V	49	50	GND
PTG6	51	52	PTG7
PTG4	53	54	PTG5
PTG2/EXTAL	55	56	PTG3
PTG0/BGND/MS	57	58	PTG1/XTAL
RESET*	59	60	IRQ

Figure 1. The evaluation kit and scheme of its extension connector.

As can be seen in the picture, the evaluation kit is equipped with plenty of useful peripherals including a breadboard area and a connector with virtually all the microcontroller outputs and inputs available for connecting to external devices. The connector is the main interface to our modules. Detail of the connector can be seen in the right-hand side of the figure 1.

3. DEVELOPED MODULES

Two of the developed modules will be described here. Both the modules connect to the extension connector of the evaluation board. The power (9V DC) is taken from the evaluation kit as well, so both the module and the kit share one power supply. For each module a basic program library (driver) was created which allows easy use of each module in students' programs without requiring deep knowledge of the hardware. Advanced programmers, of course, can control the kit directly without this driver.

3.1. Heating plant

First of the modules is a simple heating plant. The idea is to demonstrate microcontroller control of this kind of system, also allowing the students to get acquainted with temperature measurement and optionally PWM. The plant is formed by a resistor which is heated by relatively small current (about 300 mA). The current is turned on/off from the microcontroller. A thermometer is attached to the resistor, and output of this thermometer is connected to the microcontroller. In our case integrated temperature sensor SMT 160-30 is used. It can measure temperatures from -45 to +130°C, does not require any calibration and is ideally suited for use with microcontrollers because the output is PWM signal with duty cycle dependent on temperature.

The software driver for this module allows its basic use, such us obtaining the temperature or turning the heating on or off. The driver is implemented as a library in assembly programming language, so the basic operations are available as subroutines which the user calls from his/her program. Understanding the internal principles of the library, such us using input-capture timer function to measure the duty cycle of the signal from thermometer, is not required. This way the module can be useful at various stages of learning, from basics, when the driver routines are used, to advanced, where the student programs everything on his/her own. The schema of the module can be seen in figure 2. [3]

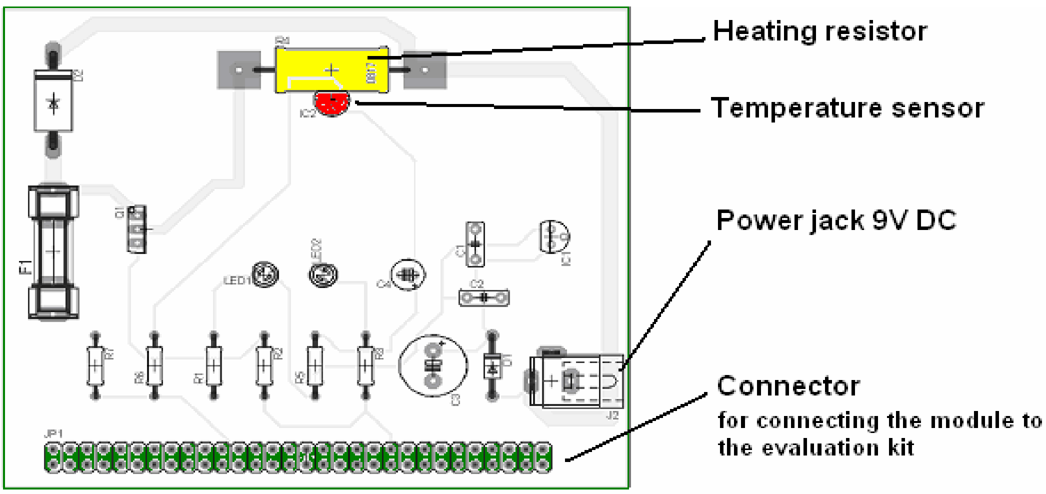


Figure 2. Schema of the heating plant module.

3.2. DC motor control

Next module contains DC motor which can be controlled from the microcontroller and also allows the rotation speed to be measured. The motor can be operated in both directions; direction is switched by relay by a signal from the microcontroller. The power to motor is switched on/off by a transistor so it is possible to control the speed using PWM. For measuring the RPM a disc with three holes is attached to the motor. The holes in this disc allow light from LED to reach phototransistor, thus creating a pulse on the input of the microcontroller. Three holes with irregular distance from each other are used so that the direction of the rotation can also be detected programmatically. Program library for this module was also created. The principle is the same as described for the previous module. The high level routines in this driver allow setting the speed of the motor in terms of duty cycle (in percent), direction of the motor, and obtaining the measured speed and direction. The module can be seen in figure 3. [4]

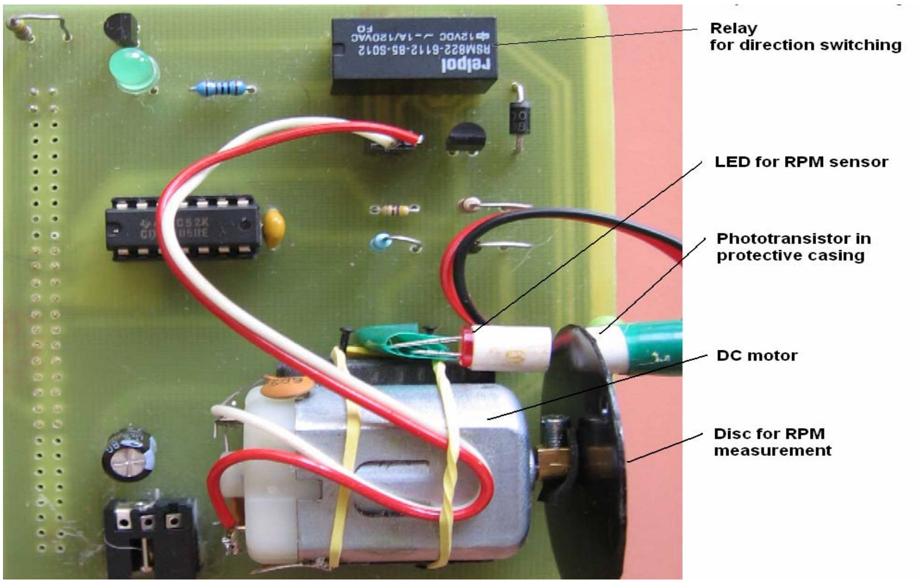


Figure 3. Schema of the DC motor module.

4. CONCLUSION

In this paper we introduced two of our educational modules for lessons on programming microcontrollers. First of the modules is a model of heating plant with heater controlled by microcontroller and temperature measured by intelligent sensor and evaluated by the microcontroller. Second module is DC motor, the speed and direction of which is controlled by microcontroller and also RPM can be measured. For each module basis program library (driver) was written which allows control of the module without deep knowledge of the hardware. This way the modules can be used by beginner programmers who take advantage of the drivers and perform relatively complex task (e.g. setting PWM output of the microcontroller) by a single call to subroutine. But advanced programmers can also find this module useful and program their own low level control algorithms.

We hope the educational modules will help motivating students to learn the skills of microcontrollers programming which can be useful in the present world where microcontroller can be found literally in every piece of electronic.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] Freescale Semiconductor, Inc.: MC9S08GB60: Technical Data Sheet for MC9S08GB/GT MCUs data sheet. Rev. 2.3, 2004.

[2] Freescale Semiconductor, Inc.: M68EVB908GB60 Development board for Freescale MC9S08GB60. 2006.

[3] Babik, Z.: Educational module for microcontrollers course: simple heating plant. Bachelors thesis at Faculty of Applied informatics, TBU in Zlin. 2007.

[4] Korcak, P.: Educational module for microcontrollers course: DC motor control and RPM measurement. Bachelors thesis at Faculty of Applied informatics, TBU in Zlin. 2007.