Low Cost, Advanced, Integrated Microcontroller Training Kit

Y Somantri*, I Fushshilat
Electrical Engineering Education Study Program
Faculty of Technology and Vocational Education
Universitas Pendidikan Indonesia
tiosoamntri@yahoo.co.id

Abstract. This paper describes the design of an AVR microcontroller training kit with a low cost and the additional feature of an integrated downloader. The main components of this device include: Microcontroller, terminal, I/O keypad, push button, LED, seven segment display, LCD, motor stepper, and sensors. The device configuration results in low cost and ease of use; this device is suitable for laboratories with limited funding. The device can also be used as a training kit for the teaching and learning of microcontrollers.

1. Introduction

Microcontroller is a microprocessor plus other functions or a single-chip microcomputer containing microprocessor units, a memory, a RAM, a ROM, an I/O, an ADC/DAC, a timer, a counter, a decoder, etc. The facilities depend upon the types of the microcontroller. “A microcontroller consists of a central processor, a Read Only Memory (ROM), a Random Access Memory (RAM), an analogue/digital converter, registers and decoders all in one chip” [1]. “A microcontroller trainer is intended for training of university, polytechnic and vocational-centre students in the interfacing of hardware and writing of programs in a microcontroller environment” [2].

The microcontroller trainers designed and made by previous researchers in general require a downloader installed in parallel to a personal computer. The downloader is functioned to write data or program to the target microcontroller; for example, the MCS 51 microcontroller family or the AVR family [3]. The downloader is commonly installed separately from the trainer. Meanwhile, the trainer designed in this study is integrated into the downloader and is equipped with a USB-to-serial connection, making it more practical and economic compared to a separate trainer.

Microcontroller is a controlling device used as a controller of an embedded system. As a controlling device, microcontroller is programmable by its users [4]. On the other hand, this training kit is used as the learning media in learning about microcontrollers, especially for training of application programming and interfacing between microcontrollers and sensors as input and output.

One of the previous applications of microcontroller by previous researchers is as follow:

Cui Yingying et al. (2015, pp. 5670-5675, IEEE). The fresh air control unit uses microcontroller STC89C51 as its core controller. In the fresh air control unit, there are a sensor module, a display module and unit control module. The microcontroller processes data of the concentration of
carbon dioxide, air temperature and relative humidity. Then it uses PID algorithm to control fan speed with sensing data of indoor air’s temperature and relative humidity. The fresh air control unit contains smoke alarm, temperature monitoring, remote communications to improve the air quality of people’s working, living and learning environment.5]

The aim of this research is to design and build a low cost microcontroller trainer integrated with a downloader that is user friendly and equipped with sensors as input and actuators or motors as output.

The Research and Development (R&D) method was used in designing the system as shown in figure 1.

**Figure 1.** Block diagram of the system design of the Low Cost, Advanced, Integrated Microcontroller Training Kit.

The descriptions of the block diagram are as follows:
- **Personal Computer (PC)**
  Personal Computer is the site for operating software compilers and downloaders. Normally, software compilers have already been installed in a PC, such as Code Vision AVR, AVRStudio, Basic Compiler, or the like. In addition, software downloaders should have also been readily installed, such as: Khazama, AVRDude, and Progisp that are already compatible with the AVR Microcontroller training kit integrated with a downloader designed in this study.
- **Downloader**
  Physically, a downloader is a unit integrated with the training kit. This part is integrated into the training kit and serves the function of receiving files with *.hex or *.bin extensions, which are compiled by the software compilers. The files will then be loaded using the loader software installed on the PC to the target IC Microcontrollers, such as: AVR ATMEGA16, ATMEGA32, or ATMEGA8535 on the training kit. The downloader can be directly connected to the Personal Computer through a Universal Serial Bus (USB) port. The USB is commonly already installed in each Personal Computer, Notebook, or Netbook.
- **AVR Microcontroller Training Kit**
The training kit integrated with a downloader designed in this study is equipped with a stable power supply to support the working system of the training kit and downloader series.

The training kit provides the following input-output modules:

On Port A, there are 8 bit I/O, LED, Motor Stepper or Motor DC modules (output). There are also Ultrasonic, LDR, and potensio modules as input. Port B contains I/O Relay, Buzzer, Seven-Segment modules (output) and PIR as input. Port C contains I/O 4 x 4 Keypad and Push Button modules (input), and Dot matrix and Seven-Segment modules as output. On Port D, there are I/O serial USB, serial Db9, and LCD, Dot Matrix, Seven Segment, and AC Motor modules. For DC Motor/Stepper, IC L298 is simultaneously used as the driver and amplifier of the DC motor controller with a voltage and current of up to 48V and 2A, respectively. Meanwhile, for processor power supply, a stable 5V is used, and for sensor it is dependent upon the standard voltage.

- **USB Downloader**
  USB downloader is used as an intermediary to input programs from the computer to the microcontroller.

- **Power Supply**
  The Power Supply uses a 5V USB on the computer with a voltage and a current of 5V and 500mA, respectively. Alternatively, an external 5V and 1A power supply can be used because the voltage distributed to the microcontroller is 5V.

Firmware is a program functioning to control the hardware. Its role here is as the brain of the downloader. The firmware in this kit uses usbasp 6]. The firmware works by receiving a series of data with *.hex or *.bin extension sent serially using the USB standard protocol from the downloader software installed on the computer. The USB then buffers and processes in such a way that the data are returned byte by byte, serially to the target microcontroller on the training kit series using the feature of In System Serial Programming (ISP) through the MOSI, MISO, SCK, and Reset pins.
Figure 2. The flowchart of the working principles of the low cost, advanced, integrated microcontroller training kit.

Flowchart Descriptions:
It starts with the user loading a program in the forms of command lines (syntax) with C programming language into the software compiler, which in this case is the CodeVision AVR (CVAVR) made by HP InFotech. Next is the compilation stage and building program syntax. At this stage, CVAVR will first check the syntax of the program before it is compiled into a file with *.hex or *.bin extension. If an error is still found in the syntax of the program, then CVAVR will give notification of error to the user, and then the user has to first repair the error parts of the syntax. However, if the results of the syntax checking by CVACR show no errors, the syntax will start to be compiled into a *.hex or *.bin
extension file, which will be subsequently loaded into the (AVR) target microcontroller on the Microcontroller Training Kit through the downloader software and hardware integrated into the kit.

After the syntax of the program—now in the forms of *.hex or *.bin extension files—has been successfully loaded into the IC of the target AVR on the microcontroller Training Kit, the working results or effects of the syntax can be seen in the output of the Microcontroller Training Kit, which can be in the form of turned on LED or LCD or Motor movement.

- **Device Performance Testing**
  The training kit integrated with a downloader built in this study was tested in the teaching and learning of the practicum of Industrial Electronics III in the Department of Electrical engineering Education, Faculty of Technology and Vocational Education, UPI, in the subject of AVR Microcontroller for two meetings, each with five hour duration with good results, or no errors/work error.

- **Device Compatibility Testing**
  A test was done on the level of compatibility and suitability of the integrated training kit with several software compilers and software downloaders installed in a computer using several types of IC AVR Microcontroller, namely ATMEGA 16, 32, and 8535, in accordance with the design specifications.

The software compilers used in the testing were the Code Vision AVR (CVAVR), AVRStudio, and Bascom-AVR, while the software downloaders used were Progisp, AvrDude GUI, and Khazama programmer. The testing was carried out by writing programs into software compilers and downloading data into several types of target microcontrollers in accordance with the design specifications, such as ATMEGA 16, 32, and 8535, with the aid of downloader software.

Based on the data on the compatibility test of the low cost, advanced, and integrated microcontroller training kit displayed in Table 1, it is clear that the kit can work well with various software compilers and software downloaders.

### Table 1. Compatibility Test of AVR Microcontroller Training Integrated with a Downloader (low cost, advanced, integrated microcontroller training kit)

| No | Software                  | ATMEGA 16          | ATMEGA 32          | ATMEGA 8535          |
|----|----------------------------|--------------------|--------------------|--------------------|
| 1  | CV AVR & Khazama           | Functions properly | Functions properly | Functions properly   |
| 2  | CV AVR & Progisp           | Functions properly | Functions properly | Functions properly   |
| 3  | CV AVR & AVRdude GUI       | Functions properly | Functions properly | Functions properly   |
| 4  | AVRStudio & Khazama        | Functions properly | Functions properly | Functions properly   |
| 5  | AVRStudio & Progisp        | Functions properly | Functions properly | Functions properly   |
| 6  | AVRStudio & AVRdude GUI    | Functions properly | Functions properly | Functions properly   |
| 7  | Bascom AVR                 | Functions properly | Functions properly | Functions properly   |

2. **Analysis of Device Making Costs**

At this stage, a comparison was made between the cost of making the AVR Microcontroller Training Kit integrated with a downloader and that of AVR microcontroller training kit with a separate downloader (trainer) from several products as shown in table 2. The latter is commonly used in the teaching and learning of the practicum on Sensor and Microprocessor or Microcontroller System in the
Actually, the price will depend on the accessories of the trainer with relatively similar device specifications. Compared to the low cost trainer developed here, however, the trainer is still cheaper than other trainers.

Table 2. Comparison of the price of the training kit integrated with a downloader with some other products in the market with a separate downloader

| No | Product | Source      | Price (IDR) |
|----|---------|-------------|-------------|
| 1  | Microcontroller Trainer Model : HTN-ATMC-0 | HT Hardtronics | 16,000,000 |
| 2  | Microcontroller Trainer AVR 8335HKJ-M005P-TM | Haka Jaya | 4,250,000 |
| 3  | AVR Microcontroller Trainer and its accessories | PT. PUDAK | 17,000,000 |

The specifications of the training kit developed in this research are as follows:
The IC microcontroller Atmega16 contains 16 pins that can be used as input/output, consisting of four ports, namely Port A, Port B, Port C, and Port D. The AVR microcontroller consists of 19 pieces of hardware integrated into the IC microcontroller, namely:

- USBASP Downloader
- 6-12V DC Supply - 5 A max
- 8 highly active 3 mm LEDs
- 8 highly active push buttons
- LM35 temperature sensor
- LDR light sensor
- 10k Potensio as ADC control simulation
- Real Time Clock (RTC) as real timing when the external supply is unplugged, using IC DS1307
- A 4x4 keypad
- PIR sensor as the motion sensor detecting human movement
- Ultrasonic sensor as distance measurement sensor
- 5VDC Relay as actuator
- 5VDC Buzzer as sound actuator.
- 2x16 LCD character.
- Four pieces of 1 inch Seven-Segment display using IC ULN2803 as amplifier
- 2 inch, 5x7 LED dot Matrix using IC shift register 74HC595N
- Motor Stepper, using ULN2003 transistor as current amplifier
- Serial communication using IC MAX232
- Serial communication using IC USB to TTL PL2303
- AC Driver motor controlled with PWM function on Atmega16A

3. Conclusion
Based on the results of device testing and analysis, it can be concluded that the Low Cost, Advanced, Integrated Microcontroller Training Kit has good performance and is able to work with various general software compilers and software downloaders. In addition, the training kit has been made compatible to various types of AVR microcontroller, namely ATMEGA 16, 32, and 8535. In terms of price and costs, the training kit is more economic and efficient compared to the trainer currently used in the practicum of AVR 8535 microcontroller in the Department of Electrical engineering Education.
Recommendations
On further research should use a double layer PCB layout. Can be equipped with extension modules that contain sensors and other actuators.

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