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Development of a Low Cost Microprocessor/Microcontroller Training Module and Laboratory Manual Designed for Outcome Based Electronics and Computer Engineering Education

ABSTRACT

This paper presents the development of a low cost microprocessor / microcontroller training module and laboratory manual. The first three kits comprise the basic training modules which includes a Gizduino v4.0 (328ATmega), LED array module, LCD module, LED matrix module, digital module, sensor module, variable resistance module, a circuit bread board, buzzer and motors module. The cost of each basic training kits is significantly lower than those available in the market with the same or equivalent features. It includes 30 experiments and exercises that will give the students the actual feel of the functionality of microprocessors and microcontrollers which they can freely do as OBE activities.

The last two kits are the advanced training modules. Each is composed of a Gizduino X (ATmega1281) v2.0, Gizduino+ 644 v3.0, gizDuino IOT 644, Gizduino USB host shield, Bluetooth shield v1.1, GPS shield, OLED shield, Keypad module, Wi-Fi module, GSM/GPRS shield v1.2, SD Card module, Ethernet shield module and a circuit bread board module. The advanced module has 20 technical experiments and exercises.

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The programming environment for both the basic and advanced modules is an open source (free) IDE Arduino v1.0.5 which may be downloaded in their website (http://www.arduino.cc/en/Main/Software). It follows the C Programming Language and Java. The interface of the hardware and software components of these training modules will be connected via universal serial bus (USB) supported by a prolific driver.

The system development method was used in this project which includes: prototyping, product development and technology transfer. The proposed low cost module is less complex, easy to construct, feasible, rugged, serviceable and versatile which allows electronics and computer engineering students to explore and gain advanced knowledge in microprocessor and microcontroller systems. These modules were utilized by fourth year computer engineering students, during the 2nd Semester of A.Y. 2014-2015 and currently being tested by fifth year electronics engineering students during the 1st Semester of A.Y. 2015-2016. The laboratory experiments were designed to achieve course outcomes for microprocessor systems course.

Upon evaluation based on the adopted and modified USE questionnaire which focused on usefulness, ease of use, ease of learning, satisfaction and cost of the development, a total of 64 students, composed of 4th year BSCpE and 5th Year BSEcE students strongly agreed that the modules are useful, can easily be used

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and learned and are satisfied with it for utilization in their laboratory course. The students also suggested that additional features such as a power supply circuit be added for experiments that requires an external power source, an organizer for additional connectors and regular updating on parts that will be available in the future. In addition, majority of them would also recommend it for purchase on their own or to another student who will be taking the microprocessor system course in the future and as an addition to the equipment of the school's laboratory.

Index Terms: microprocessor, microcontroller, laboratory training module, outcomes based education (OBE)

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INTRODUCTION

Microprocessors were developed shortly after World War II with the invention of the semiconductor diodes, transistor and integrated circuits (IC) that made up the first electronic calculator [1]. The microprocessor is a large scale or a very large scale IC that uses the architecture of the general purpose computer. It utilizes the computing power of both the hardware and software technologies [2].

The microcontroller is a complete microprocessor system built on a single integrated circuit. Microcontrollers were developed to meet the need for microprocessors to be put into low-cost products [2].

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The microprocessor system is a major field of applications in electronics engineering where design, testing, innovation and research are taking place in an exponential rate [3].

Due to the cost of this sophisticated technology, high priced and imported tools are needed to perform such tasks. Students taking up electronics engineering and computer engineering has limited laboratory equipment to perform experiments, design, prototype and research on its application because of its cost. According to the CHED Memo 37 and 46 series of 2012, an engineering graduate must be “able to design and conduct experiments, as well as analyze and interpret data;” making this project very timely for OBE [5] [6].

This study dealt with the development of a low cost version of a microprocessor/microcontroller training module and manual to be utilized in microprocessor system laboratory course making it readily available for students.

Foreign manufacturers of microprocessor and microcontroller training modules costs about 50 to 150 thousand Pesos for a single module which consists of both software and the hardware parts.

METHODOLOGY

The system development method was used in the construction of the low-cost microprocessor/microcontroller training module. The following steps were used:

1. Identification of Parts and Components

   Microprocessors acts as the brain of any complex electronic system that utilizes inputs, processes and outputs.

   The common output devices for a microprocessor and microcontroller are Light Emitting Diodes (LEDs) which are used to indicate the state of the output. It may be placed in an array or a matrix to indicate other information such as alphanumeric and special characters.

   Liquid Crystal Display (LCD) is also widely used for applications to indicate a more comprehensive output display.

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The Seven Segment Display is used to indicate digital characters (mostly numeric characters) which may be found in digital clocks, numbering systems for queue, scores, etc. Motors are also known outputs such as loading mechanism on printers and copiers, robotics, disc drives, etc.

Sounders like buzzers are output for audible signals.

The inputs used in this modules are switches; single pole-single throw, tactile switch and a keypad.

Variable resistances; light dependent resistor (LDR), 5k ohms and 10k ohms potentiometer.

The piezo (buzzer) component is also used as an input device for some applications that detect sound and surface vibrations.

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Sensors are also input devices; ultrasonic sonar, Passive Infrared (PIR) motion sensor and temperature sensor are the most commonly used sensors by microcontrollers.

Discrete components such as 74LS166, an 8 bit shift register is used to multiply the output of the microcontroller while the L293D is a motor driver IC.

2. Prototyping

a. Layout and Modularization of Parts

The project employed the plug-and-play and DIY (do it yourself) features of electronic devices that

isolated the different parts of the Training Module making it versatile. Locally manufactured circuit modules like E-Gizmo and DEECO Electronics are the suppliers of these parts and modules. In case of a part/component failure, the students can easily replace them.

b. Design of Supporting Circuitry

Support circuitry which includes input and output modules were also designed to be modular and isolated with each other to facilitate ease in troubleshooting and circuit protection. Replacement of damaged parts is possible.

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2. Product Development

a. Final Design

After multiple versions of the design, the final layout of the basic and advanced training kits were placed together. User friendly to facilitate learning and promote electronics and computer engineering principles.

b. Packaging

The training modules were placed on a plastic carrying case that may be used inside a laboratory room, a class room or even at the comforts of their own home.

The plastic case will not cause short circuit and is rugged enough to handle all the components safely inside.

4. Technology Transfer

The students enrolled in the Microprocessor System class will be the beneficiaries of this project. The instructor/professor will only be a facilitator during laboratory activities.

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RESULTS AND DISCUSSIONS

After the procurement of the needed materials, the researcher was able to make the following layout for the basic training kit.

Actual Layout of the Basic Training Kit

Figure 1. Basic Training Kit

Figure 1 is the actual layout of the Basic Training Kit which is composed of nine modules namely:

Module A – Microprocessor/Microcontroller

The Gizduino is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 6 analog pins, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP

header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

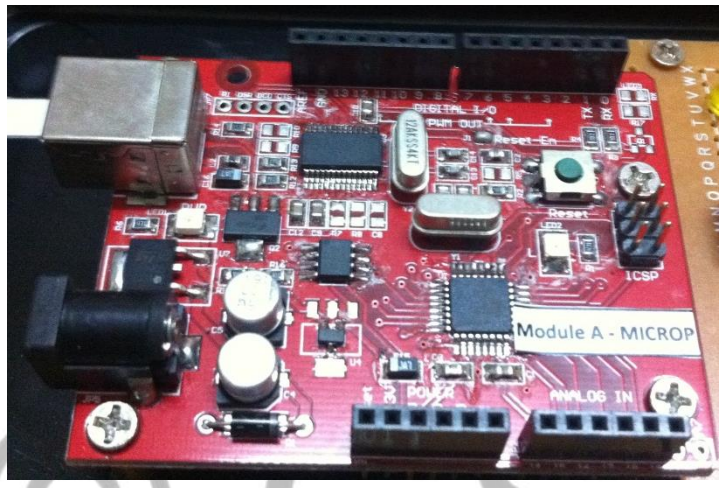

Figure 2. Module A - MICROP

Module B – LED Array

The LED array is composed of two sets of eight yellow diffused LED placed on a straight line. Four sets of three colored diffused and bright LEDs to mimic traffic lights (Green-Yellow-Red), RGB (Red-Green-Blue) color combination, White-Blue-White, and Red-Yellow-Red.

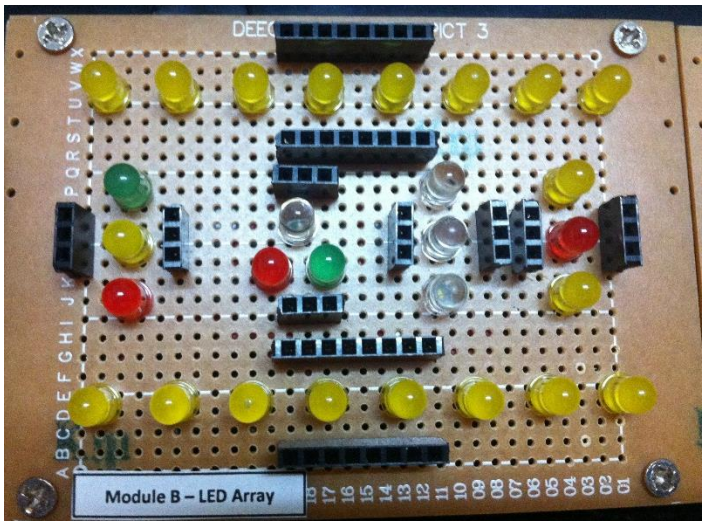

Figure 3. Module B - LED Array Module

Module C – LCD Module

The Liquid Crystal Display used was a 2x16 backlit commonly used in microprocessor embedded systems. It can display up to 32 characters in one frame.

Figure 4. Module C - LCD Module

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Module D – Keypad

The keypad is the most common input device for microprocessor based application. Numbers may be assigned with different functions depending on the program.

Figure 6. Module D - Keypad Module

Module E – LED Matrix

This LED matrix is a basic piece on electronic message displays, bus trip signage, electronic billboards and similar applications. Each circle may be treated as a pixel in an alphanumeric character or symbol. It may be cascaded and stacked to form larger rectangular displays.

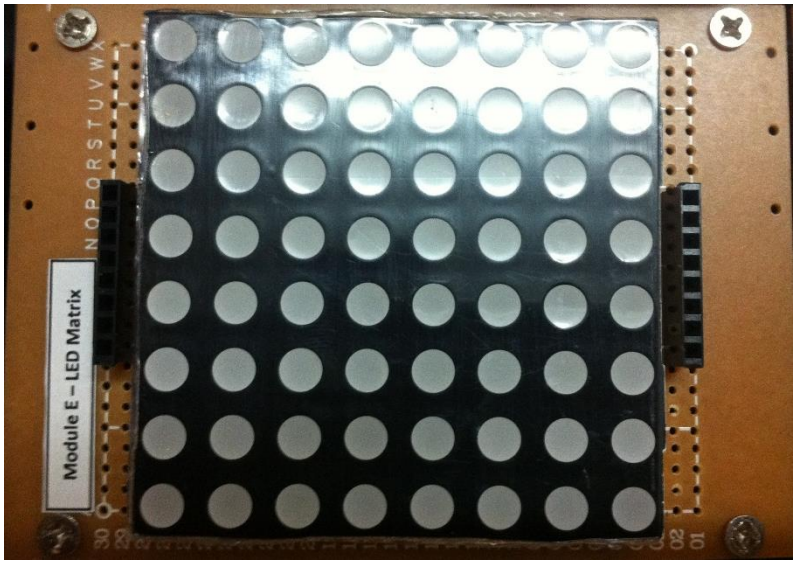

Figure 7. Module E - LED Matrix

Module F – Digital

This module contains eight parallel switches, two pieces of 74LS166, 8 bit shift register used for multiplexing output signals, and two seven segment displays, common cathode so an inverter will no longer be needed, for digital displays.

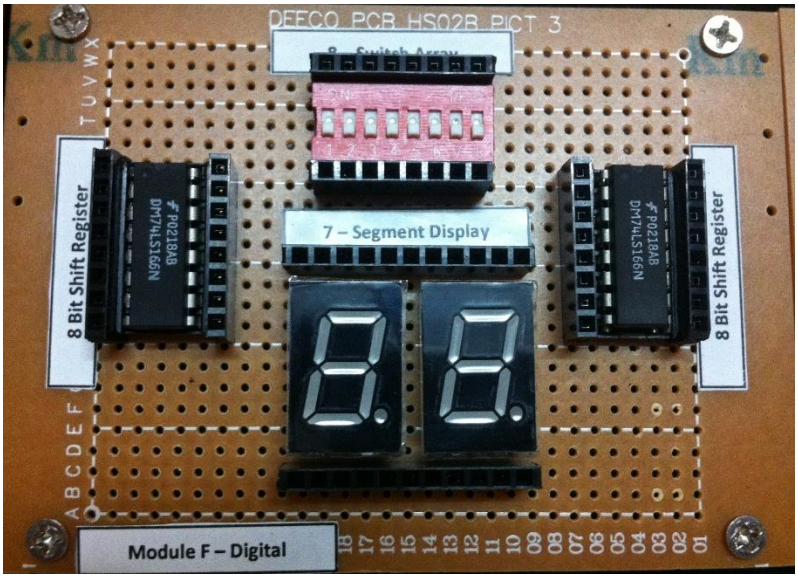

Figure 8. Module F - Digital

Module G – Sensors

This module contains two tactile switches, four pins, an ultrasonic sensor which detects objects up to three and a half meters using sonar technology, a passive infrared (PIR) sensor which can detect movement up to seven meters, the light dependent resistor (LDR) is used as a sensor for changes in light intensity, while the temperature sensor is used for converting heat into analog electrical output. The motor driver IC (L293D) is also placed in this module for close proximity with the motors module.

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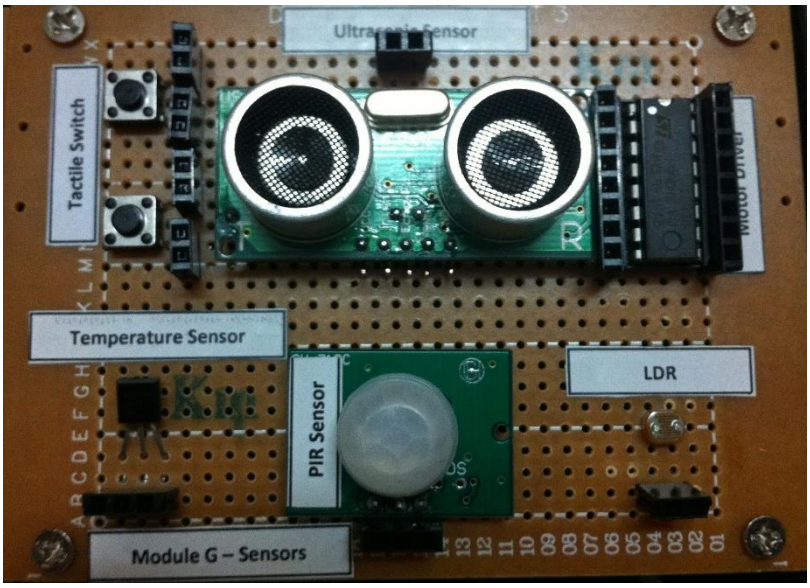

Figure 9. Module G - Sensor Module

Module H – Variable Resistance

Composed of two 10k ohms and 5k ohms potentiometers for various current control application and voltage limiting and dividing circuits.

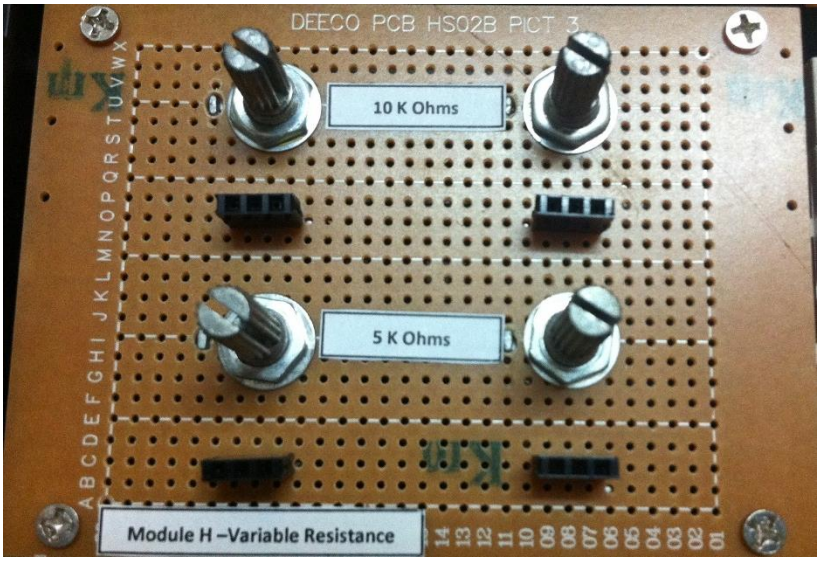

Figure 10. Module H - Variable Resistance

Three types of motors namely; DC motor, servo motor and stepper motor were included on this module. They are also called actuators that are often used on mechanical and applications that requires movement.

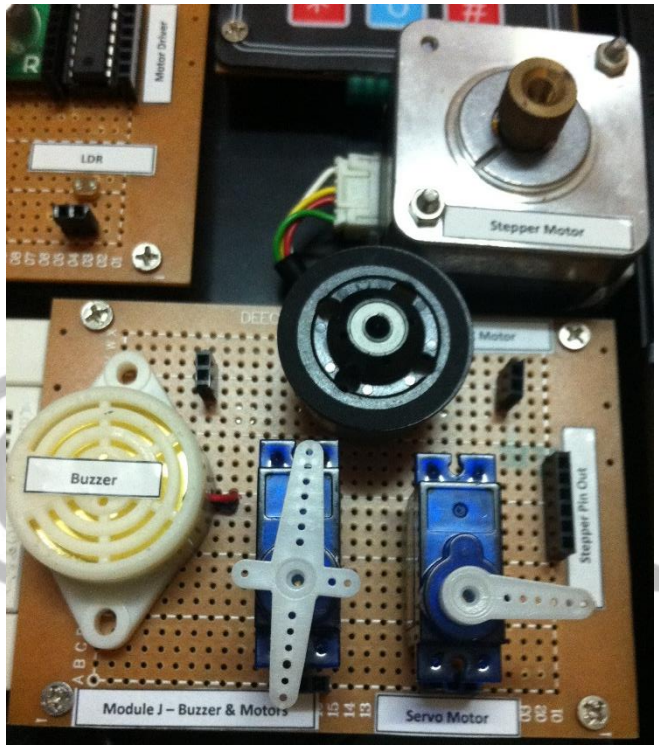

Figure 11. Module J - Buzzer & Motors

Actual Layout of the Advanced Module

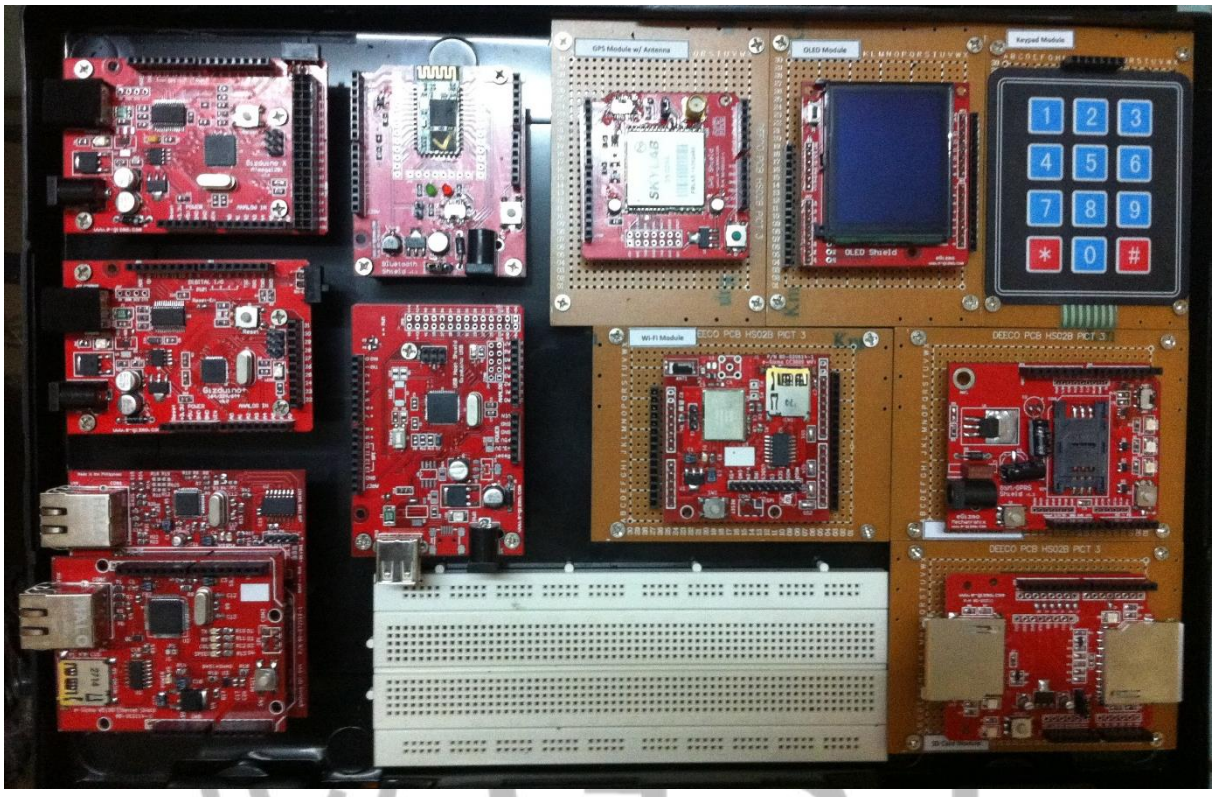

Figure 12. Advanced Training Kit

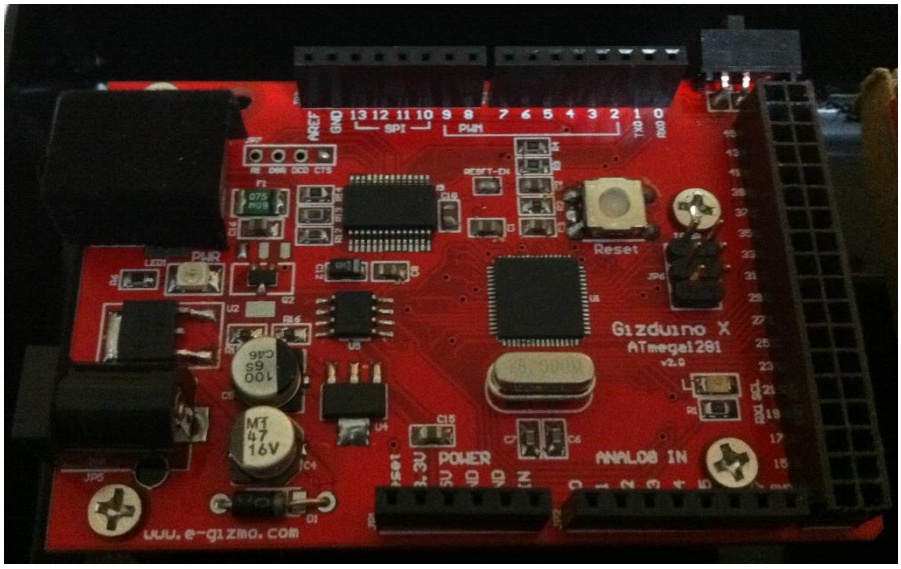

Figure 13. Gizduino X

Gizduino X

It is based on the ATmega1281 MCU, a family member of the ATMEGA1280 used in Arduino Mega Board. It offers 54 I/Os, one hardware SPI, two hardware UART and memory: 128K flash, 8K SRAM and 4K EEPROM.

Gizduino + 644

An upgrade of the Gizduino v4.0. Handles more I/Os compared to Gizduino v4.0.

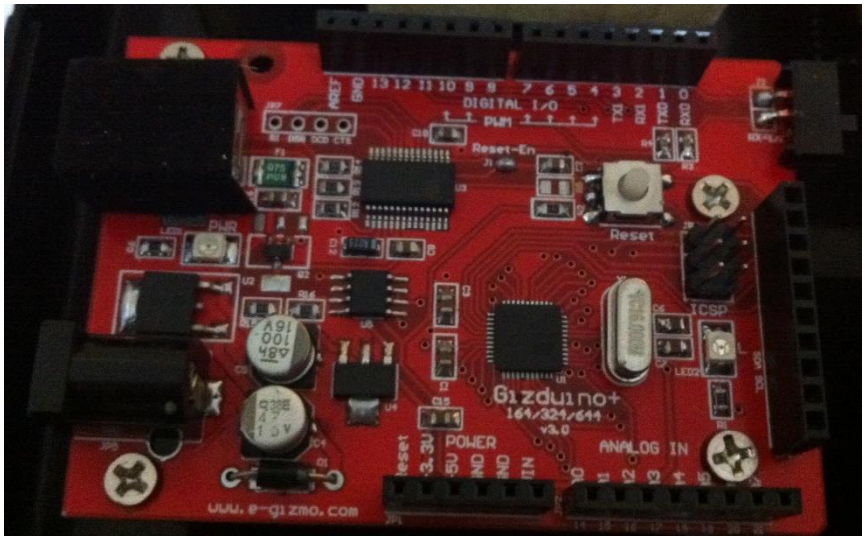

Figure 14 – Gizduino +

W5100 Ethernet Shield

Based on the Wiznet W5100 Ethernet chip and can intercommunicate with both the W5100 & Micro-SD card using SPI (ICSP header). Easy to connect on the Ethernet using RJ-45 standard connection, just provides a network local address.

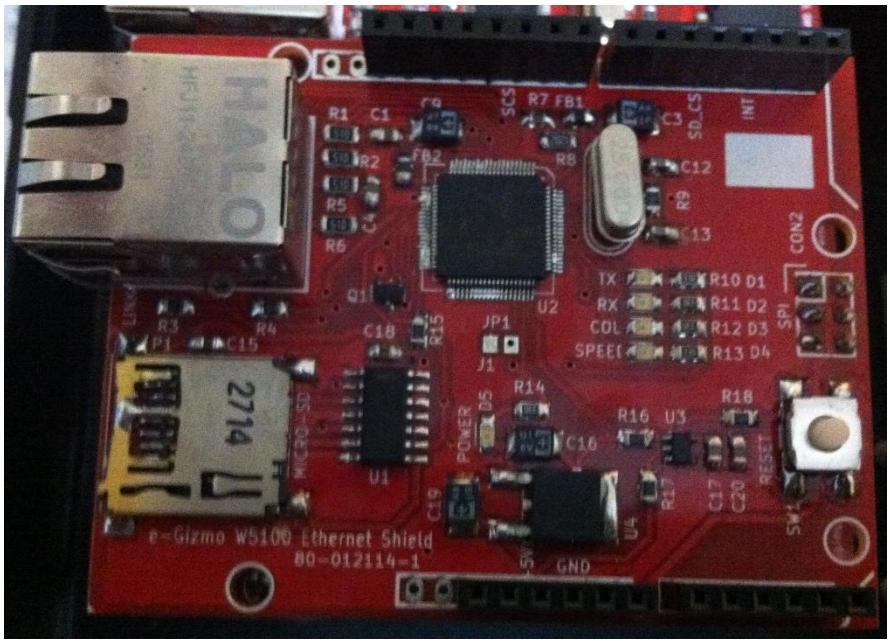

Figure 16 – W5100 Ethernet Shield

Bluetooth Shield

Class 2 Bluetooth shield with SPP profile functioning as UART port wireless cable replacement.

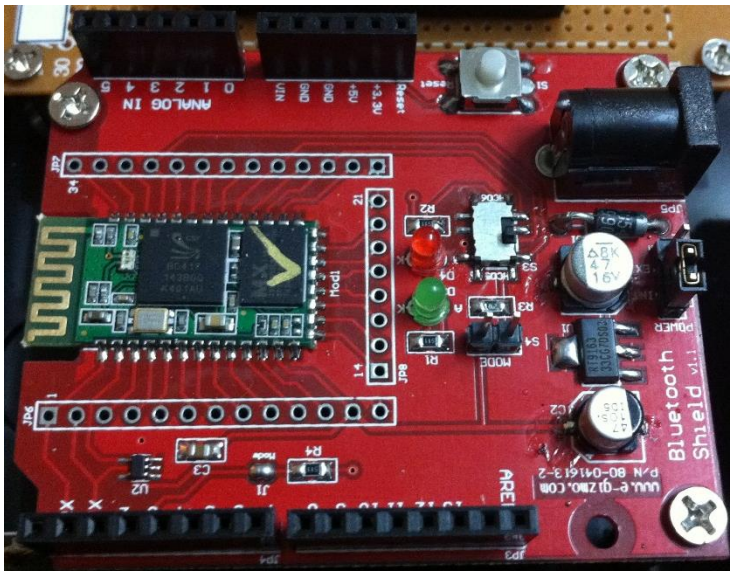

Figure 17 – Bluetooth Shield

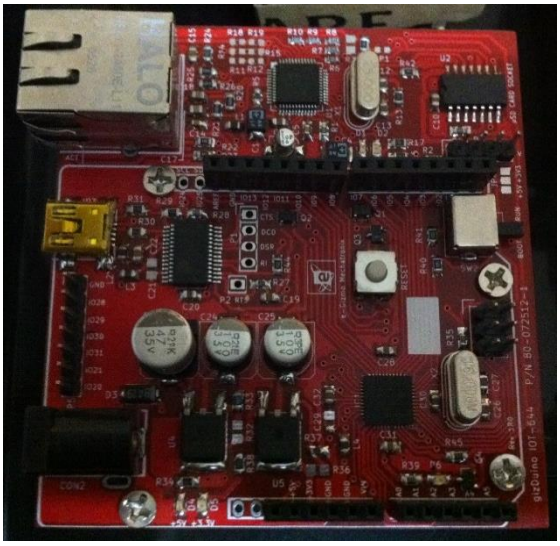

Figure 18 – Internet Of Things Shield

USB Host Shield

Is used for interfacing the USB devices such as an optical mouse or a flash drive. The shield can also be used as an input/output expander with its extension pins. USB data are sent/received via Serial communications. It is based on the AT90USB1287 that can also be used in development boards for USB AVR microcontrollers.

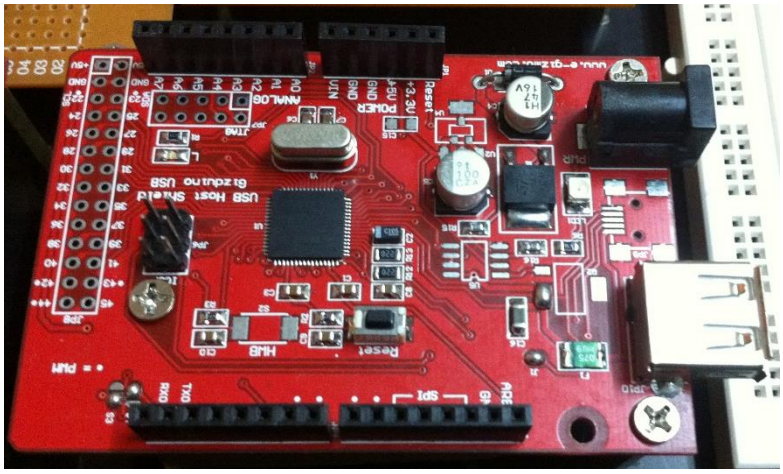

Figure 19 – USB Host Shield

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GPS Module (Shield)

This module has buffered UART serial I/O that allows it to be interfaced with any host MCU operating within 3V to 5V range. Full I/O interface functions are available through a 2x7 header connector.

Figure 20 – GPS Module

OLED Shield

The Organic Light Emitting Device (OLED) Shield is a two inch diagonal, 128x160 pixels graphic display. The shield is usually paired with an SD Card shield for image display. It includes brightness, contrast and color adjustments. One can make a DIY cellular phone using this shield and many more applications.

Figure 21 – OLED Shield

GSM/GPRS Module (Shield)

This shield is capable of sending and receiving SMS, make and receive calls, and data connection via GPRS. It contains a standard SIM slot.

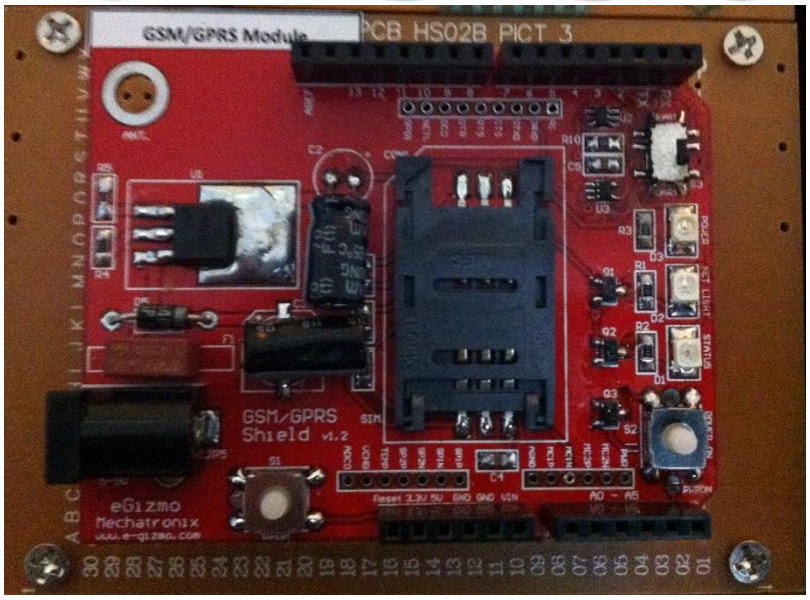

Figure 22 – GSM/GPRS Shield

SD/MMC Card Shield

gizDuino compatible card shield for SD/MMC card read and write applications. Two card sockets allows user applications to work on two SD/MMC at a time. Uncommitted I/O pin gives user the freedom to assign I/O to his/her requirements.

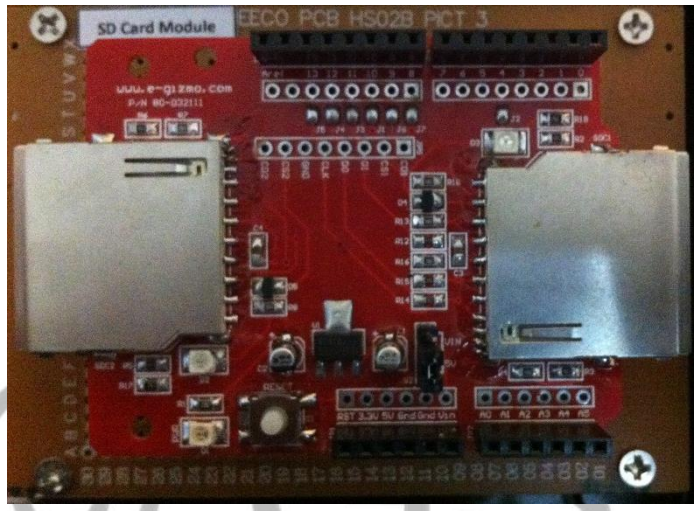

Figure 23 – SD/MMC Card Shield

Bill of Materials

Table 1 – Basic Training Kit

Part/Component	Description	Quantity	Unit Price	Amount
Gizduino v4.0	ATmega328	1	662	662
LED	Blue	2	22.50	45
	White	2	20	40
	Red	3	2	6
	Green	2	2	4
	Yellow	19	2	38
LCD	2x16	1	350	350
Keypad	4x3	1	137	137
LED Matrix	8x8	1	139	139
Parallel Switches	8 pcs	1	15	15
74LS166	8 Bit Shift Register	2	24.50	49
7 Segment	Common Cathode	2	31.25	62.5
Tactile Switch	Medium, 4 pins	2	2.50	5
Ultrasonic Sensor		1	325	325
PIR Sensor		1	378	378
LM35	Temp. Sensor	1	84	84
LDR	Light Dependent Resistor	1	12	12
L293D	Motor Driver	1	121	121
Stepper Motor		1	220	220
Buzzer	3-24 V	1	45	45
DC Motor	12 V	1	100	100
Servo Motor	Small	2	175	350
Bread Board		1	140	140
Variable	10k Ohms	2	15	30
Resistance	5k Ohms	2	10	20
Casing	Large	1	107.25	107.25
	Small	1	37.75	37.75
PCB	3x4	8	25	200
Screw	3x10	36	2	72
	3x6	38	2	76
Brass Stud Spacers	3x13	34	3.50	119
	3x25	4	6	24
Female Socket Headers	1x40 pins	20	38	760
Connecting Wires	Male-to-male	40	5	200
	Male-to-female	5	5	25
USB Cable	A to B	1	125	125
			TOTAL	**5,024.50**

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Table 2 – Advanced Training Kit

Part/Component	Description	Quantity	Unit Price	Amount
GizduinoX	ATmega1281	1	1090	1090
Gizduino+	ATmega644	1	760	45
gizDuino IOT	Internet Of Things	1	1350	1350
Ethernet Shield	Board Type	1	980	980
Bluetooth Shield	Board Type	1	935	935
Keypad	4x3	1	137	137
USB Host Shield	Board Type	1	750	750
GPS Shield	Board Type	1	1385	1385
OLED Shield	Board Type	1	675	675
Wi-Fi and Shield	Board Type	1	1990	1990
GSM/GPRS Shield	Board Type	1	1995	1995
SD Card Shield	Board Type	1	395	395
Breadboard		1	140	140
Case	Large	1	107.25	107.25
	Small	1	37.75	37.75
Brass Stud Spacers	3x25	19	6	114
	3x13	24	3.5	84
Screw	3x10	42	2	84
	3x6	42	2	82
Connecting Wires	Male-to-male	40	5	200
	Male-to-female	5	5	25
USB Cable	A to B	1	125	125
Female Socket Header	1x40 pins	25	38	950
			TOTAL	**14,066**

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As seen in tables 1 and 2, the total cost of the basic training kit and advanced training kit are far cheaper than training modules available in the market. In addition, all parts are locally available in case of fault, damage, component failure and upgrades. The students themselves may replace them whenever necessary.

USE Questionnaire: Usefulness, Satisfaction, Ease of Use and Cost

The students evaluated the microprocessor/microcontroller training module based on the following:

Table 1 – Usefulness

USEFULNESS	Evaluation Result Mean	Interpretation
1. It helps me be more effective in our laboratory course.	3.64	Strongly Agree
2. It helps me be more productive in our laboratory course.	3.63	Strongly Agree
3. It is useful.	3.73	Strongly Agree
4. It gives me control over the activities in my laboratory.	3.53	Strongly Agree
5. It makes the laboratory exercises/experiments I want to accomplish easier to get done	3.61	Strongly Agree
6. It saves me time when I use it during our laboratory course.	3.48	Strongly Agree
7. It meet my needs in our laboratory course.	3.60	Strongly Agree
8. It does everything I would expect it to do.	3.41	Strongly Agree
9. It has advantage over our traditional laboratory materials.	3.62	Strongly Agree
10. It is practical to use in our laboratory course.	3.67	Strongly Agree
OVERALL	**3.59**	**Strongly Agree**

Table 1 indicated that the students strongly agreed that the low cost microprocessor/microcontroller is a useful laboratory equipment.

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TABLE 2 – Ease of Use

EASE OF USE	Evaluation Result	Interpretation
1. It is easy to use.	3.41	Strongly Agree
2. It is simple to use.	3.39	Strongly Agree
3. It is user friendly.	3.38	Strongly Agree
4. It requires the fewest steps possible to accomplish what I want to do with it.	3.33	Strongly Agree
5. It is flexible.	3.31	Strongly Agree
6. Using it is effortless.	3.02	Agree
7. I can use it without written instructions.	2.91	Agree
8. I don't notice any inconsistencies as I use it.	3.20	Agree
9. I can recover from mistakes quickly and easily.	3.41	Strongly Agree
10. I can use it successfully every time.	3.26	Strongly Agree
OVERALL	**3.26**	**Strongly Agree**

Table 2 indicates that the modules are easy to use. Although a need for written instructions/manual of utilization may be added to guide the students during their first use.

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TABLE 3 – Ease of Learning

EASE OF LEARNING	Evaluation Result	Interpretation
1. I learned to use it quickly.	3.23	Agree
2. I easily remember how to use it.	3.33	Strongly Agree
3. I was able to create my own tests and experiments on devices that are electronic in nature.	3.38	Strongly Agree
4. I quickly became skillful with it.	3.11	Agree
5. I was able to run laboratory exercises precisely.	3.31	Strongly Agree
6. I was able to do laboratory experiments with the required input and output.	3.47	Strongly Agree
7. I was able to smoothly use the modules on one laboratory topic after the other.	3.36	Strongly Agree
8. I was able to understand the use of each module for a particular exercise/experiment.	3.47	Strongly Agree
9. It is easy to master the procedures.	3.28	Strongly Agree
10. I was able to repeatedly use the modules and apply the theories and concepts of microprocessor/ microcontroller system in laboratory experiments.	3.38	Strongly Agree
OVERALL	**3.33**	**Strongly Agree**

Table 3 also showed that the students easily learned how to utilize the modules.

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TABLE 4 - Satisfaction

SATISFACTION	Evaluation Result	Interpretation
1. I am satisfied with it.	3.45	Strongly Agree
2. I would recommend it to another student enrolled in a microprocessor/microcontroller course.	3.56	Strongly Agree
3. It is enjoyable to use.	3.48	Strongly Agree
4. It works the way I want it to work.	3.44	Strongly Agree
5. I can rely on the modules in running experiments and tests.	3.38	Strongly Agree
6. I feel I need to have it during laboratory exercises and experiments.	3.55	Strongly Agree
7. It is pleasant to use.	3.44	Strongly Agree
8. The training module is comfortable to use.	3.38	Strongly Agree
9. I was able to appreciate the concepts of microprocessor/ microcontroller system by using the module.	3.48	Strongly Agree
10. It is rugged and parts for replacement are available.	3.26	Strongly Agree
OVERALL	**3.44**	**Strongly Agree**

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Table 4 indicates that users (students) were satisfied with the use of the microprocessor system trainers.

The last part of the evaluation instrument gathered the following comments from the users:

- The addition of a Power Supply Circuit.
- Additional connecting wires and programmable ICs
- Additional power supply will help the students
- The case should be more rugged to make the input and output pins separate. To have centralized power supply

- Always update the module every time there's new materials.
- I think there's no need of any addition on this module, because almost all you need is here, easy to use, and hand carry.
- I want to put wires, LCD etc., Organizer on the training module so it will be easy for us to build the circuit that we need in a much more organized way.
- I suggest to attach a small holder for the breadboard wires to the training module.
- Make it more comfortable to use the module.
- Batteries
- Produce more modules
- Implement as early as possible.
- Provide manuals
- Labels for the power supply, ground, inputs, etc.
- Nothing to add just produce more for student's use.
- Make sure that all components are in perfect working conditions if possible add modules for the latest technologies, such as RFID tags & receivers, NFC tags & receivers, etc.
- Nothing, it has everything needed in the laboratory.

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CONCLUSION

In this paper, the researcher was able to develop three low cost basic and two advanced microprocessor/microcontroller training kits with laboratory manuals designed for outcomes based education.

The more advanced the technology, the costly it gets. One of the common problems encountered by students in using imported laboratory training modules is the unavailability of parts and components from the local market making it impossible for some activities and experiments to be realized. This problems were addressed by the development of these training kits because all of the parts and components used are locally available at competitive prices. The serviceability and replacement of parts and components due to damage or upgrades also one of the features of the developed training kits.

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