The Development of Microcontroller-based Lawn Mower

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***Abstract*— This paper present the prototype design of microcontroller-based lawn mower that can function without manual handling. The conventional lawn mower needs to be push manually in order for the machine to move and it needs more energy time to handle it. The problems encountered in the conventional lawn mower can be solved by the existence of this microcontroller based lawn mower. The PIC microcontroller act as 'the brain' for this machine where it was burned with the programme and the output are controlled based on the programme that has been designed. A battery is used as a power source in order to avoid the usage of fossil fuels and later decrease the air pollution. An electronic motor that is used to move the lawn mower will not produce a loud noise to the surrounding. Each obstacle that is detected in front of the lawn mower will be sense by an analog distance sensor. Any obstacle that is detected will cause this lawn mower stopped and turn in the other direction. However, this lawn mower will continue to move forward if no obstruction is detected. The microcontroller-based lawn mower can be utilized in a golf course, garden, football field and so on. This lawn mower offers many benefits compared with the conventional one in which it is lighter and smaller, less supervision, less air pollution and safer.**

***Index Term*— Domestic robot, Lawn mower, Microcontroller, Service robot.**

I. Introduction

NOWADAYS people used to cut the grass by using manual handling. Few problems might occur during the usage of this machine. From observations, a conventional lawn mower needs to be push in order for the machine to move. Due to the manual handling, one requires a lot of energy to move the machine and time will be wasted. The development of advanced lawn mower begin when the people are aspire to replace the conventional method of cutting the grass that need more energy to perform the task. The evolution is started by creating a tool like sickle to perform the grass cutting task. Then, the tool was evolved towards the machine that used diesel and petrol technology which are the Back-pack Type, the Pull and Push Type, and the Driver Type.

Mowing the lawn by using any conventional lawn mower is inconvenience and most of people does not takes pleasure doing it. The activity also cannot be accomplished simply by any elderly, younger or disabled people. This is due to the facts that mowing the lawn will cause the user to feel tired, bored and uncomfortable to handle the machine. The conventional lawn mower that uses motor powered will create noise and air pollution due to the loud engine and smokes that were produced from the combustion in the engine. The motor powered engine requires periodic maintenance whereby users need to change the engine fuel when it is needed. Thus, diesel and petrol are still been used as a primary source of energy for the conventional lawn mower.

So, this paper presents a project that is based on the problems encountered by a conventional lawn mower. A prototype of microcontroller-based lawn mower was designed and developed to solve the problems. This prototype is cost efficient, safe and efficient to use and environmentally friendly. Its use is also expected to save significantly on labour costs. The prototype will be automatically handled and run by using a charged battery with no cords during its operation. The usage of fuel is not required to power up the prototype whereby it was replaced by a battery charger to perform the task. Therefore, this new technology of lawn mower can be considered safe to both human and earth. The comparison between conventional lawn mower and microcontroller-based lawn mower are shown as in Table 2.

TABLE II
THE COMPARISON BETWEEN CONVENTIONAL LAWN MOWER AND MICROCONTROLLER-BASED LAWN MOWER

SYSTEM CRITERIA	CONVENTIONAL LAWN MOWER	MICRO-CONTROLLER BASED LAWN MOWER
INITIAL COST	MEDIUM	MEDIUM
MAINTENANCE COST	HIGH	LOW
SAFETY ASPECT	LOW	HIGH
MANPOWER	YES	NO
SUPERVISION/ CONTROL	HIGH	LESS
PROCESSING TIME	MEDIUM	SHORT

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II. System's Categorized

The Microcontroller-based lawn mower can be categorized as a robot because the systems itself activates or is executed under programmed or specified conditions and performs specified functions automatically. This is mentioned in which Robot is a computer controlled machine that is programmed to move, manipulate objects, and accomplish work while interacting with its environment [3]. The prototype also could be categorized as a domestic robot because it is a small robot that can perform task at home. Domestic robots are electronic robotic devices that are designed to manage various types of tasks around the house. Some of these devices are focusing on functions such as house cleaning while others are designed to operate the kitchen appliances. Domestic robot such as for vacuuming and lawn mowing are mobile units that use autonomous mobile robotics technology [2]. Fig. 1 below shows types of robot that are available whereby the domestic robot is categorized under service robots.

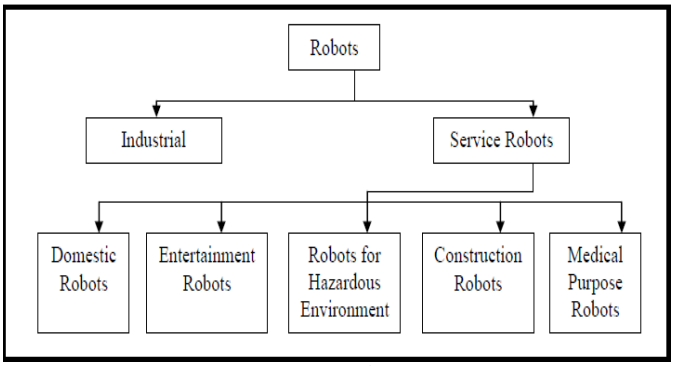

Fig. 1. Types of Robots

III. Hardware Development

The system is divided into three main parts which are: input, process and output. The input part that contains the infrared sensor will detect any object in front of the lawn mower and later the sensor will send signal to the PIC microcontroller to move the output. Meanwhile, the process part contains the PIC 16F877A microcontroller that act as the brain for the system. The output will be function based on the program install in the PIC microcontroller. The output of the system is composed of a Direct Current (DC) motor in which the motor is the cause of the mower to moves in forwards reverse direction and also functioning as the blade's motor. The Light Emitting Diodes (LEDs) that were mounted on the mower will indicate green light if the sensor does not detect any object while the orange LED will light up if the sensor detects any object at the front. The detection of object by infrared sensor in the mower will cause the mower to turn around in order to avoid any collision (orange LED turn on, green LED turn off). Else, if the sensor does not detect any object, the mower will move forward and start to mower the lawn (orange LED turn off, green LED turn on). The system will continuously function as disclosed until the lawn is completely in pieces. The block diagram and the complete circuit diagram of the microcontroller-based lawn mower are shown as in Fig. 2 and 3 respectively.

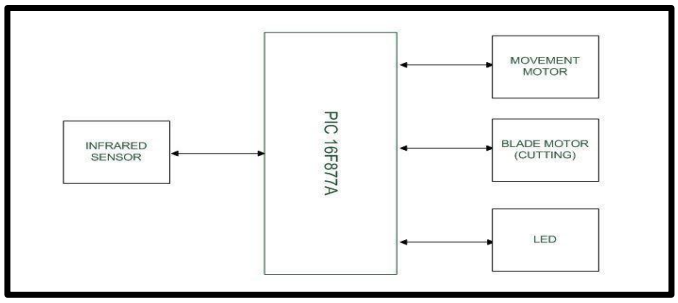

Fig. 2. The block diagram of microcontroller-based lawn mower

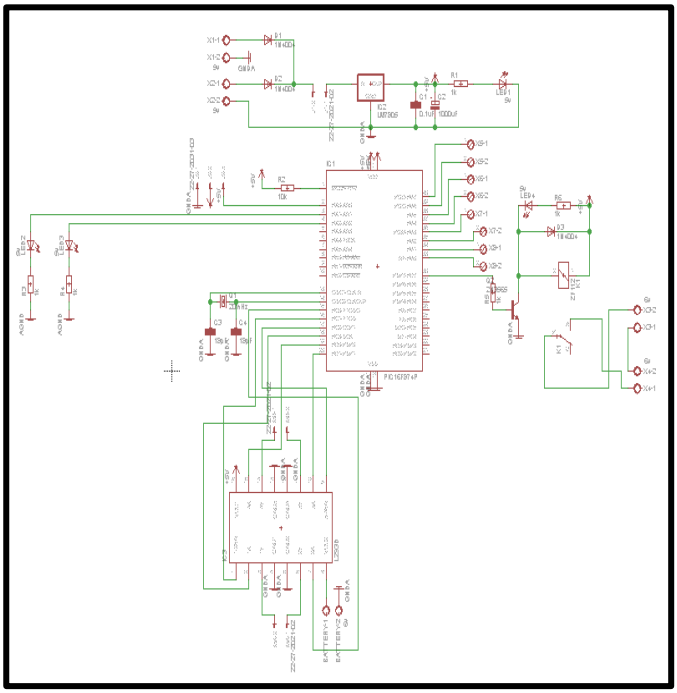

Fig. 3. The circuit diagram of microcontroller-based lawn mower

A. PIC 16F877 Microcontroller

The PIC16F877 microcontroller is used to control the whole system. A voltage of 5.0V DC is used to power up the mower's PIC. It is a DIP layout (dual in line package) with 40 pins but only 32 I/O pins can be set as digital input or digital output. The digital output of the PIC is 5V (for signal 1) and 0V (for signal 0) in which these signals will be directly connected to actuators for control purpose. The PIC will detect the input voltage 5V as signal 1 and 0V as signal 0 when the PIC pin is set as digital input. Any voltage that is less than 0V or more than 5V will cause the PIC to be damaged [5].

B. Voltage Regulator Module

The PIC and other connected sensors/actuators could be protected from overvoltage by the usage of voltage regulator module. Since the PIC and all other connected sensors/actuators could only support 5V DC, the overvoltage could cause the regulator to burn. The LM7805

could be used in order to regulate the system's voltage and the output voltage. The input voltage from 7V DC to 18V DC will be supported by the LM7805. The voltage regulator have 3 terminals which are input, ground and output. Fig. 4 shows the voltage regulator circuit for the improvised lawn mower. A diode is connected at the input of the LM7805 to avoid the voltage to be in reverse direction. An on/off switch is used to turn the system either on or off. The generated 5V from LM7805 will be filtered by the capacitors as in Fig. 4. The LED is used to indicate whether the system is turn on or off and it is connected through 1kΩ resistor to ensure the current that pass through the LED is 5mA.

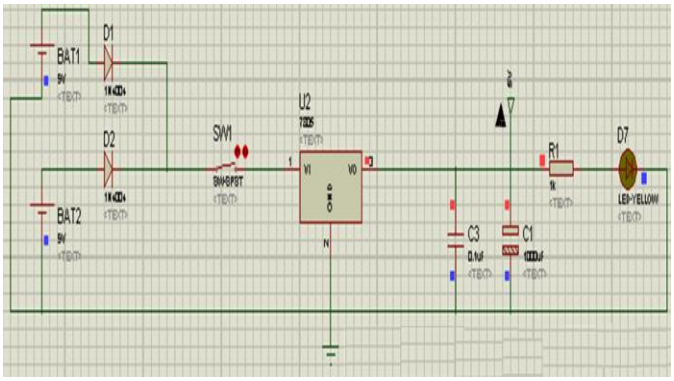

Fig. 4. Voltage Regulator circuit

C. Analog Infrared Proximity Sensor

The GP2D12 is an analog infrared proximity sensor. It can be used to detect objects or obstacles. This sensor has a LED that emits infrared light. Infrared light has an interesting property that it can bounces back on obstacles. On the front of the sensor, there is a photodiode that is sensible to infrared light. The sensor will vary the output voltage based on the amount of infrared light that bounces back to the sensor. Therefore, the more infrared light capture by the sensor, the closer is the object and the higher the output voltage generated by the photodiode. If the voltage output is connected to the microcontroller with analog to digital conversion capability e.g PIC16F877 microcontroller, this voltage could be translated to a numerical value. This value could be used to determine either there are any obstacles close to the sensor and how far these obstacles can be. The sensor outputs is a non-linear analog voltage corresponding to the distance of the reflective object. The sensor can measure in the range from 10-80 cm. The voltage is approximately 2.4V at 10cm and at 0.52V at 60cm. The sensor will also draws about 34mA of current and the maximum current is stated to be 50mA.

D. Motor Drivers

A typical digital output of a motor can supply about 10 to 20 mA of current and a small permanent-magnet motor requires from 500mA to 4000mA of current. The DC motor type used for this lawn mower is 6V DC from Mabuchi manufacturing. Two similar types of motors will be used for the blade and to control the direction of the machine. The H-bridge circuit is required in order to drive the motors [6]. In this circuit, two of four transistors are selectively enabled to control current flow through a motor and later drives the motor to move in different direction. If transistor 1 and transistor 3 is enabled, the current will flow through the motor for forward direction. If the other pair is enabled; which is transistor 2 and transistor 4, the motor will move in reverse direction [10].

E. Integrated Circuit L293D

The integrated circuit (IC) of L293D is a dual H-bridge driver IC. The IC is also referred to as a push-pull four channel driver. Since H-bridge is an ideal circuit for driving motors, the L293D can provide two H-bridges for driving both motors on the robot base. The motor direction is controlled by the logic signals from the microcontroller. Two signals per motor are required to control the direction either in forward or reverse.

F. Double Gearbox Motor

The double gearbox motor is a compact unit with two independent motors and gear trains. The kit includes two motors with all gears and parts to build any of the four possible gear ratio configurations. Although it is not typical, it is possible to assemble each side with different gear ratios. There are two possible output axle locations whereby for any given gear ratio, only one output location is possible [9]. This type of gear is used in forward and reverse direction for the mower. Since this type of gear is provided with the DC motor, so it was connected to the IC L293D to ensure that the motor could move in both directions.

G. Relay

The output of each PIC pin is 5V with max output current of 20mA or 0V with 0mA output. The voltage is not enough to run the high power device e.g. motor, solenoid etc. Thus a relay is needed to control these high power items. A simple switching circuit using NPN transistor, C9013 will be used to energize/de-energize the input coil of the relay [7]. The relay output is single pole double throw (SPDT) and its coil can be energized using 5V and de-energized using 0V. Normally the relay output NC and COM will be connected. The output of NO and COM will be connected when the input coil of relay is energized. The switching can be used to control item which is less than 250Vac and 10A [1]. A reverse diode of 1N4007 is connected with the input of relay to avoid reverse spike or overcurrent to flow back from the load. The LED indicator was mounted to show the relay is on or off. The LED will be on when the relay start to function and vice versa [8].

IV. Software Development

The microcontroller-based lawn mower has been developed in C language by using PIC Controller and Complier Kits. The software was written in C language and debug in HEX file. The C language program must be loaded into the memory of PIC 16F877 microcontroller and later the PIC is installed by using PICKIT 2 burner device. The sequential process of

microcontroller-based lawn mower is shown in flow chart of Fig. 5. The lawn mower motor is in static condition when the system is active. This will happen until the motor inside the mower select whether a high or low condition. Then the pre-loaded program is executed and sensor will start to active. The corresponding wavelength of sensor detection will impact the strength of motor movement.

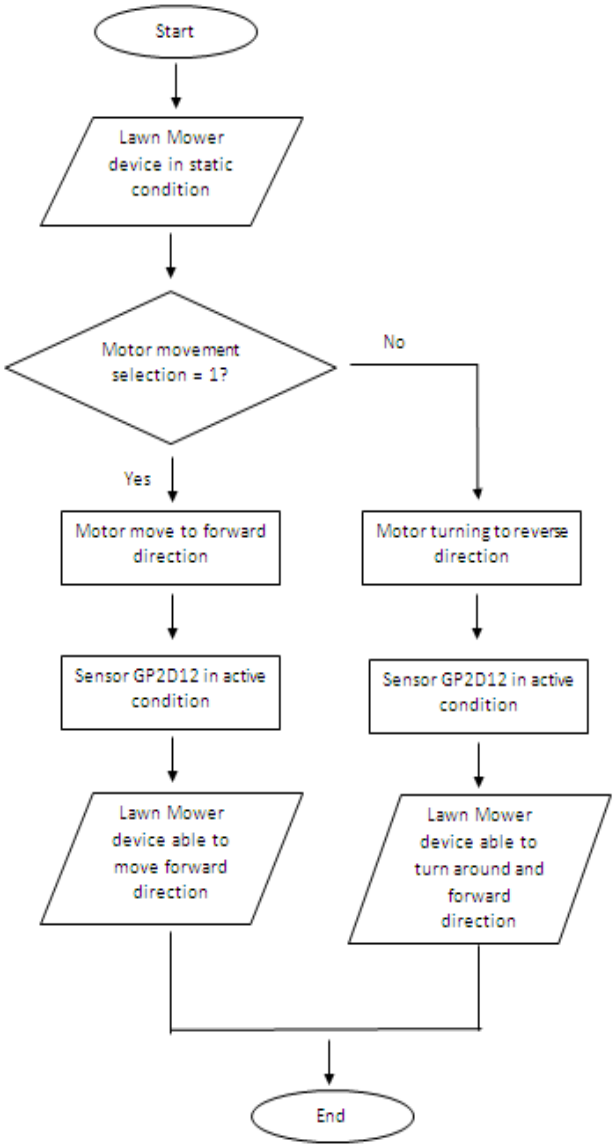

Fig. 5. The sequential process of microcontroller-based lawn mower

V. System's Limitation

Despite the benefits that are contribute by the microcontroller-based lawn mower, there are also limitations exist during the development of this prototype. This prototype uses a 9V disposable batteries as a power source. Users must replace the disposable batteries each time it runs out of energy. Moreover, this lawn mower prototype can only last until approximately 2 hours if it works without stopping. Another limitation is, the analog distance sensor that is used in this prototype can only detect an obstacle within 10-80 cm only. More than that, no obstacle will be detected due to the voltage to be obtained is smaller if the distance between the sensor and the obstacle is getting away. As for Tamiya geared motor, the motor operating voltage is 3V only. Therefore, this prototype has limitation on its strength to move forward, backward, turn left and turn right. Higher operating voltage is required so that the prototype is gaining more strength to move forward, backward, turn left and turn right.

VI. Testing and Results

The prototype of microcontroller-based lawn mower was tested and analysed based on several circuits that have been constructed. The circuit that have been tested were: voltage regulator circuit, driver motor circuit, sensor circuit and relay circuit. The descriptions for each of the tested circuits are mentioned as below:

A. Voltage Regulator Circuit

The voltage regulator circuit has a voltage regulator module that used to protect PIC and other connected sensors/actuators from over voltage. Fig. 6 below shows the voltage regulator circuit that will give 5V input supply to the electronics component such as IC, PIC and relay. A digital multimeter was used to check the output voltage of the circuit which is 5V in order to power the PIC. The output voltage produced from the regulator circuit is shown as in Fig. 7.

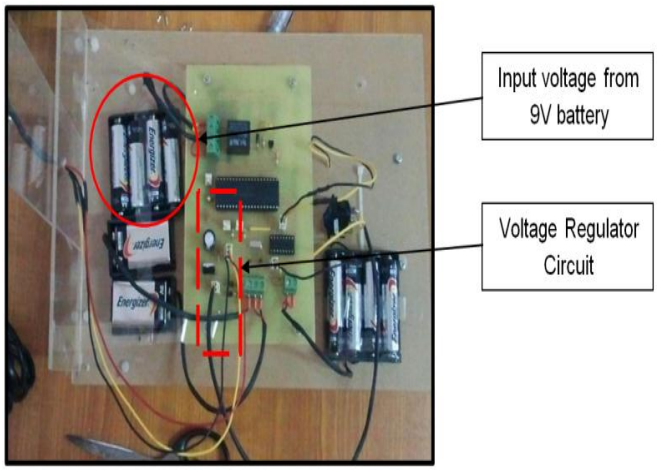

Fig. 6. The voltage regulator circuit

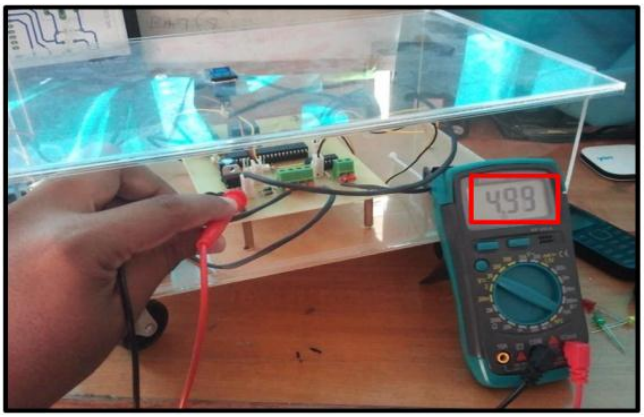

Fig. 7. The output voltage produced from the regulator circuit

B. Driver Motor Circuit

The LM293D has been used in this circuit to control the direction for two DC motors. It contains two H-Bridge that were functioning to drive both of the DC motors. Table 2 shows the sequences of the input digital when different direction of both motors were operated. The sequences later were verified by using simulation from Proteus software.

TABLE II
THE SEQUENCE OF THE INPUT DIGITAL WHEN DIFFERENT DIRECTION OF BOTH MOTORS WERE OPERATED

MOTOR MOTION	INPUT 1	INPUT 2
REVERSE	0	1
FORWARD	1	0
STOP	0	0

The simulation results of three different operations for input 1 and input 2 of driver motor were shown in Fig. 8, 9 and 10 respectively. All of the results verified that different input digital could affect the motor direction. The output waveform when the motor move in forward direction is shown in Fig. 8. It can be seen that the signal for input 1 is 1 while the signal of input 2 is 0. In this condition, signal 1 will cause the motor to move forward. By referring to Fig. 9, signal 1 is produced at input 2 while signal 0 is at input 1. So, it can be said that the signal will be inverted when the motor motion is in reverse condition and later causing the DC motor move in reverse direction. The output waveform during the motor movement is in reverse direction is shown as in Fig. 9. During the motor is in stop condition, there should be no signal will be sent to both of the inputs. This can be seen as in simulation result of Fig. 10 where the signals for input 1 and input 2 is 0 which means that no signal is sent to the driver and later cause the motor to stop. The waveform during the motor is in stop condition is shown in Fig. 10.

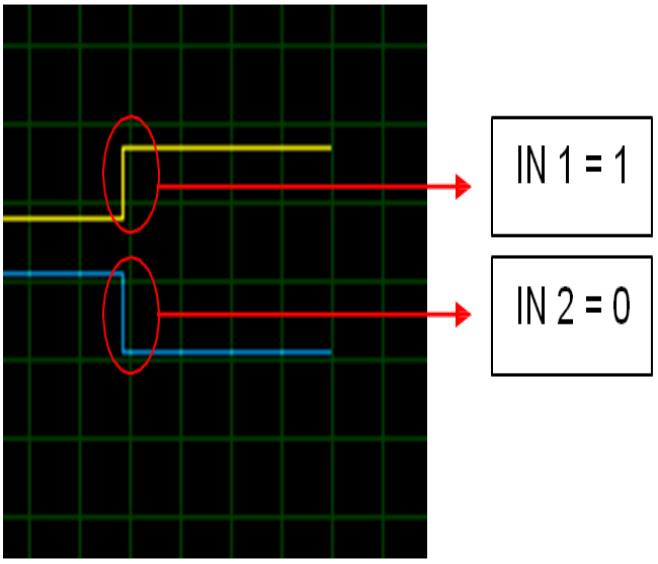

Fig. 8. The output waveform when the motor move in forward direction.

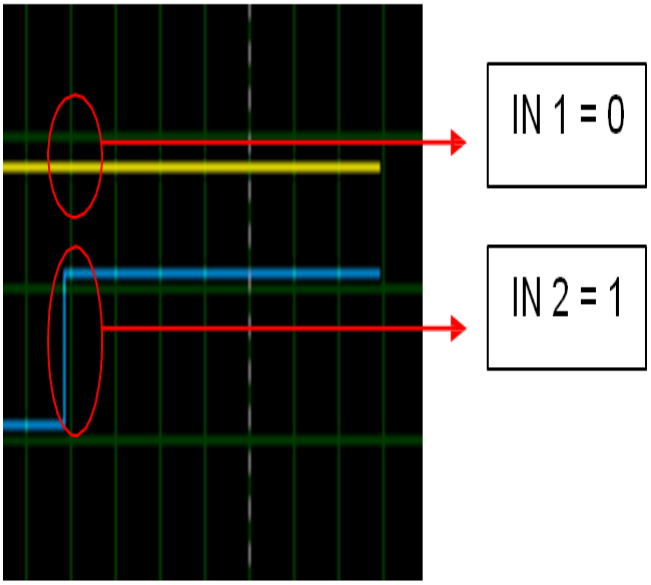

Fig. 9. The output waveform during the motor movement is in reverse direction

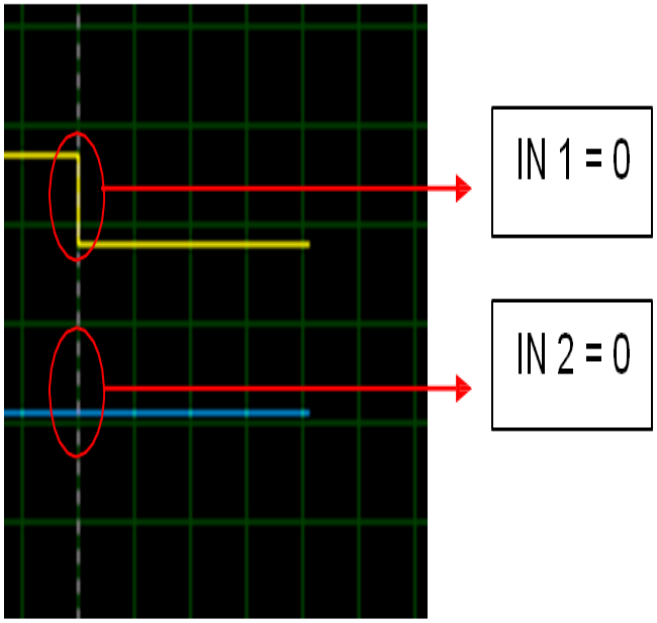

Fig. 10. The waveform during the motor is in stop condition

C. Sensor Circuit

An analog distance sensor has been used in the sensor circuit to detect an obstacle. Based on sensor characteristic shown in Fig. 12, the sensor outputs is a non-linear analog voltage corresponding to the distance of the reflective object. The sensor can measure in the range from 10-80 cm. The output voltage is approximately 2.4V at 10cm and 0.52V at 60cm. It can be analysed that more voltage will be produced if the sensor detects an object in a short distance while small voltage will be obtained during the detection of an object in a long distance. Fig. 11 shows the recorded distance during the detection of obstacle by the sensor.

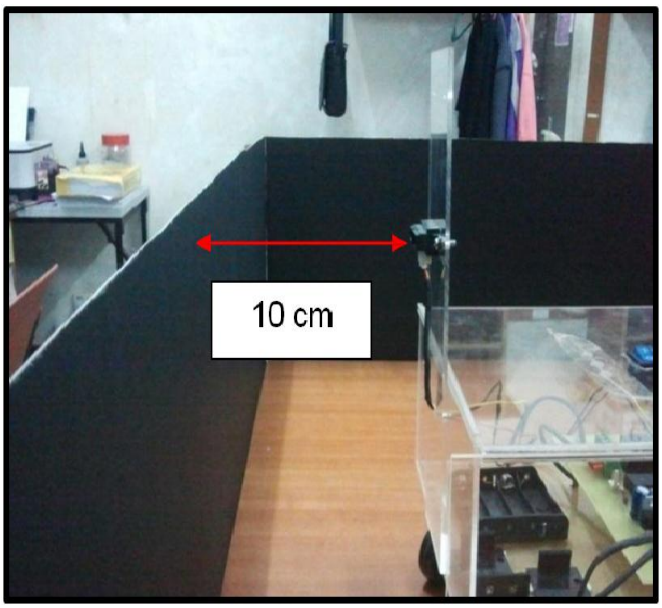

Fig. 11. the recorded distance during the detection of obstacle by the Sensor

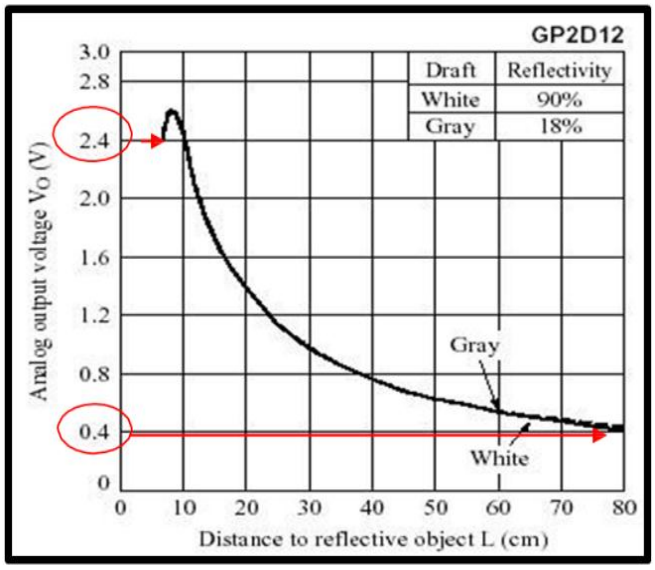

Fig. 12. Sensor characteristic [13]

D. Relay Circuit

A Relay is used in this circuit as a switching part for the blade's motor. The Relay will switch to normally open when the machine in reverse direction. The normally open relay will cause the blade's motor does not operate. The voltage for relay is 5VDC single pole type. In the relay circuit, the common leg will be connected to the 6V power source while the normally open leg is connected to the blade's motor. Fig. 13 shows the location of relay circuit. The LED in the circuit functioning as an indicator to the relay by showing the condition either the relay is open or close.

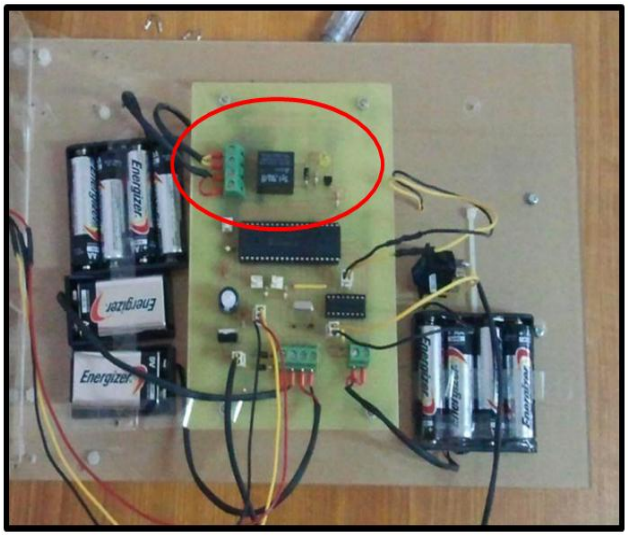

Fig. 13. Relay circuit

Similar concept has been used to control the motor blade operation by turning the relay to either normally close or open. The relay output is single pole double throw (SPDT) and its coil can be energized using 5V and de-energized using 0V. Normally the relay output of normally close (NC) and COM will be connected. The output of NO and COM will be connected when the input coil of relay is energized. The switching can be used to control item which is less than 250Vac and 10A [4].

VII. Conclusion

In conclusion, this paper presents the prototype design of microcontroller-based lawn mower that is small in size, automatically operated and less monitoring by humans. The operation of lawn mower will also not contribute to air pollution since it does not used petrol or diesel as an energy source. The lawn-mower could be used on the football field, garden, house landscaping and etc. The prototype of microcontroller-based lawn mower was developed by considering customer needs and also problems that occur in conventional lawn mower.

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