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Mapping device with wireless communication

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Mapping Device with Wireless Communication

Submitted to:

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Honors Thesis

Submitted by:

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University of Arkansas

College of Engineering

Department of Electrical Engineering

ABSTRACT

Wireless communication is one of the most powerful communication methods that people use nowadays. The key advantage of wireless communications is that it can cover large distances without having to run any cables from one end to the other. Based on this advantage, wireless communication has many important applications, such as remote controls, cell phones, and global positioning system (GPS).

This senior design project is developed to use wireless communication technology to map the geographic characteristics of an unknown place. It contains two wireless communication modules with Atmega1281 microprocessor, two robots with the 8051 microcontroller, six pairs of infrared transmitters and receivers, and a base transceiver connected to a computer. The robots are used to go through a maze and detect an unknown path with infrared sensors. The information will be sent and received through the wireless modules. Finally, this information would be sent to the base. Then the computer will display this unknown place.

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1. INTRODUCTION AND THEORETICAL BACKGROUND

1.1 Motivation for Project

Nowadays, wireless communication has become a very important technology, due to its convenience. In some cases, wireless communication is the only way to communicate with others. For example, when people are stranded in a non-populated area, they can only use a cell phone to make phone calls, or GPS to get directions. In addition, human beings are exploring the universe. Hundreds of thousands of unknowns exist in this universe. In order to be safe, only robots are sent to detect an unknown place first before human. Hence, this robot project will be designed to satisfy this requirement.

1.2 Description of Project

The project aims at robot navigation and maze mapping. In this system, two robots, two wireless modules, one base module, and six pairs of infrared (IR) transmitter and receivers will be introduced. Each robot will be equipped with three pairs of IR transmitter and receivers, one pair in front, one pair on the left, and the other pair on the right. Additionally, each robot will also be connected to one wireless module. Hence, based on the IR signals, the robot can determine if an obstacle appears. The signals received by the IR receivers will be also sent to the wireless module. Then these two wireless modules will communicate with the base module. Then the computer, which is connected to the base module, will map the maze, according to the signals received from both wireless modules.

The project uses the 8051 microcontroller to control the movement of the robots, infrared sensors to detect distance and obstacles. Additionally, each robot has a wireless communication module that contains an Atmega 1281 microprocessor to communicate with the base module that is connected to the computer.

1.3 MDE 8051 Trainer

The 8051 is a widely used microcontroller, because of its functionalities and its simplicity. The 8051 can be programmed to perform tasks based on the signals it receives. In this project, it is used to control the robot to move, process the wireless signal received from the wireless communication modules, and send signals to each other through wireless communication modules. A preloaded program, which is not yet developed, will be loaded into both the 8051 microcontrollers. Then these two microprocessors will drive the robots to move in the maze and map the path. This 8051board is shown in Figure 1.

1.4 IRIS Wireless Measurement Module

The IRIS is a 2.4 GHz Mote module used for enabling low-power, wireless communication module networks.[5] Figure 2 shows the IRIS module. This system contains the wireless communication modules and the transceiver that is connected to a computer. A software named “MotorView” is used to control the transceiver to send and gather data from the wireless communication modules. The wireless communication module can detect gravity, acceleration, voltage, humidity, etc. The wireless communication modules can also be programmed by using software “MotorView”.

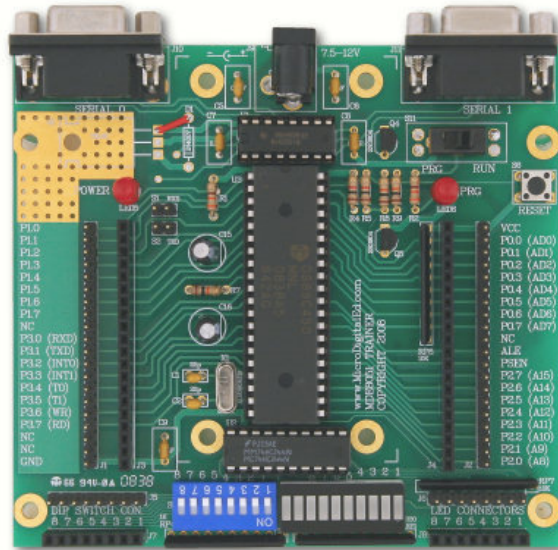


Figure 1: MDE 8051 Trainer Board



Figure 2: IRIS Wireless Module

1.5 Software

The operating system that is used is the TinyOS. The TinyOS is a component-based operating system and platform that has been created to target wireless embedded sensor networks. TinyOS is an event-driven operating system designed for sensor network nodes that have very limited resources of memory. It is implemented in nesC language. [1] The nesC language is an extension to the C programming language designed to embody the structuring concepts and execution model of TinyOS. [2] This language helps to overcome constraints in memory size in the sensor network increasing the speed in transmission of information.

Moreover, the programming code will be written in Programmer's Notepad. This program is used to write the program that will control the IRIS wireless module, and it is also the one used to compile the program. Additionally, Cygwin is also needed to program the wireless module. Cygwin is a Linux-like environment for Windows. [3] Cygwin is mainly used to load the program into the IRIS wireless module once the program has been compiled in the programmer's notepad.

Furthermore, a C program to control the 8051 microcontroller is written by using Keil uVision. The purpose of this program is to tell to the IRIS module what information is the one that is needed to be sent to the base. Additionally, a program, written in C language, will be developed for the maze mapping.

2. DESIGN OVERVIEW AND IMPLEMENTATION

2.1 Design Overview

This design contains two robots. Each robot has three infrared receivers and emitters to detect how far the robot is from the obstacles. Moreover, the robot contains a voltage translator that helps the robot's 8051 microcontroller to communicate with the wireless communication module located on the robot. Additionally, the module on each robot sends the data gathered from the Infrared (IR) sensor to the base transceiver that is connected to the computer. Then, the computer can use this data and map out the maze. Figure 3 depicts how the communication throughout the system takes place. The entire system on the robot is powered by 6 AA batteries in series. In order to be able to provide the adequate voltage levels to the system, it uses two voltage regulation circuits on each robot. One voltage regulator will step down the voltage from the batteries to 5V to supply it to the 8051, and the other one will step down the voltage to 3V to supply it to the wireless module. This design is divided into the following four parts.

1. Robot and distance sensor implementation
2. Voltage regulation implementation
3. The 8051 microcontroller to wireless communication module interface implementation
4. The 8051 microcontroller and wireless transceiver program implementation

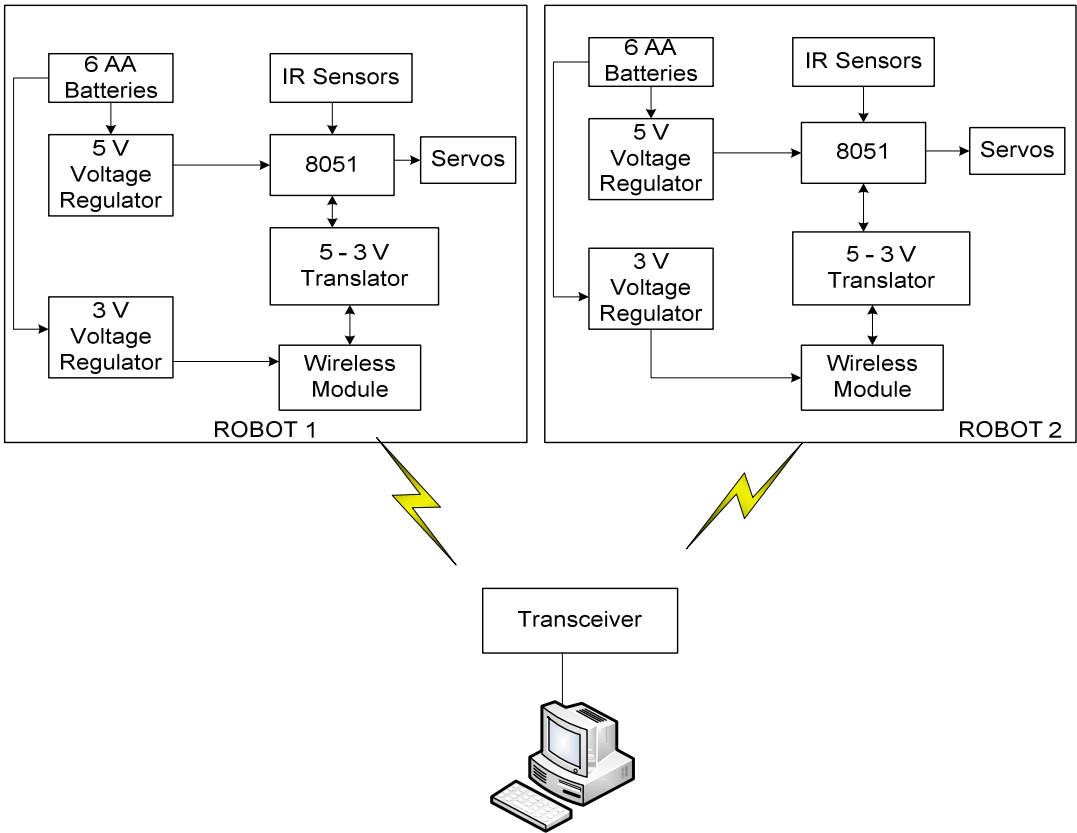


Figure 3: The Mapping System

2.2 Robot and Distance Sensor Implementation

The Boe-Bot Robot chassis is used to place the MDE 8051 Trainer board. The Boe-Bot Robot chassis comes with two servo motors. The servo motors can operate from 4.8VDC to 6VDC and are controlled by pulse width modulation (PWM).

The PWM has three forms, based on which direction the servo will rotate: clockwise, counterclockwise, or stop. In this case the PWM will be done by the 8051 microcontroller. Additionally, the plan is to use three infrared sensors to detect how far the robot is from the objects and simultaneously control it so the robot would not have any physical contact with the surroundings. Figure 3 shows the infrared sensors connected directly to the 8051, which represents the brain of the robot.

The schematic of the 8051 connected to the servos is shown in Figure 4. Two LM324/ON Op Amps are used as voltage followers to supply enough current to the servos. The two servos are connected to P1.0 and P1.1 of the 8051 microcontroller. Three transmitter and receiver circuitries are connected to 8051. The connection among transmitter circuitry, receiver circuitry, and 8051 is also shown in Figure 4. The transmitter and receiver circuitry are displayed in Figure 5 and Figure 6, respectively.

The IR receiver has three pins, a Vcc, a ground, and a signal pin. When the IR receiver detects a signal, the signal output is low; otherwise, it will stay high (5 V). The resistor is used to protect the IR receiver and 8051, in case the current happens to be very large. This is shown in Figure 5.

In the transmitter circuitry, a signal from 8051 will be generated as a square waveform at a frequency of about 38.5 kHz. The IR transmitter will be excited to send out an infrared signal at that frequency. Two BJT's are used to amplify the current so that the IR transmitter has enough current to be excited (See Figure 6). The actual built circuit is shown in Figure 7.

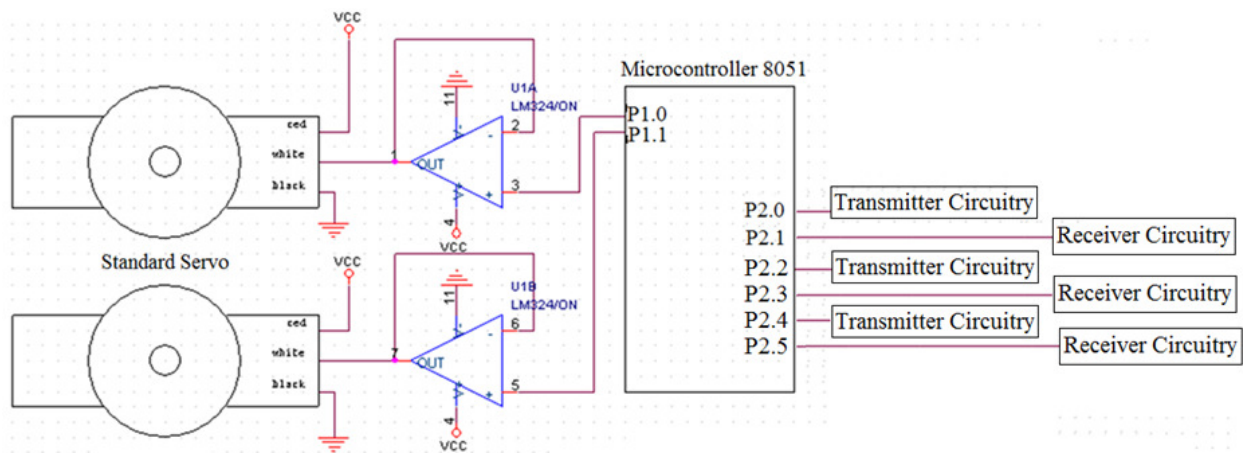


Figure 4: Connection among 8051, Servos, and IR Sensors

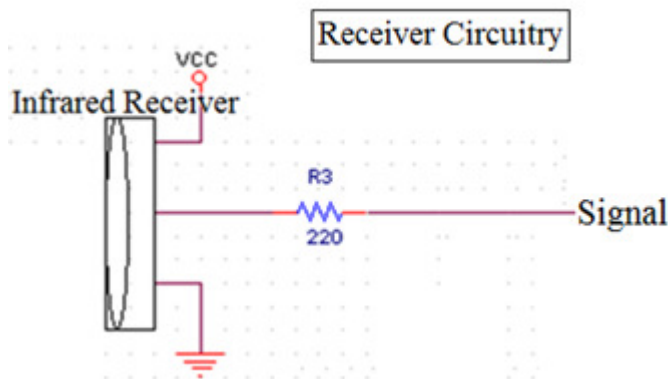


Figure 5: Receiver Circuitry

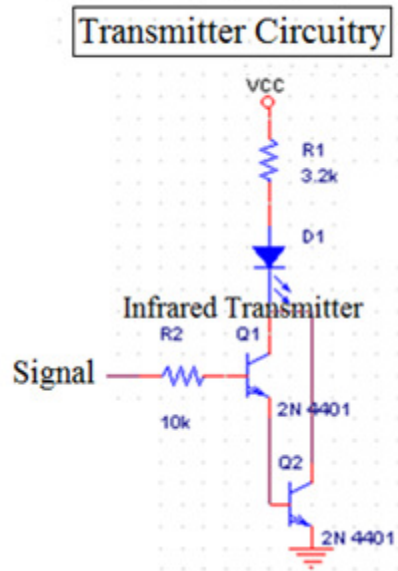


Figure 6: Transmitter Circuitry

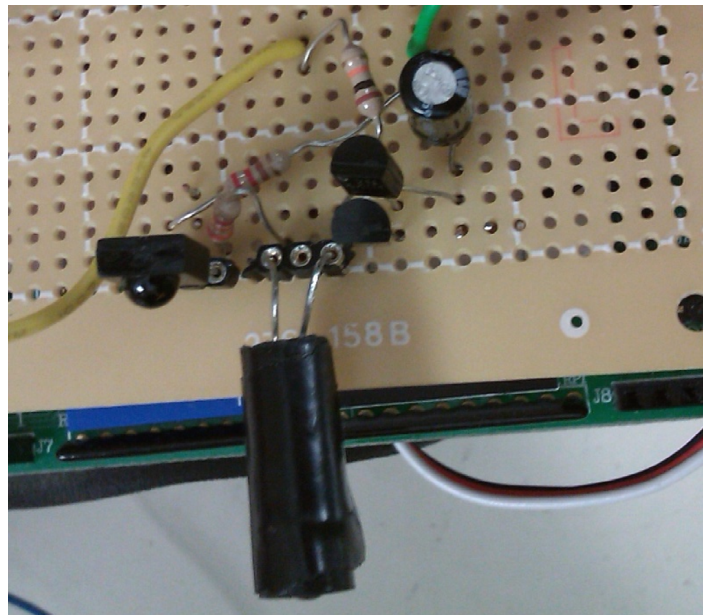


Figure 7: Infrared Transmitter and Receiver Circuitry

2.3 Voltage Regulation Implementation

The voltage regulation is needed to provide power to the entire system by using the same set of 6 AA batteries. The 8051 microcontroller and the wireless communication module use 5 V and 3 V respectively. Figure 8 shows the two voltage regulators are connected to the bank of batteries.

The left side of the source V1 is the 5 V voltage regulator. The 5 V are supplied across the RLoad1 terminals (pin 2) that are located on the left side of the circuit on Figure 8. Then, the right side of the source regulates the voltage from the batteries down to 3 V across the RLoad. In both cases, a LT1085CT-5#PBF-ND is used, which is a Positive Voltage Regulator. The output voltage is determined by the ratio of the two resistances connected to the adjust terminal (pin 1) of the integrated circuit (IC). It is important to point out that the value of these resistances can be adjusted to commercially available values as long as the ratio of both remains unchanged.

Furthermore, on OrCAD PSpice a dc sweep analysis on V1 was carried out to verify that both outputs are delivering 5 V and 3 V. The results are shown in Figure 10. In the 5 V regulation, the output voltage stays at 5 V when the input voltage is greater than 6 V, as shown in the red curve in Figure 10. Below 6 V, each battery will be providing about 0.95 V to 1 V, which in this case is considered as discharged. On the other hand, the green curve represents the 3 V regulation. When the input voltage is about 4 V, the output stays on 3 V. In addition, both Rload and Rload1 were changed to check if the output would remain as expected. As a result, the outputs stay at 5 V and 3 V, regardless of the different load values. Hence, this voltage regulator satisfies the design requirement.

In the actual circuit, capacitor C5 and C6 as shown in Figure 8 are substituted with one single 10 uF capacitor, because this capacitor is large enough to filter the noise. Then, the actual 5 V and 3 V regulation systems are shown in Figure 9.

5V regulator

3V regulator

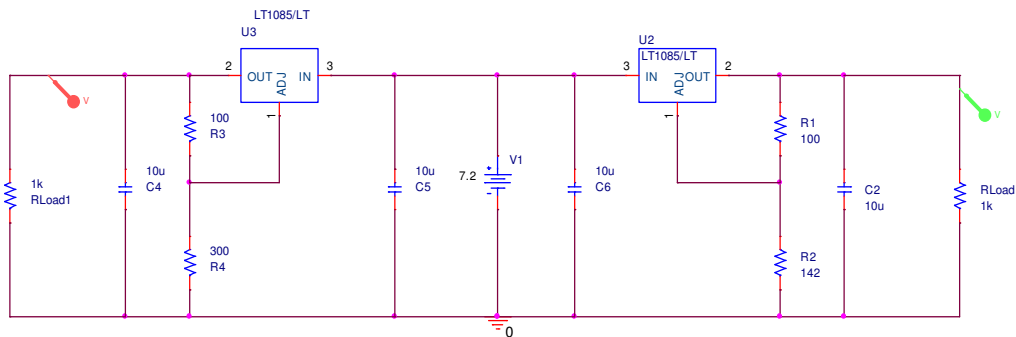


Figure 8: 5V and 3V Voltage Regulators Connected To Battery Bank V1

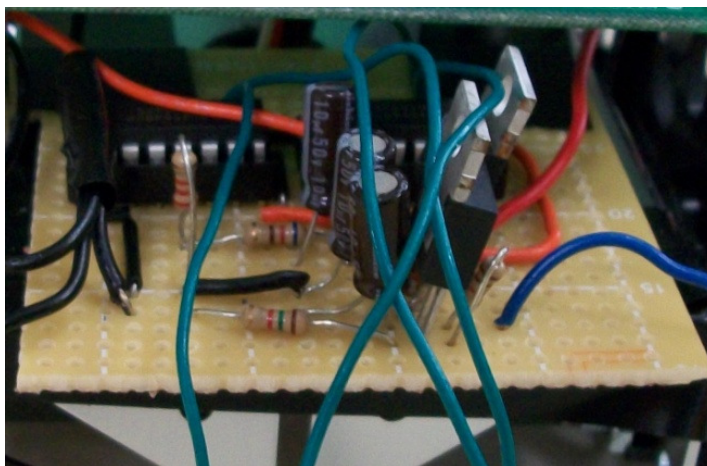


Figure 9: Actual 5V and 3V Regulation Systems

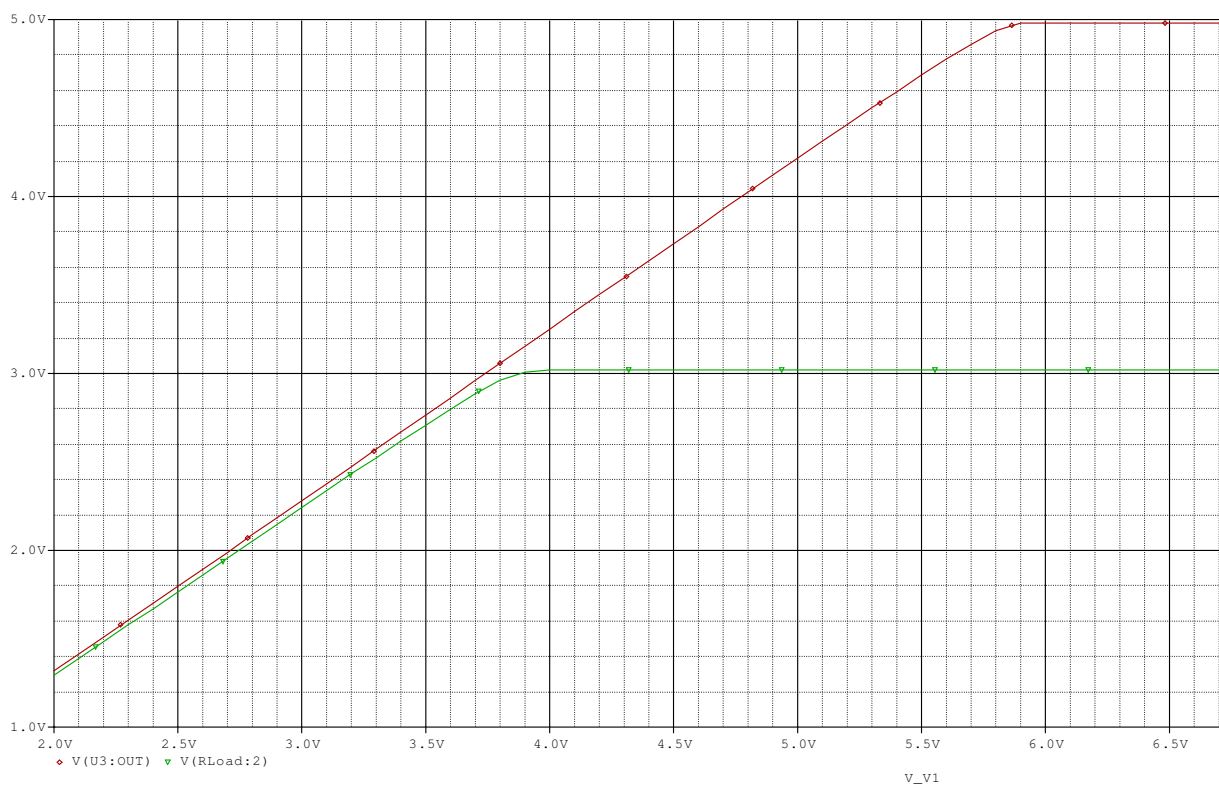


Figure 10: 5V and 3V Output Plots When Applying DC Sweep on V1

Because the simulation in PSpice is too ideal, I have to test resistors of different values, which are available, to find out the most appropriate resistor. The data of the controls are shown in Table 1. Control 1 outputs the highest voltage, but its critical input voltage is the highest too.

Control 2 requires the lowest input voltage, but its output voltage is very low. Control 3 outputs 4.95 V, which is very close to 5 V. It also has an acceptable critical input voltage 5.9 V. Therefore resistors in control 3 are chosen to implement the circuit. In order to test its stability, different resistors are applied as the load. The result is shown in Table 2. Apparently, the regulation circuit can output a constant voltage, 4.95 V, stably.

As for the 3 V regulation circuit, only the output voltage will be considered, because the critical input voltage is always lower than the one in 5 V regulation. This means that whenever the voltage satisfies the constraints in 5 V regulation circuit, the voltage will satisfy the constraints in the 3 V regulation circuit. Therefore, only the stability test is applied here, as shown in

Table 3. Figure 11 shows what the robot looks like when assembled with the voltage regulation circuit and Infrared Sensing circuit.

Table 1: Component Selected In 5-V Regulation Circuit

Control	R3	R4	Ratio	RLoad1	Critical Input Voltage	Constant Output Voltage
1	1 k Ω	3 k Ω	0.333	1 k Ω	6.2 V	5.23 V
2	1.1 k Ω	3 k Ω	0.367	1 k Ω	5.76 V	4.84 V
3	1 k Ω	2.77 k Ω	0.361	1 k Ω	5.9 V	4.95 V

Table 2: Different Loads In 5 V Regulation Circuit

Control	R3	R4	Ratio	RLoad1	Critical Input Voltage	Constant Output Voltage
1	1 k Ω	2.77 k Ω	0.361	1 k Ω	5.9 V	4.95 V
2	1 k Ω	2.77 k Ω	0.361	220 Ω	5.9 V	4.95 V

Table 3: Component Selected In 3-V Regulation Circuit

R1	R2	Ratio	Rload	Critical Input Voltage	Constant Output Voltage
1.1 k Ω	1.5 k Ω	0.733	220 Ω	4.1 V	3.043 V
1.1 k Ω	1.5 k Ω	0.733	1.1 k Ω	4.1 V	3.043 V

2.4 Wireless Module to 8051 Hardware Communication Interface Implementation

As mentioned earlier, the 8051 microcontroller uses 5 V signals to communicate, while the Atmega 1281 microprocessor uses 3 V. Because the wireless communication module is based on 3 V signals, a signal translator should be introduced into the circuit as an interface. This signal translator will translate the 3 V data into 5 V and vice versa.

Moreover, it is observed in Figure 12 that the IRIS is the wireless communication module that is connected to the translator. The wireless communication module uses a 51-pin standard connector HIROSE DF9-51P-1V, and therefore a HIROSE DF9-51S-1V connector needs to be purchased for the design to connect the expansion port on the wireless communication module to the interface. [1] By using this connector, manipulating the data in the wireless communication module becomes possible.

The translator is crucial because when the 8051 sends a logic one, which is at 5 V, the IRIS could get damaged. Additionally, if the IRIS sends a logic 1, which is at 3 V to the 8051, then the 8051 will not know whether it is logic 1 or logic 0. Furthermore, the communication between the IRIS and the 8051 will be done serially. This means that the Universal Synchronous-Asynchronous Receiver Transmitter (USART1) of the IRIS wireless module will be utilized, so are the transmit and receive pins of port 3 of the 8051. The interconnection of the interface is shown in Figure 13. Moreover, the translator would be built using two MC14504BCPG chips. This chip is a hex level shifter for voltage translation. Two of these chips are employed; one chip will be used to step down the voltage from 5 V to 3 V while the other one will step up the voltage from 3 V to 5 V.

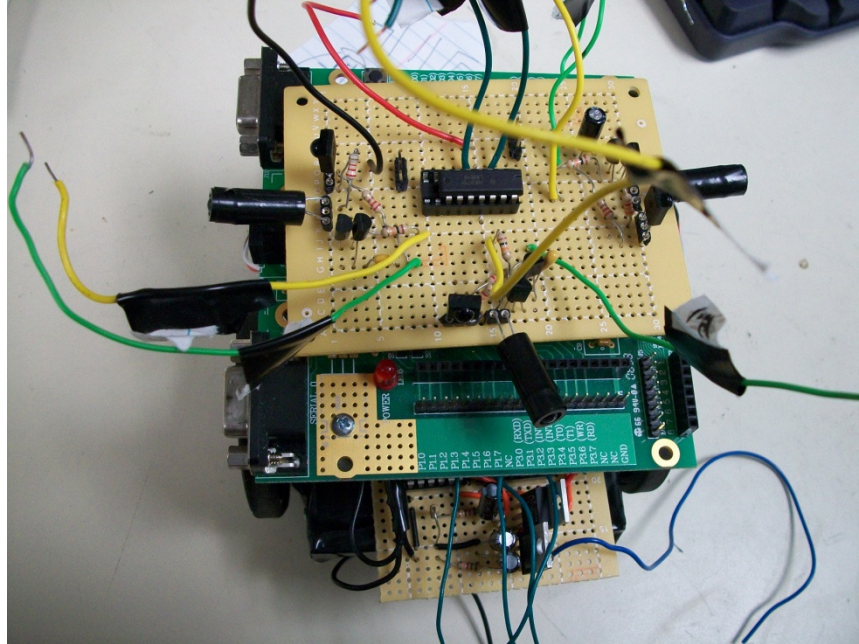


Figure 11: Robot Outlook (Without Wireless Module)

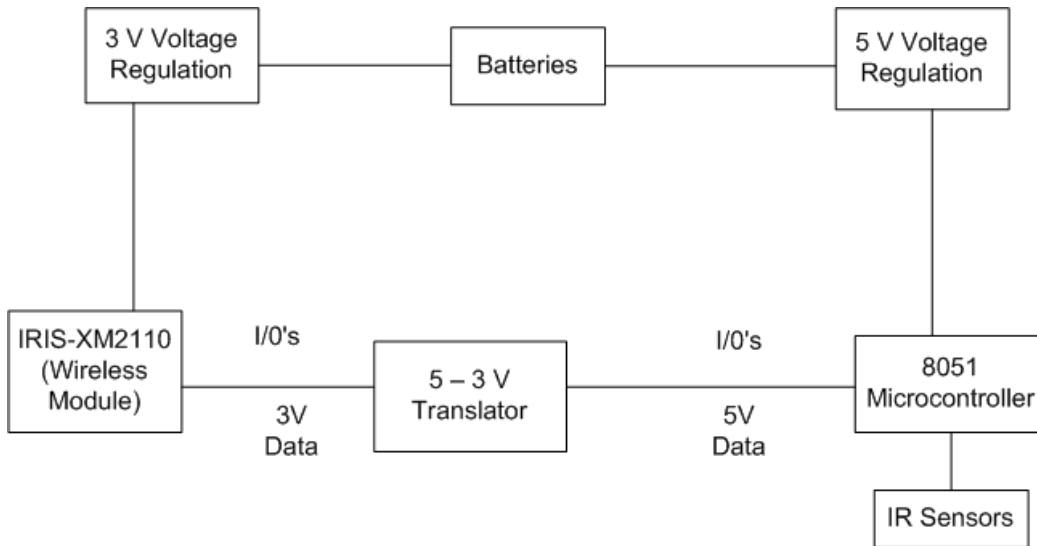


Figure 12: Robot hardware configuration

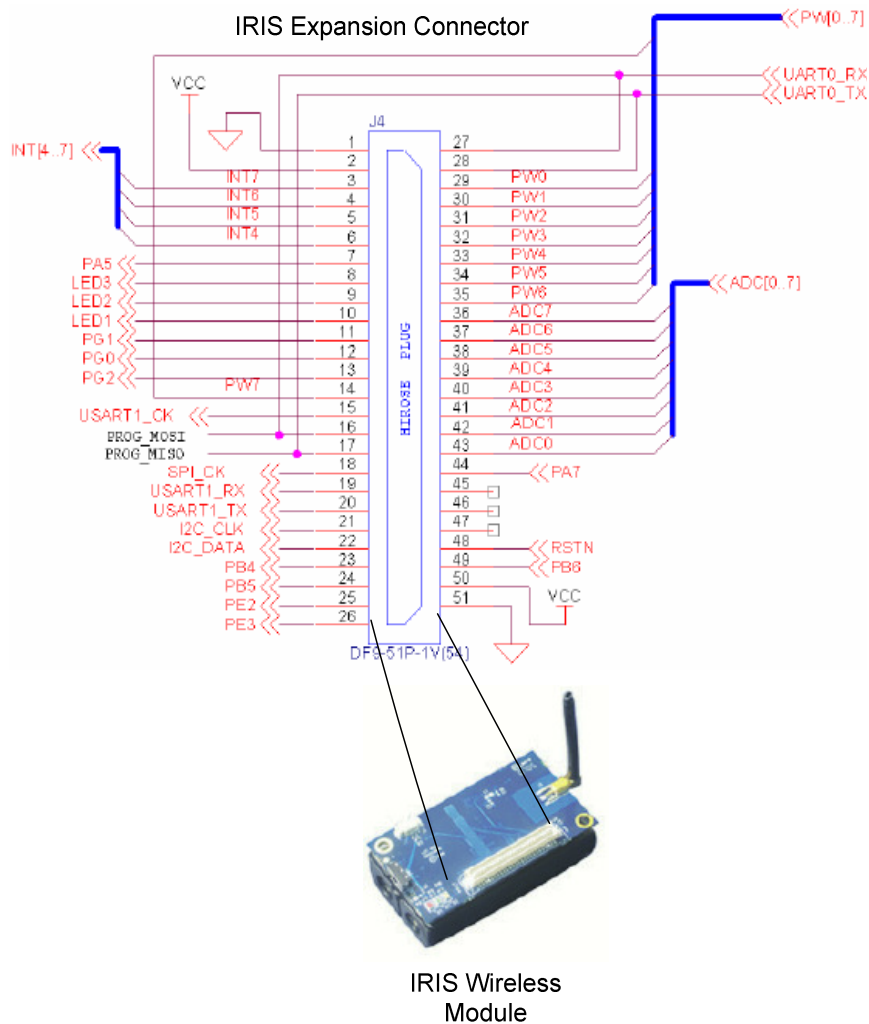
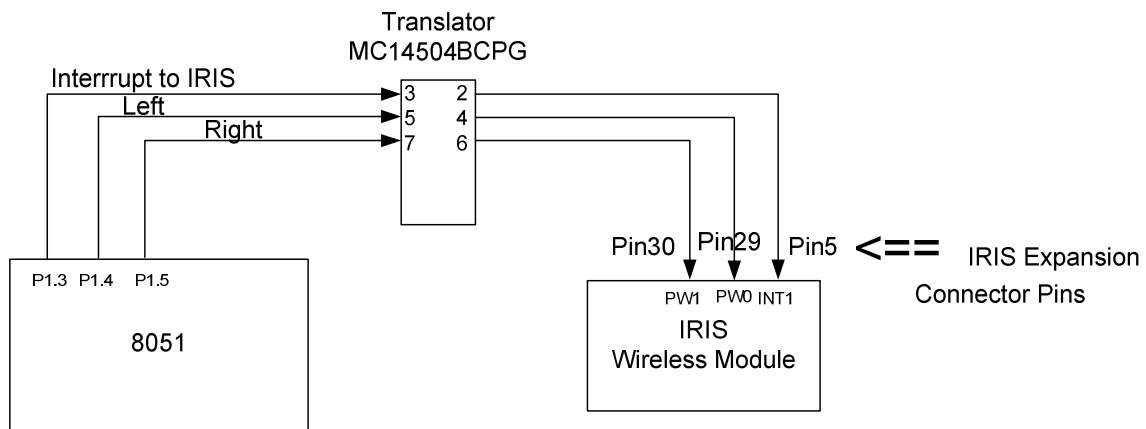


Figure 13: 8051 and Wireless Module Hardware Interface design

The MC14504BC is a 16-pin chip that can shift voltage levels and it is used in this case in Mode 0 to use it as CMOS to CMOS communication mode. This chip is used in this mode because the 8051 microcontroller is fabricated with high-density CMOS technology. [7]

Similarly, the IRIS wireless module uses CMOS technology. Furthermore, Figure 13 shows that the 8051 transmit pin (P3.1) will send an interrupt signal and turning directions of the robot through the voltage translator. Then the high voltage levels will be step down for compatibility with the high of the IRIS. Then the interrupt signal will enable the IRIS wireless mote to read the turning direction signals. After finishing reading the signal, IRIS wireless mote will send out the data to the base mote, through its own wireless channel.

2.5 Wireless Module and 8051 Software Communication Interface Implementation

The software driver for the Crossbow wireless professional kit is been studied. This is crucial to write the code of the 8051 that will allow the communication of the robot with the base transceiver.

The basic idea of this software interface is utilizing interrupts in the Atmega 1281 microprocessor, which is embedded in each wireless module. This interface is a one-way communication between these two microprocessors. Only 8051 sends signal to Atmega 1281. Atmega 1281 will not send any signal back to 8051.

When the 8051 microprocessor receives signals from the IR receivers and decides to make turns, it would send a two-bit signal to the Atmega 1281 microprocessor, after this signal is translated into 3 V signal. Then Atmega 1281 will then communicate with the base module.

2.6 Wireless Module to Base Module Software Communication Implementation

The communication between wireless module and base module is very straightforward, because Crossbow has created relevant functionalities for this type of communication. This communication is also a one-way communication. Only the wireless module sends the turning signal to the base module. Base module will not send any signal back to wireless module. Whenever the base module receives a signal, it will send this data to the computer.

2.7 Base Module to Computer Software Communication Implementation

The communication between base module and computer is serial communication. Crossbow has created relevant functionalities for this type of communication. As stated earlier, when base module receives data from either wireless module, it will send the data to the computer through USB connection.

3. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE DESIGN

Wireless Mapping devices are useful systems than can prevent the exposure of lives to hazardous environments, and simultaneously they can record electronically and send wireless the data that has been gathered. Moreover, Crossbow wireless communication systems are widely use nowadays due to their expansion connector that allows access and control the system for any task that the user needs to carry out. This makes the implementation IR sensors and 8051 possible. Finally, the voltage regulation is necessary in this wireless system to be able to provide a constant output voltage coming from the batteries to the circuitry and avoid any errors during the communication process between the IRIS Wireless module, the 8051 microcontroller, and the Base Transceiver.

This project meets the major goal of my proposal. Two robots did self-navigate through the maze and communicate with the computer through wireless notes. The paths of the two robots were drawn in the computer. However, there exist four problems, where some modification can be made.

First, the robot does not move straight, because both servos cannot start moving at the same time. This is mainly due to the servos that consist of step motors that are controlled by a chip located inside a sealed case. Its direction of the rotation depends on the period of a pulse. Different directions of rotation require different lengths of pulse. Therefore, the time difference cannot be absolutely eliminated. I would suggest substituting the servos with a simple motor that rotates according to the voltage, i.e. when positive voltage is present, the motor rotate clockwise; when negative voltage is present, the motor rotate counterclockwise. By doing this, the time difference can be avoided.

Second, the right-hand-rule does not apply to the entire maze. When the maze contains a square loop, the right-hand-rule will result in an endless loop, of which the robot can never go out. I suggest applying a two-way communication between the wireless components and the 8051. Then the 8051 will apply another algorithm, the left-hand-rule for example, to avoid this potential behavior.

Third, the mapping is not simultaneous. The reason is that Crossbow has its own software to read the base mote data from USB connection. Therefore, all the data is stored in the software first. Then once the robots walk through the maze, the data will be displayed by using Java. In the future, using real time mapping would make this design more robust.

Forth, the collision of the two robots is not considered. In this project, an assumption was made that the robots will not collide with each other. I suggest that introducing a two-way communication should solve this problem.

Nevertheless, the project is very successful. It serves as a prototype of the robot mapping. It exhibits a few basic ideas in a higher level, such as simple wall detection, voltage regulation, translation, wireless communication, and a basic self-navigation algorithm.

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