Programmable 24-bit RGB LED Color Panel via Bluetooth Technology

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A Design Report Submitted to the School of Electrical Engineering, Electronics and Communication Engineering, and Computer Engineering in Partial Fulfilment of the Requirements for the Degree

Bachelor of Science in Computer Engineering

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Approval Sheet

Mapua Institute of Technology
School of EE – ECE – CoE

This is to certify that we have supervised the preparation of and read the design report prepared by **Albert M. Agonoy, Antonio Rufo R. Cuenco, Lillette C. Daplas, and Mark Dale A. Nieveras** entitled **Programmable 24-bit RGB LED Color Panel via Bluetooth Technology** and that the said report has been submitted for final examination by the Oral Examination Committee.

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As members of the Oral Examination Committee, we certify that we have examined this design report, presented before the committee on **March 23, 2009**, and hereby recommended that it be accepted as fulfillment of the design requirement for the degree in **Bachelor of Science in Computer Engineering.**

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This design report is hereby approved and accepted by the School of Electrical Engineering, Electronics and Communications Engineering, and Computer Engineering as fulfillment of the requirement for the degree in **Bachelor of Science in Computer Engineering.**

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The design is all about the microcontroller-based RGB LED panel. This design project is very useful as a form of advertisement for small businesses. The design uses Bluetooth technology as its communication medium for the user input device to the RGB Led panel. The main purpose of the design project is to aid small businesses on their struggle against high cost advertisement techniques. It uses microcontrollers and Led drivers to manipulate the colors produced by the RGB Led panel. The design is powered by a 12 volts power supply and is controlled by the PIC microcontroller. The design uses a Bluetooth module to receive data coming from mobile phones, laptops and desktop computers. The design can be interfaced with desktop personal computers via a hyper-terminal that uses RJ11 phone jack.

Keywords: RGB LED, microcontroller, Bluetooth, wireless

Chapter 1

DESIGN BACKGROUND AND INTRODUCTION

Small Businesses are the major job providers in most economies. The most common problem faced by small businesses is bankruptcy, this is often caused by poor planning rather than economic conditions; Poor planning mainly on product marketing, on how to advertise their products effectively. They can try word of mouth, customer referrals, yellow pages directories and there are other marketing techniques but are quite expensive like television, radio, outdoor (roadside billboards), and internet marketing.

Another effective way to market a product is by digital signage. Digital signage is not yet considered by most business development experts as a marketing technique, because they are simply unaware of its value. Digital signage costs less compared to that of broad-based media such as TV, newspapers, radio and yellow pages, and it is usually a one-time investment. Another thing to keep in mind is the longevity of the medium. All other media stop as soon as you quit paying for it.

There is a need for a design of an RGB LED Panel via Bluetooth Technology that has commercial features and can allow users to change their messages in "real time", to reach target audience without delay. This can result to a more efficient and economical design that can allow low-budget establishments or small businesses to purchase their own display systems.

Statement of the Problem

Marketing techniques help small businesses promote their products or services to the general public. More exposure to the public means better revenue. This allows small businesses to increase their revenue, thus, having an opportunity to expand their market.

Small businesses spend a lot of money for the endorsement of their products. Problems may arise using various marketing techniques such as, signboards, tarpaulin, flyers, posters, etc. These marketing techniques are often costly because of printing multiple posters, flyers, and tarpaulins, and will eventually be trashed once the endorsement theme or event is done. Moreover, the disposal of these materials may cause environmental hazards, due to most of the materials are non-biodegradable.

Objective of the Design

The general objective of the design is to produce a LED panel that can display user input messages in seven different colors using Bluetooth technology. The design aims to:

1. Develop a low-cost Digital Signage that can be made using available parts and materials locally.
2. Develop a compact Digital Signage design which aims to target a specific audience.
3. Generate seven different colors that can be used as font colors for the messages that will be displayed in the RGB LED Panel.

4. Use Pulse Width Modulation or PWM on four RGB LEDs so that it can display multiple colors that the RGB LED can produce.
5. Improvise a software that can act as a bridge between the mobile phone and the RGB LED Panel.

Significance of the Study

The design has a global impact for the business owners. With the implementation of this project, marketers and business owners will have access to a cost-effective medium for advertising their products and services. It is not only simple and easy to use but the product itself is also affordable even to the small and medium Entrepreneurs. It would be a great advertising tool because it allows users to change their messages in "real time", to reach target audience without delay.

The design has an environmental impact. With the use of this design, it can minimize the use of paper posters, flyer advertisements, tarpaulins and the like which add to the amount of waste dumped. This can help in lessening the garbage in the society.

The Conceptual Framework

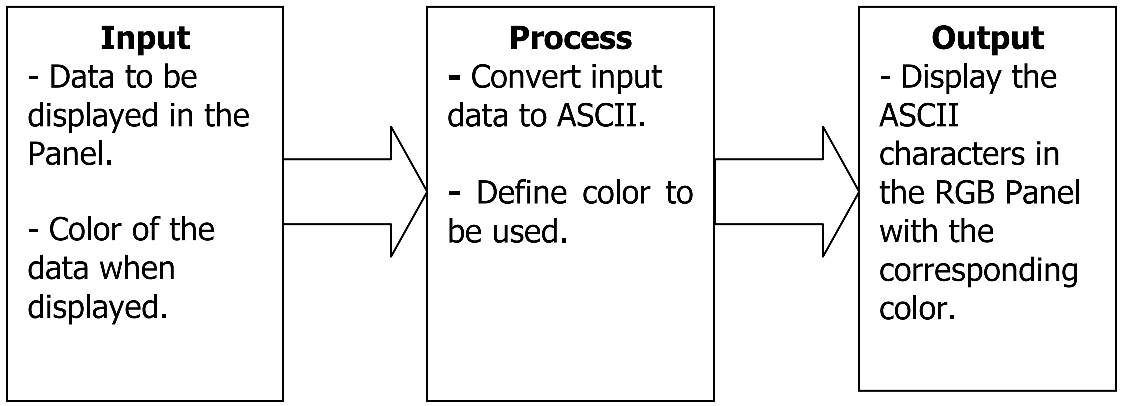

Figure 1.1 – Conceptual Framework

Figure 1.1 shows the RGB LED display system's structure and functionalities. It is divided into three stages, the Input, the Process, and the Output of the system.

Based on Figure 1.1, the user must input certain variables for the prototype to operate. First, the user must input the data he or she wishes to be displayed in the RGB Panel. This is done via Bluetooth Technology. The user must have a software application called "Bluetooth Chat" installed in his mobile phone for the data transmission to be successful. Lastly, when the message is already displayed in the RGB LED display panel, the user can change the font color of the displayed message.

After the users input data, it can now go to its processing where the Bluetooth Module converts the raw data that are sent via Bluetooth to its corresponding ASCII characters. Then, the data are sent to the input port of the microcontroller. The microcontroller processes the data and controls the Column and Row drivers of the design to which RGB LED lights up which color to emit. After the Processing Stage, the user input message or text can now be seen in the RGB LED Panel and displays the desired font color.

Scope and Delimitation

Since it is the objective of the study to develop a cost-efficient Digital Signage, the design consists of readily available components in the market. The design is compact and easy to use with the proposed operation via Bluetooth technology.

The study also covers the implementation and assessment of the prototype as to its usability in different conditions and the acceptance of both the advertisers and the target audience.

The Digital Signage displays text data that are sent thru Bluetooth. The text input comprises of letters, numbers and special characters. The letters displayed are all in upper case as a limitation on the matrix of the design.

The display panel is 8x40 RGB LED matrix. The panel displays up to 240 characters per message. The design uses Bluetooth from mobile phones to send messages which is advantageous because it doesn't require money every time the user sends a note or a message; much cheaper and much efficient compared to SMS developed designs. The input device must have a software called "Bluetooth Chat" installed. The "Bluetooth Chat" software acts as a bridge between the input device and the RGB LED Panel. Sending data to the RGB LED

Panel via SMS or infrared messaging will not work. The limited distance between the mobile phone and the design is up to 10 meters.

With constraints such as timeframe and funding for the development of the prototype, the project is limited only to a small design that can only display text messages of varying colors, though it shall consist of components that can display animated images.

Definition of Terms

LED - A light-emitting diode (LED) is a semiconductor diode that emits light when an electrical current is applied in the forward direction of the device (Basic Electronics, 2003).

RGB LED - is a LED (Light Emitting Diode) that emits three primary colors of red, green and blue (Scherz, 2000).

Battery - is a device that changes chemical energy into electrical energy. It consists of a number of connected units called cells which convert the energy into electrical current (Bell, 2007).

Hardware - is the physical components of a computer system (Stalling, 2006).

Bluetooth® Technology - is a wireless protocol utilizing short-range communications technology that facilitates data transmission over short distances from fixed and mobile devices, creating wireless personal area networks (Wireless and Cellular Telecommunications, 2006).

RGB Panel **-** Refers to the use of flat panel electronic display devices; in the designs case, a collection of RGB LEDs (Trundle, 2001).

Microcontroller – Is a chip which has a computer processor with all its support functions, memory, and input/output built into the device (Programming and customizing the microcontroller, 1999).

PSOC - most closely resembles a microcontroller in usage, since the programs written by a user execute code to interact with the user-specified peripheral functions (Programming and customizing the microcontroller, 1999).

Pulse Width Modulation (PWM) – is a signal that involves the modulation of its duty cycle, to either convey information over a communications channel or control the amount of power sent to a load (Roddy, 1995).

PCB (Printed Circuit Board) **-** is used to mechanically support and electrically connect electronic components using conductive pathways, or traces, etched from copper sheets laminated onto a non-conductive substrate *(PCB Design by Chris Stahl).*

Point-to-point communication - is a dedicated transmission link between two devices (Introduction to Mobile Communications, 2007).

Input device – is any peripheral (piece of computer hardware equipment) used to provide data and control signals to an information processing system such as a computer (Miller, 2007).

Interface – is a device or program enabling a user to communicate with a computer, or for connecting two items of hardware or software (Stone, Stone and Jarett, 2005).

Power Supply – pertains to the voltage supply needed by the RGB LED display system for operation (Gumhalter, 1986).

Wireless – It is operated by means of transmitted electromagnetic waves. No wires or connectors to be used in sending or receiving data (Wireless and Cellular Telecommunications, 2006).

Chapter 2

RELATED LITERATURE

In the development of this design, the group has explored different materials to help them in the progress of their study. The group had consulted online journals as well as publications that tackled and discussed the concepts to be used in the advancement of the prototype.

The group's design is a Programmable 24-bit RGB LED Color Panel via Bluetooth Technology. The concept of the design is to display a message or a note into an RGB LED panel where it can be modulated to produce any color that is desired. Data Transferring is achieved through Bluetooth Technology.

RGB LEDs operate in extreme outdoor conditions

One of the important concerns that the group has considered is the location of the RGB LED panel, on where it is to be used. According to Emily Gleason, Avago Technologies developed a series of high-brightness SMT tri-color LEDs that will enable designers to develop large indoor and outdoor electronic displays that will provide sharper images and graphics. The series of high-brightness RGB LEDs have been designed to operate in extreme outdoor conditions. Typical applications include stadium scoreboards, billboards, marquee signs and electronic variable messages signs.

The group's design which is similar to the 'electronic variable messages signs' knows the importance of choosing the suitable RGB LED for the project.

The group has considered the one that displays most visibility and can be seen at stiff viewing angles; the RGB Quad-LED offers a viewing angle of 120° for large display.

In this article, it stated that the RGB LED light output can be affected by the PCB temperature where the LEDs are soldered and the elevation temperatures will also result in further degradation of the light output. At 55 degrees Celsius, it would approximately cost the light output 15% - 20% lower. It is helpful for the group's design, so that if the design is to be installed, it would be placed in a shaded area, away from the sun.

Wireless Smart Remote Display System (WSRD)

An innovation that is comparable to the group's study is the Wireless Smart Remote Display System developed by Scanning Devices Inc. last 2002. This device was designed to provide fast digital readings in industrial and process control situations where a remote display is required for operator convenience.

According to the developer of WSRD, the system consists of:

- One base station - a Bluetooth enabled display linked to the data source by either RS232 or 20 milliamp current loop connection. The base station learns transmission characteristics, receives data from the source, constructs messages, manages the Bluetooth Network and transmits messages wirelessly to the remote displays.

- Up to 7 remote displays - any Scanning Devices Smart Remote Display linked to the base station by Bluetooth wireless communications.

This system uses Bluetooth radio module power class 2 with specified range of only 10 meters and a selection of bright yellow reflective electromechanical and bright red LED displays that provides readability. The group's innovation to this design is the implementation of RGB LEDs in the display which can be modulated to control the brightness and to provide excellent readability anytime and anywhere. The 10 meter range can also be extended using another version of bluetooth module that can transmit up to 100 meters.

Pulse Width Modulation

According to A.K. Gelig of IEEE, Pulse-width modulation (PWM) of a signal or power source involves the modulation of its duty cycle, to either convey information over a communications channel or control the amount of power sent to a load. In relation to the group's design, changing the duty cycle of each PWM signal can control the average current flowing through each RGB led creating any color desired. In this project, the duty cycle is the ratio of ON or OFF time to the total time the LED was ON and OFF.

The mixing of colors from red, green and blue to produce any other color is described in the CIE color chart (figure 2.1). The CIE chart is a triangular wedge which shows all the colors the eye can see where the top left corner is pure green, the bottom right is pure red and the bottom left is pure blue. The numbers on the perimeter are corresponding wavelength (in nanometers) .The inscribed triangle is a demonstration of actual color generated. For example, let's say our RGB LED can generate the following pure wavelengths: 700nm (red), 545nm (green) and 400nm (blue). These would correspond to the points plotted on the CIE chart and so we can make any of the colors *inside* the triangle, but none outside of it.

Figure 2.1 – CIE Color Chart

To change the duty cycle of the PMW signal to each of the LED, a different period of delay should be set for the time it is ON and OFF. Consider a LED set to ON state for 1ms and then set to OFF state for 3ms, since the LED is OFF 3 times longer that it was ON the positive duty cycle is 25% of the time (1ms / 4ms) and the negative duty cycle is 75% of the time (3ms / 4ms). This makes the RGB LED produces other colors.

TPS62260LED Wireless Remote Control RGB LED design kit

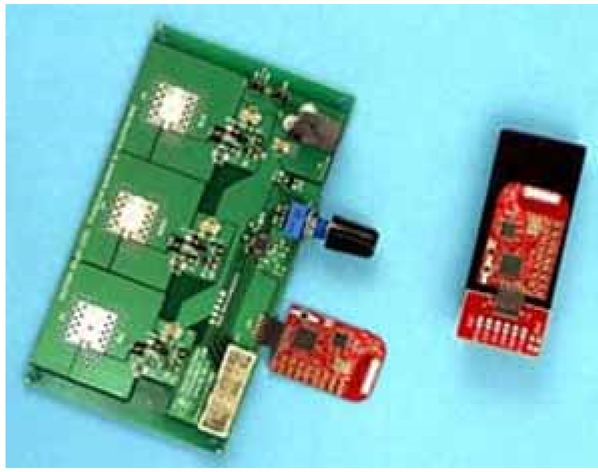

Figure 2.2 - TPS62260LED Wireless Remote Control RGB LED design kit

This design related to the group's study is a new product of Texas Instruments Incorporated. According to the author, the TPS62260LED Board controls the color and brightness of RGB LEDs or runs an automatic color light animation program. It can utilize wireless communication by using eZ430-RF2500 (RF development tool) which is plugged directly to the board. This allows designers to create a lighting network of RF controlled lamps.

Using wireless technology same as ours, flexibility is obtained as well as additional infrastructures are eliminated. Using Bluetooth will be more convenient than RF as quoted by Bortman (2002), Bluetooth is a protocol that allows short-range communication among computers, cell phones, printers, keyboards, mice and other electronic device. There are a lot of Bluetooth-enabled devices available that can be used to transmit signals.

CHAPTER 3

DESIGN METHODOLOGY AND PROCEDURES

Design Methodology

Constructive research was used as the design methodology. Constructive research is perhaps the most common computer science research method. This type of approach demands a form of validation that doesn't need to be quite as empirically based as in other types of research. The study was composed of Gathering of the Data and Materials, Prototyping, Prototype Testing and Validation. The design was patterned mainly on the existing LED matrices available in the market. This design is a stand-alone microcontroller-based prototype. The design procedure part provides further explanation of the method, and a step by step procedure is discussed.

Design Procedure

The design as stated above follows the Constructive research method. Figure 3.1 located on the next page further explains the step by step method. The design was separated in three parts: the first part being the data gathering and prototype designing, second is the hardware part and the last part is the software design. The data gathering and designing involve the library research and interviews the researchers have done. The researchers established a block diagram to guide the whole process of designing. The block diagram serves as a backbone of the design, as seen on Fig. 3.2. Fig. 3.2 shows the components to be used. The hardware part basically involves building the circuit and this part shows the interconnection of the components based on the design in the first part. The software part of the design is the programming part. This involves the proton programming to program the microcontroller. (*See each respective part for specific details*).

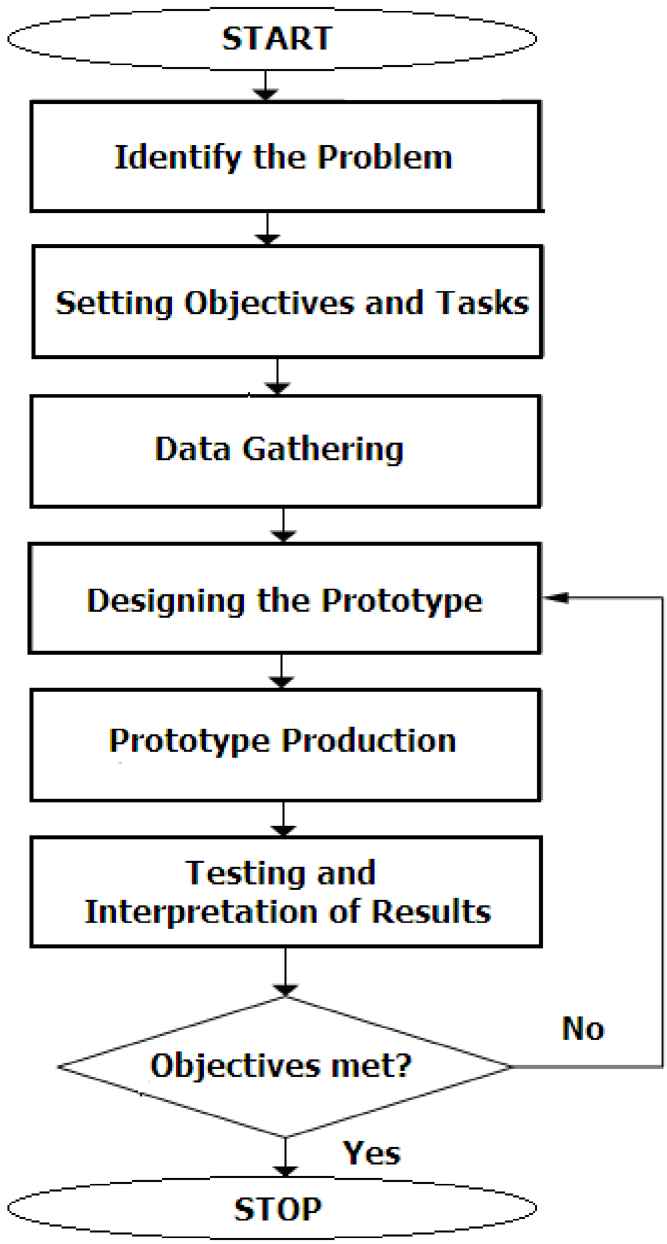

Figure 3.1: Project Design Flowchart

1. Identify the problem – Before the start of the project the researchers identified the problem. The researchers determined the ineffective means of advertising. The existing types of advertising like tarpaulins, flyers roadside billboards and other types are more expensive, and moreover after the period of time these materials will be thrown away and can cause environmental hazards.
2. Set objectives and tasks – The researchers set the different objectives and tasks and distributed equally to the members of the group. Also, the scope and limitations were considered for the outcome of the project.
3. Data Gathering – Data gathering for the project was done by the researchers. Topics from the different fields of the project have been studied. These were used during the start of the project.
4. Designing – After gathering sufficient data for the project, the researchers started the design of the project. The project generally used RGB LED that would be manipulated using Pulse width modulation to generate multiple colors. The design has eight LED drivers, three of which would be the color drivers namely Red, Green and Blue. The remaining drivers were RGB LED column drivers. Then the program needed in which it

would be responsible for the manipulation of the colors and the conversion of the raw data to its equivalent hexadecimal values. Bluetooth technology will act as the communication medium for the transfer of data from the mobile phone to the LED Panel.

5. Prototype production – After the design was laid-out, the researchers then proceeded on the production of the design. The researchers first accomplished the hardware part before proceeding to the software.
6. Testing – The prototype has undergone series of testing to ensure the functionality of the design.
7. Interpret testing results and modification – After undergoing series of testing, the researchers evaluated the test results based on the objectives set already. If some malfunction happened or some parts didn't match the objectives, then it would be modified further by reviewing steps 4 to 6 to satisfy the objectives missed.
8. Conclusion and recommendation – After the designers completed all the necessary tests and evaluations of the results, the researchers made their findings and then gave the necessary recommendation to further improve the design.

I. Data Collection

1. The first step the researchers had taken was to find the perfect RGB LED for the RGB LED display panel that the design was going to use. The researchers conducted a study about the different kinds of RGB LED.

After studying and comparing the RGB LEDs, the researchers were able to identify which RGB LED was best suited for the design. The researchers preferred to use RGB Quad-LED over Tri-LED because the former was easier to manipulate. A typical RGB Tri-LED has its Red pin as Anode, the Blue and Green pins as Cathode. While in RGB Quad-LED, the fourth pin could be an Anode or Cathode wherein the color could be easily manipulated through the concept of PWM.

2. Because the design implements communication via Bluetooth, the researchers studied about the latest on Bluetooth technology. The device is called Bluetooth module, a transceiver, will be used in receiving raw data from the input device.

3. The group had identified a way to make sure that the Bluetooth connection was secured because almost every mobile phone and laptop had an available Bluetooth device. This part of the study is the most crucial part of the design. After hours and hours of trial and error, the researchers decided to go with a special program called "Bluetooth Chat" that was installed in the input device. Also, point-to-point communication was implemented in the designs Bluetooth

communication so that only one user could access the RGB LED display panel at a time.

4. The researchers focused on how to display characters in the RGB led panel. This was done using the microcontroller that decoded the incoming data and converted it to its hexadecimal value, then it was passed to the RGB led drivers. The RGB led drivers controlled the RGB leds on which should lit on and what color. The RGB led panel matrix was 8x40 where in each character segment was 8x8.

5. Furthermore, the researchers determined the effective principles that could be used in order to control the desired output. The most suited idea that could give the desired variable output was Pulse Width Modulation (PWM). This principle was responsible for altering the duty cycle which depended on the input current coming from the drivers. During the process of designing the project, the researchers studied and applied methods and principles of Pulse Width Modulation. Pulse Width Modulation was used in the development of the design. PWM was responsible for the control of the current directed to the RGB led, thus changing the colors that it displayed.

II. Prototype Designing

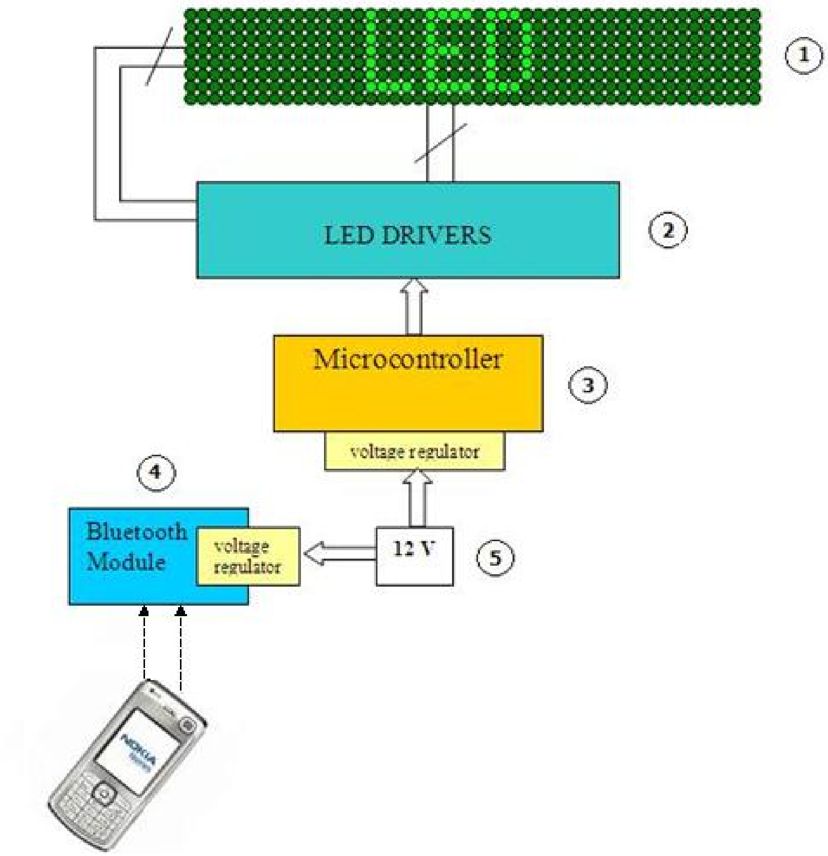

Figure 3.2: Design Block Diagram

The researchers established a block diagram to guide the whole process of designing. The block diagram served as a backbone of the design. Fig. 3.2 illustrates the block diagram used by the group. These could be broken down to 5 phases.

1. The design used RGB Quad-LED because it could be easily manipulated through the concept of Pulse Width Modulation.

2. The design used RGB LED drivers. The 8 led drivers were categorized into two. The first type was three color drivers for Red, Blue and Green. The second type was five led drivers for the RGB LED panel columns.

3. Construct a program that would be embedded in the microcontroller, so that it would be responsible for all the processes in the design which included manipulation of colors in the panel and the conversion of raw data to its equivalent hexadecimal values.

4. The design used a component called Bluetooth module, a transceiver that would be used in receiving raw data from the input device.

5. The design project used 12 volts of power supply in order to operate the whole design. The 12 volts supplied the voltage needed by the microcontroller, the LED drivers, the circuit and the Bluetooth Module. Since, the microcontroller and the RGB leds needed 5v supply while the Bluetooth module needed 3.3v supply, two voltage regulators were used.

6. After completing the 5 phases, the last step was to make a PCB layout for the connection between the microcontroller, the LED drivers and the Bluetooth module and other components in order for the design to work. After finalizing the layout, the PCB and all the components were fabricated and installed.

Design Procedure for Actual Design

The researchers discussed both software and hardware specifications separately in this section. The job done by the software part is discussed later in this section.

1. First, the group gathered all the materials needed in the development of the design as listed in Table 1 – List of Materials.

Quantity	Description
360	RGB quad-LED
1	100 uF Capacitor
3	0.1 uF Capacitor
1	1000uF Capacitor
2	20 pF Capacitor
1	1N4001 Diode
1	Phone jack
1	CON6AP connectors
1	CON5 connectors
1	Connector Rectangle 17x2
8	Connector Rectangle 8-pin
3	MAX6971 LED Drivers
3	100 ohm Resistor
3	10 ohm Resistor
1	470 ohm Resistor
1	SPDT switch
1	PIC18F4550 Microcontroller
1	LT1086 3.3 Voltage Regulator
1	LT78L05A Voltage Regulator
1	CD4049UB Buffer
5	74VHC595 Column Drivers
1	Crystal pin

Table 1 - List of Materials

Table 1 shows the list of materials significant in building of the design. The first column of Table 1 indicates the quantity or how many items are required in making the system. The second column is the name of the component.

Hardware Component

2. The researchers setup the proper placements of the main hardware components in the designed PCB as shown in Figure 3.3.

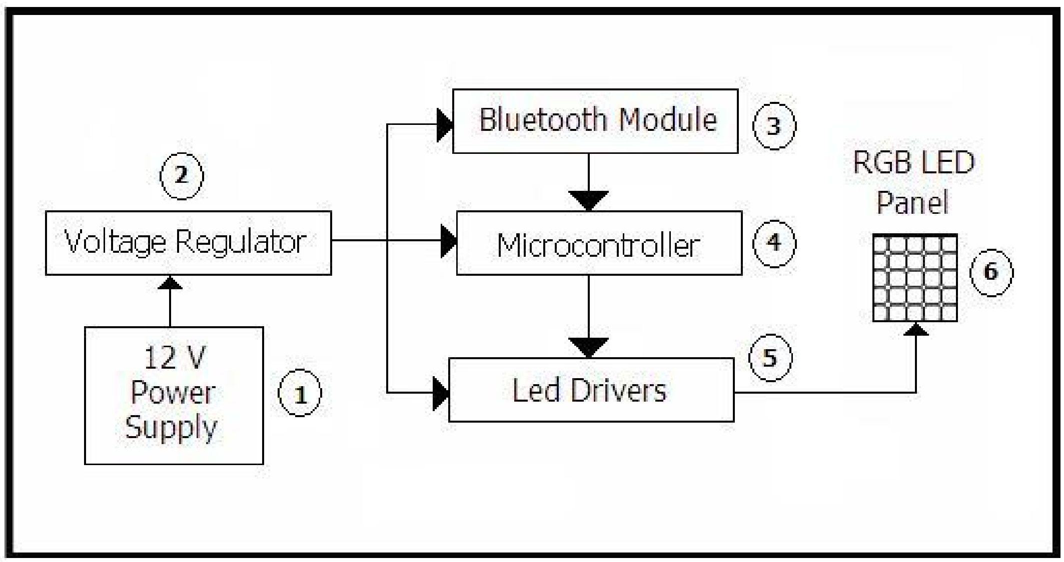

Figure 3.3 – RGB LED Panel Setup

Figure 3.3 shows the main part of the design which is the component used to display message that can vary color in the RGB Led Panel. The whole panel is powered by a 12V Power supply (1) that will be regulated so that it can be used by the panel components.

Figure 3.3 shows the setup of the whole design. The hardware components of the design are the voltage regulator (2), the Bluetooth Module (3), the Microcontroller (4), the Led Drivers (5), and the RGB Led panel (6). The main board contains the circuitry of the whole RGB display panel. The voltage regulator regulates the voltage that will be coming in from the 12V supply. There are two types of led drivers used. MAX6971 is the color drivers for Red, Blue and Green. 74VHC595 led driver is for the RGB LED panel columns. The microcontroller will control the drivers on what characters to display and which color to emit. The microcontroller will receive signals through the Bluetooth module. It will then convert the signals to its equivalent hexadecimal value. The RGB Led panel will display the message that the user will input.

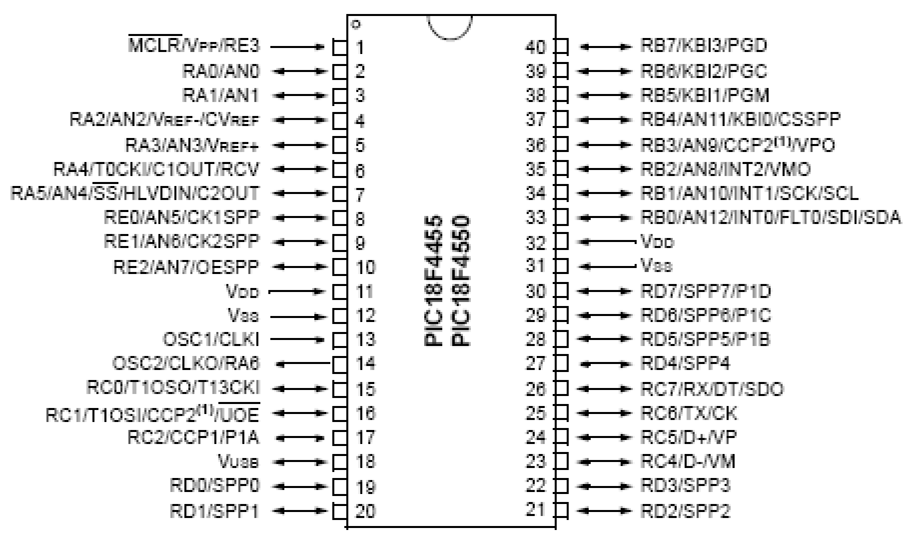

Figure 3.4 – PIC18F4550 Configuration

Figure 3.4 shows the pin configuration of microcontroller chip used in the design. The microcontroller serves as the main processor of the design which has the capability to store program that must be implemented in the design. The microcontroller used is PIC18F4550, a 40 pin 16-bit with a CMOS flash microcontroller that operates at 48MHz that can do 12 million instructions per second.

Figure 3.5 – Bluetooth Serial Converter UART Interface

The prototype will use a RGB led panel, the panel will be used to display the message or note from the user that will be sent through Bluetooth.

The prototype will use a Bluetooth Serial Converter UART Interface also known as a Bluetooth module. Figure 3.5 shows the Bluetooth module. The Bluetooth module will play a major factor in the system because it translates data between parallel and serial forms. The Bluetooth module requires a 3.3V to operate.

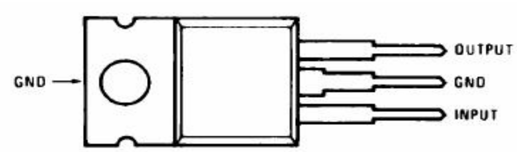

Figure 3.6: Three Terminal Voltage Regulator

Figure 3.6 shows the voltage regulator to be used in order to produce 5V for the microcontroller. LM7805 is the model name of the voltage regulator used. This voltage regulator is a three terminal regulator that produces fixed output voltage which is 5V. This is important because the driver voltage of the microcontroller is only 5v. Excess voltage may damage the IC.

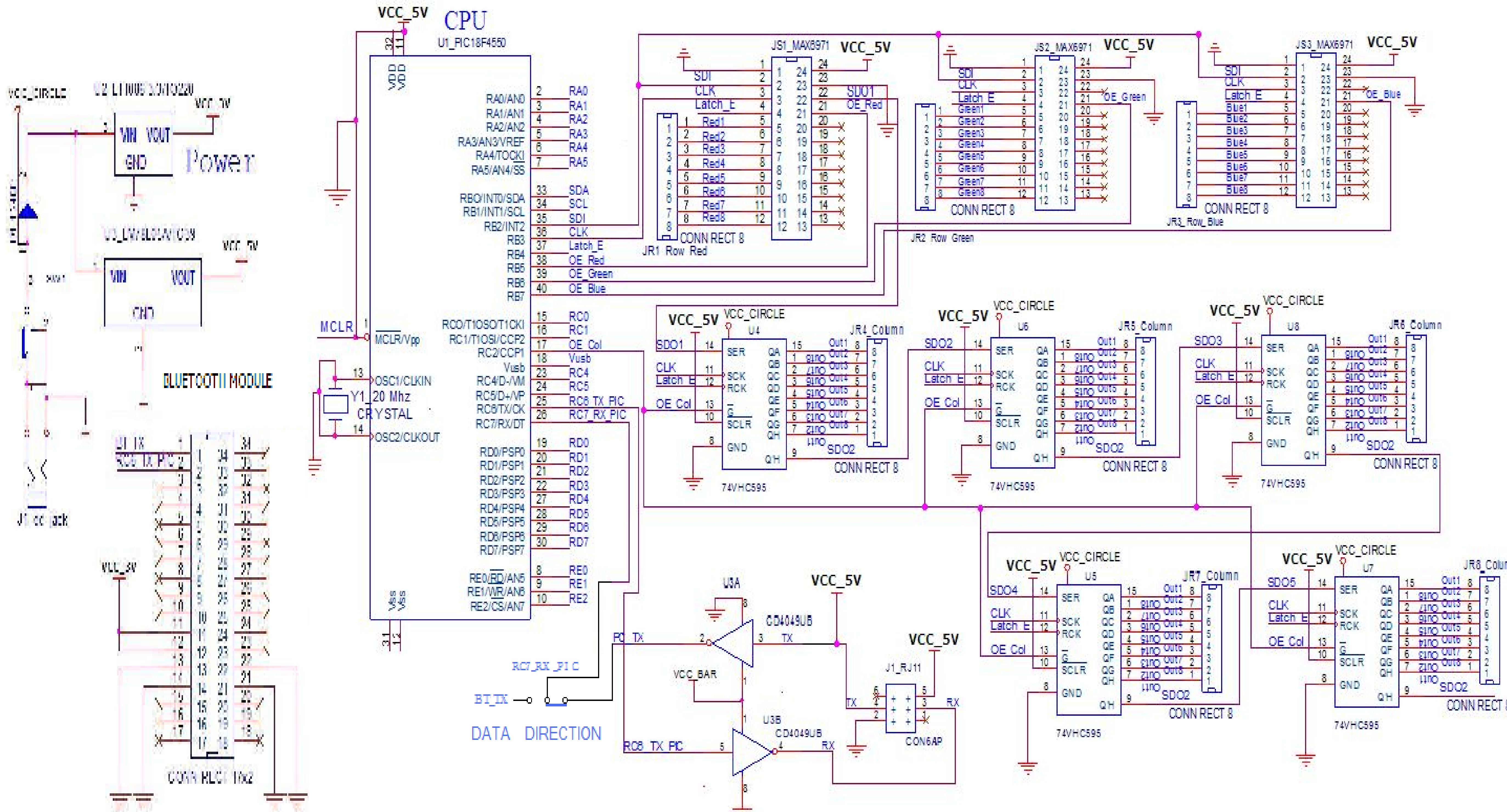

Figure 3.7 – Schematic Diagram

3. The group laid out the circuit diagram of the whole project to guide the development of the design. Figure 3.7 illustrates the circuit diagram of the Power Supply and the Bluetooth Module. The Power Supply as two output voltages, 3V and 5V. The 3V supplies the Bluetooth Module; while the 5V supplies the Microcontroller and the other design components, which is found in Figure 3.8. Figure 3.8 illustrates the circuit diagram for the Color and the Row Drivers implemented by the researchers. It is shown in Figure 3.8 that the Drivers get their voltage input from the Voltage Output that is in Figure 3.7, additional voltage input for the column drivers is taken from the Unregulated Voltage also found in Figure 3.7. Both illustrations show the interconnection between the Microcontroller, the RGB LED drivers, the Drivers, the Bluetooth Module, and the other hardware components. The output ports are the ones that are connected to the RGB Led panel.

Software Design

4. Next is the development of the software component that operates the microcontroller.

Software Component

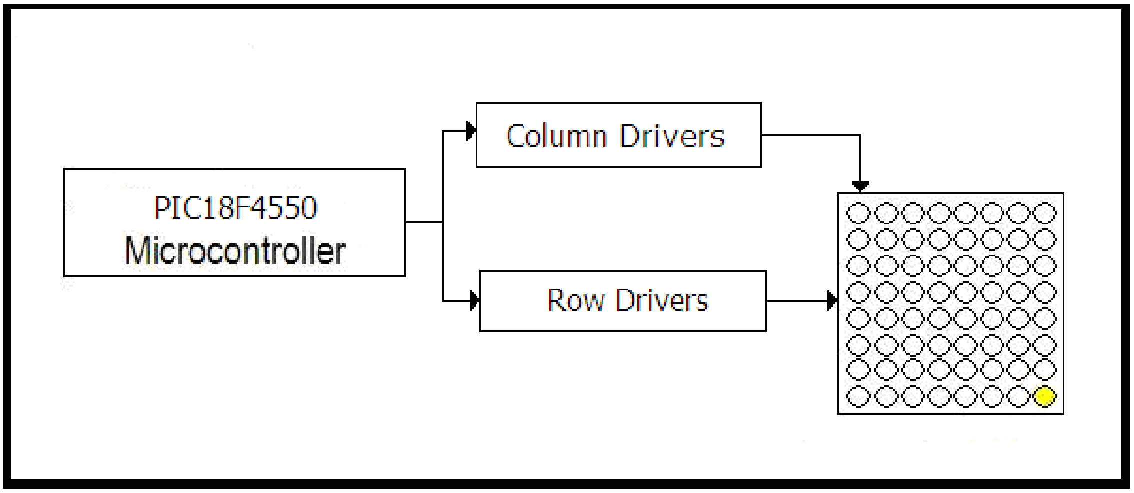

Figure 3.9 –The PIC18F4550 Microcontroller controlling the Led drivers

For the program in the microcontroller, the researchers have used Proton, a python based compiler, to program the PIC18F4550 microcontroller that was used. This software is a powerful application with user-friendly graphical development environment for Windows with integrated simulator (emulator), basic compiler, assembler, disassembler and debugger. It supports the Microchip Technology PIC microcontrollers, which mostly controls the other parts of the design such as the Color Drivers. Figure 3.9 shows the Microcontroller controlling the Column Drivers and the Row Drivers.

Using Pulse Width Modulation to generate multiple colors

Pulse-Width Modulation (PWM) control signal is widely used in embedded control applications for a variety of tasks that include light dimming, output voltage control and communication between devices. In the groups' design, PWM is responsible for the demonstration of multiple colors when “@demo” command is used.

To create different color combinations, the researchers changed the duty cycles of the three PWM outputs over time. One way to do this was to control the three PWM duty cycles with a three phase sinusoidal profile. This generated a rotating (color) vector that would sweep smoothly across the chromaticity plane generating a wide range of color combinations. The three PWM signal would be used to control the brightness of the Red, Green and Blue emitters.

5. After the software design was finished, the next step was to use the PIC programmer kit in order to transfer the program into the PIC Microcontroller.

System Flowchart

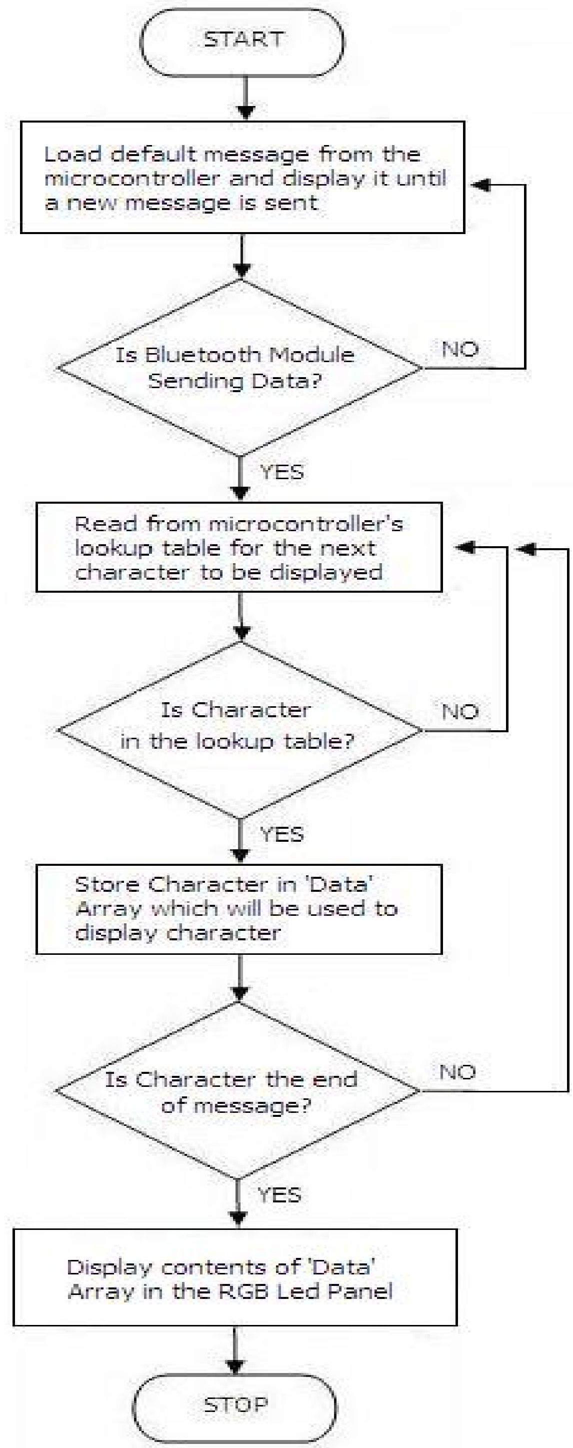

Fig 3.10 – System Flowchart

Figure 3.10 is the system flowchart of the prototype. It briefly shows how the operation of the design starts and when does it end. As shown in the figure, the process starts as the system is turned ON. It will first display the default message that is stored in the Flash storage that is in the microcontroller. Then it will then check on whether the Bluetooth Module is sending a message.

If the Bluetooth Module is sending a message, each character in the message will be then checked, if each character is in the microcontroller's lookup table. If a character is not in the microcontroller's lookup table, it will skip this character and move on to the next one. Meanwhile if the character is in the microcontroller's lookup table, this character will be sent to the 'Data' Array which will be used in displaying the characters.

It will now check if the character is the end of the message character, if not it will go back and get the next character that is sent. Meanwhile, if it is the end character, then it will not display all contents of the 'Data' Array in the RGB Led Panel.

Prototype Development

6. Last is the development of the circuit board and the RGB LED panel.

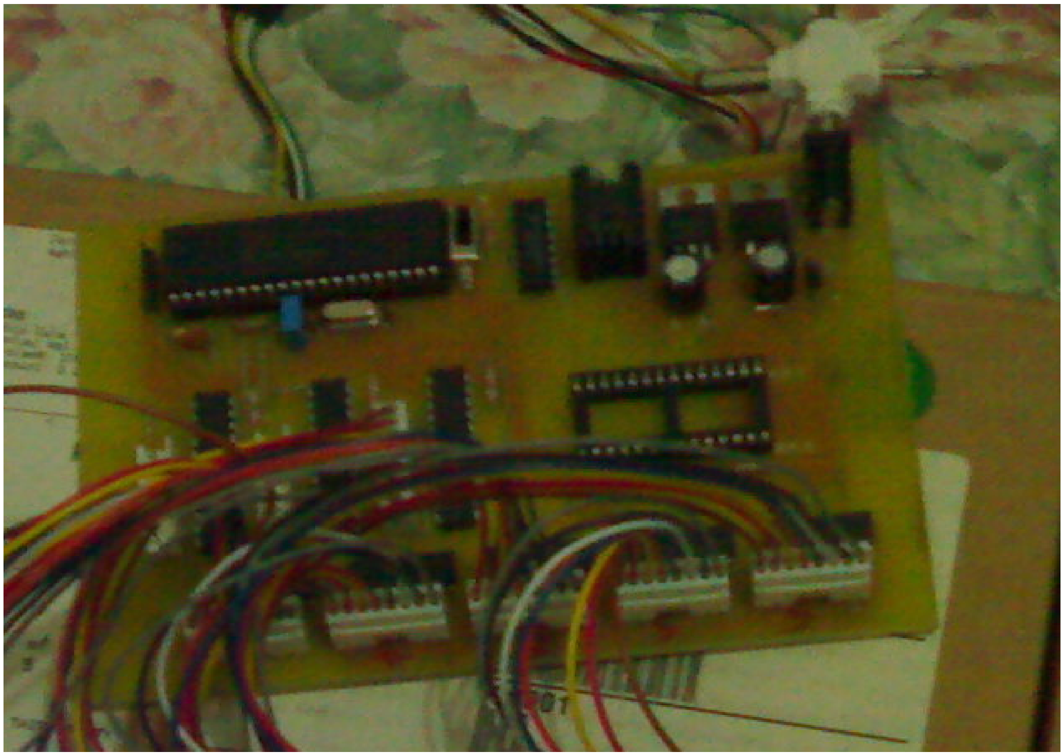

Fig 3.11 – The Circuit Board

The circuit board consists of several components such as the PIC microcontroller which is the overall controller of the RGB LED panel. It also has two types of drivers. The first type is the column drivers; these drivers manipulate the column segment of the panel. The second type is the row and color drivers; these manipulate the color of the panel and the row part of the panel. The circuit board has five ports of an eight-pin connected to the panel. Lastly, it has a voltage regulator that supplies the power for the whole design project.

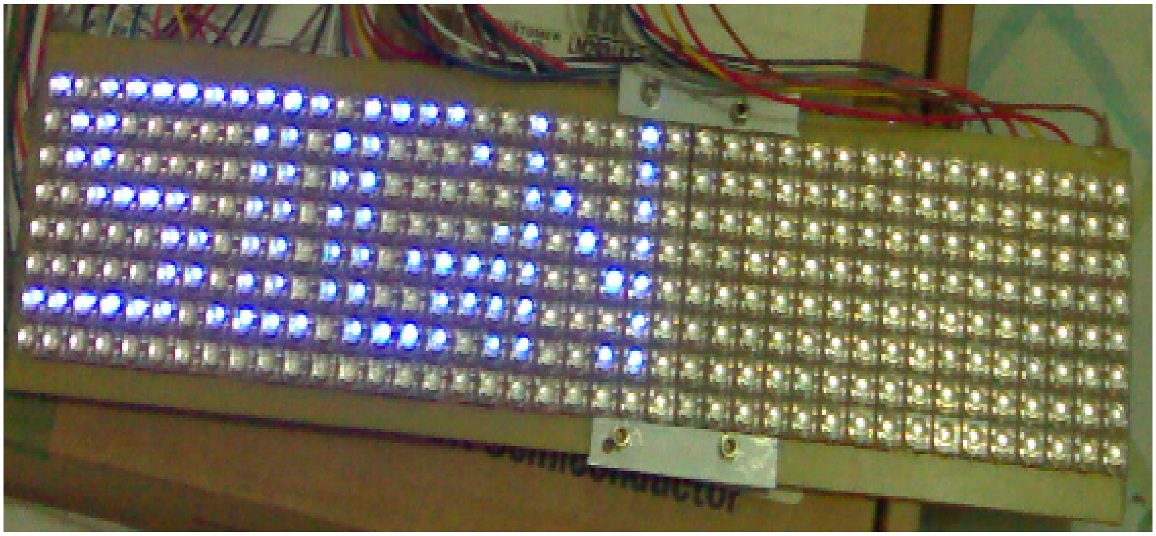

Fig 3.12 – The RGB Led Panel

The RGB LED panel consists of series of RGB LEDs lined up. The actual size of the panel per segment is 8 x 8 RGB. The panel has five segments with a total of 320 RGB LEDs. At the back side of the panel, it has the provision of wires that will be connected to the circuit board thorough via an 8-pin port; 1 8-pin port for each segment also 1 8-pin port for each color.

Chapter 4

TESTING, PRESENTATION AND INTERPRETATION OF DATA

In this chapter, the design was tested to further determine its capability in handling the operation of the whole system. This aspect was important for the design, to determine whether the design would work out as expected or not. Results of the tests are shown below.

Testing was done in four parts. The first part was displaying text messages on the RGB led panel using mobile phone through Bluetooth Technology. This was to test if the design could display user defined messages. The second part was about changing the font color of the message displayed. The third part was to determine whether or not the RGB Quad-LED could generate different colors. The fourth part was concerned with the software that would act as a bridge between the mobile phone and the RGB LED Panel.

Part I: Display characters

The purpose of this test was to display the characters sent via Nokia N70 Music Edition using Bluetooth and to display it to the RGB LED Panel. The characters used were alphabets from A to Z, numbers from 0 to 9 and some special characters.

The researchers assumed that all the characters that were sent would be displayed on the RGB LED panel. These included all alphabets, numeric and some special characters. All sent characters would be displayed with respect to their types and cases.

The procedure conducted by the researchers for this part is as follows:

1. Connect the mobile phone (N70 Music Edition) to the RGB LED Panel via Bluetooth Technology. The mobile phone must have an application called "Bluetooth Chat", which acts as a communication medium for both parties. After a successful connection;

2. The researchers typed the default syntax, "@msg" then followed by the desired characters for testing. After typing the desired characters;

3. The researchers send the message to the RGB LED Panel. The table below shows the results of the test.

Input Character	Output Character
A , a	A , A
B , b	B , B
C , c	C , C
D , d	D , D
E , e	E , E
F , f	F , F
G , g	G , G
H , h	H , H
I , i	I , I
J , j	J , J
K , k	K , K
L , l	L , L
M , m	M , M
N , n	N , N
O , o	O , O
P , p	P , P
Q , q	Q , Q
R , r	R , R
S , s	S , S
T , t	T , T

U , u	U , U
V , v	V , V
W , w	W , W
X , x	X , X
Y , y	Y, Y
Z , z	Z , Z

Table 2 - Character Display (Alphabet)

Input	Output
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

Table 3 - Character Display (Numerical)

Input Character	Output Character
!	!
@	@
<	<
>	>
?	?
.	.
,	,
:	:

Table 4 - Character Display (Special Characters)

The researchers sent characters A to Z to the RGB LED Panel and the same characters were displayed on the RGB LED panel. When the researchers sent lower case characters a to z to the RGB LED Panel, the output characters remained in their respective upper case equivalent. The Panel encountered problems displaying lower case characters that exceeds the 5x7 character frame, characters such as “g”, “q”, “j”, “y” and “p”; that is why the RGB LED Panel is programmed to display all Alphabet characters to be in their respective upper case equivalent. The test results for sending numerical characters 0 to 9 to the RGB Panel are shown in Table 6. The test results for sending special characters are shown in Table 7.

Part II: Testing the seven colors that can be displayed in the RGB Panel.

The testing is about changing the font color of the messages displayed on the RGB LED panel. It is important to have different font colors for an RGB LED Panel that is designed for product marketing. This allows users to have the flexibility on promoting their products, by trying on different colors to attract audiences.

Table 8 shows the expected values for color variations of the font colors for the RGB LED Panel. The left arrow button of the mobile phone is connected to the Red color driver; while the up arrow button of the mobile phone is connected to the Green color driver, and the right arrow button of the mobile phone is connected to the Blue color driver. Pressing these buttons will result to different color combinations. The default color is White.

Condition	Output Color
Default	White
White + Left Button	Aqua Blue
Aqua Blue + Up Button	Blue
White + Right Button	Yellow
Yellow + Left Button	Green

Default + Up Button	Violet
Violet + Right Button	Red

Table 5 – Expected values for color variation

The procedure conducted by the researchers for this part is as follows:

1. First connect the mobile phone (N70 Music Edition) to the RGB LED Panel via Bluetooth Technology with Bluetooth Chat application to be able to communicate to the RGB LED Panel. After a successful connection,

2. Type a test message, "@msg FONT COLOR TEST". After typing the desired characters,

3. Send the message to the RGB LED Panel. When the message is already displayed,

4. Use the keypad arrows (left, right and up) on the mobile phone to create different color combinations.

The table below shows the results of the test.

Condition	Output Color
Default	White
White + Left Button	Aqua Blue
Aqua Blue + Up Button	Blue
White + Right Button	Yellow
Yellow + Left Button	Green
Default + Up Button	Violet
Violet + Right Button	Red

Table 6 – Actual values for color variation

Referring to the results taken during the test, each button would result to a different color combination as expected. When the default color was displayed, this would mean that the red, green and blue colors were on, resulting to the color white. As the left button was pressed, the color red would shut off, resulting to the color Aqua Blue. Going back to the default color white, if the right button was pressed, this would shut off the color Blue and would display the color Yellow. Going back again to the default color white, if the up button was pressed, the color green would be turned off, displaying color Violet. Pressing these arrow keys would result to different color combinations. This would result to 7 different colors as shown in Table 9.

Part III: Generate the multi-colors produced by the RGB Led

The purpose of this test was to verify if the Pulse Width Modulation actually work to the design. It also tested if the special command "@demo" which when transmitted from the mobile phone to the RGB LED Panel would actually display different colors continuously for 26.22 seconds. The distinct number of colors displayed was not 16 million because a person's eye was not capable of distinguishing every color transition.

The researchers assumed that using Pulse Width Modulation (PWM) it would display multiple colors. Table 10, shows the expected distinguishable colors that would be displayed when the "@demo" was transmitted:

Time	**Color Displayed**
1 second	White

2 seconds	Pink
3 seconds	Orange
4 seconds	Yellow
5 seconds	Neon
6 seconds	Light Green
7 seconds	Green
8 seconds	Bright Turquoise
9 seconds	Turquoise
10 seconds	Turquoise
11 seconds	Purple
12 seconds	Light Blue
13 seconds	Aqua Blue
14 seconds	Blue
15 seconds	Azure
16 seconds	Amaranth Pink
17 seconds	Cherry Blossom Pink
18 seconds	Bright Pink
19 seconds	Carrot Orange
20 seconds	Amber
21 seconds	Chartreuse Yellow
22 seconds	Lime
23 seconds	Green-Yellow
24 seconds	Jade
25 seconds	Aqua
26 seconds	Cyan

Table 7 – Expected values for colors that will be generated

The procedure conducted by the researchers for this part is as follows:

1. Connecting the Nokia N70 Music Edition to the RGB LED Panel via Bluetooth Technology. The "Bluetooth Chat" application is used in order to establish the communication between both parties. Then,

2. The command sent is "@demo" which is the default command for producing multiple colors. The demo lasted 26.22 seconds displaying expected color transitions that are shown in Table 11.

Time	Color Displayed
1 second	White
2 seconds	Pink
3 seconds	Orange
4 seconds	Yellow
5 seconds	Neon
6 seconds	Light Green
7 seconds	Green
8 seconds	Bright Turquoise
9 seconds	Turquoise
10 seconds	Turquoise
11 seconds	Purple
12 seconds	Light Blue
13 seconds	Aqua Blue
14 seconds	Blue
15 seconds	Azure
16 seconds	Amaranth Pink
17 seconds	Cherry Blossom Pink
18 seconds	Bright Pink
19 seconds	Carrot Orange
20 seconds	Amber
21 seconds	Chartreuse Yellow
22 seconds	Lime
23 seconds	Green-Yellow
24 seconds	Jade
25 seconds	Aqua
26 seconds	Cyan

Table 8 – Actual values for colors that will be generated

The starting color is White which has an RGB intensity range of 255, 255, and 255. From the initial color, the four LEDs will then transition colors in a counter clockwise direction based on the CIE chart. The colors will be the transition based on the varying clock pulse. For example at time interval 1 sec, the transition is from (white) RGB 255-255-255, to (pink) RGB 255-17-255, to (orange) RGB 255-17-17, to (yellow) 255-255-0, and so on and so forth.

Part IV: Security Tests

The purpose of this test was to know if the "Bluetooth Chat" software could work as a communication medium between the mobile device and the RGB LED Panel.

Tables 10 and 11 show the expected results for the Communication Tests that are divided into two parts; the first test is connecting a mobile phone without a "Bluetooth Chat" to the RGB Panel. The researchers assumed that the RGB Panel would not acknowledge the invitation of Mobile Phones without the application "Bluetooth Chat". The second part is testing whether the Bluetooth communication is a point-to-point connection or not. The researchers assumed that the RGB LED Panel would only accept one user at a time; thus rejecting other user invitation while a user is currently connected.

Table 10 shows the expected comparative result for mobile phones with and without "Bluetooth Chat":

Transmitter	**Result**		
	Trial 1	**Trial 2**	**Trial 3**
Mobile Phone without BT Chat	NOT Acknowledged	NOT Acknowledged	NOT Acknowledged
Mobile Phone with BT Chat	User Acknowledged	User Acknowledged	User Acknowledged

Table 9 – BT Chat Acknowledgement

Table 11 shows the expected results for multiple mobile phones trying to connect to the RGB LED Panel:

Transmitter	Result		
	Trial 1	Trial 2	Trial 3
Mobile Phone A with BT Chat	Connected	Connected	Connected
Mobile Phone B with BT Chat	Not Connected	Not Connected	Not Connected

Table 10 – Point-to-point connection

The procedure conducted by the researchers for this part is as follows:

1. Connect two mobile phones (Nokia N70 Music Edition and a Nokia N90) to the RGB LED Panel via Bluetooth Technology. One mobile phone (Nokia N70 Music Edition) has an application of "Bluetooth Chat", which acts as a communication medium for both parties. The other mobile phone (Nokia N90) has no application installed. Mobile A and Mobile B will try to connect simultaneously to the RGB LED Panel. After finishing the first part,

2. The researchers followed the second test by which two mobile phones (Nokia N70 Music Edition and Nokia N73) would try to connect to the RGB LED Panel via Bluetooth Technology. Both mobile phones have an application of "Bluetooth Chat" to communicate to the RGB LED Panel. Both mobile phones will simultaneously try to connect.

The table below shows the results of both actual tests:

Transmitter	**Result**		
	Trial 1	**Trial 2**	**Trial 3**
Nokia N90 without BT Chat	NOT Acknowledged	NOT Acknowledged	NOT Acknowledged
Nokia N70 with BT Chat	User Acknowledged	User Acknowledged	User Acknowledged

Table 11 – Actual values for BT Chat Acknowledgement

Transmitter	**Result**		
	Trial 1	**Trial 2**	**Trial 3**
N70 with BT Chat	Connected	Connected	Connected
N73 with BT Chat	Not Connected	Not Connected	Not Connected

Table 12 – Actual values for Point-to-point connection

Referring to Table 12, the results are clearly seen in the three trials made, that the RGB LED Panel only accepts the mobile with the "Bluetooth Chat" application. The "Bluetooth Chat" application acts as a communication medium between the mobile phone and the RGB LED Panel. In the second part of the test, Table 13 shows what kind of Bluetooth connection is used in the design; based on the results of the test, the design uses point-to-point communication. Meaning, if a mobile phone is connected to the design, the design will reject all incoming invitations. The design will be available again, when the mobile phone that is currently connected decides to disconnect.

Chapter 5

CONCLUSION AND RECOMMENDATION

Conclusion

The group was able to develop a design called Programmable 24-Bit RGB LED Panel via Bluetooth® Technology, using RGB Quad Led to display text messages in different colors. The design cannot display the 16 million colors distinctively due to eye limitation which is not capable of seeing each color transition. The security of the design is very important to keep the integrity of the data being displayed; this was accomplished by improvising application software on mobile phones to limit the use of the design.

With the use of the system, small businesses or stores can have an alternative way to lessen the cost of their advertisement for their products, due to sending data via Bluetooth® Technology does not require the user to have load on their mobile phones unlike previous designs that used SMS Technology.

Recommendation

More improvements can be made to further enhance the systems functionality and capability. Security feature such as authorization of mobile device before changing the displayed message is one of the enhancements that the group recommends, so that no one can easily change the displayed message in the display panel. Also, for the Bluetooth® range to be extended. The display panels can be enlarged as those seen on main highways in the metropolis. Additional features like display large images and animated images can further improve this design.

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APPENDICES

APPENDIX A

Programmable 24-bit RGB LED Color Panel via Bluetooth Technology

User's Manual

Prepared by:

Albert M. Agonoy
Antonio Rufo R. Cuenco
Lillette C. Daplas
Mark Dale A. Nieveras

Mapua Institute of Technology
May 2009

WARNINGS

To avoid electrical shock, refrain from holding any exposed wires of the device.

- This device is intended for adults use only. If the child wants to use the device, parents should supervise him/her.
- Avoid prolonged use of the product in dark rooms/areas so to avoid eye strains.

SAFETY PRECAUTIONS

- ✓ For your safety, always unplug the device while it is not in use.
- ✓ The device is mainly used for indoors.
- ✓ The device uses 220 V of electricity.
- ✓ Only use the authorized plug adaptor for this device.

THE 24-BIT PROGRAMMABLE RGB LED DISPLAY

This device is a small-scale model for digital display that uses RGB LED (light emitting diode). This LED displays multiple colors and uses the Bluetooth technology. The Bluetooth acts as a communication medium between the display panel and the mobile phone.

BEFORE USING THE DEVICE

- Only Nokia N70 version mobile phones or early Symbian 60 OS mobile phones can interact with the device provided that the mobile phone has an installed application called "BT CHAT".
- Make sure that the operating condition of the area is dry and well-ventilated.

OPERATING THE DEVICE

THE RGB LED Panel Display:

1. Open the top flip of the box.
2. Connect the power adaptor to the panel’s power port.
3. Plug the power adaptor to the wall outlet.
4. The panel shows the pre-installed message; the panel is ready for use.

Using the Mobile Bluetooth Chat:

1. Press the  menu button of the N70 mobile phone
2. Select Connectivity → Bluetooth
3. Highlight Bluetooth, then press
   Options→ Change→ ON
4. Then press Exit
5. To operate Bluetooth, Select My Own → Bluetooth Chat
6. To connect the mobile phone to the RGB Panel via Bluetooth, select Options → Connect.
7. When it searches “E-gizmo” Select and press Connect.
8. You are now connected to the Panel.
9. To disconnect, press Option → Disconnect.
10. To Exit, just press the EXIT then it will go back to the My Own Folder.

TO Send Messages

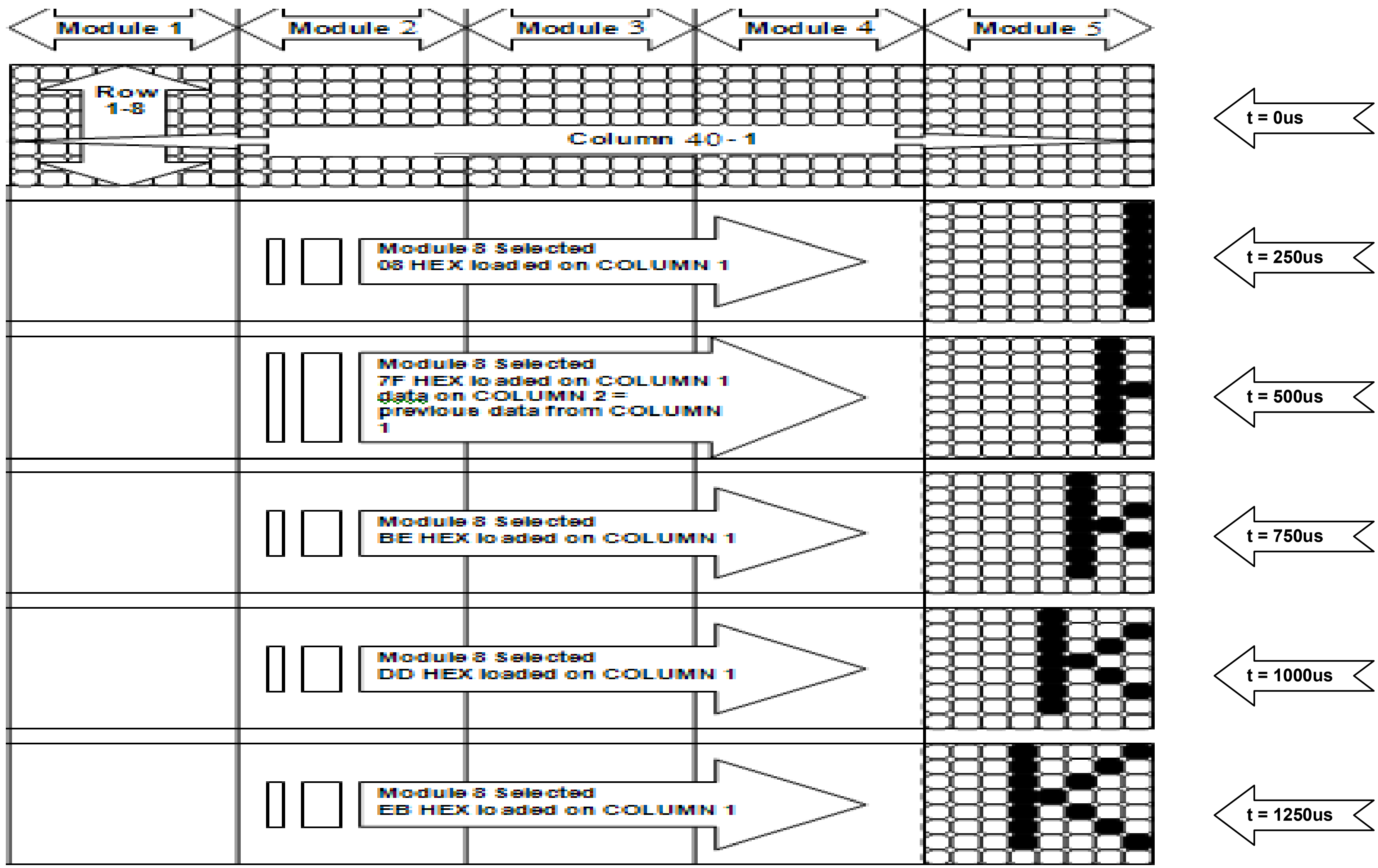
1. Type on the textbox, the “@msg” syntax then followed by 5 spaces then type the desired message you want to be displayed.
2. Press Options → Send.

3. Then it will display the Message you have sent.

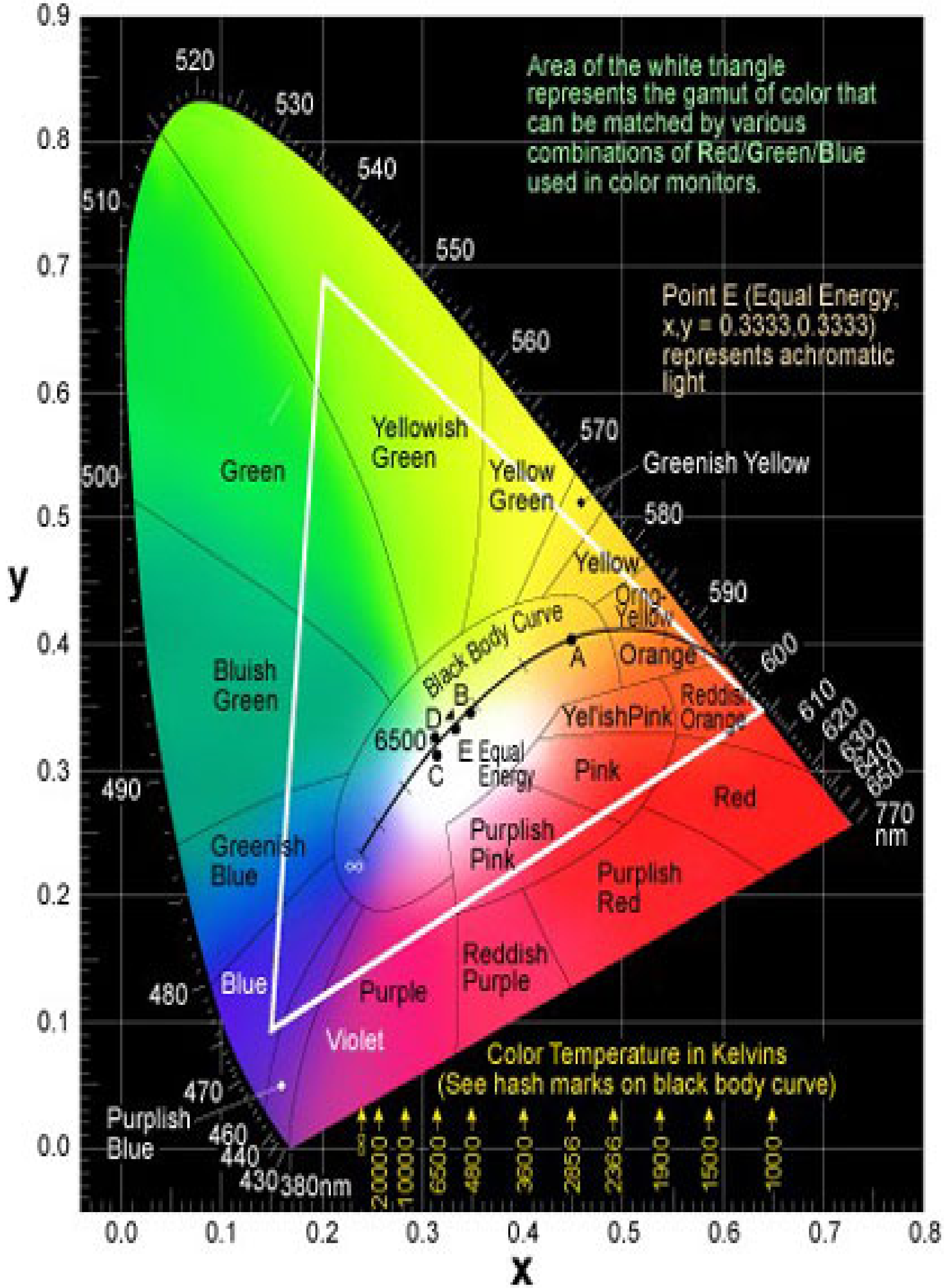
TO Show the Color spectrum

1. Type on the textbox “@demo”
2. Press Options → Send.
3. It will show the color spectrum of the Panel.

APPENDIX B
Diagram for Character Loading



APPENDIX C
Color Spectrum



APPENDIX D
Data Sheet of Maxim 6971

19-3508; Rev 1; 1/07

EVALUATION KIT AVAILABLE

MAXIM

16-Port, 36V Constant-Current LED Driver

MAX6971

General Description

The MAX6971 serial-interfaced LED driver provides 16 open-drain, constant-current-sinking LED driver outputs rated at 36V. The MAX6971 operates from a 3V to 5.5V supply. The MAX6971 supply and the LEDs' supply or supplies can power up in any order. The constant-current outputs are programmed together to up to 55mA using a single external resistor. The MAX6971 operates with a 25Mb, industry-standard, 4-wire serial interface.

The MAX6971 uses the industry-standard, shift-register-plus-latch-type serial interface. The driver accepts data shifted into a 16-bit shift register using data input DIN and clock input CLK. Input data appears at the DOUT output 16 clock cycles later to allow cascading of multiple MAX6971s. The latch-enable input, LE, loads the 16 bits of shift register data into a 16-bit output latch to set which LEDs are on and which are off. The output-enable, $\overline{OE}$, gates all 16 outputs on and off, and is fast enough to be used as a PWM input for LED intensity control.

For applications requiring LED fault detection, refer to the MAX6983, which automatically detects open-circuit LEDs.

For safety-related applications requiring a watchdog timer, refer to the MAX6983, which includes a fail-safe feature that blanks the display if the serial interface becomes inactive for more than 1s.

The MAX6971 is one of a family of 12 shift-register-plus-latch-type LED drivers. The family includes 8-port and 16-port types, with 5.5V- or 36V-rated LED outputs, with and without open-circuit LED detection and watchdog. All versions operate from a 3V to 5.5V supply, and are specified over the -40°C to +125°C temperature range.

Applications

Variable Message Signs

Marquee Displays

Point-of-Order Signs

Traffic Signs

Gaming Features

Architectural Lighting

Features

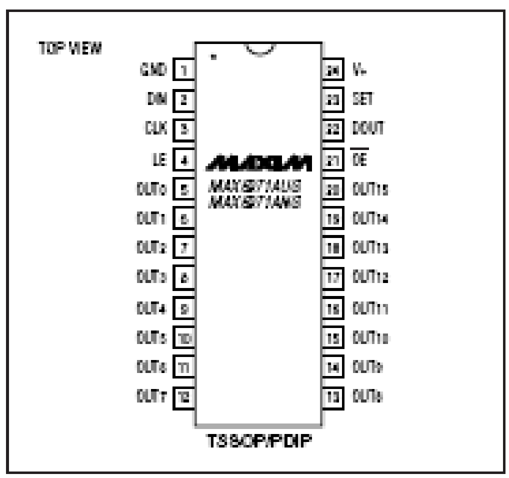
- 25Mb, Industry-Standard, 4-Wire Serial Interface
- 3V to 5.5V Logic Supply
- 16 Constant-Current LED Outputs Rated at 36V
- Up to 55mA Continuous Current per Output
- Output Current Programmed by Single Resistor
- 3% Current Matching Between Outputs
- 6% Current Matching Between ICs
- High-Dissipation, 24-Pin Packages
- -40°C to +125°C Temperature Range

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX6971AUG	-40°C to +125°C	24 TSSOP
MAX6971ANG	-40°C to +125°C	24 Narrow PDIP

Typical Application Circuit and Selector Guide appear at end of data sheet.

Pin Configuration



Detailed Description

The MAX6971 LED driver comprises a 4-wire serial interface driving 16 constant-current-sinking, open-drain output ports. The outputs drive LEDs in either static or multiplex applications (Figure 1). The constant-current outputs are guaranteed for current accuracy not only with chip-supply voltage variations (5V ±10% and 3V to 5.5V), but also over a realistic range of driver output voltage drop (0.8V to 2.5V). The drivers use current-sensing feedback circuitry (not simple current mirrors) to ensure very small current variations over the full allowed range of output voltage (see the *Typical Operating Characteristics*).

The 4-wire serial interface comprises a 16-bit shift register and a 16-bit transparent latch. The shift register is written through a clock input, CLK, and a data input, DIN, and the data propagates to a data output, DOUT. The data output allows multiple drivers to be cascaded and operated together. The contents of the 16-bit shift register are loaded into the transparent latch through a latch-enable input, LE. The latch is transparent to the shift register outputs when high, and latches the current state on the falling edge of LE.

Each driver output is an open-drain, constant-current sink that should be connected to the cathode of either a single LED or a series string of multiple LEDs. The LED anode can be connected to a supply voltage of up to 36V, independent of the MAX6971 supply, V+. The constant-current capability is up to 55mA per output, set for all eight outputs by an external resistor, R_{SET}.

4-Wire Serial Interface

The serial interface on the MAX6971 is a 4-wire serial interface using four inputs (DIN, CLK, LE, $\overline{OE}$) and a data output (DOUT). This interface is used to write display data to the MAX6971. The serial-interface data word length is 16 bits, D0–D15. See Figure 2.

The functions of the five interface pins are as follows. DIN is the serial-data input, and must be stable when it is sampled on the rising edge of CLK. Data is shifted in, MSB first. This means that data bit D15 is clocked in first, followed by 15 more data bits finishing with the LSB, D0.

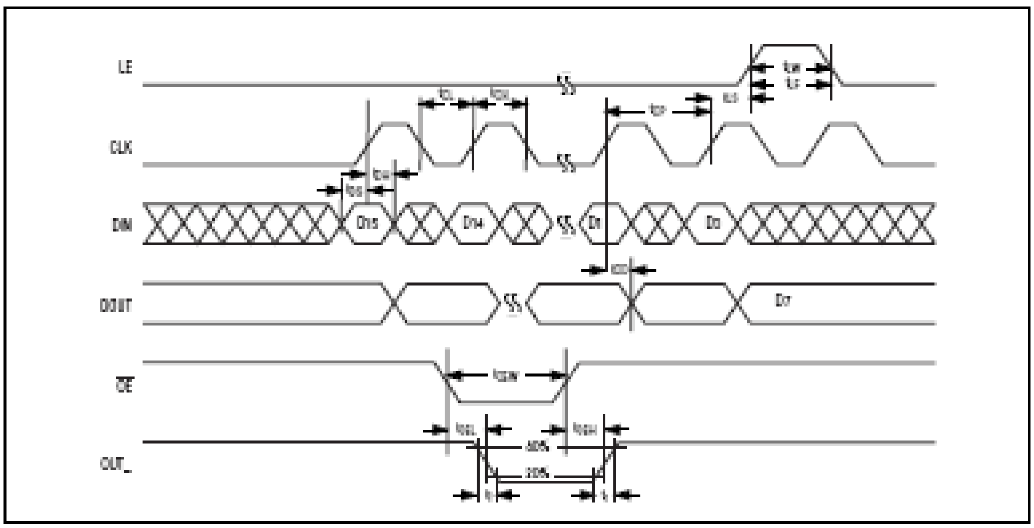


Figure 2. 4-Wire Serial-Interface Timing Diagram

APPENDIX E
Bluetooth Serial Converter UART Interface

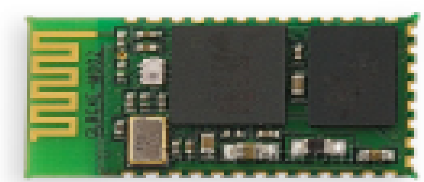
SURE electronics

BLUETOOTH SERIAL CONVERTER
UART INTERFACE
USER'S GUIDE

Chapter1. Bluetooth Serial Converter UART Interface

Key Features

- Bluetooth Spec v2.0+EDR Compliant
- Enhanced Data Rate (EDR) compliant with V2.0.E.2 of specification for both 2Mbps and 3Mbps modulation modes
- Class 2 Type Output Power
- Full Speed Bluetooth Operation with Full Piconet Support
- Scatternet Support
- 3.3V Operation
- Minimum External Components
- UART Interface
- Support for 8Mbit External Flash Onboard
- Support for 802.11Co-Existence
- RoHS Compliant



Product Description

GL-6B is a Class 2 Bluetooth module using BlueCore4-AudioROM chipset from leading Bluetooth chipset supplier Cambridge Silicon Radio.

Applications

- Bluetooth Carkit
- PCs
- Computer Accessories
- Access Points

Bluetooth Serial Converter UART Interface

Specifications

Operating Frequency Band	2.4GHz-2.48GHz unlicensed ISM band
Bluetooth Specification	V2.0+EDR
Output Power Class	Class2
Operating Voltage	3.3V
Host Interface	UART
Dimension	26.9mm(L)×13mm(W)×2.2mm(H)

* Specification are subject to change without prior notice

Electronics Characteristics

Absolute Maximum Ratings		
Rating	Min	Max
Storage Temperature	-40℃	+150℃
Supply Voltage	-0.4V	5.6V
Other Terminal Voltage	VSS-0.4V	VDD+0.4V

Recommended Operating Conditions		
Operating Conditions	Min	Max
Operating Temperature Range	-40℃	+150℃
Guaranteed RF Perfomance Range*	-40℃	+150℃
Supply Voltage	2.2V	4.2V

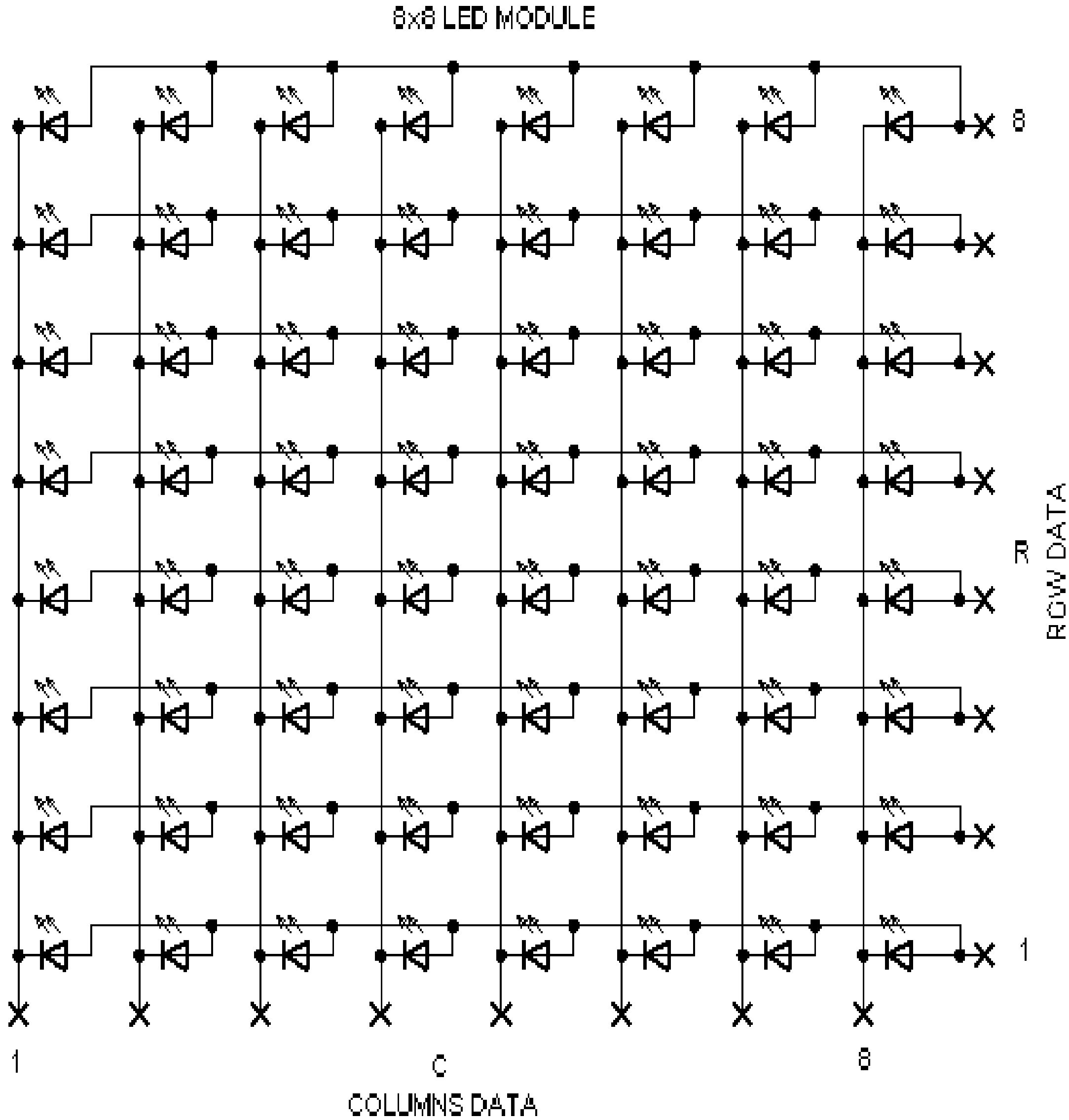
* Typical figures are given for RF performance between -40℃ and +105℃.

Power Consumption

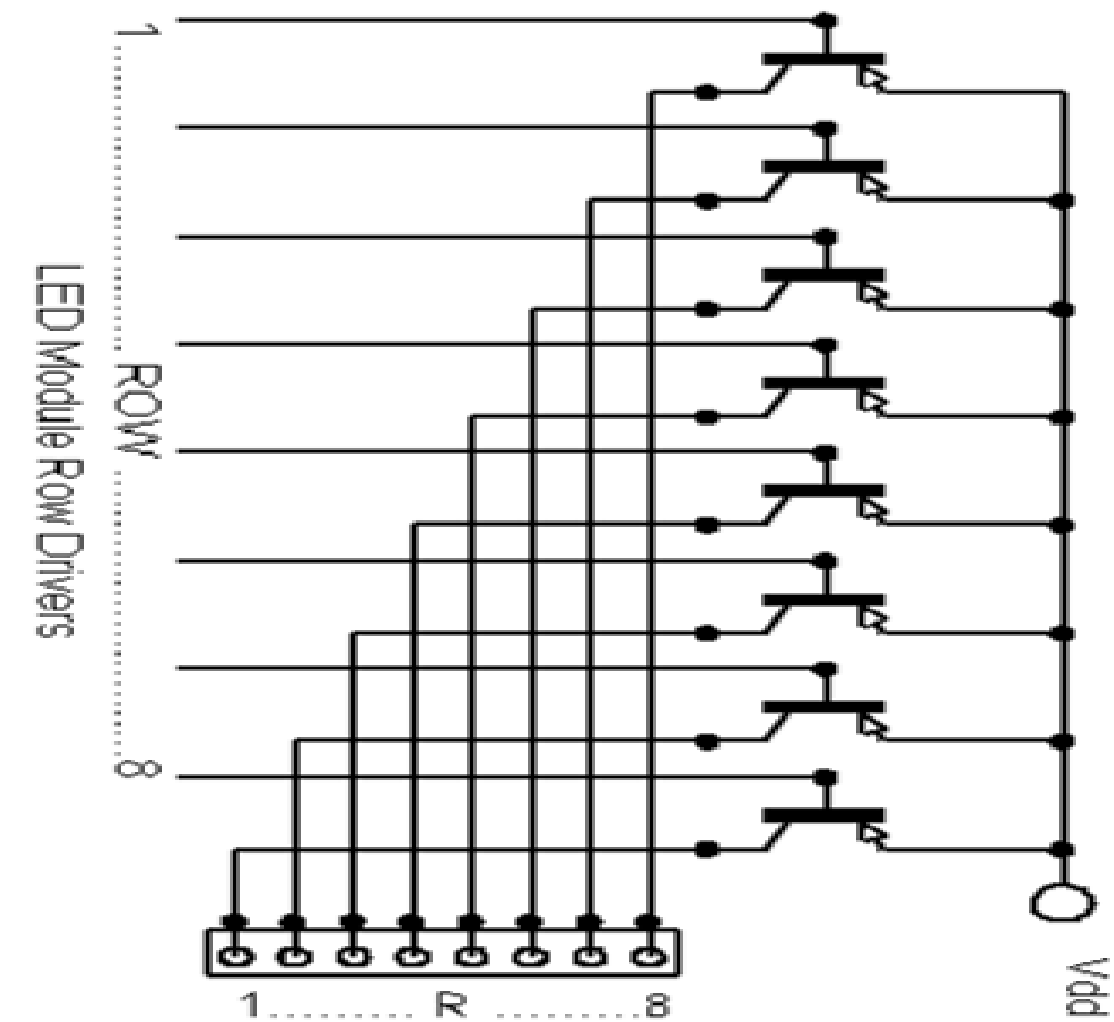
Operation Mode	Connection Type	UART Rate (Kbps)	Average	Unit
Page Scan	-	115.2	0.42	mA
ACL No Traffic	Master	115.2	4.60	mA
ACL with File Transfer	Master	115.2	10.3	mA
ACL 1.28s Sniff	Master	38.4	0.37	mA
ACL 1.28s Sniff	Slave	38.4	0.42	mA
Standby Host Connection	-	38.4	40	µA

* Low power mode on the linear regulator is entered and exited automatically when the chip enters/leaves Deep Sleep mode. For more information about the electrical characteristics of the linear regulator, see section 4 in this document.

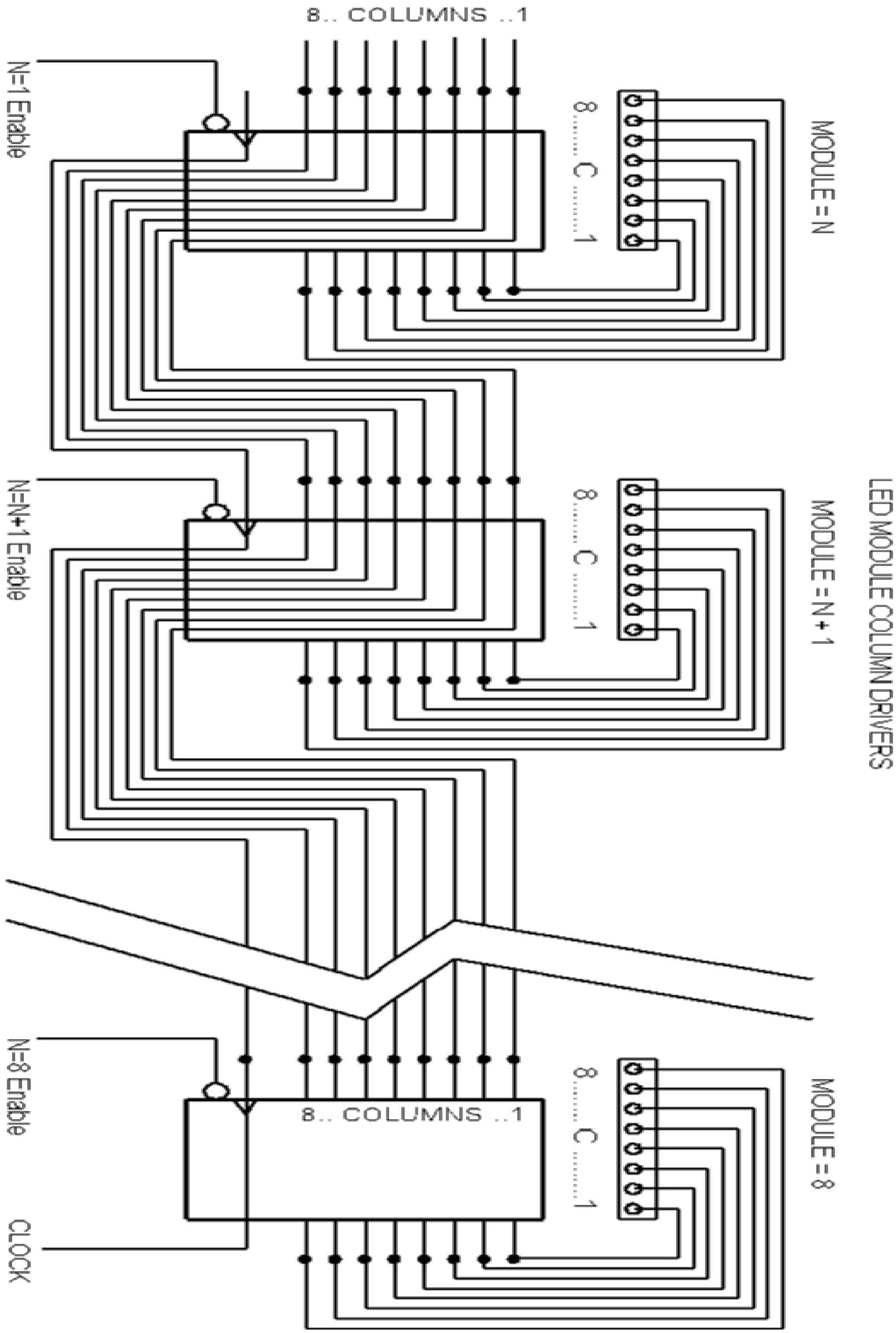
APPENDIX F
Figures



8 x 8 LED MODULE; FIVE OF THESE MODULES MAKE UP THE RGB LED PANEL.



LED MODULE ROW DRIVERS



LED MODULE COLUMN DRIVERS

APPENDIX G
Source Code

```
'****************************************************************
'*  Name    : UNTITLED.BAS
'*  Author  : Antonio Rufo R. Cuenco
'*  Notice  : Copyright (c) 2008 Strategic Instruments
'*          : All Rights Reserved
'*  Date    : 11/26/2008
'*  Version : 1.0
'*  Notes   : Sourcecode to test DM135 shift-registers
'*          :
'****************************************************************

Device = 18F4550

'Declare XTAL 20

CONFIG_START
        PLLDIV = 5              ' prescale (Divide by 5 (20 MHz oscillator input)
                        ' default 4mhz result in 48mhz with PLL enabled other osc
input needs to be prescaled
                        ' or divided to have a reult of 4mhz example 20/5 = 4 always
should be 4!!!
        CPUDIV = OSC1_PLL2      ' postscale [OSC1/OSC2 Src: /1][96 MHz PLL
Src: /2]
        USBDIV = 2              ' USB clock source comes from the 96 MHz
PLL divided by 2
        FOSC = HSPLL_HS     'HS    'HS oscillator, PLL enabled, HS used by USB
        FCMEN = OFF                     ' Fail-Safe Clock Monitor disabled
        IESO = OFF              ' Oscillator Switchover mode disabled
        PWRT = On               ' PWRT enabled
        BOR = On                ' Brown-out Reset enabled in hardware only
(SBOREN is disabled)
        BORV = 3                ' Minimum setting
        VREGEN = OFF            ' USB voltage regulator disabled
        WDT = OFF               ' HW Disabled - SW Controlled
        WDTPS = 1024            ' 1:1024
        MCLRE = On              ' MCLR pin Disabled' RE3 input pin enabled
        LPT1OSC = On            ' Timer1 configured for low-power operation
        PBADEN = OFF            ' PORTB<4:0> pins are configured as digital
I/O on Reset
        CCP2MX = On                     ' CCP2 input/output is multiplexed with
RC1
        STVREN = OFF            ' Stack full/underflow will not cause Reset
```

```
        LVP = OFF                   ' Single-Supply ICSP disabled
        ICPRT = OFF                 ' ICPORT disabled
        XINST = OFF                 ' Instruction set extension and Indexed
Addressing mode disabled
        Debug = OFF                         ' Background debugger disabled, RB6
and RB7 configured as general purpose I/O pins
        CP0 = OFF                   ' Block 0 (000800-001FFFh) not code-
protected
        CP1 = OFF                   ' Block 1 (002000-003FFFh) not code-
protected
        CP2 = OFF                   ' Block 2 (004000-005FFFh) not code-
protected
        CP3 = OFF                   ' Block 3 (006000-007FFFh) not code-
protected
        CPB = OFF                   ' Boot block (000000-0007FFh) not code-
protected
        CPD = OFF                   ' Data EEPROM not code-protected
        WRT0 = OFF                  ' Block 0 (000800-001FFFh) not write-
protected
        WRT1 = OFF                  ' Block 1 (002000-003FFFh) not write-
protected
        WRT2 = OFF                  ' Block 2 (004000-005FFFh) not write-
protected
        WRT3 = OFF                  ' Block 3 (006000-007FFFh) not write-
protected
        WRTB = OFF                  ' Boot block (000000-0007FFh) not write-
protected
        WRTC = OFF                  ' Configuration registers (300000-3000FFh)
not write-protected
        WRTD = OFF                  ' Data EEPROM not write-protected
        EBTR0 = OFF                         ' Block 0 (000800-001FFFh) not
protected from table reads executed in other blocks
        EBTR1 = OFF                         ' Block 1 (002000-003FFFh) not
protected from table reads executed in other blocks
        EBTR2 = OFF                         ' Block 2 (004000-005FFFh) not
protected from table reads executed in other blocks
        EBTR3 = OFF                         ' Block 3 (006000-007FFFh) not
protected from table reads executed in other blocks
        EBTRB = OFF                         ' Boot block (000000-0007FFh) not
protected from table reads executed in other blocks
CONFIG_END

'************************** Variables Allocations
**************************
Dim CHAR_String[256]    As Byte
```

```
Dim S_Holder As String * 4
Dim BytesIn[256]       As Byte
Dim A_Holder[4]        As Byte
Dim null               As Byte
Dim CHAR_Column[40]    As Byte
Dim CHAR_count         As Word
Dim Matrix_Column      As Word
Dim Matrix_Column1     As Word
Dim Matrix_Column2     As Word
Dim Matrix_Column3     As Word
Dim Matrix_Column4     As Word
Dim Matrix_Column5     As Word
Dim Segment            As Byte
Dim Segment_holder     As Byte
Dim Speed              As Byte
Dim Segment_Count      As Word
Dim Total_Segment      As Word
Dim Loop               As Word
Dim ind                As Word
Dim Loop_COUNT         As Word
Dim Ram_LEFT           As Byte
Dim CHAR_Reload        As Word
Dim MSSG_END           As Word
Dim dummy              As Word
Dim TIMER0             As TMR0L.Word
Dim Ph_Val             As Byte
Dim StrReload_bit      As Bit
Dim CHANGE_BIT         As Bit
Dim first_run_bit      As Bit
Dim Color_Red          As Bit
Dim Color_Green        As Bit
Dim Color_Blue         As Bit
Dim PWM0               As Bit
Dim PWM1               As Bit
Dim PWM2               As Bit
Dim Loop_bit           As Bit
Dim Demo_bit           As Bit
Dim Demo_flag          As Bit


Dim IntCount As Byte
Dim DutyCycle0 As Byte                    ' Holds duty cycle for PWM channel
0
```

```
Dim DutyCycle1 As Byte                    ' Holds duty cycle for PWM channel
1
Dim DutyCycle2 As Byte                    ' Holds duty cycle for PWM channel
2
Dim PWMFlags As Byte                      ' Used for software flags

Dim Temp As Byte
Dim Phase As Word                         ' Holds the sinusoidal pointer location
Dim BeginPWM As PWMFlags.0

Clear

'*************************** Peripherals Setup
***************************
ONBOARD_USB = False                                  ' Disable the USB and
free the extra RAM
OPTIMISER_LEVEL = 3                                           ' Maximum
optimiser
DEAD_CODE_REMOVE = On                     ' Remove redundant ASM
ALL_DIGITAL = True
WARNINGS = OFF
REMINDERS = OFF


TRISA=%00000000                'set ports for input or output

TRISB = %00000001                          ' Make the last four bits of PortB
Outputs
INTCON2.7 = 0                            ' Enable Internal PortB Pullup Resistors

TRISC=%10000000                'just make sure the USART RX Port C.7 is an
input
TRISD=%00000000                'and the LCD ports are set up correctly
TRISE=%00000000

'**************************** USART Interrupt Setup
***************************

'Declare FSR_CONTEXT_SAVE = off
'On_Interrupt GoTo USART_Int        ' define interrupt handler
'INTCON = %11000000
PIE1.5 = 1 ' enable interrupt on USART receive

'RCSTA = $90   ' Enable serial port & continuous receive
'TXSTA = $20   ' Enable transmit, BRGH = 0
```

```
'SPBRG = 112   ' 4800 Baud @ 48MHz, 0.0%
'SPBRGH = 2
'BAUDCON.3 = 1 ' Enable 16 bit baudrate generator


RCSTA = $90   ' Enable serial port & continuous receive
TXSTA = $24   ' Enable transmit, BRGH = 1
SPBRG = 225   ' 9600 Baud @ 48MHz, 0.0%
SPBRGH = 4
BAUDCON.3 = 1 ' Enable 16 bit baudrate generator


'**************************** T0CON: TIMER0 Control Register Interrupt
Setup    ***************************
'
' T0CON: TIMER0 Control Register
'
        Symbol TMR0ON = T0CON.7                                        '
TIMER0 On/Off Control bit

                    '       1 = Enables TIMER0

                    '       0 = Stops TIMER0
        Symbol T08BIT = T0CON.6
        ' TIMER0 8-bit/16-bit Control bit

                    '       1 = TIMER0 is configured as an 8-bit timer/counter

                    '       0 = TIMER0 is configured as a 16-bit timer/counter
        Symbol T0CS = T0CON.5                                          '
TIMER0 Clock Source Select bit

                    '       1 = Transition on T0CKI pin

                    '       0 = Internal instruction cycle clock (CLKO)
        Symbol T0SE = T0CON.4                                          '
TIMER0 Source Edge Select bit

                    '       1 = Increment on high-to-low transition on T0CKI pin

                    '       0 = Increment on low-to-high transition on T0CKI pin
        Symbol PSA = T0CON.3                                           '
TIMER0 Prescaler Assignment bit
```

```
                '       1 = TIMER0 prescaler is NOT assigned. TIMER0 clock input
bypasses prescaler.

                '       0 = TIMER0 prescaler is assigned. TIMER0 clock input
comes from prescaler output.
        Symbol T0PS2 = T0CON.2
        '|
        Symbol T0PS1 = T0CON.1
        '  TIMER0 Prescaler Select bits
        Symbol T0PS0 = T0CON.0
        '/

                '       111 = 1:256 prescale value

                '       110 = 1:128 prescale value

                '       101 = 1:64 prescale value

                '       100 = 1:32 prescale value

                '       011 = 1:16 prescale value

                '       010 = 1:8 prescale value

                '       001 = 1:4 prescale value

                '       000 = 1:2 prescale value



'**************************** Interrupt Priority Setup
***************************

' INTCON1: Interrupt Control Register 1
'
        Symbol GIE = INTCON.7                                           '
Global Interrupt Enable bit

                '       When IPEN (RCON.7) = 0:

                '               1 = Enables all unmasked interrupts

                '               0 = Disables all interrupts
```

```
'	When IPEN (RCON.7) = 1:
'		1 = Enables all high priority interrupts
'		0 = Disables all interrupts
	Symbol PEIE = INTCON.6				' |
	Symbol GIEL = INTCON.6								'/
Peripheral Interrupt Enable bit
'	When IPEN (RCON.7) = 0:
'		1 = Enables all unmasked peripheral interrupts
'		0 = Disables all peripheral interrupts
'	When IPEN (RCON.7) = 1:
'		1 = Enables all low priority peripheral interrupts
'		0 = Disables all low priority peripheral interrupts
	Symbol TMR0IE = INTCON.5							'
TIMER0 Overflow Interrupt Enable bit
										' 1 = Enables
the TIMER0 overflow interrupt
'	0 = Disables the TIMER0 overflow interrupt
	Symbol TMR0IF = INTCON.2							'
TIMER0 Overflow Interrupt Flag bit
'	1 = TIMER0 register has overflowed (must be cleared in
software)
'	0 = TIMER0 register did not overflow
'
' INTCON2: Interrupt Control Register 2
'
	Symbol TMR0IP = INTCON2.2							'
TIMER0 Overflow Interrupt Priority bit
'	1 = High priority
'	0 = Low priority
```

```
''**************************** PIR1: Peripheral Interrupt Request
Register 1 Setup    **************************

' RCON: Reset Control Register
'
        Symbol IPEN = RCON.7                                          '
Interrupt Priority Enable bit

                '       1 = Enable priority levels on interrupts

                '       0 = Disable priority levels on interrupts


'-----------------------------------------------------------------------

        INTCON =  0
        ' Disable Interrupts (just in case)
'
' Setup TIMER0
'
        T0PS2 = 0
        ' |
        T0PS1 = 0                           '   TIMER0 Prescaler to 1:2
        T0PS0 =      0                          ' /
        PSA = 0
                ' Assign the prescaler
        T0CS = 0
        ' Increment on the internal Clk
        T0SE = 0                            ' 0 = Increment On low-to-high
transition On T0CKI pin
   T08BIT = 0
        ' TIMER0 is configured as a 16-bit counter
        TIMER0 = 0
        ' Clear TIMER0

        TMR0ON = 0
                ' Enable TIMER0 off for a while
        TMR0IE = 1
                                        ' Interrrupt Priorities
        TMR0IP = 0
        IPEN   = 0
```

```
'******************************* Constants
***************************

IntCount = 32                  ' Initialise IntCount to 32
DutyCycle0 = 0                 ' |
DutyCycle1 = 0                 '   Clear the Duty Cycle Variables
DutyCycle2 = 0                 ' /
Symbol True = 1
Symbol False = 0
Symbol DTA PORTB.2
Symbol CLK PORTB.3
Symbol Latch_E PORTB.4
Symbol OE_Red PORTB.5
Symbol OE_Green PORTB.6
Symbol OE_Blue PORTB.7
Symbol OE_Col PORTC.2
Symbol EOM = 255 '"`"
Symbol Loop_START = 0
Symbol Loop_END = 39

'******************************* Initial Values
***************************

Demo_bit = 0
TIMER0 = 63670
Ph_Val = 255
Phase = 0                      ' Initialise the sinusoidal pointer to 0
first_run_bit = 0
Loop_bit = 1
Speed = 3
Latch_E = 1
OE_Red = 1
OE_Green = 1
OE_Blue = 1
OE_Col = 1
Color_Red = 0
Color_Green = 0
Color_Blue = 0

   HRSOut "Type some characters in the terminal window\n\r",_
      "and they will appear on the LCD.",_
      "Note that no characters are missed\n\r",_
      "even though there is a stupidly large delay within the receiving
loop.\n\r"     ' USART Tx Test
```

```
'---------------------------------------------------------------------------------------------
----------------------------------

'     Include "BUFFERED_HSERIN.INC"    ' Load the USART 1 interrupt handler
and buffer read subroutines into memory
'
'     INIT_USART_INTERRUPT            ' Initiate the USART 1 serial buffer
interrupt
'     CLEAR_SERIAL_BUFFER             ' Clear the serial buffer and reset its
pointers
'---------------------------------------------------------------------------------------------
----------------------------------

'      StrN CHAR_String = "     <<<<<....MAPUATECH BLUETOOTH MOVING
MESSAGE DISPLAY >>>>>>"
     StrN CHAR_String = "     MAPUATECH BLUETOOTH RGB LED MATRIX
DISPLAY!!! ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234567890 < > ! ? @ . , _ "


    ON_HARDWARE_INTERRUPT GoTo Int_Handler
'     ON_HARDWARE_INTERRUPT GoTo PWM_InterruptHandler
    Declare FSR_CONTEXT_SAVE = Off

    GoSub CHANGE_CONTENT
    GoSub STORE_ARRAY

    INTCON.7 = 1  ' enable interrupts
    INTCON.6 = 1

    GoTo Start

'''' S T O R E   C H A R A C T E R   C O L U M N   S E G M E N T S   I N   A R
R A Y ''''

STORE_ARRAY:


    For ind = 0 To CHAR_count                          ' Fill in Character Arrays
with Segments
                                                   ' 5 characters at a time

       If  CHAR_String[ind] >= "A" And CHAR_String[ind] <= "_" Then
```

```
While Segment_holder <> EOM
     GoSub UPPERcase
     If Segment_holder = EOM Then Break

    If StrReload_bit = 1 Then
      If CHAR_Reload = Segment_Count Then
        Segment_Count = 0
         CHAR_Column[Segment_Count] = Segment_holder
         StrReload_bit = 0
       EndIf
    EndIf
    If StrReload_bit = 0 Then
      If Segment_Count < 40 Then CHAR_Column[Segment_Count] =
Segment_holder
     EndIf

    Segment_Count = Segment_Count + 1
     Segment = Segment + 1
     If first_run_bit = 0 Then Total_Segment = Total_Segment + 1
 Wend
Segment = 0
 Segment_holder = 0
EndIf

If  CHAR_String[ind] >= "a" And CHAR_String[ind] <= 127 Then '"z"
Then
 While Segment_holder <> EOM
     GoSub LOWERcase
     If Segment_holder = EOM Then Break

    If StrReload_bit = 1 Then
      If CHAR_Reload = Segment_Count Then
        Segment_Count = 0
         CHAR_Column[Segment_Count] = Segment_holder
         StrReload_bit = 0
       EndIf
    EndIf
    If StrReload_bit = 0 Then
      If Segment_Count < 40 Then CHAR_Column[Segment_Count] =
Segment_holder
     EndIf

    Segment_Count = Segment_Count + 1
     Segment = Segment + 1
     If first_run_bit = 0 Then Total_Segment = Total_Segment + 1
```

```
      Wend
     Segment = 0
      Segment_holder = 0
    EndIf

    If  CHAR_String[ind] >= " " And CHAR_String[ind] <= "@" Then
       While Segment_holder <> EOM
            GoSub NUMcase
            If Segment_holder = EOM Then Break

           If StrReload_bit = 1 Then
             If CHAR_Reload = Segment_Count Then
               Segment_Count = 0
                CHAR_Column[Segment_Count] = Segment_holder
                StrReload_bit = 0
              EndIf
           EndIf
           If StrReload_bit = 0 Then
             If Segment_Count < 40 Then CHAR_Column[Segment_Count] =
Segment_holder
            EndIf

           Segment_Count = Segment_Count + 1
            Segment = Segment + 1
            If first_run_bit = 0 Then Total_Segment = Total_Segment + 1
      Wend
     Segment = 0
      Segment_holder = 0
    EndIf

  Next ind

  If first_run_bit = 0 Then
    MSSG_END = Total_Segment
     first_run_bit = 1
  EndIf

Return

Start:



Display_Char:
```

```
Matrix_Column = 1
Matrix_Column1 = 1
Matrix_Column2 = 1
Matrix_Column3 = 1
Matrix_Column4 = 1

For Loop = Loop_START To Loop_END          ' Create a loop of 10

  If Matrix_Column.9 <> 1 Then
    SHOut DTA , CLK , lsbfirst , [ 0, 0, 0 ,0 ,0 ,0 ,0 ]
     SHOut DTA , CLK , lsbfirst , [ Matrix_Column ]
     Matrix_Column = Matrix_Column << 1
  EndIf

  If Matrix_Column.9 = 1 Then
    If Matrix_Column1.9 <> 1 Then
      SHOut DTA , CLK , lsbfirst , [ 0, 0, 0 ,0 ,0 ,0 ,0 ]
       SHOut DTA , CLK , lsbfirst , [ Matrix_Column1 ,0 ]
       Matrix_Column1 = Matrix_Column1 << 1
    EndIf
  EndIf

  If Matrix_Column1.9 = 1 Then
    If Matrix_Column2.9 <> 1 Then
      SHOut DTA , CLK , lsbfirst , [ 0, 0, 0 ,0 ,0 ,0 ,0 ]
       SHOut DTA , CLK , lsbfirst , [ Matrix_Column2 ,0 ,0 ]
       Matrix_Column2 = Matrix_Column2 << 1
    EndIf
  EndIf

  If Matrix_Column2.9 = 1 Then
    If Matrix_Column3.9 <> 1 Then
      SHOut DTA , CLK , lsbfirst , [ 0, 0, 0 ,0 ,0 ,0 ,0 ]
       SHOut DTA , CLK , lsbfirst , [ Matrix_Column3 ,0 ,0 ,0 ]
       Matrix_Column3 = Matrix_Column3 << 1
    EndIf
  EndIf

  If Matrix_Column3.9 = 1 Then
    If Matrix_Column4.9 <> 1 Then
      SHOut DTA , CLK , lsbfirst , [ 0, 0, 0 ,0 ,0 ,0 ,0 ]
       SHOut DTA , CLK , lsbfirst , [ Matrix_Column4 ,0 ,0 ,0 ,0 ]
       Matrix_Column4 = Matrix_Column4 << 1
    EndIf
  EndIf
```

```
        If Matrix_Column4.9 = 1 Then
          Matrix_Column = 1
           Matrix_Column1 = 1
           Matrix_Column2 = 1
           Matrix_Column3 = 1
           Matrix_Column4 = 1
         EndIf

        SHOut DTA , CLK , msbfirst , [  0, CHAR_Column[Loop] ]
'Total of 56 shifts using 74HC595 for rows of 40
        PulsOut Latch_E,1                                          'And MAX6971 For
columns of 8 shifted 8 Bit more than needed 8-bit only
                                                          'To compensate For its 16
Bit Output
        OE_Col = 0                      'Turn on Column

        OE_Red = Color_Red                 'Mix Colors
        OE_Green = 1
        OE_Blue = 1
        DelayUS 200
        OE_Red = 1
        OE_Green = Color_Green
        OE_Blue = 1
        DelayUS 200
        OE_Red = 1
        OE_Green = 1
        OE_Blue = Color_Blue
        DelayUS 200
'        DelayMS 1

        OE_Col = 1                        ' Turn off Everything
        OE_Col = 0
        OE_Red = 1
        OE_Green = 1
        OE_Blue = 1

'        If demo_bit = 1 Then
           While Demo_bit = 1                          ' let the TMR0 ISR do its
thing infinitely!!!!

               If Demo_flag = 1 Then
                Demo_flag = 0
                 SHOut DTA , CLK , lsbfirst , [ %00000010 ,0 ,0 ,0 ,%01000000
]
```

```
                SHOut DTA , CLK , msbfirst , [  0, %10000001 ]            'Total
of 56 shifts using 74HC595 for rows of 40
                PulsOut Latch_E,10
             EndIf


            If BeginPWM = True Then
              BeginPWM = False
               Ph_Val = 4092'2046
               Ph_Val = Ph_Val >> 1           ' Make the value 7-bits wide
               Ph_Val = Ph_Val + 1           ' Add the offset
               Phase = Phase + Ph_Val         ' Add this to the Phase variable
         '
         ' To get the three duty cycle values, The upper 7-bits of Phase are used
as a lookup index to the sine table.
         ' Offsets of $55 (120 degrees) and $AA (240 degrees) are used for the
2nd and 3rd duty cycles.
         '
         ' Phase 1
                Temp = Phase.HighByte >> 1      ' Make the value 7-bits wide
                  GoSub GetSin                ' Sine value returned in Temp
                  DutyCycle0 = Temp             ' Place the Sine value into
DutyCyle0
         '
         ' Phase 2
                Temp = Phase.HighByte >> 1      ' Make the value 7-bits wide
                Temp = Temp + $55              ' Phase2 = Phase1 + $55 for the
first phase shift of 120 degree
                GoSub GetSin                  ' Sine value returned in Temp
                  DutyCycle1 = Temp             ' Place the Sine value into
DutyCyle1
         '
         ' Phase 3
                Temp = Phase.HighByte >> 1      ' Make the value 7-bits wide
                Temp = Temp + $AA              ' Phase3 = Phase1 + $AA for the
second phase shift of 240 degree
                GoSub GetSin                  ' Sine value returned in Temp
                  DutyCycle2 = Temp             ' Place the Sine value into
DutyCyle2
             EndIf

         Wend
'        EndIf

    Next Loop
```

```
    If Loop_bit = 1 Then Loop_COUNT = Loop_COUNT + 1

    If Loop_COUNT = Speed Then
      Loop_COUNT = 0
      CHAR_Reload = CHAR_Reload + 1
      If CHAR_Reload > MSSG_END Then
        CHAR_Reload = 0
        CHAR_count = 0                  ' Empty total character holder
        GoSub CHANGE_CONTENT
      EndIf
    EndIf


    If CHAR_Reload <> dummy Then
      dummy = CHAR_Reload
      StrReload_bit = 1
      Segment_Count = 0
      GoSub STORE_ARRAY
    EndIf

GoTo Start

CHANGE_CONTENT:          ' "                                  "

    For ind = 0 To 255
       If CHAR_String[ind] = $00 Then Break
      CHAR_count = CHAR_count + 1
    Next ind

Return


NUMcase:
      Select Case CHAR_String[ind]
         Case " "
            LookUp Segment,[$00,$00,$00,$00,$00,EOM],Segment_holder

         Case "1"
            LookUp Segment,[$00, $42, $7F, $40, $00, $00,
EOM],Segment_holder
         Case "2"
```

```
            LookUp Segment,[$42, $61, $51, $49, $46, $00,
EOM],Segment_holder
         Case "3"
            LookUp Segment,[$21, $41, $45, $4B, $31, $00,
EOM],Segment_holder
         Case "4"
            LookUp Segment,[$18, $14, $12, $7F, $10, $00,
EOM],Segment_holder
         Case "5"
            LookUp Segment,[$27, $45, $45, $45, $39, $00,
EOM],Segment_holder
         Case "6"
            LookUp Segment,[$3C, $4A, $49, $49, $30, $00,
EOM],Segment_holder
         Case "7"
            LookUp Segment,[$01, $71, $09, $05, $03, $00,
EOM],Segment_holder
         Case "8"
            LookUp Segment,[$36, $49, $49, $49, $36, $00,
EOM],Segment_holder
         Case "9"
            LookUp Segment,[$06, $49, $49, $29, $1E, $00,
EOM],Segment_holder
         Case "0"
            LookUp Segment,[$3E, $51, $49, $45, $3E, $00,
EOM],Segment_holder
         Case ":"
            LookUp Segment,[$00, $36, $36, $00, EOM],Segment_holder
         Case "<"
            LookUp Segment,[$00, $08, $14, $22, $41, $00,
EOM],Segment_holder
         Case ">"
            LookUp Segment,[$41, $22, $14, $08, $00, $00,
EOM],Segment_holder
         Case "?"
            LookUp Segment,[$02, $01, $51, $09, $06, $00,
EOM],Segment_holder
         Case "!"
            LookUp Segment,[$5F,$00,EOM],Segment_holder
         Case "."
            LookUp Segment,[$60,$60,$00,EOM],Segment_holder
         Case ","
            LookUp Segment,[$80,$E0,$60,$00,EOM],Segment_holder
         Case "@"
```

```
            LookUp Segment,[$32, $49, $79, $41, $3E, $00,
EOM],Segment_holder
          Case Else
            LookUp Segment,[$00,EOM],Segment_holder

        End Select
Return


UPPERcase:
        Select Case CHAR_String[ind]
          Case "A"
            Segment_holder = LookUp Segment,[$7E, $11, $11, $11, $7E, $00,
EOM]
          Case "B"
            Segment_holder = LookUp Segment,[$7F, $49, $49, $49, $36, $00,
EOM]
          Case "C"
            Segment_holder = LookUp Segment,[$3E, $41, $41, $41, $22, $00,
EOM] 'same as the other syntax below!!!
          Case "D"
            LookUp Segment,[$7F, $41, $41, $22, $1C, $00,
EOM],Segment_holder
          Case "E"
            LookUp Segment,[$7F, $49, $49, $49, $41, $00,
EOM],Segment_holder
          Case "F"
            LookUp Segment,[$7F, $09, $09, $01, $01, $00,
EOM],Segment_holder
          Case "G"
            LookUp Segment,[$3E, $41, $41, $51, $32, $00,
EOM],Segment_holder
          Case "H"
            LookUp Segment,[$7F, $08, $08, $08, $7F, $00,
EOM],Segment_holder
          Case "I"
            LookUp Segment,[$41, $7F, $41, $00, EOM],Segment_holder
          Case "J"
            LookUp Segment,[$20, $40, $41, $3F, $01, $00,
EOM],Segment_holder
          Case "K"
            LookUp Segment,[$7F, $08, $14, $22, $41, $00,
EOM],Segment_holder
          Case "L"
```

```
      LookUp Segment,[$7F, $40, $40, $40, $40, $00,
EOM],Segment_holder
    Case "M"
      LookUp Segment,[$7F, $02, $04, $02, $7F, $00,
EOM],Segment_holder
    Case "N"
      LookUp Segment,[$7F, $04, $08, $10, $7F, $00,
EOM],Segment_holder
    Case "O"
      LookUp Segment,[$3E, $41, $41, $41, $3E, $00,
EOM],Segment_holder
    Case "P"
      LookUp Segment,[$7F, $09, $09, $09, $06, $00,
EOM],Segment_holder
    Case "Q"
      LookUp Segment,[$3E, $41, $51, $21, $5E, $00,
EOM],Segment_holder
    Case "R"
      LookUp Segment,[$7F, $09, $19, $29, $46, $00,
EOM],Segment_holder
    Case "S"
      LookUp Segment,[$46, $49, $49, $49, $31, $00,
EOM],Segment_holder
    Case "T"
      LookUp Segment,[$01, $01, $7F, $01, $01, $00,
EOM],Segment_holder
    Case "U"
      LookUp Segment,[$3F, $40, $40, $40, $3F, $00,
EOM],Segment_holder
    Case "V"
      LookUp Segment,[$1F, $20, $40, $20, $1F, $00,
EOM],Segment_holder
    Case "W"
      LookUp Segment,[$7F, $20, $18, $20, $7F, $00,
EOM],Segment_holder
    Case "X"
      LookUp Segment,[$63, $14, $08, $14, $63, $00,
EOM],Segment_holder
    Case "Y"
      LookUp Segment,[$03, $04, $78, $04, $03, $00,
EOM],Segment_holder
    Case "Z"
      LookUp Segment,[$61, $51, $49, $45, $43, $00,
EOM],Segment_holder
    Case "_"
```

```
            LookUp Segment,[$80, $80, $80, $80, $80, $00,
EOM],Segment_holder
         Case Else
            LookUp Segment,[$00,EOM],Segment_holder

      End Select
Return


LOWERcase:
      Select Case CHAR_String[ind]
         Case "a"
            Segment_holder = LookUp Segment,[$7E, $11, $11, $11, $7E, $00,
EOM]
         Case "b"
            Segment_holder = LookUp Segment,[$7F, $49, $49, $49, $36, $00,
EOM]
         Case "c"
            Segment_holder = LookUp Segment,[$3E, $41, $41, $41, $22, $00,
EOM] 'same as the other syntax below!!!
         Case "d"
            LookUp Segment,[$7F, $41, $41, $22, $1C, $00,
EOM],Segment_holder
         Case "e"
            LookUp Segment,[$7F, $49, $49, $49, $41, $00,
EOM],Segment_holder
         Case "f"
            LookUp Segment,[$7F, $09, $09, $01, $01, $00,
EOM],Segment_holder
         Case "g"
            LookUp Segment,[$3E, $41, $41, $51, $32, $00,
EOM],Segment_holder
         Case "h"
            LookUp Segment,[$7F, $08, $08, $08, $7F, $00,
EOM],Segment_holder
         Case "i"
            LookUp Segment,[$41, $7F, $41, $00, EOM],Segment_holder
         Case "j"
            LookUp Segment,[$20, $40, $41, $3F, $01, $00,
EOM],Segment_holder
         Case "k"
            LookUp Segment,[$7F, $08, $14, $22, $41, $00,
EOM],Segment_holder
         Case "l"
```

```
      LookUp Segment,[$7F, $40, $40, $40, $40, $00,
EOM],Segment_holder
    Case "m"
      LookUp Segment,[$7F, $02, $04, $02, $7F, $00,
EOM],Segment_holder
    Case "n"
      LookUp Segment,[$7F, $04, $08, $10, $7F, $00,
EOM],Segment_holder
    Case "o"
      LookUp Segment,[$3E, $41, $41, $41, $3E, $00,
EOM],Segment_holder
    Case "p"
      LookUp Segment,[$7F, $09, $09, $09, $06, $00,
EOM],Segment_holder
    Case "q"
      LookUp Segment,[$3E, $41, $51, $21, $5E, $00,
EOM],Segment_holder
    Case "r"
      LookUp Segment,[$7F, $09, $19, $29, $46, $00,
EOM],Segment_holder
    Case "s"
      LookUp Segment,[$46, $49, $49, $49, $31, $00,
EOM],Segment_holder
    Case "t"
      LookUp Segment,[$01, $01, $7F, $01, $01, $00,
EOM],Segment_holder
    Case "u"
      LookUp Segment,[$3F, $40, $40, $40, $3F, $00,
EOM],Segment_holder
    Case "v"
      LookUp Segment,[$1F, $20, $40, $20, $1F, $00,
EOM],Segment_holder
    Case "w"
      LookUp Segment,[$7F, $20, $18, $20, $7F, $00,
EOM],Segment_holder
    Case "x"
      LookUp Segment,[$63, $14, $08, $14, $63, $00,
EOM],Segment_holder
    Case "y"
      LookUp Segment,[$03, $04, $78, $04, $03, $00,
EOM],Segment_holder
    Case "z"
      LookUp Segment,[$61, $51, $49, $45, $43, $00,
EOM],Segment_holder
    Case 127
```

```
            LookUp Segment,[$FF, $FF, $FF, $FF, $FF, $FF,
EOM],Segment_holder
          Case Else
            LookUp Segment,[$00,EOM],Segment_holder

      End Select
Return


GetSin:
        Temp = Temp & %01111111            ' Make sure only 7-bits are present
   Temp = LookUp
Temp,[16,17,17,18,19,20,20,21,22,22,23,24,24,25,26,26,27,27,28,28,28,29,29,
_

30,30,30,30,31,31,31,31,31,31,31,31,31,31,31,30,30,30,30,29,29,28,28,_

28,27,27,26,26,25,24,24,23,22,22,21,20,20,19,18,17,17,16,15,15,14,13,_

12,12,11,10,10,09,08,08,07,06,06,05,05,04,04,04,03,03,02,02,02,02,01,_

01,01,01,01,01,01,01,01,01,01,02,02,02,02,03,03,04,04,04,05,05,06,06,_
                        07,08,08,09,10,10,11,12,12,13,14,15,15]
Return



' -----[ Interrupt Handler ]--------------------------------------------------------

Int_Handler:

USART_Int:
   If PIR1.5 = 1 Then
     PIE1.5 = 0
'      INTCON.7 = 0 ' disable interrupts
'      INTCON.6 = 0
      Context SAVE

         If RCSTA.1 = 1 Then
            WREG = RCREG
             RCSTA.4 = 0
             RCSTA.4 = 1
             GoTo USART_RECEIVE_EXIT
          EndIf
```

```
HSerIn 10000,Just_Rx,[ Wait("@"), Str BytesIn ]

Just_Rx:

    For ind = 0 To 3
        A_Holder [ind] = BytesIn [ind]
    Next ind

    A_Holder [3] = " "
    S_Holder = Str A_Holder

    If S_Holder = "msg " Then GoTo MSSG_RECEIVE

    If S_Holder = "ryt " Then Color_Red = Color_Red ^ 1

    If S_Holder = "lft " Then Color_Green = Color_Green ^ 1

    If S_Holder = "fwd " Then Color_Blue = Color_Blue ^ 1

    If S_Holder = "bck " Then Loop_bit = Loop_bit ^ 1

    If S_Holder = "dem " Then
      Demo_bit = Demo_bit ^ 1

        If Demo_bit = 1 Then
'           SHOut DTA , CLK , lsbfirst , [ 0 ,0 ,%00011000 ,0 ,0 ]
'           SHOut DTA , CLK , lsbfirst , [  0, %00011000 ]          'Total of
56 shifts using 74HC595 for rows of 40
'           PulsOut Latch_E,1

;           SHOut DTA , CLK , lsbfirst , [ 0 ,0 ,%11111111 ,0 ,0 ]
;           SHOut DTA , CLK , msbfirst , [  0, %00100100 ]          'Total of
56 shifts using 74HC595 for rows of 40
;           PulsOut Latch_E,10
            Demo_flag = Demo_bit
            TMR0ON = Demo_bit

        EndIf
'         If Demo_bit = 0 Then
'           StrN CHAR_String = "    MAPUATECH BLUETOOTH RGB LED
MATRIX DISPLAY!!! ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234567890 < > ! ? @
. , _ "
'           TMR0ON = 0
'           goto Demo_Exit
```

```
'           endif
        EndIf

        GoTo USART_RECEIVE_EXIT


  MSSG_RECEIVE:

        For ind = 0 To 255
           CHAR_String[ind] = BytesIn[ind+5]' + NULL_String'Str$ (Dec null)
        Next ind

        For ind = 0 To 255
           BytesIn[ind] = $00
        Next ind
 Demo_Exit:
        first_run_bit = 0
        StrReload_bit = 0
        Segment_Count = 0
        Total_Segment = 0
        CHAR_Reload = 0
        Loop_COUNT = 0

        GoSub CHANGE_CONTENT
        GoSub STORE_ARRAY

        For ind = 0 To 3
           A_Holder [ind] = $00
        Next ind

  USART_RECEIVE_EXIT:

        While PIR1.5 = 1                              ' Keep reading until RCIF
is clear to flush buffer
              null = RCREG                           ' after EOM is received
        Wend

'          If Demo_bit = 1 then PIE1.5 = 0
'          If Demo_bit = 0 Then PIE1.5 = 1

        PIE1.5 = 1

  Context Restore

'     INTCON.7 = 1 ' enable interrupts
```

```
'     INTCON.6 = 1

   EndIf

'-------------------------------------------------------------------------------------

PWM_InterruptHandler:

   If TMR0IF = 1 Then
'     INTCON.7 = 0 ' disable interrupts
'     INTCON.6 = 0
      Context SAVE
      TMR0ON = 0


      '-------------------------------------------------------------------------------------
--
      ' Interrupt Handler for three software PWM signals using the Timer0
interrupt.
      ' The resolution is 6 bits per channel (0 to 31)
      '
      ' Input     : DutyCycle0, DutyCycle1, and DutyCycle1 hold the 6-bit Duty
Cycles for channels 1 to 3
      '           : BeginPWM is true when the interrupt is able to have it's duty
cycle variables altered

       TIMER0 = 63670 '65348 35537                    ' Write TIMER0 to setup
next interrupt interval
      '
      'State Machine for PWM starts from here
      '
         Dec IntCount                     ' Decrement the IntCount variable
         If IntCount = 0 Then               ' If IntCount is 0, then it is time to
start a new PWM signal period
          IntCount = 32 '32                              ' Initialise IntCount
to 32
          BeginPWM = True                          ' Set flag for main software
loop
            If Demo_bit = 1 Then
             OE_Red = 0               ' |
              OE_Green = 0              '  Set all PWM output pins low
              OE_Blue = 0              ' /
            EndIf
```

```
        Else                        ' Otherwise.. if IntCount is not zero then
check the DutyCycle of the signal

            ' If it's not the beginning of the PWM period, we need to compare
each DutyCycle to the value of IntCount.
            ' This is done by performing a subtraction and checking to see
whether the result is 0.
            ' When a match occurs, the output pin for the PWM channel is set to
0.
            '
            If Demo_bit = 1 Then

             null =  IntCount - DutyCycle0
              If null = 0 Then OE_Red = 1

              null =  IntCount - DutyCycle1
              If null = 0 Then OE_Green = 1

              null =  IntCount - DutyCycle2
              If null = 0 Then OE_Blue = 1

            EndIf

         EndIf
       TMR0IF = 0                            ' Clear the T0IF bit in the INTCON
register
       TMR0ON = 1
'          INTCON.7 = 1 ' enable interrupts
'          INTCON.6 = 1
   Context Restore                       ' Context restore and exit the interrupt

   EndIf

End
```