Addressable RGB LED Light Strip

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1 Design Overview

In this milestone, an MSP430G2553 microcontroller was used to connect several RGB LEDs in a chain. A packet of data was sent into the system that contained enough data to individually address each LED in the chain. A Universal Asychronous Receiver/Transmitter (UART) serial communications interface was used to interact between each LED in the chain. The serial UART interface from the microcontroller proved to be an effective way of communicating between the LEDs in the chain.

1.1 Design Features

This design features the following:

- Individually addressable RGB LEDs
- Serial UART communication between nodes
- Hardware PWM integration to control RGB LED duty cycles
- 2^8 steps of PWM based brightness levels
- Implementation on MSP430G2553 microcontroller

1.2 Featured Applications

A list of different technologies this system could be applied to:

- Programmable LED Strips
- A really cool Christmas tree

1.3 Design Resources

For all relevant resources and files, visit the linked repository:

Scrumbology the Study of Scrumbo Repository

1.4 Block Diagram

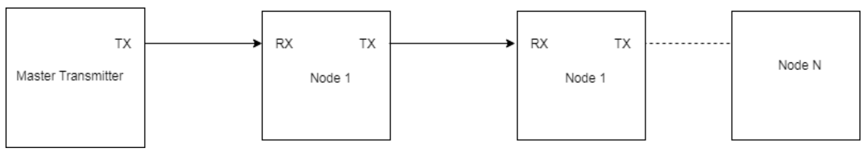

Figure 1: Simple diagram of node interaction

1.5 Board Image

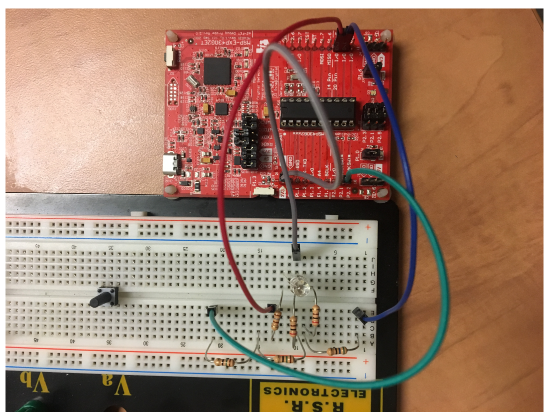

Figure 2: Image of microcontroller connected to RGB LED

2 Key System Specifications

Parameter	Specification	Description
Voltage	5V Power Supply	5V power input to the microcontroller.
CCRx	16 Bit Registers	16 bit registers that store the values that control the PWM period and pulse width.
Baud Rate	Data Transmission Frequency	The baud rate is the rate at which data is transferred between two UART devices. If the baud rates are not the same frequency, the data will not transfer properly and there will be timing issues.
Packet	Data Transferred	The packet is the data being transferred from one node to another. Packets will vary in size depending on the amount of LEDs in the chain. The packet consists of the amount of bytes in the packet, the RGB data for each LED, and the null character
RX/TX Buffer	Data In/Out 8 Bit Registers	The RX Buffer is a register which stores a byte of data to be taken in by the microcontroller. The TX buffer stores the data to be transferred to the next node.

3 System Description

This project was designed to emulate the Stranger Things Christmas wall lights. The project is made up of a master transmitter sending a large packet of information to multiple nodes, with each node pulling its corresponding data and sending on the rest of the packet to the next node. Each node represents one light of the wall lights, with each node containing an RGB LED. Each node is programmed to handle any size packet and send it on to the rest of the nodes connected to it.

3.1 Detailed Block Diagram

In Figure 3, the master transmitter is the computer and program being used to generate the packets of data to sent into the first node. The generated packets are the RGB data that are transferred to the LEDs. Each node is another microcontroller that processes the received data.

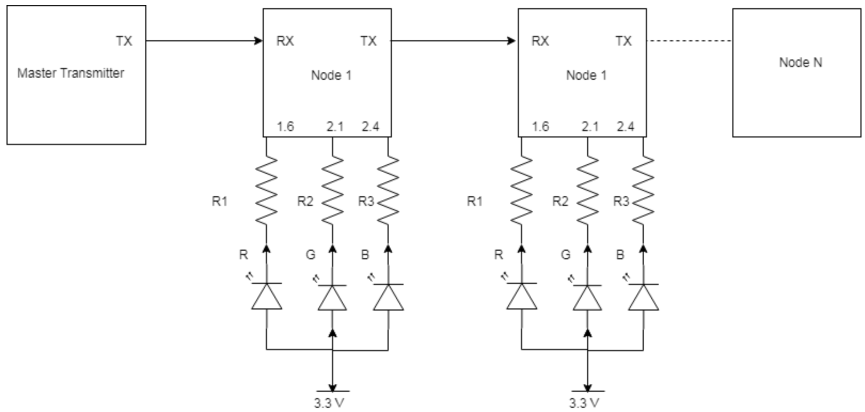

Figure 3: A detailed diagram of the chain of nodes and LEDs

Table 1: Values of resistors in Figure 3

Resistor	Value
R1	180
R2	230
R3	250

3.2 Highlighted Devices

Essential components list:

- MSP430G2553
- RGB LED

3.3 MSP430G2553

The device being used is the MSP430G2533. Inside of the processor, a couple of different components were used: The timer module and its corresponding CCRs, UART communication, and the RX and TX buffers. The timer A module was used to control the duty cycle of the 1kHz PWM which allowed a varying brightness of the RGB LED. Two instances of the timer were used in order to implement the use of three different CCRs. The CCRs were used to control what value the timer counts to when counting in Up mode. Three CCR's were necessary in order to implement the different colors of the LED; RGB. The UART protocol was used to allow communication between nodes and set different settings like Baud rate. Finally, the RX and TX buffers were used to capture the data being grabbed from the large packet of information, and capture the rest of the packet that needs to be sent to the other nodes.

3.4 RGB LED

The RGB LEDs used are standard through hole LEDs that are common anode. The RGB LED is actually composed of three individual LEDs for each color (red, green, and blue) that are diffused to show a merged color. Power is connected to one pin, and the other three pins are the cathodes of each individual LED. The forward voltage of each LED was measured by using a voltmeter across each diode. The resistances used, shown in Table 2, were calculated using Ohm's Law ($\triangle V = IR$) to use a 10 mA current for sufficient brightness without burning out the diodes.

4 SYSTEM DESIGN THEORY

The main components of this project that determine its functionality are the PWM controls and the UART data transmission and reception between nodes. These components required specific applicational usage described in sections 4.1 and 4.2.

4.1 Pulse Width Modulation Control

The Pulse With Modulation Control was used to create the duty cycle of each color for the LED. This allowed the use of all 255 shades of RGB to be implemented. It also allowed the brightness of the LED to be changed based on the duty cycle. The timer that was originally running at 1 MHz was divided by 4 using the internal divider. This set the clock at a value of 250 kHz. Using two CCR's set to 255, this allowed the PWM to operate at a frequncy of 1 kHz. The output mode was set to three which is used for set and reset.

4.2 UART Communication

The serial UART communication protocol interface implemented in the MSP430G2553 was essential for relaying information from the master transmitter to each node in the chain. The microcontroller was configured to receive and send data from pins designed in the microcontroller to have those functions (P1.1 and P1.2, respectively). Data would be sent from the master transmitter to the first node in the chain. Immediately, the first node must read how big the packet is to determine if it should be transmitting data to the next node in the chain. The first byte in the received packet determines this. If the packet size is greater than 5, then there is additional data for the next node to receive. The first byte is altered to display the packet size that the next node will receive, and the TX buffer will be loaded with the data to be transmitted. Immediately afterwards, the packet is analyzed to see which color LED the next byte of data applies to. That data is sent to the corresponding CCRx register to change the PWM pulse width of the desired color.

5 Getting Started/How to use the device

The functionality of this system is determined entirely by simple wire connections to the proper pins. On the RGB LED, there is one pin for power (3.3V), and one pin for each of the three colors. For this system, use jumpers to connect P1.6 to the LED pin corresponding to red, 2.1 to the pin corresponding to green, and 2.4 corresponding to green. Ensure that the desired resistors are in series with the microcontroller pins and the LED pins as shown in Figure 2. Connect a jumper from the 3.3V pin on the development board to the power pin on the LED. Using a USB UART cable, connect the TX pin from the cable to the RX pin on the development board. Connect the TX pin from the development board to the RX pin of the next node in the chain which should be configured in the same manner. This setup will allow the user to send data to each node in the chain. The data is sent out initially using the RealTerm software.

6 Test Setup

Connect the device as described in section 5, and pictured in Figure 2.

6.1 Test Data

Expected Output	Packet (each number is a byte in decimal)
Red	5 255 0 0
Green	5 0 255 0
Blue	5 0 0 255
White 100% Brightness	5 255 255 255
White 50% Brightness	5 127 127 127
Cyan and Red	8 0 255 255 255 0 0