

Bluetooth Racer

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December 2015

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1 Design Documentation

2 Introduction

This document describes the design and process of changing a remote control car into a Bluetooth controlled racer. A simple App was developed so that the movement of a smartphone controls the acceleration and steering of the car. The object is to enable the car to turn left and right, and move forward and backward, all controlled by the Bluetooth connection to the phone.

3 Scope

This document discusses, in detail, the electrical and software design for the Bluetooth Racer. It includes the requirements, dependencies and theory of operation. Schematics and code segments are used to give a more thorough explanation of the design. Testing procedures and results of each requirement are included. The complete code is located in Appendix A.

4 Design Overview

4.1 Requirements

The following are the given requirements for Bluetooth Racer:

1. The system shall use the Tiva C Series TM4C123GH6PM microcontroller.
2. The system shall use two external batteries. A 5 volt battery with USB connection to the microcontroller and a 9 volt DC supply for the drive and steering.
3. The system shall use a Bluetooth 4.0 Module.
4. The system shall use a Dual TB6612FNG Motor Driver (H-Bridge).
5. The Racer shall have PWM output to controller variable motor speed.
6. Working LEDs should be used for the front and tail lights, as well as an inside light.
7. Upon powering up, the inside light should be turned on.
8. Upon connecting to Bluetooth, the front and tail lights should turn on.
9. The microcontroller will transmit and receive data from the Bluetooth module through UART.
10. The user shall command the Racer with a smartphone over Bluetooth connection. The movement of the phone will control the direction in which the car will move.
11. The Racer shall be able to turn and drive forward and backward on command of the user.

4.2 Materials

The following are dependencies for the Bluetooth Racer:

Table 1: Material List

Item	Price
An RC car with working motors for both steering and driving	Free
9 volt DC power supply	\$2.20
5 volt DC power supply with USB connection	Free
Dual TB6612FNG Motor Driver	\$8.95
Tiva C Series TM4C123GH6PM microcontroller	\$14.00
Bluetooth 4.0 Module	\$13.95
Schmidt Trigger	\$0.40
5 LEDs	\$0.20 ea
Spray Paint	\$1.00
NPN Transistor	\$0.25
Assorted resistors and capacitors	\$1.00

5 Bluetooth Racer Design

5.1 Software Design

The Software design is very simple, using an iOS smart-phone app a one byte message will be transmitted via Bluetooth to the Bluetooth module located on the RC car. The micro-controller's UART module is then connected to the Bluetooth module and the message is received. This message is then parsed into two bit sections that in turn enable/disable the two motors on the car and set the variable speed of the two motors.

We begin with the UART's initialization, the Bluetooth module by default transmits at 9600 baud, therefore we configure the UART to also receive messages at 9600 baud in order to ensure messages are received correctly. Interrupts are enabled to trigger on the UART when the fifo buffer is 1/8 full, in our configuration we only use the lower 8 bits, so the upper 8 bits are discarded. The UART Handler function will be discussed in greater detail below. Next to configure the motors for Pulse Width Modulation(PWM) a systick timer was enabled, the systick timer was set to trigger an interrupt every 10 milliseconds, the systick handler function will be discussed below. When the car is turning, feedback is sent back to the microcontroller to stop the motor as it has already traveled its full distance. This feed back is inputted to Port A, Port A is configured to trigger an interrupt on both edges and is set as a pull up resistor. The RC car has tail lights and head lights, in order to turn these lights we use the GPIO port E, the port direction is set to output and as a pull up resistor. Finally we use GPTM Timer 1A to act as a watchdog timer, The timer is set to trigger every .5 second. If the timer triggers we turn off all the lights and set the PWM speed to 0, to disable the car. This ensures that once the app is disengaged that the car will not continue driving away.

We will now discuss the interrupt handler functions with their associated logic. When the UART buffer is 1/8 full the UART interrupt is triggered. Inside of the UART handler GPTM timer 1A is reloaded with a .5 second delay, this is done so the only time the watchdog timer expires is when we have not received data from the smartphone for .5 second. This is followed by reading in the data received from the Bluetooth module. As mentioned before we actually receive two bytes of data but only need the lower 8 bits so the upper 8 are discarded. The byte of data is then parsed into 2 bit parts. The first 2 bits are to enable H-bridge1 which is followed by the 2 bits to determine the PWM frequency. The next 4 bits follow the same format but are for H-bridge2 and its associated PWM frequency. GPIO port A is responsible for receiving feedback from the steering module, if an interrupt is triggered on this port it is determined if we have steered all the way left or right. Once determined we set either the variable "turningRight"=0

or "turningLeft" =0. After parsing the data in the UART handler continues by checking the variables "turningRight" and "turningLeft" and if they are equal to 1 and if H-bridge1 is enabled we send a command to turn the desired direction. Finally we write the desired PWM value to the variable PWM0Duty and PWM1Duty which are used in the systick handler. When the systick handler interrupt is triggered we begin by incrementing two count values that represent PWM0 and PWM1, if the count is greater than 100 we reset the value back to 0. Next the PWM duty cycles are updated and we exit the function. This process is continued until the user terminates transmission and the car then shuts down.

5.2 Hardware Design

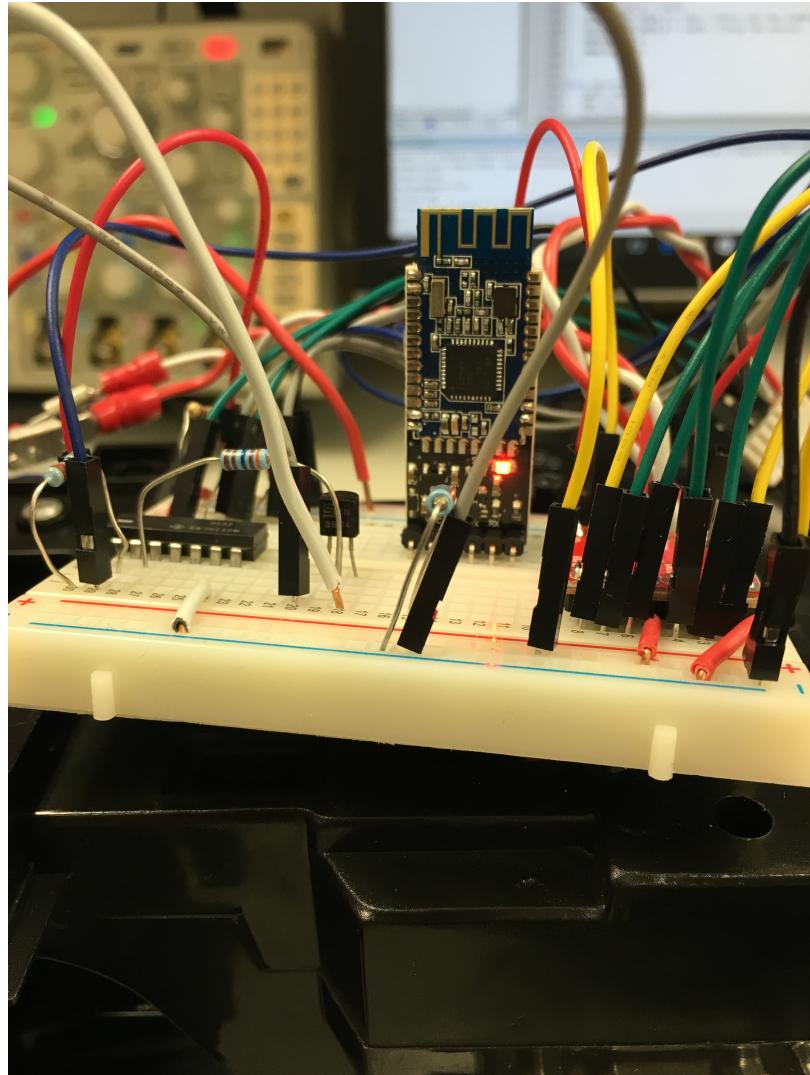


Figure 1: Bluetooth Module

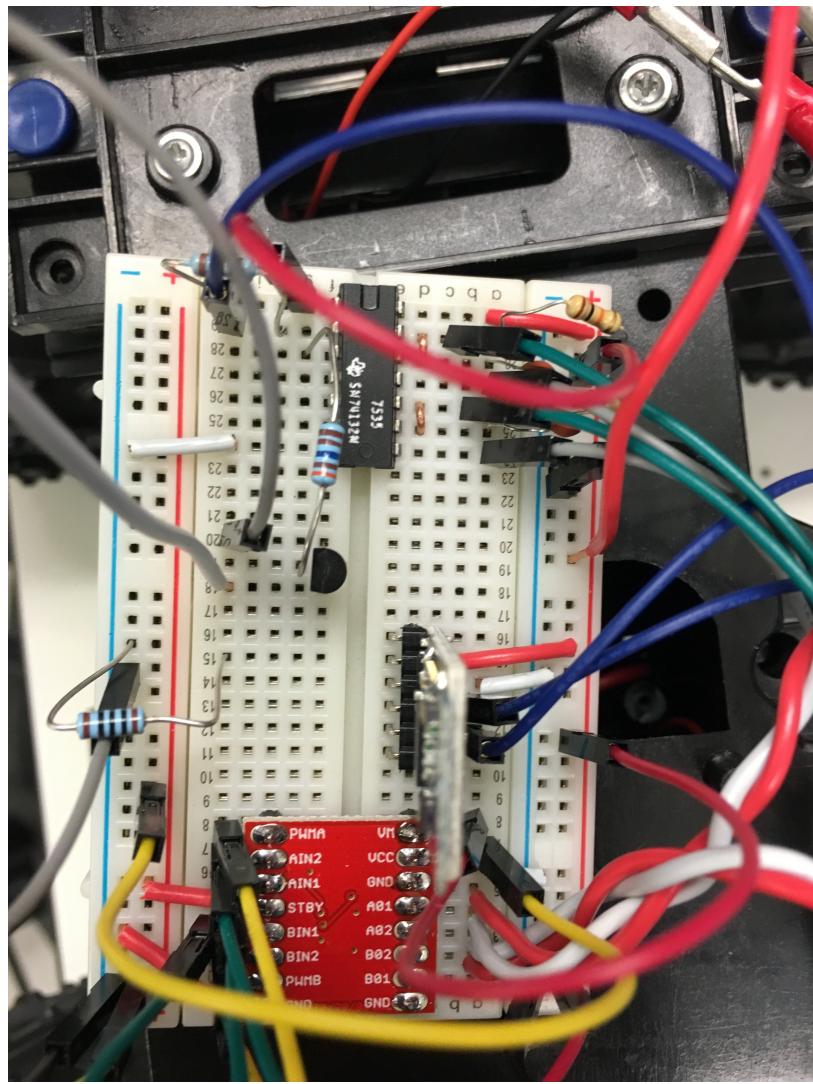


Figure 2: Breadboard

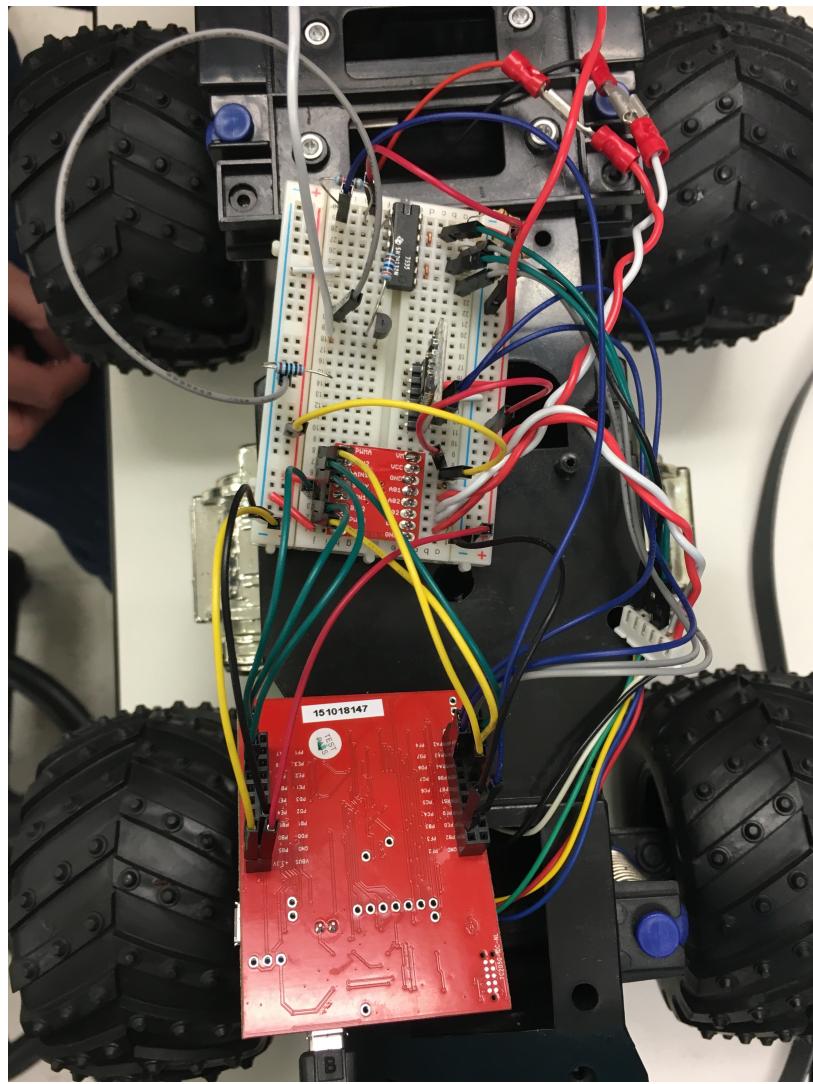


Figure 3: Under the Hood



Figure 4: Steering Controller

6 Testing

In order to verify our iOS app was sending the correct signal and the RC car was receiving the proper command 3 tests were performed. The first test shows the message received on the micro-controller via the Bluetooth module. The second and third screen-shots demonstrate pulse width modulation(PWM) acting on the motor to drive the car at different speeds.

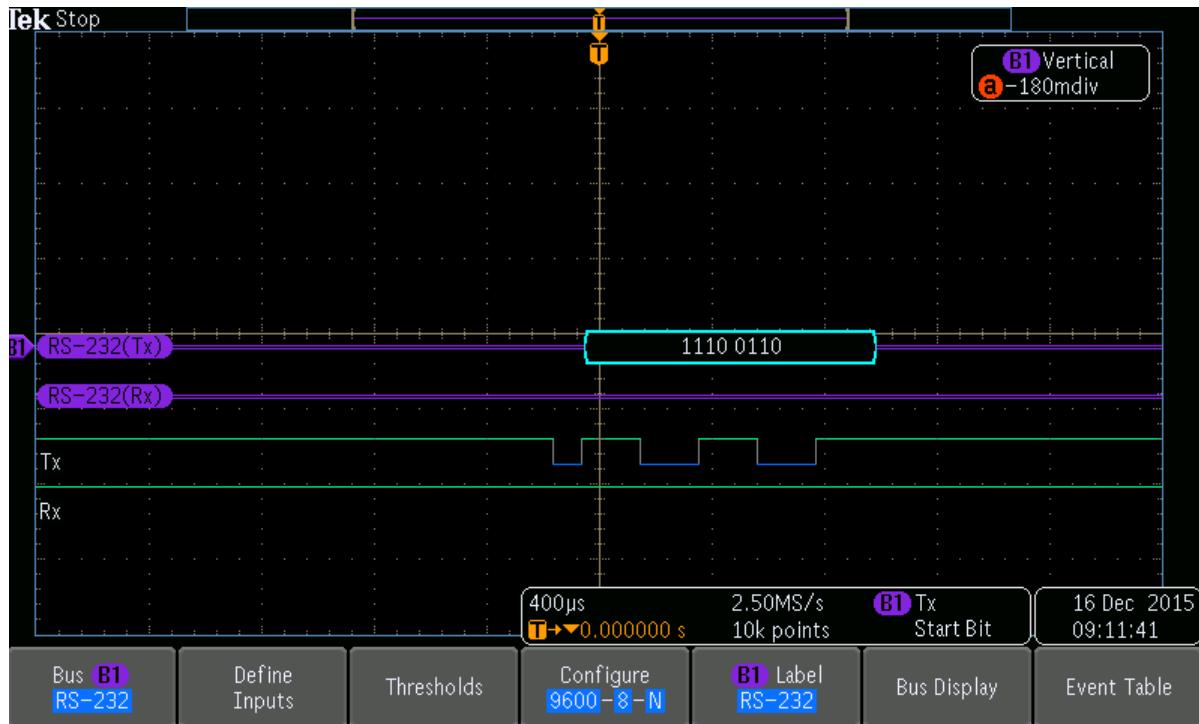


Figure 5: UART Data Message

As specified before, the car is controlled via Bluetooth. The iOS app sends a 1 byte command that the UART module on the micro-controller receives. This byte of data contains the information necessary to enable the two H-bridges and the data to set the variable speed for PWM. The byte of data is represented in the following format: two bits for H-bridge drive followed by two bits to set the variable speed, these four bits are followed by two bits for H-bridge turn followed by two bits to set the variable speed. Above is a print out of the message received by the Bluetooth module

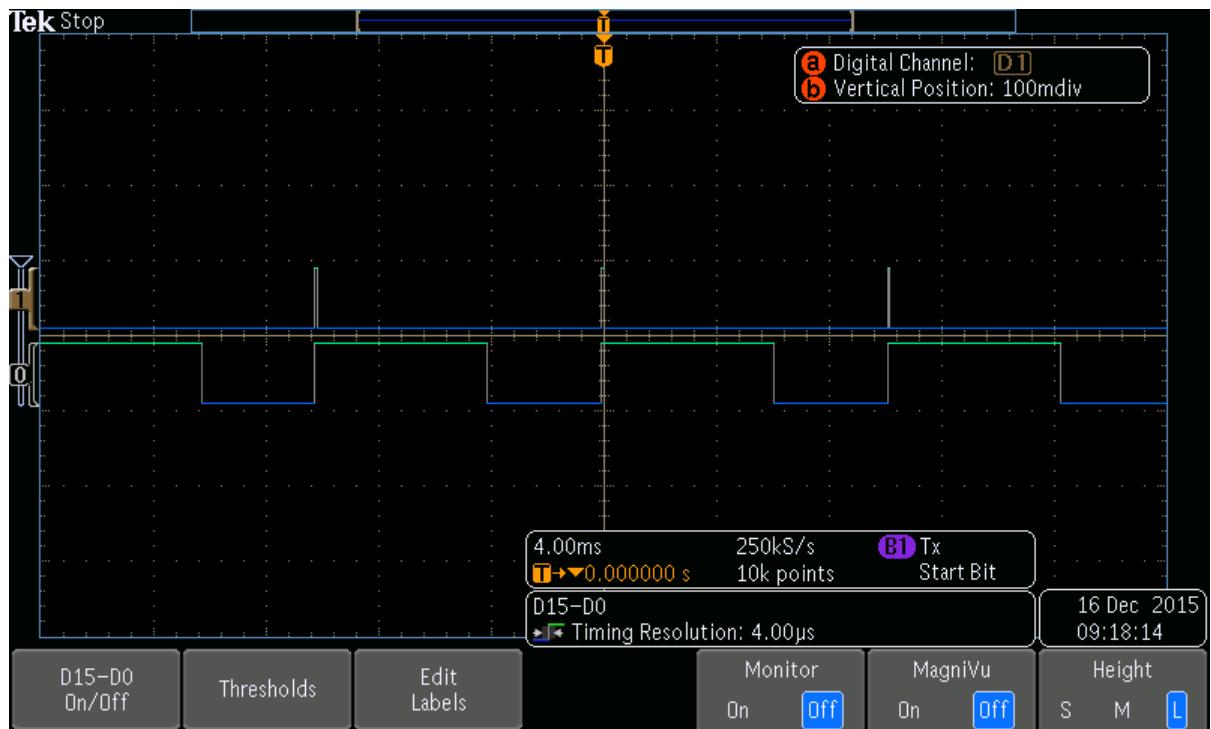


Figure 6: Half Power PWM

The RC car is designed to drive at different speeds, using PWM we are able to enable the motor for specified amounts of time. The longer the motor is enabled the faster the car will travel. In this screen shot from the logic analyzer, the wave form is high for little more than half of the entire wave, this means the car is driving slightly faster than half speed.

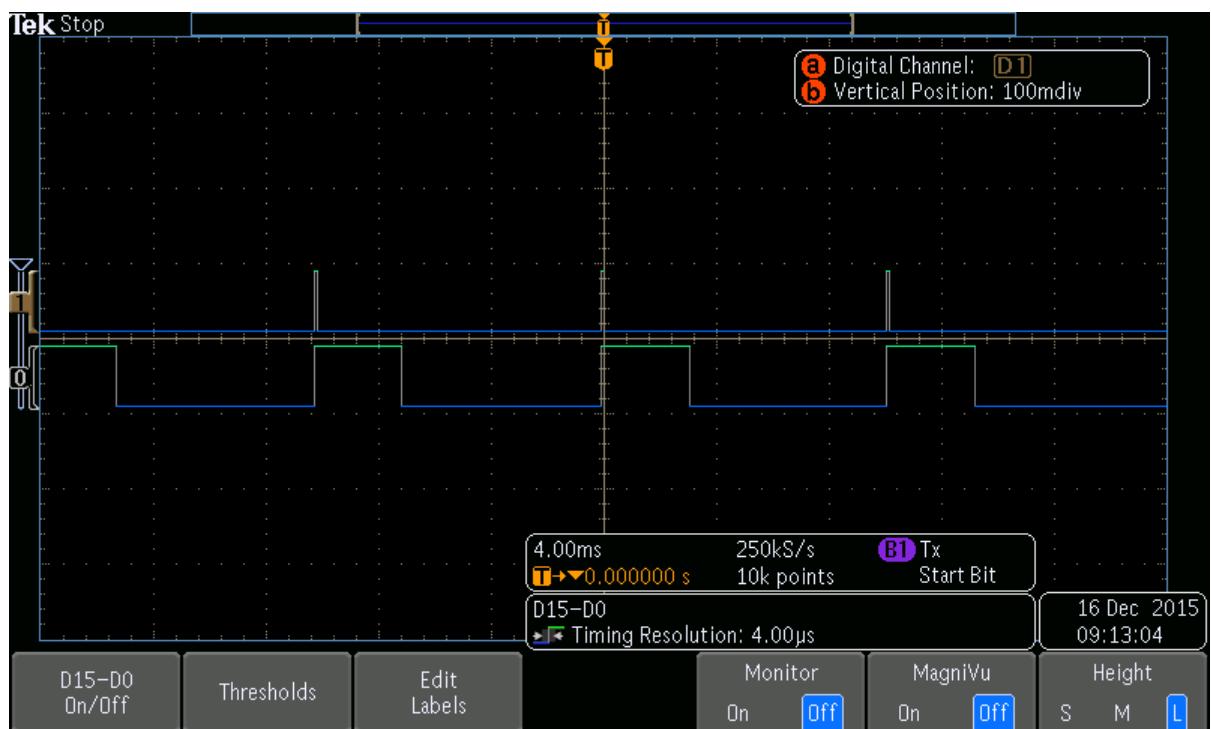


Figure 7: Quarter Power PWM

The RC car can also travel at slower speeds as when it is first starting to accelerate. Above is a screen shot from the logic analyzer, the wave form is high for close to quarter of the entire wave, this means the car is driving half as fast compared to the half-power wave form.

7 Conclusion

In conclusion our Bluetooth racing car meet all of our specified requirements of being able to drive forward/backward and be able to steer left and right all the time being controlled by a smartphone app. As we progressed on the project we had numerous ideas that we would of been able to implement if we had a larger time frame to do so. The biggest restriction we confronted was associated with getting enough power to run our car at 100% capacity. The RC car we used to implemented the Bluetooth Racer was a used car that had seen better days, and unfortunately the 9V batter that came with the car was depleted and our efforts to recharge it were in vain. It was exciting to see all the skills we learned in lecture and past labs come together to build the Bluetooth Racer, these skills include but are not limited to: systick timer, GPTM timer, GPIO port interrupts, PWM, UART and c logic. This project has given us the skills and confidence to find everyday devices that with the help of a micro-controller can be put to new use with exciting results.

8 Appendix A

8.1 Main.c

```
#include "GPIO.h"

volatile int UART2_NVIC_R __attribute__((at(0xE000E104)));

int PWM0Count = 0, PWM1Count = 0, PWM0Duty = 0, PWM1Duty = 0;
char turningRight = 0, turningLeft = 0;
char inData, hBridge1, hBridge2, drive1, drive2;

void PWM_init() { //page 1233
    SYSCTL_RCGC2_R |= 0x2;
    SYSCTL_RCGCPWMLR = 0x1;
    //enable PWM clock in RCGC0 register
    __nop();
    __nop();
    __nop();

    while((SYSCTL_PRGPIO_R&SYSCTL_PRGPIO_R1) == 0){};//wait for clock to stabilize

    //Setup GPIO port B
    GPIO_PORTB_LOCK_R = 0x4C4F434B;
    GPIO_PORTB_PUR_R = 0xC0;
    GPIO_PORTB_DIR_R = 0xC0;
    GPIO_PORTB_DEN_R = 0xC0;
}

void UART2_INIT() {
    //UART2 D6,D7
    SYSCTL_RCGCUART_R = 0x4;
    SYSCTL_RCGCGPIO_R |= 0x8;
    __nop();
    __nop();
    __nop(); //clock needs some time to initialize
    GPIO_PORTD_LOCK_R = 0x4C4F434B; //unlock port c
    GPIO_PORTD_CR_R |= 0xC0; //enable control register, i dont think we need this
    GPIO_PORTD_AFSEL_R |= 0xC0; //alternative functionality enabled
    GPIO_PORTD_DEN_R |= 0xC0; //digital enable enabled
    GPIO_PORTD_PCTL_R = 0x11000000; //page 686 PD6 (1), PD7 (1)
    UART2_CTL_R = 0x0; //disable uart
    //(16e6)/(9600*16) = 104.167
    UART2_IBRD_R = 0x68; //104
    //167 * 64 + .5 = 8.5 rounddown to 11
    UART2_FBRD_R = 0xB; //11
    UART2_LCRH_R |= 0x72; //Set serial parameters: 8-bit word, start/stop/parity bits
    UART2_CTL_R = 0x301; // Enable rx, tx on uart
    //we can turn off tx if we can somehow link the phone
    //and bluetooth without needing to tx
    //INTERRUPT INIT for UART
    UART2_IFLS_R = 0x0; //set interrupts rx 1/8 full queue
    UART2_RIS_R = 0x10; //page 925
    UART2_IM_R = 0x10; //interrupt mask, Rxim page 921
    UART2_NVIC_R = 0x2;
}

//Trigger when queue is 1/8 full
```

```

void UART2_Handler() {
    TIMER1_TAILR.R = 0x7A1200;           // Reset watchdog timer value
    GPIO_PORTE_DATA.R = 0x0;             // Turn on headlights
    if((UART2.FR.R & 0x10) == 0x0) { // RxFE bit Read 1/8 full
        inData = UART2_DR.R;
    }

    //parse incoming data
    hBridge1 = inData & 0x3;
    drive1 = (inData & 0xC) >> 2;
    hBridge2 = (inData & 0x30) >> 4;
    drive2 = (inData & 0xC0) >> 6;

    //Only turn the drive motor if it is not on the stop
    if (hBridge1 == 0x1 && turningRight == 1) {
        hBridge1 = 0x11;
    }
    else if (hBridge1 == 0x10 && turningLeft == 1) {
        hBridge1 = 0x11;
    }

    // Write new command to gpio port
    GPIO_PORTA_DATA.R = (((hBridge1 << 2) | (hBridge2))<<4);
    PWM0Duty = drive1 * 30;
    PWM1Duty = drive2 * 30;

    UART2_ICR.R = 0x1;
}

//Systick initialization. Used for PWM output
void SystickConfig() {
    NVIC_ST_CTRL.R = 0;
    NVIC_ST_RELOAD.R = 0x640;
    NVIC_ST_CTRL.R = 0x7;
}

//Output PWM when systick expires
void SysTick_Handler(){
    PWM0Count++;
    PWM1Count++;

    if (PWM0Count > 100) {
        PWM0Count = 0;
    }

    if (PWM1Count > 100) {
        PWM1Count = 0;
    }

    if (PWM0Count > PWM0Duty) {
        GPIO_PORTB_DATA.R &= ~0x40;
    }
    else {
        GPIO_PORTB_DATA.R |= 0x40;
    }

    if (PWM1Count > PWM1Duty) {
        GPIO_PORTB_DATA.R &= ~0x80;
    }
    else {

```

```

        GPIO_PORTB_DATA_R |= 0x80;
    }

    NVIC_ST_CTRL_R = 0x7;
}

//Initialize port A, used for controlling the motors
void GPIOA_INIT() {
    //A2, A3, A4, A5, A6, A7
    SYSCtrl_RCGC2_R |= 0x1;      //Enable clock for PortA
    GPIO_PORTA_DIR_R = 0xF0;    //Set direction to output
    GPIO_PORTA_PUR_R = 0xC;     //Pull up resistor
    GPIO_PORTA_DEN_R = 0xFC;    //Digital enable
    GPIO_PORTA_IS_R = 0x1;      //Edge triggering
    GPIO_PORTAIBE_R = 0x1;      //Trigger both edges
    GPIO_PORTA_IM_R = 0xC;      //Pin interrupt
    NVIC_EN0_R = 0x1;          //NVIC
}

//One of the interrupts from the turning feedback was triggered
void GPIOA_Handler() {
    char PORTADATA = GPIO_PORTA_DATA_R;
    //Check and see if it is turned to the right
    if ((PORTADATA & 0x8) != 0) {
        turningRight = 0;
        turningLeft = 1;
    }
    //Check and see if it is turned to the left
    else if ((PORTADATA & 0x4) != 0) {
        turningRight = 1;
        turningLeft = 0;
    }
    //Otherwise, somewhere in the middle
    else {
        turningRight = 0;
        turningLeft = 0;
    }
    GPIO_PORTA_ICR_R = 0xFF; //Service the interrupt
}

//Setup the GPIO port for the LED output (head and break lights)
void setupLED(){
    SYSCtrl_RCGC2_R |= 0x10; //Enable clock for PortE
    GPIO_PORTE_DIR_R = 0x1; //set direction to output
    GPIO_PORTE_PUR_R = 0x1; //Pull up resistor
    GPIO_PORTE_DEN_R = 0x1; //digital enable

    GPIO_PORTE_DATA_R = 0x1; //turn off LED lights
}

//Initialize timer 1, used as a watchdog
void Timer1A_init() {
    SYSCtrl_RCGCTIMER_R = 0x2;
    TIMER1_CTL_R = 0x0;           //Stop timer
    TIMER1_CFG_R = 0x0;           //Select 32 bit mode
    TIMER1_TAMR_R = 0x2;          //Periodic mode
    TIMER1_TAILR_R = 0x7A1200;    //Timer set to expire after 1 second
    TIMER1_IMR_R = 0x1;           //Enable interrupt on port
    NVIC_EN0_R |= (1 << 21);    //Enable in NVIC
}

```

```

        TIMER1_CTL_R = 0x1;           // Start timer
}

//Respond to the watchdog call
void TIMER1A_Handler() {
    TIMER1_ICR_R = 0x1F;
    GPIO_PORTE_DATA_R = 0x1; //Turn off the lights
    GPIO_PORTA_DATA_R = 0xF0; //Stop the motors

    //Put the motors in stop mode
    PWM0Duty = 0;
    PWM1Duty = 0;
}

int main(void) {
    //Setup everything
    UART2_INIT();
    PWM_init();
    SystickConfig();
    GPIOA_INIT();
    setupLED();
    Timer1A_init();

    //Wait for bluetooth command
    while(1);
}

```

8.2 GPIO.h

This is a file provided by Valvano, please see link for GPIO.h file.
<http://users.ece.utexas.edu/~valvano/arm/>

8.3 iOS Code

```

// ViewController.swift
// RCCar
//
// Created by Erik Sargent on 11/26/15.
// Copyright 2015 eriksargent. All rights reserved.
//

import UIKit
import CoreBluetooth
import CoreMotion

class ViewController: UIViewController {
    //MARK: - Properties
    var centralManager: CBCentralManager!
    var carPeripheral: CBPeripheral?

    var motionManager = CMMotionManager()

    var label: UILabel!

    //MARK: - View Lifecycle
    override func viewDidLoad() {
        super.viewDidLoad()

```

```

centralManager = CBCentralManager(delegate: self, queue: nil)

label = UILabel(frame: CGRect(x: view.frame.width / 2 - 150, y: view.frame.height / 2 - 15, width: 300, height: 30))
label.text = "Searching for car..."
label.textAlignment = .Center
label.font = UIFont.systemFontOfSize(20)

view.addSubview(label)

motionManager.deviceMotionUpdateInterval = 0.1
motionManager.startDeviceMotionUpdatesToQueue(NSOperationQueue.mainQueue()) {
    motionData, error in
    guard let data = motionData where error == nil else {
        return
    }

    let steer = atan2(data.gravity.x, data.gravity.y) - M_PI / 2
    let drive = atan2(data.gravity.x, data.gravity.z) - M_PI / 2
    self.label.transform = CGAffineTransformMakeRotation(CGFloat(steer))

    // | Turn Power | Turn H-Bridge | Drive Power | Drive H-Bridge |

    var transmitData: UInt8 = 0;

    let steerParam = 0.2
    let driveParam = 0.2

    transmitData |= min(UInt8(abs(drive) * 3), 3)

    transmitData = transmitData << 2

    if drive > -driveParam && drive < driveParam {
        transmitData |= 0x3
    } else if drive > driveParam {
        transmitData |= 0x2
    } else {
        transmitData |= 0x1
    }

    transmitData = transmitData << 2

    transmitData |= min(UInt8(abs(steer) * 3), 3)

    transmitData = transmitData << 2

    if steer > -steerParam && steer < steerParam {
        transmitData |= 0x3
    } else if steer > steerParam {
        transmitData |= 0x2
    } else {
        transmitData |= 0x1
    }

    let dataBytes = NSData(bytes: &transmitData, length: sizeof(UInt8))
    print(String(transmitData, radix: 2))

    if let characteristic = self.carPeripheral?.services?.first?.characteristics?.first {

```

```

        self.carPeripheral?.writeValue(dataBytes, forCharacteristic:
            characteristic, type: CBCharacteristicWriteType.WithoutResponse)
    }
}
}

//MARK: - CoreMotion
extension ViewController: CBCentralManagerDelegate, CBPeripheralDelegate {
    func centralManagerDidUpdateState(central: CBCentralManager) {
        if central.state == CBCentralManagerState.PoweredOn {
            // Scan for peripherals if BLE is turned on
            central.scanForPeripheralsWithServices(nil, options: nil)
            print("Searching")
        } else {
            // Can have different conditions for all states if needed - print generic
            // message for now
            print("Bluetooth not initialized")
        }
    }

    func centralManager(central: CBCentralManager, didDiscoverPeripheral peripheral:
        CBPeripheral, advertisementData: [String: AnyObject], RSSI: NSNumber) {
        let deviceName = "RCCAR1"
        let nameOfDeviceFound = (advertisementData as NSDictionary).objectForKey(
            CBAccreditedDataLocalNameKey) as? NSString

        if nameOfDeviceFound == deviceName {
            // Update Status Label
            print("Found device")

            // Stop scanning
            centralManager.stopScan()
            // Set as the peripheral to use and establish connection
            carPeripheral = peripheral
            carPeripheral?.delegate = self
            centralManager.connectPeripheral(peripheral, options: nil)
        } else {
            print("Found \(nameOfDeviceFound) instead")
        }
    }

    func centralManager(central: CBCentralManager, didConnectPeripheral peripheral:
        CBPeripheral) {
        print("I found it! Now discover services")
        peripheral.discoverServices(nil)
    }

    func peripheral(peripheral: CBPeripheral, didDiscoverServices error: NSError?) {
        guard let services = peripheral.services where error == nil else {
            return
        }

        print("Periferal services: \(services.map{\$0.UUID})")

        for service in services {
            peripheral.discoverCharacteristics(nil, forService: service)
        }
    }
}

```

```

        }

    }

func peripheral(peripheral: CBPeripheral, didDiscoverCharacteristicsForService service
    : CBService, error: NSError?) {
    print("enabling_peripheral")

    guard let characteristics = service.characteristics where error == nil else {
        return
    }

    NSOperationQueue.mainQueue().addOperationWithBlock {
        self.label.text = "Connected_to_car"
    }

    print("Characteristics:\n(\(characteristics.map{\$0.UUID}))")

    for characteristic in characteristics {
        var enableValue = 65 as UInt8
        let enableBytes = NSData(bytes: &enableValue, length: sizeof(UInt8))

        // carPeripheral.writeValue(enableBytes, forCharacteristic: characteristic,
        type: .WithoutResponse)
        carPeripheral?.setNotifyValue(true, forCharacteristic: characteristic)
    }
}

func peripheral(peripheral: CBPeripheral, didUpdateValueForCharacteristic
    characteristic: CBCharacteristic, error: NSError?) {
    guard let dataBytes = characteristic.value else {
        return
    }

    let dataLength = dataBytes.length
    var dataArray = [UInt8](count: dataLength, repeatedValue: 0)
    dataBytes.getBytes(&dataArray, length: dataLength * sizeof(UInt8))

    print(dataArray)
    print(String(bytes: dataArray, encoding: NSASCIIStringEncoding))
}

func centralManager(central: CBCentralManager, didDisconnectPeripheral peripheral:
    CBPeripheral, error: NSError?) {
    label.text = "Searching_for_car..."
    print("Car_disconnected")
    central.scanForPeripheralsWithServices(nil, options: nil)
}

func peripheral(peripheral: CBPeripheral, didWriteValueForCharacteristic
    characteristic: CBCharacteristic, error: NSError?) {
    print(error)
}

func peripheral(peripheral: CBPeripheral, didUpdateNotificationStateForCharacteristic
    characteristic: CBCharacteristic, error: NSError?) {
    print(characteristic.properties)
}
}

```