Microcomputer-Controlled Car Project

Reference Manual
version 1.0

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Chapter 1: Overview

This is the microcomputer-controlled car project. This project's purpose is to make available an inexpensive test platform for ground vehicle control algorithms. Following are the major components of this project:

- 1 x RC race car (AE Team Associated SC10)
- 1 x Raspberry Pi Model B microcomputer (revision 1 or 2)
- 1 x Arduino Pro Mini 5V 16MHz microcontroller
- 1 x Adafruit 16 Channel 12-bit PWM/Serbo Driver – I2C Interface – PCA9685
- 1 x FTDI friend board from Adafruit (or Sparkfun equivalent)
- Software for the Arduino written in the Arduino C-like language
- Python interface module for the Raspberry Pi to communicate with the Arduino
- Custom 5V power regulation circuitry

Chapter 2: RC Car

The RC race car that was selected for this project is the AE Team Associated SC10, a 1:10 scale, ready-to-run 2WD, electric off road race truck. The stock car consists of the following major components:

- Independent suspension for the front and rear wheels
- 1 x Servo (XP DS1903MG) that steers the front wheels
- 1 x Radio Receiver 4 Channel 2.4GHz (XP TRS403-ssi)
- 1x Radio Transmitter (XP 2G 29215) 2.4GHz
- 1x Motor Controller (XP SC200)
- 1 x Ni-MH Battery Pack 7.2V 3600mAh

The motor controller must receive power from the 7.2V battery pack. The motor controller can and should be set to disable its low voltage cutoff when using a Ni-MH battery. The low voltage cutoff can be disabled by plugging in the motor controller to the battery, turning on the power switch, and pressing the SET button on the motor controller 2 times. The LED will flash green 5 times when low voltage cutoff is disabled. To turn on low voltage cutoff, press the SET button 2 times and the LED will flash red 5 times.

The servo, radio receiver, and motor controller are all compatible with 5V logic. The acceptable logic level range for the signals is between 4.8V and 6.0V. The PWM signals between the radio receiver and the motor controller and the PWM signals between the radio receiver and the steering servo operate at 72Hz. *NOTE: when reading the pulse width of the PWM signals with the Arduino pulseIn() function, the Arduino will report pulse widths that are not the true value, but will report them consistently.*

According to oscilloscope measurements, the steering servo's PWM input signal ranges from a minimum pulse width of 1.067ms to a maximum of 2.090ms. The Arduino's pulseIn() function, however, reports a minimum pulse width of 1.140ms to a maximum of 2.720ms. In both cases, a short pulse corresponds to a maximum right turn and a long pulse corresponds to a maximum left turn.

According to oscilloscope measurements, the motor controller's PWM input signal ranges from a minimum pulse width of 1.020ms to a maximum of 2.020ms. The Arduino's pulseIn() function, however, reports a minimum pulse width of 1.304ms to a maximum of 2.650ms. In both cases, a short pulse corresponds to full reverse throttle and a long pulse corresponds to full forward throttle.

Chapter 3: Raspberry Pi (RPi)

The project currently uses a Raspberry Pi Model B revision 1. The Raspberry Pi Model B revision 2 is also compatible with a few minor tweaks to the RPi's configuration. Other models of the RPi were not tested with this project.

The RPi in this project runs the 2012-12-24 version of the raspbian-wheezy operating system. The following tutorial may be helpful for setup: http://elinux.org/RPi_Hub#Getting_Started

The RPi in this project uses Python with the following packages: pySerial, numpy, and matplotlib. Python will most likely be pre-installed on the RPi's operating system but pySerial, numpy, and matplotlib may need to be installed.

The RPi in this project is used as a platform to run a control algorithm for the car as well as to log data about the car's steering angle and throttle. The RPi is not strictly necessary for the car to function – the Arduino's software handles all of the signal reading and generation needed to control the car so a control algorithm could be run directly on the Arduino instead of on the RPi if it was written in the Arduino C-like language. The RPi is necessary for the data logging however but because the RPi is a general purpose Linux machine, the Python module could be run on any other Linux machine with a USB port.

The RPi is connected to the Arduino via USB. One of the RPi's USB type A ports is connected to a mini USB type B port on a FTDI breakout board which is connected to the Arduino. The RPi can send data to the Arduino using Python's serial module (pySerial). The pySerial interface was wrapped into a Python module called “car” which provides a standard interface of function calls for sending commands to the Arduino without having to construct the commands byte for byte. The basic idea is that the RPi will send a null-terminated string of characters that represents a command to the Arduino and the Arduino may respond with a null-terminated string of characters.

The file “car.py” is the Python module that provides the API for the car. The API provides an class “Car” that represents the rc car. The class methods are setMode, setSteer, setThrottle, getData, testSteer, testThrottle, beginLog, and endLog. The setMode method is used to pick between the control modes of the car. The setSteer and setThrottle are used to control the car when it is in RPi mode. The getData command retrieves the current control data of the car. The beginLog method starts logging the car's control data in a csv file. The endLog method terminate the logging process. A sample plotting program, “plotter.py”, that parses and plots the log data is included in the “rpi” project directory. See the file “car.py” for complete documentation on the car Python module.

Chapter 4: Arduino

The project currently uses an Arduino Pro Mini 5V 16MHz microcontroller. The standard Arduino IDE was used for this project to develop the code.

The project uses some of the standard Arduino libraires (namely Serial) as well as a library written by Adafruit for the PWM board. If not already present, the library for the PWM board must be downloaded and saved in the “libraries” sub-directory of the “arduino” project directory. The Adafruit PWM board library can be obtained at the following url: https://github.com/adafruit/Adafruit-PWM-Servo-Driver-Library.

The Arduino is connected to the Adafruit PWM board via I2C. The Arduino is the I2C master and the PWM board is an I2C slave. The Arduino sends commands using the Adafruit PWM board library to set the frequency and duty cycle of the PWM signals. See the Adafruit documentation for details on the commands.

The Arduino is connected to the Raspberry Pi via USB. The Arduino Pro Mini does not include FTDI circuitry so a FTDI board (available from Sparkfun or Adafruit) is connected to the Arduino's serial pins, then to the Raspberry Pi's USB port. The Raspberry Pi will send commands to the Arduino which controls the control mode, the steering angle, or the throttle of the car. The commands are sent as C strings which are then parsed and interpreted by the Arduino. See “Chapter 5: Communication Protocol” for a detailed description of the commands.

The Arduino runs a program that continuously waits for a command and sets the PWM signals for the steering servo and the motor controller accordingly. The program has 3 control modes, “idle” (do nothing), “rc” (controlled by the radio transmitter), and “rpi” (controlled by the serial commands sent by the Raspberry Pi). The Arduino will always respond to a serial “setMode” command, however, regardless of the mode it is currently in. When the Arduino is in the “idle” mode, it sets the steering angle to a center position and the throttle to a neutral position. When the Arduino is in “rc” mode, it reads in the PWM signals for the steering servo and the motor controller from the radio receiver. It then keeps track of the values and instructs the PWM module board to output the same PWM signals that it read in. When the Arduino is in “rpi” mode, it instructs the PWM module board to output PWM signals according to the setSteer and setThrottle commands it receives from the RPi. When the Arduino receives a getData command, it responds by sending the current steering angle and throttle value to the RPi.

Chapter 5: Communication Protocol

The RPi and the Arduino communicate with each other via through a serial connection. One of the RPi's USB ports is connected via a USB to micro USB cable to an FTDI board that is then connected to the Arduino's serial pins. Data is sent over the serial connection in the format of null-terminated C-strings. The format of the commands sent from the RPi to the Arduino is shown in Table 1 and the format of the responses sent from the Arduino to the RPi is shown in Tabe 2 below.

Table 1: Format of RPi to Arduino Commands

RPi Command	C-string Sent to Arduino	Minimum number of bytes sent	Maximum number of bytes sent
setMode(“idle)	'A I\0'	4	4
setMode(“rc”)	'A R\0'	4	4
setMode(“rpi”)	'A P\0'	4	4
setSteer(number*)	'B ascii_number\0'	4	7
setThrottle(number**)	'C ascii_number\0'	4	7
getData()	'D\0'	2	2

* The number is an integer in the range [-100, 100] that represents [max left turn, max right turn]
** The number is an integer in the range [-100, 100] that represents [max reverse, max forward]

Table 2: Format of Arduino to RPi Responses

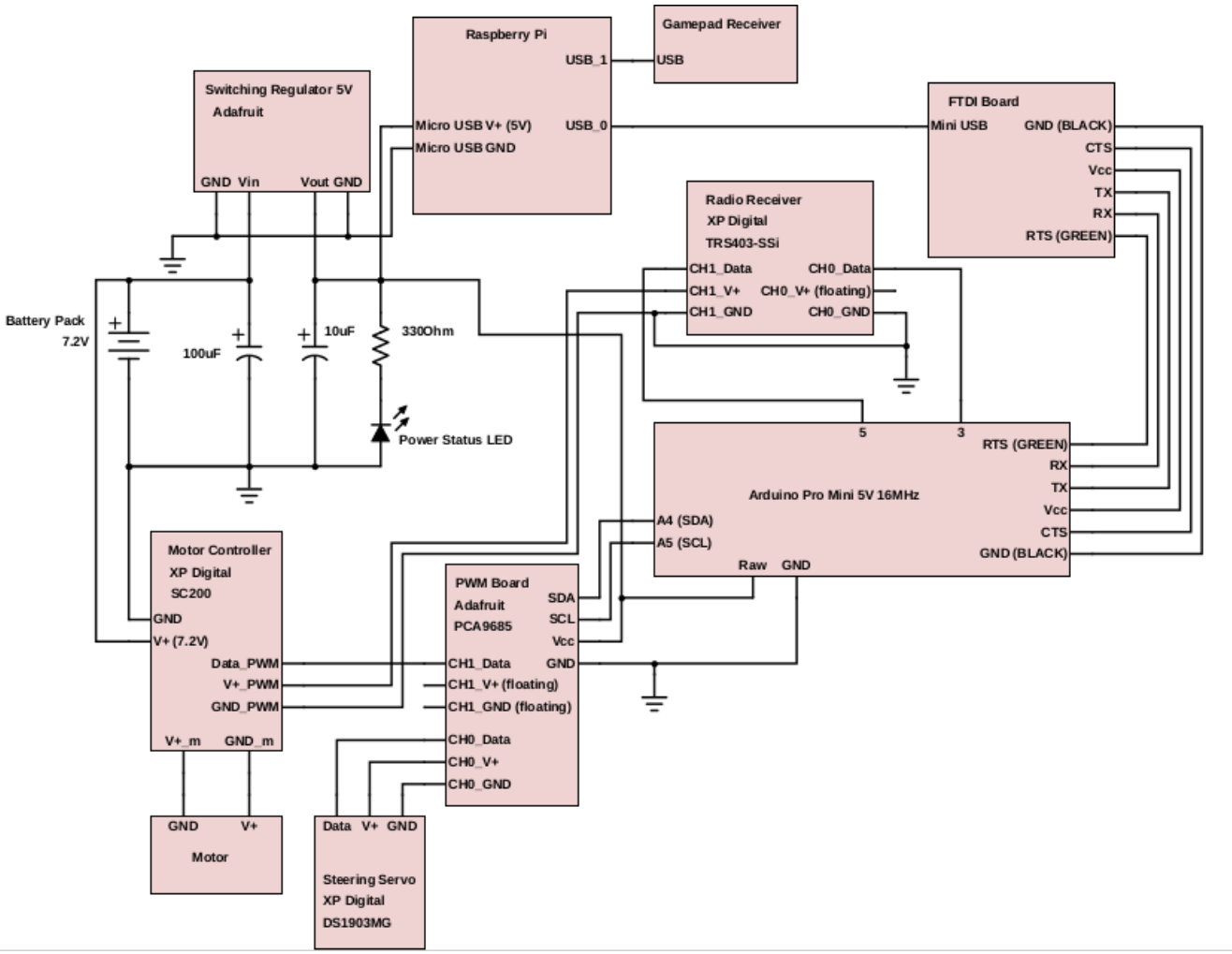
RPi Command	Response C-string Sent to RPi	Minimum number of bytes sent	Maximum number of bytes sent
setMode(“idle)	NONE	0	0
setMode(“rc”)	NONE	0	0
setMode(“rpi”)	NONE	0	0
setSteer(number*)	NONE	0	0
setThrottle(number**)	NONE	0	0
getData()	'E ascii_number ascii_number\0' ***	6	12

*** The first number is the steering percentage* and the second number is the throttle percentage**

Chapter 6: Circuitry

The project uses custom power regulation circuitry to provide a steady 5V DC to the Raspberry Pi and the Arduino. The 5V switching regulator used is the UBEC DC/DC Step-Down (Buck) Converter - 5V @ 3A output, available from Adafruit. The 7.2V and GND lines from the battery pack are soldered directly to the leads on the battery pack plug that is connected to the motor controller. Below is a diagram of the circuitry that shows all of the connections between components. Some of the unused pins (pins left floating) on the components are not shown.

Figure 1: Circuitry Schematic



Chapter 7: Future Plans

Plans for improvement in the next versions of the project include:

- Improve efficiency and reliability of serial command structure
- Improve game pad control of car
- Integrate IMU with Arduino
- Integrate robotic arm and accompanying step-up power circuitry
- Devise a way to measure rear wheel speed (doesn't seem to be enough room for an encoder)