CENTRO UNIVERSITÁRIO DA FEI

Smart Car Race Brazil 2011 Technical Report

MicroFEI Team

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CONTENT

INTRODUCTION

The challenge of "The Freescale Cup – Smart Car Race" is to build a car able to run in a track using only sensors, motors and a microcontroller, guided by a reference line. In the Brazilian edition each team receives a car chassis, motors, battery, a linescan camera and a development board and teams must be creative to provide their own solutions to make the car complete the challenge.

The development board chosen was the TRK-MPC5604B, which have a 32-bit Qoriwa family microcontroller. Additional hardware, sensors and actuator must be developed and joined to work together.

This document provides information about MicroFEI Team car, which uses a RCA camera as the main sensor of the car, and it controls the motors based on the image processing.

SYSTEM BLOCK DIAGRAM

The Figure 1 shows a simplified block diagram of the car. There are presented each key part of firmware and hardware.

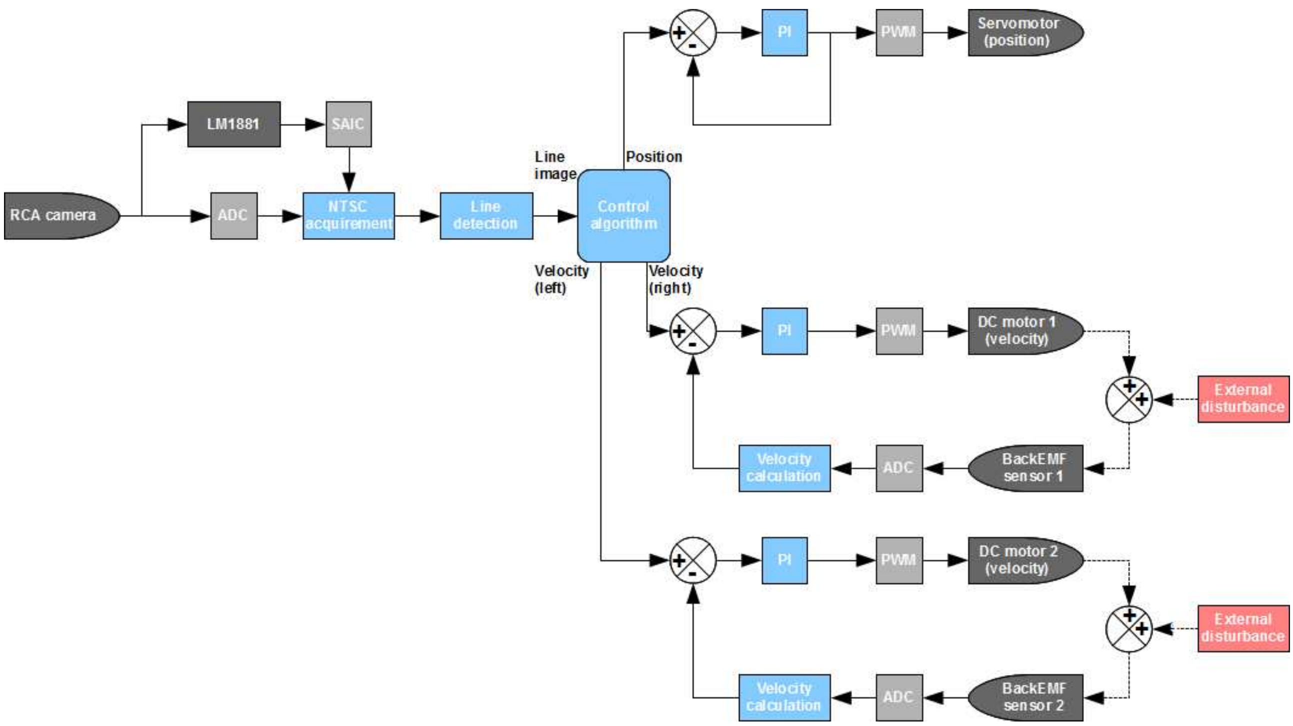


Figure 1: system block diagram

Dark gray blocks are the hardware. Gray blocks are the drivers, which are the parts of the firmware which access directly the peripherals of the microcontroller. Blue blocks are the firmware which does not depend on the microcontroller.

Using this diagram is possible to understand the data flow and how the data shall be processed to go from the sensors to the actuators. It is also possible to know how the microcontroller accesses the hardware.

The following is a brief description of the sensors and actuators used in the car, as well as the basic concepts related to these components.

RCA CAMERA:

This is a common small analog camera, usually used as surveillance cameras. The output is a composite video signal coded in NTSC or PAL standard and the sensor type can be C-MOS or CCD.

In the car the camera works as the navigation sensor. The camera chosen was a CCD camera that provides a NTSC output video signal.

The NTSC signal is composed by sync levels, color bursts and video levels. Each line of a frame comes after a horizontal sync signal and a color burst. Each frame is divided in two fields (odd and even fields) of 240 lines each field. A NTSC video line signal is presented in the Figure 2.

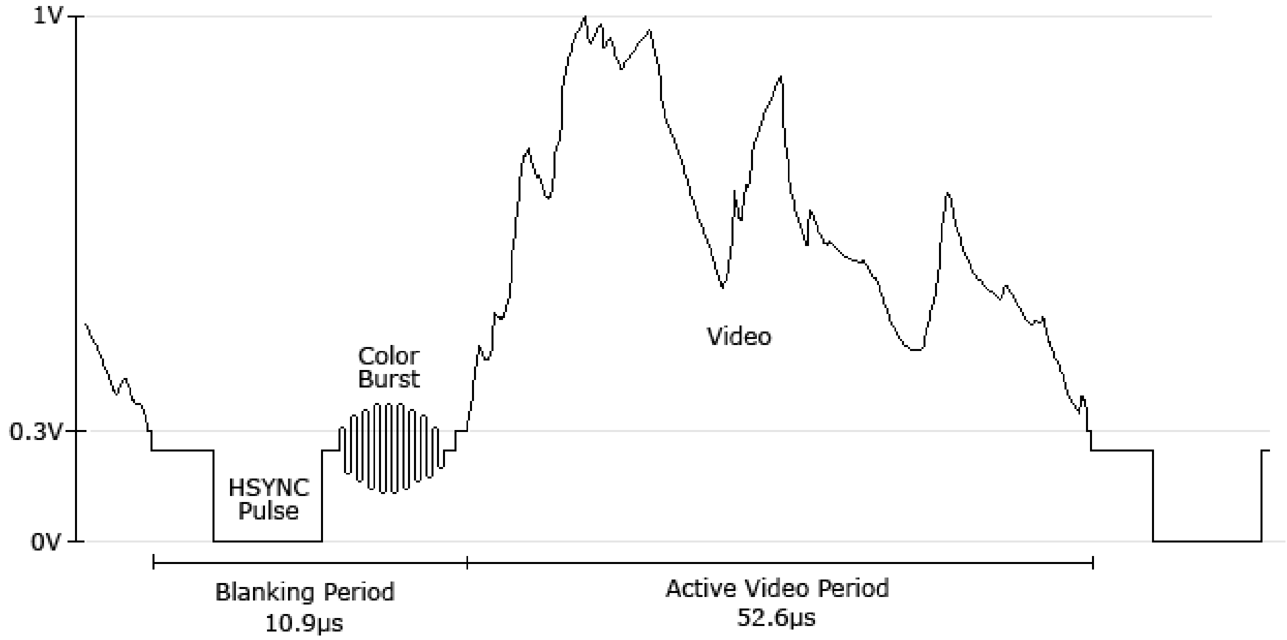


Figure 2: NTSC line signal

With this signal is possible to rebuild each frame of camera. In order to make this task simpler, a video sync separator integrated circuit (LM1881) was used to separate some sync signals from the composite video. So the microcontroller receives the composite video signal (in an ADC channel) plus the sync signals (in three SAIC channels). Sync signals are used by the microcontroller to start video acquirements in right time .The NTSC standard give 240 lines per field (each frame has two fields), however this application does not need all lines each field, so just 120 lines are processed.

DC MOTORS:

DC motors works as the propulsion engines in the car. There is one DC motor in each rear wheel, thus it is possible to control the velocity in each wheel independently.

The velocity of a DC motor is directly proportional to the supply voltage, so the velocity can be controlled lowering the supply voltage, for example with a PWM signal. In addition, the rotation direction is defined by the current direction.

To control both velocity and direction the most used scheme is the H-bridge, which is a topology of 4 switches, which work in pairs and can be controlled with PWM signals. One H-bridge is necessary to control each motor, then it is needed two H-bridges.

The car uses two TLE 5260-2G, which is an integrated circuit that implements an H-bridge with MOSFETs as switches, and it can be controlled by TTL levels.

VELOCITY (BACK EMF) SENSORS:

DC motors and DC generators are physical similar. Thus if a motor is spinning it generate a voltage proportional to their speed of rotation. This is called back electromotive force (EMF). So, it can be used to conclude the speed of motor's rotation simply by reading the voltage at the motor terminals, making possible a low cost and easy to implement motion feedback.

An important limitation of this method is that the supply of motor must be interrupted for a period of time, to ensure that the voltage generated by the motor inertia stays constant. Typically this procedure runs in a frequency around 50 Hz. An example of a back EMF measurement is shown in Figure 3.

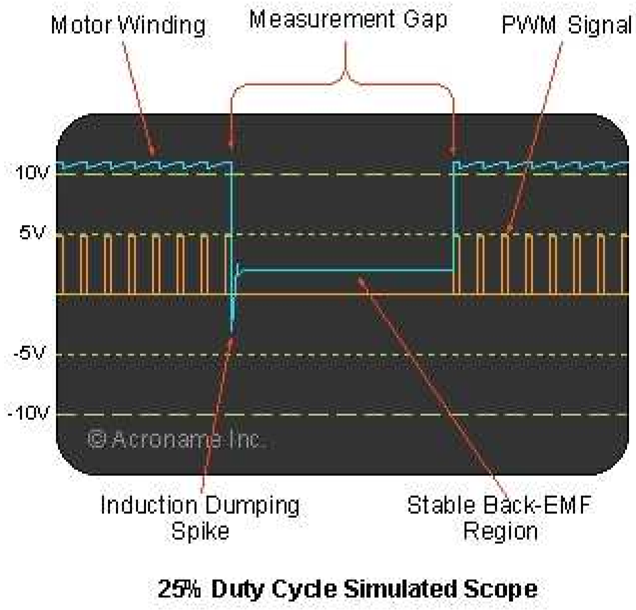


Figure 3: back EMF example (1)

In practical terms, the additional hardware required to implement a back EMF motion feedback is just a voltage divider adjusted to match the motor voltage levels to the microcontroller levels.

SERVOMOTOR:

To control the steering of the car a servomotor is a good choice. A servomotor is a DC motor combined with a position control circuit and a gear, able to maintain a position according to an input PWM signal. The position (in degrees) is proportional to duty cycle, which should be between 1 ms and 2 ms, as shown in Figure 4.

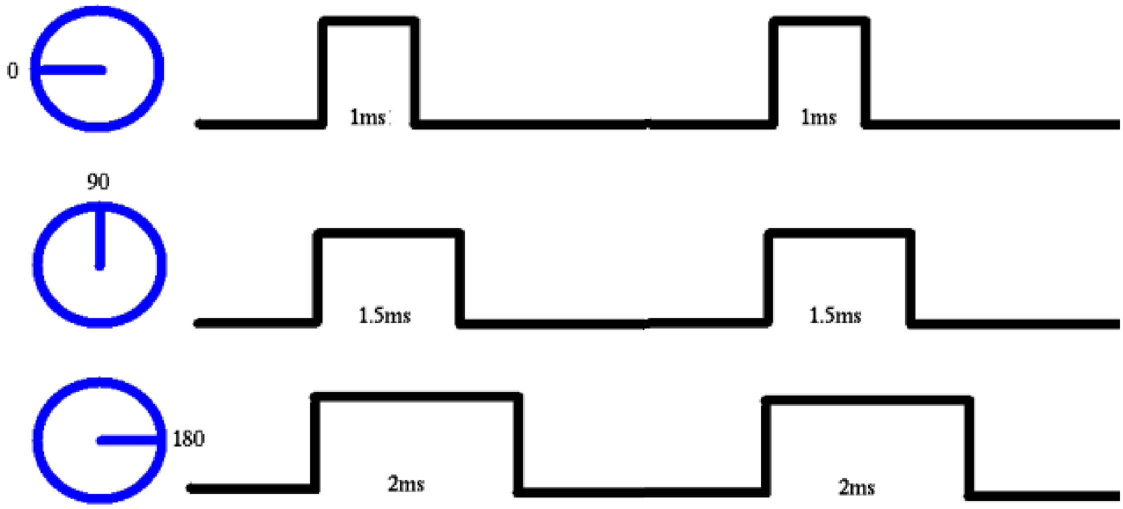


Figure 4: servomotor PWM signals

The limits of servomotor must be adjusted according to the mechanical characteristics of the car, to ensure that the wheels will not hit the chassis. In this, case considering the position 0 as the wheels pointing forward the limits are +- 25 degrees in the servomotor.

HARDWARE DESCRIPTION

A printed circuit board was made for the additional hardware required. This board can be called “drivers board” and the camera, DC motors, servomotor e battery are first connected to this board.

With the entire hardware solution completed, the two boards (development board and drivers board) were mounted on the car chassis. The total maximum current consumption is around 960 mA at 7.6 V.

VIDEO SYNC SEPARATOR:

Figure 5 shows the LM1881 schematic mounted on the PCB.

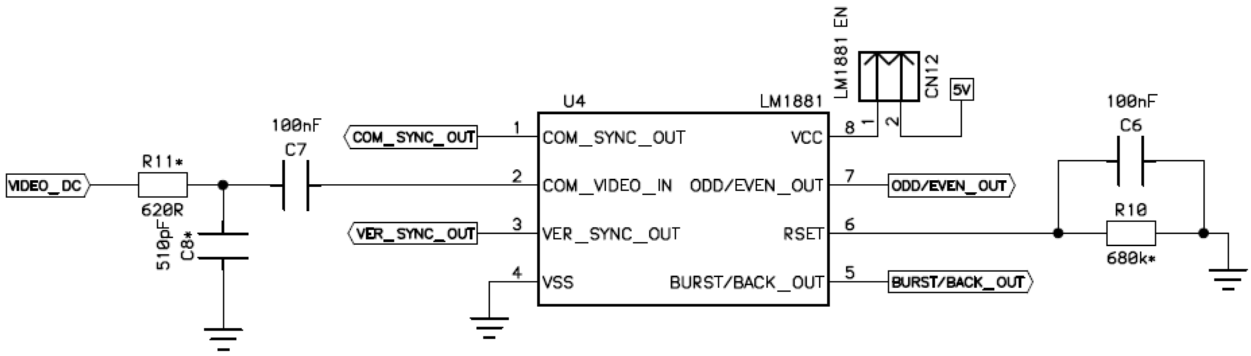


Figure 5: LM1881 schematic

The LM1881 is a video sync separator that extracts signals named “composite sync”, “vertical sync”, “burst/back porch timing”, an “odd/even information” from standard composite video signals (in this case a NTSC signal).

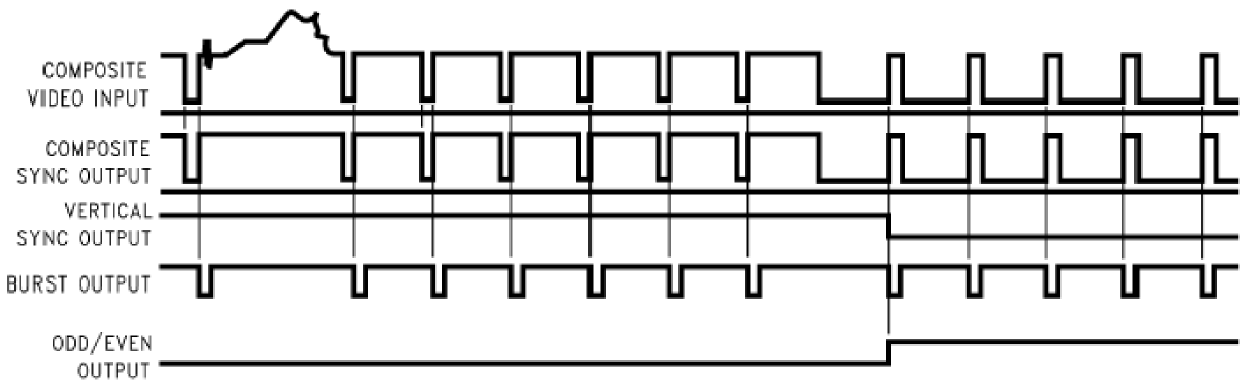


Figure 6: LM1881 signals (2)

An example of sync signals extracted from a composite video signal is shown in the Figure 6. All these signals are connected to the microcontroller, both the LM1881 outputs and the composite video signal. The sync signals are connected to the SAIC channels pins, and the microcontroller uses theses signals to know when start the analog to digital conversions of composite video signal, which is connected to an ADC channel pin.

H-BRIDGES:

Two H-bridges ICs are mounted on the PCB, one to each DC motor. The schematic of TLE 5206-2G H-bridges is shown in the Figure 7.

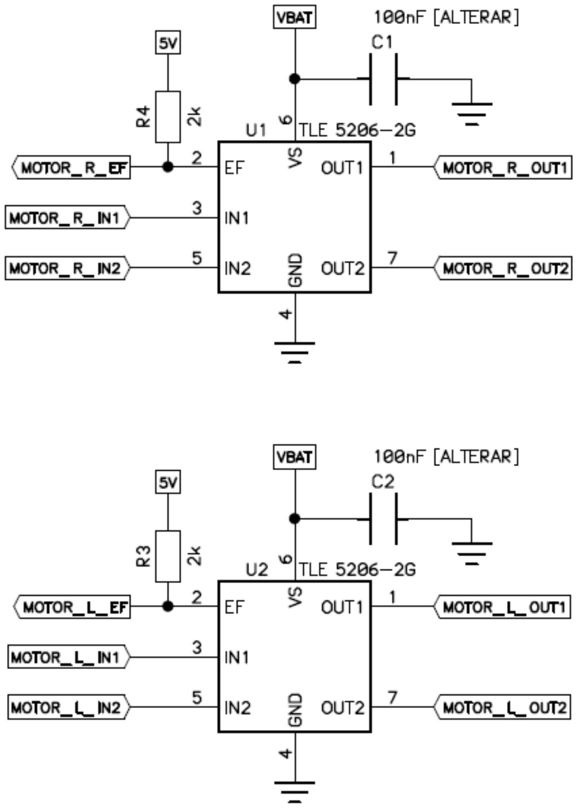


Figure 7: H-bridges schematic

The TLE 5205-2G is an H-bridge for DC motors applications with CMOS/TTL compatible inputs in a P-TO263-7-1 package. It supports up to 5 A continuous and 6 A peak current.

The H-bridge is controlled by inputs IN1 and IN2, and dependent on the combination of inputs switches will short the outputs OUT1 and OUT2 to GND or to VBAT. Then, motor receive its supply from battery by the H-bridge.

A pair of PWM signals is used to control velocity and direction of rotation of the motors, in a mode called “Sign/Magnitude Control”. When the input IN1 is kept high and IN2 is switched with a PWM, the motor turns clockwise, for example, and vice-versa. In this case, the velocity of motor is inversely proportional to PWM duty cycle. When both inputs IN1 and IN2 are kept to high or low, the motor is short-circuited, it makes the motor break. An example of this mode is in Figure 8.

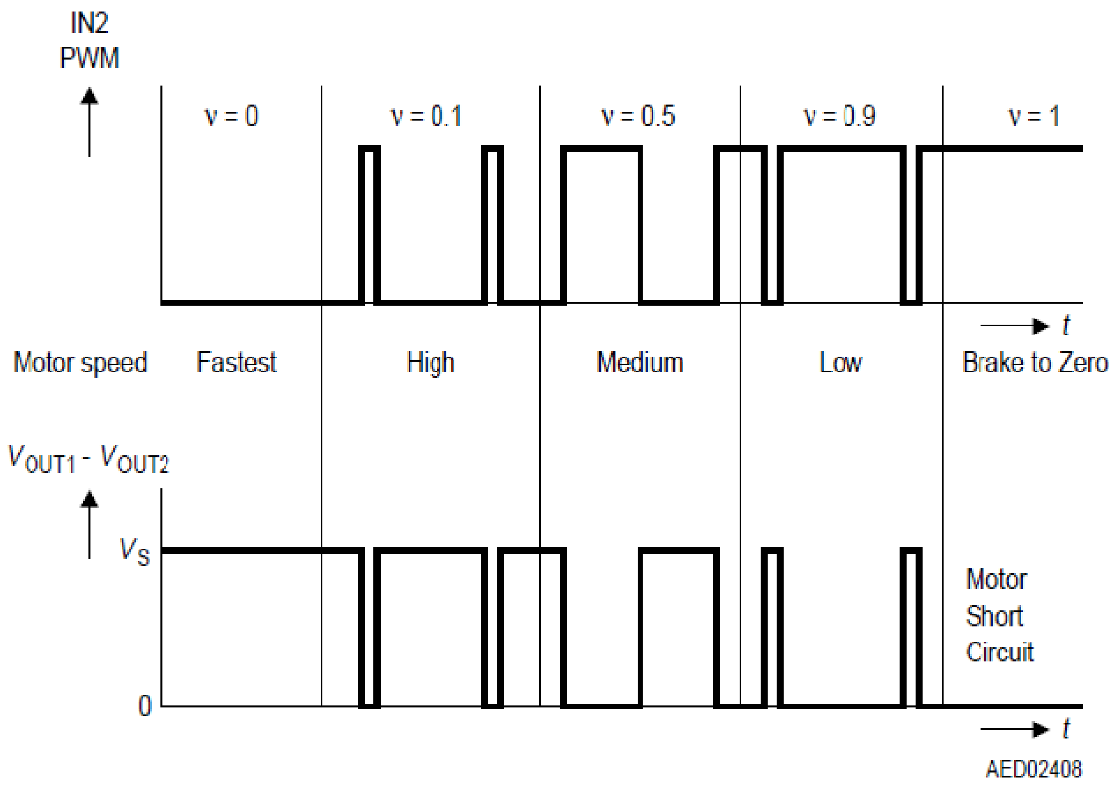
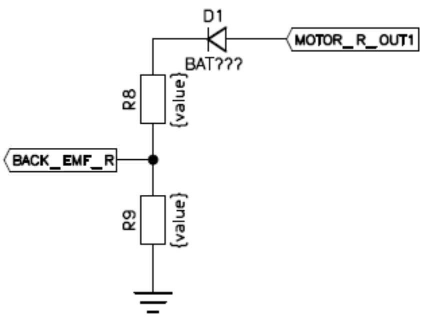


Figure 8: TLE 5206-2G signals (3)

BACK EMF SENSORS:

The simple velocity sensors schematics are shown in the Figure 9. It is just a voltage divider that must be adjusted to lower the voltage generated by DC motor compatible with microcontroller.



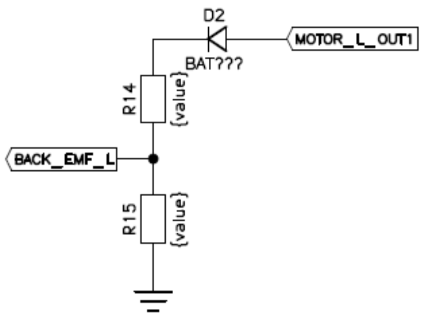


Figure 9: back EMF sensors schematic

SERVOMOTOR CONTROL:

Servomotors typically works with a 5 V power supply and a 5 Vp PWM control signal. Just to protect the microcontroller there is a TBJ between microcontroller output and servomotor input. In this case, the PWM signal generated by microcontroller must be inverted. This schematic of servomotor control is shown in Figure 10.

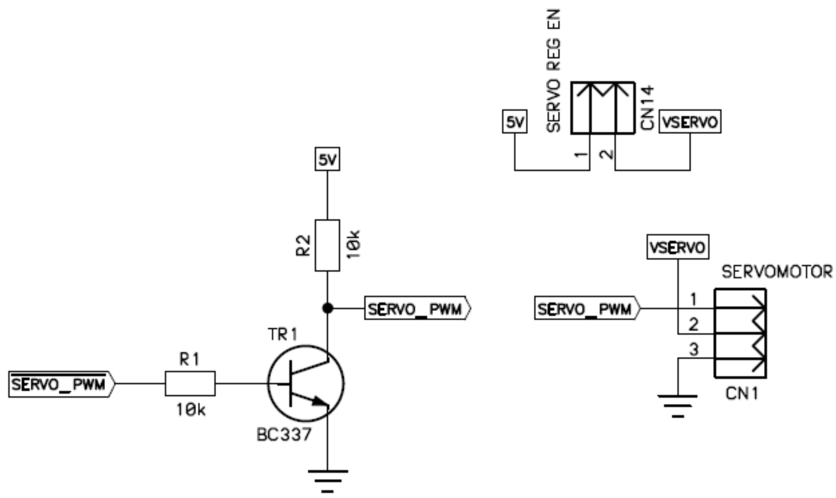
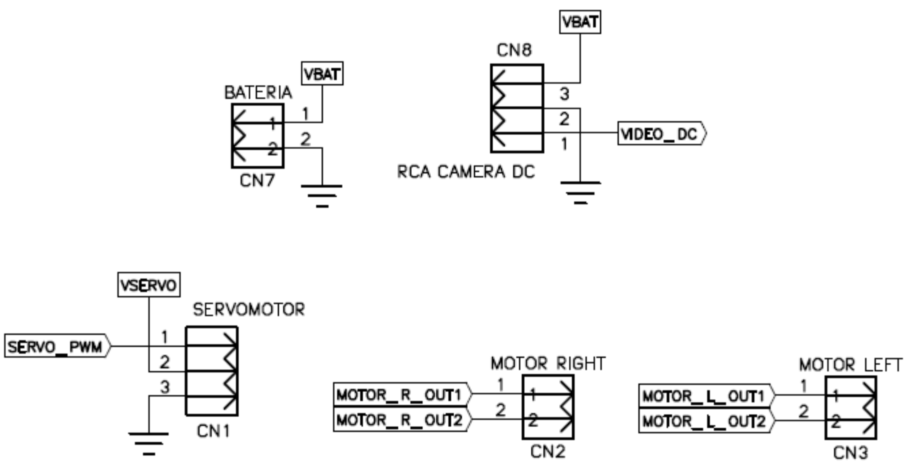


Figure 10: servomotor control schematic

BOARD CONNECTIONS:

Since all sensors and actuators are connected to drivers board first, before connecting to microcontroller, there are input and output connectors. The connectors CN6 and CN10 are the interface between the TRK-MPC5604B board and the drivers board.



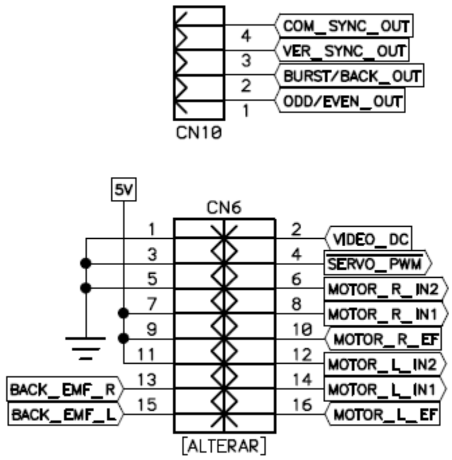


Figure 11: board connections schematic

Figure 11 shows the board connectors and the name of respective signals.

SOFTWARE DESCRIPTION

The software (or firmware) which runs in the MPC5604B can be divided in three basic layers: “Peripheral Drivers”, “Data Processors” and “Central Control”, as shown in Figure 12.

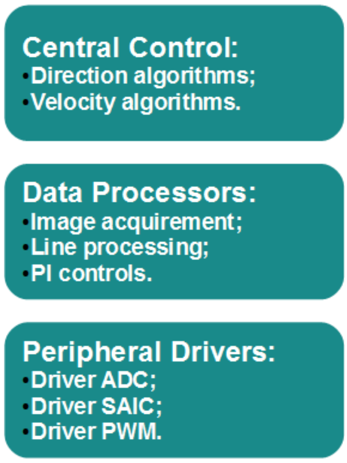


Figure 12: software diagram

In order to optimize the software, the “Image acquirement” and “Line processing” run together, line by line of frame capturing.

All software runs synchronized with the video signal, thus it is the clock of the system, which represents the natural frequency of the control. Each captured frame, there is an update of outputs.

IMAGE ACQUIREMENT AND LINE PROCESSING:

The algorithms used to process the black line in the image are very specific. Using the maximum frequency of ADC it is possible to read almost 57 times each NTSC line. Thus to estimate where is the black line in the video line the microcontroller find me maximum difference between the converted levels. Higher levels represent white dots and lower levels represent black dots. To a black dot be determined a part of black line, there must be a white dot followed by black dots and a white dot again. If there is more than one black dot in the same NTSC line, the last dot position is considered to determine the right position to new dot.

The Figure 13 is an example of a line processing result.

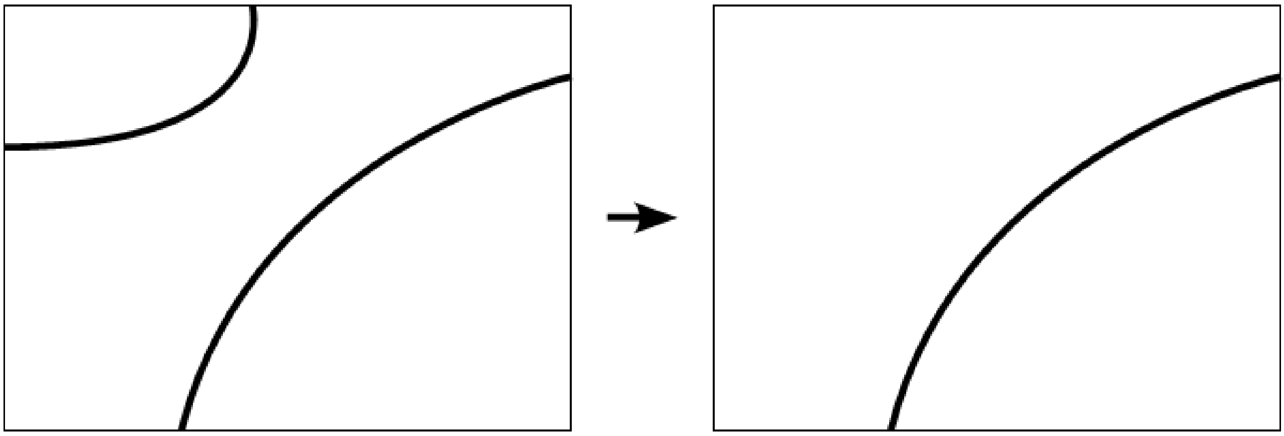


Figure 13: line processing example

With this processing is possible to extract the more likely line.

CAR DIRECTION AND VELOCITY:

Based on the line processed the microcontroller can decide to where and how fast the car will go.

The direction is determined looking for the most ahead point. Then the angle from this point to the lower central point (where the car should be) is calculated and passed to the servomotor. In this pass a gain may be applied to correct the gear differences. It can be seen in the Figure 14.

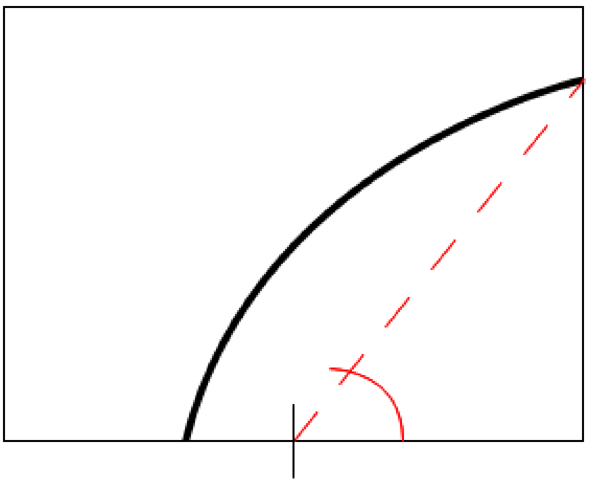


Figure 14: direction determination

With the direction calculated, the velocity should be determined. In this case there are some velocity levels: both motors fast forward (used in line tracks) and one motor fast and other slow (to the car to turn the corners).

MECHANICAL CHARACTERISTICS

To ensure that the camera will capture a great area o track and to avoid much distortion of image, the support of can be adjusted up to 35 cm high. The post is made by aluminum and the base is fixed to servomotor's support, as can be seen in Figure 15 and Figure 16.

Figure 15: camera support

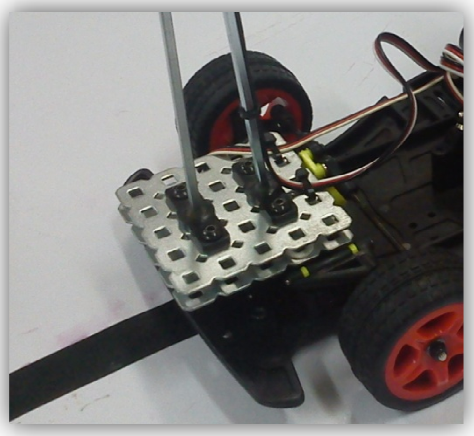


Figure 16: fixing stem

The original dimensions of car chassis were not modified. The final dimensions are:

Width: 16.2 cm;

Length: 19.5 cm;

Height: 35 cm;

Weight: 0.9 kg.

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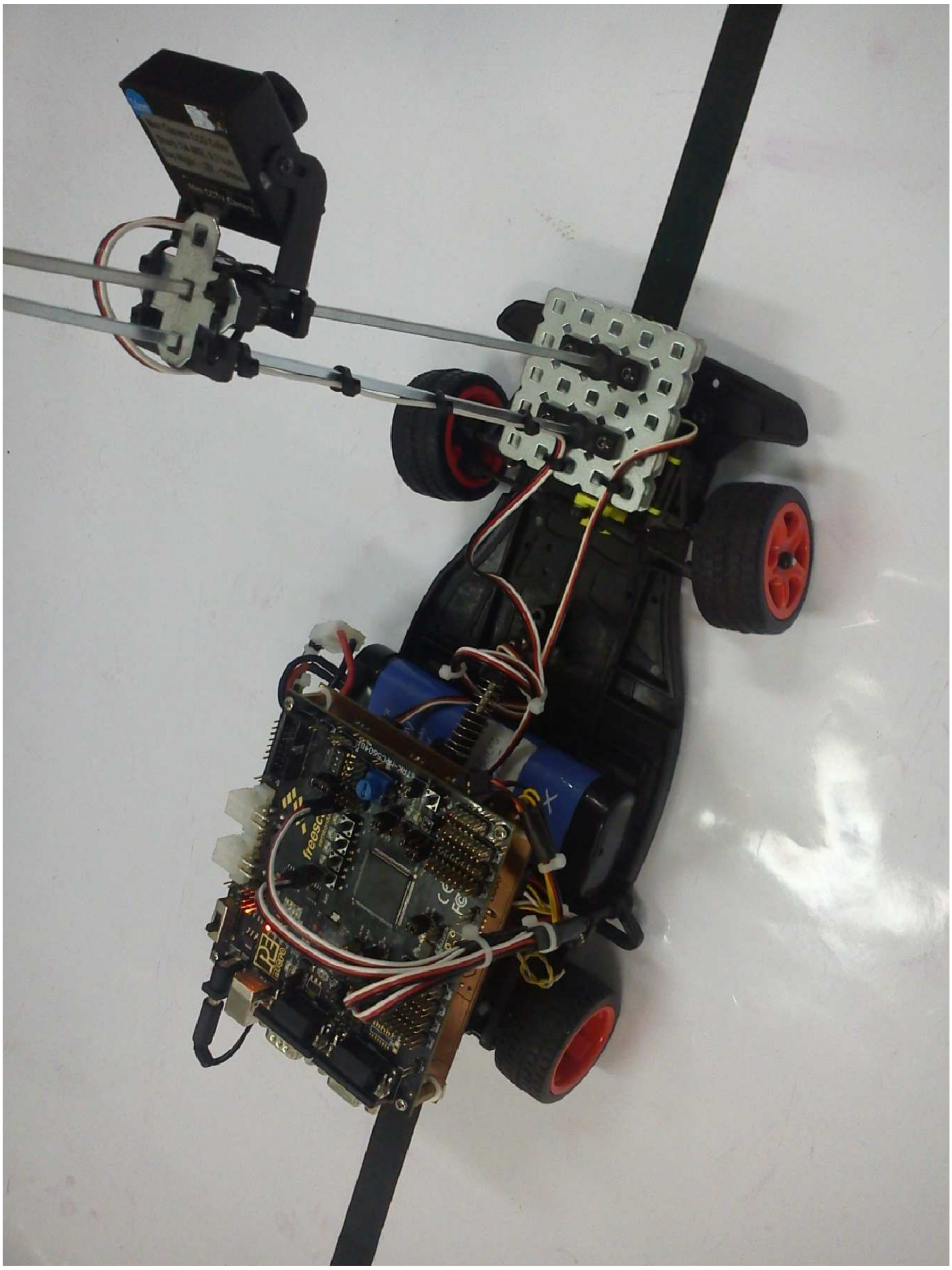
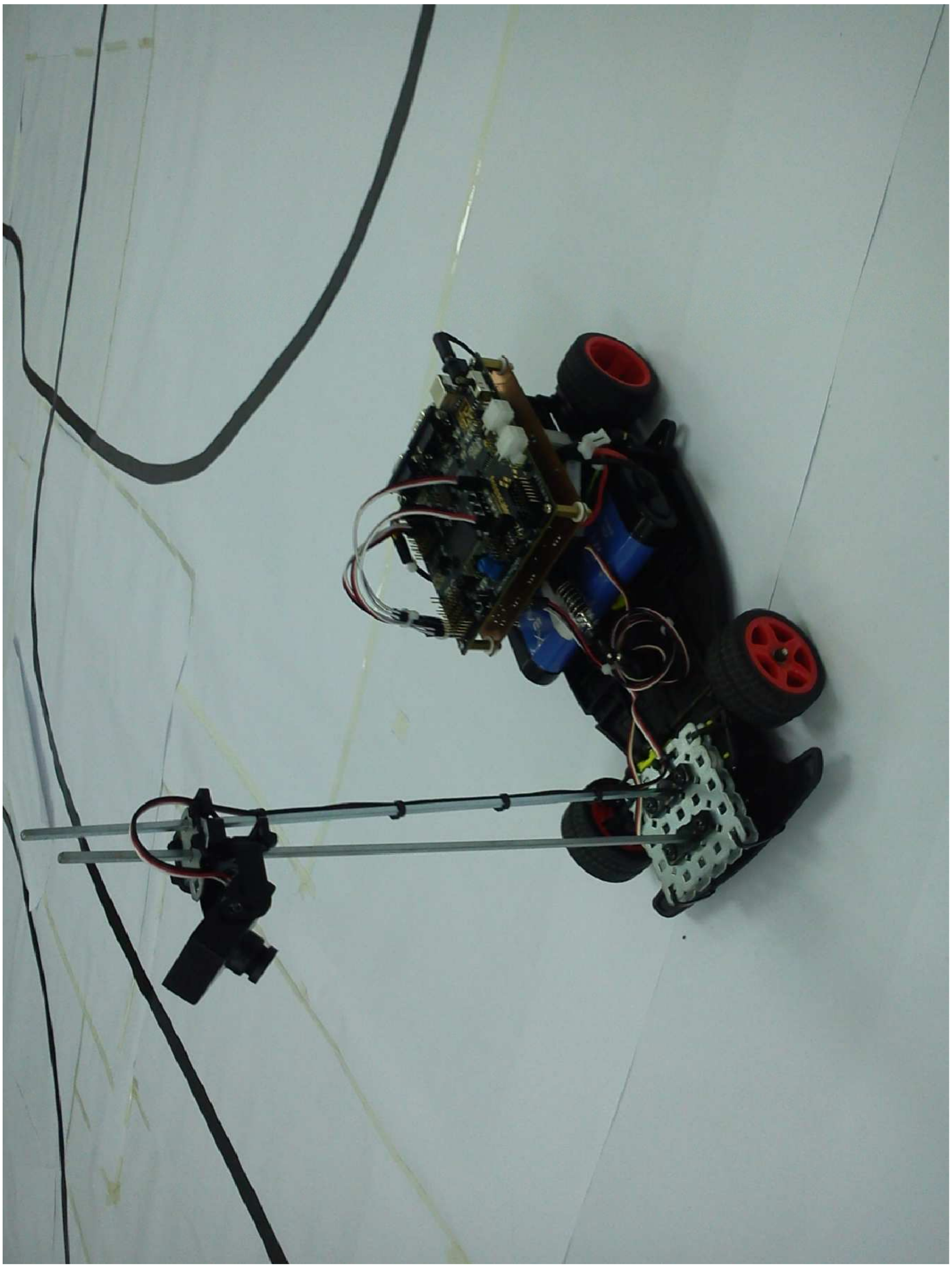
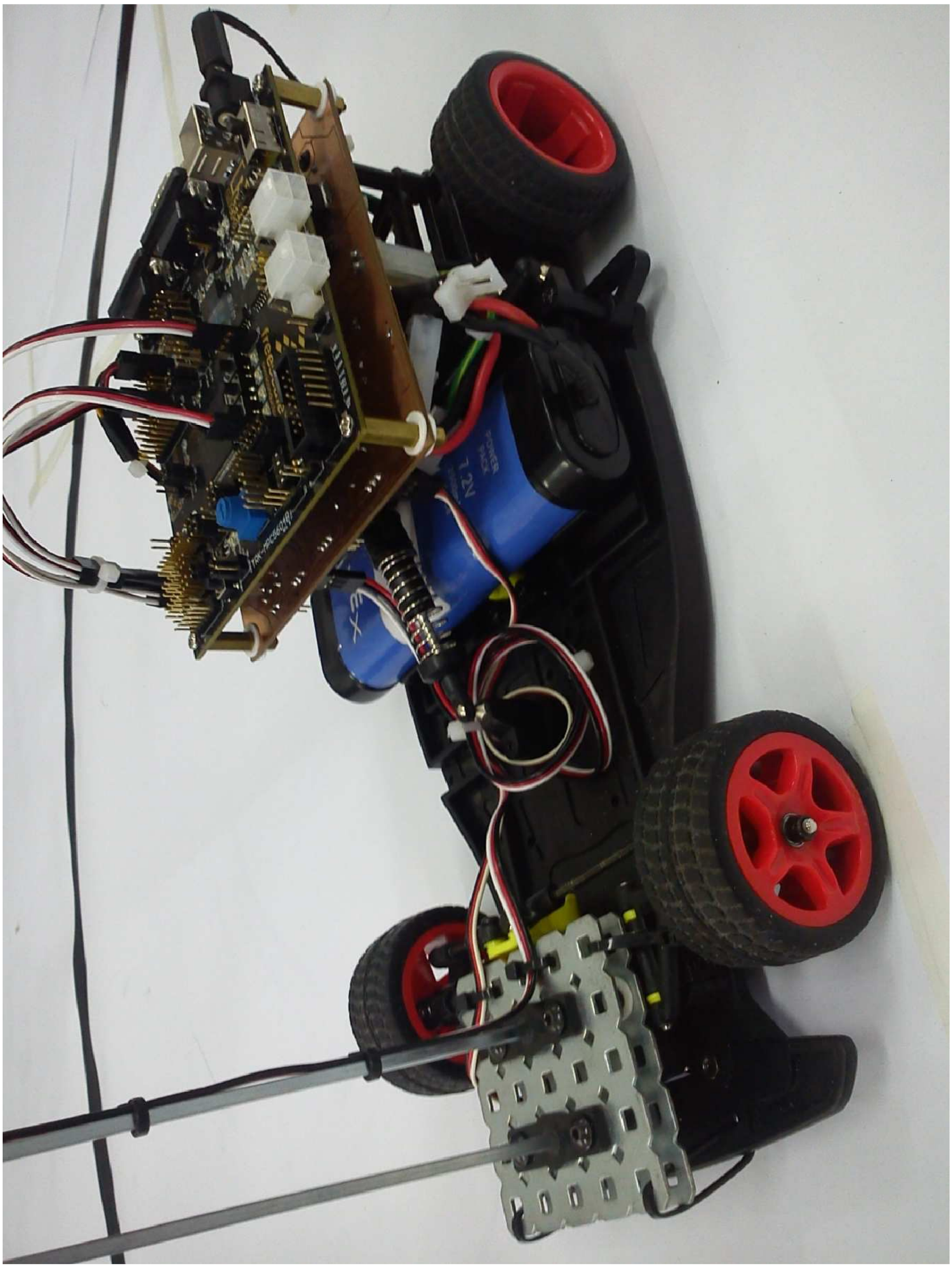
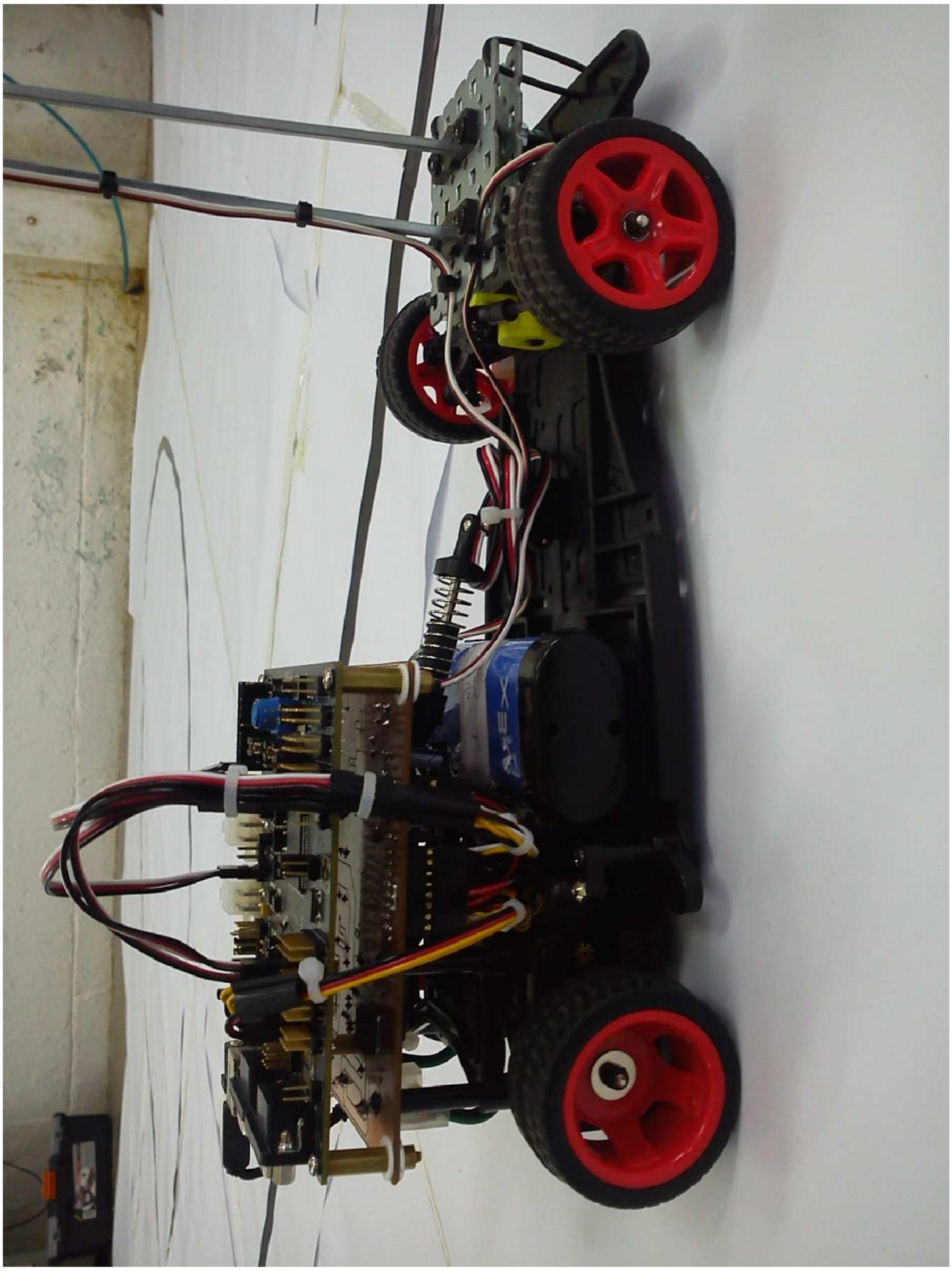
ANNEXES

ANNEX A: CAR PICTURES









ANNEX B: SCHEMATICS