

DEVELOPMENT OF MOBILE ROBOT WITH 4WD AND 4WS CAPABILITY

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Abstract

This paper describes the design and development process of a mobile robot with 4WD and 4WS capability. Robot is equipped with four DC drives, each driving one wheel, and four RC servo drives, each steering one wheel. This gives us unique capability of testing various traction control and stability algorithms. This robot is used mainly for educational purposes in mechatronics: including control design, system identification, electronics, kinematics, dynamics, programming etc. To speed up the development process, we have used tools from Mathworks: parameter estimation toolbox to estimate various parameters of the vehicle, and tools for rapid code generation for on-board microcontrollers.

1 Introduction

A recent trend in product development (which includes some sort of programming) includes rapid code generation. This technique well prepared and supported in Mathworks MATLAB Simulink, which with some toolboxes allows automatic C code generation directly from the model, another blockset allows the direct code generation for target platform such as PIC microcontroller.

We have designed four-wheel steered and four-wheel drive vehicle as an experimental platform for testing of various traction control algorithms and also as an educational platform for our mechatronics courses. Besides the 4WD and 4WS capability the vehicle features many interesting tasks, ranging from mechanical design of the chassis, suspension, transmission, over electronics design: power electronics, microcontrollers, sensory array and communication, to firmware: motor control, remote communication, data processing – filtration and analysis, traction control and vehicle stability control.

2 Mechanical construction

Mechanical construction was partially custom designed – aluminum main frame, and partially is using standard 1:5 RC buggy parts – transmission, steering and suspension. Whole vehicle is about 80 cm long, 45 cm wide and 20 cm high, it weighs about 15 kg, and rated speed is about 13 kmph.

Each wheel is driven by a separate DC motor, and steered by its own RC model servo. Wheel suspension is also individual for each wheel. This gives us great flexibility with the traction and other stability control algorithms. Modified Ackerman algorithm (for 4WS) is used to compute the steering angles, we do not use the speeds – it has proven more useful and robust to use torque control than speed control.

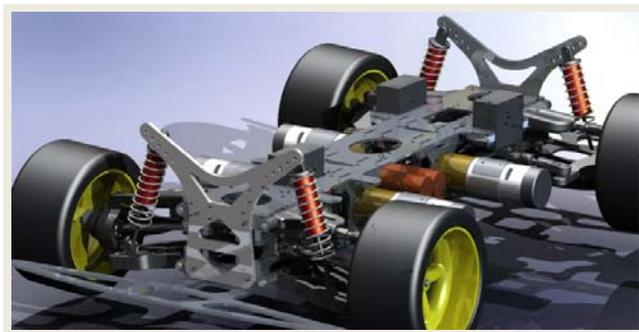


Fig. 1.: Main body frame (CAD render)

3 Electronics

Electronics design divides into power board, designed to power the DC drives, low level – on-board microcontroller units, primary and secondary sensory array and remote control unit. Complete on-board scheme is shown in figure 1.

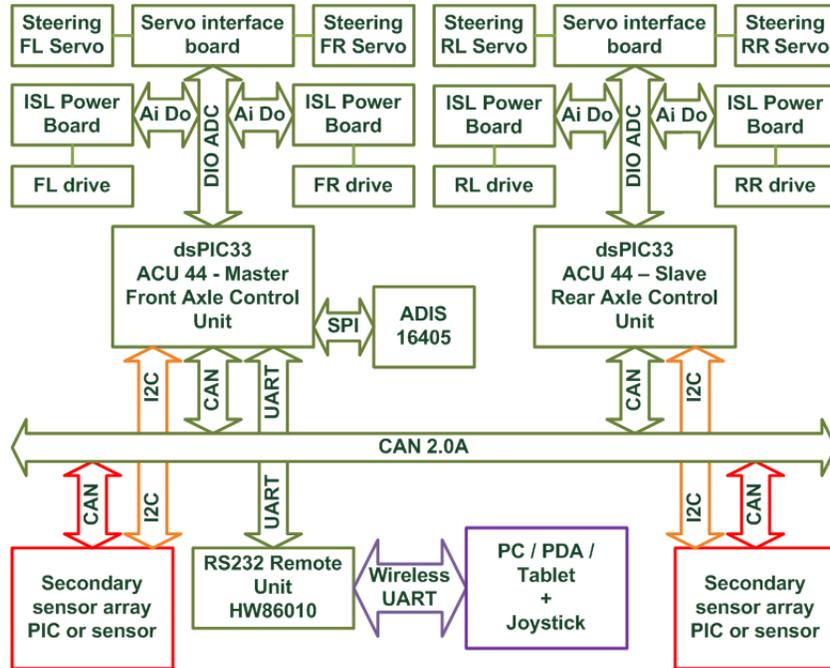


Figure 1.: On-board electronics scheme

3.1 Power electronics

Power electronics, dedicated as “ISL Power Board” is an h-bridge based on N-channel FET driver ISL83204A. This circuit operates up to 60V, we have used N-FETs which allows currents up to 104A, giving us more than enough power for our DC motors (rated 24V 35W). Board is equipped with current transducer from LEM giving us information about current flowing through the motor – which is proportional to the motor torque. Each of four motors has its own h-bridge power board. Energy for the main drive is provided by 28.8V LiFe pack (8x A123), servos are powered from 6V NiMH pack, same for the microcontrollers, but there is a separate pack for them – to prevent brownout reset.

3.2 Control electronics

On-board electronics is controlled with two identical microcontroller units designated ACU44. ACU44: Axle Control Unit is based on 44-pin dsPIC microcontroller dsPIC33fj128mc804, which is designed to provide motor control features including QEI peripheral (Quadrature Encoder Interface) and HW PWM module. We are using the QEI and also the PWM module, but without all its features. This is due to the way the ISL Power Board is driven (one PWM signal, DIRection logical signal, and DISable), so there is no need to use i.e. the dead-time settings.

Each ACU drives one axle: two DC drives and two servos. This is due to limited number of QEI (two modules) on each microcontroller. Communication between the units is realized over the CAN bus, this gave us great flexibility when we have decided to use more powerful on-board microprocessor MPC555 - only minor code changes have been needed.

3.3 Sensor array

Sensor array is divided into primary and secondary: Primary array deals with the most important data such as motor currents, motor positions, vehicle acceleration, angular speed etc. Secondary array deals with comfort and safety issues: collision avoidance, parking, suspension position, and motor overheat protection.

3.4 Remote control

Remote control is necessary as we need to be able to drive the vehicle in different environments to test it under various driving conditions, so wireless control is a must. Also it is preferable to have the data from on-board telemetry online then storing them i.e. in onboard memory. We have chosen wireless RS-232 modem operating in free band “DECT” standard.

Currently, two variants are used: first is connecting RC to RS-232 port on PC running MATLAB with Simulink model which is reading data from joystick and sending drive commands to the vehicle, and receiving back and processing the telemetry. Second option, that is currently under development is using embedded module based also on dsPIC microcontroller. This option is at the moment limited due to the fact that it has no memory to store telemetry data, but it allows easier field testing i.e. when some minor parameter tuning is required online.

4 Firmware

Low level firmware for both ACUs and for remote control is almost completely generated from graphical representation using MATLAB: Real time workshop, Real time embedded coder, Stateflow and Kerhuel Toolbox from Lubin Kerhuel.

Almost entire design process of the vehicle was supported with tools from Mathworks: starting with some initial simulations and models of the vehicle behavior, over the first programming of the dsPIC microcontroller driving H-bridge controlling the DC motor, then the parameter estimation of the DC motor, later of the entire vehicle. Almost entire on-board firmware was coded using Kerhuel Toolbox, only few lines for yet unimplemented functionality have been written in C and added as an external source code. This approach did speed up the design process significantly and it can make the code more readable and easier to modify for a non-programmer.

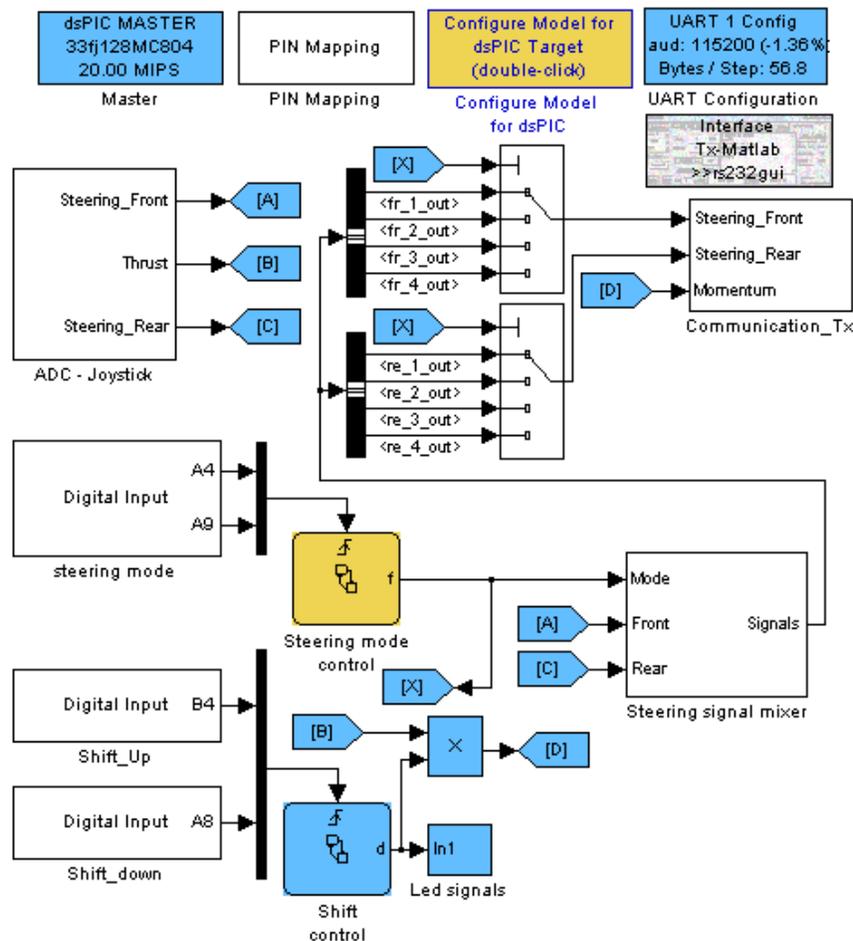


Fig. 2.: MATLAB Simulink – part of source model for remote control

5 Conclusions

In this paper, we have presented the design process of an experimental and educational mobile robot platform, which was strongly supported by tools for Rapid code generation and Rapid control prototyping mainly from Mathworks. This vehicle is currently used in educational process as a demonstration tool in several mechatronics courses, and also as a platform for student final thesis.

Acknowledgement

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