

# DSP-Based Control of Autonomous Vehicle Driven PMDC Motor

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**Abstract:** In this paper a direct current (DC) motor drive system for a vehicle tracking a given route is developed. The control of the system is performed using TMS320F2808 digital signal processor (DSP). The algorithm, which is used for DC motor control, is designed using Matlab/Simulink simulation software. The generated codes are built into the TMS320F2808 directly via CCS (Code Composer Studio) by favour of this software.

A permanent magnet DC (PMDC) motor is used in the vehicle. Motor control is performed based on digital signal controller. The H-bridge dc-dc converter which is driven by the pulse-width modulation (PWM) signals generated by micro controller changes the average value of the voltage applied to the motor and as a result the speed of the motor is controlled

**Keywords:** Autonomous vehicle, Permanent magnet DC machine, TMS320F2808 DSP, eZdsp F2808, Microcontroller

## I. INTRODUCTION

Innovations in automation technology reduce the need for human beings. Although owning cost of technological machinery is high enough, operating and maintenance costs are low. In addition, owing to this machinery, errors caused by humans are eliminated. Firstly the important thing is the control of the motor, which is chosen for the system.

It is common to use special processors like DSP's for motor control applications. On the other hand codes generally generated with classical code generation methods in these applications. Developers generated long and different codes for each Project. For DSP-based control of machines, the structure, development methods and code generation methods should be known for the DSP, which is used. The code generation process can be done in short time. Also it is possible to change the codes quickly when the system is running with some assistant tools.

The codes, which are generated for DSPs, can be created automatically. Pre-design process can be done very fast with using this process. With the help of assistant softwares; code generation, compilation and transfer processes can be done automatically. After that the changes in the assistant software is enough for any changes on the system that user wants.

In this work, the programming process for the DSP which is used for controlling a permanent magnet direct current motor (PMDC) that put on the vehicle which can work autonomously; is done by using Matlab/SIMULINK's "Embedded Target for TI C2000 DSP" library. The codes that we generated with this software are compiled by using Code Composer Studio (CCS) and embedded to the eZdspF2808 circuit board. CCS has emulators for this circuit

board, so we can communicate computer and circuit board [1].

The PMDC motor speed control is done with the system and experimental results saved which are taken from the system. The code generation of the DSP is done with block diagrams and as a result of this the design process is abbreviated.

## II. SYSTEM PARTS

In this study there is different power electronic circuits for the system, which can move, appointed direction. Furthermore the control of the motor, which drives vehicle, is done by eZdspF2808 circuit board, which includes TMS320F2808 digital signal controller. This circuit board also controls designed H-bridge converter motor driver card. It takes and evaluates the data from the encoder and with using these data it controls the vehicle's movement.

### A. Settlement Plan for the Vehicle

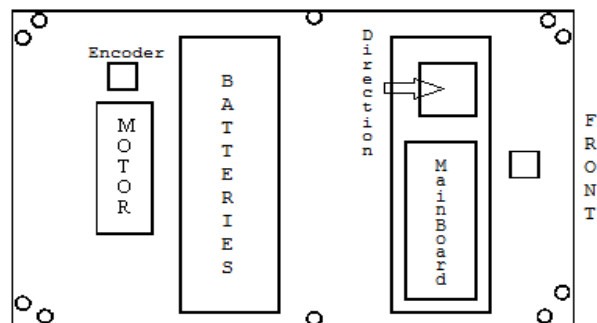


Fig. 1. Schematic of the vehicle

The designed vehicle's general schematic is given in figure 1. Batteries, motor and encoder were placed underside of the vehicle. eZdspF2808 DSP board and other power electronic circuits were placed top of to the vehicle.

### B. Vehicle Parts

The PMDC motor that used for the system runs with 24 V direct voltage. Motor's maximum power is 0,75kW and its maximum current value is 30 A. It has 1000 revolutions per minute (RPM). The motor's torque is transferred to the wheels via the gear system. The PMDC motor can move forward and backward with the help of the pulse Width Modulation (PWM) signal that we generated with eZdspF2808 DSP board.

We used encoder for getting the speed value of the motor. Encoder generates 50 square waves in each round. So 50 square waves mean is a tour of the wheels. The wheels circumference is divided to 50 by eZdspF2808 and with this calculation we get the "distance" data for each square wave. front wheels were connected to steering box for vehicle's turning [2]. This steering box's shaft is turned by a geared step motor. So, we can control the side of the movement.

### C. Designed Circuit Boards

#### 1. Motor Drive Circuit

Motor driver circuit can drive the PMDC motor with different power values and in forward or backward direction, with using PWM signals, which generated by microcontroller. The board is shown below in figure 2.

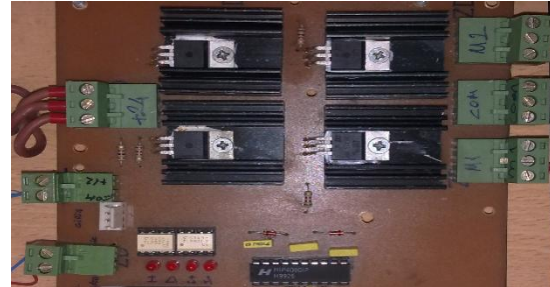


Fig. 2. Direction Control Circuit

#### 2. Direction Control Board

The wheels, if required, can turn right and left by using direction control board. After the time that we chose, the wheels turn their first state. The designed board is shown below in figure 3.

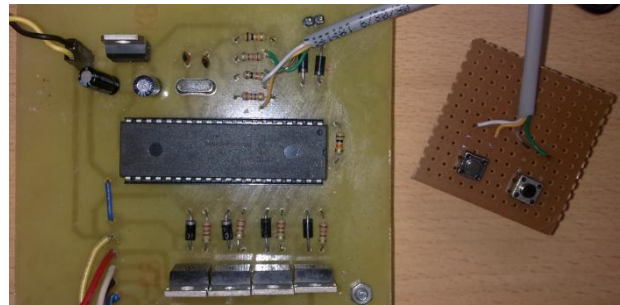
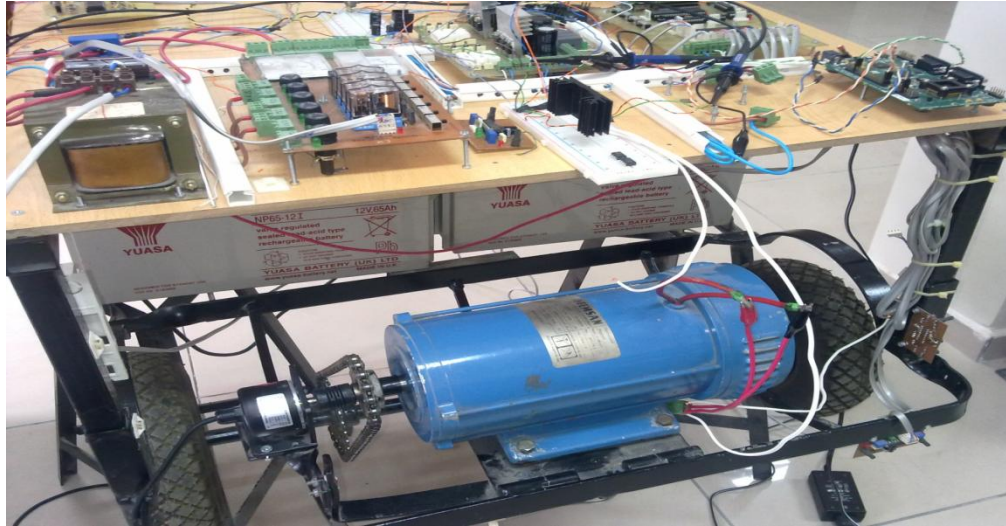


Fig. 3. Direction control circuit



Fig. 4. Main power source circuit.



### 3. Main Power Source Board

The board of the main power source takes the power from batteries and sends it to the other boards and PMDC motor via relays. The main board is shown in figure 4. Also the whole system is given in figure 5.

### III. COMMUNICATION BETWEEN MATLAB AND eZDSPF2808

In this study, DSP TMS320F2808 micro controller has been used for controlling the whole vehicle. MATLAB/Simulink simulation program has been used for programming the micro controller via eZdspF2808 DSP. The first aim of this work was transferring necessary codes into the DSP without writing any code on Code Composer or any other programming language editor, with the help of the SIMULINK blocks. Thus it is not going to be necessary to write different long codes for any other motor control applications, it will be handled by changing some input values, parameters and Simulink blocks.

#### A. Program Compatibility

The only way for embedding codes into the DSP micro controllers is using Code Composer Studio (CCS) program. Matlab has used for generating codes but it is not exactly possible to do embed codes into the DSP just using MATLAB, because only CCS program has the emulators that we need for connect DSP to the computer. But it is not necessary to run CCS for creating DSP codes [3]. When it is needed to create the codes for designed block system, MATLAB will run the CCS on the background and automatically embed the codes into the DSP.

For connecting the DSP micro controller to the computer there are some compatibility conditions between CCS, DSP and MATLAB versions.

TABLE I

MATLAB – CCS COMPATIBILITY

Software Hardware	Code Composer Studio Version	MATLAB/Simulink Version	Application Area
eZdsp-F2812	CCS3.1	R2006b	Control
DSK6416	CCS3.1	R2006b	Visualization
DSK6713	CCS3.1	R2006b	Signal Processing and Communication
eZdsp-F2808	CCS3.3	R2008A	Control
DM6437DVDP	CCS3.3	R2008A	Video

In this table the CCS and Matlab versions are shown for suitable DSP's and application areas. The other versions of MATLAB can also be used with downloading proper emulators for CCS program.

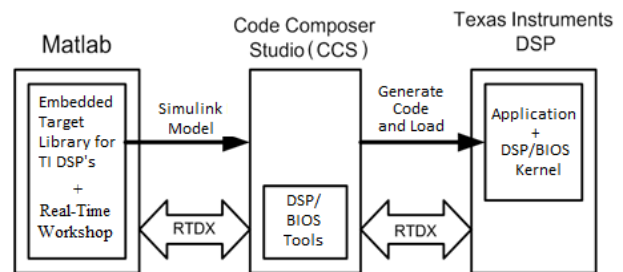


Fig. 6. MATLAB, CCS and DSP relations [5]

### IV. CREATING PWM SIGNAL WITH MATLAB/SIMULINK FROM TMS320F2808

In this section it is explained that how to create a Pulse Width Modulation (PWM) signal which can change duty cycle of MOSFET switching semi-conductor which are placed into H-Bridge DC-DC converter circuit.

#### A. Modeling PWM Generator with SIMULINK C2000 Blocks

With this PWM application which will be explained in this section, it will be shown that how to use PWM and ADC SIMULINK blocks. It will be possible to adjust duty cycle of the PWM signal with controlling ADC input voltage value, which is created by DSP codes. The period of signal is kept constant and the changes on the analog voltage signal can be adjusted simultaneously with the help of “Hardware Interrupt” block.

In this part of the study, it is explained that how ADC block can sample an analog voltage signal and how a PWM block can create an impulse signal. This analog signal, which comes from ADC block, will control PWM signals duty-cycle. Also an oscilloscope is used for observing changes on the duty-cycle.

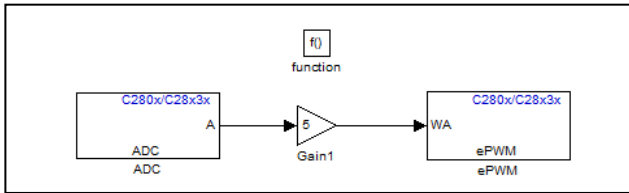


Fig. 7. ADC – PWM block.

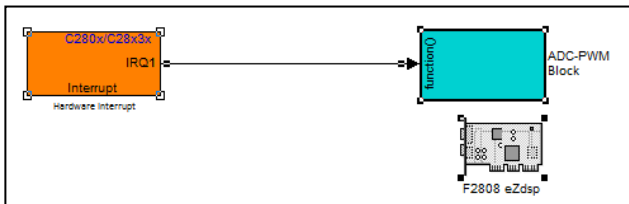


Fig. 8. Simulink model for generating PWM signal.

Here, Hardware Interrupt block creates a loop for ADC section (ISR) and when the signal is created (ADCINT) it adjust the time of the working period for ADC-PWM subblock.

ADC-PWM subblock includes a PWM block and an ADC block, which controls the input port of PWM signals duty-cycle. PWM is adjusted for triggering the conversion of ADC block (SOC).

### B. Application

eZdspF2808 DSP board, oscilloscope, signal generator, transistor and 12V fan motor are used for preparing application circuit. Signal generator is connected to the ADC input pin, which assigned as ADCINA0 into the model. Oscilloscope is connected to the PWM port of the DSP board for observing the PWM signal. Also PWM output is connected to the transistors collector pin for driving fan motor.

Firstly “Incremental Build” button is used for creating DSP codes from SIMULINK and as a result of this the codes that we need are embedded into the eZdspF2808 DSP board via Code Composer Studio.

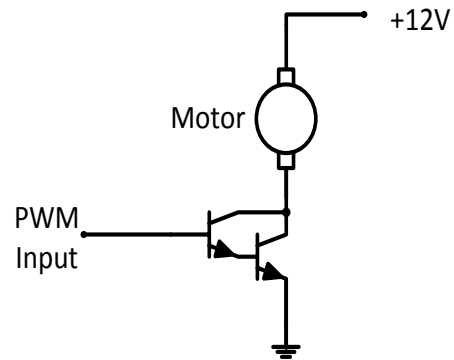


Fig. 9. Application circuit for PWM motor drive.

In figure 9, it is shown that how to connect pins together like a chopper. The peak voltage of PWM is measured  $V_{pp}=3,46$  V and transistor is switched with this voltage value. The duty cycle is 100% when signal generator output is 0 V. And also it is 0% when signal generator output is 3 V. The generated voltage signal from signal generator is connected to the ADCINA0 pin and changes on this signal adjust the output duty-cycle of the PWM signal. The on-off condition of the transistor has been adjusted with this input value. So, with adjusting the output voltage value, the speed of fan motor has also adjusted. Here, ADCINA0 input values has checked instantly with the help of “Hardware Interrupt” block. Two different output signal value are shown in the figures given below.

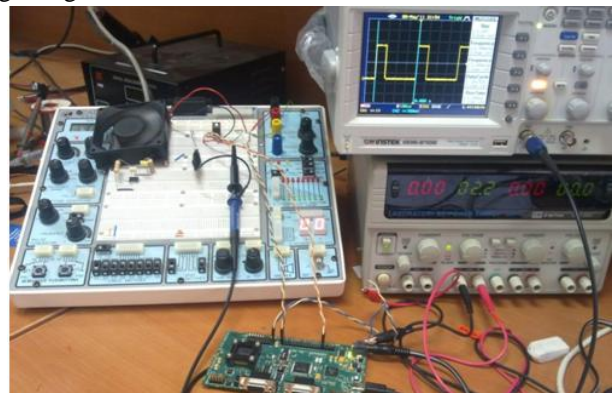


Fig. 10.  $V_s=2.2$  V, Duty-Cycle = %24.52,  $V_{pp}= 3.28$  V



Fig. 11.  $V_s=0.2$  V, Duty-Cycle = %93.15,  $V_{pp}= 3.28$  V

## V. SIMULINK MODEL OF THE VEHICLE APPLICATION

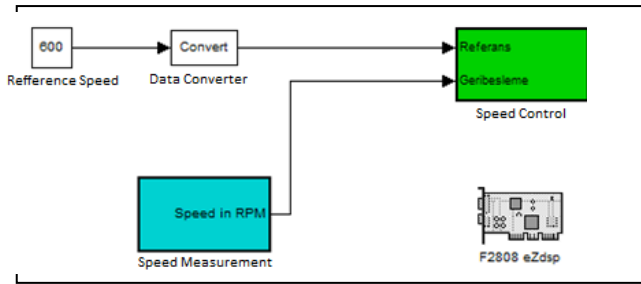


Fig. 12. Designed Simulink model.

In the main model; the speed reference value is converted to the real value. The speed measurement block is connected to the speed control block as a feedback.

### A. Created Blocks on SIMULINK

#### 1. Speed Measurement Block

The main proposal here, is taking the motors instant speed and creating feedback data. The encoder is used for doing this process. eQEP block has been used for reading data from encoder (GPIO20 pin of DSP). With eQEP block it is possible to create a rotor angle data. Rotor angle and speed signals are connected to the DMC speed measurement block.

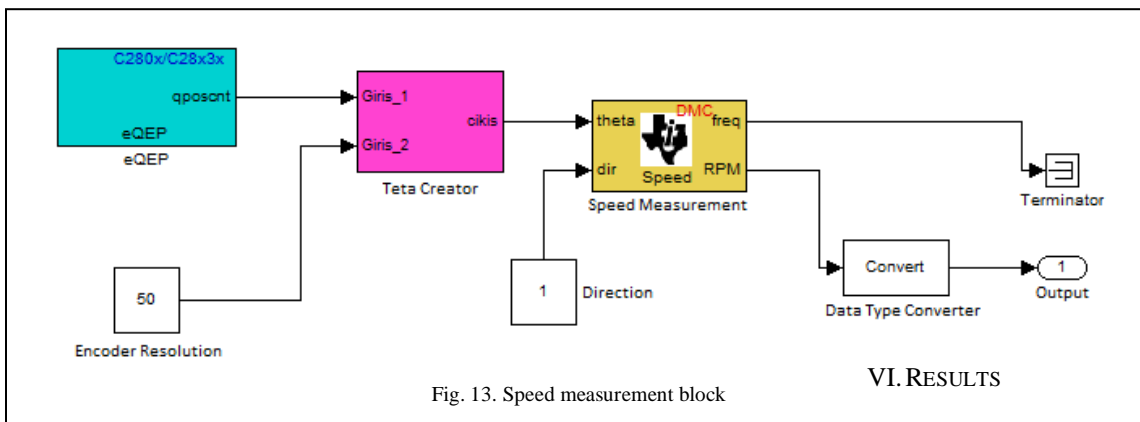


Fig. 13. Speed measurement block

So, the output of DMC block is the real speed value of PMDC motor (RPM). The SIMULINK blocks are shown in figure 13.

#### 2. Speed Control Block

The real instant speed signal created by speed measurement block is connected to the speed control block. There is a PID controller in the speed control block. The control signal is generated by the controller block. The inputs of the PID controller are reference value and the feedback value. Control signal output is connected to the ePWM block. It is possible to create a duty-cycle value with the help of the parameters, which is in the ePWM block. ePWM1A pin has been used as the output and it is matched with GPIO0 pin on the TMS320F2808 controller. The Simulink simulation block is shown in figure 14.

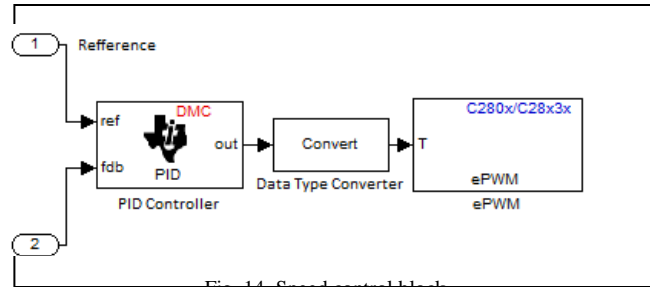


Fig. 14. Speed control block.

### 3. Application on the Vehicle

The code transferring process is done by using “Incremental Build” section on the menu. With this section, CCS software can define eZdspF2808 DSP board and transfer the generated codes into the memory of the board.

The PMDC motor driver card is driven by PWM signal which is generated by eZdspF2808 DSP board. The speed control of the motor is done with adjusting the duty cycle of the PWM signal.

## VI. RESULTS

In this study, an algorithm has been designed and implemented using TMS320F2808 embedded DSP board. The speed control of the PMDC motor was performed. Time scaling can be changed on the code and rotating period can be adjusted. PMDC motor driver system has been done using SIMULINK blocks and an H-Bridge DC-DC converter.

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### BIOGRAPHIES



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