

Teaching Stepper Motors and Brushed DC Motors Using the Medium Voltage Digital Motor Control Platform, Part II - Brushed DC Motors Control

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Abstract – The paper shows the teaching methodology of the Brushed DC motors control, using Texas Instruments platforms. The present report examines the implementation of the control methods (bipolar and unipolar) for BDC motors and the main points of the students teaching process during the laboratory work. The software available with the kit is completely open source, which allows students to create their own projects and thus to better understand the basics of applying DSP in power electronics and digital motor drive control. The experimental results are presented.

Keywords – Digital motor control, Brushed DC motor

I. INTRODUCTION

The power electronics as a subject is not readily assimilated by students because of the different areas involved, the complexity of the necessary knowledge and skills [1,5]. Furthermore, students expressed interest in power electronics integrated with digital controls and digital signal processor (DSP). The students need to graduate with skills that make them easily marketable to potential employers.

Taking into consideration these trends in the education of the modern power electronics and motor drives in [4] is explained about offered an eligible course entitled "Electronic converters for motors control" as a part of the Master's program in "Electronics". As a development environment the Medium Voltage Digital Motor Control (DMC) kit was chosen, DRV8412-C2, from Texas Instruments (TI), which provides a great way to learn and experiment with digital control of medium voltage motors. In the DRV8412 DMC kit are included two brushed DC motors and 8-wire bi-polar stepper motor [6].

Universal brushed DC and stepper motors comprise the majority of motor applications given their low cost and simplicity of control. The teaching methodology of stepper motors control, using Texas Instruments platforms, was discussed in [4]. The present report examines the implementation of the control methods (bipolar and unipolar) for Brushed DC (BDC) motors during the laboratory work.

The software available with the kit is completely open source which allows students to create their own projects and thus to better understand the basics of applying digital signal processor (DSP) in power electronics and digital motor drive control [3].

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II. BRUSHED DC MOTOR CONTROL PWM MODULATION TECHNIQUES

At the beginning of the laboratory session, the teacher gives a brief explanation, presenting an overview of the experiment and the relation with the theory. The teaching process is focused on the different PWM techniques, along with their advantages and disadvantages, in an effort to pick the one that is right for a particular motor control application.

The brushed DC motors are driven by the conventional H-bridge configuration (Fig.1). With the flexibility of four switches, a number of different control methods (bipolar or unipolar) can be used to produce fourquadrant output voltage and current as no two switches in the same leg conduct simultaneously [2].

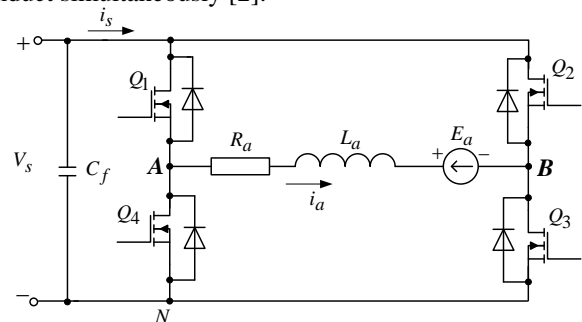


Fig.1. Four-quadrant H-bridge converter

A. PWM with unipolar voltage switching

PWM with unipolar voltage switching, in classic view, is realized as follows (Fig. 2): a triangular waveform is compared with the control voltage v_{cont} and $-v_{cont}$ for determining the switching signals for leg A and leg B of the H-bridge, respectively. A comparison of v_{cont} with v_{tri} controls leg A transistors, whereas leg B transistors are controlled by comparing $-v_{cont}$ with v_{tri} . As a result all three output voltage states, namely $\pm V_s$ and $0V$, are possible.

B. PWM with bipolar voltage switching

A triangular waveform is compared with the one control voltage v_{cont} for determining the switching signals for leg A and leg B of the H-bridge, respectively. For example, when $v_{cont} > v_{tri}$ high side FET in half bridge A and low side FET in half bridge B will be on and low side FET in half bridge A and high side FET in half

bridge B will be off. Otherwise, a high side FET in half bridge B and low side FET in half bridge A will be on. As a result, only two voltage output states, are possible, $+V_s$ and $-V_s$.

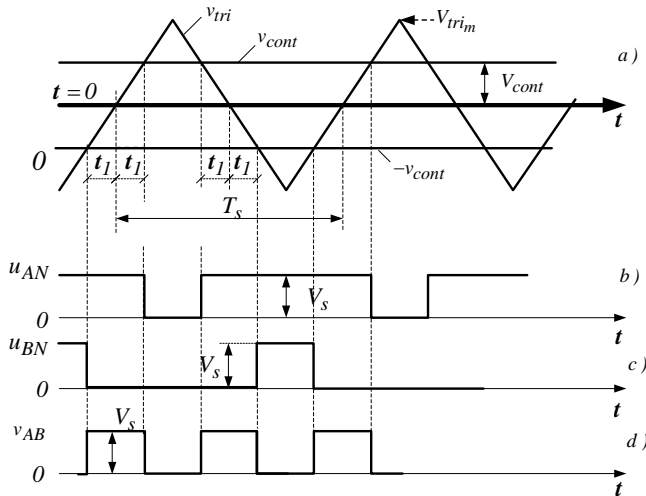


Fig. 2. PWM with unipolar voltage switching

C. The Medium Voltage Digital Motor Control (DMC) kit description

At the beginning of the laboratory work, students are given a tutorial that guides them through the hardware description, the experiments and the actions to be performed in each step. Except the development board, the necessary equipment includes a personal computer with an installed development environment Code Composer Studio v6.0, an oscilloscope and a current probe.

Fig.3 shows the block diagram of the DRV8412 evaluation kit (DRV8412-C2-KIT). It consists of the DRV8412 motor driver, a C2000 Piccolo F28035 MCU controlCARD, example software, code development environment (Code Composer Studio) and the motors. The DRV8412 is high-performance, integrated dual full-bridge motor driver with an advanced protection system [7].

The F28035 device generates the four pulse-width modulation (PWM) signals needed to drive the DRV8412 Dual-Full-Bridge PWM Motor Driver. Two input currents of each motor are measured from the H-bridge and 4 ADCs send these currents to the F28035 device. This system demonstrates current control of a Brushed DC Motor. The examples start out with a single axis demonstration and end with a multi-axis demonstration. Dependent of Mode Jumpers – DRV8412 mode can be set to enable/disable cycle-by-cycle (CBC) current limit, latched over-current (OC) and parallel or dual full-bridge mode – generally four operation modes [7].

D. Projects Organization

Using the included project in the kit one PWM sequence is generated that appears on output PWM-A or output PWM-B depending on the motors rotation (for one H-bridge). With the resulting signals unipolar and bipolar PWM technique for motor control can be accomplished, which is determined by the operating mode of the driver DRV8412. These projects are built up into four levels - on

each level the modules are tested and the software is checked for the correct operation of the hardware [7]. The platform allows change and adjustment of various parameters in real time. This can be configured in 2xDC_Motor-Settings.h header file.

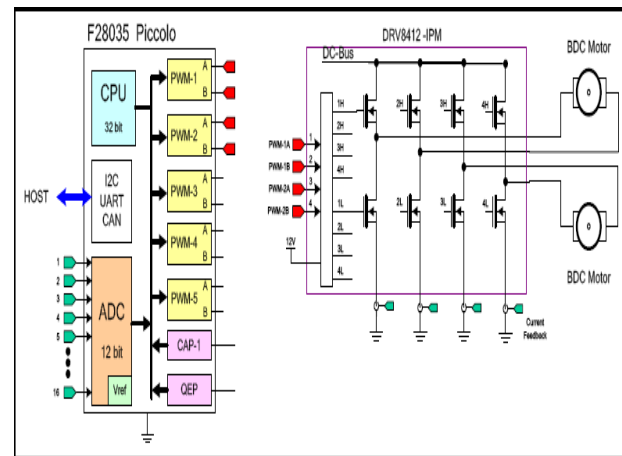


Fig. 3. Dual-Axis, Brushed DC Motor Drive

For the proper work we put mode 2 of DRV8412. As mentioned above, the software available with the kit is completely open source and allows both to be studied from the students and to be modified. Furthermore, it is possible to change the different PWM techniques. Thus, students acquire practical skill and obtained knowledge about the most common methods for PWM control of the BDC.

The triangle carrier signal, which is used to perform PWM sequences digitally, represents the increase of the value of the counter TBCTR from 0 (0x0000) to a given value for a time equal to a half-period of the modulated signal (TBPRD), which is set by the function **PWM_Macro**, and depends on the output of the PID controller, and therefore the reference current I_{ref} . Since ePWM module works with the frequency of the processor core, so in the span of time TBPRD the value, which the TBCTR counter reaches, is the value recorded in the register TBPRD.

At Level 1 step, the motor is kept disconnected. This section describes the steps for a “minimum” system check-out, which confirms operation of system interrupt and the peripheral dependent PWM_MACRO (PWM initializations and update) modules. Open 2xDC_Motor-Settings.h and select level 1 incremental build option by setting the BUILDLEVEL to LEVEL1 (#define BUILDLEVEL LEVEL1). The variable, named “IsrTicker”, will now keep on incrementing - confirm this by watching the variable in the watch window, which verifies that the system interrupt is working properly. The corresponding block diagram for this level is shown on Fig. 4.

In the software, one of the key variables to be adjusted is VRef1 (for changing the motor voltage in per-unit).

In this level we will test the PWM Generator Macro (PWM_MACRO). The VRef1 value is specified to the PWM_MACRO via the RC_MACRO module (RC Ramp Controller). The rate of change of the PWM duty cycle is therefore slew rate limited and will not change instantaneously with VRef1. When VRef1 is positive, PWMA should show a switching frequency – a square

wave with a duty cycle corresponding to the magnitude of VRef1 and PWM_B should be held low. Then students check the PWM test points on the board to observe PWM pulses (PWM_A and PWM_B), as shown in Fig.5.

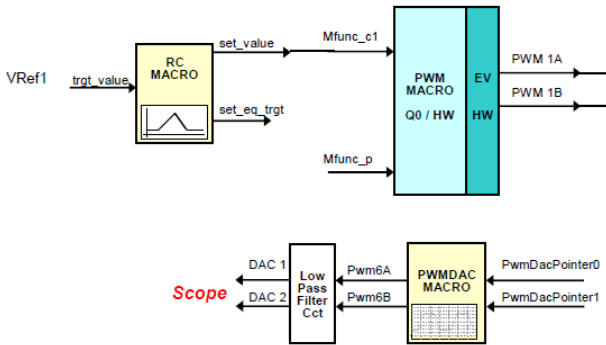


Fig.4. Level 1 -Incremental System Build Block Diagram

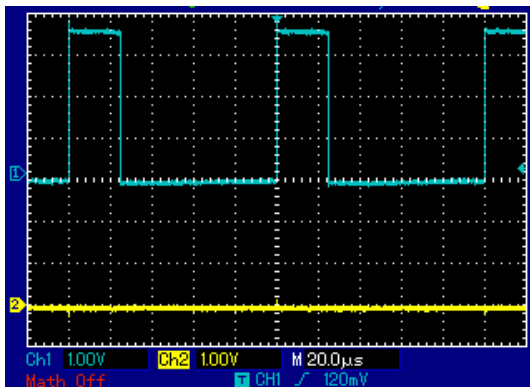


Fig. 5. 1-PWMA and 2- PWMB for VRef1 = 0.25

When VRef1 is negative PWM_B should show a switching frequency, square wave with a duty cycle corresponding to the magnitude of VRef1 and PWM_A should be held low – Fig.6.

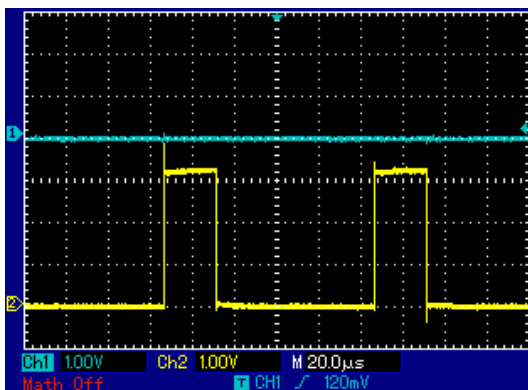


Fig. 6. 1-PWMA and 2- PWMB for VRef1 = -0.25

After successfully testing Level1, operation moves to Level 2, where the analog-to-digital conversion is verified. In this phase the motor is connected to the board. In the software, one of the key variables to be adjusted is Vref1.

After the previous build phases are completed successfully, Level3 verifies the current regulation performed by the PID_REG3 module. The corresponding block diagram for this level is shown in Fig. 7. To confirm the operation of the current regulation, the gains of these

two PID controllers are necessarily tuned for proper operation.

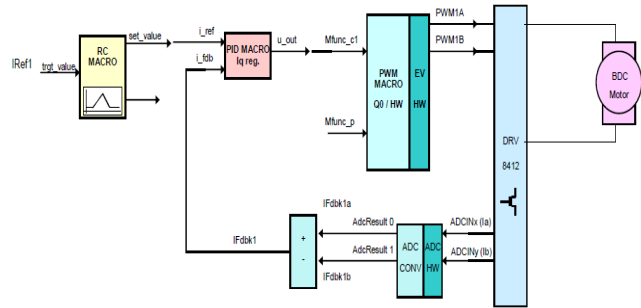


Fig. 7. Block diagram for Level 3

On level 4 two motors are connected to the device, and the previous phases are completed successfully. This build verifies the multi-axis concept - which is two DC motors running simultaneously with current control. The block diagram of this level is presented in Fig. 8.

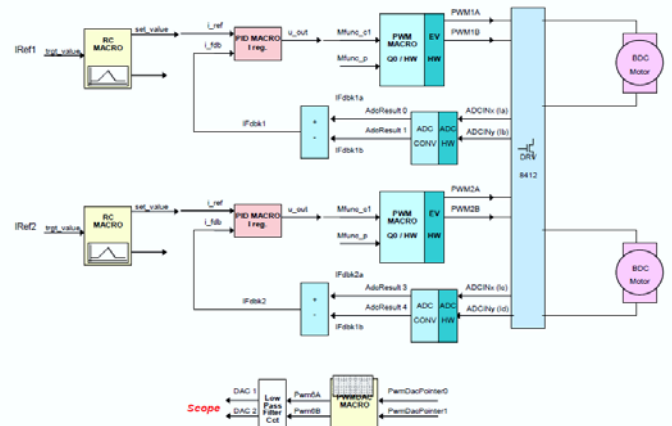


Fig. 8. Block diagram for Level 4

III. EXPERIMENTAL RESULTS

In this section the realization of the PWM techniques for motor control using the included project in the kit is discussed. The experimental results are obtained using the default PWM frequency of 10kHz.

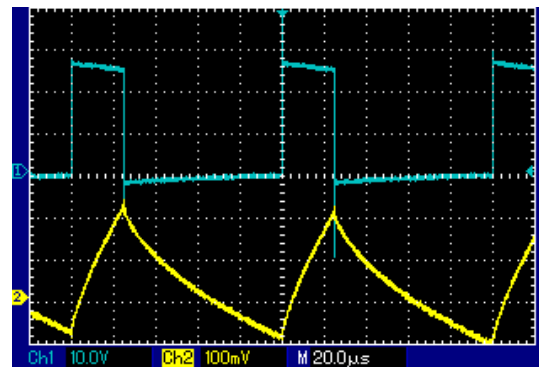


Fig.9. Output voltage (trace1) and output current (trace2)

The first example shows how using the H-Bridge configuration (Fig.1) to create a two-quadrant unipolar drive, i.e. forward motion with positive torque, or reverse motion with negative torque. With the control signals shown in Fig.5 the unipolar modulation for forward direction can be realized as follows: low side FET in half

bridge B is turned on continuously, while PWM signal to high side FET in half bridge A is applied. The output voltage and current waveforms for duty ratio $D = 25\%$ are shown in Fig.9 (forward).

If we want the motor to spin in the other direction (Fig.6), then continuously turn on low side FET in half bridge A and PWM high side FET in half bridge B instead. The output voltage and current waveforms for reverse direction and duty ratio $D = 25\%$ are shown in Fig. 10.

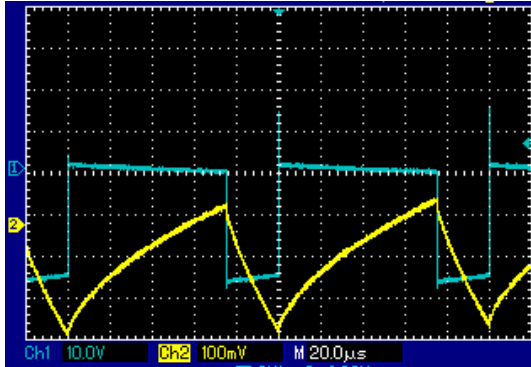


Fig. 10. Output voltage (trace1) and output current (trace2)

The second example shows how the H-Bridge configuration (Fig.1) can be used to create a bipolar PWM. DRV8412 is switched on mode 4. It is necessary ePWM1 processor module to simultaneously generate two PWM sequences (ePWM1A and ePWM1B). These two signals are connected to the inputs and PWM_A PWM_B of DRV8412. Both control signals must be opposite, so as to switch both pairs in the bridge circuit, i.e. they are inverted relative to one another. In the classic bipolar PWM signals for generating ePWM1A and ePWM1B triangular signal from the register TBCTR of ePWM1 module is used as well as the value of the register CMPA.

The duty ratio D is defined through variable VRef1. The VRef1 values are from 0 to 1. The waveforms for duty ratio $D = 75\%$ are shown in Fig. 11.

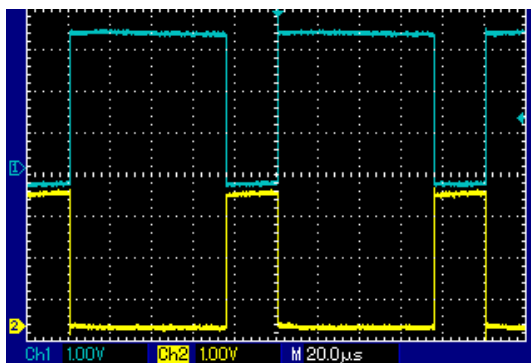


Fig. 11. 1- ePWM1A and 2 - ePWM1B) signals

The waveforms for duty ratio $D = 25\%$ are shown in Fig. 12.

The laboratory works are organized so that after studying these different control methods, the students can make conclusion about the advantages and disadvantages. As mention above, the software available with the kit is completely open source and allows both to be studied by the students and to be modified. Using multi-axis concept (Fig. 8) in [3] is presented the Master's thesis results of the

software realization for controlling one DC motor with bipolar PWM and the other DC motor with unipolar PWM in the same mode of the driver DRV8412. This removes the need for hardware changes in the kit while the various methods of modulation are studied. Moreover a 4-Quadrant Unipolar technique with double PWM output frequency is shown.

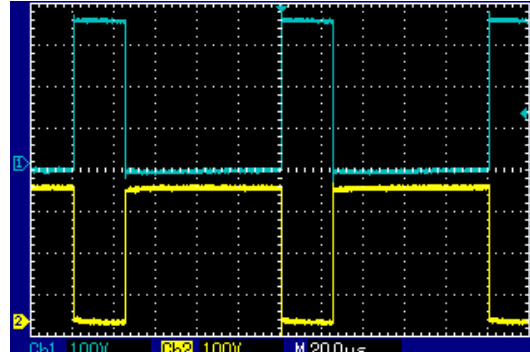


Fig. 12. Fig. 7. 1- ePWM1A and 2 - ePWM1B) signals

IV. CONCLUSION

The paper presents the teaching methodology of the Brushed DC motors control by using Texas Instruments platforms. The present report examines the implementation of the control methods (bipolar and unipolar) for BDC motors and the main points of the students teaching process during the laboratory work. The software available with the kit is completely open source, which allows students to create their own projects and thus to better understand the basics of applying DSP in power electronics and digital motor drive control. The experimental results are presented.

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