

## Experiment 2 Microcontroller Programming and BLDC Modulation ECE 482

The objectives of this experiment are:

- To become familiar with microcontroller programming and the MSP430 to be used later in this course
- To understand and implement the gate driver signals of the Boost converter to be constructed in Experiment 3
- To understand and prototype basic BLDC motor drive modulation

In this lab, you will use Texas Instruments' Code Composer Studio to program your central controller in order to implement a pair of PWM signals using the MSP430 Launchpad development board. Then, using the PWM and digital I/O functionality of the MSP paired with a commercial BLDC motor drive, you will demo trapezoidal modulation of the e-bike hub motor. The MSP430 family User's Guide, Datasheet, and example code files and the EV6532 and MP6532 datasheets are available from the experiment webpage.

### I. Voltage-Controlled PWM

In order to drive the MOSFETs in a synchronous boost converter, two complementary, constant-frequency PWM signals are needed, as shown in Fig. 1

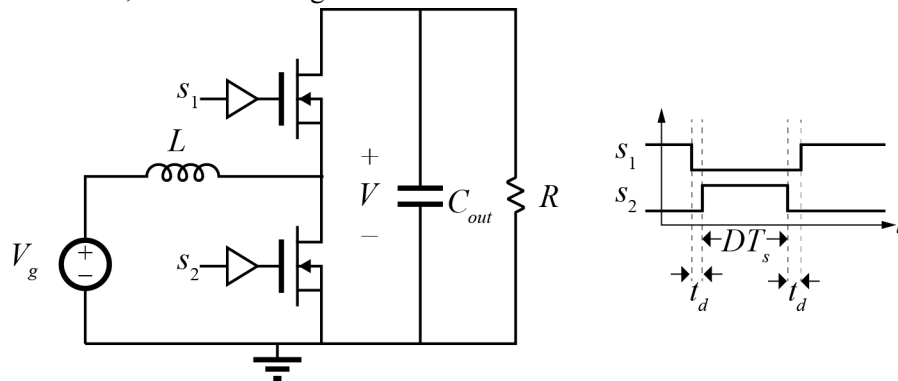


Figure 1: Boost converter gate drive signals  $s_1$  and  $s_2$ , with deadtime  $t_d$  shown.

Using the example codes from Texas Instruments, or starting from scratch, write code to generate two complementary 20kHz PWM signals. Set the two deadtimes  $t_d$  to 500 ns. The duty cycle of the signal should be determined dynamically and set proportional to an analog input voltage. Limit the duty cycle so that at zero input voltage, the duty cycle is 1% and at 3.3V input, the duty cycle is 99%. You are free to have some error on all values mentioned here, as long as the basic functionality is achieved.

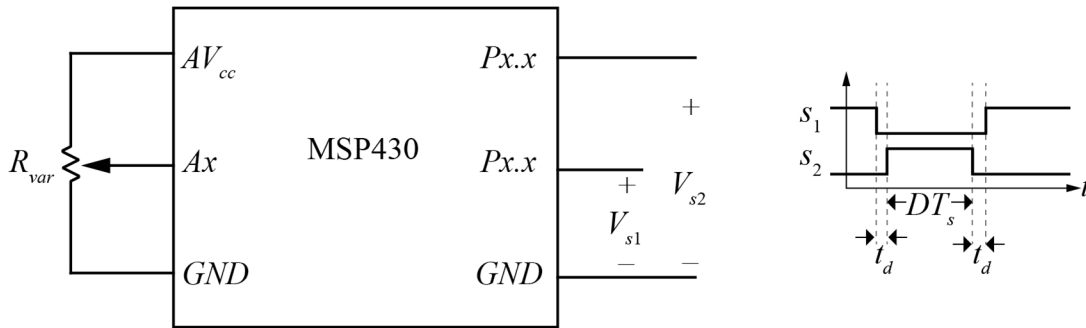


Figure 2: Connections to MSP430 board

Connect a variable resistor  $R_{var}$  as shown in Fig. 2 to one of the analog inputs of the MSP430. Alternately, you can use a voltage supply between  $Ax$  and  $GND$ , but you should add series resistance to limit the possible current flowing into the pin. In your code, output the PWM signals to available GPIOs  $Px.x$  of your choice so that you can view them on the oscilloscope.

In your report, include waveforms of the complementary PWM signals and a plot of the analog voltage  $A_x$  versus the measured duty cycle  $D$ , spanning the complete 3.3V range.

*Extra credit:* For full credit, complete the lab using the TimerA modules of the MSP430G2553 included in the Launchpad. For 25% extra credit on this lab, complete using the TimerD modules of the MSP430F5172. To receive extra credit, demonstrate the maximum achievable resolution of the TimerD modules experimentally.

## II. Motor Drive Demonstration

Read through the datasheet of the EV6532-R-00A BLDC driver evaluation board and MP6532 control IC. Connect the motor, MSP430, and driver board together as dictated in the datasheets and summarized in Fig. 3.

Using your code from the previous section, generate a 10% duty cycle, 20 kHz signal for PWM and set DIR and nBRAKE as needed for proper operation. Complete the connections between the motor, eval board, and MSP as detailed in the quick start guide of the EV6532-R-00A datasheet. Ensure that your connections to the hall sensors and your connections to the motor phases correspond to a positive power flow driving sequence as found in Experiment 1. Also, make sure to include pullup resistors on the hall sensor outputs as used in Experiment 1.

Start with the motor driver  $V_{in}$  voltage at 6V and do not increase it until you have verified proper operation and connections. You must have the sequence of hall sensors and motor phases wired correctly throughout your circuit; trace your connections between the motor, connection wires, driver board PCB phase legs, hall sensor PCB connections, connection wires, and motor hall connections. Examine waveforms and ensure that the correct phases are active during the appropriate hall sequences. Note that with an incorrect connection, the motor may still spin but will require excessive torque due to a combination of positive-torque and negative-torque intervals in the six-step modulation. Also, ensure that the motor is spinning in the correct direction (clockwise when viewing from the geared side of the wheel).

Once you have verified that the motor drive is working as expected, you can increase  $V_{in}$ , being careful not to exceed a safe and stable speed of rotation. Adjust the duty cycle by changing the analog input voltage to demonstrate MSP control of the motor speed.

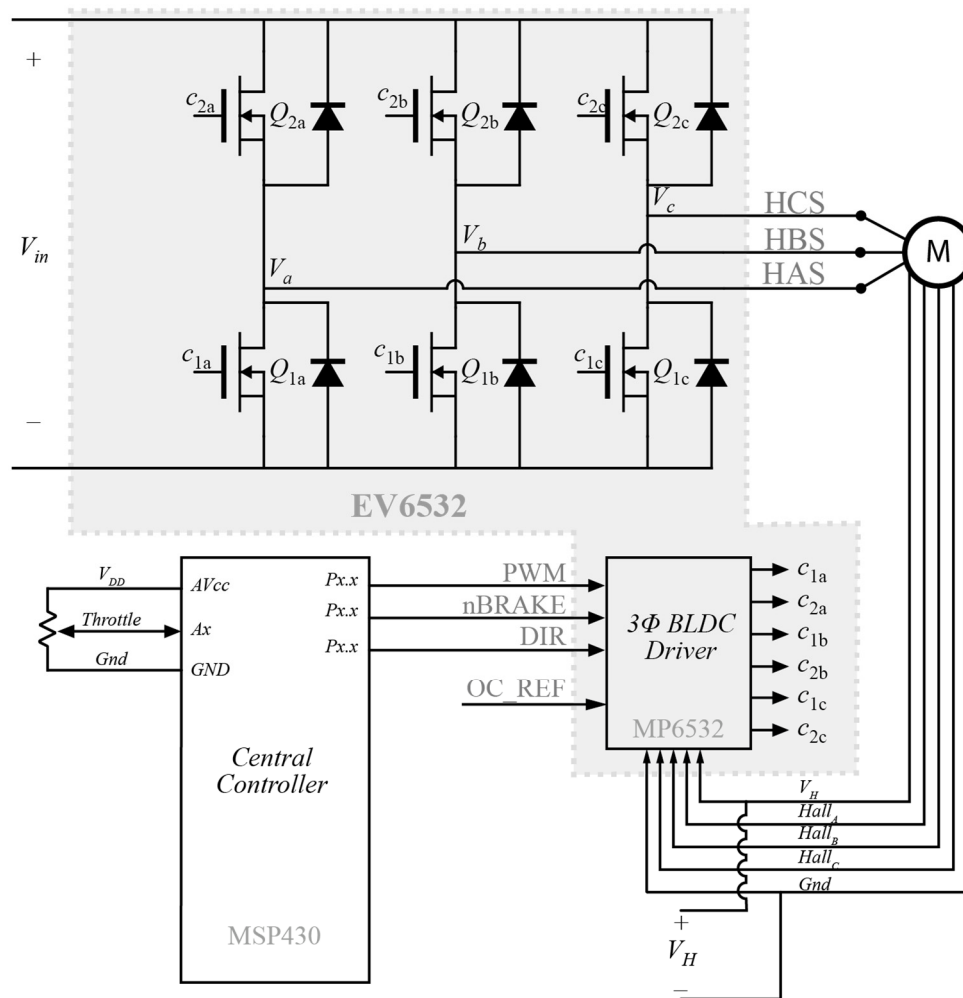


Figure 3: Connections for MSP-controlled BLDC motor drive

In your report include, at minimum, the following plots of experimental measurements

- $V_{in}$ ,  $V_a$ ,  $V_b$ , and  $V_c$  on a single plot
- $H_A$ ,  $H_B$ ,  $H_C$ , and  $V_a$  on a single plot
- $I_{in}$ ,  $V_{in}$ ,  $I_a$ ,  $V_a$  on a single plot