Driving BLDC Motors with PWM Generation Mode

Introduction

In gate driver applications used by TI's brushless-DC (BLDC) DRV8x portfolio, there are a few control modes that are typically used to toggle the output gates for MOSFET switching. These control modes are: 1x, 3x, 6x, and independent pulse-width modulation (PWM) mode.

However, a new technology in the DRV8x portfolio, such as the DRV8311, includes PWM Generation mode. PWM Generation mode allows the user to turn on and off MOSFET gate outputs by writing to the devices registers over Texas Instruments SPI (tSPI). The benefit of this new control mode is that the control mode allows for the PWM period, frequency, and duty cycle to be configured over the serial interface.

As a result, the impact with this control mode is that the user can achieve a more compact system with robust motor control by sending SPI read/write signals instead of requiring multiple GPIO inputs from the MCU.

tSPI System Design Benefits

One system level benefit of using PWM Generation mode with the DRV8311P (the tSPI variant of the DRV8311), comes with the elimination of the INHx and INLx pins. BLDC DRV8x devices generally require three INHx pins and three INLx pins to control the gate driver outputs. As a result, if the user wanted to drive multiple motors, six times the number of motors GPIO pins from the MCU is required.

By using PWM Generation mode over tSPI, four wires to communicate over SPI as shown in Figure 1 are required. Additionally, tSPI allows random access to the DRV8311P devices with a general call address and the ability to perform read/writes in any order.

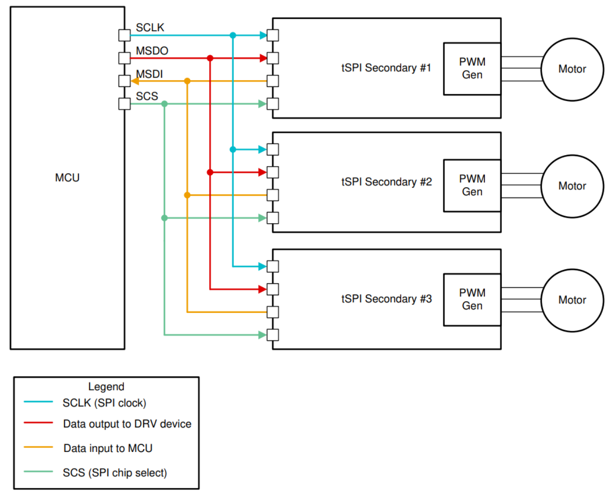

Figure 1. Multi-Motor Control using tSPI

For more information regarding using tSPI in multi-motor systems, see Reduce Wires for Your Next Multi-Motor BLDC Design With tSPI Protocol.

PWM Generation Mode

With PWM Generation mode, the following commutation methods are possible: trapezoidal, sinusoidal, and field-oriented control (FOC). These methods can be accomplished using SPI to set the Phase Driver Outputs to the correct state. For example, the DRV8311P allows the user to write to the PWM_STATE register to turn control the behavior of both the high- and low-side MOSFETs for each of the phases.

Additionally, this control mode allows the user to configure the duty cycle of the PWM signals with precise granularity. For example, with a PWM frequency of 20 kHz, a user can achieve a duty cycle granularity of 0.2% per bit. To achieve this with the DRV8311P, calculate the following:

1. Set the PWM period output by configuring the PWM_PRD_OUT bits to generate a PWM frequency using Equation 1.

$$PWM_{PRD} = 0.5 \times \left(\frac{F_{SYS}}{F_{PWM}}\right) \tag{1}$$

   - PWM_{PRD} = PWM_PRD_OUT value
   - F_{SYS} = internal system clock frequency (approximately 20 MHz)
   - F_{PWM} = PWM frequency
2. Set the duty cycle for each of the phase outputs by configuring the PWM_DUTY_OUTx bits using

$$\Delta_{value} = 0.01 \times PWM_{PRD} \times \Delta_{per} \tag{2}$$

   - Δ_{value} = PWM_DUTY_OUTx value
   - Δ_{per} = duty cycle (%)
3. To calculate what level of granularity can be achieved, solve for Δ_{per} using Equation 2 which becomes:

$$\Delta_{per} = \frac{\Delta_{value}}{0.01 \times PWM_{PRD}} \tag{3}$$

For this example, PWM_{PRD} is 500 and Δ_{value} is set to 250. By solving for Δ_{per} using Equation 3, Δ_{per} becomes 50.0%. If Δ_{value} increases by one (so that Δ_{value} = 251), Δ_{per} becomes 50.2%. Therefore, the granularity of the duty cycle at a PWM frequency of 20 kHz must be 0.2%.

DRV8311P Duty Cycle Step Accuracy

To show the level of granularity mentioned in the previous section, the input duty cycle given to DRV8311P started at 50.0% and incremented by 0.2% until the input duty cycle reached 51.0%. For this test, the high-side (HS) of phase A was PWM'd and the low-side (LS) of phase B was turned ON, with the HS and LS for phase C left off. Table 1 shows the level of granularity that was observed.

Table 1. DRV8311P Duty Cycle Granularity

Input Duty Cycle (%)	Measured Duty Cycle (%)	Target Duty Step (%)	Measured Duty Step (%)
50.0	49.78	-	-
50.2	49.98	0.20	0.20
50.4	50.18	0.20	0.20
50.6	50.38	0.20	0.20
50.8	50.58	0.20	0.20
51.0	50.78	0.20	0.20

Figure 2 and Figure 3 are waveforms that were captured measuring the duty cycle observed at OUTA that is seen in the first two rows of Table 1.

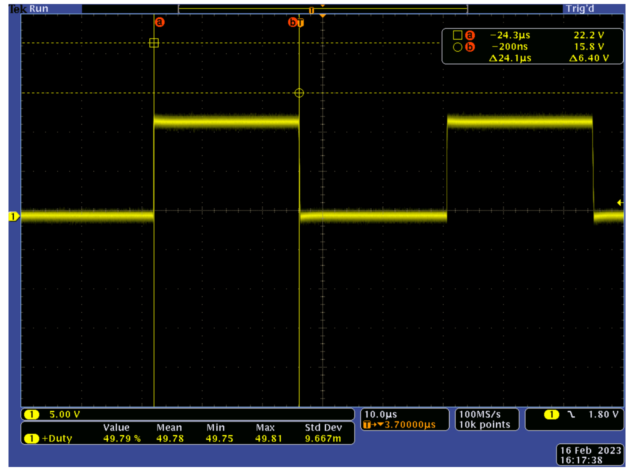

Figure 2. DRV8311P Measured Duty Cycle at 50.0%

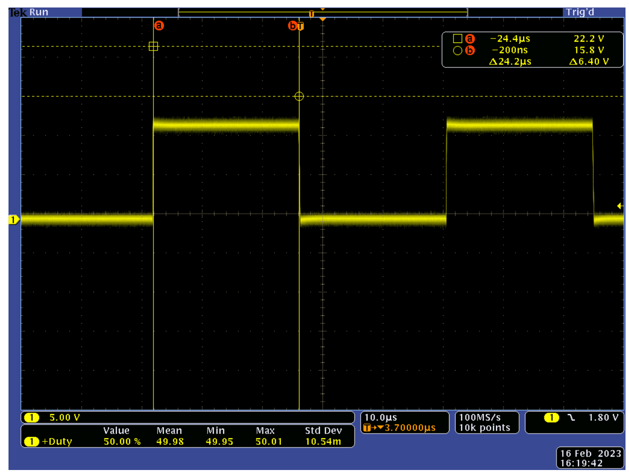

Figure 3. DRV8311P Measured Duty Cycle at 50.2%

As Figure 2 and Figure 3 show, the measured duty cycle increased by 0.2% as expected.

DRV8311H Duty Cycle Step Accuracy

To compare the level of accuracy observed by the tSPI variant of the DRV8311 using PWM Generation mode, the same test was conducted using the DRV8311H (hardware variant). Again, the high-side (HS) of phase A (INHA) was PWM'd and the low-side (LS) of phase B (INLB) was pulled HIGH, with the HS and LS for phase C was both left LOW Table 2 shows the duty cycle step granularity for the DRV8311H.

Table 2. DRV8311H Duty Cycle Granularity

Input Duty Cycle (%)	Measured Duty Cycle (%)	Target Duty Step (%)	Measured Duty Step (%)
50.0	50.13	-	-
50.2	50.35	0.20	0.22
50.4	50.56	0.20	0.21
50.6	50.76	0.20	0.2
50.8	50.93	0.20	0.17

Figure 4 and Figure 5 are waveforms that were captured measuring the duty cycle observed at OUTA that was seen in the first two rows of Table 2. Channel 1 (yellow) captures the input PWM signal while channel 2 (blue) captures the measured PWM signal.

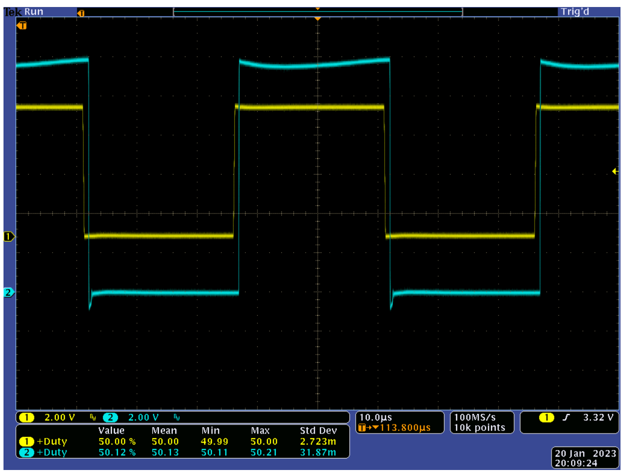

Figure 4. DRV8311H Measured Duty Cycle at 50.0%

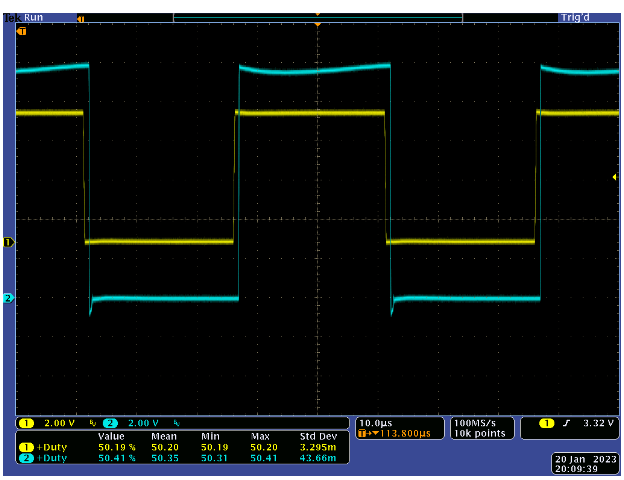

Figure 5. DRV8311H Measured Duty Cycle at 50.2%

Conclusion

As discussed, PWM Generation mode can be a powerful tool to help reduce the number of unnecessary signals in systems, if the user designs the PCB and operates the system appropriately. As shown by the duty cycle step accuracy data, the PWM Generation mode is a robust method that is viable for motor control.

References

For additional references, see the following:

- Texas Instruments, *How to spin 4 motors using DRV8311 with just 5 wires demo video*, video.
- Texas Instruments, *Reduce Wires for Your Next Multi-Motor BLDC Design With tSPI Protocol*, application note.
- Texas Instruments, *Delay and Dead Time in Integrated MOSFET Drivers*, application note.
- Texas Instruments, DRV8311, product page.
- Texas Instruments, *DRV8311 Three-Phase PWM Motor Driver*, data sheet.
- Texas Instruments, DRV8311HEVM, product page.
- Texas Instruments, *DRV8311HEVM User's Guide*, user's guide.