Texas Instruments

Application Report

SLAA699–April 2016

Adaptive Drive Angle Adjust

ABSTRACT

This application report provides details about the adaptive drive-angle adjust algorithm supported by the DRV10970 device. This document also provides a comparison between the commutation of a motor based on fixed drive angle versus adaptive drive angle. For details about the DRV10970 device, refer to the DRV10970 data sheet (SLVSCU7).

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1 Introduction to Drive Angle

For brushless DC (BLDC) motors, the user often wants to control the drive state of the motor so that the phase current of the motor is aligned with the back electromotive-force (BEMF) voltage of the motor. The BLDC motor can be represented as shown in Figure 1.

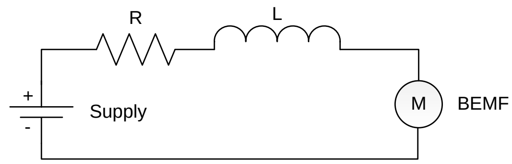

Figure 1. BLDC Motor Model

As shown in Figure 1, the motor has an inductive effect. Because of this inductive effect of the motor, the phase current lags phase voltage. To achieve optimal efficiency, the phase voltage should be applied in advance compared to the BEMF voltage and must be adjusted to keep the BEMF voltage aligned with the phase current. As shown in Figure 2, this difference between the applied phase voltage and the BEMF voltage is known as drive angle (advance angle).

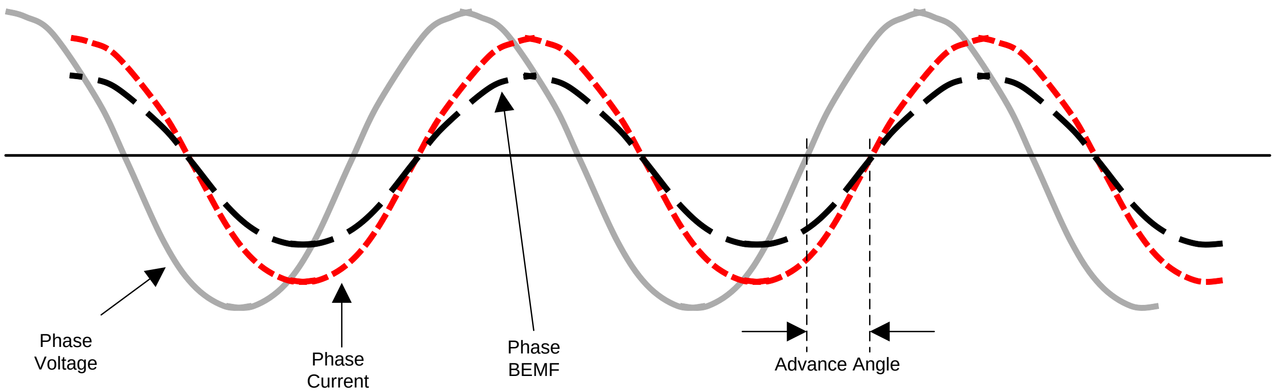

Figure 2. Drive Angle (Advance Angle) Definition

2 Adaptive Drive-Angle Adjust (ADAA)

The BLDC motor operates efficiently when the stator flux and rotor flux are in quadrature (90°). To achieve this 90° angle between the stator and rotor flux, the BEMF voltage must be aligned with the phase current. This alignment between the BEMF and phase current can be achieved by adjusting the drive angle

The drive angle can be adjusted to achieve better efficiency by measuring the phase current and comparing it with the Hall signals. But, because of variation in parameters such as motor resistance and inductance with operating point, the BEMF voltage and phase current are not aligned for fixed drive angle when an operating condition is changed.

The drive angle must be adjusted when an operating condition, such as speed and load, is changed to operate the motor at optimal efficiency. This dynamic change of the drive angle requires continuous monitoring of phase current and additional processing of data. To overcome this problem of manually adjustment the drive angle, Texas Instruments' new adaptive drive-angle adjust (ADAA) algorithm can be used. The ADAA algorithm continuously monitors the phase difference between the BEMF voltage and phase current, and adjusts the drive angle between the phase voltage and BEMF voltage. In devices like the DRV10970 device, the current is measured internally and BEMF information is available from hall sensors.

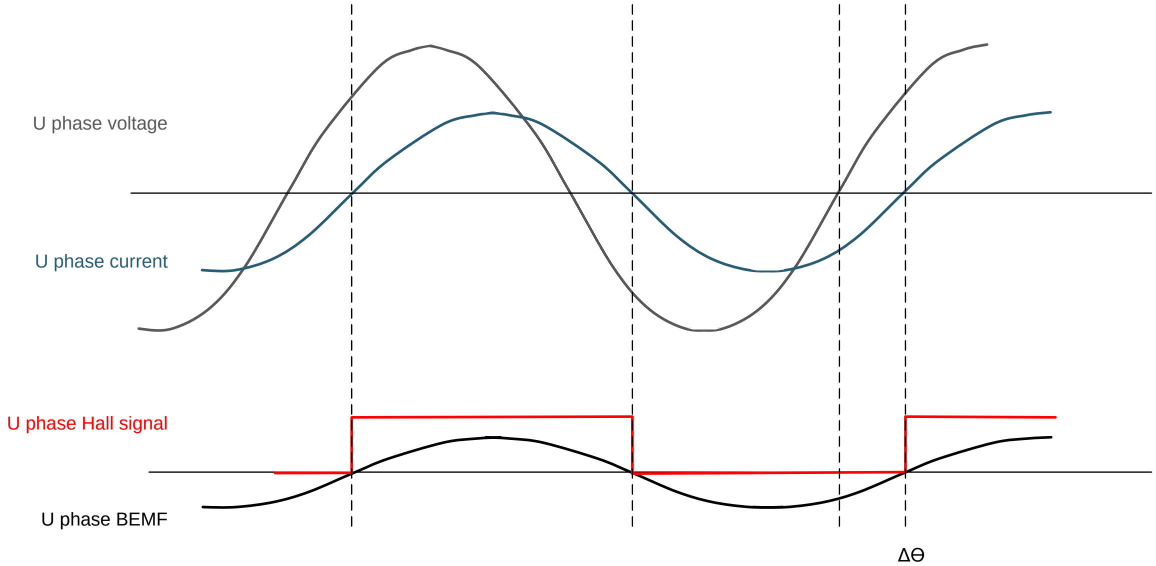

Figure 3. ADAA Operation

When the Hall sensor is placed at 0°, the BEMF voltage is in-phase with the respective Hall signals. The ADAA logic takes advantage of this fact and aligns the U-phase current to the U-Hall sensor input. The device continuously monitors the phase difference between the U-phase current and U-phase Hall signal while adjusting the phase voltage driving angle, Δθ (with respect to the U-Hall sensor signal, same as U-BEMF zero crossing), to align the current and Hall signal (as shown in Figure 3). ADAA mode is the recommended mode of operation where the motor efficiency is maximized irrespective of motor parameters, load conditions, and motor speeds.

2.1 Configuration of DRV10970 for ADAA Mode

ADAA mode works only when a 0° phase difference exists between hall signal and BEMF. As shown in Figure 4 and Figure 5, there is a 0° phase difference between the output of hall sensor and the BEMF. The user must be careful with placement of the Hall sensor so that the Hall signals are aligned with BEMF for the ADAA feature to work efficiently.

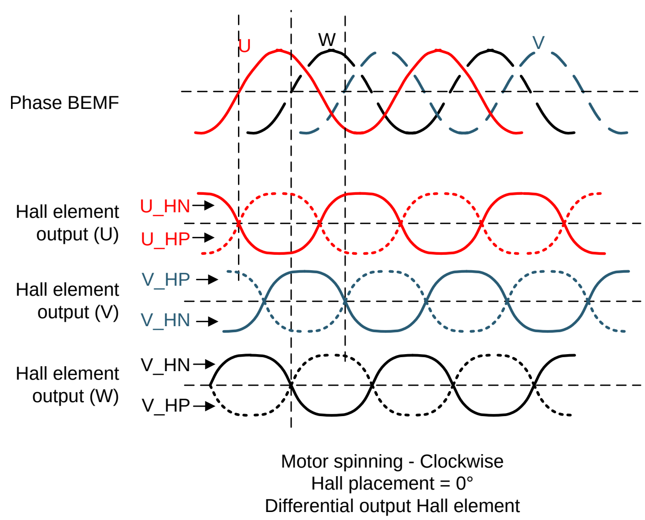

Figure 4. Output of Differential Hall Sensor With 0° Hall Placement

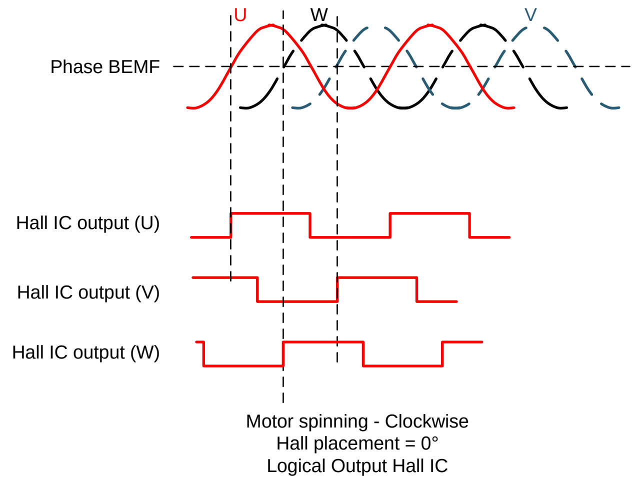

Figure 5. Output of Single Ended Hall Sensor With 0° Hall Placement

The ADAA feature can be configured with the DRV10970 device by connecting the CMTMOD pin to ground (0° mode) and leaving the DAA pin floating (ADAA mode). ADAA mode is supported with both hall configurations such as when all three Hall sensors are used for all U-V-W phases or when a single Hall sensor (U-phase) is used in the system.

2.2 Fixed Drive-Angle Adjust versus Adaptive Drive-Angle Adjust

In fixed drive-angle mode, the phase difference between the applied voltage and the BEMF voltage is fixed for all operating points. Therefore, in fixed drive angle mode, the device applies the voltage based on BEMF zero crossing with a fixed advance angle. In ADAA mode, the phase difference between the applied voltage and the BEMF voltage is adjusted to align the phase current to BEMF.

Figure 6 shows the device operating in ADAA mode. When an external load was applied to the motor, the ADAA-adjusted phase voltage is such that the U-Hall signal is aligned to phase current.

Figure 7 and Figure 8 shows the motor operation in fixed drive-angle mode. Because the motor is operated with a fixed drive angle, the U-Hall signal is not aligned to the phase current. Because of misalignment, the power consumption is greater in fixed drive-angle mode compared to ADAA mode.

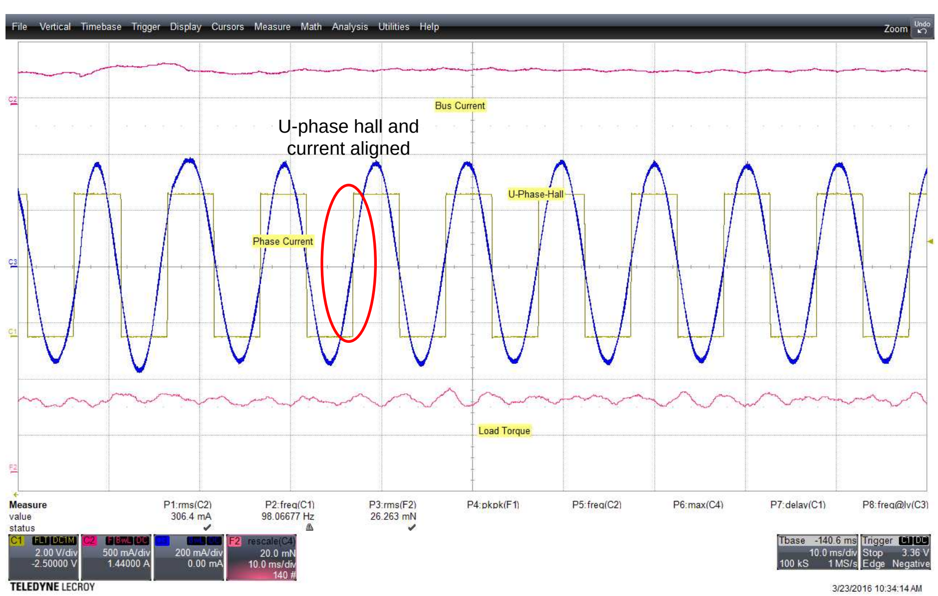

Figure 6. Operation of Motor With ADAA Enabled

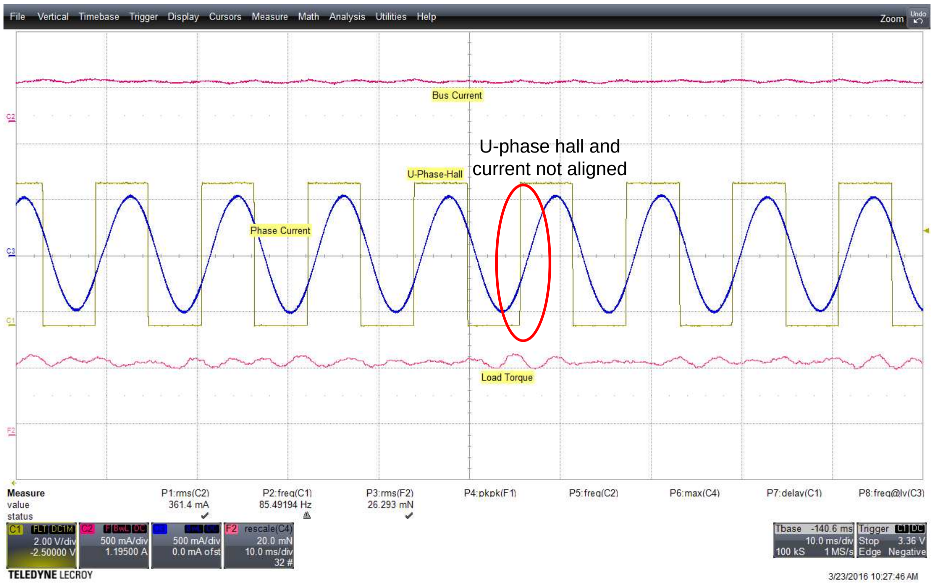

Figure 7. Operation of Motor With Fixed Drive Angle (10°)

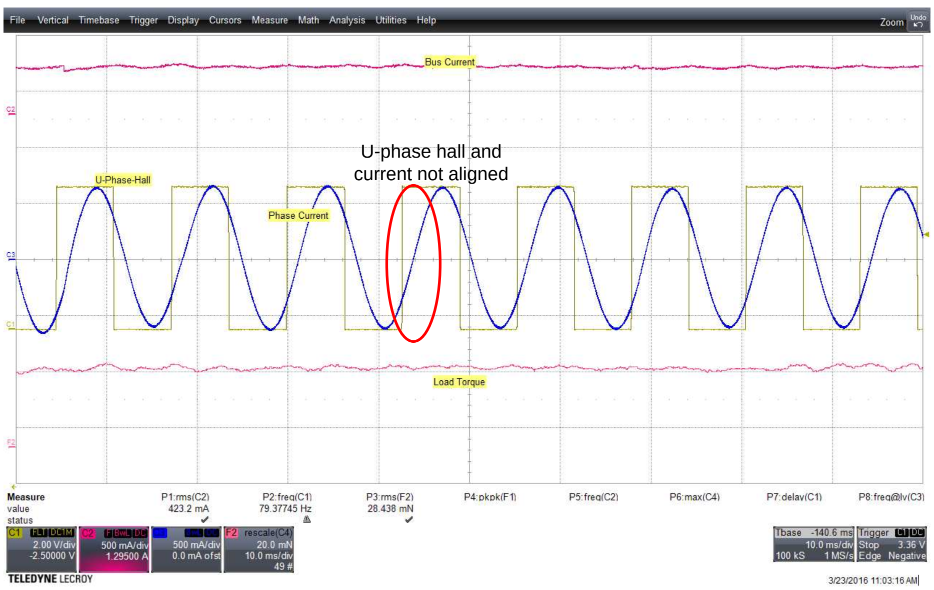

Figure 8. Operation of Motor With Fixed Drive Angle (5°)

The advantage of using ADAA over fixed drive-angle adjust is that the power consumption is optimized for all operating points and the system is more efficient. As shown in Figure 9, when the load changes from 0 mN-m to 100 mN-m, the motor consumes less power in ADAA mode compared to fixed drive-angle adjust. Fixed drive-angle based commutation is optimal only at a full load and therefore there is less difference in power consumption between fixed drive angle and ADAA. But, when the load is changed, the power consumption is more for fixed drive-angle adjust compared to ADAA mode. The ADAA algorithm is able to adjust the angle and optimize the power consumption. Figure 9 also shows that the DRV10970 device is able to operate motor at higher speed for given load for ADAA mode as compared to fixed drive angle.

The data shown in Figure 9 was collected using a motor from Hurst (DMA0102024D2010). Figure 9 also shows that because power consumption is less for ADAA mode, the system is more efficient compared to fixed drive-angle based commutation. For example when operating at a 50-mN-m load, the efficiency is improved around 10% and 15% for ADAA mode compared to 10° and 5° fixed drive-angle (respectively). The average improvements in efficiency between 10 to 100 mN-m load torque is around 13% and 17% for ADAA mode as compared to 10° and 5° fixed drive angle (respectively).

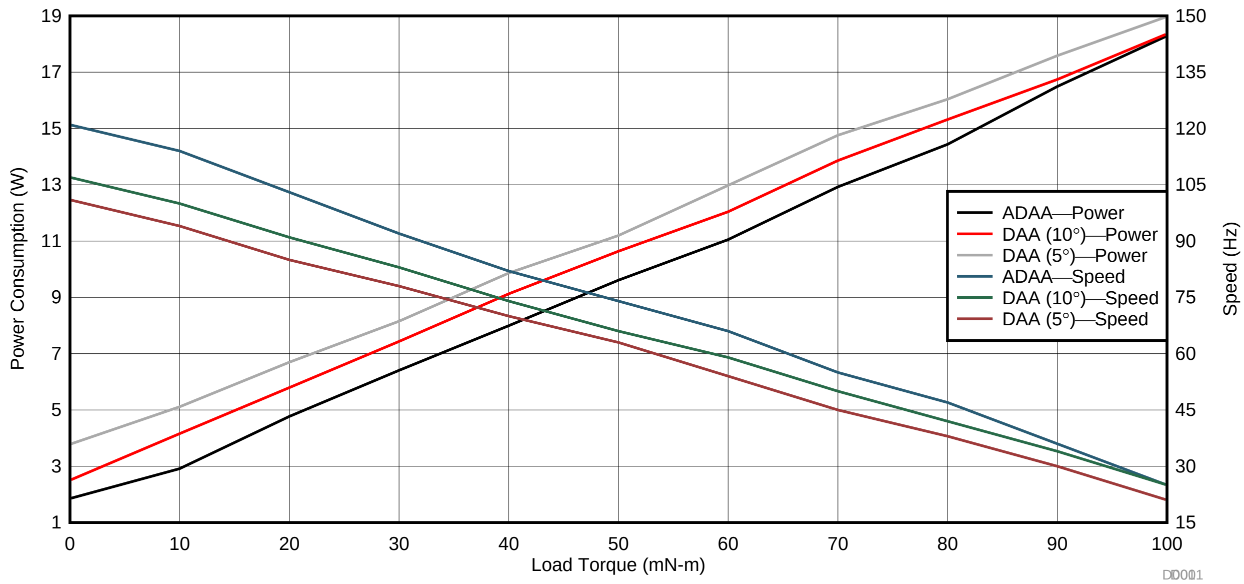

Figure 9. Comparison Between ADAA and Fixed Drive Angle for Different Operating Condition

NOTE: ADAA mode is only available in sinusoidal mode and 0° Hall-sensor placement. The motors with 30° Hall placement can use the fixed drive-angle feature to achieve maximum system efficiency for a given application.

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