# Single Versus Three Hall Sensor Configuration

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## ABSTRACT

This document provides an overview of the single and three sensor mode supported by the DRV10970.

**Contents**

## 1    Introduction

This document describes the usage of the *Three-Phase Brushless DC* motor (BLDC) or *Permanent Magnet Synchronous* motors (PMSM) with the sensored sinusoidal driver DRV10970. BLDC or PMSM motors have a variety of advantages such as superior torque-to-weight ratio, higher efficiency, lower cost, electronic based commutation, and so forth. Some BLDC motors have Hall elements to provide feedback about the position of the rotor. The DRV10970 uses this feedback from Hall signals for a 180° sine-wave commutation algorithm. The advantage of using sinusoidal commutation is that the driver can achieve higher efficiency, low torque ripple, and superior acoustic performance. Hall sensors can be placed in many different ways to provide feedback for the rotor position. The DRV10970 supports sinusoidal operation with single and three Hall signal output. Section 2 describes different Hall signals supported by the DRV10970.

## 2    Three Hall Sensor Mode

In a three Hall system, Hall sensors are placed 120° apart and are aligned to three phases so each Hall sensor will correspond to one of the 3-phases. The DRV10970 supports two different ways in which a Hall sensor can be placed, that is, 0° Hall placement and 30° Hall placement. The DRV10970 also supports two kinds of Hall signals, that is, differential Hall signals from Hall elements and logical signals from Hall ICs.

### 2.1    Differential Hall Sensor

The output of Hall elements is a differential sinusoidal signal and it can be connected directly to the DRV10970. As seen in Figure 1 and Figure 2, the DRV10970 supports both series- and parallel-Hall element connections. The DRV10970 has a built-in regulator (VINT) and can be used to supply power to Hall elements. In series connection, Hall elements have a cascaded connection and VINT can be connected to one of the Hall elements. In parallel connections, all the Hall elements are powered separately and VINT can be connected to them individually.
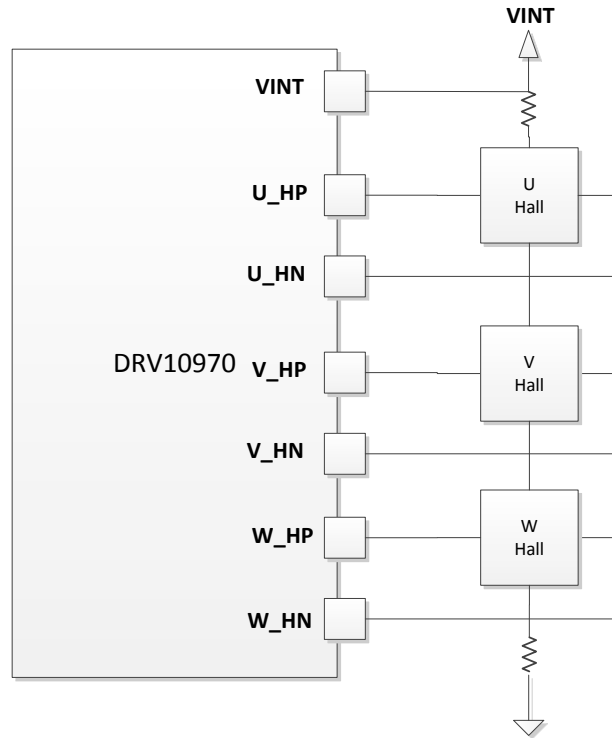
**Figure 1. DRV10970 Connection With Series-Connected Hall Elements**
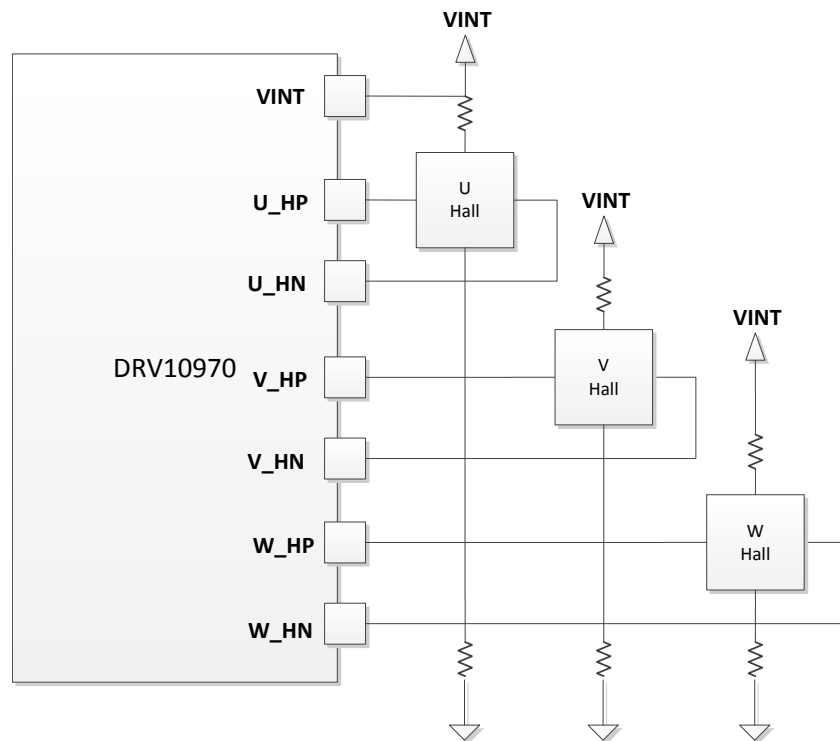


**Figure 2. DRV10970 Connection With Parallel-Connected Hall Elements**

DRV10970 supports 0° and 30° Hall placement for differential Hall signals in sinusoidal mode of operation.

There is 0° phase difference between zero crossing of Hall signals and BEMF signals for motors with 0° Hall placements (see Figure 3) . The DRV10970 supports *Adaptive Drive Angle Adjustment* (ADAA) for such motors with 0° Hall placement.
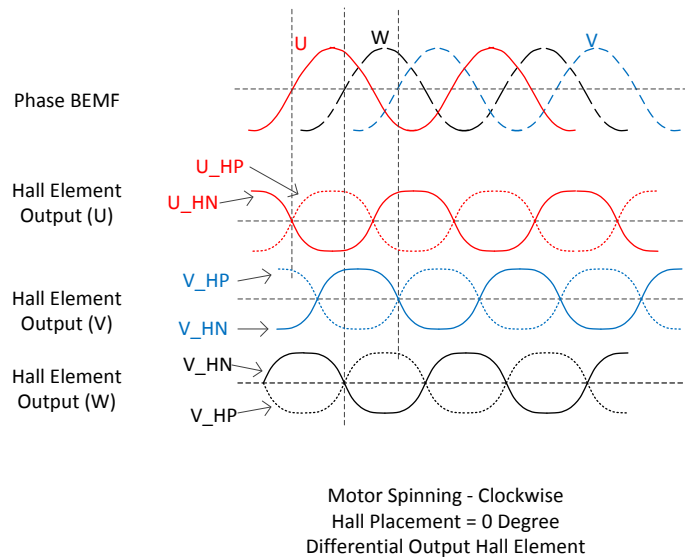


Motor Spinning - Clockwise
Hall Placement = 0 Degree
Differential Output Hall Element

**Figure 3. Phase Relation Between BEMF and Output of Hall Elements for 0° Hall Placement**



Motor Spinning - Clockwise
Hall Placement = 30 Degree
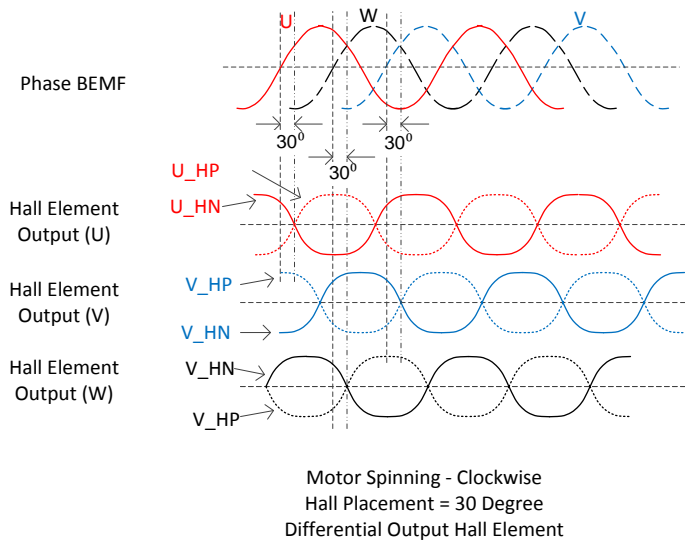Differential Output Hall Element

**Figure 4. Phase Relation Between BEMF and Output of Hall Elements for 30° Hall Placement**

## 2.2   *Hall IC*

In some of the BLDC motors, the Hall IC is connected to provide feedback of the rotor position. Hall sensors are embedded inside the IC and provide logical output. These Hall ICs can be connected directly to the DRV10970. Typically, output of the Hall IC is open drain type and needs to be pulled high. VINT can be used to provide Hall power and pullup supply for output of Hall IC signals.

Hall signals are connected to an internal comparator inside the DRV10970 and negative input of the comparator needs to be biased. As shown in Figure 5, connect VINT/2 to the V_Hx pins of the device.
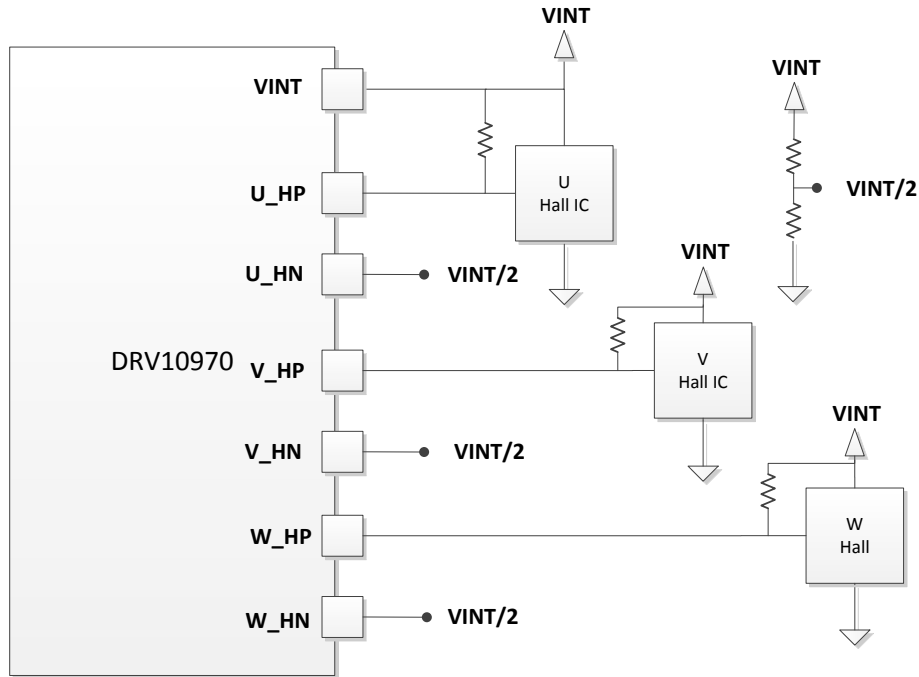
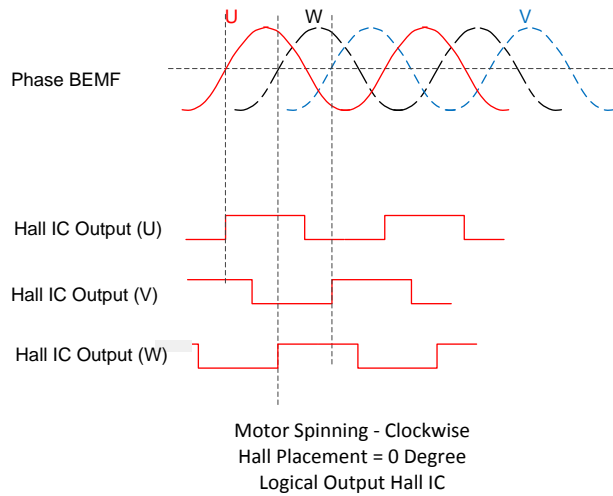**Figure 5. DRV10970 Connection With Hall IC**



**Figure 6. Phase Relation Between BEMF and Output of Hall IC for 0° Hall Placement**
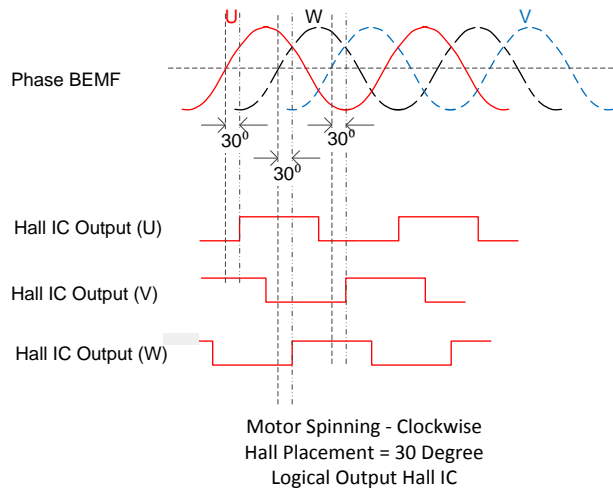
Figure 7. Phase Relation Between BEMF and Output of Hall IC for 30° Hall Placement

## 2.3 Startup Sequence for a Motor With a 3 Hall Sensor

When sinusoidal mode of operation is selected, the DRV10970 will start the motor with trapezoidal operation using all 3 Hall signals. The DRV10970 drives the motor in trapezoidal mode based on the commutation state table (see Table 1 and Table 2). Trapezoidal commutation is different for 0° and 30° Hall placements motors. Table 1 shows the trapezoidal commutation sequence for a motor with 0° Hall placement. Table 2 shows trapezoidal commutation sequence for a motor with 30° Hall placements.

### Table 1. Trapezoidal Commutation with 0° Hall Placement

| State | Hall Signals | | | Phase Output for Clockwise Rotation | | |
|-------|------|------|------|------|------|------|
|       | U | V | W | U | V | W |
| 1 | 1 | 1 | 0 | PWM | Hi-z | Low |
| 2 | 1 | 0 | 0 | High | ~PWM | Hi-z |
| 3 | 1 | 0 | 1 | Hi-z | Low | PWM |
| 4 | 0 | 0 | 1 | ~PWM | Hi-z | High |
| 5 | 0 | 1 | 1 | Low | PWM | Hi-z |
| 6 | 0 | 1 | 0 | Hi-z | High | ~PWM |
| 1x | 0 | 0 | 0 | Hi-z | Hi-z | Hi-z |
| 2x | 1 | 1 | 1 | Hi-z | Hi-z | Hi-z |

### Table 2. Trapezoidal Commutation with 30° Hall Placement

| State | Hall Signals | | | Phase Output for Clockwise Rotation | | |
|-------|------|------|------|------|------|------|
|       | U | V | W | U | V | W |
| 1 | 1 | 1 | 0 | PWM | Hi-z | Low |
| 2 | 1 | 0 | 0 | High | ~PWM | Hi-z |
| 3 | 1 | 0 | 1 | Hi-z | Low | PWM |
| 4 | 0 | 0 | 1 | ~PWM | Hi-z | High |
| 5 | 0 | 1 | 1 | Low | PWM | Hi-z |
| 6 | 0 | 1 | 0 | Hi-z | High | ~PWM |
| 1x | 0 | 0 | 0 | Hi-z | Hi-z | Hi-z |
| 2x | 1 | 1 | 1 | Hi-z | Hi-z | Hi-z |

The DRV10970 will start driving a motor in trapezoidal mode as shown in Figure 8 and switch to sinusoidal mode after 6 electrical cycles. After switching to sinusoidal mode, the DRV10970 uses only 1 Hall signal (U Hall sensor) for commutation.
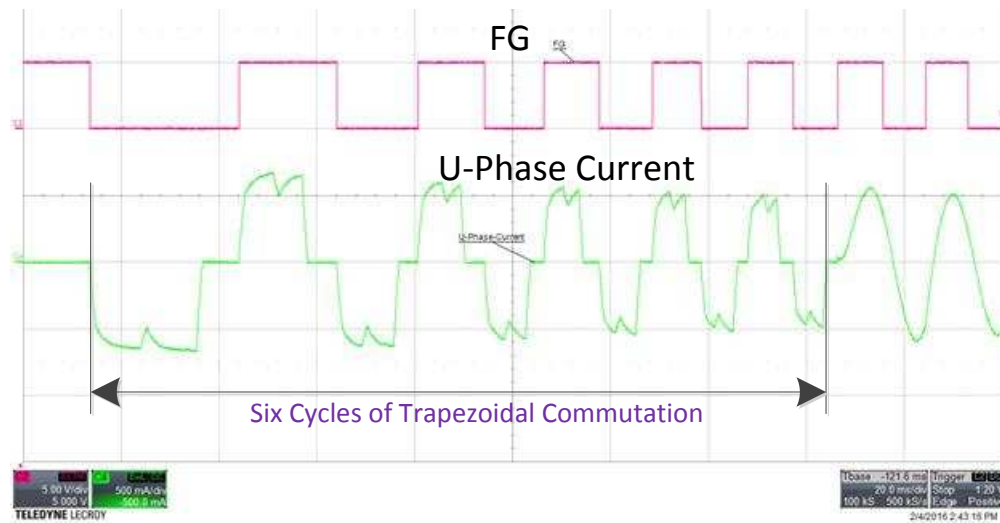


**Figure 8. Phase Current During Startup With 3 Hall Sensor**

## 3 Single Hall Sensor Mode

The DRV10970 supports sinusoidal commutation when only one Hall signal (U Hall sensor) is available. If the V and W phase Hall sensors are not connected, the DRV10970 automatically switches to single Hall mode.

### 3.1 *Differential Single Hall Sensor Mode*

As shown in Figure 9, the DRV10970 supports a single Hall element input in differential mode. VINT can be used to power Hall elements.
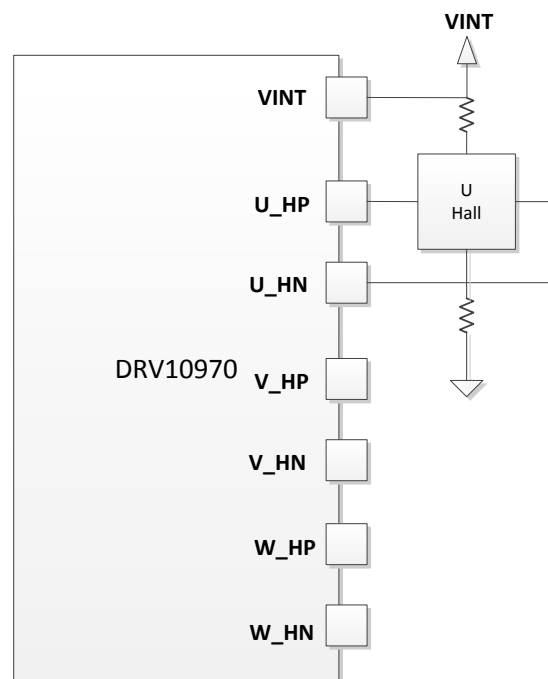


**Figure 9. DRV10970 Connection With Single Hall Element**

The DRV10970 supports both 0° and 30° differential Hall signals for sinusoidal operation in single Hall mode. There is 0° phase difference between zero crossing of the Hall signal and the BEMF zero crossing for the U phase as shown in Figure 10 for 0 ° Hall placement.
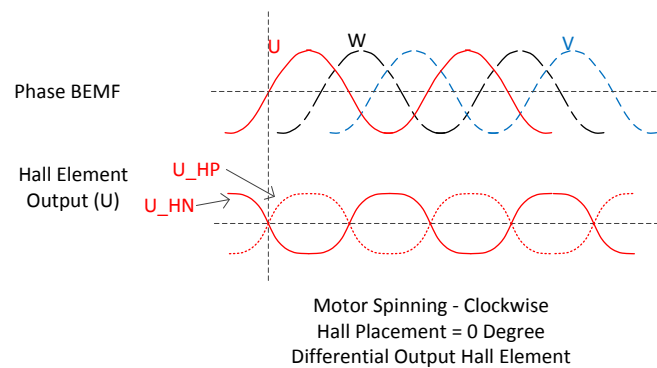


Motor Spinning - Clockwise
Hall Placement = 0 Degree
Differential Output Hall Element

**Figure 10. Phase Relation Between BEMF and Output of Single Hall Element for 0° Hall Placement**

As shown in Figure 11, for 30° Hall placement, there is a 30° phase difference between the zero crossing of the Hall signal and the BEMF zero crossing for the U phase.



Motor Spinning - Clockwise
Hall Placement = 30 Degree
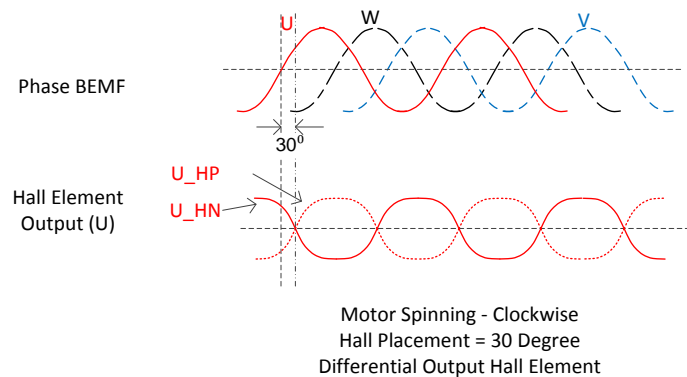Differential Output Hall Element

**Figure 11. Phase Relation Between BEMF and Output of Single Hall Element for 30° Hall Placement**

## 3.2   Single Hall IC

The single Hall IC can be connected directly to the DRV10970 for sinusoidal commutation. The DRV10970 supports both 0° and 30° Hall placement for motors with single Hall signals.
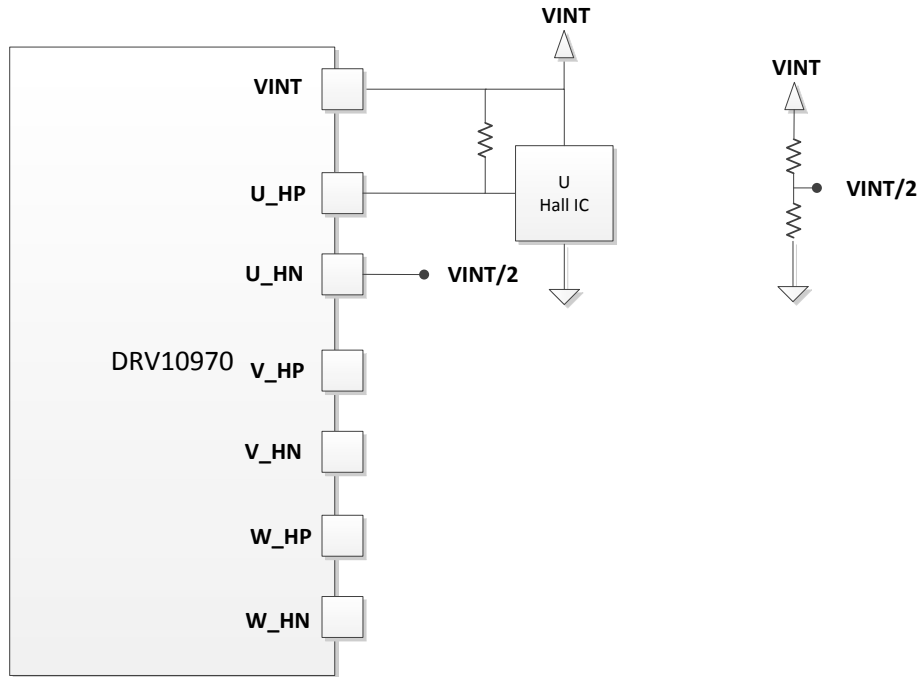
**Figure 12. DRV10970 Connection With Single Hall IC**



Motor Spinning - Clockwise
Hall Placement = 0 Degree
Logical Output Hall IC
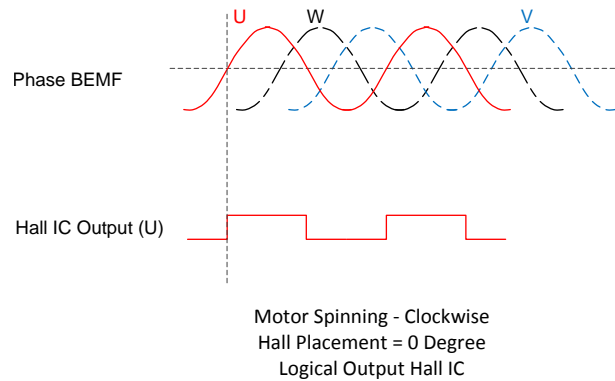
**Figure 13. Phase Relation Between BEMF and Output of Single IC for 0° Hall Placement**



Motor Spinning - Clockwise
Hall Placement = 30 Degree
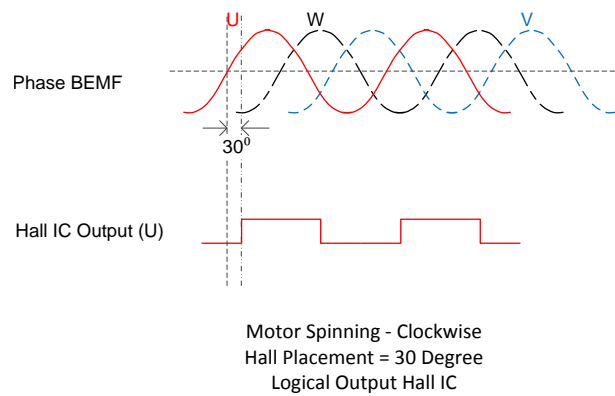Logical Output Hall IC

**Figure 14. Phase Relation Between BEMF and Output of Single Hall IC for 30° Hall Placement**

## 3.3   Startup Sequence for a Motor With Single Hall Sensor

Startup with a single Hall sensor in the DRV10970 is divided into 2 states, that is, align and '2-step' commutation. If the motor is initially located exactly at the middle of the positive torque range and the negative torque range, neither of 2 driving patterns can provide effective torque to the motor no matter the Hall input polarity (shown in Figure 15). So, the "2-step" startup has the limitation of starting the motor with two initial positions (dead points) among one electrical cycle although the change is very low. To prevent this startup failure in 2-step commutation, the motor is first aligned. The motor is aligned based on the commutation state table (see Table 3).

### Table 3. Single Hall Sensor Startup Mode

| Hall Placement | Hall Signal U | Phase Output for Clockwise Rotation | | |
|---|---|---|---|---|
| | | U | V | W |
| 0° | 1 | PWM | Low | Low |
| 0° | 0 | Low | PWM | PWM |
| 30° | 1 | PWM | Low | Hi-z |
| 30° | 0 | Low | PWM | Hi-z |
| Single Hall Align | | Hi-z | Low | PWM |
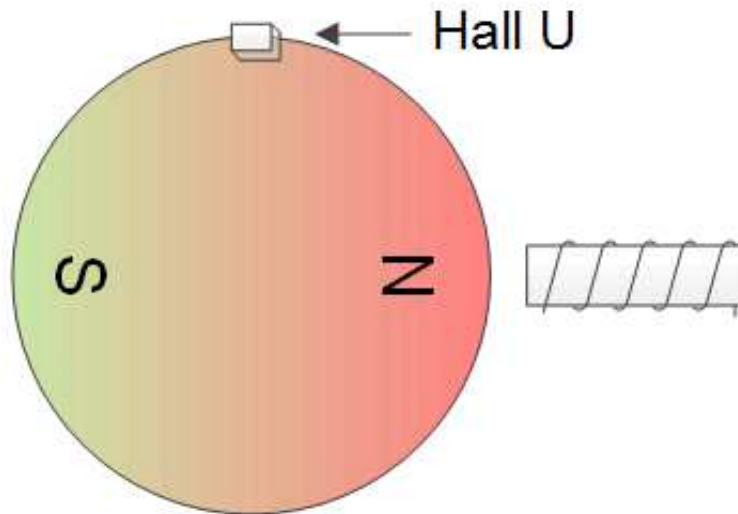


**Figure 15. Dead Point in Single Hall Sensor Mode**

After *Align* state, the DRV10970 starts the motor by driving "2-step" DC current into the coil which means, instead of "6-step" control, the device only outputs 2 steps based on the U phase Hall sensor signal (see Figure 16). The direction of the driving current is based on the motor spinning direction and Hall placement. A different driving state during 2-step commutation is shown in Table 3. For example, if 0° Hall placement is selected and clockwise rotation is desired and the U phase Hall sensor signal is high, the DRV10970 will drive U phase PWM and both the V and W phase low.

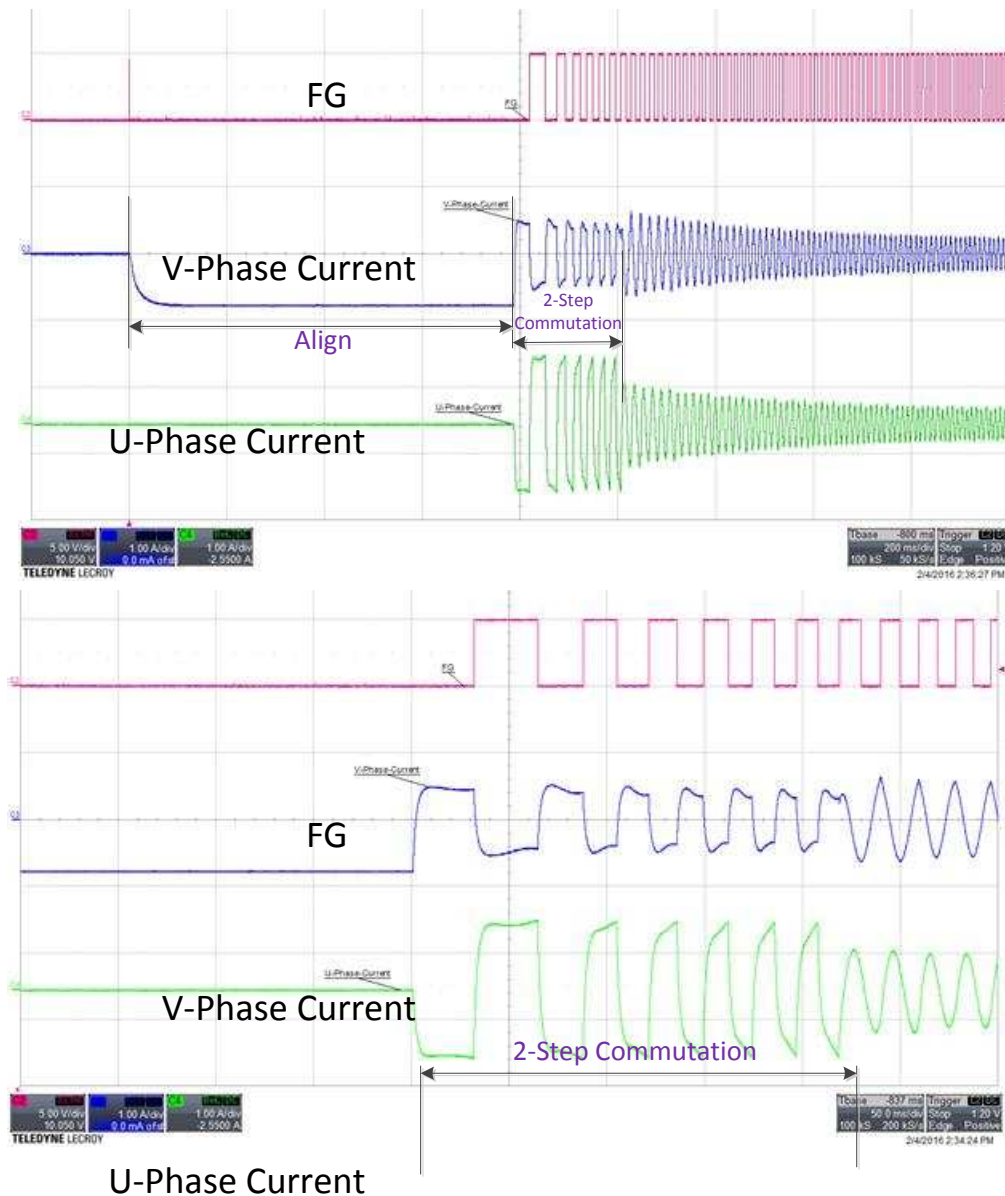**Figure 16. Phase Current During 2-Step Commutation With Single Hall Sensor**

## 3.4 *Advantages and Disadvantages of Using Single Hall Sensor Mode*

The main advantage of using a single Hall sensor over a three Hall sensor is the cost-savings of two additional sensors. The other advantage is that the effort of aligning two additional sensors to BEMF is saved; now the user has to take care of aligning one sensor to phase BEMF.

The disadvantage of using a single sensor is that there is possibility of the motor spinning in the reverse direction during the align state during motor startup. Single sensor mode is not recommended for applications which are sensitive to reverse spin. Torque ripples are bigger in amplitude for 2-step commutation in comparison to trapezoidal commutation, so torque ripples during startup in single Hall sensor can be higher.

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