Selecting Among DRV88xx Devices to Drive Brushed or Stepper Motors

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ABSTRACT

This document is provided as a supplement to the DRV8802/12/13/14/28/29/40 data sheets. It details the circumstances in which each one of these devices can be utilized to drive either brushed DC motors or bipolar stepper motors, and the ENABLE pin behavior from which this circumstances stem.

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1   Introduction

An H Bridge is a power stage topology consisting of four FETs which grants us the ability to:

Control Current Flow: By enabling the FET switches, it is possible to allow current flow into and out of a load. By disabling the FET's, the load remains disconnected from the power supply.
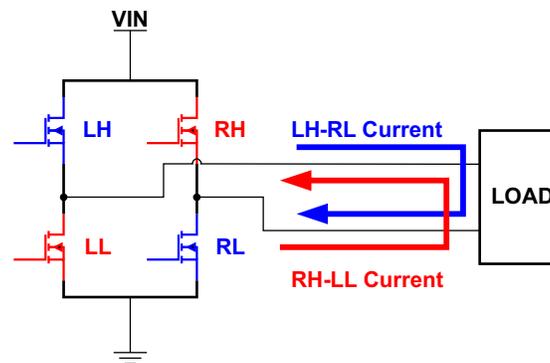
Figure 1. Current Flow

Control Current Flow Direction: Depending on which pair of FET switches is enabled, the current can be made to flow from right side to left side or vice versa. For example, on Figure 1, we can see that if the FET LH and RL are enabled, the current moves from left side to right side. If on the other hand the FETs RH and LL are enabled, then the current flows from right to left.

Control Current Magnitude: By applying a PWM signal which in turn enables and disables the FETs periodically and at specified rate, we can control how much time the FETs are turned ON, which for an inductive load this translates to how long the current can increase across the inductive element. Once averaged out, we have gained the ability to regulate current.

As long as an H Bridge is just the four FETs and the circuitry necessary to enable/disable them, this power stage is good enough to drive either a DC motor or half of a bipolar stepper motor. However, when adding some forms of intelligence, such as current regulation and automated decay mode control, then an H Bridge can be tailored to drive one load style better than the other.

On this Application Note we study how application specific H Bridges can still be utilized to drive other inductive loads.

2   Problem Statement

The DRV8802/12/13/14 devices are dual H Bridge devices capable of driving either two brushed DC motors or a single bipolar stepper motor. The DRV8828/29/40 are single H Bridges capable of driving a DC motor or half of a bipolar stepper motor. While looking at each of these devices' datasheet, the user will find the particular device to be tailored to drive either a DC motor load or a stepper motor load. Although following these suggestions will yield the fastest component selection for any given application, it is still possible to utilize the same device to drive the "non-suggested" load. That is, a stepper optimized H bridge can still be used to drive a DC motor, and vice versa, as long as some design guidelines are followed.

Ultimately, what we will find is that the algorithms behind each type of control on a per inductive load style basis, will be dependent on the programmed behavior for the respective device's ENABLE pin. This is because although the ENABLE pin is intended to control whether current flows through the H Bridge or not, on a device offering current regulation capabilities, the truth table behind ENABLE will also define which current decay mode is engaged once the H Bridge is disabled.

For example, DRV8802/14/40 are optimized to drive brushed DC motors, because when the ENABLE pin is made LO, the H Bridge outputs are programmed to follow current decay mode as specified by the DECAY pin. If the DECAY pin is configured for slow decay (DECAY = LO), then the outputs are both set to enable the low side FETs in which case a BRAKE mode is employed. If the DECAY pin is configured for fast decay (DECAY = HI), the opposing FETs are enabled until current reaches zero at which point the H Bridge is tri stated (HiZ).

This behavior could make the operation of a stepper undesirable as the stepper shaft will be cogged (resists external motion) when the MODE pin is configured for slow decay. This cogging behavior is present because in this scenario, the H Bridge outputs are basically shorting the stepper winding and subsequently whatever back EMF would be present as the shaft rotates. In the event the shaft is externally rotated, extra torque must be supplied on a per mechanical step basis to overcome the imposed braking condition.

On the other hand, the DRV8812/13/28/29 are optimized to power up stepper motors, because when the ENABLE pin is made LO, the H Bridge outputs are programmed to be tri stated (Hi-Z) and enter asynchronous fast decay, taking the current to zero while discharging through the H Bridges' body diodes. When the shaft is rotated, the motor moves freely with the generated back EMF flowing through the body diodes, not any power FETs. Since stepper current only needs to be defined when the H Bridge is enabled (ENABLE = HI), this behavior is akin to stepper driving techniques.

However, this very same behavior makes the operation of brushed DC motors not as feasible with these devices. As we will see later on this document, DC motors do require current control during both states on the ENABLE line. This is especially true when controlling speed by applying a PWM control signal at the ENABLE line. On the DRV8812/13/28/19 we lose current control during the ENABLE = LO state, as they are programmed to enter asynchronous fast decay. In this case, the average current is not as high as when using slow decay, which translates into a poor speed regulation when applying a PWM signal at the ENABLE line.

All of the erratic behaviors aforementioned indicate that the driver may respond poorly if the problematic scenarios are employed. However, there are still ways in which we can skip these problems, allowing us to use the same power stage to drive both motor topologies. The following table summarizes the behaviors found when making the ENABLE line LO and why each particular device is recommended to be optimized for one motor style over the other.

Table 1. DRV88xx Suggestions on a per Motor Style Basis

DEVICE	H BRIDGES	CURRENT	ENABLE BEHAVIOR
STEPPER OPTIMIZED DRIVERS			
DRV8812	2	1.6A	H Bridge is disabled and tri stated when ENABLE is LO
DRV8813	2	2.5A	H Bridge is disabled and tri stated when ENABLE is LO
DRV8828	1	3A	H Bridge is disabled and tri stated when ENABLE is LO
DRV8829	1	5A	H Bridge is disabled and tri stated when ENABLE is LO
BRUSHED DC MOTOR OPTIMIZED DRIVERS			
DRV8802	2	1.6A	H Bridge is disabled, follows MODE pin when ENABLE is LO
DRV8814	2	2.5A	H Bridge is disabled, follows MODE pin when ENABLE is LO
DRV8840	1	5A	H Bridge is disabled, follows MODE pin when ENABLE is LO

3 DC Motor Driving

When driving DC motors, it is often imperative to control its speed. For applications in which the speed of the motor does not need to be controlled, then any of the aforementioned devices will work in driving the DC motor.

When controlling the speed of the motor while using an H Bridge power stage, a common technique is to employ a Pulse Width Modulation (PWM) control signal in which the H Bridge is enabled and disabled at such a high frequency, what the motor sees is a fraction of the input voltage equal to the ratio of how long the H Bridge was ON to the total period of time. In other words:

$$\text{VOUT} = \text{VIN} \times \left(\frac{\text{TIMEON}}{\text{T}} \right)$$

(1)

Where:
    VIN is the voltage at the H Bridge power stage
    VOUT is the voltage the motor load will see
    TIME ON is the amount of time the H Bridge is enabled
    T is the inverse of the PWM frequency
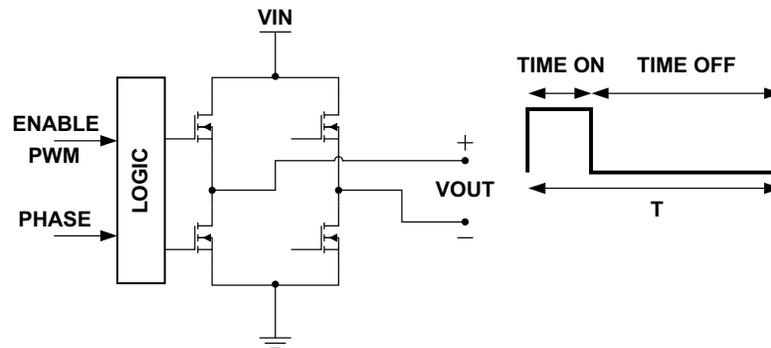
Figure 2. A ENABLE/PHASE H Bridge and the ENABLE PWM Control Technique

For PWM to better work in controlling the motor speed, the motor current must be maintained as close as possible to the actual load requirements. When the H Bridge is enabled, the current increases as determined by the application voltage (VIN) and the motor inductance (L). This current increase will only be maintained until the H Bridge is disabled. Once the H Bridge is disabled, current decays according to the selected current decay mode (either slow or fast decay).

When current decays, this translates into a torque ripple. In average terms, the torque the motor will be able to deliver will be directly proportional to the average current. If the current ripple is too high, then the average current will be lower. In order to maximize the efficiency during the PWM actuation, it is best to use slow decay mode. Figure 3 shows the effect of using slow decay versus fast decay when applying a PWM control signal at the ENABLE line.
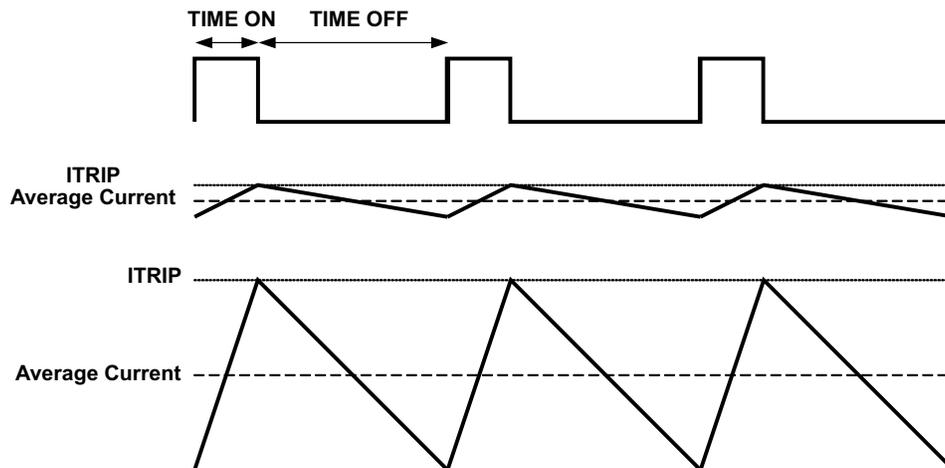

Figure 3. Effects of using Slow or Fast decay modes while applying a PWM Control signal at the ENABLE input

Since DRV8812/13/28/29 can not enter slow decay current recirculation when the ENABLE line is made LO, applying a PWM at the ENABLE line can not offer the same higher average current and low current ripple slow decay mode offers. This often translates into a loss of speed regulation for some duty cycle values (i.e. a motor may be able to start up with a duty cycle of 30% when using slow decay, but may require higher duty cycles to equally start when using fast decay).

3.1 Brushed DC PHASE PWM

On some servo applications, the PWM signal can be used to drive the PHASE input instead of the ENABLE input. In this scheme, the PWM Duty cycle is used for both controlling the motor speed and the direction of rotation, as the H Bridge is no longer being enabled/disabled when the control signal cycles through the ON and OFF position. Instead, what the PWM control signal is determining is whether the current flows in one direction (e.g. say from left to right) or the other (e.g. from right to left), which in turns controls whether the motor rotates in one direction (e.g Clock Wise, CW) or the other (e.g. Counter Clock Wise, CCW).
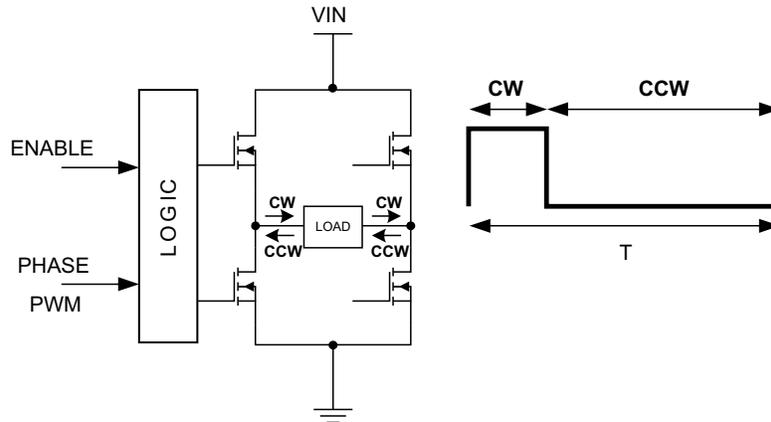
Figure 4. Applying a PWM Control Signal at the PHASE Input

When applying a PWM to the PHASE pin, a duty cycle equal to 50% results in no motor motion as the motor current is flowing forward and backward the same amount of time. As a result, we obtain an average current equal to zero. As the duty cycle starts to move away from 50%, current starts to build such that one direction prevails more than the other. As a result, as the duty cycle grows larger or smaller than 50%, the motor rotates faster. Figure 5 details what the current is doing for different duty cycle values at, above or below 50%.

(a) PWM duty cycle is below 50%, so CCW direction prevails.

(b) PWM duty cycle is 50%, so motor does not move.

(c) PWM duty cycle is above 50%, so CW direction prevails.
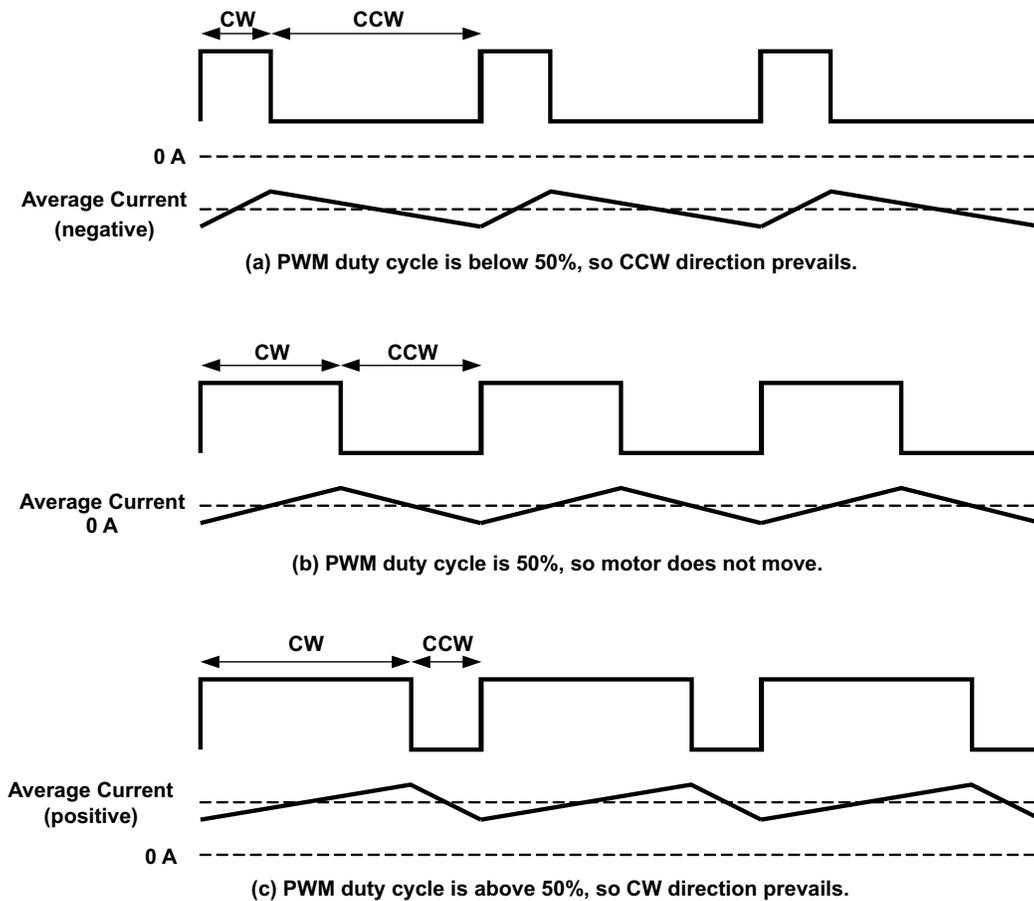
Figure 5. PWM Duty Cycle

Because a PWM signal on the PHASE control input by definition causes the alternate actuation of the current flow direction, we are in essence applying fast decay current recirculation at all times, regardless of whether the device has been configured to use one current regulation mode or the other. Note that the DECAY pin on any of these devices is used to determine how current will flow once the H Bridge is disabled either through the de-assertion of the ENABLE line or an ITRIP event. Since during a PHASE actuation cycle none of these events are taking place, the current regulation is independent of the DECAY pin setting.

At the same time, it is safe to assume that since the ENABLE line is not actuated during this type of implementation, it is possible to effectively use the DRV8812/13/28/29 devices to drive brushed DC motors.

4 Stepper Motor Driving

When studying the implementation of a bipolar stepper driver with any of the devices in question (i.e., DRV8802/12/13/14/28/29/40), the selection method will not be constricted in complexity as when driving the brushless DC motors. In fact, by nature any of these devices can be used to drive bipolar stepper motors with no consideration whatsoever other than how will the motor behave when the motor is disabled (ENABLE =LO).

If using the DRV8802/14/40 H Bridge with BRAKE capability, the motor shaft will feel cogged, due to a continuously collapsed back EMF, when external rotation is attempted, if the device is configured for slow decay (DECAY = LO). If the H Bridge is configured for fast decay (DECAY = HI), after disablement the motor shaft will rotate freely when external rotation is attempted.

4.1 VREF Modulation Microstepping

When using the internal DAC and current regulation engine, the system will coordinate H Bridge enablement and disablement and follow current regulation schemes as defined by the state of the DECAY pin. Since the ENABLE pin is not used to coordinate this current regulation, any of the aforementioned devices will work towards driving a bipolar stepper motor.

4.2 Voltage Mode Microstepping

Another algorithm used to achieve microstepping is to apply a PWM signal at the ENABLE line and then control the duty cycle on a per microstep basis. Whether this is done open loop (current information at the SENSE pin is ignored) or closed loop (current is regulated through a PID loop and after looking at the SENSE pin), is irrelevant as the factor to keep in mind is the PWM control signal at the ENABLE input. In this case, the same guideline considerations detailed in Section 3 must be followed.

5 Conclusion

Table 2 details the particular conditions for which each device can be used to drive a given motor style, once we understand the behavior behind the ENABLE pin logic.

Table 2. DRV88xx Recommendations on a per Motor Style and Driver Basis

DEVICE	MOTOR STYLE	CONDITIONS
DRV8802	Brushed DC Motor	As per Design
DRV8802	Bipolar Stepper Motor	If back EMF induced shaft cogging not an issue
DRV8812	Brushed DC Motor	If using PHASE PWM control
DRV8812	Bipolar Stepper Motor	As per Design
DRV8813	Brushed DC Motor	If using PHASE PWM control
DRV8813	Bipolar Stepper Motor	As per Design
DRV8814	Brushed DC Motor	As per Design
DRV8814	Bipolar Stepper Motor	If back EMF induced shaft cogging not an issue
DRV8828	Brushed DC Motor	If using PHASE PWM control
DRV8828	Bipolar Stepper Motor	As per Design
DRV8829	Brushed DC Motor	If using PHASE PWM control
DRV8829	Bipolar Stepper Motor	As per Design
DRV8840	Brushed DC Motor	As per Design
DRV8840	Bipolar Stepper Motor	If back EMF induced shaft cogging not an issue

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