

Solenoid Driving With DRV8841/42

*Jose Quiñones**Analog Motor Drives*

ABSTRACT

This document is provided as a supplement to the DRV8841 ([SLVSAC0](#)) and DRV8842 ([SLVSAB8](#)) datasheets. It details a technique utilizing either the DRV8841 or DRV8842 as a multiple half H-Bridge power output to drive solenoid inductive loads.

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1 Introduction

A solenoid is an electro-mechanical device consisting of an electromagnet and a ferromagnetic piston element which can be pushed or pulled as current is made to flow through its inductive component. Driving a solenoid is a rather simple task with very little need for sophisticated electronics. Still, the basics of inductive load driving must be taken care of if we are to safely actuate this load. These requisites are:

1. A large enough voltage must be applied across the winding in order to supply a current with enough magnitude as to push/pull the piston.
2. The switch or power stage must be sized according to the dc current we expect to see flowing across the solenoid winding.
3. An alternate path must be applied to take care of the flowing current once the switching element is disabled.

The typical solenoid drive is a single FET transistor with enough current handling capability to drive the load, and a free wheeling diode which is forward biased when the FET is disabled. When the FET is enabled, it sinks all the current needed to polarize the inductor. When the transistor is disabled, the current flowing through the inductance must be allowed to decay down to zero. The free wheeling diode is forward biased taking this current and avoiding damage to the power FET. [Figure 1](#) shows the two possible states a solenoid will experience as it is energized.

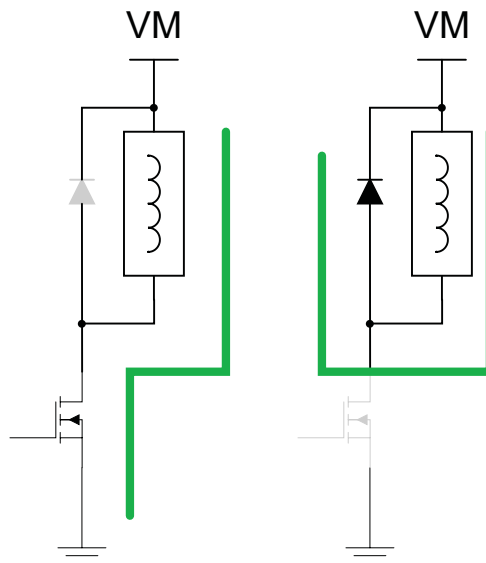


Figure 1. A Power FET Transistor and a Freewheeling Diode Used to Drive a Solenoid Valve

In essence, an H-Bridge could be used to drive a solenoid as well. The advantages around this implementation result from the fact that today's H-Bridges are economically feasible and contain numerous forms of protection such as thermal shutdown (TSD), current regulation (I-Trip) and over current protection (OCP). [Figure 2](#) shows how an H-Bridge can be utilized to drive a conventional solenoid valve.

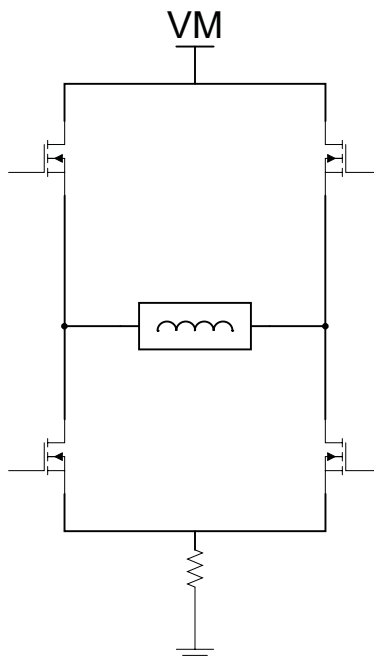


Figure 2. An H-Bridge Block Utilized to Drive a Solenoid Valve

As useful as it may be, an H-Bridge will most likely result in resource over usage, as four FETs, instead of two, are utilized. After all, the idea behind an H-Bridge is to grant the ability to control current flow direction, as when controlling DC or stepper motors, but with the great majority of solenoid applications this feature is seldomly required. If it is required, as with bistable solenoid where direction of motion is directly proportional to magnetic field polarity, an H-Bridge would result in the optimal implementation.

For the great majority of solenoid applications, namely single direction actuation solenoids, we propose an alternate operation mode in which only two FET transistors are needed to control its actuation. In this case, half of an H-Bridge suffices. It is then possible to utilize an H-Bridge with IN1 and IN2 interface style, such as the DRV8841 or DRV8842, which consists of a multiple of half H-Bridges configured to operate as a full H-Bridge. Nonetheless, their independent half H-Bridge behavior can be capitalized upon, obtaining the ability to drive a pair of solenoids. This will in turn offer a considerable amount of integration while best utilizing the H-Bridge's existing resources.

2 DRV8841/42 H-Bridge Power Stage

The DRV8841 consists of a pair of identical full H-Bridges with independent leg control. On the typical PHASE/ENABLE H-Bridge (as with DRV8800/01/02/12/13/14/28/29/40 per example), the signal ENABLE determines whether the H-Bridge is enabled while the signal PHASE defines the direction of current flow. On the DRV8841, on the other hand, the H-Bridge is in essence enabled at all times (e.g. two of the four FETs are always enabled), with the AINx inputs determining whether current flows or not and on what direction. The previous statement holds true as long as the programmed current is larger than zero, or otherwise the H-Bridge is effectively tri-stated and no FET is enabled. This may seem confusing so [Figure 3](#) shows the DRV8841 Block Diagram for H-Bridge A while [Table 1](#) shows its possible 4 states.

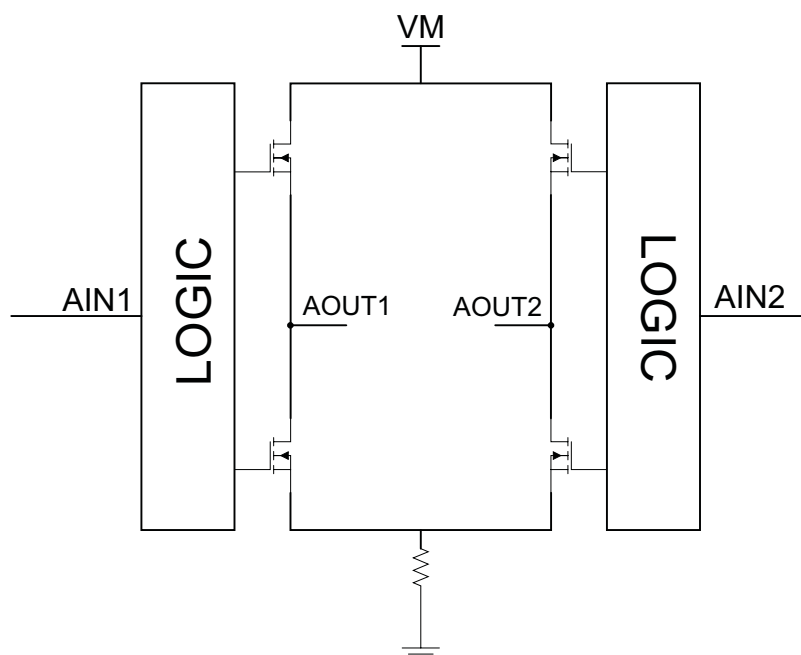


Figure 3. DRV8841 H-Bridge A Block Diagram

Table 1. INx Inputs to OUTx Outputs Relationship

AIN1	AIN2	AOUT1	AOUT2	DESCRIPTION
LO	LO	GND	GND	Both outputs are tied to GND
LO	HI	GND	VM	AOUT1 is tied to GND, AOUT2 is tied to VM
HI	LO	VM	GND	AOUT1 is tied to VM, AOUT2 is tied to GND
HI	HI	VM	VM	Both outputs are tied to VM

What we can deduce from the block diagram and its respective table is that each leg's output is directly proportional to its respective input. That is, when the input is HI, its high side FET is enabled, whereas if the input is logic LO, then the low side FET is enabled. The only time in which the device will not operate according to the previous logic table is if the H-Bridge is commanded to supply zero current, as when both Ix bits are made HI. In this case, all FETs are disabled, effectively tri-stating the H-Bridge.

2.1 DRV8841/42 as Half H-Bridges

Although all we have discussed how the DRV8841 device makes it look and operate like an H-Bridge, in essence what we have are four identical half H-Bridges. The same can be said about the DRV8842, with a pair of half H-Bridges in this case. They look as shown in [Figure 4](#).

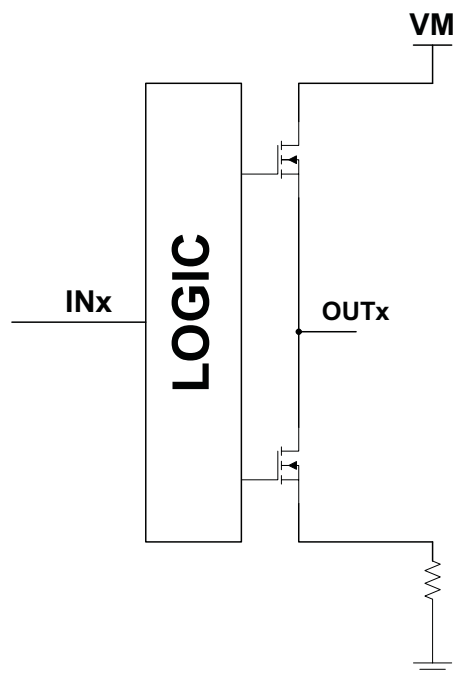


Figure 4. The Half H-Bridge

The half H-Bridge is the perfect structure to drive a solenoid valve as it has precisely the number of components we need to achieve this task. It has two power mosfets which will supply the current as required by the load in question. There is no diode, as we saw on [Figure 1](#), but the second FET actually works better as we can control both when it turns ON and OFF as well as its resistance ($R_{DS(on)}$). This makes the system much more efficient.

2.2 Half Bridge Operation

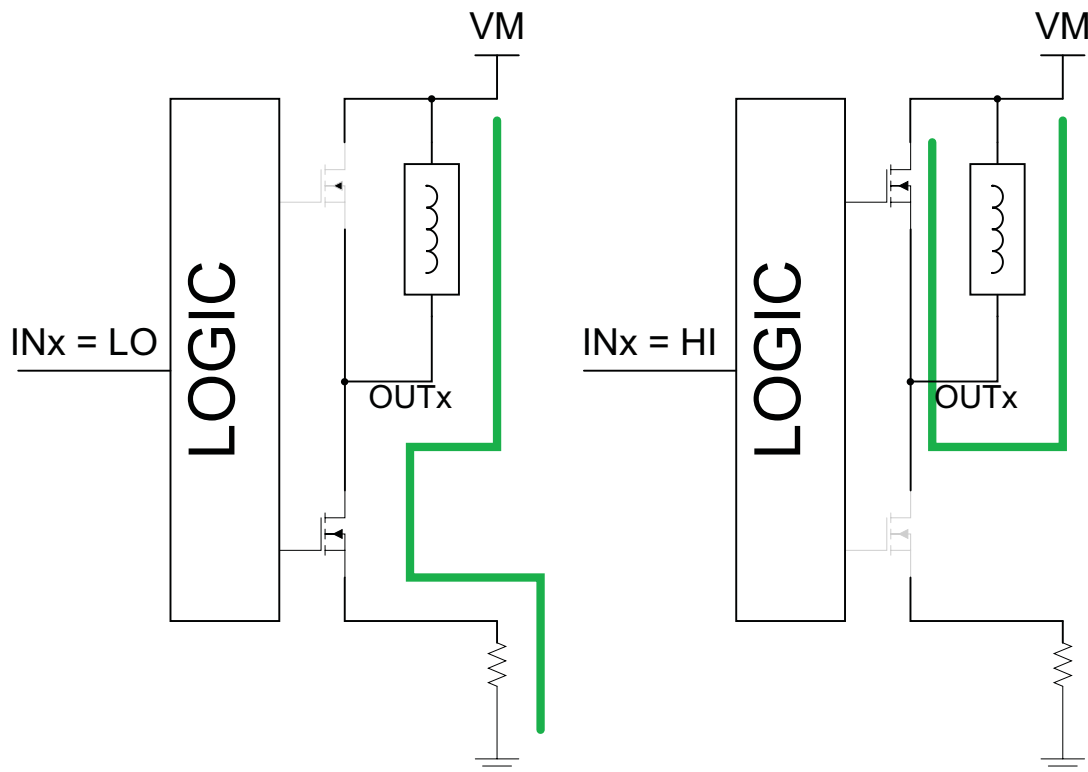


Figure 5. DRV8841's Half H-Bridge Driving a Solenoid Valve

Figure 5 shows how a solenoid connected from VM to a DRV8841 output can be safely driven. When the INx is LO, the low side FET conducts closing the circuit from VM to GND. Current increased until it reaches saturation with the induced magnetic field pulling the ferromagnetic element and actuating the solenoid.

For this application, DRV8841 is rated at up to 1.5 A, whereas DRV8842 is rated at up to 3 A. As long as the currents being driven are below these maximum ratings (as well as enough thermal heat sinking provisions have been put in place), the solenoid can remain actuated for an indefinite amount of time.

Eventually the solenoid will be deactivated with power being removed from its magnetic core. Since the solenoid is an inductor, the current flowing through it must remain until it fully discharges to zero. An alternate path must be provided for this means and in this implementation the opposing FET is utilized. This actuation is automatic as taking the INx input to HI immediately signals the half H-Bridge to disable the low side FET and enable the high side FET.

There is always a period of time, called dead time, in which no FET is enabled. This small period of time, about 500 ns, is put in place to ensure no shoot through is generated. Shoot through (the enablement of both high and low side FETs on a per leg basis) would cause a short from supply (VM) to GND.

During this dead time, the opposing FET body diode will conduct. This is the asynchronous portion of the current decay. Once the FET is enabled, we enter synchronous current decay.

2.3 INx Input PWM

In some applications, it is beneficial for the solenoid load to be PWM'd. This offers the capability to control the current the inductive component sees, yielding a directly proportional magnetic field and a predetermined position. INx inputs can be safely PWM'd. However, to close the loop the user must read the current information from the SENSE resistor. This technique will not work if there are two solenoids being driven by the same H-Bridge.

If current regulation is needed as to obtain directly proportional position control, we recommend the usage of a full H-Bridge per solenoid load. A myriad of DRV88xx devices already contain current regulation so it would be a matter of administering the correct VREF value, and current would be regulated according to its respective ITRIP equation. Each device's datasheet will contain the information on how to regulate current and its respective ITRIP equation.

3 Connection Styles

A pair of solenoids can be connected to each H-Bridge in two different configurations. These connections styles are shown in [Figure 6](#).

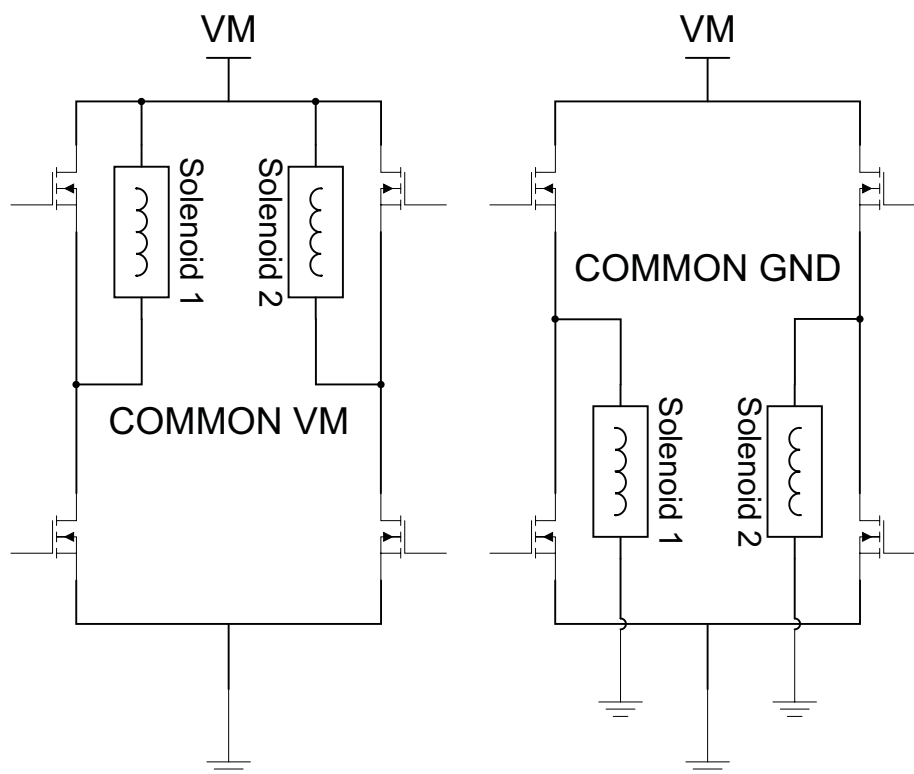


Figure 6. Different Solenoid Connection Styles on a Per H-Bridge Basis

3.1 Common VM

If both solenoids are connected from VM to a respective power output, driving the solenoid is through the low side FET. In this connection style, a LO at the respective INx signal will enable the solenoid and a HI will disable it. Since the LO side FETs are conducting, current flow will also go through the SENSE pin.

Since current is flowing through the SENSE pin, care must be ensured so that no ITRIP events are generated. The easiest solution is to tie the SENSE pin directly to GND. If a SENSE resistor is used (not recommended as ITRIP events caused on one of the half H-Bridge will affect the other half H-Bridge), VREF can be made large enough so that ITRIP events are not registered.

3.2 Common GND

If both solenoids are connected from a respective power output to GND, driving the solenoid is through the high side FET. In this connection style, a HI at the respective INx signal will enable the solenoid and a LO will disable it. In this scenario, current never flows through the low side FET or the SENSE resistor so ITRIP events can not be generated.

3.3 SENSE Pin and RSENSE

Regardless of connection style, it is recommended that the SENSE pin is connected to GND. On COMMON VM implementations this will disable further ITRIP current regulation events. On the COMMON GND scenario, ITRIP events are simply not possible as current does not flow through the low side FET, hence the usage of a SENSE resistor is unnecessary.

Looking back at the COMMON VM connection style, although each H-Bridge leg is independent in terms of control, when it comes to current regulation, independence is lost. An ITRIP event caused by AIN1, will affect AIN2.

For example, if AIN1 is LO (solenoid 1 is enabled) whereas AIN2 is HI (solenoid 2 is disabled), an ITRIP event will cause AIN2 to go LO enabling solenoid 2. If ITRIP is set such that it can not be reached, the previous scenario can not take place.

It is worthwhile noting that if both solenoids are enabled with a COMMON VM connection style, current regulation is intrinsically disabled when both LO side FETs are enabled. This is so as the DRV8841/42 device's logic states that both half H-Bridges configured to be driving the outputs LO will be considered to be under slow decay current recirculation mode.

In this event, current recirculation is simply not possible as current does not flow through the SENSE resistor, but instead decays to zero while flowing through the power FETs. As a result, current chopping is internally disabled whenever both AINx signals are LO.

4 Protection

Although current regulation is not available on a per channel basis, solenoid driving implementation with the DRV8841/42 devices still enjoy from a fair number of protection schemes. Thermal Shutdown (TSD) is still enabled and fully operational. As the device gets too hot, a TSD even would be triggered effectively tri-stating all the half H-Bridges. Current on the solenoids would then decay asynchronously through the internal body diodes.

The biggest threat to any H-Bridge application is the occurrence of high current spikes that can adversely affect the power FETs. The Over Current Protection feature on the DRV8841/42 devices will still operate regardless of the connection method. Each FET is protected by this powerful block adding reliability to the system.

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