Hit and Hold Solenoid Driver

Description

This solenoid driver provides a means to lower static power draw of a solenoid system. The driver takes advantage of the lower current to hold than to actuate of the solenoid as well as the inductive nature of the coil. The driver is also designed to be easily and transparently integrated into both new and existing systems. This is accomplished by installing in line with the solenoid and utilizing the systems power switching technique. By applying a timed configurable full power pulse to the coil the solenoid can be actuated. After the time out period the driver switches to a current regulating mode thereby reducing power and heat dissipation from the solenoid while holding position and compensating for supply voltage fluctuations.

Features

Wide operating range 10 to 18V
Low quiescent current
Reduced static power

Applications

Solenoid valves and Actuators
Battery Operated Oceanographic
Instrumentation

Electrical Specifications

Maximum Ratings

Rating	**Symbol**	**Value**	**Unit**
Storage Temperature	T_{stg}	0 to 125	^{o}C
Operating Temperature	T_a	0 to 70	^{o}C
Supply Voltage	V_{CC}	36	V
Humidity	RH	10 to 95% non-condensing	%RH
Maximum Hit Current	I_{hit}	10	A
Maximum Continuous Current[1]	$I_{max\ cont}$	2	A
Current Sense Resistor Power	P_R	1	W

Recommended Ratings

Rating	**Symbol**	**Value**	**Unit**
Supply Voltage Range	V_{CC}	10 to 36	V
Peak Current	I_{peak}		A
Continuous Current	I_{cont}		A
Hit Time	T_{hit}	100	ms
Quiescent Current	I_q		A
Minimum On Time	T_{on}	2	us
Minimum Vcc Ramp Time	T_{ramp}	10	ms

Notes:

1. Maximum current is dependent upon the power dissipation of the current sense resistor. While the circuit is designed to handle the maximum current the sense voltage may need to be adjusted to accommodate the power in the sense resistor.

Circuit description

The circuit is based around hysteretic control of the solenoid current. The solenoid, connected to J2, is wired in such a way that during the coil charge cycle D2 is reverse biased and forward biased by the coil discharge during the switch off time. The current sense resistor is located within this loop and grounded such that coil current may be continuously measured during switch on and off times. The main switch Q1 is driven by the MOSFET driver U1. U1 is controlled by the wire or'd comparators U2A and B. The wired or'd line voltage is controlled by the pull up resistor R2 and the constant current source Q4. The purpose of this configuration is to limit the gate voltage to 20 volts when the source supply is higher. U2B provides the "Hit" or full voltage time from startup while U2A control current during the "Hold" phase. As the reference voltage for U2B is defined by R4 and R5 to be 2/3 of the R-C charge voltage the "Hit" time is approximately the time constant of R6 and C1. Since there is no feedback on this comparator it provides a once per power cycle pulse that turns Q1 on, thus energizing and actuating the solenoid. The series combination of R4 and R5 in conjunction with the constant current source from Q1 provides a reference voltage for the current control loop controlled by U2A. After the "Hit" time U2B releases the line and allows U2A to begin controlling current. At this point the current should be above the "Hold" current threshold as measured by R7. This has caused U2A, as well, to release the line and thus turn the switch off. At this time the current in the solenoid begins to drop as it dischargers across the now forward biased D2. While the line is high Q3 is pinched off disconnecting R3 from the feedback loop. Once the current sense voltage from R7 drops below the reference voltage, U2A switches and pulls the line low and there by turning the switch back on. With U2A output now low Q3 is no longer pinched off and the hysteresis resistor R3 forms a constant current drain with a drop in measured voltage to U2A input and there by providing hysteric control. Once the coil charges above the reference voltage the switch will again be turned off and the cycle repeats.

Configuration

Hold and Hysteresis Current

Two key parameters are configurable by resistor selection; Peak Hold Current and the Hysteretic Hold current. The Peak Hold is the value at which the driver will turn power off to the solenoid allowing the current to drop. This value is determined by the user and the particular solenoid being used. The current should be at such a level as to account for all environmental conditions such that the coil provides adequate holding force. The Hysteretic Hold is the amount that the current will drop from the Peak Hold until the coil is reenergized. This allows for a relaxation time and the bases of the Pulse Width Modulation to the coil.

Calculation

To configure the driver a few things need to be determined about the solenoid to be actuated. These are as follows:

I_{peak}	Peak value the driver will obtain before relaxing (Amps)
I_{hyst}	How far the current will relax from peak before re-energizing (Amps)
L	Inductance of coil (Henry)
V_{cc}	Voltage Supply

These constants are from the driver and are used in the calculations:

V_{ref}	Reference voltage	1.3	Volts
V_{fwd}	Forward voltage drop of diode	0.26	Volts
R_3	Resistance of Hysteresis Resistor	100	kΩ
I_{ho}	Hysteresis Offset Current	10	μA

The first calculation is to determine the current sense resistor.

$$R7 = \frac{Vref}{Ipeak - Ihyst}$$

Before the hysteresis resistor can be determined the time delay offset current needs to be calculated.

$$\Delta I = \frac{(Vcc - Vref) \bullet 2\mu s}{L}$$

The hysteresis resistor may now be determined.

$$R9 = \frac{(Ihyst - \Delta I) \bullet R7}{Iho}$$

In the basic driver Hysteretic Offset Current (Iho) is nominally 10μA. This can be adjusted as follows:

$$R3 = \frac{Vref}{Iho}.$$

The purpose of ΔI is to compensate for the propagation delay within the circuit. It generally can be disregarded when the charge time of the Inductor is greater than 20μs.

$$Ton = \frac{L * Ihyst}{Vcc - Vref} + 2\mu s$$

Minimum on Time

The drive is capable of turning the output switch on and then off with in 2 us. This along with the hysteresis and inductance determine the minimum inductance of the coil. This can be calculated using the following equation:

$$L\min = \frac{Vcc \bullet 2us}{Ihyst}.$$

Further customizations

Voltage Reference Level

The voltage reference level that the driver uses for switching may be adjusted by varying the values of R4 and R5. One reason to change this value will be to reduce power loss in the sense resistor. The current source is a nominal 250 µA and the ratio of R4 and 5 should be kept at:

$$R5 = 2 \bullet R4.$$

Hit time

The time that the driver is held on during initial power cycle is determined by R6 and C1.

$$Thit = R6 \bullet C1$$

The charge current should be kept below 25 µA as to not affect the voltage reference level during start up.

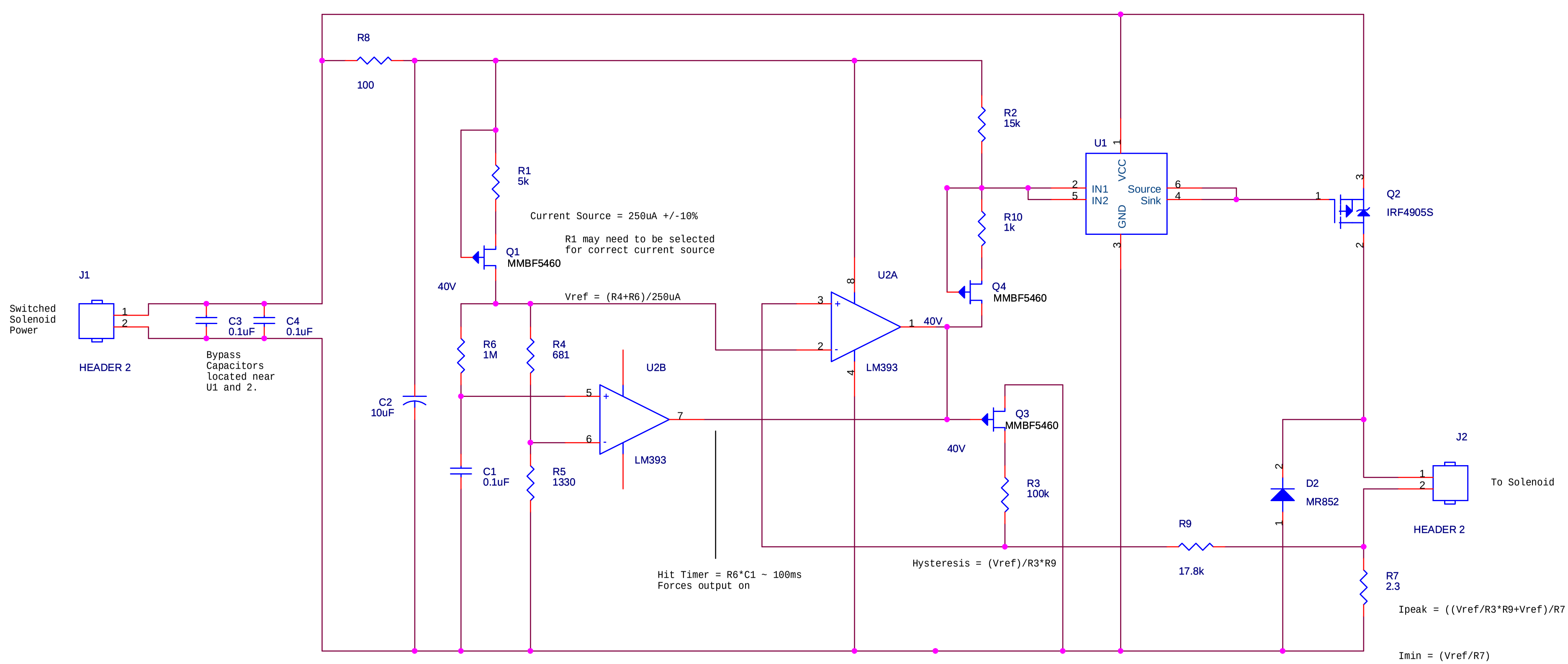
Hysteresis Offset Current

This current may be adjusted to allow a change in range of the hysteresis resistor R9 as follows:

$$R3 = \frac{Vref}{Iho}.$$

Mechanical Characteristics

TBD



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