Power-Saving PWM Solenoid Controller

The project described here is a power-saving pulse-width modulator (PWM) controller for solenoids with an internal supply regulator. The board is based on the DRV110 IC which is a PWM current controller which is specifically designed for solenoid and relay applications. The project regulates the current with a well-controlled waveform to reduce power dissipation on the load. The solenoid current is ramped up fast to ensure the opening of the valve or relay. After initial ramping, the solenoid current is kept at a peak value to ensure correct operation, after which the current is reduced to a lower hold level to avoid thermal problems and reduce power dissipation.

Note: The board operates with 24VDC supply, but it can be used with a wide range of power supplies, you may need to calculate resistor value R2, it is advisable to read the datasheet of DRV110 for more information.

Features

- Supply 24V DC (RANGE 15 TO 48D DC Read Note)
- Load Current Read Note 2
- Fast Ramp-Up of Solenoid Current to Ensure Activation
- Protection, Thermal Shutdown, Undervoltage Lockout (UVLO)
- Solenoid Current is Reduced in Hold Mode for Lower Power and Thermal Dissipation
- I Peak (Peak Current) Adjustable Using Trimmer Pot Pr1
- I HOLD (Holding Current) Adjustable Using Trimmer Pot Pr2
- Jumper J1 Pull Low Disables the Output, pull high or Floating Enables the Output
- D2 Power LED
- Operating Frequency 20Khz (Can be alter), Resistor R6
- PCB Dimensions 46.06 x 23.36 mm

Components

- D1 Power LED,
- Q1 MOSFET to drive the Load
- D1 Clamp Diode
- CN1 power supply input
- CN2 solenoid Connections
- PR1 peak current adjust
- PR2 Hold Current Adjust
- Jumper J1 Enable or disable the Output
- Resistor R6 Frequency Adjust

Example Application Value When R-Sense R8 = 1Ohms

- Peak Current 150mA When R-Peak (PR1 + R4) = 400Kohms
- Holding Current 50mA When R-Hold (PR2 + R5) =200kOhms
- Keep Time 100mS When Capacitor C2 = 1uF
- PWM Frequency 20Khz

07005
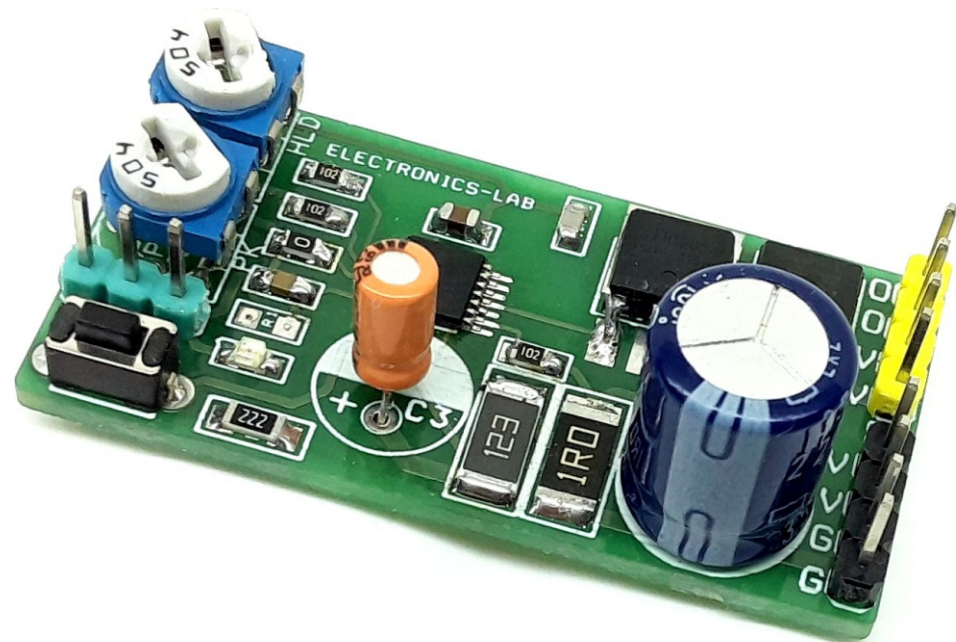
The peak current duration is set with an external capacitor C2. The peak and hold levels of the current ramp can be adjusted using trimmer potentiometer PR2 and PR1, as well as the PWM frequency can independently be set with external resistor R6. External setting resistors can also be omitted if the default values for the corresponding parameters are suitable for the application. The DRV110 device has an internal Zener diode that limits the supply at VIN to VZENER for applications that require a higher supply voltage. High DC voltages such as 48-V can also be accommodated this way.

Enable Jumper J1

Enable and disable of the switch is controlled by the EN pin. The EN pin contains an internal resistor network to set the pin to logic HIGH when the EN pin is floating. This feature can be used for situations where a control signal is not required and the solenoid is only energized when a supply voltage is present. Such applications could be valves or contactors. By pulling down Enable pin disable the output.

Configuring Peak and Hold Currents

IPEAK and IHOLD depend on PR1 and PR2 trimmer pot resistance values RPEAK-PR1 and RHOLD-PR2 as shown in circuit. If the PEAK pin or HOLD pin is connected to ground or RPEAK or RHOLD is less than 43.33 kΩ (typical), then IPEAK is at its default value of 300 mA for IPEAK and 50 mA for IHOLD.

The IPEAK value can alternatively be set using trimmer pot PR1. For example, if a PR1 60-kΩ (= RPEAK) is connected between PEAK and GND, and RSENSE = 1 Ω, then the externally set IPEAK level will be 900 mA. If RPEAK -PR1 = 200 kΩ and RSENSE = 1 Ω, then the externally set IPEAK level will be 300 mA. It is not recommend using a resistor from 30 kΩ and 55 kΩ to avoid the IPEAK or IHOLD current slipping from the maximum current setting to the default setting. In case RSENSE = 2 Ω instead of 1 Ω, then IPEAK = 450 mA (when RPEAK-PR1 = 55 kΩ) and IPEAK = 150 mA (when RPEAK-PR1 = 200 kΩ

Configuring the PWM Frequency Resistor R6 (Default Frequency 20Khz Resistor R6 Value 0 Ohms)

Frequency of the internal PWM clock signal, PWMCLK, that triggers each OUT pin ON-cycle can be adjusted by external resistor R6, ROSC, connected between OSC and GND. Frequency as a function of resistor value is shown in Figure 1. Default frequency is used when OSC is connected to GND directly. Use Equation 1 to calculate the PWM frequency as a function of the external fixed adjustment resistor value (greater than 160 kΩ).

fPWM=60Khz/R6-ROSC X 66.67kOhm; 160Kohm<R6-ROSC<2MOhms

OFF STATE

OFF state In the OFF state, the EN pin is low and the PWM output is off.
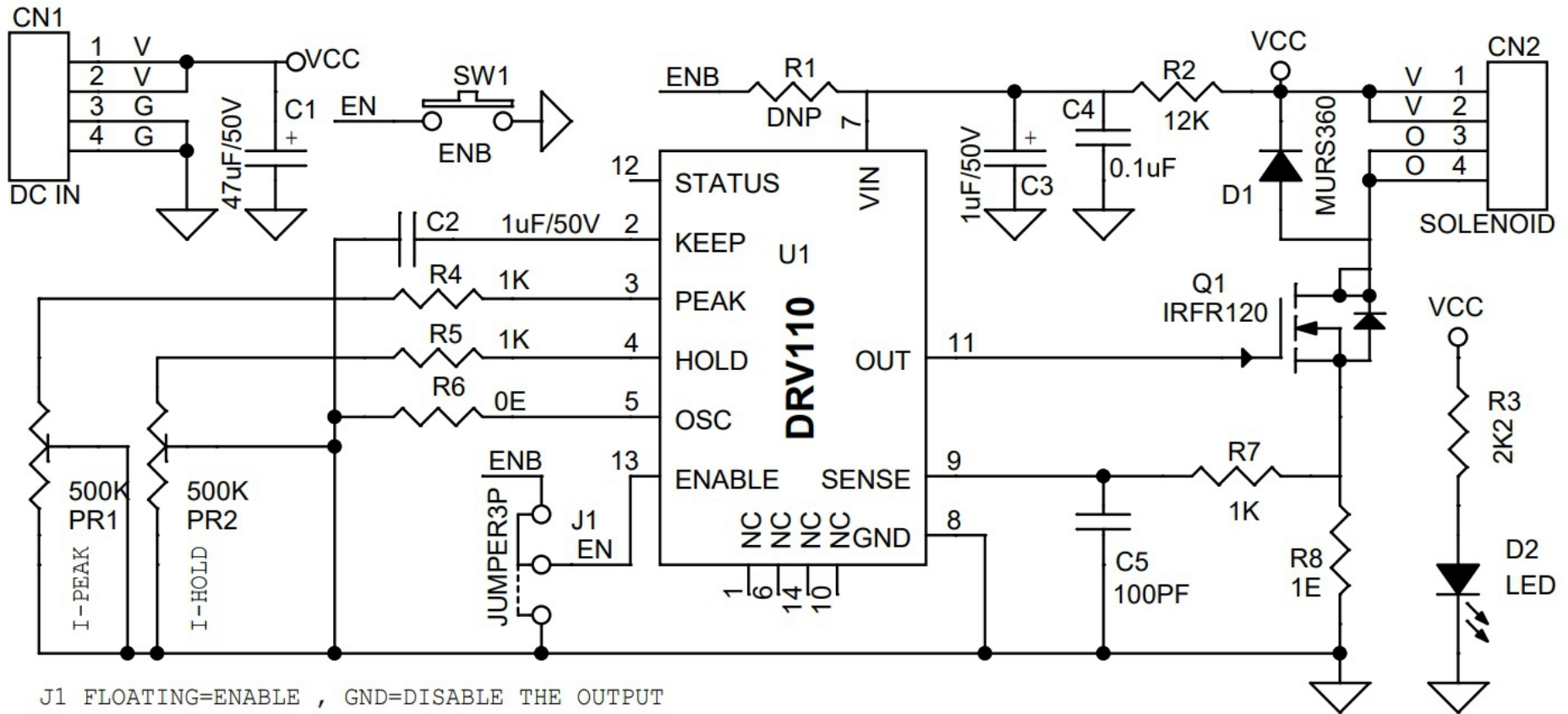
PEAK STATE

The PEAK state begins when the EN pin is set high, and ends when the tKEEP time has been reached. During this state, the PWM operates to reach the IPEAK current set by the RPEAK resistor.
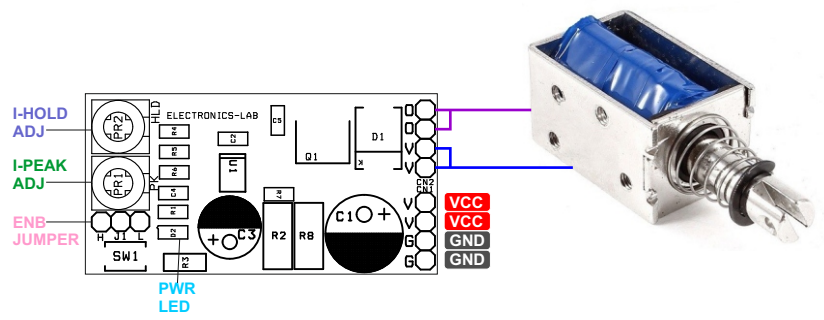
Hold STATE

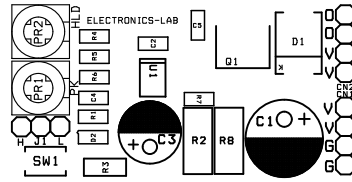HOLD state In the HOLD state, the tKEEP time has been reached, and the PWM continues to operate but at the IHOLD level. This continues until the EN pin is set low again and the PWM turns off.
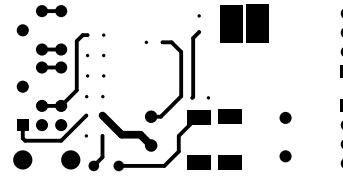
SHUTDOWN

The DRV110 turns off the gate driver in undervoltage lockout (VIN < 4.6 V) or thermal shutdown (TJ > 160°C). If temperature shutdown is activated, the DRV110 resumes operation when the junction temperature is below 140°C.

CN1

1 V
2 V
3 G
4 G

DC IN

VCC

C1
47uF/50V
+

EN

SW1

ENB

ENB   R1
DNP

STATUS   12   VIN   7

C2   1uF/50V   2
KEEP   U1

R4   1K   3
PEAK

R5   1K   4
HOLD   DRV110   OUT   11

R6   0E   5
OSC

ENB   13
ENABLE   SENSE   9

JUMPER3P   J1   EN   GND   8

NC NC NC NC

1 6 14 10

500K
PR1

500K
PR2

I-PEAK   I-HOLD

J1 FLOATING=ENABLE , GND=DISABLE THE OUTPUT

VCC   R2   12K   C4   0.1uF   CN2

V 1
V 2
O 3
O 4

SOLENOID

C3
1uF/50V
+

D1   MURS360

Q1
IRFR120   VCC

R3
2K2

R7
1K

C5
100PF   R8
1E

D2
LED

07005

I-HOLD
ADJ

I-PEAK
ADJ

ENB
JUMPER

PWR
LED

ELECTRONICS-LAB

VCC
VCC
GND
GND

SILK SCREEN TOP   BOTTOM LAYER   TOP LAYER
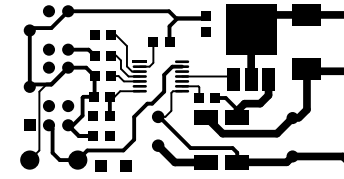
PCB DIMENSIONS 46.06MM X 23.36MM

			BOM			
NO.	QNTY.	REF.	DESC	MANUFACTURER	SUPPLIER	SUPPLIER PART NO
1	1	CN1	4 PIN MALE HEADER PITCH 2.54MM	WURTH	DIGIKEY	732-5317-ND
2	1	CN2	4 PIN MALE HEADER PITCH 2.54MM	WURTH	DIGIKEY	732-5317-ND
3	1	C1	47uF/50V	RUBYCON	DIGIKEY	1189-3770-1-ND
4	2	C2,C3	1uF/50V	KEMET	DIGIKEY	399-ESS105M050AB2EACT-ND
5	1	C4	0.1uF/50V SMD SIZE 0805	MURATA/YAGEO	DIGIKEY	
6	1	C5	100PF/50V SMD SIZE 0805	MURATA/YAGEO	DIGIKEY	
7	1	D1	MURS360	VISHAY	DIGIKEY	MURS360-E3/57TGITR-ND
8	1	D2	LED SMD SIZE 0805	LITE ON INC	DIGIKEY	160-1427-1-ND
9	1	J1	JUMPER3P WITH SHUNT	WURTH	DIGIKEY	732-5316-ND
10	2	PR1,PR2	500K TRIMMER POT	BOURNS INC	DIGIKEY	3362H-504LF-ND
11	1	Q1	IRFR120	VISHAY	MOUSER	844-IRFR120TRLPBF
12	1	R1	DNP			
13	1	R2	12K 5% SMD SIZE 2512	STACKPOLE	DIGIKEY	RMCF2512JT12K0CT-ND
14	1	R3	2K2 5% SMD SIZE 1206	MURATA/YAGEO	DIGIKEY	
15	3	R4,R5,R7	1K 5% SMD SIZE 0805	MURATA/YAGEO	DIGIKEY	
16	1	R6	0E SMD SIZE 0805	MURATA/YAGEO	DIGIKEY	
17	1	R8	1E 1% SMD SIZE 2512	PANASONIC	DIGIKEY	PT1.0YTR-ND
18	1	SW1	TACTILE SWITCH	TE CONNECTIVITY	DIGIKEY	450-1665-ND
19	1	U1	DRV110 TSOP14	TI	DIGIKEY	296-30453-1-ND

07005