PWM SOCKET MANUAL

What is PWM (Pulse Width Modulation)?

Before discussing pulse width modulation, it is helpful to understand braking systems in vehicles. As is well known, ABS (Anti-lock Braking System) prevents the wheels from locking up, thus maintaining steering control. It achieves this not by applying constant pressure to the wheels when braking, but by applying intermittent pulses of pressure. While traditional braking requires a longer stopping distance and generates more heat—often resulting in loss of steering control—ABS allows for safer driving with shorter stopping times, less heat buildup, and better maneuverability.

Pulse Width Modulation (PWM) can be likened to ABS braking. PWM is the process of converting voltage from a power source into pulses of specific durations using special circuits. It involves adjusting the time periods during which the voltage is continuously on or off.

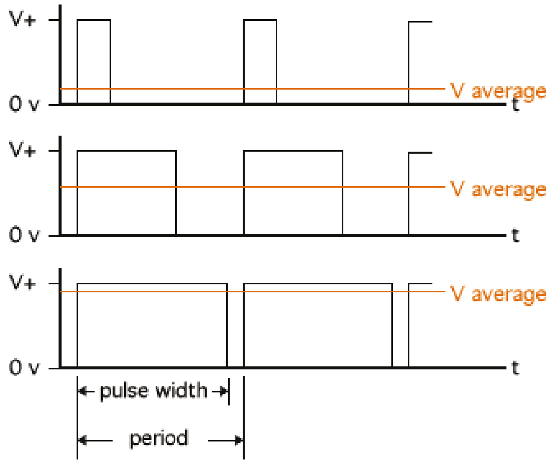

Figure 1. Pulse Examples

Figure 1 shows examples of pulses. As illustrated, the peak values (amplitudes) of the pulses remain constant. The only variable is the width or duration of the pulses. What appears at the output is the average value of these pulses, referred to as Vaverage.

The durations of these pulses are determined by a switching process. Depending on the components used in specially designed circuits, a switching frequency is set. The pulse width is also adjusted using circuit elements, allowing operation at a specified frequency and pulse width.

The ratio of the pulse duration (i.e., the time the pulse is ON) to the total period is called the Duty Cycle. This ratio is used to regulate the output voltage relative to the input voltage. The power delivered to the output is directly proportional to the Duty Cycle—the lower the Duty Cycle, the lower the power transmitted to the output.

How is Pulse Width Modulation (PWM) Applied to a Solenoid Valve?

The inductance element L draws current under direct current as shown in Figure 1. After a certain delay time, the current settles into a steady state where it only affects the resistance of the inductance. From the zero moment until the steady state is reached, the coil provides the necessary magnetic force, pulls the core, and from then on, the current only affects the coil's resistance. The power consumed here is only used for heating the winding.

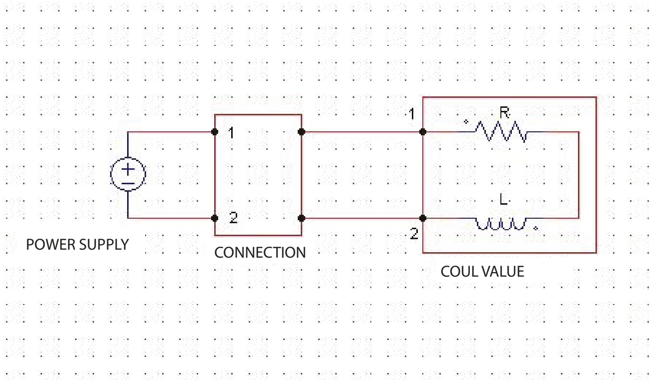

Figure 2. Operating Circuit of the Solenoid Coil

In coils operating with direct current, to save energy lost as heat, the voltage level can be adjusted using Pulse Width Modulation (PWM) after providing the necessary magnetic force to hold the core. Electronic circuits have been designed to enable this.

Thanks to the socket's built-in delay feature, time is allowed for the coil to pull the core. After the core is pulled, less energy is required to keep it in this position. The PWM socket ensures that just enough power is supplied to hold the core in place, thereby saving energy.

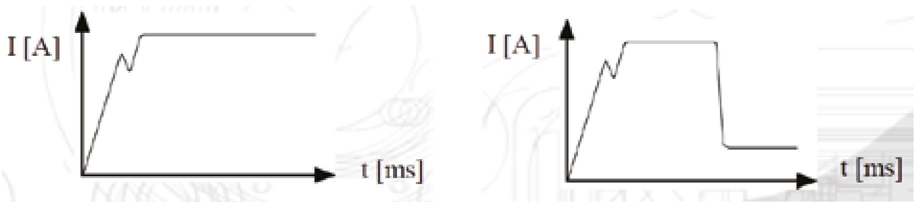

Figure 3. Current Waveforms. (a) Without PWM socket, (b) With PWM socket.

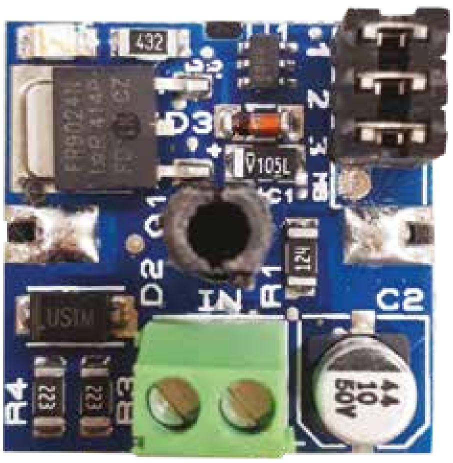
Figure 4. Electronic Circuit of the Socket

The TORK PWM socket, which provides energy savings in solenoid coils, has 3 jumpers on its electronic board. The jumpers are numbered 1, 2, and 3. The PWM ratio is adjusted according to the positions of the jumpers on the board.

When connecting the supply voltage to the PWM socket, attention must be paid to the positive (+) and negative (–) terminals. When holding the PWM socket as shown in Figure 5, the side labeled D2 should be connected to the +VDC terminal, and the side labeled R1 should be connected to the –VDC terminal. Otherwise, the PWM socket may be damaged.

Program	1	2	3	4	5	6	7	8
SW1	0	1	0	1	0	1	0	1
SW2	0	0	1	1	0	0	1	1
SW3	0	0	0	0	1	1	1	1
Duty Cycle (On:Off)	1:8	2:7	3:6	4:5	5:4	6:3	7:2	8:1
Operating Ratio	11%	22%	33%	44%	56%	67%	78%	89%

Table 1. PWM Ratios According to Jumper Settings

In this study, a PWM ratio of 67% was selected.

Figure 5 shows the current-voltage waveforms. In the initial current waveform, the delay time can also be observed. Afterwards, the voltage pulse waveform is visible. The current flowing during the Toff period is the current through the protection diode in the electronic circuit.

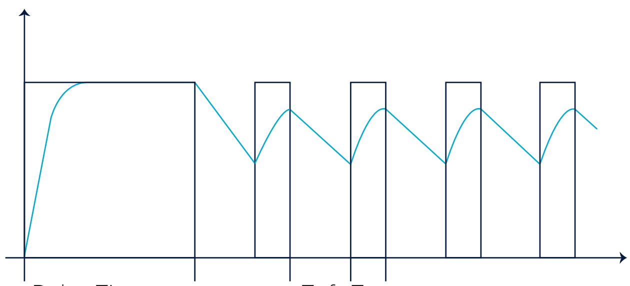

Figure 5. PWM Socket Voltage-Current Waveform

In the waveforms shown in Figure 6, the blue waveform represents the voltage, and the yellow waveform represents the current. As can be seen, the voltage is in the form of pulses, while the current is continuous. A similar waveform is expected to be obtained in the experimental study.

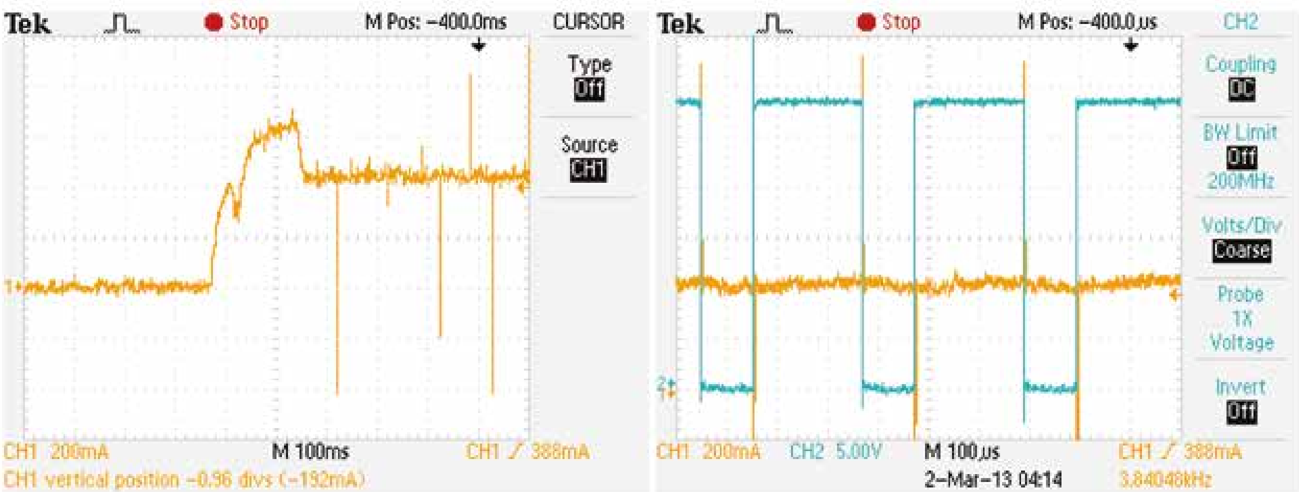

Figure 6. Voltage-Current Waveforms

(a) (b)

Figure 7. Measured Values on the Coil: (a) Current Value, (b) Voltage Value.

What Are the Advantages of PWM Socket?

With the PWM socket, pulse width modulation is applied to the output voltage, which eliminates excess energy consumption. This reduces the energy lost as heat and prevents heating problems in the coil. Naturally, coils that heat less will have a longer service life. Additionally, the PWM socket includes a protection diode that prevents reverse current flow through the coil to the system during power outages.

Which Solenoid Coils Can Use PWM Sockets?

The PWM socket can be used with coils operating at voltages between 12–48 VDC, with a maximum holding current of 3A and a maximum pull-in current of 8A (for 1 second). The socket can be used as long as its size fits the hydraulic coils operating under these conditions. Although the same application can theoretically be applied to mini coils, the size of mini sockets is not suitable for this type of application. Additionally, since mini coils operate at low power, the need for PWM implementation is generally minimal.

Figure 8. PWM socket

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Label Information

Jumpers Duty Ratio

3	2	1	Duty Ratio
0	0	0	11%
0	0	1	22%
0	1	0	33%
0	1	1	44%
1	0	0	56%
1	0	1	67%
1	1	0	78%
1	1	1	89%

T_g : 150ms
f : 2.8kHz
V_s : 12-48VDC
I_{MAX} : 3A (hold)

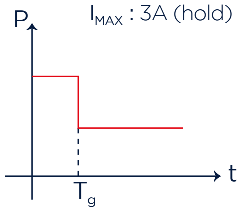

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Table of Maximum Temperature and Current Values for PWM Socket

	Jumper Configuration			24 V DC 18 W Coil				12 V DC 18 W Coil		
	3	2	1	Power Ratio	Max Temp. Reached by Coils(°C)	Current Drawn When the Coil is at 24 °C (A)	Current Drawn When the Coil is at Max Temp.(A)	Max. Temp. Reached by the Coils(°C)	Current Drawn When the Coil is at 24 °C Temp	Current Drawn When the Coil is at Max. Temp.(A)
1	0	0	0	11%	30,6	0,011	0,011	29,2	0,012	0,012
2	0	0	1	22%	34,8	0,039	0,039	34	0,058	0,056
3	0	1	0	33%	42,4	0,085	0,083	38,2	0,142	0,014
4	0	1	1	44%	53,2	0,15	0,14	51,4	0,26	0,244
5	1	0	0	56%	67,2	0,241	0,214	63,4	0,428	0,383
6	1	0	1	67%	82,4	0,347	0,29	76,2	0,626	0,512
7	1	1	0	78%	94,8	0,465	0,378	90	0,855	0,684
8	1	1	1	89%	104	0,604	0,474	104	1,125	0,847

Table 2. Maximum Temperature and Current Values of the PWM Socket