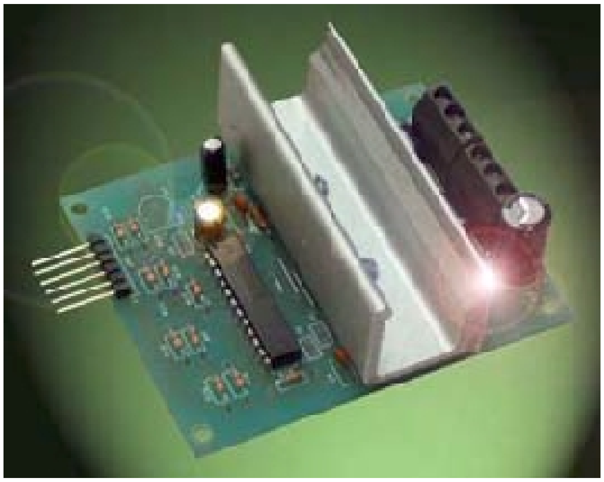
Universal PWM Stepping Motor Driver



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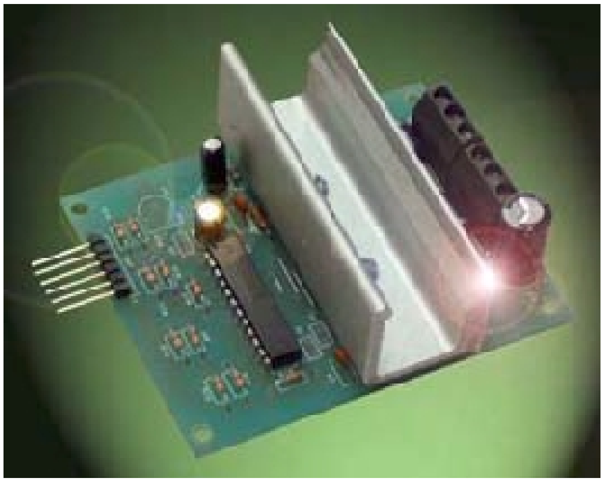
Stepping motors are the first choice in systems where precise and repeatable position control is called for. Although more superior motion control technologies are in existence today, a stepping motor system is still unbeatable when it comes to cost and availability.



Stepping motors, unlike ordinary DC or AC motors, requires an electronic ***driver*** circuitry to run them. Overall system performance depends on both. High performance stepping motor will give a mediocre performance when run with a mediocre driver, and vice versa.

High performance drivers, unfortunately, always carry a hefty price tag. The good news is, a driver with performance approaching those pricey stuff can be built with a string budget! The Universal PWM Stepping Motor driver kit we will be discussing hereon is one such low priced good stuff no self respecting robotic hobbyists should be without.

Unipolar vs. Bipolar Stepping Motor

Stepping motors comes in a variety of forms and configurations, and can be described according to their type and/or according to the drive method. Types may beVR (Variable Reluctance), PM (Permanent Magnet), or HB (Hybrid). Drive method can be 2 phase unipolar and bipolar. More advanced (and expensive) 5 phase types are also available and are widely in use in high end industrial equipment.

Examples of stepping motor: (Right to Left) 4-wire bipolar, 6-wire unipolar, 5 phase stepping motor.

You can easily spot a unipolar or a bipolar stepping motors by looking at the number of wires sprouting out of its body. Unipolar drive has 5 or 6 wires. Bipolar drive has 4. Some even have 8, these are the types that can be wired either as bipolar or unipolar.

The unipolar stepping motor requires only a simple, hence, cheaper electronic driver circuitry. But this advantage comes at a price- you get lower torque performance compared to an equally sized bipolar type. With the unipolar, only half of the total winding can be driven ON simultaneously, resulting in a low 50% utilization factor. In sharp contrast, the bipolar windings can all be driven ON at the same time, generating a torque roughly twice as much compared to the unipolar. However, bipolar electronic driver circuit technology of the past proved to be too expensive and complicated, hence, for a time, designers stayed away from the bipolar drive.

Fortunately, thanks to fast advances in IC manufacturing technology, the cost and complexity gap between the two drivers has considerably narrowed. Today, you can build a high performance bipolar stepping motor driver at a price of a unipolar driver. It is not surprising to note then that bipolar stepping drive becomes the preferred choice for new designs. E-Gizmo's Universal PWM stepper motor drive is one product that will highlight this point.

The Pulse Width Modulation (PWM) Advantage

One important thing that limits the performance of a stepping motor is the fact that, because of its electrical inductance, the current that flows through its windings drops as the stepping frequency is increased. Readers who had fool around with stepping motor may have already observed the negative consequence of this phenomenon; that is, as the motor is revved up, it loses its power (the torque drops). This is an unavoidable problem attached with simple non – PWM drive.

It is obvious at this point that in order to get the maximum torque at increasing speed, the driver must be able to supply the same current as when the motor is at zero speed. The key here is just right ***constant current*** driving. Too much current will cook the motor, too little, you already know the consequence.
This is the function performed by the Pulse Width Modulation PWM circuitry; it keeps the current drawn by the motor constant at all speed. PWM technique assures you of efficient power utilization. With the Universal PWM stepping motor driver, you get the maximum power your motor can deliver even at high speeds.

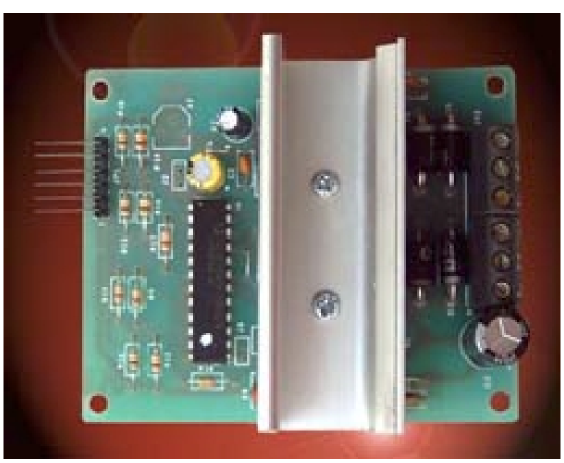


Figure 1. e-Gizmo's Universal PWM driver circuit looks surprisingly simple. All the PWM circuit complexities are hidden inside the driver IC itself, making it possible to come up with a high performance driver that is easy to build, easy to use, and very affordable!

Circuit Operation

The circuit operation can be better explained by with the aid of the block diagram as shown in figure 2. The circuit consists essentially of two functional blocks, the step logic steering IC, and the Dual H-Bridge PWM driver IC.

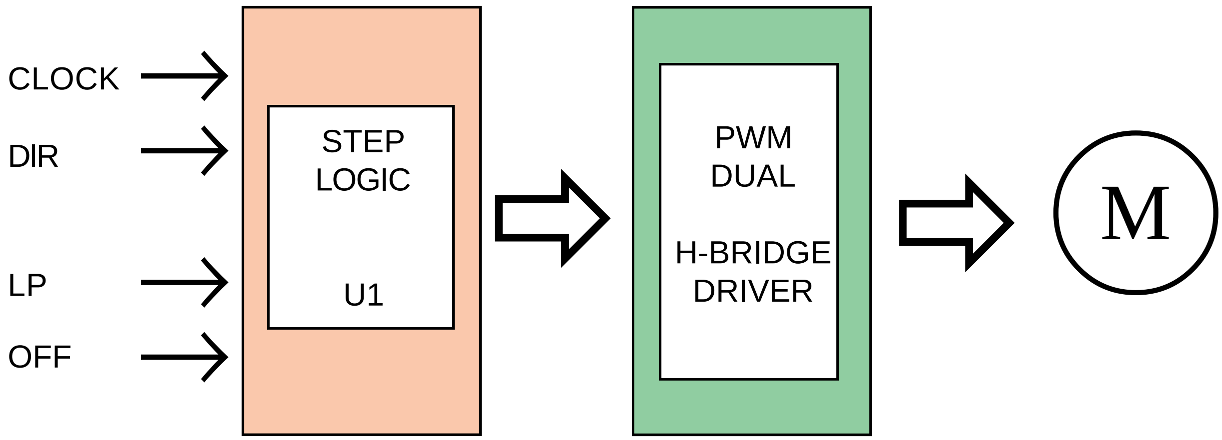


Figure 2. Simplified block diagram of the Universal PWM Stepping Motor Driver

The Step Logic IC converts the logic signal coming from an external controller into a sequence of steps that can be understood by the PWM driver IC. The PWM Driver IC, on the other hand, translate this logic steps into a well defined sequence of constant current flow reversals into the motor to make it run to intended speed and angular displacement.

Four control signals are available for external control:

Clock Input is the main driving signal of the stepping motor system. Each pulse input rotates the motor by one full step. For example, 10 clock input will cause a 1.8 degree/step motor to rotate by 10 x 1.8, or 18 degrees. The clock input rate, on the other hand, sets the rotational speed rpm of the motor. Faster clock rate (higher frequency) will run the motor faster.

Direction Input tells the driver the direction of rotation. When left open or driven at logic high, the motor is rotated in clockwise direction (see note below). When shorted to logic ground or driven low, the motor rotates in the opposite counterclockwise direction.

Note: Actual direction of rotation depends on how the motor is connected with the driver.

Low Power (**LP**) Input reduces the current flowing through the motor to 1/3 of its set value when driven low or connected to line ground. This feature is generally used when the motor is (frequently) stopped but need to maintain a holding torque while at rest. This will keep the motor temperature down. When holding torque during stop is not needed, use the Off input as described next.

Off Input, when driven low or connected to ground, will turn off the output driver circuit and remove altogether power to the motor.

The full schematic diagram is shown in Figure 3. All inputs, if unconnected, defaults to logic high through the action of pull up resistors R13 to R16. R9 and R18 configures the clock input of U1 to behave as Schmitt trigger input – this will help make the circuit work even with clock pulse input having very slow transition. All logic inputs are resistor protected; the circuit will not sustain damage even if fed with voltage as high as 24V AC or DC. Of course, this does not apply to the +5V supply input. The +5V input must stay within +/-10% of its nominal value, or else circuit damage may occur.

The outputs of the PWM Driver IC U2 are protected from currents that may go the wrong way by schottkey diode D2 to D5. The PWM current output is set through R7.

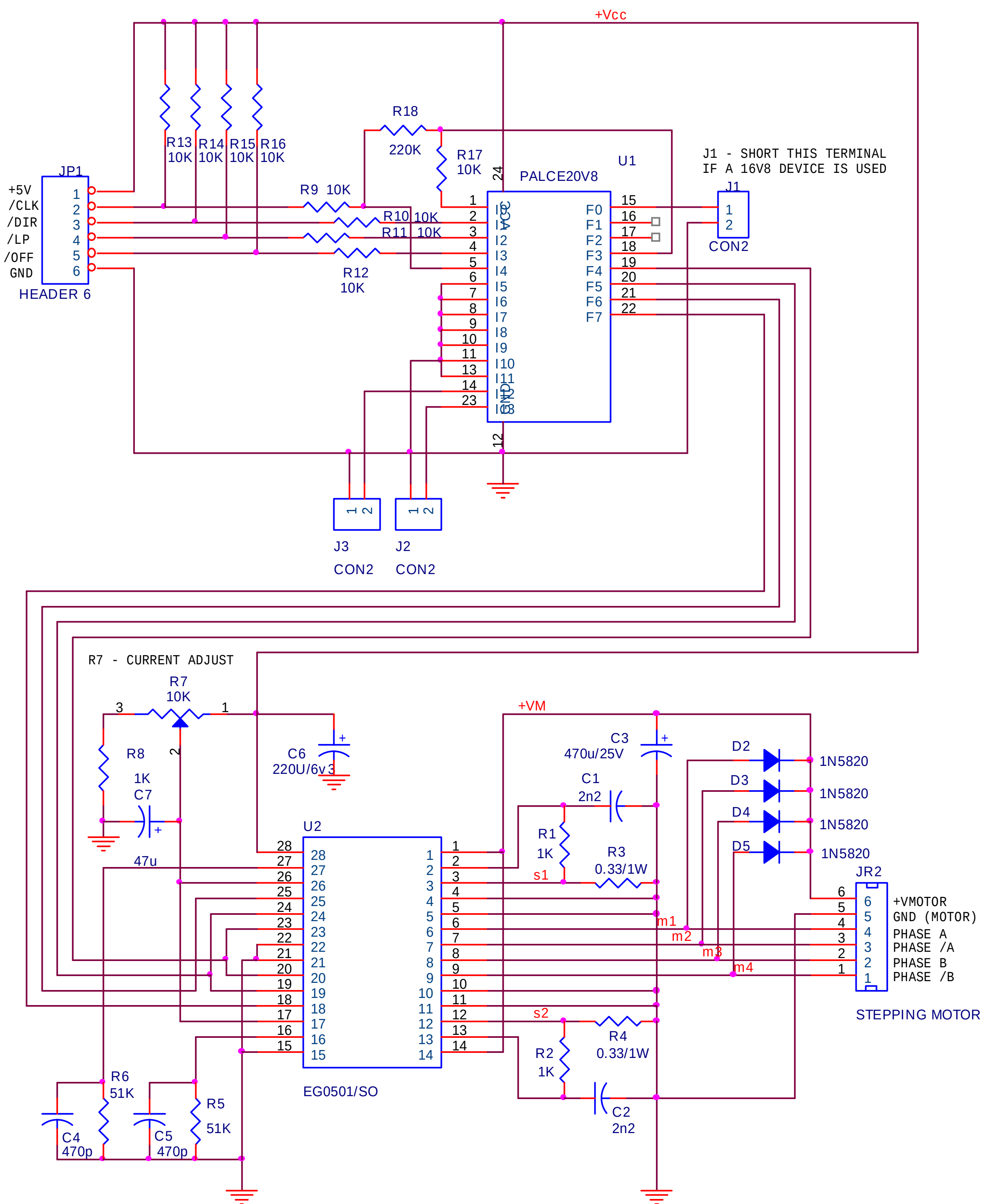


Figure 3. Complete schematic diagram of the Universal PWM Stepping motor driver.

Construction Hints

The project must be constructed diligently. The step logic IC U1 is a CMOS device, and must be handled with extra caution. Follow the recommended construction steps as discussed in the PCB Assembly General Procedure. In addition, you should observe the following:

1. Solder U2 only after the heat sink is mounted! PWM IC U2 must be inserted fully leaving no noticeable gap in between its lower body and the PCB surface. Watch the IC polarity. Ample heat sink is required for operation. Apply a thin layer of thermal compound over the IC. Then securely fasten the heat sink clamping U2 in between with the PCB. PCB fastening holes passing through the IC are provided for this purpose.

Figure 4. Apply a thin layer of heat sink (thermal) compound on top of U2 (right) before you mount the heat sink.

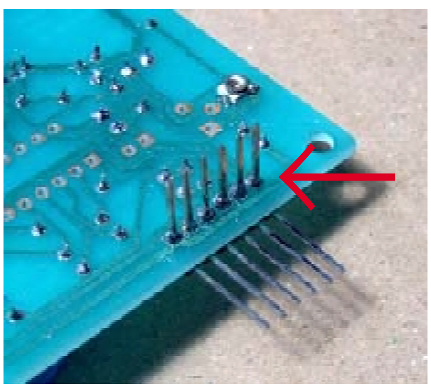


Figure 5. Angled header connector with long terminals allows you to connect the board two ways.

2. The driver PCB can accept two types of PLD step logic devices, a 20 pin and a 16 pin device. If you use a 16-pin device, you must solder a jumper wire across J1 as shown in Figure 6.

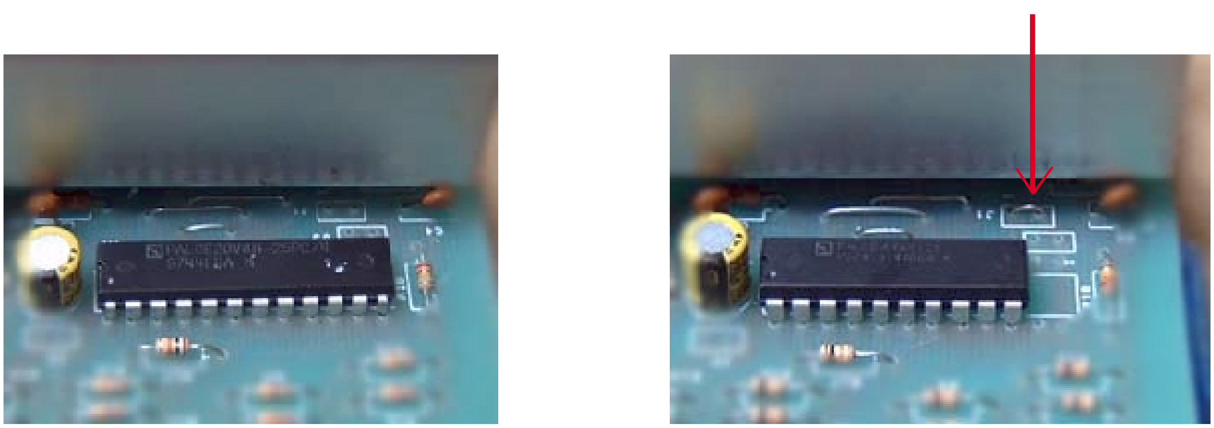
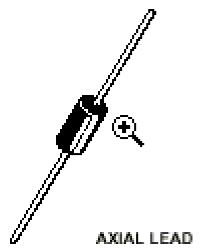
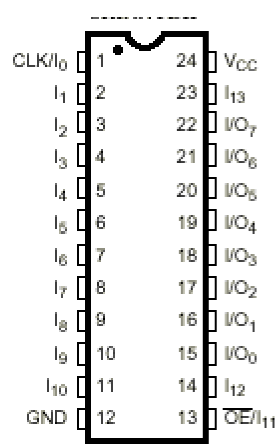
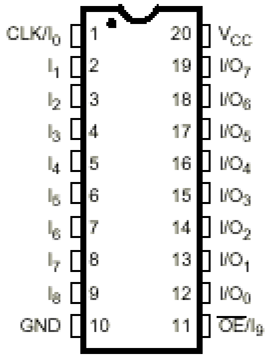
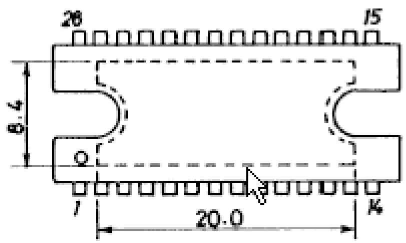


Figure 6. You can use a 20V8 or 16V8 PLD device for U1. Make sure you put a jumper wire to short J1 holes if a 16V8 is used.

Bill Of Materials

Item	Quantity	Reference	Part
1	2	C1,C2	2n2 50V ceramic capacitor
2	1	C3	470u/25V electrolytic capacitor
3	2	C5,C4	470p ceramic capacitor
4	1	C6	220u/6v3 electrolytic capacitor
5	1	C7	47u electrolytic capacitor
6	4	D2,D3,D4,D5 	1N5820 3A schottky diode
7	1	JP1	6 pin angled HEADER
8	2	JR2	3 way Block Connector
9			
10	3	R1,R2,R8	1K 1/4W carbon film
11	2	R3,R4	0.5/1W
12	2	R5,R6	51K 1/4W carbon film
13	10	R7,R9,R10,R11,R12,R13, R14,R15,R16,R17	10K 1/4W carbon film
14	1	R18	220K 1/4W carbon film
15	1	U1  PALCE20V8H	PALCE20V8 or PALCE16V8 PLD IC (Note: Preprogrammed for this

		 PALCE16V8H	
16	1		EG0501 PWM Driver IC
17	2		d3mm x 12mm bolt and nut
18	1		Aluminum Heatsink
19			Heatsink Compound

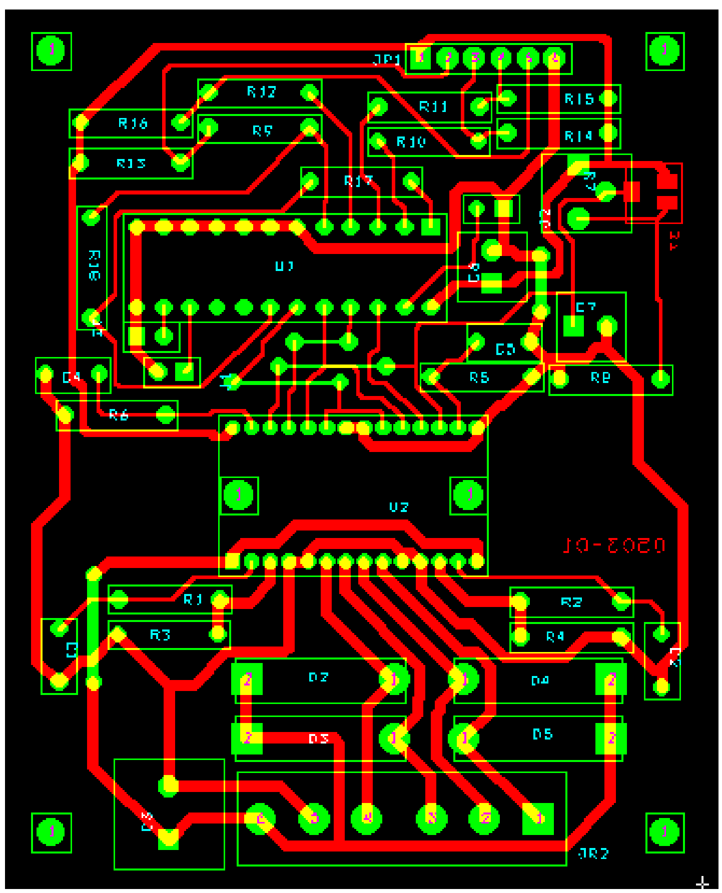


Figure 7. A screen capture of the PCB Layout shows how the components are connected together. Camera ready artwork for PCB fabrication is shown in page 13.

Features and specifications

Motor Power DC Input:	10 to 42VDC
Output Current:	1.5A continuous, 1.75A Peak PWM Current Control
Logic Supply Voltage:	5V +/- 10%
Thermal Shutdown Protection.	

Preparation

This driver can run both the 4-wire bipolar and 6-wire unipolar stepping motors. Before using the driver, you have to adjust the drive current to match the motor. Following is the recommended adjustment procedure.

Equipment needed:

- DMM or VOM
- 5V and 24V 3A DC Power Supply
- Small Screwdriver

1. Note the ampere specification of your stepping motor and connect it to the Universal driver output terminals (see Figure 9). The driver can supply up to 1.5A of drive current. You can use a motor with current requirement slightly exceeding that of 1.5A, but you should be aware that the motor will be under utilized.

2. With power still OFF, connect the 5V and 24V DC power source to the logic and motor supply terminals respectively. The complete setup is shown in Figure 8.

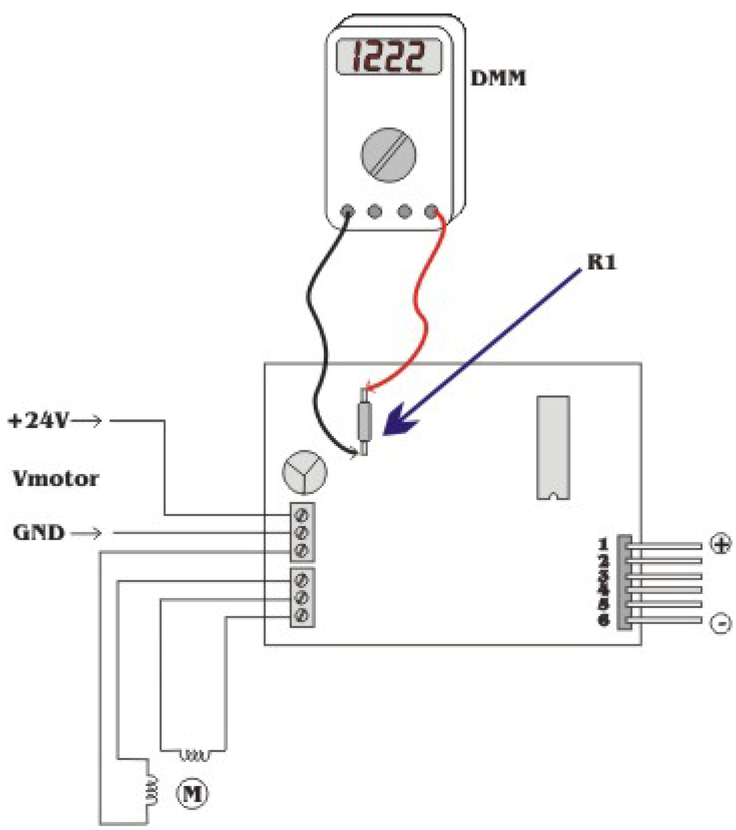


Figure 8. Connection setup for the initial drive current adjustment.

3. Connect the DMM/VOM probe across R3 (or R4). Set the DMM/VOM range to 2V or 3V DC. Switch ON Power to the circuit.

4. The current sourced by the driver is approximately the voltage measured on step3 divided by 3.3 Ampere (VR4/3.3) . Slowly adjust R7 until the desired motor current is obtained. If the motor requires more than 1.5A, simply adjust R7 for the maximum current.

5. Turn OFF the supply source. Your driver is now ready to use.

Application Notes and Examples

The Universal PWM Stepping Motor Driver will work with motor input supply voltage as low as 10VDC to as high as 42VDC. As a rule, use power supply with a current rating that is at least twice that of driver setting.

The motor voltage source choice depends on several factors, with motor inductance, impedance and maximum working speed putting the most weight. Too much voltage is wasteful and generates lots of heat. Too little voltage, on the other hand, will result to insufficient drive and falling torque at high speed. Most stepping motor with winding voltage of 8V or less generally work well with motor supply voltage of 24VDC. Increase the supply voltage as may be necessary (note: 42VDC maximum) if there is a noticeable loss of running torque when running at high speed, especially when using motor with higher voltage rating.

Finally, know the resonant frequency of your stepping motor assembly. Using an adjustable frequency pulse generator, you sweep the clock input with increasing frequencies and observe what happens to your stepping motor assembly. You know you are at resonance when the whole thing vibrates like crazy. You don't want to operate your system at this frequency because, asides from the annoying noises it creates, you will get plenty of miss steps and a dive in output power. In some instances, the motor will even rotate in the wrong direction! Test your system for resonance, and avoid the input frequencies where resonance occurs!

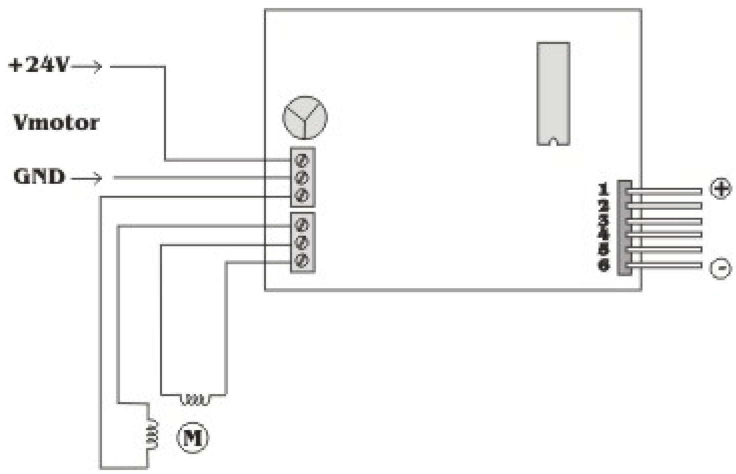
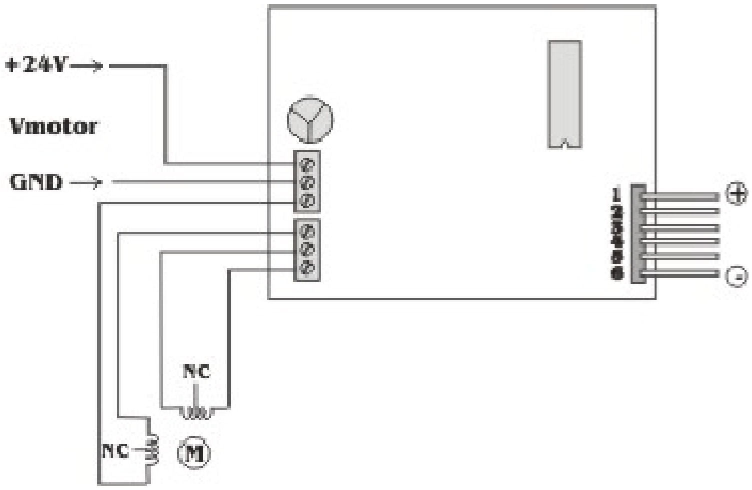


Figure 9a. 4-wire Bipolar Connection Example



1 Vlogic - +5V supply
2 /Clock - Pulse Input
3 /DIR - Direction Input
4 /LP - Low Power Input
5 OFF - Motor Off Input
6 GND

Figure 9b. 6-wire Unipolar Connection Example

Figure 10 illustrate a way to connect the Universal PWM Driver to a microcontroller device. In the example circuit, P00 feeds the clock input of the driver. P01 sets the direction. P02 puts the driver in Low Power mode. All other components not relevant to our discussion are omitted for clarity. Although a z86 device is used in the example, you can use your own choice of microcontroller or microprocessor.

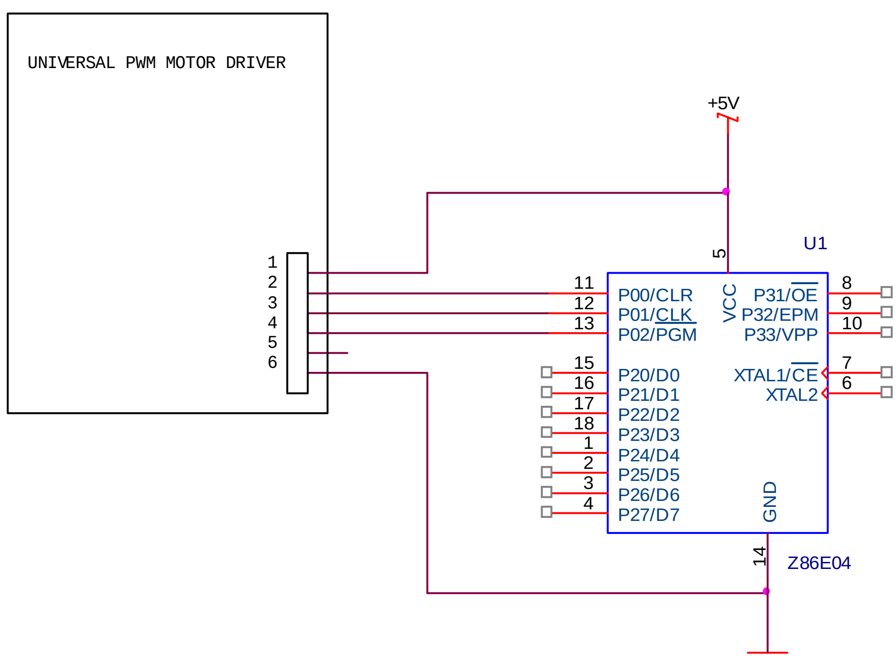


Figure 10. Connecting the driver to a microcontroller.

Figure 11 shows how to connect the Universal Driver to a PC printer port. Program your PC so that D2 (pin 4) supplies the clock, D1 (pin3) sets the direction, and D0 (pin 2) put the driver in Low Power mode. Note that a +5V source is required. Pin 18 to 21 are all logic ground connections.

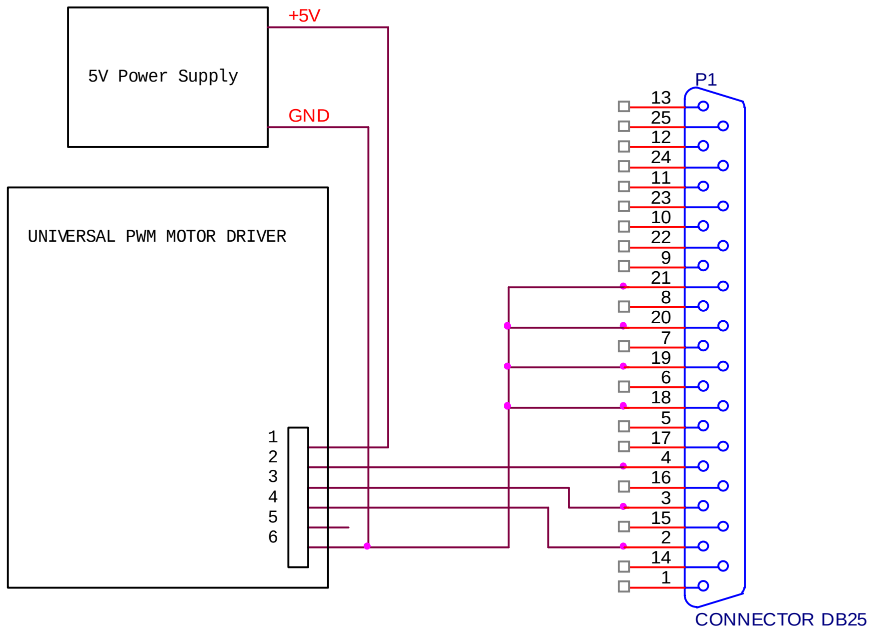


Figure 11. Interfacing to a PC parallel (printer) port.

PCB ARTWORKS

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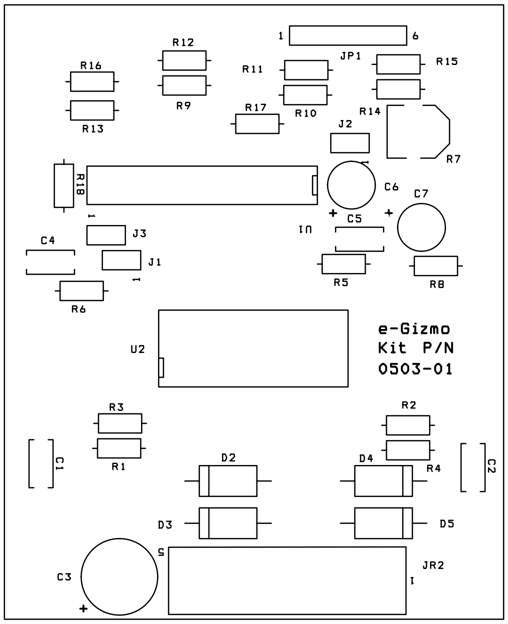
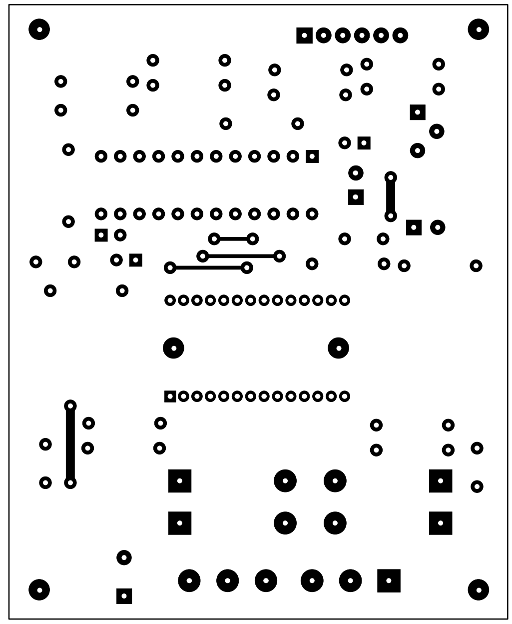
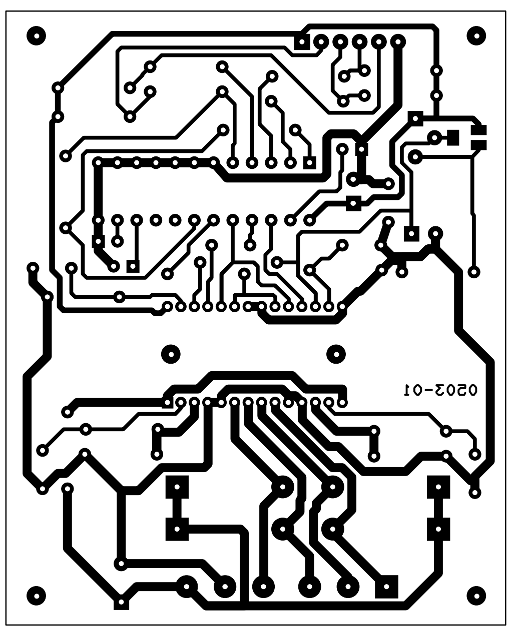


Component Layout



Component side Jumper



Copper pattern (shown on component side)