A Parker Hannifin Whitepaper

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Methods for Pump Speed Control on Parker Hannifin Miniature Diaphragm Pumps

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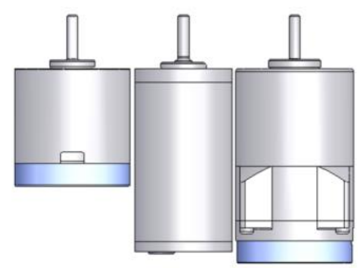
Contents

Introduction

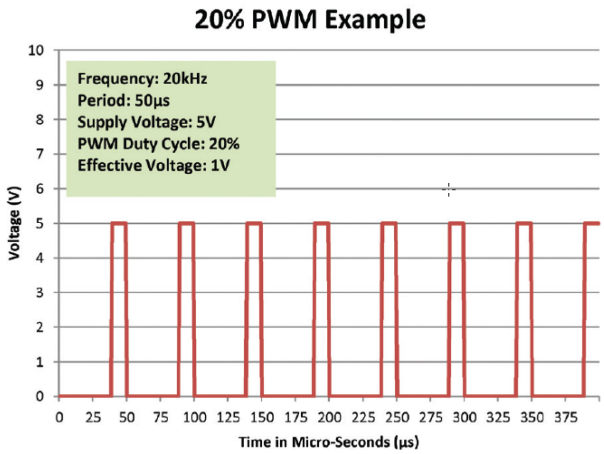
Flexibility in performance is one of the key advantages to diaphragm pump technologies. Parker Precision Fluidics Division (PPF) specializes in customizing diaphragm pumps by configuring hundreds of component options to meet a device designer's requirements as closely as possible. It is often the case that a system will need multiple performance levels using only one pump in the device. When this is a requirement, the designer will typically benefit from having the option to adjust the pump speed to change the flow rate produced by the pump.

Speed control is commonly used for all of the available Parker Precision Fluidics motor types, Iron Core Permanent Magnet Direct Current (PMDC) motor (often called "brush motor", Coreless DC brush motor, and Brushless Direct Current (BLDC) motors.



Example of some BTC Pump Series Brushless DC (BLDC) Motor Options

PMDC brush motors have two methods for changing speed: Pulse Width Modulation (PWM) or directly adjusting the input voltage to the motor. Due to the cost and complexity of variable power supplies, direct adjustment of the motor voltage is not common; it is more typical for designers to use PWM to change the effective voltage to the motor.



Example of a 20% Duty Cycle PWM Signal

Like brush motors, BLDC motors can be controlled with direct input voltage adjustment or PWM of the input voltage but because BLDC motors use an electronic controller to operate (built-in on most Parker Precision Fluidics pumps), these motors have more options for controlling the speed. Many of Parker Precision Fluidics' BLDC motors can also be controlled separate of the input voltage using a low current PWM signal, or a low current 0-5Vdc analog speed control.

The four most common methods for controlling the motor/pump speed:

1. **Input Voltage (brush or BLDC):** adjusting the voltage changes the speed of a motor proportionally. For example, a 12Vdc pump can have the flow rate reduced by operating the pump slowly at 6Vdc (depending on the application).

2. **Input Voltage PWM (brush or BLDC):** similar to adjusting the voltage, the speed of the motor is reduced with a lower effective voltage. A lower voltage is simulated by turning off the fixed input voltage at a fast rate, often 20kHz. The ratio of on-time to off-time (duty cycle) defines the effective voltage applied to the motor.

3. **External PWM (BLDC only):** the input voltage on the first two wires of the motor is fixed and does not change; the speed is adjusted by applying a PWM signal to a 3rd wire. A low current signal is externally switched to ground at a high frequency (by the system controller). The internal BLDC motor controller responds to this signal to reduce the speed proportionally to the signal duty cycle.

4. **0-5Vdc analog Speed Input (BLDC only):** the input voltage on the first two wires of the motor is fixed and does not change; the speed is adjusted using an externally supplied DC voltage applied to the 3rd wire. The internal BLDC motor controller responds to this signal to reduce the speed linearly with the input voltage. For example, 5Vdc could be 100% speed, 2.5Vdc 50%, and at 0Vdc the motor would be off.

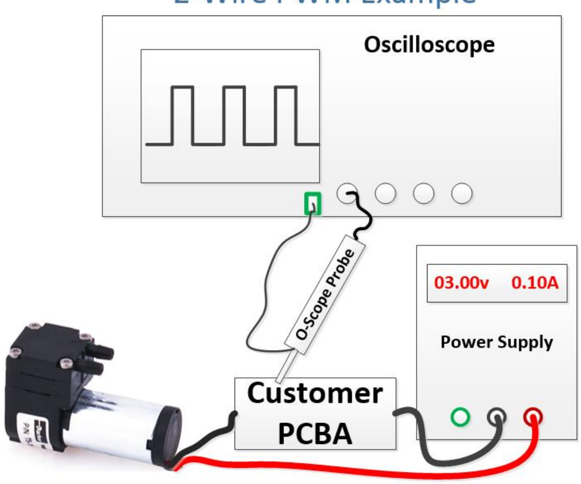
Implementation

Although external PWM control is what PPF recommends when speed control is required, customers must decide the best control style for their application. The following detailed descriptions will assist with properly integrating the motor speed control with whichever option chosen.

2-Wire Input Voltage PWM

Often referred to as “2-wire” PWM, it is one of the simplest methods for controlling pump speed in a device. The basic requirement from the customer device is a PWM signal, often generated from a microcontroller and a power transistor. The input voltage to the motor is turned on and off at a high frequency so that the average power to the motor is reduced. The image below shows an example of a “low side” PWM driver where the ground to the motor being switched by the “customer PCBA” to reduce the speed.

2-Wire PWM Example

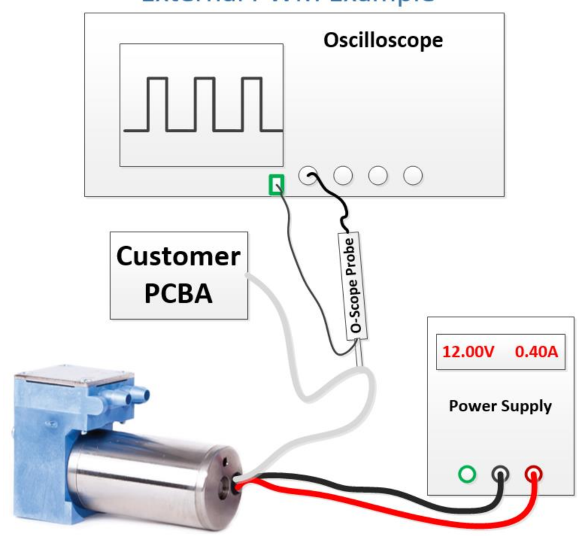


For brush motors, it is the most common method for control, and very effective. Likewise with BLDC motors, it is effective; however, it does present some limitations. Precision Fluidics BLDC motors have an internal controller that must maintain a minimum voltage to operate properly. When applying a PWM cycle to the input voltage it is also reducing the effective voltage to the controller electronics; this limits the available speed control range. Using an external PWM control can provide more range in this situation.

BLDC External PWM

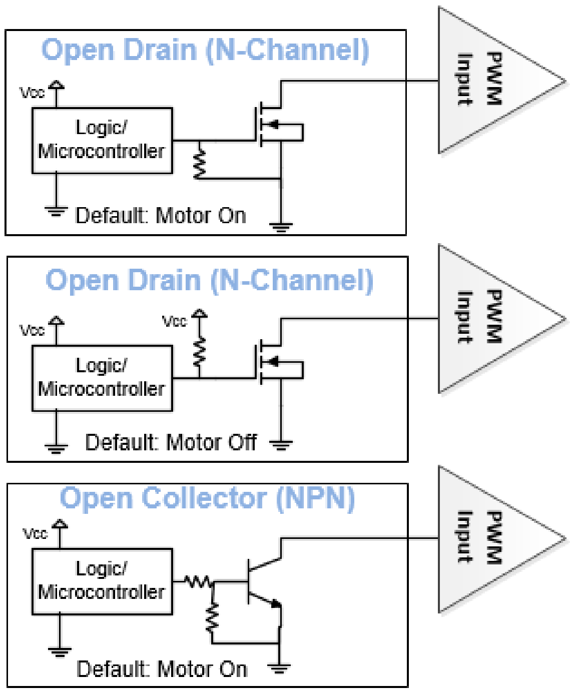
This is the recommended method for controlling the speed of a Precision Fluidics BLDC diaphragm pump when possible. This method provides the most dynamic control of a pump, and also can simplify the customer’s electrical circuit in some cases because only a low current transistor is required for the switching signal.

External PWM Example



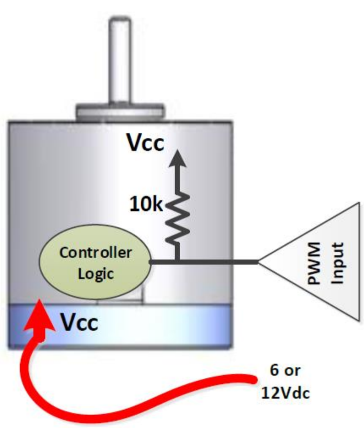
Most of Precision Fluidics diaphragm pumps with external PWM require an “open-drain” or “open-collector” circuit on the customer device PCBA to provide the PWM signal. The BLDC motors have an internal pull-up resistor so the open-drain or open-collector circuits will actively bring this voltage to ground for the low part of the PWM signal. The illustrations below show the generic recommended circuits.

The pull-up resistor network and pull-up voltage varies depending on the motor, this is also described in the illustrations below.

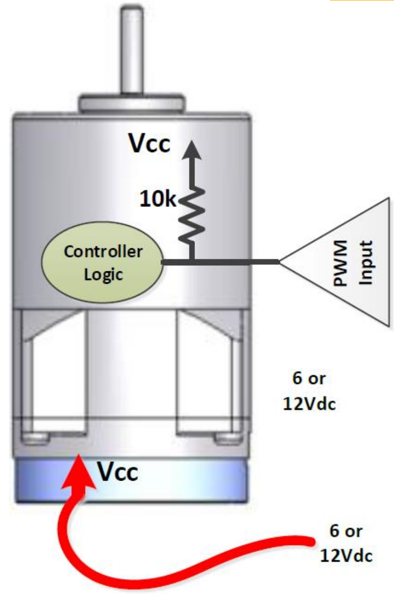


Open-Drain/Open-Collector Circuit Examples

The standard BLDC motor and high-torque BLDC motor share the same controller designs. For the 6 and 12 Vdc versions of the pump there is an internal 10k Ohm pull-up resistor to Vcc. The Vcc voltage is approximately equal to the input voltage, so if 12Vdc is provided to the motor (red wire) then the PWM signal wire (white wire) will have an approximate voltage of 12Vdc. This is shown in the illustrations below.

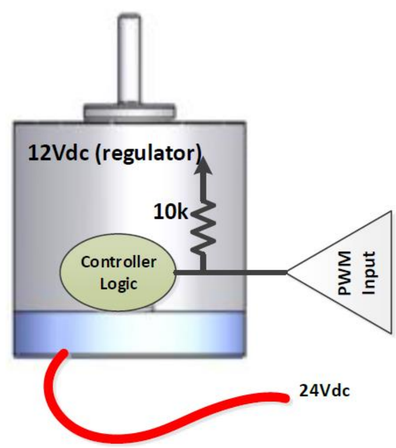


6 or 12 Vdc Standard BLDC Internal Circuit

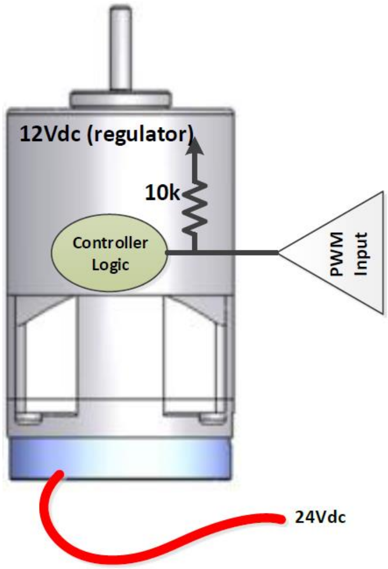


6 or 12 Vdc High-Torque BLDC Internal Circuit

The 24Vdc standard and high-torque BLDC motors with external PWM have a 10k pull-up to 12vdc that is maintained by a regulator. If the input voltage to the motor is 24 Vdc, the PWM signal wire (white wire) will remain at 12Vdc high.

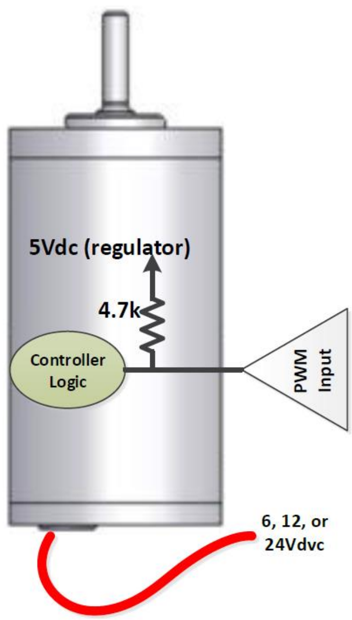


24 Vdc Standard BLDC Internal Circuit



24 Vdc High-Torque BLDC Internal Circuit

The premium BLDC motor only has one configuration regardless of the voltage. The 6, 12, and 24Vdc motors all have a 4.7k Ohm pull-up resistor to 5Vdc that is maintained by a regulator.

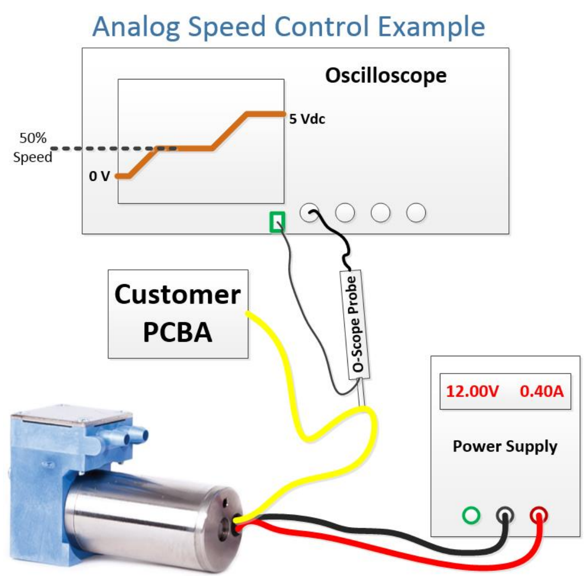


6,12, or 24 Vdc Premium BLDC Internal Circuit

Analog External Speed Control

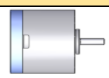
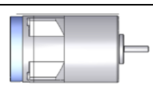
In some applications a PWM signal is not feasible, or is not preferred by the system designer. Many of Parker Precision Fluidics BLDC motors offer an external analog DC signal input. In this case the motor is provided a direct voltage to operate the motor, but a separate low current 0 to 5Vdc input (yellow wire) controls the speed of the pump.

The actual control voltage range may vary depending on the motor; however, the concept is the same: a 0 Vdc signal will disable the motor, 5 Vdc would represent full speed, and the range between 0 and 5Vdc will adjust the speed of the pump.



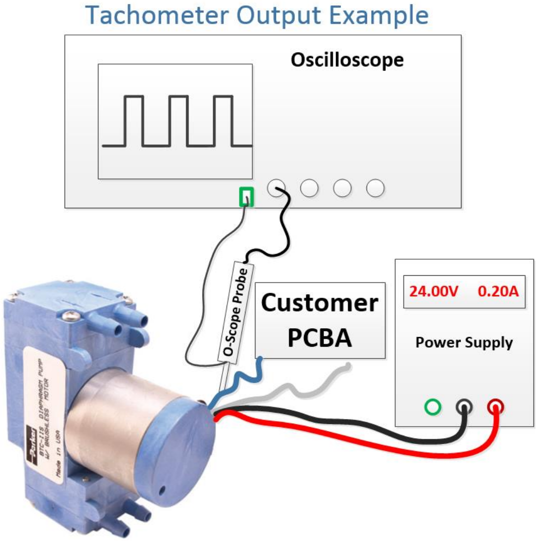
Speed Monitoring - Tachometer

Many of Precision Fluidics Division's BLDC motors also have the ability to output a tachometer signal so the customer's device can monitor the actual pump speed. The signal is a digital pulse that can be used to determine the speed of the pump. This pulse rate can vary depending on the motor type.

	Pulse per Rotation	Voltage of Pulse
 Standard BLDC "Short Stack"	4	5Vdc
 High Torque BLDC "Long Stack"	4	5Vdc
 Premium BLDC "28mm Slotless"	1	5Vdc

This is very useful in applications where the pump will need to operate very slowly; with this information the device controller could increase the speed if the pump begins to stall (pump speed approaches zero). It is also an additional safety and/or diagnostics feedback for confirming proper system function.

Tachometer Output Example



Example of Tachometer Output Signal

Design Challenges

Control input vs. Speed

The speed control offered by Parker Precision Fluidics BLDC motors do not maintain a fixed speed, all methods change the effective voltage supplied to the motor stator coil. For example, at a fixed 50% PWM signal, the speed of the pump will be reduced, but not by exactly 50%. Also, as the load on the pump changes, the speed of the pump will also change, even while the PWM signal is fixed.

The maximum motor speed can be reduced by the pump configuration or the pressure/vacuum load on the pump in the application. Torque and speed have a linear relationship, when more torque is required to turn the pump, the motor will slow down.

Motor Stall

Many of Parker Precision Fluidics motors may be damaged if the pump stalls and no longer is rotating. When the motor's rotor is locked in this position and power is being supplied to the motor, heat will increase and can damage the internal controller.

The 20mm BLDC motor offered on the CTS Series of pumps has a stall protection feature so if the rotor is locked on this motor, the power will be disabled internally.

It is recommended that system designers implement a safety current limit or fuse to power the pump. This can help prevent damage to the pump motor and system if a stall event occurs, *Restart with Reduced Speed*

Using any speed control method reduces the effective power to the motor stator. If the speed is reduced during restart the starting torque will be reduced. Designers must ensure that the pump is capable of restarting under all conditions (such as pressure load and environmental temperature) when the speed is reduced.

Recommended Frequency

When using a PWM speed control method, the recommended frequency is 20 kHz. Frequencies less than 20 kHz may create an audible buzzing sound as the audible frequency range for humans is 20 Hz to 20 kHz. Using higher frequencies can limit the control range because of transistor rise and fall time; it is possible to switch so quickly that a low or high duty cycle signal appears as 0% or 100% because the transistor cannot switch fast enough. Also, with some motors and control circuits, PWM frequencies greater than 20kHz can reduce efficiency.

Summary

Parker Precision Fluidics understands the needs of pneumatic system design engineers, and offers a broad range of motor options to meet their requirements. The applications engineering team at PPF is always available to provide recommendations and even make customizations when required, so if there any questions not answered by this paper, please contact Parker for superior customer service!

For more information please email ppfinfo@parker.com , call 1-800-525-2857, *or find product details on the web*: http://www.parker.com/precisionfluidics/

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