USER'S MANUAL

MODEL 400 / 400A
PULSE WIDTH MODULATION DRIVER / CONTROLLER

DOCUMENT NO. 00202-09

Applied Processor and Measurement, Inc.

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Again, thank you for purchasing and using our product.

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REVISION HISTORY

Rev	Date	Pages	Description
-	5/31/17	All	Initial Release

SAFETY SUMMARY

THE FOLLOWING GENERAL SAFETY PRECAUTIONS MUST BE OBSERVED DURING OPERATION AND INSTALLATION OF THIS PRODUCT. FAILURE TO COMPLY WITH THESE PRECAUTIONS AND WARNINGS HERE, AND ELSEWHERE IN THIS MANUAL VIOLATES THE SAFETY STANDARDS OF DESIGN, MANUFACTURE, AND INTENDED USE OF THIS PRODUCT. APPLIED PROCESSOR AND MEASUREMENT, INC. ASSUMES NO LIABILITY FOR THE FAILURE TO COMPLY WITH THE SAFETY RECOMMENDATIONS PROVIDED IN THIS MANUAL.

INTENDED USE

The Model 400 / 400A Pulse Width Modulation Driver / Controller is intended to be used in a laboratory / industrial / automotive (passenger compartment) environment. It is not intended for use in, or in conjunction with, any medical or life support appliances, devices, or systems. Other than automotive (passenger compartment) applications, the device is not designed for outdoor use. Applied Processor and Measurement, Inc. assumes no liability from the use of this design in this context.

Applied Processor and Measurement, Inc. does not assume any liability for the malfunction of electronic components contained in any of its products nor any damage incurred from the improper use of the product to the user, product, or any connecting equipment.

GROUND THE SYSTEM

Even though the Pulse Width Modulation Driver / Controller requires an external DC source, care should be taken that the total system is properly grounded. Use only power supplies that have three conductor AC power cable with the grounding wire properly connected to an electrical (safety) ground. This will minimize shock hazards.

DC POWER ONLY

The Pulse Width Modulation Driver / Controller requires an external DC source of 9V DC to 24V DC. Do not connect the Pulse Width Modulation Driver / Controller directly to 120 or 240 V AC.

USB POWER

The Pulse Width Modulation Driver / Controller may be USB powered for configuration, a connection to the PWR +/- input pins are not required in this case. When power is applied to the Model 400 on the PWR +/- connections, USB 5V is not used to power the unit. The PWM output is intended for high power (up to 4A) applications and therefore can **NOT** powered from the USB interface.

DO NOT SERVICE THE UNIT

Do not attempt to service the unit. NEVER open the unit while it is operating. Do not attempt to substitute parts or modify the system internally.

1.0 Introduction

This manual describes the features, installation, and operating procedures for the Model 400 / 400A Pulse Width Modulation Driver / Controller (referred to in this manual as: Model 400, PWM Driver, PWM Controller, PWMC-400, or PWMC).

The Model 400 Pulse Width Modulation Driver / Controller generates a variable pulse width modulated electrical switching signal. The product is used in many industrial situations where valves, solenoids, actuators, or other magnetic / mechanical elements are applied and / or tested.

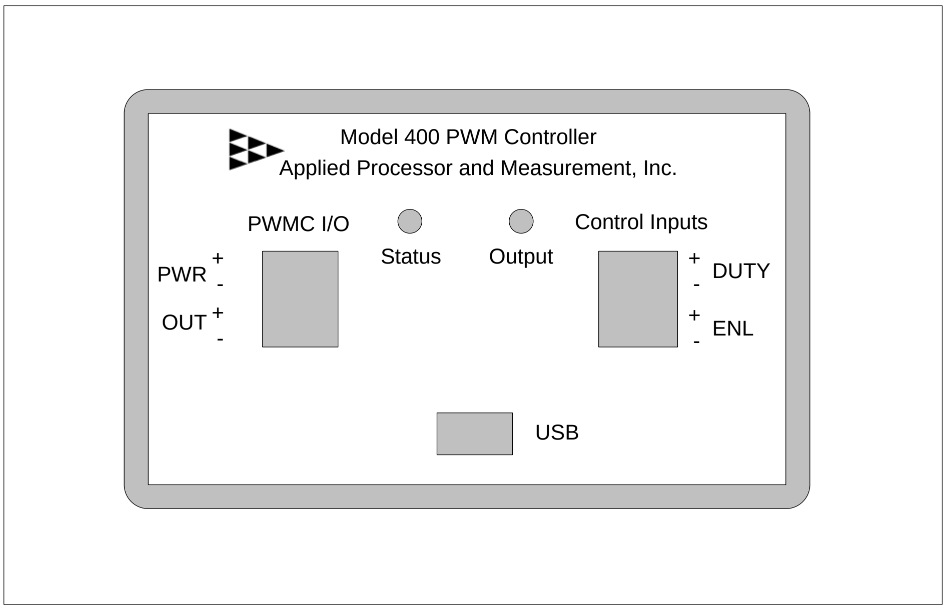

Figure 1.0-1 Model 400 PWM Controller.

The PWM Controller contains microcomputer based circuitry which allows for precision generation of the output frequency and duty cycle. The Model 400 PWMC functions as a signal conditioning module, translating an analog signal to a proportional duty cycle. The PWMC analog input allows the user to control the output duty cycle with an analog control signal, such as 0 to 5V, or, 0 to 20 mA across a 250 ohm load. An external control system (for example: a PC with data acquisition cards, or a PLC) could provide an analog output to the PWM Controller in order to control a PWM device. In this manner, the PWM Controller is the signal conditioning element for the host computer and/or control system which is unable to produce a PWM signal or unable to drive the PWM load directly. The PWMC 400A provides a second analog control input in lieu of the external enable control. The additional analog control translates an analog signal to a proportional frequency.

The PWM Controller may also be controlled via a USB port. This capability allows the PWM Controller to be controlled by a host computer USB port (e.g. PC compatible) under program or manual control.

The PWM Controller output is an open drain power MOSFET output. This provides low side control of the load to be pulse width modulated. An external power source must be provided, which may be used to power both the load and the PWMC. This provides maximum flexibility since the load voltage can be set by the user using any variable bench-top power supply or it can derive power directly from the system under control (provided the controller is operated within the rated specifications). Note that a USB only powered Model 400 will NOT drive the PWM output.

The operation of the PWM Controller is highly configurable. User programmable configuration options are available to set the power-up state of the PWM Controller and it’s operational state with respect to analog input operation, the output frequency and the enabling and disabling of features.

1.1 Features

The following is a summary of the feature set of the Applied Processor and Measurement, Inc. Model 400 / 400A PWM Driver / Controller.

• user / computer adjustable pulse width modulated output switching signal 0 to 100 % duty cycle

• PWM frequency of 0.08 Hz to 5,000 Hz

• duty cycle adjustable in 1%, 0.5%, or 0.2% steps

• PWM output provides low side load control

• Power MOSFET output - PWM output sinks up to 4 amps at 12 volts

• internally fused output

• controller operates from same power source that powers the load - an external power source, 9V to 24V DC must be supplied, also supports a dual supply configuration allowing load voltages up to 50V

• input power reversal protection, PWMC circuitry protected by resettable polyfuse

• differential analog input, over +/- 100V common mode rejection – PWM output ground does not need to be referenced to analog input ground

• analog input, 0 to 5V, controls output duty cycle proportionally

• analog input to duty cycle output, configurable for normal or reverse acting
  normal acting: 0 to 5V input proportional to 0 to 100% output
  reverse acting: 0 to 5V input proportional to 100% to 0% output

• optically isolated external enable input signal, enable PWM output from a 5V to 24V digital signal (Model 400), OR, 2nd analog input (Model 400A), 0 to 5V, controls output frequency proportionally

• inherent PWM monitoring
  monitors for open load
  monitors for open output fuse

• status LED and output LED

• remote operation via USB interface
  control PWM output frequency and duty cycle
  configure power-on settings

• configurable
  output duty cycle resolution (1%, 0.5%, 0.2%)
  PWM output frequency
  analog input control or USB control
  normal or reverse acting analog input operation
  enable or disable external enable feature

• all settings are digitally controlled, NO potentiometers, no drift, high noise rejection

• industrial temperature range: -40 to 80 Deg C operation

• high reliability, single multi-layer circuit board construction, using surface mount technology

1.2 Applications

The Model 400 PWM Controller was specifically designed for product development activities, and, durability and validation testing of electromechanical devices requiring a PWM control signal. The PWM Controller may be used as a signal conditioner to provide a PWM signal in a PLC based or computer based control system for life testing of solenoid valves, actuators, or relays. The Model 400 may also be used in PWM signal generation applications for control of fan, heater, motor and blower modules and lighting controls / dimming applications.

Due to its small form factor, industrial temperature rating and low cost, the Model 400 PWM Controller may also be used in OEM/production control applications. Contact Applied Processor and Measurement, Inc. for applications assistance and regarding variations or customizations of the Model 400 and volume pricing.

2.0 Specifications

Parameter	Description	Rating
Output Power	Open Drain Power MOSFET	Pd $_{max}$ = 50 watts at 25˚C
Output Current	Example Output Current, 100% duty cycle Power must not exceed maximum Pd	4A at 12V maximum
Output Voltage	Must use dual power supply configuration for voltages not within PWM Controller Input range	5V minimum 50V maximum
Frequency	1 Hz to 5,000 Hz, adjustment resolution of 1Hz 0.08 Hz to 1.0 Hz, adjustment resolution of 1mHz	max error < 0.2 % of setting
Duty Cycle Analog Control	0 to 100 %, adjustable in 1, 0.5, or 0.2 % steps, minimum and maximum duty cycle based on frequency 0% to minimum → output duty cycle is forced to 0% maximum to 100% → output duty cycle is forced to 100% approximate limits as below: 0.08 to 1000 Hz, minimum 0.5%, maximum to 99.5% 1000 to 5000 Hz, minimum 1.5%, maximum 98.5%	typical error < 0.1 %
Frequency Source	Internal Oscillator	24.000 MHz, +/- 0.5%
Input Power	9V to 24V DC, regulated or un-regulated external source. Dual supply required for operating loads outside this range.	35 mA (typical)
Operating Temp.		-40 °C to 80 °C
Analog Control Duty cycle Frequency Model 400A only	PWM Parameter Control Input Resolution Duty Cycle 50mV / 1% Duty Cycle 25 mV / 0.5% Duty Cycle 10 mV / 0.2% Frequency, 100 Hz range, 50mV / 1Hz Frequency, 500 Hz range, 50mV / 5Hz Frequency, 1000 Hz range, 50mV / 10Hz Frequency, 5000 Hz range, 50mV / 50Hz	+/- 5 mV
Analog Inputs	Absolute Maximum Input Voltage	5.25 V
External Enable Input Model 400 only	Internal series resistance (3kΩ) allows for direct connect to voltage source, enabled when voltage is applied	0 V (disabled) 5 V to 24 V (enabled) V $_{max}$ = 28V at 25˚C
USB	mini-B connector, standard pinout	
Dimensions		3.625 in. x 2.25 in. x 1.0 in. height (1.25 in. height by connectors)

2.1 Model 400 Pinout

Pin Name	Description / Function
PWMC I/O	
PWR +	PWM Controller power input
PWR -	PWM Controller reference input, power supply or system ground (see note 1)
OUT +	PWM Controller output positive connection (see note 2)
OUT -	PWM Controller switching output, open drain power MOSFET, switches load from open to IN - (power supply or system ground), see figure 4.1-1
Control Inputs	
DUTY +	Duty Cycle control analog voltage, 0 to 5V, positive differential input
DUTY -	Duty Cycle control analog voltage, negative differential input (see note 1)
ENL +	External Enable control, positive input, digital signal, 0V (PWM disable), 5 to 24V (PWM enable)
ENL -	External Enable control, negative input (see note 1)

Notes:

(1) PWR-, DUTY-, and ENL- are electrically isolated (not internally connected). The PWMC-400 may be connected in a common ground configuration, however, the application must connect these pins together to utilize the same reference (ground). See figure 3.1-2 for a typical installation, see figure 3.2-4 for an example of an installation using a common ground.

(2) The positive input is internally connected to a protective diode (see figure 4-1). If operating in a dual supply load and the diode is not needed, then the positive connection to OUT+ is not required (see figure 3.2-2). The positive side of the load may be directly connected to the power source.

2.2 Model 400A Pinout

Pin Name	Description / Function
PWMC I/O	
PWR +	PWM Controller power input
PWR -	PWM Controller reference input, power supply or system ground (see note 1)
OUT +	PWM Controller output positive connection (see note 2)
OUT -	PWM Controller switching output, open drain power MOSFET, switches load from open to IN - (power supply or system ground), see figure 4.1-1
Control Inputs	
IN1 +	Duty Cycle control analog voltage, 0 to 5V, positive differential input
IN1 -	Duty Cycle control analog voltage, negative differential input (see note 1)
IN2 +	Frequency control analog voltage, 0 to 5V, positive differential input
IN2 -	Frequency control analog voltage, negative differential input (see note 1)

Notes:

(1) PWR-, IN1-, and IN2- are electrically isolated (not internally connected). The PWMC-400A may be connected in a common ground configuration, however, the application must connect these pins together to utilize the same reference (ground). See figure 3.1-3 for a typical installation.

(2) The positive input is internally connected to a protective diode (see figure 4-1). If operating in a dual supply load and the diode is not needed, then the positive connection to OUT+ is not required (see figure 3.2-2). The positive side of the load may be directly connected to the power source.

3.0 Installation and Start-up

This section provides information on how to connect the PWM Controller for operation and provides the start-up instructions for configuration of the unit. Section 3.1 provides a Quick Start Installation intended to provide an easy step-by-step procedure to configure, connect and start using the Model 400 PWM Controller (PWMC-400).

3.1 PWMC-400 Quick Start Instructions

The Model 400 PWM Controller/ Model 400A PWM Controller will begin operation in the analog to PWM duty cycle signal conditioning mode upon power-on of the unit. Prior to connecting to your PWM device, the Model 400 must be configured for operation. Note these steps pertain to the Model 400A as well unless otherwise indicated. Configuration involves setting the following parameters:

- frequency of operation
- mode of operation: analog to PWM duty cycle or USB control of duty cycle
- output PWM duty cycle resolution: 1.0%, 0.5%, 0.2%
- analog control output action: normal or reverse acting
- enabling or disabling the external enable control input (Model 400 only)
- enabling or disabling analog control of the PWM frequency, and setting the analog input range (Model 400A only)

The Model 400 is configured using a PC USB port. For configuration, the Model 400 may be USB powered. All that is needed is the Model 400 unit and a USB cable.

1. Connect the Model 400 to your PC as shown in the figure below. Note that no other connections to the Model 400 are required. The PWM-400 status LED will flash orange briefly, then turn to flashing green (about once per sec.).

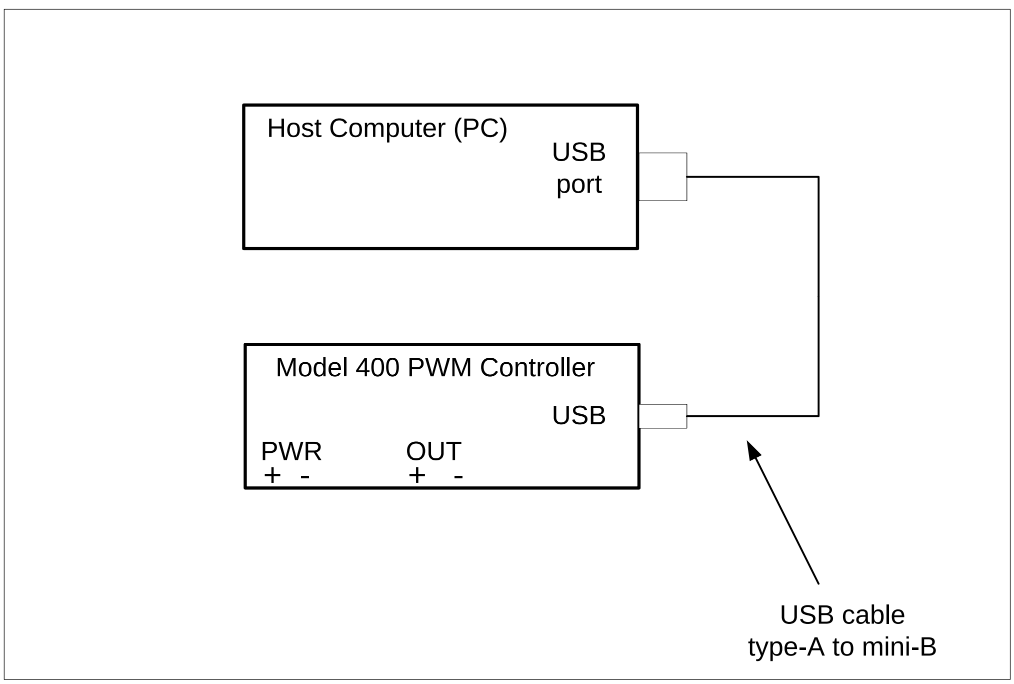

Figure 3.1-1 Model 400 PWM Controller – set-up for configuration.

2. Start the PWMC-400 Configuration Program (graphical user interface – GUI) on the PC.

3. From the Program Menu, select Connect. The PC finds the PWMC400, reads the current settings and populates the fields on the GUI.

4. Set the following parameters on the GUI screen:

   a. Frequency Controls – enter the desired operating PWM frequency for the unit. On the Model 400 unit, this control is fixed to be under USB control. The Model 400A allows the control to be under USB or Analog Input control. When set to analog control, the 0 to 5V conversion range may also be configured:
      a. 100 Hz range, 1Hz resolution
      b. 500 Hz range, 5 Hz resolution
      c. 1000 Hz range, 10 Hz resolution
      d. 5000 Hz range, 50 Hz resolution

   b. Duty Controls – enter the desired values
      - Duty Cycle
      - Duty Cycle resolution
         a. selecting 1.0% sets 50mV per 1.0% step
         b. selecting 0.5% sets 25mV per 0.5% step
         c. selecting 0.2% sets 10mV per 0.2% step
      - Output Action - set normal for 0 to 5V analog control of the duty cycle from 0 to 100%. Reverse Acting is set for 0 to 5V analog control of the duty cycle from 100 to 0%.
      - Command Source – sets the control mode: Analog Input or USB

   c. External Enable Input (ENL/IN2 setting) – set the External Enable Input Control on the PWMC-400 to be active or inactive. If the control is active, then a 5V to 24V input must be present on the External Enable Input for the PWMC-400 to provide a PWM output. If the control is inactive then the feature is disabled, the PWMC-400 will output a PWM signal at all times ignoring the External Enable Input state. On the Model 400A, the setting allows for the IN2 input (frequency control) to be enabled or disabled.

5. Confirm the settings. To save the PWMC-400 configuration to non-volatile memory, press the 'Save Configuration' button. A message will be displayed in the text box indicating the status of the operation. When complete, disconnect the PWMC-400 from the USB cable. It is configured and now ready to be installed / used in your application.

6. Check that the internal fuse rating is suitable for your application. The factory installed fuse in the PWMC-400 is rated at 4 Amps. This is sufficient to protect the PWMC-400 output stage in most 12V solenoid / load applications. If you need to protect your load, or your application is not 12V, a proper fuse should be installed. Consult the section on Fusing in this manual (section 3.3). This paragraph contains information on selecting the fuse, accessing and replacing the fuse, and the fuse part numbers used in the PWMC-400 product. A standard in-line wired fuse and glass type fuse may be used on the output if the PWMC-400 parts are not readily available.

7. Determine whether to have the output diode installed. The PWMC-400 contains an internal 1N4004-like diode on the Out + connection to suppress inductive kickback pulses. If your application already has a diode in the solenoid, or in any external circuits, you may disconnect the internal PWMC-400 diode. See section 3.4 on information on disconnecting the diode. The diode may be disconnected by removing a jumper internal to the PWMC-400 unit. The factory default position for the diode / jumper is: installed.

8. Connect the PWM Controller to your target system. Use one of the figures and the descriptions as shown below for assistance as necessary.

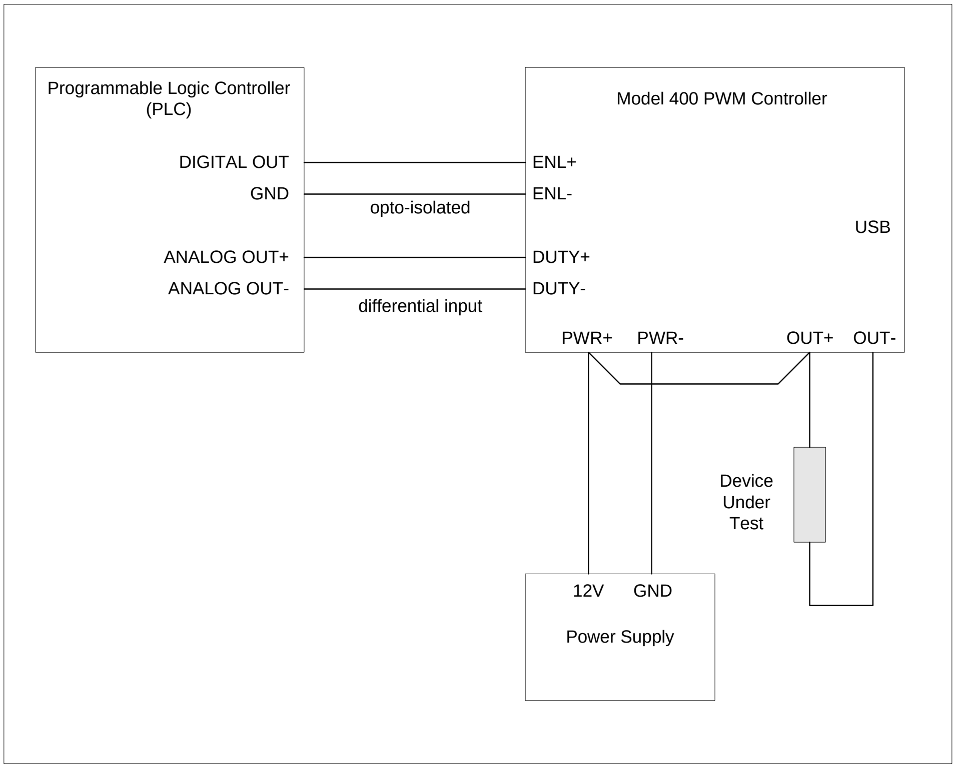

Figure 3.1-2 Model 400 PWM Controller – typical installation.

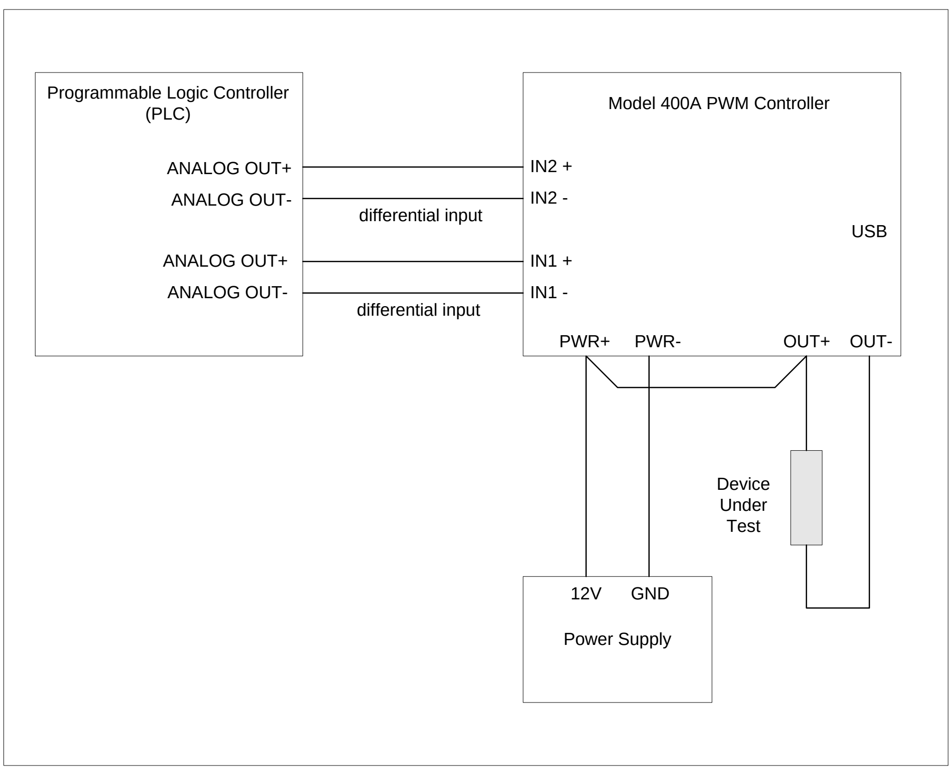

Figure 3.1-3 Model 400A PWM Controller – typical installation.

Note that in the above figures the PWMC-400 / PWMC-400A is powered from the same power supply as the load (Device Under Test). The PWMC-400 / PWMC-400A must be powered by 9 to 24 V DC, therefore, if the load must be run at higher than 24 V DC, a dual supply configuration must be used. Various configurations (including a dual supply configuration) are illustrated in section 3.2. Also, note that there is no common ground connection required between the analog control input and the power supply. The PWMC-400 / PWMC-400A analog input is fully differential and is designed to reject common mode voltages. Finally, note that, on the PWMC-400, the opto-isolated digital control input is only required if the External Enable Control feature configured to be active. This input is useful in controlling the PWM output from another source in your application (for example, a system E-Stop).

9. When the power supply is powered on, the PWMC-400 / PWMC-400A will flash orange on the status LED then turn solid green, and immediately begin operating as configured. If in analog to PWM mode, the analog input will be measured and a proportional duty cycle will be output at the frequency that has been configured. The Model 400A will convert analog to frequency as well, if configured.

The above paragraphs describes a typical procedure to set-up the PWMC-400 / PWMC-400A unit. Consult the applicable sections in this User's Manual for further information as necessary. For applications assistance, use the customer support forms on our website at www.appliedprocessor.com.

3.2 PWM Controller Installation

WARNING

FOLLOW THE INSTALLATION INSTRUCTIONS CAREFULLY TO AVOID POSSIBLE DAMAGE TO THE PWM CONTROLLER, TO YOUR LOAD DEVICE OR SYSTEM UNDER CONTROL. REMEMBER TO PROPERLY SELECT ALL WIRE SIZES FROM THE POWER SOURCE TO THE PWM CONTROLLER OUTPUT AND TO THE DEVICE UNDER CONTROL IN ORDER TO MINIMIZE HAZARDS AND TO PROVIDE A SUITABLE RETURN PATH FOR INDUCTIVE LOADS.

This section provides installation instructions and figures which illustrate typical connections for the PWM Controller and the device to be controlled.

Figure 3.2-1 shows connection of the PWM Controller to a single device using a single power supply in the analog to PWM signal conditioning mode of operation. The power supply sources current for both the PWM Controller and the device under control.

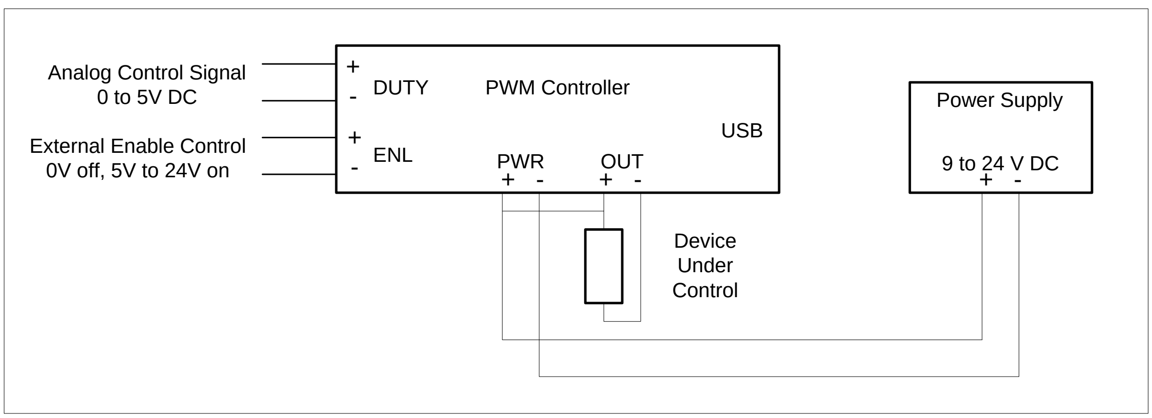

Figure 3.2-1 PWM Controller - Single Supply Connection.

This figure illustrates the low side drive connection of the PWM Controller. Also note that because of the open drain output, an external connection <u>must</u> be added between the positive terminal (+) for the power input, and the positive terminal on the output of PWM Controller.

The analog control input on the PWM Controller is a differential input, therefore, there is no ground connection required between the power supply negative terminal and the control system sourcing the analog control signal. The External Enable Control Input on the PWM Controller is driven by a digital 5 to 24V DC amplitude input. This input will enable the PWM Controller PWM output signal when on and disable the PWM Controller PWM output when off (0V). This feature may be configured inactive if it is not to be used in your application. Note that for the PWMC-400A, there are two analog inputs and no external enable input. The IN2 frequency control input may also be configured off (fixed frequency in configuration).

Figure 3.2-2 illustrates the recommended connection for a dual power supply connection (analog and external enable control inputs not shown for clarity). This configuration would be used for a load that is under test whose operational voltage is not in the PWM Controller operating range of 9V to 24V DC. The PWM Controller must be supplied 9V to 24V DC for its operating power. The output of the unit may operate at any voltage from 5V to 50V (within the recommended power specifications – see Section 2). In this case, 42V DC is required for the device under control (load).

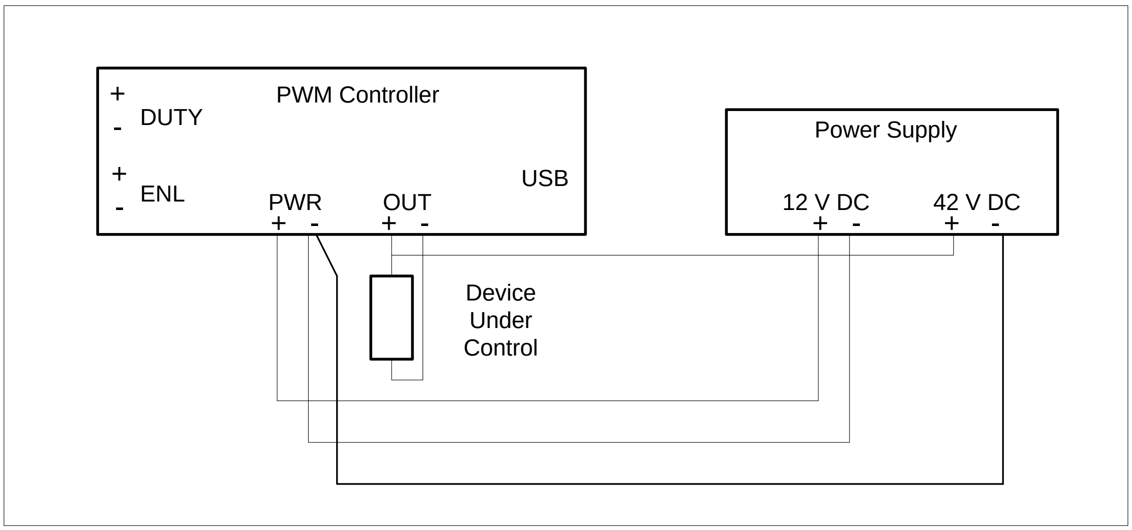

Figure 3.2-2 PWM Controller - Dual Supply Connection.

In the dual supply configuration example above, the power supply has a +12 V and a +42 V output. Only 35 mA of 12V is required to supply the PWM Controller whereas the +42V supply must be rated to accept the load under control. Note that the power supply negative output (- terminal) is commoned at the PWM Controller. This connection must be made if the power supply outputs are isolated. Some laboratory power supplies have one common ground for +12V, -12V, and +V variable outputs that are produced from the same supply, then, this connection may not be required. Consult the manual from the power supply that you are using in this application to check if it is required to common the negative terminals externally. Additionally, applying the common connection at the PWM controller will assist in providing a return path for the power being “dumped” by the load when switching. This will help keep the power for the PWM Controller cleaner especially when the power supply is a greater distance from the load and the PWM controller.

Since the Model 400 requires a small amount of power to operate, a small AC/DC adapter may be used for the controller power and an external source used for the drive power. An example power connection using the external AC/DC unregulated power adapter is illustrated in Figure 3.2.3.

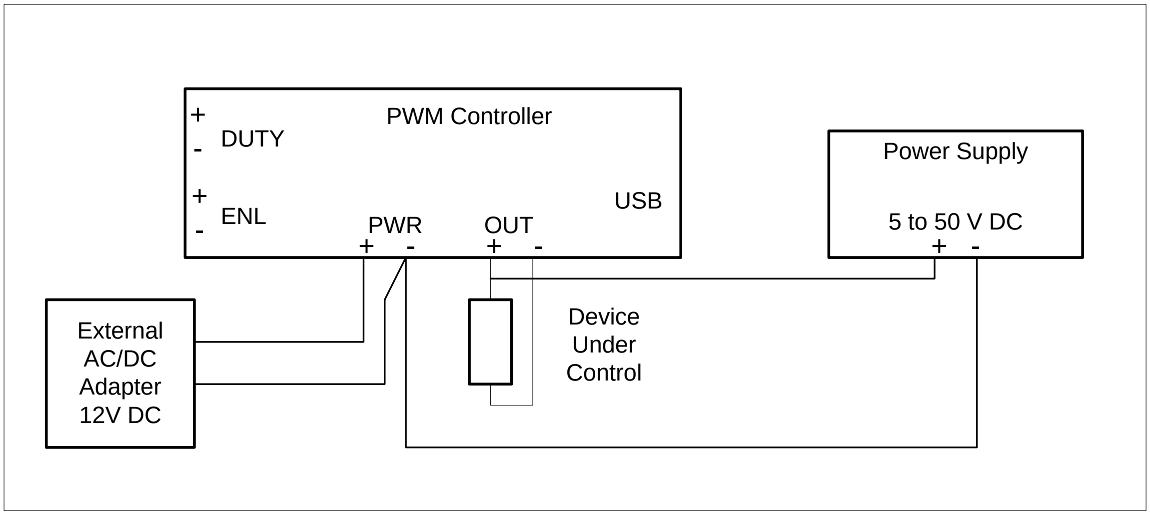

Figure 3.2-3 PWM Controller - Dual Supply Connection, using an AC/DC adapter for PWMC power.

Finally, note that the PWM Controller analog input, the external enable input, and the power input are electrically isolated. That is, on the PWMC-400 (and PWMC-400A), the DUTY- (IN2-), ENL- (IN1-) and PWR- pins on the PWM Controller are not electrically connected. This allows the PWM Controller, and the device under control, to be electrically isolated from the supervisory control system analog and digital outputs. This configuration eliminates ground loops prevalent in industrial control systems and laboratory test cells. If ground loops are not an issue, as in a simple bench test set-up where all controls are operated from a single reference, the PWM Controller may also be connected and operated in common ground configuration. A sample common ground configuration is illustrated below.

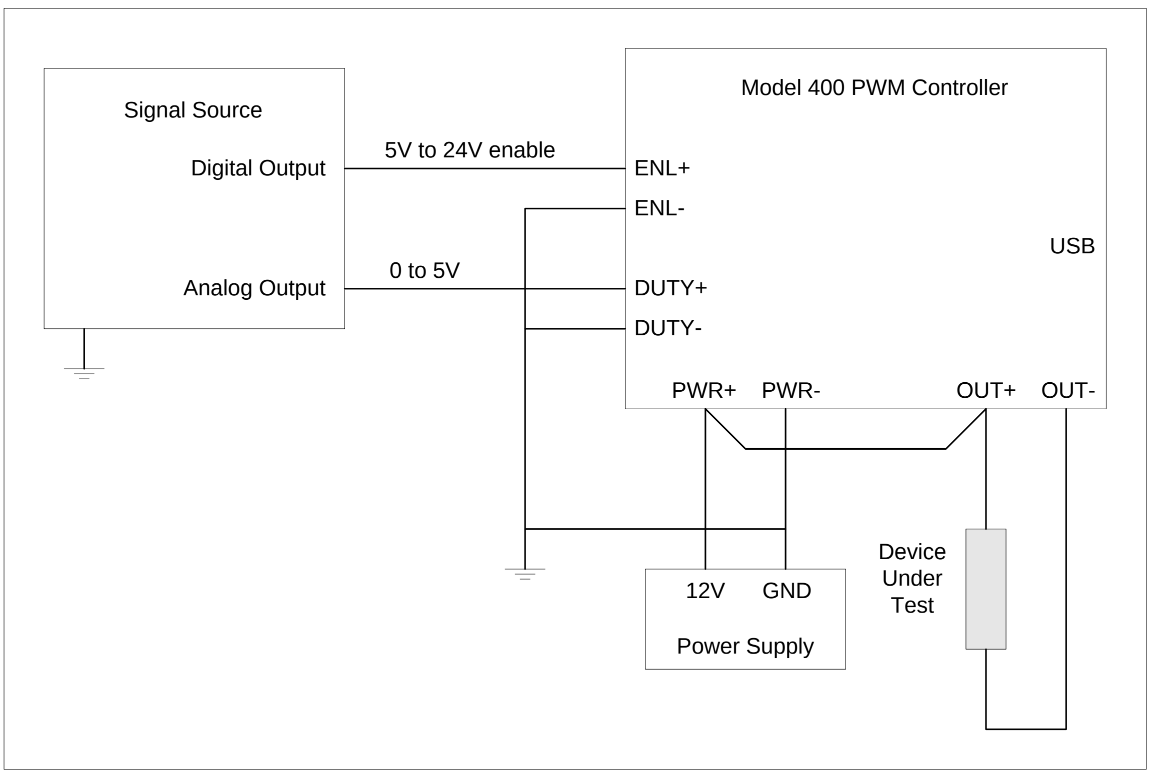

Figure 3.2-4 PWM Controller - Common Ground Connection.

In the common ground configuration of figure 3.2-4, connections to the DUTY- (IN2-), ENL- (IN1-) and PWR- pins on the PWM Controller must be physically made to the same reference ground in the application for proper operation. The control system / signal source must also be referenced to the same ground / reference point.

3.2.1 Using the PWM Controller as a Signal Generator

The PWM Controller may also be used to simply supply a variable duty cycle PWM square wave signal at a fixed frequency for a supervisory data acquisition and / or control system. One example of this would be to connect the low level (low current) PWM output to a device that is controlled by duty cycle. Additionally, this configuration may be used to drive a higher current capable device such as a high current solid state 'brick' style relay.

To use the PWM Controller as a signal generator, connect the unit as shown in figure 3.2-1 using a resistor as the "Device Under Control". For example, using a 12V power supply, a 1000 Ω, ¼ W resistor could be placed directly across the PWM Output terminals on the controller. Note that the PWM Controller output is an open drain output. Any input with an internal pull-up resistor may be controlled by simply connecting the PWM Controller output directly to the pulled-up input.

Note that this configuration may also be used to supply a signal which drives the gate of a higher power rated (voltage and / or current) MOSFET or a high amperage power module. This configuration allows the current and voltage ratings of the PWM Controller to be extended to any rating based on the external components available. Remember that adding another N-type MOSFET or power module in the circuit adds another level of inversion.

3.3 Fusing

WARNING

BE SURE TO FUSE THE PWM CONTROLLER PROPERLY IN ORDER TO AVOID POSSIBLE DAMAGE TO THE PWM CONTROLLER, TO YOUR LOAD DEVICE OR SYSTEM UNDER CONTROL. WHEN CHANGING THE FUSE, OR REMOVING THE COVER, BE SURE THAT THE PWM CONTROLLER IS NOT CONNECTED TO ANY POWER SOURCE.

The PWM Controller contains an internal fuse for device / load protection and for the PWM Controller output MOSFET electronics itself. The input fuse is connected in series with the load and the output Power MOSFET (see the PWM Controller Block Diagram in figure 4.1-1 for details on the fuse connection) therefore the fuse will protect both the PWM output drive circuitry as well as the device / load under test.

A fuse holder is provided on the back of the PWM controller main circuit board. To replace the fuse in the unit, remove the cover (there are four screws accessible from the rear of the unit). Note that the circuit board need not be removed from the enclosure, the fuse is completely accessible from the top of the unit by simply removing the cover. The PWM Controller contains static sensitive circuitry, be sure to handle the unit so as to avoid touching any other circuitry on the circuit board and pins or connectors on the back of the circuit board. The fuse is a Littelfuse Nano SMF type 451 series fuse. A 4 Amp fuse is installed in the unit from the factory (Littelfuse part number 0451004.MRL). Be sure to fuse the PWM Controller properly based on the current draw of the device / load under test. Refer to table 3.3-1 for maximum recommended fuse ratings for different voltages.

Operating Voltage	Maximum Fuse Recommended	Littelfuse Part Number
5V	4A	0451004.MRL
12V	4A	0451004.MRL
15V	3A	0451003.MRL
24V	2A	0451002.MRL

Table 3.3-1 PWM Controller – Maximum Recommended Output Fuse Ratings.

Littelfuse Nano SMF type 451 fuses are available from electronics component distributors and catalog vendors (such as Digi-Key Corporation, Newark Electronics, and Mouser Electronics). Additional 4A or 2A fuses may also be purchased from APM, Inc. See the website at www.appliedprocessor.com for ordering information on PWM Controller accessories.

3.4 Internal Diode

The PWM Controller possesses an internal S2BA diode across the output terminals to suppress inductive current kick-back from the load under test (see the PWM Controller Block Diagram in figure 4.1-1 for details on the diode connection). The S2BA is a general purpose rectifier / diode and suits most needs when working with inductive loads such as valve solenoids and relays (similar to using a 1N4001). If your application uses another type of diode, the S2BA may be easily removed from the circuit and your diode may be installed on the PWM Controller externally, across the + and - output terminals (attach cathode to +, anode to -). The PWM Controller comes from the factory with the jumper (diode) installed.

To remove the diode from the output circuit, remove the cover (there are four screws accessible from the rear of the unit). A black shorting jumper (JP1) is present on the circuit board near the PWMC I/O connector J1. To remove the S2BA from the output circuit simply remove the jumper. Note that the circuit board need not be removed from the enclosure, the diode jumper is completely accessible from the top of the circuit board by simply removing the cover. The PWM Controller contains static sensitive circuitry, be sure to handle the unit so as to avoid touching any other circuitry on the circuit board and pins or connectors on the back of the circuit board. Store the jumper for later use by placing it on only one of the pins.

3.5 USB Connections to the Model 400

The PWM Controller possesses a standard USB port, with a standard mini-B pinout, for remote operation capability. To connect a host computer, control system or PC to the PWM Controller, use a standard type A to mini-B USB cable.

Note that the USB port contains a ground connection (which is electrically connected to the PWR- pin on the PWM I/O terminal block). The PWM Controller USB port is not electrically isolated. If the PWM Controller is connected to a power supply while connected to a USB port, a ground loop is created with the USB port ground between the external power supply and the PC USB ground which is typically connected to the safety / earth ground. If operated in this configuration, and there is the need to isolate the grounds, an opto-isolated USB converter module must be used. Many vendors offer isolated USB modules at a low cost. For applications assistance from APM, Inc., contact support@appliedprocessor.com.

The Model 400 may also be configured using a USB connection only. In this case, the PC USB power will power the Model 400. If an external power supply is used, the Model 400 senses the external power and uses this supply for its primary power. Note that under no circumstances will a USB powered Model 400 drive the PWM output using 5V USB power. Optional Model 400 / 400A units are available which provide a 5V level signal output on the PWM output. This can be used for low-drive, PWM signal generator applications. Contact APM, Inc. (sales@appliedprocessor.com) for available Model 400 units with a USB only, 5V drive output.

3.6 Notes on the Analog Input Connection

WARNING

CONSULT THE SPECIFICATIONS FOR SIGNAL LIMITS ON THE ANALOG INPUT PORT. ALTHOUGH THE PWM CONTROLLER ANALOG INPUTS ARE PROTECTED, APPLYING VOLTAGES TO THESE INPUTS BEYOND THE RATINGS SPECIFIED MAY DAMAGE THE PWM CONTROLLER.

The primary function of the Model 400 PWM Controller is to operate as an analog to PWM (duty cycle) drive signal conditioner or in the case of the PWMC-400A as an analog to PWM(duty cycle and or frequency) drive signal conditioner. The analog input on the PWM Controller is differential and capable of rejecting common mode voltages of over +/- 100 V DC with respect to the PWM Controller and load power source. This feature prevents ground loops between the PWM Controller and the load power supply, and, the control system sourcing the analog input.

Apply the analog control signal to the input terminals on the PWM Controller labeled +/- DUTY (or +/-IN2 on the PWMC-400A) .

If the negative DUTY input is a common ground with respect to the PWM Controller input power (for example: when using a variable resistor (pot) to control the duty cycle output), the negative terminal may be connected to ground.

In the case of the PWMC-400A, the discussion above also applies to the +/- IN2 input and PWM frequency control.

3.7 External Input Enable Connection (PWMC-400 only)

The External Enable Input on the PWM Controller is intended to enable or disable the PWM output from an additional digital signal source. This allows the user to disable the PWM output without setting the analog output to 0V.

The control signal may be any signal in the range of 0 to 5V DC or 0 to 28V DC. An input of 0V disables PWM output, a high input enables PWM output. The input is optically isolated and has an internal series resistor (3kΩ) such that all that is required is the input voltage level. The digital control signal should be applied to the PWM Controller terminals labeled +/- ENL.

Do not apply a digital 0 to 28V DC level to the IN2 +/- inputs on a Model 400A unit.

4.0 Operation

This section describes operation of the Model 400 PWM Driver / Controller. In addition to describing the theory of operation of the PWM Controller, both operational modes are described: analog input control and USB control. The configuration command interface for the PWM Controller is also described.

4.1 Theory of Operation

All operations of the PWM Controller, including the generation of the pulse width modulated output signal, are controlled by a highly integrated microcomputer circuit. A block diagram of the Model 400 PWM Driver / Controller is shown in figure 4.1-1.

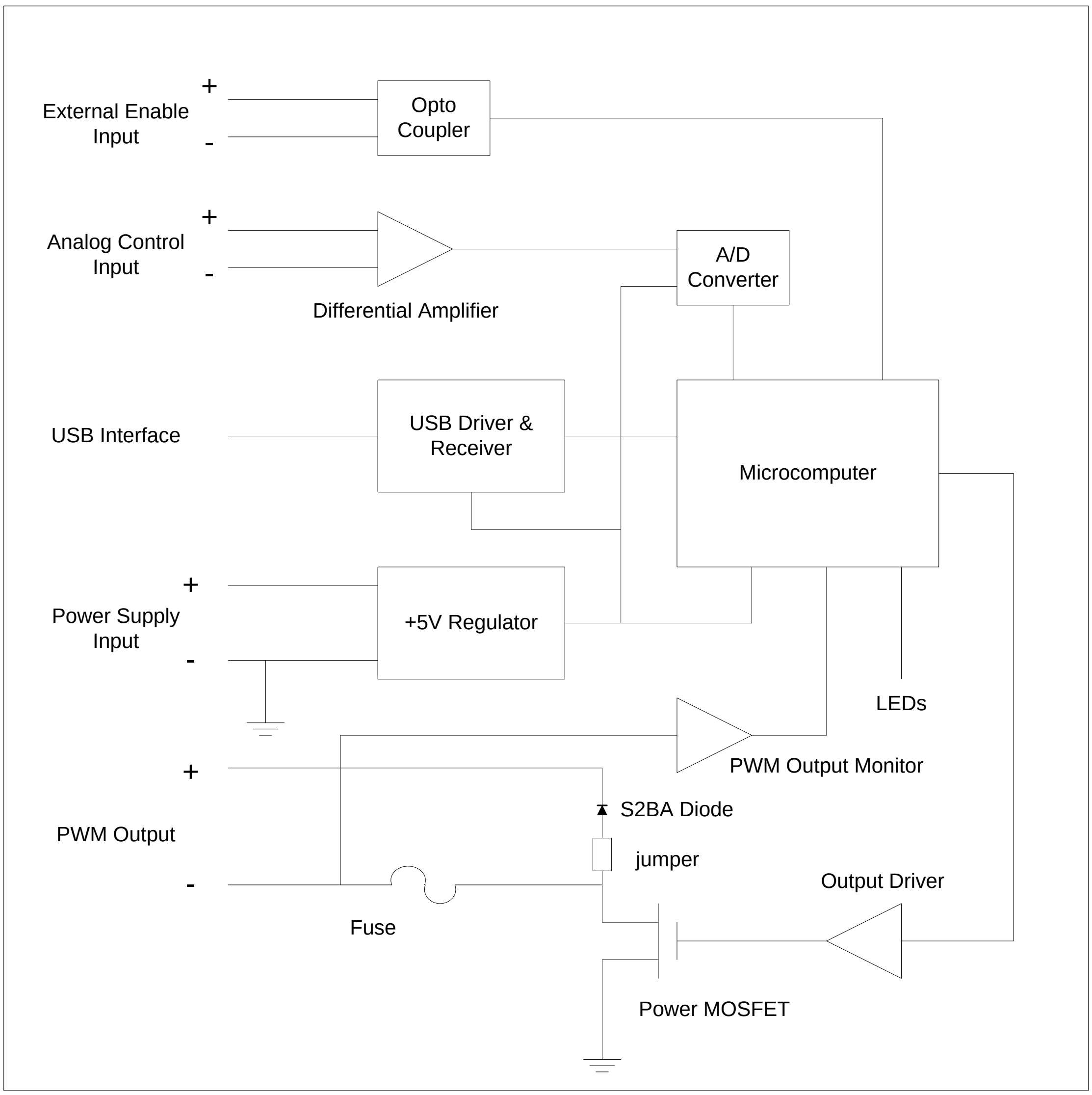

Figure 4.1-1 Model 400 PWM Driver / Controller - Block Diagram.

The PWM Controller output timing is based on timer / counter resources internal to the microcontroller. In the analog to PWM duty cycle signal conditioning mode of operation, the analog input is converted to a proportional duty cycle setting. The microcontroller calculates signal timings based on the configured frequency of operation and the duty cycle setting. The analog to frequency signal conditioning mode of operation works in much the same way with the analog input converted to a proportional frequency setting. The PWM output timing is then driven by the microcomputer. A power MOSFET output transistor provides an open drain current sink for the device under control. This MOSFET output stage is fuse protected to prevent damage to the MOSFET and / or the output load being driven. The PWM Controller includes an internal diode for suppressing back currents from inductive loads. This diode may be removed from the circuit by removing a jumper in order to easily accommodate user diode configurations (other than a S2BA). The microcomputer is also interfaced to a PWM output monitor circuit to verify output switching at the load. Discrepancies are reported via the bi-color status LED. The microcomputer also monitors the external enable input command via an opto-isolated digital input.

In addition to analog to PWM operation, the PWM Controller possesses a USB interface for output control. The Model 400 may be configured to operate in USB to PWM output mode as well. In this mode, the USB interface may be used to issue commands to vary the output PWM duty cycle or frequency. The USB port also facilitates configuration of the unit.

PWM Controller embedded microcomputer software provides the operational functionality of the controller. The controller software and configuration parameters are stored in FLASH memory and EEPROM memory respectively. Configuration parameters may be easily set using the USB interface and the PC User Interface configuration software (APM, Inc. website) or the USB interface command set (section 4.4 below). The embedded software in the FLASH microcomputer memory cannot be re-programmed in the field. However, it is re-programmable, in-system at APM, Inc. for upgrades, customization, or servicing.

4.1.1 PWM Output

Note the open drain output configuration, with respect to the control of the load, shown in the block diagram in figure 4.1-1. When the digital output of the internal microcontroller is logic low, the MOSFET is off and the device / load receives no current. When the microcontroller bit is high, the MOSFET is turned on, allowing current to pass through the load to ground. The PWM Controller actuates the load in this manner using the MOSFET as a low side control element.

Consider the signal shown in figure 4.1.1-1. The figure illustrates a 10 Hz PWM signal as would be seen by attaching a scope between the Output Negative (OUT-) terminal and ground. When the signal is 12V, the load is not engaged and no current is flowing. When the signal is 0V, the MOSFET is on and current is being driven through the load. Based on the above discussion of low side drive, the signal shown represents a 80% duty cycle PWM signal with a 10Hz carrier frequency.

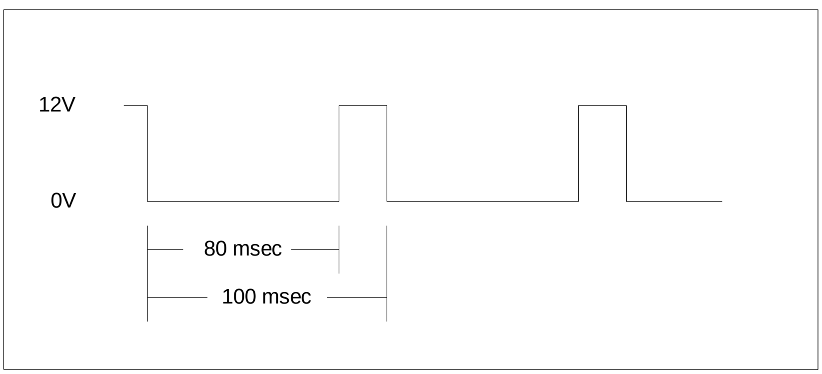

Figure 4.1.1-1 PWM Controller – Low Side Drive Output and Duty Cycle Definition.

When operating in analog to PWM duty cycle mode, for example, operational capabilities within the PWM Controller include the ability to set the analog action as either normal or reverse acting. Setting normal acting will cause the duty cycle to increase from 0% to 100% as the analog input increases from 0V to 5V. For reverse acting, the duty cycle decreases from 100% to 0% as the input voltage increases from 0V to 5V. See section 4.3 for equations relating the analog voltage input to the PWM duty cycle output.

4.1.2 PWM Output – Maximum and Minimum Duty Cycle Limitations

The Model 400 PWM Controller utilizes embedded software algorithms and timer / counter modules within a microcomputer to digitally create the output PWM signal. Due to the oscillator stability and repeatability of the timer / counter design, the frequency and duty cycle values over the operating range of the PWM Controller (0.08 Hz to 5,000 Hz, 1%, 0.5%, and 0.2% duty cycle resolution) are very accurate. However, due to the nature of the processing and requirement to change the duty cycle in real-time, the fixed period of time required to process changes becomes noticeable at higher frequencies of operation. This prohibits the capability of the PWM Controller to output very low or very high duty cycles. In most PWM solenoid control applications this is not an issue since operating at 1% or 99% duty cycle is typically not useful.

Due to the processing time inherent in the PWM Controller timing algorithms, duty cycles out of the range of possible operation are forced to a maximum or minimum duty cycle depending on the value. The minimum and maximum operating duty cycles for various operating frequencies are provided in the specification table in Section 2.0. The limits are specified for the maximum operating resolution of the PWM Controller (0.2%)

For example, if the PWM carrier frequency is 2,000 Hz, the operating duty cycle is limited to approximately 1.5% to 98.5%. When operating at 2,000 Hz, if the command (analog or USB) issued to the PWM Controller results in a duty cycle output request of (for example) 0.8%, the PWM Controller will force the output to 0%. Likewise any command that would request a duty cycle greater than 98.5% would force the output to 100%.

This is a limitation of the Model 400 PWM Controller and the microcomputer timer / counter processing. For applications that require a greater frequency, greater resolution capability, or no minimum / maximum limitation on the operating duty cycle, the Model 205 PWM Controller is recommended.

4.2 PWM Controller Operation - Operational Modes and Features

The PWM Controller output operates in either the Analog Input control mode which allows the analog control of the PWM Duty Cycle and/or Frequency or the USB mode which allows the user to issue commands to control the PWM Duty Cycle and/or Frequency. The mode of operation is configured using USB commands. Configuration settings are saved in non-volatile EEPROM memory. Once the PWM Controller is configured, it will power-on and immediately perform the analog or USB to PWM function.

The PWM output, in either mode, may be engaged / disengaged by using the external input enable digital input (Model 400 only). The external enable input is an opto-isolated digital input. This feature may also be enabled or disabled in PWMC-400 configuration.

4.3 PWM Controller Operation - Analog Input Control Mode

The PWM Controller operating in the Analog Input Control mode provides for adjustment of the output duty cycle and/or frequency via the analog input voltage.

The analog input voltage is connected via a terminal block on the right side of the front of the PWMC400 unit, labeled Control I/O. (For an illustration, see Figure 1.0-1.) The analog signal should be connected to the Duty + and – inputs (IN2 +/- on the PWMC400A) on the terminal strip. A 0V to 5V input will adjust the PWM output duty cycle proportionately. The PWMC400A allows for a second 0V to 5V analog control, connected to the IN1 +/- terminals, to adjust the PWM frequency.

The resolution of the analog input to the duty cycle output for the Model 400 PWM Controller may be configured to one of three steps: 1.0%, 0.5% or, 0.2%. Therefore, the transfer function for voltage to duty cycle will depend on the configured resolution setting. Table 4.3-1 provides the relationship between analog input voltage and PWM output duty cycle for the three configurable resolutions.

Resolution Setting	Number of Steps (0.0% to 100.0%)	mV / step	Equation (normal acting operation)
1.0%	100	50 mV	duty = 1% * (analog mV in / 50)
0.5%	200	25 mV	duty = 0.5% * (analog mV in / 25)
0.2%	500	10 mV	duty = 0.2% * (analog mV in / 10)

Table 4.3-1. Duty Cycle vs. Analog Input

Three resolutions are provided to enable the user to match the resolution of the intended source or the requirements of an intended application. For example, a 8-bit analog output with an output range of 0 to 5V can resolve at most 19.5mV. Operating the PWMC-400 using a resolution setting of 0.2% steps and achieving this resolution in this application is not possible. Another example would be in applications where the PWM average current is to be controlled. In this case, the highest resolution possible may be desired. For other applications, such as lighting control, a 100 step resolution (1%) may be sufficient.

The analog control input of duty cycle may be configured to operate as normal acting or reverse acting. For a normal acting output, the duty cycle is varied from 0% to 100% in proportion to a 0V to 5V input. For a reverse acting setting, the duty cycle is varied form 100% to 0% for a 0V to 5V input. This setting is configurable and is stored in EEPROM in the PWM Controller to be read on controller power-up.

For the Model 400A, the IN1 +/- input may be used to control the PWM output frequency. Table 4.3-2 provides the relationship between analog input voltage and PWM output frequency for the four configurable frequency ranges.

Range Setting	Number of Steps (min to max freq)	mV / step	Equation
1 to 100 Hz	100	50 mV	freq = 1Hz * (analog mV in / 50)
5 to 500 Hz	100	50 mV	freq = 5Hz * (analog mV in / 50)
10 to 1000 Hz	100	50 mV	freq = 10Hz * (analog mV in / 50)
50 to 5000 Hz	100	50 mV	freq = 50Hz * (analog mV in / 50)

Table 4.3-1. Duty Cycle vs. Analog Input

In analog input mode the output is updated 'continuously'. Since the PWM Controller utilizes a microcomputer and an A/D converter, the unit is essentially a sampled data system. Therefore, there is sampling and processing time required to convert the analog input and calculate and update the timer / counter system in the microcomputer with the new duty cycle information. Depending on the PWM carrier frequency, it is possible to achieve cycle by cycle update rates. This means that the PWM Controller would sample the analog input and update the duty cycle on the next cycle. The processing time is approximately 5 msec. Therefore, in practicality, the PWM Controller will be able to update the PWM output with a new duty cycle command from the analog input port when the PWM carrier frequency is 200 Hz or less. For carrier frequencies above 200 Hz it will take additional PWM output cycles for the output to update.

Note that since the analog output commanding the PWM Controller is not synchronized to the input sampling, intermediate values of analog voltage may be sampled by the PWM Controller. For example, if the analog signal to the PWM Controller changes from 1.0 V to 3.0V (20% to 60% duty cycle) it is possible that the PWM Controller will output an interim cycle (or more) of 38% (for example). This is not a problem for the PWM Controller, however, it is noted here for application information.

4.4 PWM Controller Operation – USB Interface

The PWM Controller possesses a USB port for remote operation. The USB port may be used to command the PWM Controller when operating in a USB to PWM mode (no analog input). This allows the PWM Controller to be commanded remotely via a computer executing custom host software, or, from an industrial control system or PLC (Programmable Logic Controllers). Additionally, the PWM Controller features may only be configured from the USB port. Operation and configuration is accomplished via the USB port using an ASCII character based command set.

When the PWM Controller is powered on, the PWM Output will begin operating at the default or configured settings (see section 4.6 on Configuration). If the PWM Controller is configured for operation in USB mode (not analog to PWM) then the output will be set to the configured start-up duty cycle and frequency and the PWM Controller will await command input via the USB interface.

Features of the PWM Controller are controlled via a command set that is ASCII character based. All commands are terminated by a star (*) character. A table of all Model 400 PWM Controller commands is shown in table 4.4-1.

All commands respond with either the dollar sign character ($) or a pound sign character (#). The $ indicates that the command was accepted and processed correctly. The # indicates that the command was not accepted and had no effect.

The Q, F, I and RD commands reply with additional information, such as the settings of the controller. Descriptions of the responses are provided in table 4.4-2. Note that it is not necessary to query the controller for its settings. If desired, a program may be designed to issue and set all the parameters to the desired settings without reading back settings.

Note that when issuing the commands, character positioning is important, do not add extra spaces or punctuation. Characters may be entered in uppercase or lowercase characters. All numeric values shown are ASCII character representation of numbers, that is, the number 100 is actually three ASCII characters - “1”, “0”, and “0”. All numbers are represented in base 10.

Only one command may be issued at any one time. Do not issue a string of commands unless the $ character response has been received. This indicates that the command has been accepted and has completed processing.

The PWM Controller output is always operating when powered on (PWR +/- input). Any commands issued to the PWM Controller using the USB interface, once processed internally, will be immediately reflected on the output of the PWM controller.

The Graphical User Interface software (APM, Inc. website, Model 400 USB product page) provides a PC windows based screen for manual operation (and configuration) of the Model 400.

The duty cycle command uses a number from 0 to 5000 that represents 0.0% to 100.0% duty cycle (that is, 1 count of 0 to 5000 represents 0.02% of duty cycle). Note that the Model 400 does not resolve to 0.02% steps, 0.2% step resolution maximum is recommended.

Note that the R commands only apply to the Model 400A unit.

Command	Format	Response	Notes
A	Ax*	pass = $ fail = #	set analog control to x = [0,1] 0 = off (USB) or 1 = on (analog input)
HZ	HZxxxx*	pass = $ fail = #	set PWM frequency to xxxx = [1 to 5000] Hz
HM	HMxxxx*	pass = $ fail = #	set PWM frequency to xxxx = [80 to 1000] mHz
D	Dxxxx*	pass = $ fail = #	set PWM duty cycle to xxxx = [0 to 5000] ignored if in analog control mode
V	Vx*	pass = $ fail = #	set analog control duty cycle resolution to x = [1,2,5] x = 1 = 1.0%, x = 2 = 0.2%, x = 5 = 0.5%
P	Px*	pass = $ fail = #	set analog input action to x = [0,1] x = 0 = normal, x = 1 = reverse
X	Xx*	pass = $ fail = #	set external enable to x = [0.1] x = 1 = enabled, x = 0 = disabled
Q	Q*	see below	readback all parameters
I	I*	see below	display serial number, h/w version, and s/w version
E	EAV*	pass = $ fail = #	save configuration in EEPROM
F	Fxxxxx*	pass = $ fail = #	command to directly set PWM counts xxxxx = [1000 to 65535]
G	Gxx*	pass = $ fail = #	command to directly set PWM clock frequency x = 1 for 24MHz x = 4 for 6MHz x = 12 for 12MHz x = 48 for 500KHz x = 10 for 10KHz x = 40 for 4KHz
RE	REx*	pass = $ fail = #	set to use analog input as frequency control input x = 1 = enabled, x = 0 = disabled
RG	RGxxxx*	pass = $ fail = #	set frequency control analog input range to [100,500,1000,5000] Hz
RD	RD*	see below	readback analog control of frequency parameters

Table 4.4-1 Model 400 / 400A USB Commands

Command	Response	Response Format Notes
Q	FxxxxxGxxxxxHyxxxxxDxxxxxAxPxVxxxxxXx$	xxxxx = numerical values y = 'Z' for Hertz y = 'M' for milliHertz
I	model=xxxxxhwrev=xxxxxswrev=xxxxxserno=xxxxx$	xxxxx = numerical values model = 400 for Model 400 model = 499 for Model 400A
RD	RAxRExRGxxxxx$	x, xxxxx = numerical values

Table 4.4-2 Model 400 / 400A USB Command Responses

4.4.1 Configuring the PWM Controller Operating Frequency

Note that the frequency of the Model 400 may be set using the HZ and HM commands. This allows for integer settings of the frequency (such as 200 Hz). It is possible using the command interface to set the PWM output frequency to any frequency that may be calculated using the internal clocks of the controller.. This is done using the F and G command interface. The G command sets the clock source while the F command sets the number of counts. The counts value is limited to 65535. Target PWM frequencies may be created using 2 or 3 of the clock sources, however, for best frequency accuracy it is better to pick a clock source that yields a higher counts value for better duty cycle resolution. For example, say a PWM frequency of 127.5Hz is required. Calculations follow as below:

Target PWM Frequency =	127.5 Hz	
Target PWM Period =	7.843 msec	
Counts using a 24MHz clock source =	188,232	(too high)
Counts using a 6 MHz clock source =	47,058	(best choice)
Counts using a 2 MHz clock source =	15,686	(ok, will work as well)

From the calculations above, the best choice would be to use the 6 MHz PWM clock source. Therefore, to set the PWM frequency to 127.5 Hz, use the G4 command and the F47058 command. The final setting may be calibrated by adjusting the count value as necessary to obtain the exact desired PWM frequency.

The recommended operating range for the frequency of the Model 400 PWM Controller is 0.08 Hz to 5000 Hz. PWM operating frequencies outside of this range may be realized by using the F and G commands directly to set the operating frequency. While this is not recommended, it is certainly possible to use the controller at, for example, a frequency of 8000Hz if the operation (duty cycle resolution) meets the needs of your application.

Note that when using the G and F commands to set the frequency directly, the Q command only displays the last integer value of the frequency set using the HZ or HM command. F and G do NOT update the Hertz or milliHertz fields in the PWM controller.

Also note that the HZ and HM commands actually calculate the optimum G and F values and set them. Therefore, the HZ and HM commands change the F and G settings.

4.5 PWM Controller LED Indicators

The Model 400 PWM Controller has two LED indicators on the front / face of the unit (see illustration of figure 1.0-1) labeled Status and Output. These indicators allow the user to monitor the operation of the PWM Controller while in service.

The Output LED is a single green LED and is connected directly to the signal driving the internal Power MOSFET. When the MOSFET is to be turned on (engagement portion of PWM cycle, driving current) the LED will be on. Likewise, the LED is off during the off portion of the PWM cycle. At low frequencies, the Output LED will flash and its on/off time will be visible. That is, for higher duty cycles the LED will be on more than off. For higher frequencies, the LED intensity will increase with increasing duty cycle (appear to dim / brighten).

Note that the Output LED is the state of the signal commanding the internal MOSFET PWM switch. It is possible to use the Output LED in conjunction with external equipment (ammeter, scope) to diagnose system problems. The Output LED will be active PWM even if the load is open or misconnected. The output LED will also be driven when the unit is USB powered and no power is on the PWR +/- pins. While the LED is driven in this case, the output is not. Since the MOSFET is unpowered, there is no PWM output on the actual OUT +/- pins. Also note that the USB interface cannot supply power to the PWM output.

The Status LED is a bi-color (red/green) LED which is driven by the PWM microcontroller. The Status LED provides an output based on the examined operational state of the PWM Controller. Definition of LED states are provided in table 4.5-1 below. Note that at power on, the Status LED will start on at orange (both red and green on) and will turn to a slow flashing green, if powered by USB only, and to a steady green if connected to an operational power source. The PWMC400/PWMC400A is not designed to drive the PWM output using USB power only. The initial orange setting identifies PWM Controller start-up, self-test and initialization.

Status LED color	Definition
green	PWM output operating normally
slow flashing green	PWM Driver / Controller powered by USB only
steady red	PWM Driver / Controller internal output fuse blown
flashing red	PWM Driver / Controller sensing open load
fast flashing green	PWM Driver / Controller is saving configuration to internal non-volatile EEPROM memory (save configuration command executed)
orange, steady or flashing other than at power-on, or, dark	does not turn green at power-on or stays or flashes orange, power-on failure, or microcontroller failure, return for service

Table 4.5-1. PWM Controller Status LED State Definitions.

Internal PWM Controller sensing circuitry and microcontroller algorithms determine the state of the output and report potential error conditions. This includes the state of the internal output fuse and an assessment of the load being pulse width modulated. The algorithm requires an operating duty cycle of between 10% and 90% to effectively determine these states. Also, the PWM Controller will only report the potential error state, it will not shut down its output. The controller will only report the condition via the state of the Status and Output LEDs.

4.6 PWM Controller Configuration

When the PWM Controller is powered on, the parameters of PWM output are initialized to settings contained within the EEPROM configuration memory of the PWM Controller microcontroller system. The user is able to configure these initial power-up settings. Note that this must be done for every PWM Controller prior to placing the unit in service. (For special / high volume orders, please contact APM, Inc. sales. Units can be configured to your requirements during factory test).

WARNING

WHEN INITIALLY POWERING ON THE PWM CONTROLLER (BEFORE IT IS CONFIGURED FOR THE FIRST TIME) IT IS RECOMMENDED NOT TO HAVE THE TARGET LOAD CONNECTED TO THE PWM CONTROLLER. THE FACTORY DEFAULT OPERATING FREQUENCY IS 100 HZ AND ANALOG OPERATING MODE. THE PWM CONTROLLER WILL POWER ON AND RESPOND TO THE ANALOG INPUT AND PWM AT 100 HZ. IF YOUR LOAD CANNOT TOLERATE THIS, IT SHOULD NOT BE CONNECTED UNTIL THE UNIT IS CONFIGURED. IT IS ALSO RECOMMENDED NOT TO HAVE THE OUTPUT DEVICE (LOAD) CONNECTED DURING CONFIGURATION. EVEN THOUGH THE OUTPUT IS SET TO 0% DUTY CYCLE DURING CONFIGURATION, THE LOAD SHOULD NOT BE CONNECTED.

Prior to placing the PWM Driver / Controller in service it is necessary to configure the following features:

- PWM output operating frequency, of 0.08 Hz to 5,000 Hz
- command source, analog input or USB to PWM duty cycle operation
- command source, analog input or USB to PWM frequency operation (analog - Model 400A only)
- PWM output duty cycle resolution, 1.0%, 0.5%, 0.25%
- PWM output frequency range, 100Hz, 500Hz, 1000Hz, 5000Hz (Model 400A only)
- analog input action, analog to PWM duty cycle output operating mode
  - normal, 0V to 5V analog input to 0% to 100% duty cycle output
  - reverse acting, 0V to 5V analog input to 100% to 0% duty cycle output
- external enable input, active or inactive (Model 400 only)

Table 4.6-1 below specifies the factory default settings for the configurable parameters in the PWM Controller.

Parameter	Factory Default Setting
Operating Frequency	100 Hz
Duty Cycle Command Source	analog input
Analog to PWM Output Duty Cycle Resolution	0.5%
Analog Output Action	normal
External Enable Input (Model 400 only)	active
Frequency Command Source (Model 400A only)	USB
Analog to PWM Frequency Range Setting (Model 400A only)	100Hz

Table 4.6-1. PWM Controller Configuration Default Settings.

Configuration may only be accomplished using the USB port on the PWM Controller. The unit may be easily connected to a host PC where the APM, Inc. user interface application software, described below, or another PC application program may be used.

A PC Windows based Graphical User Interface (GUI) host program is available from APM, Inc. for configuration. See the quick start section (section 3.1) of this user manual for instructions on using the GUI to configure the PWM Controller. Instructions are provided with the GUI files from the APM, Inc. website.

The PWM Controller may be configured using either the PC USB port and, the GUI software or a user developed application and the commands of section 4.4. If using the GUI to configure the PWM Controller, follow the instructions in section 3.1 of this manual and the instructions within the PC GUI software

5.0 Warranty and Service

5.1 Warranty

The Model 400 / 400A PWM Controller is warranted for 1 year from the time of purchase. This includes workmanship and manufacturer defects. It does not include failures caused by misuse.

5.2 Service

WARNING

OTHER THAN FUSE REPLACEMENT OR DIODE JUMPERING THERE ARE NO USER SERVICEABLE PARTS INTERNAL TO THE PWM CONTROLLER. DO NOT ATTEMPT TO SERVICE THE UNIT. COMPONENTS INTERNAL TO THE PWM CONTROLLER ARE STATIC SENSITIVE AND MAY BE DAMAGED WITHOUT PROPER HANDLING.

The PWM Controller requires no maintenance or calibration.

If you detect a malfunction with your unit, obtain a Return Authorization (RA) Number from the Applied Processor and Measurement, Inc website. Information on how to have your unit serviced, the shipping address, and service policies are shown on the website. There is a minimum service charge for non-warranty service. Applied Processor and Measurement, Inc. will repair or replace the unit at its option. If the return is for non-warranty repair, you will be notified of any applicable charges prior to work being performed.

Applied Processor and Measurement, Inc. may be contacted as follows:

Applied Processor and Measurement, Inc.
8201 Old Post Rd. E.
East Amherst, NY 14051 USA

Phone: (716) 741-1141
FAX: (716) 741-1142
E-mail: support@appliedprocessor.com

5.3 Diagnostics

The Output and Status LED indicators (refer to section 4.5) serve as self diagnostic tools within the PWM Controller. However, there are additional steps that may be taken to diagnose problems within the unit and verify its operation as stand-alone (as opposed to operating in your application).

Basically, the PWM Controller is a signal generator, therefore, any test equipment used to detect or measure signals may be used to check the PWM Output. If it appears that you are still in control of your PWM Controller, but you are in doubt of the PWM Output, simulate your load by connecting a resistor across the output as described in section 3.0. Connect your test equipment across the negative terminal on the PWM Output (the OUT– terminal) to ground (the PWR– terminal on the power input). Depending on the level of diagnosis desired, any of the following methods may be used to determine whether the PWM Controller is generating an output signal.

Check the Output Fuse – the output fuse may have been blown. See section 3.1 on replacing the internal fuse. Note again, that the PWM Controller Status LED may report a blown fuse.

Check the Command Input – using a DMM measure the voltage across the analog control + and – input.

Oscilloscope - best method of observing the output. The change in frequency and duty cycle may be observed and measured.

Frequency Counter - will be able to measure the output frequencies. Some DMM's have frequency and duty cycle measurement capability.

DMM - setting the DMM to measure DC Volts will provide some "average" value of voltage that will allow you to conclude that the PWM Output is not stuck high or low. Changing the duty cycle should change the DMM value displayed.

In conclusion, do not attempt to service the PWM Controller internally. The methods provided above give a visual indication of operation of the unit. This indication is intended to isolate problems with your application of the PWM Controller to the unit itself or the system connection.

5.4 Software Upgrades / Updates

The PWM Controller has in-circuit programmable microcomputer based circuitry and software. Applied Processor and Measurement, Inc. is committed to supplying a high quality product and will issue new software releases which will enhance capability and maintain the software. When purchasing the PWM Controller, your unit will be automatically registered. This registration will allow you to receive notices and pricing information on software releases and new software versions containing operational enhancements and new features. The PWM Controller software is capable of being upgraded for the life of the unit. Watch our website for information on available software revisions for the Model 400 PWM Controller. The unit may be returned to APM, Inc. for upgrade (minimum service charges apply). Upgrades for bug-fixes, depending on the severity and the nature of the user application, will be performed at no charge.

5.5 Customization

The accurate and reliable digitally generated PWM technology inherent in the Model 400 PWM Controller from APM, Inc. is also extremely flexible. The Model 400 (as well as other APM, Inc. PWM, interface, and signal conditioning products) may be easily and cost effectively modified to suit your specific application. Call and discuss your requirements with one of our engineers. Our engineering staff has extensive experience in test applications and embedded system applications. Applied Processor and Measurement, Inc. will respond quickly with a quotation upon your request.

Applied Processor and Measurement, Inc. engineers have been designing microprocessor based instrumentation and embedded control systems since 1980. We welcome inquiries on custom designs, variations on this design, as well as customized software for your application. Call and discuss your engineering needs with one of our engineers.