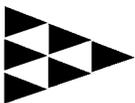


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# **USER'S MANUAL**

**MODEL 400  
PULSE WIDTH MODULATION DRIVER / CONTROLLER**

**DOCUMENT NO. 00071-14**



**Applied Processor and Measurement, Inc.**

---



**THANK YOU!**

Thank you for purchasing the Applied Processor and Measurement, Inc. Model 400 Pulse Width Modulation Driver / Controller.

Applied Processor and Measurement, Inc. is pleased to provide this high quality, feature rich, and value minded piece of test equipment for use in your laboratory. We appreciate your business and look forward to serving you for many years to come with both the Pulse Width Modulation Driver / Controller and other future equipment, equally as innovative.

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Again, thank you for purchasing and using our product.

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## REVISION HISTORY

Rev	Date	Pages	Description
-	12/18/03	All	Initial Release
A	2/6/09	4-6, 4-8 4-9, 4-11 4-14	Descriptions of 'A' and 'H' commands added. Other affected text changed.

## **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 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.

### **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.

## **Table Of Contents**

Table Of Contents .....	v
List of Figures .....	vi
List of Tables .....	vi
1.0 Introduction .....	1-1
<u>1.1 Features</u> .....	1-2
<u>1.2 Applications</u> .....	1-3
2.0 Specifications and Pinout .....	2-1
3.0 Installation and Start-up .....	3-1
<u>3.1 PWMC-400 Quick Start Instructions</u> .....	3-1
<u>3.2 PWM Controller Installation</u> .....	3-4
<u>3.2.1 Using the PWM Controller as a Signal Generator</u> .....	3-6
<u>3.3 Fusing</u> .....	3-7
<u>3.4 Internal Diode</u> .....	3-7
<u>3.5 RS-232 Connections</u> .....	3-8
<u>3.6 Note on Analog Input Connection</u> .....	3-9
<u>3.7 External Input Enable Connection</u> .....	3-9
4.0 Operation .....	4-1
<u>4.1 Theory of Operation</u> .....	4-1
<u>4.1.1 PWM Output</u> .....	4-2
<u>4.1.2 PWM Output – Maximum and Minimum Duty Cycle Limitations</u> .....	4-3
<u>4.2 PWM Controller Operation - Operational Modes and Features</u> .....	4-3
<u>4.3 PWM Controller Operation - Analog Input Control Mode</u> .....	4-4
<u>4.4 PWM Controller Operation – RS-232 Interface</u> .....	4-6
<u>4.4.1 Configuring the PWM Controller Operating Frequency</u> .....	4-11
<u>4.5 PWM Controller LED Indicators</u> .....	4-12
<u>4.6 PWM Controller Configuration</u> .....	4-13
5.0 Warranty and Service .....	5-1
<u>5.1 Warranty</u> .....	5-1
<u>5.2 Service</u> .....	5-1
<u>5.3 Diagnostics</u> .....	5-2
<u>5.4 Software Upgrades / Updates</u> .....	5-2
<u>5.5 Customization</u> .....	5-2

## **List of Figures**

Figure 1.0-1	Model 400 PWM Controller.....	1-1
Figure 3.1-1	Model 400 PWM Controller – kit set-up.....	3-1
Figure 3.1-2	Model 400 PWM Controller – typical installation.....	3-3
Figure 3.2-1	PWM Controller - Single Supply Connection.....	3-4
Figure 3.2-2	PWM Controller - Dual Supply Connection.....	3-5
Figure 3.2-3	PWM Controller - Dual Supply Connection using kit adapter for PWMC power..	3-5
Figure 3.2-4	PWM Controller - Common Ground Connection.....	3-6
Figure 3.5-1	6 pin mini-DIN RS-232 Pin Orientation (front facing view).....	3-8
Figure 4.1-1	Model 400 PWM Driver / Controller - Block Diagram.....	4-1
Figure 4.1.1-1	PWM Controller – Low Side Drive Output and Duty Cycle Definition.....	4-2
Figure 4.3-1	Analog Input Measurement Timing to the PWM Output Pulse Period.....	4-5
Figure 4.6-1	Recommended Set-up for PWM Controller Configuration.....	4-14

## **List of Tables**

Table 3.3-1	PWM Controller – Maximum Recommended Output Fuse Ratings.....	3-7
Table 3.5-1	6 pin mini-DIN RS-232 Remote Port Pinout.....	3-8
Table 3.5-2	RS-232 Cable Wiring.....	3-8
Table 4.3-1	Duty Cycle vs. Analog Input.....	4-4
Table 4.3-2	Analog Input Measurement Timing – Parameters.....	4-5
Table 4.4-1	PWM Controller Remote Port Command Summary.....	4-6
Table 4.4.1-1	PWM Controller Operating Frequencies – Configuration Values.....	4-11
Table 4.5-1	PWM Controller Status LED State Definitions.....	4-12
Table 4.6-1	PWM Controller Configuration Default Settings.....	4-13

## 1.0 Introduction

This manual describes the features, installation, and operating procedures for the Model 400 Pulse Width Modulation Driver / Controller (PWM Driver, PWM Controller 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.

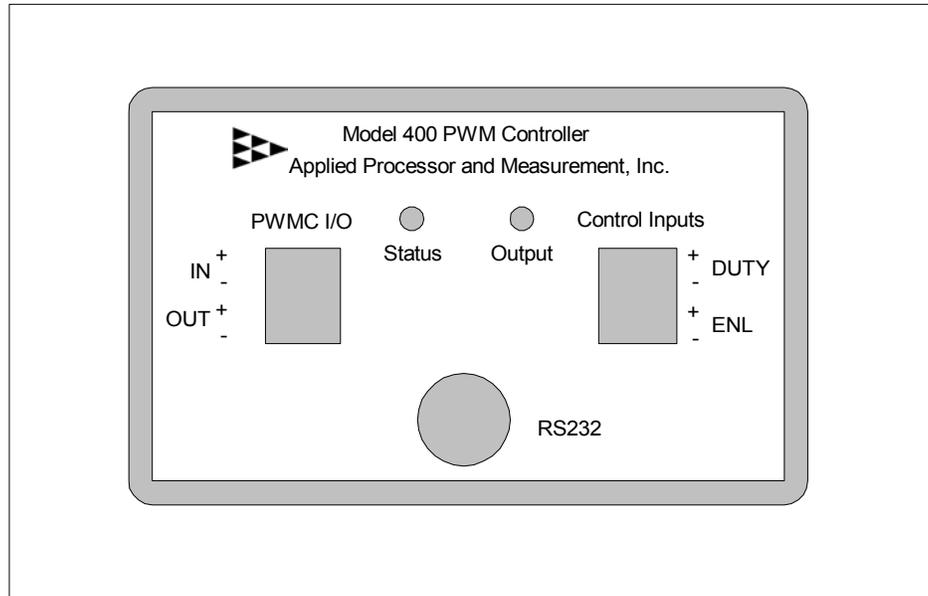


Figure 1.0-1 Model 400 PWM Controller.

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 PWM Controller may also be controlled via an RS-232 port. Single letter ASCII based commands allow the duty cycle to be set and displayed. This capability allows the PWM Controller to be controlled by a host computer serial 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).

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 its 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 PWM Driver / Controller.

- user / computer adjustable pulse width modulated output switching signal 0 to 100 % duty cycle
- fixed frequency operation, configurable by user in 1 Hz steps from 2 to 500 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
- inherent PWM monitoring
  - monitors for open load
  - monitors for open output fuse
- status LED and output LED
- remote operation via RS-232 interface commands:
  - set duty cycle
  - read duty cycle
- configurable
  - output duty cycle resolution (1%, 0.5%, 0.2%)
  - PWM output frequency
  - analog input control or RS-232 control
  - normal or reverse acting analog input operation
  - enable or disable external enable feature
- 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.

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

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## 2.0 Specifications and Pinout

Parameter	Description	Rating
Output Power	Open Drain Power MOSFET	$P_{d \max} = 50$ watts at 25°C
Output Current	Example Output Current, 100% duty cycle Power must not exceed maximum $P_d$	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	Fixed, set in configuration to 2 to 500 Hz, adjustment resolution of 1Hz	max error < 0.2 % of setting
Duty Cycle	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% 50 Hz, minimum 0.4%, maximum to 100% 100 Hz, minimum 0.8%, maximum 99.6% 200 Hz, minimum 1.4%, maximum 99.2% 400 Hz, minimum 2.8%, maximum 98.4% 500 Hz, minimum 3.4%, maximum 98.0%	typical error < 0.1 %
Frequency Source	Crystal Oscillator Circuit	18.432 MHz, 50 ppm stability
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	PWM Parameter Control Input Accuracy Duty Cycle 50mV / 1% Duty Cycle 25 mV / 0.5% Duty Cycle 10 mV / 0.2%	+/- 4 mV
Analog Inputs	Absolute Maximum Input Voltage	5.25 V
External Enable Input	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
RS-232	TX, RX, GND, 9600 baud, no parity, 8 data bits, 1 stop bit 6 pin mini-DIN connector	
Dimensions		3.625 in. x 2.25 in. x 1.0 in. height (1.25 in. height by connectors)

Pin Name	Description / Function
<b>PWMC I/O</b>	
IN +	PWM Controller power input
IN -	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
<b>Control Inputs</b>	
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) IN-, DUTY-, and ENL- are electrically isolated. 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.

### **3.0 Installation and Start-up**

This section provides information on how to connect the PWM Controller for operation and start-up instructions addressing the 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 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. This involves setting the following parameters:

- frequency of operation
- mode of operation: analog to PWM duty cycle or RS-232 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.

The PWMC-400 KIT is available to facilitate for configuration of the PWMC-400 unit. The kit provides a power adapter and cabling in order to readily connect the PWMC-400 unit to your personal computer (PC). The PC is required to set the configuration memory of the PWMC-400, setting the 5 configuration parameters listed above.

1. Connect the PWMC-400 to your PC as shown in the figure below. Note that the output load is not connected at this time.

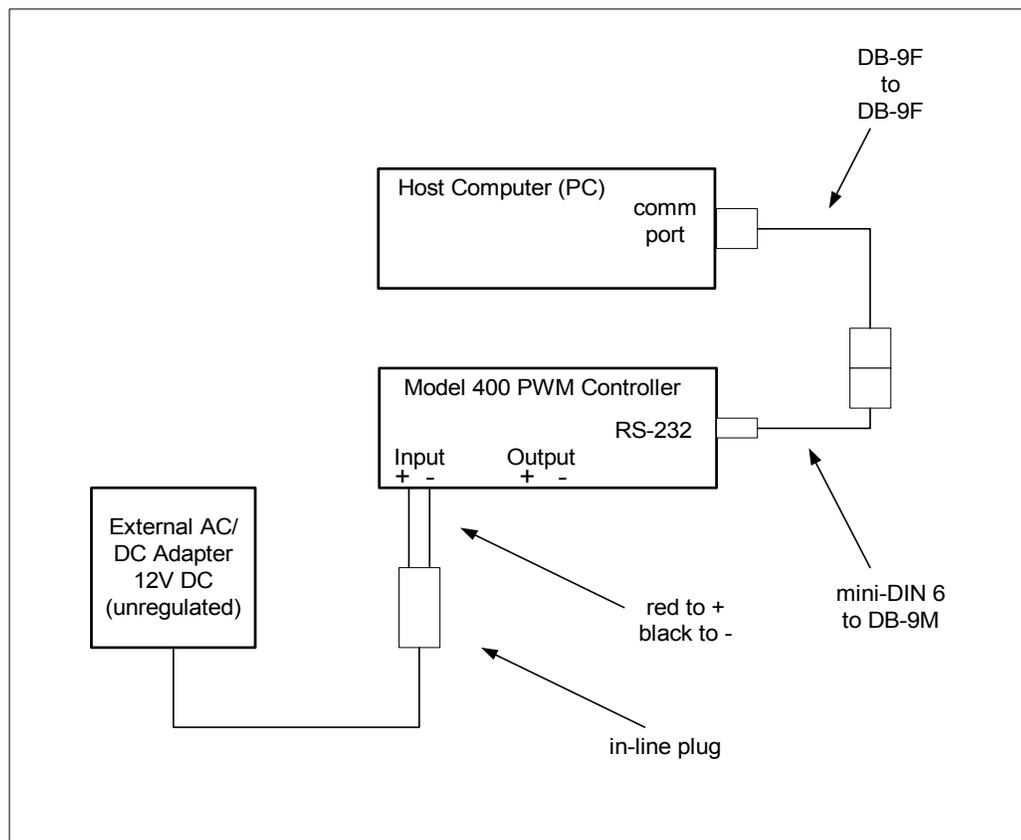


Figure 3.1-1 Model 400 PWM Controller – kit set-up.

2. Power on the PWMC-400 unit using the wall adapter. The PWM-400 status LED will flash orange briefly, then turn to steady green.
3. Start the PWMC-400 Configuration Program (graphical user interface – GUI) on the PC.
4. From the Configuration Menu, select Communications Set-up and select the PC Communications port that is connected to the PWMC-400, COM1 or COM2.
5. From the Configuration Menu, select Connect/Reconnect to establish a connection between the GUI and PWMC-400 hardware unit. The GUI will read and display the current settings of the PWMC-400 unit. The status LED on the PWMC-400 unit will flash green to indicate that its PWM output is stopped and the unit is now in configuration mode.
6. Set the following parameters on the GUI screen:
  - a. Frequency of Operation – enter the desired operating PWM frequency for the unit.
  - b. Command Source – set the radio button to Analog Input to use the analog input of the PWM Controller to set the PWM output duty cycle. Choosing the Serial Port will allow the PWMC-400 duty cycle to be set using serial input commands.
  - c. External Enable Input – 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.
  - d. Output – 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%. Note that this parameter is not used when in RS-232 control mode.
  - e. Duty Cycle Resolution – select the required output duty cycle resolution, 1.0%, 0.5%, 0.2%. This controls the analog to PWM duty cycle transfer function as below:
    - i. selecting 1.0% sets 50mV per 1.0% step
    - ii. selecting 0.5% sets 25mV per 0.5% step
    - iii. selecting 0.2% sets 10mV per 0.2% step
7. Confirm the settings. To set the PWMC-400 configuration memory, select Set PWMC Parameters from the Configuration Menu. A message will be displayed in the text box indicating the status of the operation. When complete, disconnect the PWMC-400 from the power supply and remove the cabling. It is configured and now ready to be installed into the application.
8. 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.
9. 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.

10. Connect the PWM Controller to your target system. Use one of the figures and the descriptions in section 3.2 for assistance as necessary. A typical system connection is shown in the figure below. Remember that the power adapter supplied with the PWMC-400 KIT is unregulated and rated at less than 1A. It is not intended for powering the application load. It may be used to power the PWMC-400 in a dual supply application.

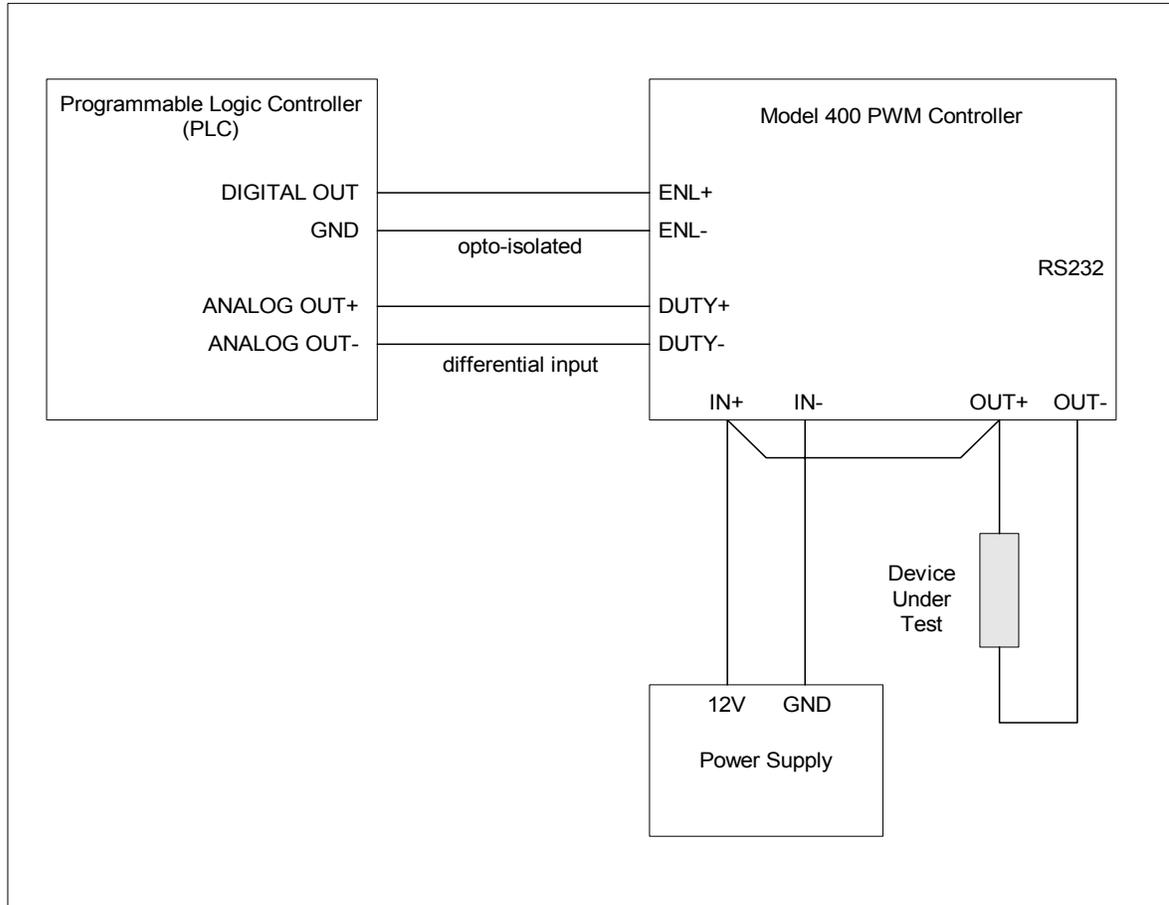


Figure 3.1-2 Model 400 PWM Controller – typical installation.

Note that the PWMC-400 is powered from the same power supply as the load (Device Under Test). The PWMC-400 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 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 analog input is fully differential and is designed to reject common mode voltages. Finally, note that the opto-isolated digital control input is only required if the External Enable Control feature on the PWMC-400 is configured to be active. This input is useful in controlling the PWM output from another source in your application (for example, the clutch control in automotive air conditioning applications).

11. When the power supply is powered on, the PWMC-400 will flash orange on the status LED 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 above paragraphs describes a typical procedure to set-up the PWMC-400 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](http://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.

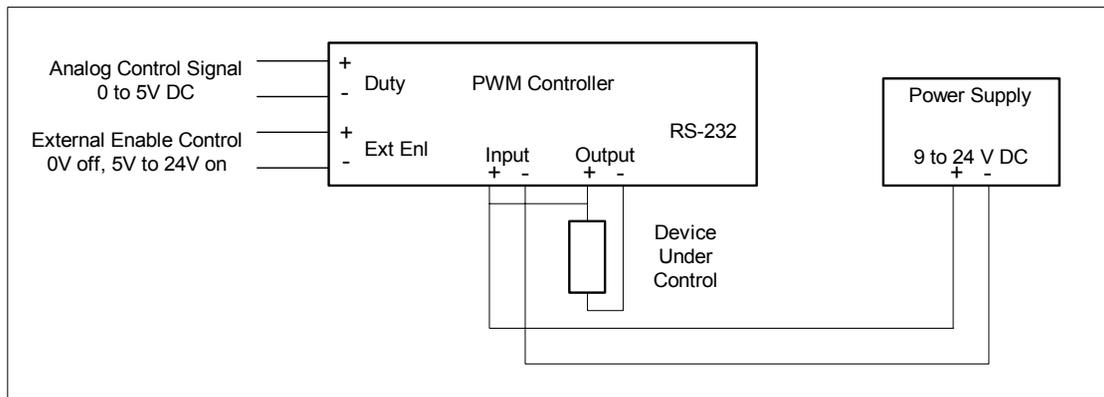


Figure 3.2-1 PWM Controller - Single Supply Connection.

This figure illustrates the low side drive connection of the PWM Controller. Also note that because of the open drain output, an external connection must 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.

Figure 3.2-2 (top of next page) shows 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).

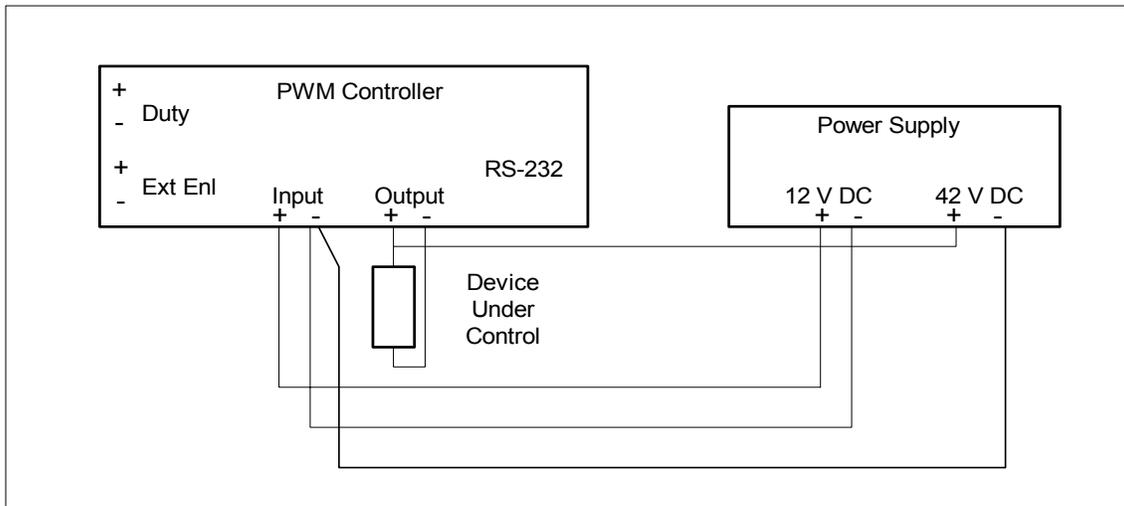


Figure 3.2-2 PWM Controller - Dual Supply Connection.

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.

Note that Figure 3.1-1 (in section 3.1 above) essentially illustrates another variation of the dual supply configuration. Any 12V source, even the unregulated AC to DC adapter supplied with the PWMC-400-KIT may be used for the PWM Controller power (additional adapters are available from APM, Inc., see the website for PWM Controller Accessories). In this case, the load power is to be obtained from an external power supply or an external source where the device under control is applied. Note that the common connection at the PWM Controller is still required. An example power connection using the external AC/DC unregulated power adapter is illustrated in Figure 3.2.3 below.

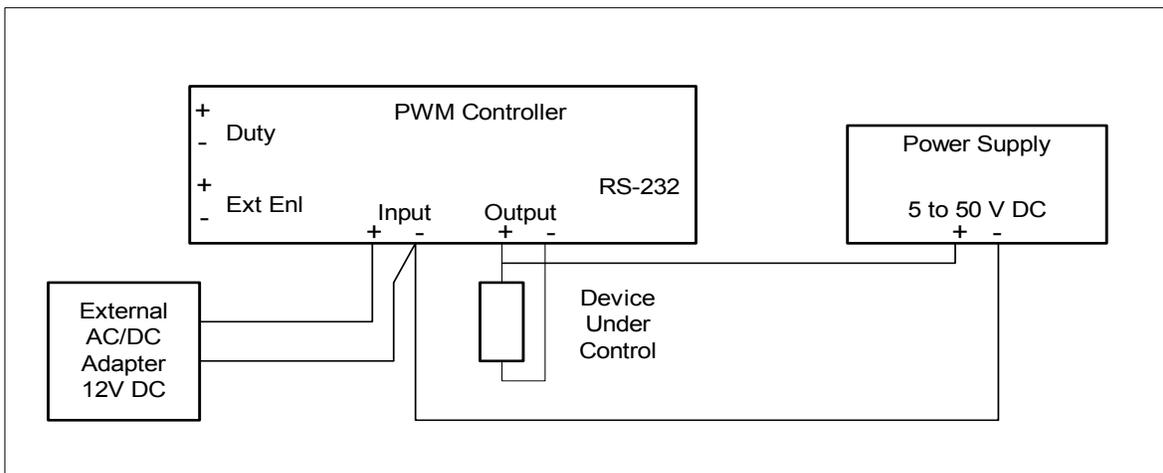


Figure 3.2-3 PWM Controller - Dual Supply Connection, using the kit adapter for PWMC power.

Finally, note that the PWM Controller analog input, the external enable input, and the power input are electrically isolated. That is, the DUTY-, ENL- and IN- 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.

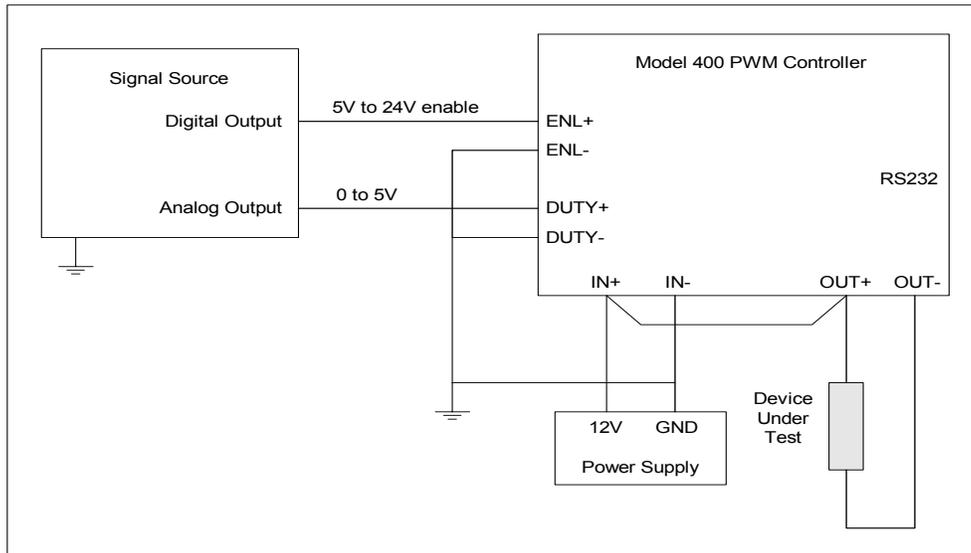


Figure 3.2-4 PWM Controller - Common Ground Connection.

In the common ground configuration of figure 3.2-4, connections to the DUTY-, ENL- and IN- 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  $\Omega$ , 1/4 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 R451 series fuse. A 4 Amp fuse is installed in the unit from the factory (Littelfuse part number R451 004). 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	R451 004
12V	4A	R451 004
15V	3A	R451 003
24V	2A	R451 002

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

Littelfuse Nano SMF type R451 fuses are available from electronics component distributors and catalog vendors (such as Digi-Key Corporation and Newark Electronics). Additional 4A fuses are also supplied with the PWMC-400-KIT and are available from APM, Inc. See the website at [www.appliedprocessor.com](http://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 RS-232 Connections

The PWM Controller possesses an RS-232 port for remote operation capability. The RS-232 port is available on the PWM Controller from the 6 pin mini-DIN connector on the face of the unit. The pinout of the 6 pin mini-DIN is provided in table 3.5-1. Figure 3.5-1 shows the pin orientation when looking at the face of the 6 pin mini-DIN connector. Pins not shown in the table are not connected internally within the PWM Controller.

6 pin Mini DIN Pin Number	Signal
1	Transmit Data (TXD)
2	Receive Data (RXD)
3,5	GND

Table 3.5-1. 6 pin mini-DIN RS-232 Remote Port Pinout.

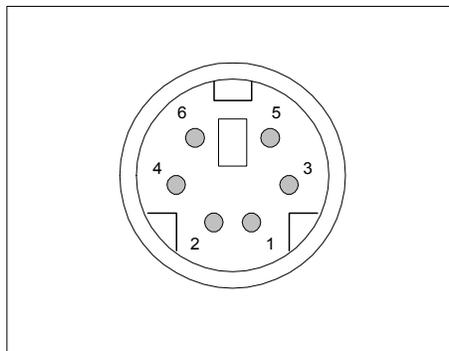


Figure 3.5-1. 6 pin mini-DIN RS-232 Pin Orientation (front facing view).

To connect a host computer, control system or PC to the PWM Controller, use a cable wired as defined in table 3.5-2. This table provides connections to standard RS-232 connectors for PC's. Both 9 pin and 25 pin versions are shown. Consult your PC or equipment manual for proper RS-232 pinout. RS-232 cabling is provided with the PWMC-400-KIT and is available as an accessory from APM, Inc.

PWM Controller Signal	PWM Controller 6 pin mini-DIN Pin	PC Signal	DB-9 Pin	DB-25 Pin
TXD	1	RXD	2	3
RXD	2	TXD	3	2
GND	3 or 5	GND	5	7

Table 3.5-2. RS-232 Cable Wiring.

Note that the RS-232 port contains a ground connection (which is electrically connected to the IN- pin on the PWM/O terminal block). The PWM Controller RS-232 port is not electrically isolated. If the PWM Controller is operated in the RS-232 to PWM duty cycle output mode and a ground loop is created with the RS-232 port ground, then, an opto-isolated RS-232 converter module must be used. Many vendors offer isolated RS-232 modules at a low cost. For applications assistance from APM, Inc., contact [support@appliedprocessor.com](mailto:support@appliedprocessor.com).

The remote port communication parameters are set for the following:

Baud Rate: 9600 bps  
 Parity: none  
 Data Bits: 8  
 Stop Bits: 1  
 Flow Control: none.

### **3.6 Note on 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 a analog to PWM (duty cycle) 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.

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.

### **3.7 External Input Enable Connection**

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 24V DC. An input of 0V disables PWM output, a high voltage enables PWM output. The input is optically isolated and has an internal series resistor (3k $\Omega$ ) 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.

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## 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 RS-232 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.

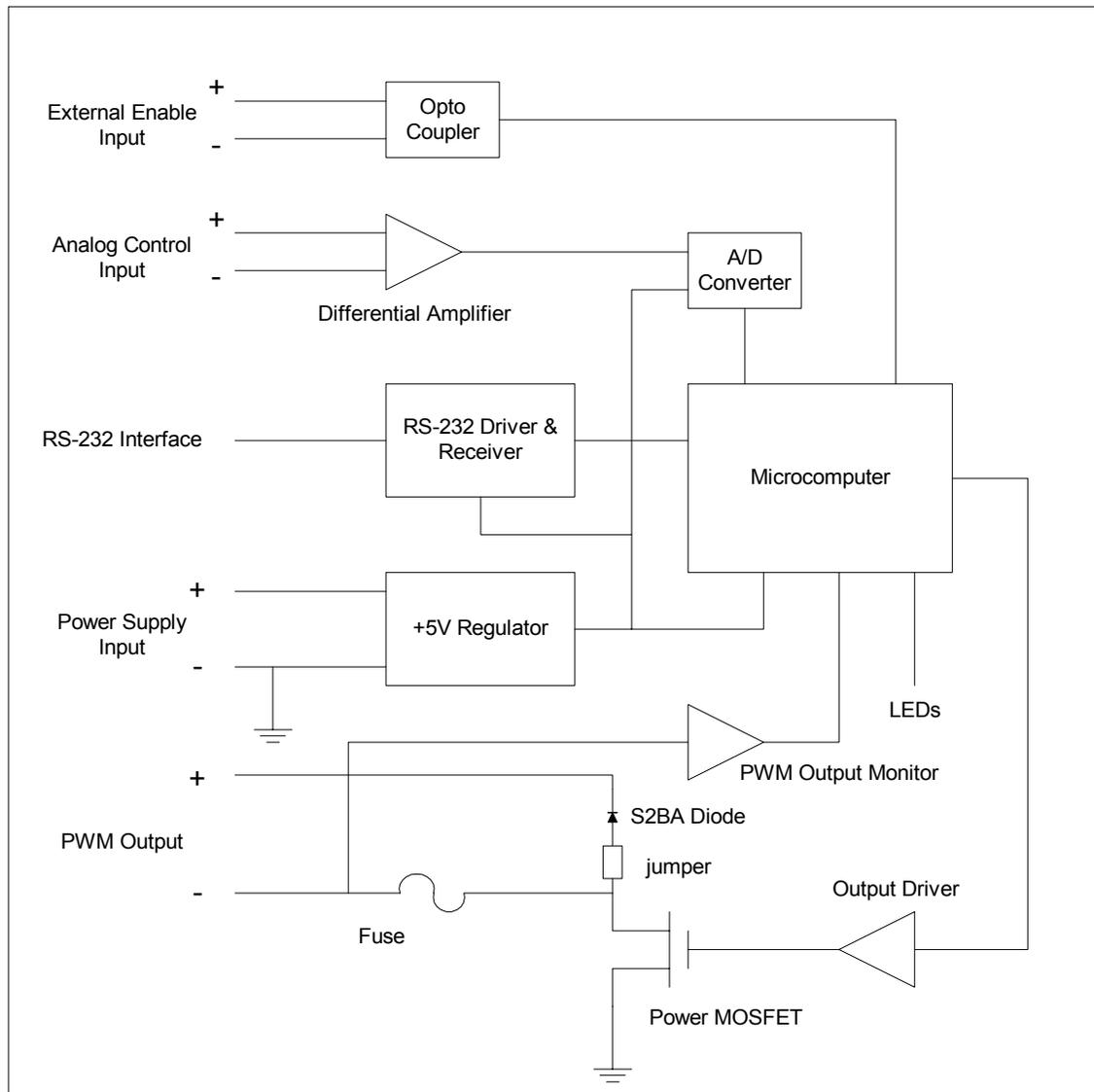


Figure 4.1-1 Model 400 PWM Driver / Controller - Block Diagram.

The PWM Controller output timing is based on a crystal oscillator which drives 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 PWM output timing is controlled by timer / counter resources internal to 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 an RS-232 interface for output control. The Model 400 may be configured to operate in an RS-232 to PWM duty cycle output mode as well. In this mode, a single line command using ASCII characters may be issued to vary the output PWM duty cycle. The RS-232 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 RS-232 command interface or the Visual BASIC configuration software for a PC. The embedded software in the FLASH microcomputer memory can not 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 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.

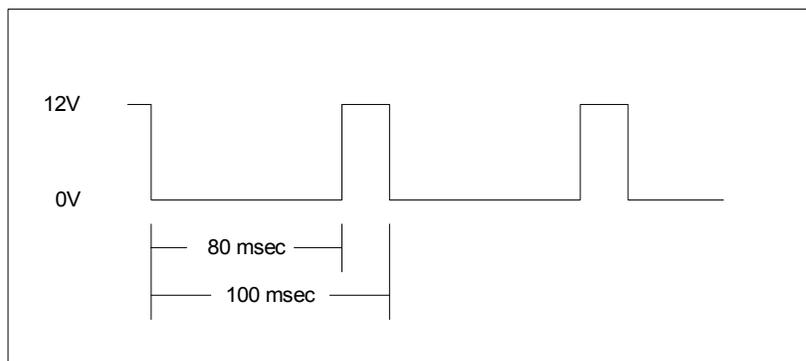


Figure 4.1.1-1 PWM Controller – Low Side Drive Output and Duty Cycle Definition.

When operating in analog to PWM duty cycle mode, 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 (2 to 500 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% 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 be either 0% or 100% 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 200 Hz, the operating duty cycle is limited to 1.4% to 99.2%. When operating at 200 Hz, if the command (analog or RS-232) issued to the PWM Controller results in a duty cycle output request of 0.8%, the PWM Controller will force the output to 0%. Likewise any command that would request a duty cycle greater than 99.2% 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 one of two modes: Analog Input to PWM Duty Cycle Output, or RS-232 to PWM Duty Cycle Output. The mode of operation is configured using RS-232 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 RS-232 to PWM function.

Note that the PWM carrier frequency is configurable, but fixed. That is, the PWM Controller carrier frequency can be set to any value from 2 to 500 Hz, however, while the unit is operating in its analog or RS-232 to PWM mode, the frequency cannot be changed.

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

The modes of operation may be summarized as below:

#### Analog Input to PWM Duty Cycle Output:

The PWM Controller will measure the analog input, calculate a duty cycle proportional to the analog input, and output the duty cycle on the PWM output. The PWM Controller will continuously monitor the analog input for changes and update the PWM duty cycle accordingly.

#### RS-232 to PWM Duty Cycle Output:

The PWM Controller will receive a duty cycle change command via the RS-232 interface and will output the duty cycle on the PWM output. The PWM Controller will continuously be ready to receive RS-232 characters and update the PWM duty cycle accordingly upon the receipt of the end of command line.

Note that later in the User's Manual, the PWM Controller is referred to as having a Configuration Mode. This is not an output operating mode. That is, the duty cycle output of PWM Controller is 0% (off) when the PWM Controller is being configured. See section 4.6 on PWM Controller 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 via the analog input voltage.

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

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 Model 400 PWM Controller analog input and processing algorithm is designed to 'switch' duty cycle steps halfway between the corresponding voltage step. For example, when the resolution is set to 0.5% steps, the output will change from one duty cycle to the next 0.5% up or down with a 25mV change in the input voltage. If the analog input is 1.000V a duty cycle of 20% is output. A 20.5% duty cycle is output with an analog input of 1.025V. The transition point between the 20% and 20.5% step change is approximately 1.012V (or half the voltage step between 1.000V and 1.025V).

The analog control input 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 from 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.

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 may take 2 to 3 cycles for the output to update.

The analog input sampling is synchronized to the PWM output frequency. In any one period of the output, the engagement portion of the cycle (i.e. the duty cycle) is executed first. Once the output is engaged, the microcomputer samples the analog input for the duty cycle for the next period. The sample is then processed and posted to the timer / counter routines in the microcomputer for use in the next cycle. An

example of the synchronized timing and analog input measurement is shown in figure 4.3-1. As per the previous paragraph, the waveform period shown is > 5msec such that the PWM Controller is able to output a new duty cycle in response to an analog command every waveform cycle. For frequencies higher than 200 Hz, the output will not be updated until later cycles. Detailed timing data is provided in table 4.3-2.

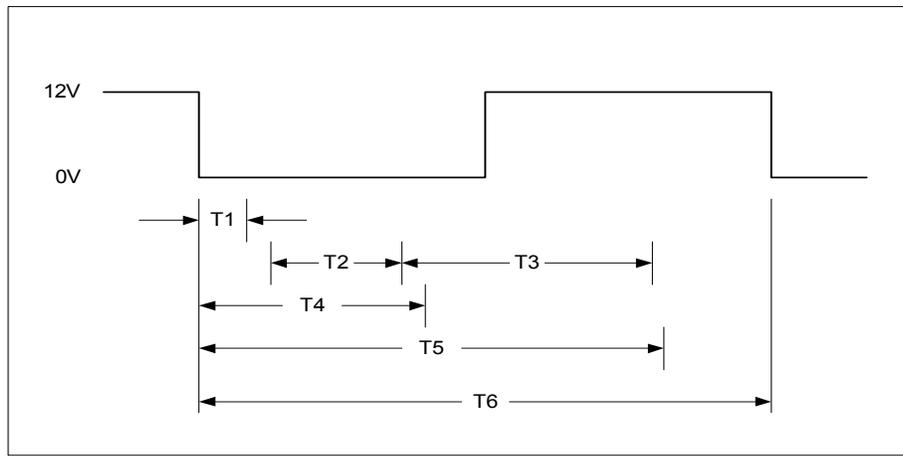


Figure 4.3-1. Analog Input Measurement Timing to the PWM Output Pulse Period (not to scale).

Parameter	Designation (figure 4.3-1)	Time	Notes
PWM start-up engagement processing time	T1	15 usec	approximate maximum time
analog input sample time	T2	1.7 msec	approximate maximum time, occurs after T1
analog input to duty cycle conversion / processing	T3	2.8 msec	approximate maximum time, occurs after T2
analog input sample complete	T4	2 msec	absolute maximum
total analog mode processing time	T5	4.6 msec	approximate maximum time
PWM cycle	T6	n/a	PWM operating period (for this example, $T6 \geq 10$ msec)

Table 4.3-2. Analog Input Measurement Timing – Parameters.

Based on the fact that the PWM Controller analog input sampling is synchronized to the PWM output cycle it is possible, given the proper carrier frequency, to update the PWM output on a cycle by cycle basis. In cases where the update rate is two or three times the operating period, PWM controller changes may still be synchronized to the output cycle such that intermediate analog values are not sampled by the PWM Controller hardware.

A sample waveform and timing data is shown in Figure 4.3-1 and Table 4.3-2. The waveform shows a typical PWM output waveform cycle of period  $T6$ .  $T1$  is the processing time needed by the PWM Controller when the output is switched and the load is engaged (driving current). A short time after this processing is completed, the analog input is sampled during  $T2$ . Assuming that the analog input is directing a change in the output duty cycle, the conversion from analog in to duty cycle value is executed in time  $T3$ . The entire time for the PWM output processing, analog input sample, and conversion to a duty cycle output varies depending on the numbers being processed, however, in the figure, an approximation for the total time is shown as  $T5$ . Note that  $T4$  is the parameter relevant for synchronization.  $T4$  is the maximum time for the analog input to be captured after the PWM output is engaged. Therefore, to synchronize a commanding system (e.g. an analog output from a PLC D/A module), the analog output should be changed 2 msec after the PWM output is engaged.

Note that if the analog output commanding the PWM Controller is not synchronized to the PWM waveform, 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 applications where non-synchronous operation is used. Also note that it is not possible to attempt to synchronize the PWM Controller to a source by simply matching operating frequencies. Two unsynchronized oscillator sources will inherently drift and an interim change (as described above) will occur when the two frequencies 'cross' each other. The recommended method of synchronization to the PWM Controller is described in the previous paragraph(s).

Finally, note that when cycle by cycle synchronization is achieved, the PWM Controller output may actually be modulated. Depending on the analog source, the PWM Controller output duty cycle may be alternated between 2 values, or, a burst of cycles may be generated.

When using the Analog Input control feature, be sure to operate the inputs within the specified limits for the analog inputs as described in Section 2.0. The system commanding these inputs should not exceed the range of 0.0 V to 5.0 V. While the inputs are protected, command signals over 5.0 V may damage the PWM Controller internal A/D converter or the signal source.

#### 4.4 PWM Controller Operation – RS-232 Interface

The PWM Controller possesses an RS-232 port for remote control. The RS-232 port may be used to command the PWM Controller when operating in an RS-232 to PWM mode (no analog input). This allows the PWM Controller to be commanded remotely via a computer executing a terminal emulation program or custom software, or, from an industrial control system or PLC (Programmable Logic Controllers). Additionally, the PWM Controller features may only be configured from the RS-232 port. Operation and configuration is accomplished via the RS-232 port using an ASCII character based command set.

When the PWM Controller is powered on, a sign on message will be transmitted out the serial interface. After the sign-on message, 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 RS-232 mode (not analog to PWM) then the output will be set to 0% duty cycle and the PWM Controller will await a duty cycle command via the serial port. After the sign on message is complete, a greater than ( > ) prompt will be transmitted, signifying that the controller is ready for commands.

Features of the PWM Controller are controlled via a command set that is ASCII character based. All commands are terminated by a carriage return (Return, Enter Key on your keyboard - ASCII value of 13H). A summary of all Model 400 PWM Controller commands is shown in table 4.4-1.

<u>Operating Mode Commands</u>	
Dxxx<CR>	set duty cycle to xxx = [0..5000]
D<CR>	read current duty cycle
C1<CR>	go to configuration mode
<u>Configuration Mode Commands</u>	
Ax<CR>	set analog control to x = [0,1]
Hxxx<CR>	set operating frequency to xxx = [2..500]
Fxxxx<CR>	set frequency counter value to xxxxx = [0..65535]
Gxx<CR>	set frequency range counter value to xx = [0..11]
Vxx<CR>	set duty cycle resolution to xx = [10,25,50]
Px<CR>	set analog input action to x = [0,1]
Xx<CR>	set external input enable to x = [0,1]
Q<CR>	read back current settings
I<CR>	report system information
E<CR>	save current settings to EEPROM
C0<CR>	exit configuration mode

Table 4.4-1 PWM Controller Remote Port Command Summary

In the summary table and the command listings below, the carriage return is shown as <CR>. Note that 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.

Note that while operating, only two commands will be accepted by the PWM Controller: set (or read) duty cycle and go to configuration, all other commands will be ignored and the PWM Controller will only respond with a prompt. Furthermore, when operating in the analog to PWM duty cycle mode of operation, only the read version of the duty cycle command is accepted. Finally, note that when in configuration mode the output is disabled (set to 0% duty cycle).

When operating in the RS-232 to PWM output duty cycle mode, the end of the command line signals to the microcomputer software to process a change in the duty cycle output. The new duty cycle output is synchronized to the start (engagement) portion of the PWM output cycle by the microcomputer embedded firmware. A synchronous system design could be realized by using a host system that would sample the PWM output engagement edge, then output a serial command to the PWM Controller. At 9600 baud a command will take over 6msec to send. Considering processing time, a maximum synchronous rate (one update per PWM output cycle) of approximately 80 to 100 Hz should be attainable.

Detailed descriptions of the Model 400 PWM Driver / Controller follow:

#### Operating Mode Commands:

**Command:** Set the PWM Output Duty Cycle  
**Syntax:** Dxxxx<CR>  
**Parameters:** xxxx, where xxxx = 0 to 5000, representing 0 to 100% duty cycle  
**Active:** RS-232 to PWM duty cycle mode of operation  
**Description:** Use the D command to remotely set the pulse output duty cycle. The value xxxx must be in the range of 0 to 5000 and represents 0.02% steps. Note that the duty cycle in the PWM Controller is always in terms of 0 to 5000 where 0 represents 0% and 5000 represents 100%. (Note that the normal and reverse acting setting is ONLY for the analog input when operating in the analog to PWM duty cycle mode.) The minimum step resolution of the PWM Controller is dependent on the number of internal counts used at a particular operating frequency, however, the PWM Controller will accept any input in the range of 0 to 5000 and output the duty cycle accordingly. The duty cycle value supplied may be 1, 2, 3, or 4 numeric characters in length, leading zeroes are ignored. This allows software formatting of the digits to be used in computer control applications. For example, a value for xxx of "004" is equivalent to "4". A percent sign is not required and should not be used.  
**Example:** D0<CR> - will set the output duty cycle to 0%  
**Example:** D2500<CR> - will set the output duty cycle to 50%  
**Example:** D5000<CR> - will set the output duty cycle to 100%

**Command:** Report the current PWM Output Duty Cycle  
**Syntax:** D<CR>  
**Parameters:** none  
**Active:** analog input or RS-232 to PWM duty cycle mode of operation  
**Description:** Use the D command report the current PWM pulse output duty cycle. The value will be reported in terms of a number from 0 to 5000 where 0 represents 0% and 5000 represents 100%. Each digit represents 0.02% of duty cycle. Note that this command will execute in either operating mode, analog to PWM duty cycle or RS-232 to PWM duty cycle.  
**Example:** D<CR> - will report the current duty cycle, a value of 0 to 5000

**Command:** Enter Configuration Mode  
**Syntax:** C1<CR>  
**Parameters:** none  
**Active:** analog input or RS-232 to PWM duty cycle mode of operation  
**Description:** Issuing this command will cause the PWM output to go to 0% (stop) and cause the PWM Controller to await configuration commands. The PWM output will remain stopped until configuration mode is exited, or the unit's power is cycled.  
**Example:** C1<CR> - enter configuration mode

Configuration Commands:

Command: Set Analog or RS232 Operating Mode  
Syntax: Ax<CR>  
Parameters: x, where x = 0 or 1  
Active: configuration only  
Description: Use the A command to set the analog or RS232 operating mode. For operation using the analog input on the Model 400 type the 'A1' command. For RS232 operation, use the 'A0' command. Only the numbers 0 or 1 are accepted by the command interpreter.  
Example: A1<CR> - will set analog input operation

Command: Set the PWM Operating Output Frequency  
Syntax: Hxxx<CR>  
Parameters: xxx, where xxx = 2 to 500  
Active: configuration only  
Description: Use the H command to configure the pulse output frequency directly in Hz. The value supplied on the command line may be 1 to 5 characters in length, leading zeroes are ignored. For example, a value for xxxxx of "00240" is equivalent to "240" Hz. The engineering units designation of "Hz" should not be typed. Note that if the H command is used it is not necessary to set the frequency counters directly using the F and G commands. The H command will set the proper values of the counters.  
Example: H00240<CR> - will set the output frequency to 240Hz

Command: Set the PWM Output Frequency Low Variable  
Syntax: Fxxxxx<CR>  
Parameters: xxxxx, where xxxxx = 0 to 65535  
Active: configuration only  
Description: Use the F command to configure the pulse output frequency only when non-integer values of operating frequency are desired. Setting the value of the output frequency is accomplished using two commands ('F' and 'G') and is discussed in section 4.4.1 below. Note that the 'F' command must be issued before the 'G' command. The value supplied on the command line may be 1 to 5 characters in length, leading zeroes are ignored. For example, a value for xxxxx of "00107" is equivalent to "107". The engineering units designation of "Hz" should not be typed.  
Example: F00107<CR> - will set the output frequency low variable

Command: Set the PWM Output Frequency Operating Range (High Variable)  
Syntax: Gxx<CR>  
Parameters: xx, where xx = 0 to 11  
Active: configuration only  
Description: Use the G command to configure the pulse output frequency. Setting the value of the output frequency is accomplished using two commands ('F' and 'G') and is discussed in section 4.4.1 below. Note that the 'F' command must be issued before the 'G' command. The value supplied on the command line may be 1 or 2 characters in length, leading zeroes are ignored. For example, a value for xx of "02" is equivalent to "2". The engineering units designation of "Hz" should not be typed.  
Example: G2<CR> - will set the output frequency high variable

Command: Set the Analog to PWM Duty Cycle Output Mode Duty Cycle Resolution  
Syntax: Vxx<CR>  
Parameters: xx, where xx = 10, 25 or 50  
Active: configuration only  
Description: Use the V command to set the PWM output duty cycle resolution. Setting 10, 25, or 50 will configure the duty cycle resolution to 0.2%, 0.5% or 1.0% duty cycle steps respectively. Only the numbers 10, 25, or 50 are accepted by the command interpreter. Note that this only effects the duty cycle resolution when operating in the analog to PWM output duty cycle mode of operation.  
Example: V25<CR> - will set the output duty cycle resolution to 0.5%

**Command:** Set the Analog to PWM Duty Cycle Output Mode Analog Input Action  
**Syntax:** Px<CR>  
**Parameters:** x, where x = 0 or 1  
**Active:** configuration only  
**Description:** Use the P command to set the analog input operating action. For normal action use the 'P0' command. For reverse action, the 'P1' command is used. 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 from 100% to 0% for a 0V to 5V input. Only the numbers 0 or 1 are accepted by the command interpreter. Note that this only effects the duty cycle when operating in the analog to PWM output duty cycle mode of operation.  
**Example:** P1<CR> - will set the analog input action as reverse

**Command:** Set the External Input Enable  
**Syntax:** Xx<CR>  
**Parameters:** x, where x = 0 or 1  
**Active:** configuration only  
**Description:** Use the X command to configure the Model 400 PWM Controller to use (or not use) the external enable input. When the external input enable is active, a digital signal on the ENL +/- inputs on the PWM Controller will enable or disable the PWM output. The X command activates or de-activates this feature. When the external enable is inactive, the external enable input will be ignored. Use the 'X0' command to set the external enable input inactive. Use the 'X1' command to activate the external enable input. The external enable applies to both analog and RS-232 to PWM output duty cycle modes of operation.  
**Example:** X1<CR> - will activate the external enable input

**Command:** Query / Read Back the Current Settings  
**Syntax:** Q<CR>  
**Parameters:** none  
**Active:** configuration only  
**Description:** Use the Q command to display all of the current configuration settings of the Model 400 PWM Controller. Note that the output responses (numbers) are encoded as per the input parameters for each command. See command definitions for the interpretation of the response.  
**Example:** Q<CR> - will display all configuration settings  
 Current Settings - PWM Controller response (7 lines)  
 freq hi=00000  
 freq lo=03840  
 dutyres=00050  
 out act=0  
 analog =0  
 ext enl=0  
 hertz=00400

**Command:** Report Information on System  
**Syntax:** I<CR>  
**Parameters:** none  
**Active:** configuration only  
**Description:** Use the I command to provide information on the PWM Controller model number, serial number and hardware and software version numbers. This information is useful in service calls to Applied Processor and Measurement, Inc. and for maintaining your unit with respect to software upgrades and feature requests. See Section 5.4 for information on upgrades and customization.  
**Example:** IS <CR> - reports the system information  
 PWMC400 rev 0.3 (c)20034/5/ APM, Inc. - PWM Controller response (2 lines)  
 ser no=00120 hw=00002 sw=00003

Command: Save Configuration Information

Syntax: E<CR>

Parameters: none

Active: configuration only

Description: The E command is used to save the power on start-up settings of the PWM Controller into internal EEPROM memory. After a configuration is completed, the PWM Controller will start-up and operate using the last parameter settings saved in configuration memory. The parameters saved are: frequency (2 to 500 Hz), duty cycle resolution (1.0%, 0.5%, 0.2%), analog input action (normal or reverse), analog input or RS-232 input operation, and external input control active / inactive. See section 4.6 for details on the configuration process.

Example: E<CR> - save configuration

Command: Exit Configuration Mode

Syntax: C0<CR>

Parameters: none

Active: configuration only

Description: Issuing this command will cause the PWM Controller to restart as if power was cycled. The configuration memory will be read and the PWM Controller will operate in the mode that was last configured.

Example: C0<CR> - exit configuration mode

#### 4.4.1 Configuring the PWM Controller Operating Frequency

When in the configuration mode, the output carrier frequency of the PWM waveform may be set. The 'H' command may be used to set the operating frequency value directly in Hz. It is also possible to set the frequency generation counter values directly with the 'F' and 'G' commands. This may be used to generate frequency values that are not integers (for example: 12.5 Hz). This method must also be used for Model 400 units with software versions lower than version 0.3 (the software version is displayed when using the configuration utility provided by APM, Inc. on the website).

The PWM Controller operating frequency is based on two entries in the PWM Controller EEPROM. The entries are calculated based on the internal operating frequency of the PWM Controller timer / counter resource which is 1.536 MHz. A count value is calculated based on the closest number of counts required to create the PWM waveform period. This is given in equation 4.4.1-1 below.

$$\text{counts} = (1 / \text{PWM\_frequency}) / (1 / 1.536 \text{ MHz}) \quad \text{Equation 4.4.1-1}$$

Since integer values are required for the entry, the value of counts should be rounded to the nearest integer value. The values for the 'F' and 'G' commands are given by the two equations below which calculate the number for the PWM Controller in terms of counts in 16-bit low and high values.

$$\text{low} = \text{counts} \% 65536 \quad \text{Equation 4.4.1-2}$$

$$\text{high} = \text{counts} / 65536 \quad \text{Equation 4.4.1-3}$$

The '%' in equation 4.4.1-2 signifies the modulus operator, which provides the remainder of the value of counts divided by 65536. In equation 4.4.1-3, the high value should be an integer only. Once the values of low and high are calculated, the operating frequency may be set by using the following command sequence:

Fxxxxx<CR>                      - where xxxxx is the low value  
Gxx<CR>                            - where xx is the high value

Note that the 'F' command must be issued before the 'G' command.

Table 4.4.1-1 lists the F and G values for various operating frequencies.

PWM Operating Frequency (Hz)	counts	F value	G value
2	768000	47104	11
10	153600	22528	2
25	61440	61440	0
50	30720	30720	0
80	19200	19200	0
100	15360	15360	0
200	7680	7680	0
400	3840	3840	0
500	3072	3072	0

Table 4.4.1-1. PWM Controller Operating Frequencies – Configuration Values.

The recommended operating range for the frequency of the Model 400 PWM Controller is 2 Hz to 500 Hz. A PWM operating frequency of less than 2 Hz cannot be processed by the PWM Controller. A PWM operating frequency of up to 1000 Hz may be programmed into the unit, however, increased minimum and maximum duty cycle limitations (see section 4.1.2) and reduced resolution capability will be realized as the frequency increases over 500 Hz. Check your application for these limitations when operating over 500 Hz.

Any value of PWM operating frequency that may be calculated using this method can be set (i.e. it does not have to be an integer frequency value) For example, the commands of F32600 and G5 will cause an output frequency of 4.26 Hz. The limitation is only in the values that can be exactly realized with a period of 1/(1.536 MHz). Note that the Q command only displays the integer value of the frequency in the 'Hertz' field.

#### 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.

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 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 solid green. The initial orange setting identifies PWM Controller start-up, self-test and initialization.

Status LED color	Definition
green	PWM output operating normally
flashing green	PWM Driver / Controller in configuration mode
steady red	PWM Driver / Controller internal output fuse blown
flashing red	PWM Driver / Controller sensing open load
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. NOTE THAT 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, 2 to 500 Hz
- command source, analog input or RS-232 to PWM duty cycle operation
- PWM output duty cycle resolution, analog to PWM output operating mode, 1.0%, 0.5%, 0.25%
- analog input action, analog to PWM 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

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

Parameter	Factory Default Setting	Sample RS-232 Command(s)
Operating Frequency	100 Hz	f15360 g0
Command Source	analog input	a1
Analog to PWM Output Duty Cycle Resolution	0.5%	v25
Analog Output Action	normal	p0
External Enable Input	active	x1

Table 4.6-1. PWM Controller Configuration Default Settings.

Configuration may only be accomplished using the RS-232 serial port on the PWM Controller. The unit may be easily connected to a host PC where HyperTerm or another PC terminal emulation program may be used.

A kit is available from APM, Inc. which provides all the necessary cables and a power adapter for easily connecting the PWM Controller to a host PC for configuration and operation.

A Visual BASIC Graphical User Interface (GUI) host program is also 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 serial port, a terminal emulator such as HyperTerm and the commands of section 4.4, or, the VB GUI software. 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 – it is therefore not necessary to use the procedure below.

A recommended procedure for configuring the PWM Controller manually using a terminal emulation program is provided below. Refer to the RS-232 command definitions in section 4.4 of this manual.

1. Connect the PWM Controller to your PC as in figure 4.6-1 below. Note that the load is left unconnected.

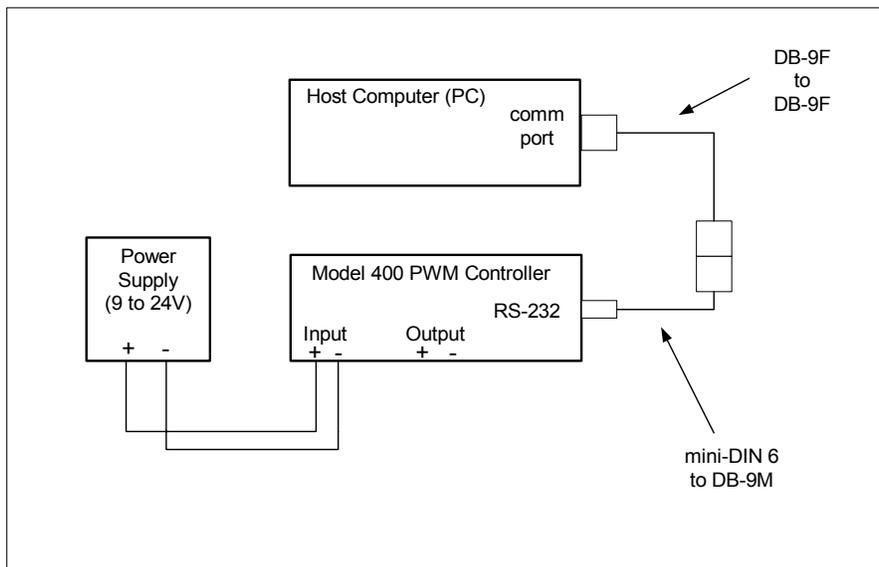


Figure 4.6-1. Recommended Set-up for PWM Controller Configuration

2. Apply power to the PWM Controller by turning on the power supply. The PWM Controller will start-up, display a start-up banner and display the '>' prompt for a command. The PWM function of the controller is currently active.
3. Enter configuration mode using the 'CO' command. The PWM Controller will respond that the controller is ready for configuration and its Status LED will flash green.
4. If this is the first time configuring the unit, type the 'I' command and record the serial number of your unit for future use.
5. Enter in commands to set the operating frequency, command source (analog or RS-232), duty cycle resolution in the analog operating mode, analog input action (normal or reverse), and an active or inactive external enable input.

Notes:

- a. Refer to the command syntax in section 4.4 of this manual.
- b. When operating in the RS-232 to PWM duty cycle output mode, settings to the duty cycle resolution and the analog input action are ignored.
- c. When setting RS-232 operation, the D command may be used to configure the start-up duty cycle.

6. Use the 'Q' command to verify / check all settings.
7. Use the 'E' command to save all settings in EEPROM. The PWM Controller will now power-up using these settings.
8. To exit configuration mode, type the 'C0' command.

Note that the PWM Controller may be re-configured at any time using either the manual procedure or using the VB GUI.

It is recommended that after configuration the user re-verify the power up settings prior to connection to the output device in order insure the settings and prevent any possible damage to the device under control.

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## **5.0 Warranty and Service**

### **5.1 Warranty**

The Model 400 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.

For reference, record the Model No. and Serial No. of your unit in the spaces provided below. The serial number may be recorded during configuration process of your unit.

PWM Controller Model	_____ 400 _____
Serial Number	_____

### **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. You must obtain an RA number for either warranty or non-warranty service. There is a minimum service charge for non-warranty service. This number must appear on the outside of a suitable shipping carton or on the packing list. 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 to ground (the negative 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 DUTY + 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 and interface 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. ***We have Solutions!***