USER'S MANUAL

MODEL 200
PULSE WIDTH MODULATION CONTROLLER

DOCUMENT NO. 00037-11

APPLIED PROCESSOR AND MEASUREMENT, INC.

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THANK YOU !

Thank you for purchasing the Applied Processor and Measurement, Inc. Model 200 Pulse Width Modulation 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 Modulator Controller and other future equipment, equally as innovative.

Applied Processor and Measurement, Inc. is committed to customer satisfaction and continuous improvement. We welcome your comments on the product and our services. Please use the forms in the Appendix for comments on the product and this manual.

Again, thank you for purchasing and using our product.

NOTICE

The information contained within this manual has been carefully checked and is believed to be accurate and up to date.

Applied Processor and Measurement, Inc. operates under the guidance of quality standards which include activities governing continuous improvement. Applied Processor and Measurement, Inc. may in the future make changes to this product or this manual, without notice, to improve the product reliability, performance, function, or design. Customers are welcomed to contact Applied Processor and Measurement, Inc. at any time for information on their product version, or potential future versions.

REVISION HISTORY

Rev	Date	Pages	Description	Chg No.
0	5/8/98	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 200 Pulse Width Modulator Controller is intended to be used in a laboratory / industrial environment. It is not intended for use in, or in conjunction with, any medical or life support appliances, devices, or systems. 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 Modulator 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 hazard.

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.

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1.0 Introduction

This manual describes the features, operating parameters, and operating procedures for the Model 200 Pulse Width Modulator Controller (PWM Controller or PWMC).

The Model 200 Pulse Width Modulated Controller generates a pulse width modulated variable frequency and duty cycle 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.

The PWM Controller contains microcomputer based circuitry which allows for precision generation of the output frequency and duty cycle. The microcomputer also provides digital control of the output parameters via the switches on the front panel. Using the switches and the integral LCD, the output frequency and duty cycle may be adjusted digitally, in 1 Hz and 0.5% steps respectively.

The PWM Controller may also be controlled via an RS-232 port. One letter ASCII based commands allow the frequency and duty cycle to be set and displayed. This capability allows the PWM Controller to be controlled by a host computer (e.g. a PC compatible).

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 controller. 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).

An analog input control is also available for the PWM Controller. This input allows the user to control the output frequency and duty cycle with analog control signals, 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, a laptop PC with a PCMCIA data acquisition card, or a PLC) could provide analog outputs to the PWM Controller in order to control a PWM device. In this manner, the PWM Controller is a signal conditioning element for the host computer and/or control system.

User programmable configuration options are available to set the power-up state of the PWM Controller.

1.1 Features

The following is a summary of the feature set of the Applied Processor and Measurement, Inc. Model 200 Pulse Width Controller.

- user / computer adjustable pulse width modulated output square wave with the following characteristics:
  - 1 to 200 Hz
  - 0 to 100 % duty cycle

- frequency and duty cycle adjustable in 1 Hz and 0.5% steps respectively

- duty cycle polarity control

- PWM output provides low side load control

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

- internally fused output - standard fuse, easily replaced

- controller operates from same power source that powers the load - an external power source, 7V to 24V DC must be supplied

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

- built-in user interface for adjustment of frequency and duty cycle (3 switches and LCD) allows precision digital control of the output parameters

- integral LCD, 2 line by 16 character, displays current frequency and duty cycle

- remote operation via RS-232 interface commands:
  - set frequency and duty cycle
  - readout current settings
  - enable/disable output
  - controller configuration

- analog input control - control frequency and duty cycle output with 2 analog inputs

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

1.2 Model Variations

Note that the Model 200 PWM Controller has all the features of the previous Model 100-01. The PWM Model 200 is only available as a 200-01. The previous Model 100 had three variants, providing options for RS-232 operation only (i.e. no LCD) and no analog control. Contact Applied Processor and Measurement, Inc. regarding variations or customizations of the Model 200.

1.3 Applications

The Model 200 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 to provide a PWM signal for life testing of solenoid valves, actuators, or relays.

The PWM Controller may also serve as a signal conditioning element for computer control systems since it may be commanded by either analog signals or an RS-232 command.

Application examples are provided in the Appendix.

2.0 Specifications

Parameter	**Description**	**Rating**
Output	Open Drain Power MOSFET	Pd_{max} = 50 watts 10A @ 5V 5A @ 9V 4A @ 12V 3A @ 15V 2A @ 24V
Frequency	1 to 200 Hz, adjustable in 1 Hz steps	max error < 0.2 % of setting
Duty Cycle	0 to 100 %, adjustable in 0.5 % steps	max error < 0.25 % duty cycle
Power	7V to 24V DC, regulated or un-regulated external source. Dual supply required for operating 5V loads	50 mA (typical)
RS-232	TX, RX, GND, 9600 baud, no parity, 8 data bits, 1 stop bit, DB9-M	
Operating Temp.		5 °C to 50 °C
Size	7.5 in. x 4 in. x 1.1 in. height (2.1 in. height by LCD)	
Display	2 Line x 16 Character Liquid Crystal	
Analog Control	PWM Parameter Control Inputs Frequency 20 mV / 1 Hz Duty Cycle 20 mV / 0.5%	+/- 4 mV +/- 4 mV
Analog Control	Absolute Maximum Input Voltage	5.00 V

3.0 Installation

WARNING

FOLLOW THE INSTALLATION INSTRUCTIONS CAREFULLY TO AVOID POSSIBLE DAMAGE TO THE PWM CONTROLLER, TO YOUR LOAD DEVICE OR SYSTEM UNDER CONTROL.

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

Figure 3.0-1 shows connection of the PWM Controller to a single device using a single power supply. The power supply sources current for both the PWM Controller and the device under control.

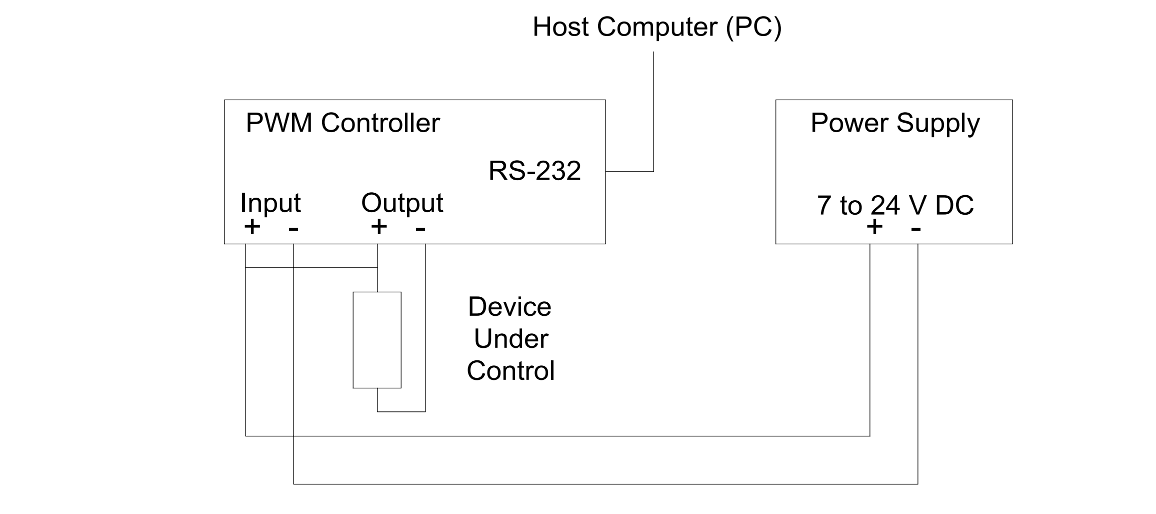

Figure 3.0-1 PWM Controller - Single Supply Connection.

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.

Figure 3.0-2 shows the recommended connection for a dual power supply connection. This configuration would be used for a load that is under test at 5V DC. (Note that the PWM Controller must be supplied 7V to 24V DC.)

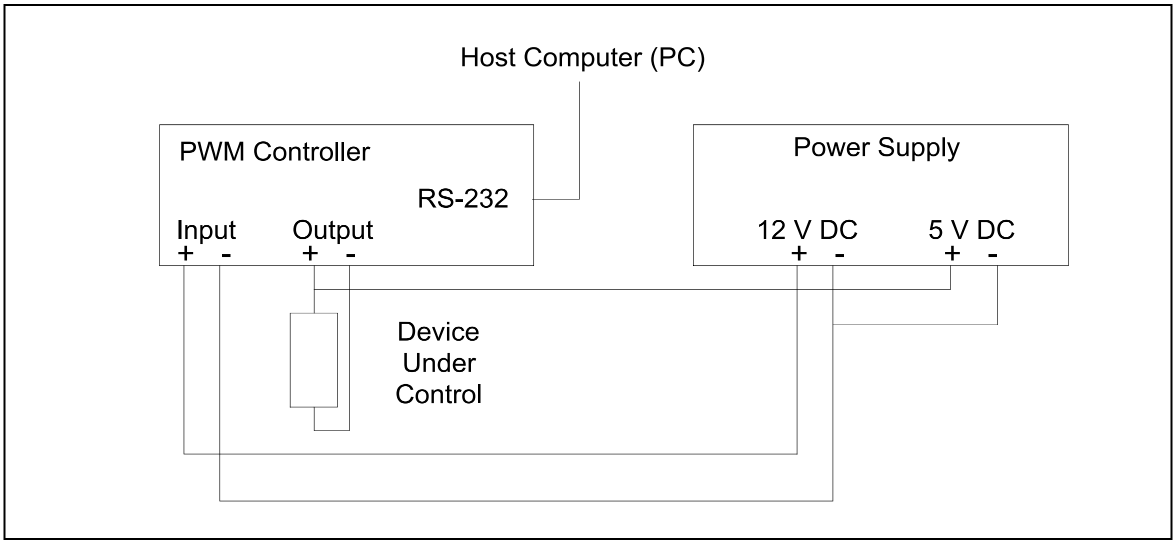

Figure 3.0-2 PWM Controller - Dual Supply Connection.

In the dual supply configuration, the power supply has a +12 V and a +5 V output. Only 50 mA of 12V is required to supply the PWM Controller whereas the +5V supply must be rated to accept the load under control. Note that the power supply negative output (- terminal) is commoned at the power supply. This connection must be made if the power supply outputs are isolated. Many laboratory power supplies have one common ground for +12V, -12V, and +5V outputs that are produced from the same supply, and 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.

Multiple loads may be tested using the PWM Controller. An example is shown in figure 3.0-3. Figure 3.0-3 illustrates the connection for controlling 3 loads with the PWM Controller. Any number of loads could be controlled provided that the total current of these devices is less than the maximum ratings defined in the PWM Controller specifications in Section 2.

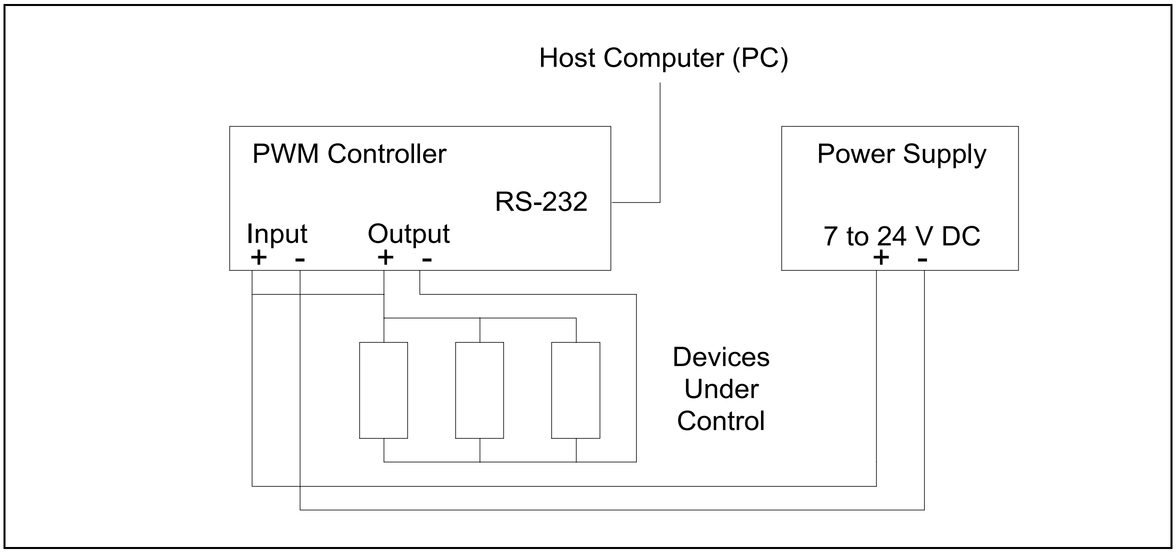

Figure 3.0-3 PWM Controller - Testing Multiple Loads.

The PWM Controller may also be used to simply supply a variable frequency and duty cycle square wave signal for a supervisory data acquisition and / or control system. One example of this would be to connect the PWM output to a device that is driven / controlled by a low level PWM signal.

To use the PWM Controller as a signal generator, connect the unit as shown in figure 3.0-1 using a resistor as the "Device Under Control". For example, using a 12V power supply, a 330 Ω, ½ W resistor could be placed directly across the PWM Output terminals on the controller.

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. Use the polarity function (see section 4.1.1) built-in to the PWM Controller to account for the desired signal level.

For more information and applications on using the PWM Controller as a signal generator / signal conditioner for control systems, see Appendix A.

3.1 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.

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.

Fuse holder clips are provided on the back of the PWM controller main circuit board. To replace the fuse in the unit remove the back cover. Note that the circuit board need not be removed from the top of the enclosure, the fuse is completely accessible from the back of the unit by simply removing the back cover. The PWM Controller contains static sensitive circuitry, be sure to handle the unit so as to avoid touching the circuitry on the front of the circuit board. The fuse is a standard 3AG size glass fuse. A 3AG Slo-Blo 12 Amp fuse is installed in the unit from the factory (Littelfuse part number 313 012). Be sure to fuse the PWM Controller properly based on the current draw of the device / load under test.

3.2 Internal Diode

The PWM Controller possesses an internal 1N4004 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 fuse connection). The 1N4004 is a general purpose diode and suits most needs when working with inductive loads such as valve solenoids and relays. If your application uses another type of diode, the 1N4004 may be easily removed from the circuit and your diode may be installed on the PWM Controller externally, across the + and - output binding posts.

To remove the diode from the output circuit, remove the back cover. A black shorting jumper is present on the circuit board near the fuse. To remove the 1N4004 from the output circuit simply remove the jumper. Note that the circuit board need not be removed from the top of the enclosure, the diode jumper is completely accessible from the back of the unit by simply removing the back cover.

3.3 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 DB-9 connector on the upper right corner of the unit. The pinout of the DB-9 is provided in table 3.3-1. Pins not shown in the table are not connected internally within the PWM Controller.

DB-9 Pin Number	Signal
2	Transmit Data (TXD)
3	Receive Data (RXD)
5	GND

Table 3.3-1. DB-9 RS-232 Remote Port Pinout.

To connect a host computer, control system or PC to the PWM Controller, use a cable wired as defined in table 3.3-2. This table provides connections to standard RS-232 connectors for PC's. Both 9 pin and 25 pin versions are shown. Note that for a PC with a DB-9, a straight through cable may be used. Consult your PC or equipment manual for proper RS-232 pinout.

PWM Controller Signal	PWM Controller DB-9 Pin	PC Signal	DB-9 Pin	DB-25 Pin
TXD	2	RXD	2	3
RXD	3	TXD	3	2
GND	5	GND	5	7

Table 3.3-2. RS-232 Cable Wiring.

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.

3.4 Analog Input Connections

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.

Analog control allows control of the PWM output frequency and duty cycle from the analog input port on the upper left side of the unit. The pinout of this port is shown in table 3.4-1. In order to maintain compatibility with future versions of the PWM Controller, make no connections to the pins labeled as "Do Not Connect". The port pins are connected via a standard, commercially available, 8 pin connector (AMP part number 640440-8, 8 pin, discrete, insulation displacement connector housing) . A mating plug is supplied with the unit when purchased, and is installed in the analog input port at the factory. If you are not going to use analog input mode for PWM control, remove the connector from the unit and store it with the operations manual for later use.

Pin Number	Signal
1	Frequency Control
2	Duty Cycle Control
3	Do Not Connect
4	GND
5	Do Not Connect
6	Do Not Connect
7	Do Not Connect
8	Do Not Connect

Table 3.4-1. Analog Input Port Pinout.

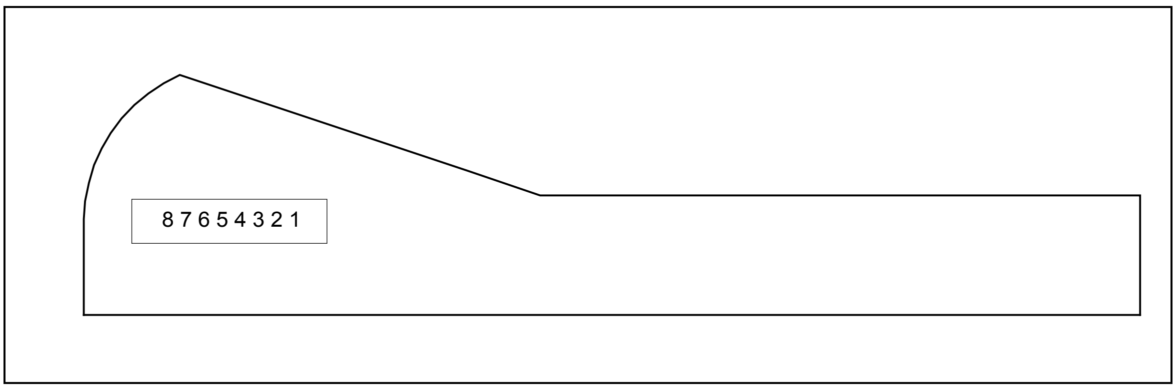

Figure 3.4-1 Analog Input 8 Pin Connector Pinout Orientation.

Figure 3.4-1 illustrates the 8 pin connector pinout as viewed when looking directly at the connector (from the left side of the PWMC unit).

Operation using the Analog Input for control of the PWM Output Frequency and Duty Cycle is described in the Operation section of this manual, section 4.4.

4.0 Operation

This section describes operation of the PWM Controller. All operational modes are described: pushbutton interface (front panel), RS-232, and analog input control.

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 PWM Controller is shown in figure 4.1-1.

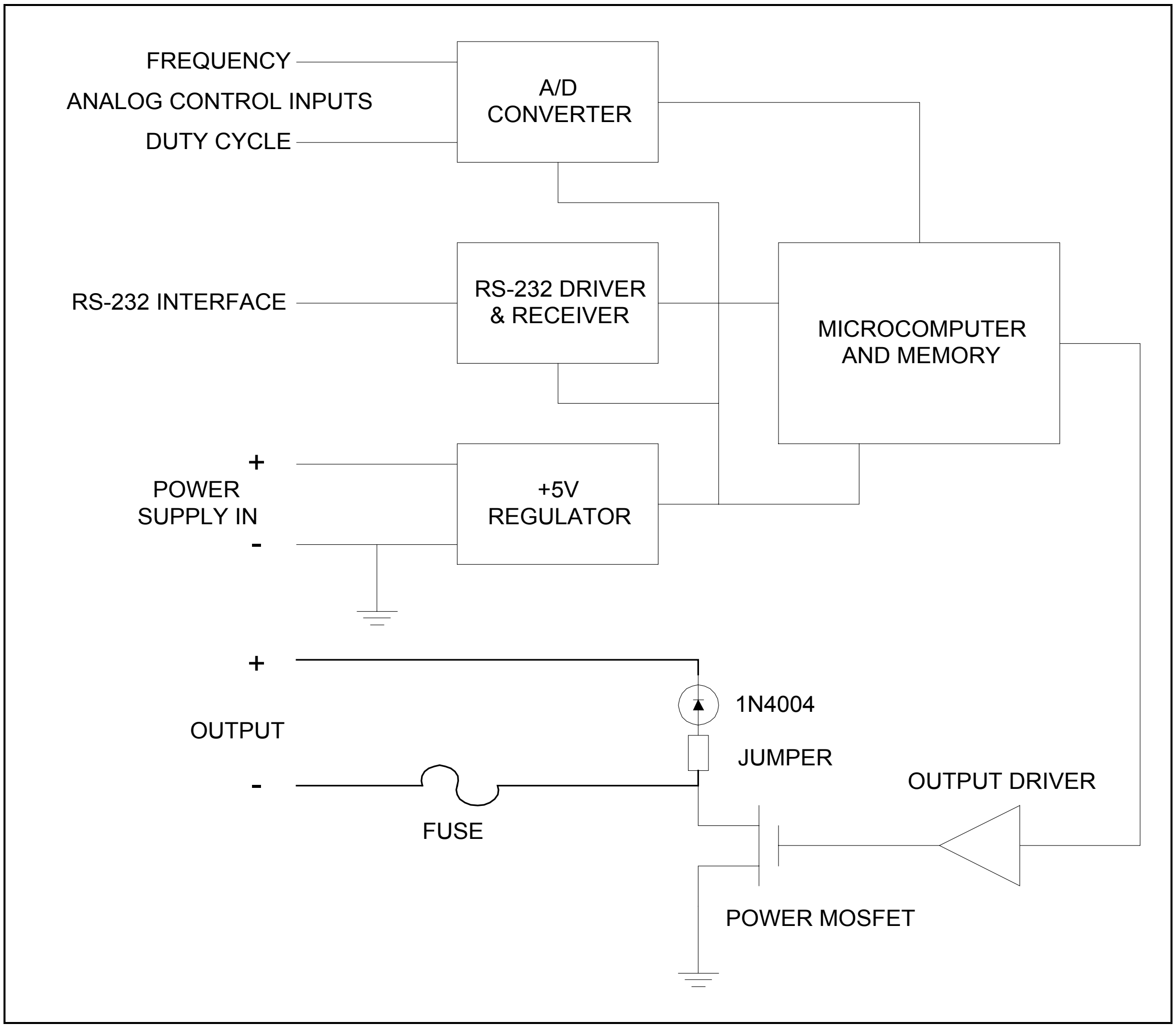

Figure 4.1-1 PWM Controller - Block Diagram.

The PWM Controller output timing is based on a crystal oscillator which drives timer / counter resources internal to the microcontroller. The user enters the output parameters into the PWM Controller via the RS-232 port or the pushbutton / LCD interface. The microcontroller calculates signal timings based on these parameters and controls a digital output bit on 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 1N4004).

The PWM Controller analog input control capability is provided by an on board A/D converter IC. This 12-bit converter produces a digital representation of the frequency and duty cycle control inputs. The microcomputer scales the digital representation in order to produce the proper frequency and duty cycle ranges.

PWM Controller embedded microcomputer software provides the operational functionality of the controller. The controller software and configuration parameters are stored in EEPROM. This allows for field upgrade and customization of the PWM Controller (see Section 5).

4.1.1 Polarity

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.

Operational capabilities within the PWM Controller include the ability to set the PWM Output polarity to either low or high. Observing the voltage from the negative terminal of the control output to ground, when the load is energized, the voltage measured will be zero. Conversely, when the load is not energized, the supply voltage will be measured across the output. This signal state and the action of the load in this manner occurs when the polarity of the PWM Controller is set to low. Setting the polarity to high will reverse the action of the PWM Output.

Consider the signal shown in figure 4.1.1-1. The figure illustrates a 10 Hz PWM signal. Using the above discussion of polarity, the signal shown represents a 80% duty cycle PWM signal with low polarity, or, 20% duty cycle at high polarity. When setting the PWM Controller to a specific duty cycle, consider the polarity setting and the effect on the load / device under control.

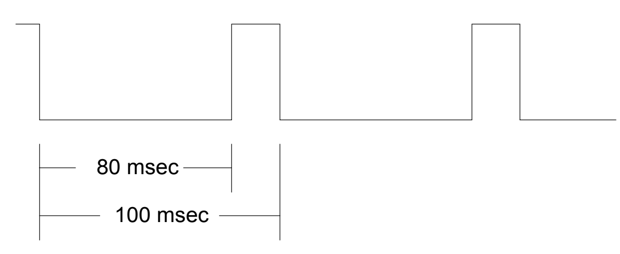

Figure 4.1.1-1 PWM Controller - Polarity Example.

4.2 PWM Controller Operation - Operational Modes

The PWM Controller operates in one of three modes: Run, Analog Input (Ain) or Off. This is displayed as a three letter "code" under the status field on the LCD. The characteristics of the three modes are as follows:

Run:

The PWM Output is operational: output frequency, duty cycle, and duty cycle polarity are displayed, and the output is operating at these settings. Both the front panel interface pushbuttons and the remote port are active and ready to accept commands. Changes requested by either interface shall be translated to the output and to the LCD immediately.

Ain:

The PWM Output is operational: output frequency, duty cycle, and duty cycle polarity are displayed, and the output is operating at these settings. The PWM output frequency and duty cycle are controlled by the analog inputs. See section 4.4 for details on the analog input voltage translation to frequency and duty cycle. In Ain mode, the front panel pushbuttons and the remote port (RS-232) control of frequency and duty cycle are disabled. Changes may be made to the duty cycle polarity and the mode of operation from either the pushbuttons or the remote port.

Off:

The PWM Output is disabled: the values of the frequency, duty cycle, and duty cycle polarity are displayed and are controlled by either the pushbuttons or the remote port (RS-232) or the analog inputs. However, these values are not translated to the output until the Run mode is enabled. The output is set in accordance with the current polarity setting.

4.3 PWM Controller Operation

4.3.1 Front Panel Interface

The PWM Controller is equipped with a front panel interface which possess three pushbuttons for control of the PWM Output and a 2 line by 16 character Liquid Crystal Display (LCD) for display of the output parameters. This section describes how to operate the PWM Controller using the front panel interface.

The PWM Controller may also be controlled using the remote port (RS-232 interface). The remote port may be used in conjunction with a PC running Windows Terminal. All the operational capabilities of the front panel interface are available via the remote port as well. See section 4.3.2 for details on operation using the remote port.

There are three pushbuttons on the front panel interface for use in operating the PWM Controller, they are labeled: UP, DOWN and SELECT. Their function is defined as follows:

UP - will change value by incrementing
DOWN - will change value by decrementing
SELECT - selects field on the display that UP or DOWN will operate on (moves cursor).

The PWM Controller front panel interface uses a 2 line by 16 character alphanumeric LCD for display of the PWM Output parameters.

When the PWM Controller is powered on, a sign on message will be displayed on the LCD. During this time the PWM Output will begin operating at the configured settings (see section 4.6 on Configuration). After the sign on message is complete, the LCD shall display the operational screen. The main operational screen for default power on configuration is shown below:

```
Freq  Duty  Stat
  1    0.0L Off_
```

the main operational screen format can be represented as follows:

```
FreqssDutyssStat
XXXssYYY.YPsZZZ_
```

with the display fields defined as follows:

XXX	- frequency [1..200 Hz]
YYY.Y	- duty cycle [0.0 .. 100.0 %]
P	- duty cycle polarity [H or L]
ZZZ	- current mode [Run, Ain, or Off]
s	- whitespace
_	- cursor.

To change any value displayed on the LCD, use the SELECT pushbutton to locate the cursor on the field to be changed, then, use the UP or DOWN pushbuttons to change the current value. The pushbuttons possess a "fast" increment or decrement feature that begins a few seconds after holding the button down. This allows large changes in the frequency or duty cycle to be accomplished quickly.

The description above provides the current values or ranges available for each parameter. For example, the duty cycle may be varied to any value between 0.0% and 100.0% (inclusive). Pressing the UP pushbutton when the value of the duty cycle is at 100.0% will no longer change the value. This is true for any maximum or minimum value for frequency and duty cycle. When using the UP or DOWN pushbuttons to change the polarity, the controller simply cycles through the values available (H or L). This is also true for changes in the mode (Run or Off) on models without analog input capability. On models with the analog input, the UP pushbutton is used to enter Run mode, DOWN to enter Ain. When operating in either Run or Ain mode, either pushbutton (UP or DOWN) will cause the controller to return to the Off state.

4.3.2 Remote (RS-232) Interface

All model variations of the PWM Controller possess an RS-232 port for remote control. All operational features are accessible via the RS-232 port using ASCII character based commands. This allows the PWM Controller to be commanded remotely via a computer executing a terminal emulation program, or, a computer executing software. This feature also allows the PWMC to be commanded via industrial control systems or PLC’s (Programmable Logic Controllers).

When the PWM Controller is powered on, a sign on message will be transmitted out the serial interface. During this time the PWM Output will begin operating at the default or configured settings (see section 4.6 on Configuration). After the sign on message is complete, a star (*) 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 command summary is shown below. The carriage return is shown as <CR>.

A x <CR>	analog input enable (x = 1) disable (x = 0)
D xxx.x <CR>	set duty cycle to xxx.x = [0.0 ..100.0] %
E <CR>	enable output
F xxx <CR>	set frequency to xxx = [1..200] Hz
IS <CR>	report system information - Model No., Serial No., S/W rev.
P x <CR>	set duty cycle polarity, active high (x = 1), active low (x = 0)
R <CR>	report current frequency, duty cycle, polarity and mode
S <CR>	disable (stop) output
CFN <CR>	save configuration data

Detailed descriptions of the instructions follow. Note that in all cases spaces are ignored. No other punctuation or symbols should be used. Characters must be uppercase. 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 decimal.

Command: Enable / Disable Analog Input Control
Syntax: A x <CR>
Parameters: x, where x = 0 or 1
Description: The A command enables or disables PWM Controller operation using the analog input ports accessible on the DIN connector. Use the parameter “0” for disabling analog input control, use “1” for enabling analog input control. Sending commands to a PWM Controller that is already operating in that mode will have no effect. Note that the output must be enabled with the E command for the A 1 command to have effect.
Example: `A 0 <CR>` - will disable analog input operation

Command: Set the PWM Output Duty Cycle
Syntax: D xxx.x <CR>
Parameters: xxx.x, where xxx.x = 0.0 to 100.0, in 0.5 % increments
Description: Use the D command to remotely set the pulse output duty cycle. The value xxx.x must be in the range of 0.0 to 100.0 and represents % steps. The minimum step resolution of the PWM Controller is 0.5%. The duty cycle value supplied may be 1, 2, 3, or 4 characters in length, leading zeroes are ignored, and the decimal is assumed to be zero when not present. 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”. The percent sign is not required and should not be used.
Example: `D 34 <CR>` - will set the output duty cycle to 34%
Example: `D 0.5 <CR>` - will set the output duty cycle to 0.5%

Command: Enable Output
Syntax: E <CR>
Parameters: none
Description: The E command will enable the PWM Controller output. This allows the controller to operate in the (normal) run mode, or, the analog input mode (if enabled).
Example: `E <CR>` - will enable the output

Command: Set the PWM Output Frequency
Syntax: F xxx <CR>
Parameters: xxx, where xxx = 1 to 200, in 1 Hz increments
Description: Use the F command to remotely set the pulse output frequency. The value xxx must be in the range of 1 to 200 and represent 1 Hz steps. The minimum step resolution of the

PWM Controller is 1 Hz. The frequency value supplied may be 1, 2 or 3 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”. The engineering units designation of “Hz” should not be typed.

Example: `F 105 <CR>` - will set the output frequency to 105 Hz

Command: Information on System
Syntax: IS <CR>
Parameters: none
Description: Use the IS command to provide information on the PWM Controller model number, serial number and software version number. This information is useful in service calls to Applied Processor and Measurement, Inc. and maintaining your unit with respect to software upgrades. (See section 5.3).

Example: `IS <CR>` - reports the system information

```
Model No. 200-01
S/W rev.   0
S/N 100115
```

- PWM Controller response (3 lines)

Command: Set Output Polarity
Syntax: P x <CR>
Parameters: x, where x = 0 or 1
Description: The P command sets the PWM Controller output polarity. Use the parameter “0” to set the polarity to active low, use a “1” for active high. Sending commands to a PWM Controller that is already operating in that polarity will have no effect.

Example: `P 1 <CR>` - will set active high polarity

Command: Report PWM Output Parameters
Syntax: R <CR>
Parameters: none
Description: The R command reports the current PWM pulse parameters - the frequency, duty cycle, polarity and operational mode. Note that when operating in the Analog Input control mode, the frequency and duty cycle reported will be the settings that are derived from the analog input control signals.

Example: `R <CR>` - reports output parameters

```
Frequency  = 100
Duty Cycle =  30.0L
Mode = Run
```

- PWM Controller response (3 lines)

Command: Disable (Stop) Output
Syntax: S <CR>
Parameters: none
Description: The S command will disable the PWM Controller output. The controller output will be forced to a permanently high or low output state depending upon the polarity setting. The PWM Controller will remain stopped until the E command is issued (or the Run, or Ain modes are enabled from the pushbutton interface).

Example: `S <CR>` - will disable the output

Command: Save PWM Output Configuration
Syntax: CFN <CR>
Parameters: none
Description: The CFN command is used to save the power on settings of the PWM Controller. After a configuration is completed, the PWM Controller will start up and operate using the last parameter settings. The parameters saved are: frequency, duty cycle, polarity, and mode. The

PWM Controller will stop operation after saving the parameters, the unit must be power cycled. See section 4.6 for details on the configuration process.

Example: `CFN <CR>` - save configuration

4.4 PWM Controller Operation - Analog Input Control

The PWM Controller operating in the Analog Input Control is able to provide adjustment of the operating frequency and duty cycle via analog inputs. The analog input controls are connected via an 8 pin connector on the front left side of the unit. (For connector pinout, see section 3.4.)

As per the specifications (section 2.0), the analog control signal varies the frequency or duty cycle at a rate of 20 mV per Hz or 0.5% duty respectively. The relationship is given in the equations below:

Output Frequency = Voltage Input / 0.020

and

Output Duty Cycle = Voltage Input / 0.020 * 0.5%.

Note that the control signals are limited by the operating specifications of the controller. That is, the frequency output is limited to operating from 1 to 200 Hz and the duty cycle operates over a range of 0.0 to 100.0%. The table below quantifies these values and the corresponding analog control signal values. Note that the values of frequency and duty cycle "saturate" over the maximum values.

Analog Voltage	Frequency
0.0 V	1 Hz
0.020 V	1 Hz
0.200 V	10 Hz
1.000 V	50 Hz
2.000 V	100 Hz
4.000 V	200 Hz
5.000 V	200 Hz

Table 4.4-1. Frequency vs. Analog Input

Analog Voltage	Duty Cycle
0.0 V	0%
0.020	0.5%
0.040 V	1%
0.400 V	10%
2.000 V	50%
4.000 V	100%
5.000 V	100%

Table 4.4-2. Duty Cycle vs. Analog Input

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 4.0 V. Command signals over 5.0 V could damage the PWM Controller internal A/D converter.

4.5 PWM Controller Operation - Precedence

The PWM Controller software uses rules of precedence with respect to its modes of operation. Dependent on the operational mode selected, the rules of precedence within the PWM Controller software govern how the controls effect the PWM Controller output.

The following paragraphs outline the operation of the PWM Controller with respect to its current mode of operation.

Mode: Run (normal)
Controls Effected: no restrictions
Summary: commands to change mode, frequency, duty cycle and polarity via the pushbuttons or the RS-232 interface are accepted and implemented immediately (on the output).

Mode: Ain (analog input)
Controls Effected: Front Panel Pushbuttons, RS-232
Summary: changes to the frequency and duty cycle via the pushbuttons and remote port (RS-232) are disabled, analog inputs translate to action on the frequency and duty cycle of the output, mode and polarity can be controlled with RS-232 and / or pushbuttons.

Mode: Off
Controls Effected: no restrictions
Summary: values of frequency, duty cycle and polarity may be changed from any source, output does not reflect it until re-enabled by entering Run or Ain mode.

Note that commands (from any source: remote port or pushbuttons) that change the mode of operation are always allowable. Only commands that change the frequency and the duty cycle are subject to the rules of precedence.

4.6 PWM Controller Configuration

When the PWM Controller is powered on, the parameters of PWM output are initialized to settings contained within the memory of the PWM microprocessor system. The user is able to configure these initial power-up settings. This enables tests to be continued on devices even though the overall system may have suffered a power loss.

Factory default settings for the PWM parameters are as follows:

frequency	1 Hz
duty cycle	0%
polarity	low
output	disabled (off).

The factory default settings guarantee a non-energized condition on the output (assuming an active low polarity). If your device is opposite polarity, the default settings may be changed to insure a non-energized condition for that device.

Configuration may be accomplished using either the front panel interface (depending on your particular model), or, the RS-232 port (for all models).

To change the power on settings of the PWM Controller, connect the unit to a power source as shown in the installation instructions.

WARNING

IT IS RECOMMENDED NOT TO HAVE THE OUTPUT DEVICE (LOAD) CONNECTED DURING CONFIGURATION. IF YOUR SYSTEM CANNOT TOLERATE A FULL ON OR OFF OUTPUT STATE, THE LOAD SHOULD NOT BE CONNECTED DURING CONFIGURATION. AFTER COMPLETION OF INTERNAL PROGRAMMING, THE PWM CONTROLLER WILL DE-ENERGIZE THE OUTPUT TO THE CURRENTLY CONFIGURED POLARITY. IF YOUR SYSTEM CANNOT TOLERATE THIS, DISCONNECT IT AND RE-CONNECT AFTER CONFIGURATION IS COMPLETE.

Power on the PWM Controller, wait for the initial messages, and let the system start-up. If you are doing this for the first time, the system will initialize to the factory default settings shown above. Adjust the frequency, duty cycle, and polarity to the desired settings using either the front panel interface or the RS-232 remote commands. Lastly, set the desired operational mode. Note that the mode selected shall be the operational mode that the PWM Controller use on subsequent power up conditions. Normal rules of operational precedence apply. For example, if the Analog Input operational mode is selected, the PWM Controller shall power on, and immediately measure the frequency and duty cycle analog inputs, and set the output parameters accordingly. In this mode, the frequency and duty cycle values cannot be set on the screen using the front panel interface, the analog inputs are used.

The configuration can now be saved such that the PWM Controller will power on in this state for all subsequent power cycles until re-configured by the user. The settings are stored in the PWM Controller internal EEPROM and may be reprogrammed at any time using this procedure. The parameters can be saved by using one of two methods. Using the front panel interface, place the cursor on the “Stat” field using the SELECT pushbutton. Simultaneously press the UP and DOWN pushbuttons until the LCD displays “PWMC Stop Cfg_”. The parameters may also be saved using the remote command interface (RS-232) and typing CFN <Enter>.

After commanding the PWM Controller configuration using either method above, the unit will stop operating, force the output to a de-energized state (based on the polarity setting), and display a stop message. The PWM Controller must be powered off in order to become operational again. When subsequently powered on, the unit will begin operating under the conditions just set during the configuration procedure above.

It is recommended that the user 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.

4.7 PWM Output at Power On

The PWM Controller output transistor is directly connected via a FET driver to a digital output on the internal microcontroller. At power up, the microcontroller executes a power on reset for approximately 200 msec. During this time the microcontroller digital outputs are forced to a logic high state. This causes the output transistor to be momentarily on at power up. For devices that are active low polarity, this could cause a start up pulse on the device. This anomaly can also occur on power down as the internal 5V power drops forcing a low voltage reset on the microcontroller, however, the external device still has enough power to pulse. For devices that are active high polarity, this phenomena will have no effect.

In most cases this should pose no problem to the test or application in question. Often the power source in question may rise such that the reset sequence completes before there is enough power to source the device under control. In this case, this phenomena should be unnoticeable. The anomaly is described here for completeness.

There is no solution internal to the PWM Controller for this problem. If this anomaly is disturbing to your system, a manual switch or relay placed on the power to the load / device would delay power to the device long enough for the PWM Controller to reset.

5.0 Warranty and Service

5.1 Warranty

The PWMC-200 is warranted for 90 days from the time of purchase. This includes workmanship and manufacturer defects. It does not include defects caused by misuse.

For reference, record the Model No. and Serial No. of your unit in the spaces provided below.

PWM Controller Model ____________________________

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, you must call Applied Processor and Measurement, Inc. to obtain a Return Authorization (RA) Number. You must obtain an RA number for either warranty or non-warranty service. This number must appear on the outside of a suitable shipping carton. B.D.B Solutions, 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 may be contacted at the following address / phone / E-mail:

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

Phone: (716) 741-1141
FAX: (716) 741-1142
E-mail: BDBeng@aol.com

5.3 Diagnostics

Currently, there are no self diagnostic tools within the PWM Controller. However, there are 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).

If the unit is typically operated using the front panel interface, connect the remote port to a PC as described in section 3.3. It is possible that the LCD has failed, in which case, the remote port interface may be used to operate the controller until the unit may be serviced. If the unit is still not operable, observation of the messages on the remote port may assist in diagnosing the unit.

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.

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 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.

LED and resistor - placing an LED with a current limit resistor on the output will provide an easy diagnostic tool. The LED should visibly flash up to approximately 25 Hz. A variance in intensity should be discernible at higher frequencies by varying the duty cycle.

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

As described in section 4.1, the PWM Controller has field 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 field upgraded (connection to a PC is required). Releases for bug-fixes will be provided at no charge.

5.5 Customization

Since the PWM Controller functionality is software controlled, and, the controller may be field upgraded, the unit may be customized to suit your 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 problem with one of our engineers. ***We have Solutions!***

Appendix A - Application Examples

Below are listed only a few ideas regarding the use of the PWM Controller. Applied Processor and Measurement, Inc. welcomes information on your application. Use the comment form in Appendix C or FAX us a description on your application. Our goal is to design and supply the products you need.

Thank you!

A.1 Using the PWM Controller as a Signal Conditioner

Beyond using the PWM Controller as a durability tester for electromechanical devices, the controller may be used as a signal generating element. This example illustrates a potential control system architecture using the PWM Controller as a signal conditioner.

As discussed in the User's Manual installation section, the PWM Controller may be used as a signal conditioner (signal generator) for use in data acquisition and control systems. This appendix section describes how this is accomplished and potential uses for this arrangement.

The application of pulse width modulation as a method of transmitting control information in electromechanical systems is steadily increasing. Beyond using the PWM Controller as test equipment for durability and life cycle testing of devices, the controller may be used as an interface for an electromechanical control element.

As discussed in the installation section of this manual, the PWM Controller will provide a PWM square wave signal by simply applying a load across the output terminals of the controller. This arrangement is shown in figure A.1-1. A resistor provides the load, and, the signal can be obtained from the controller as shown in the figure. This signal can then be supplied to any device requiring a PWM square wave for control. Be sure to apply the correct voltage level to your device.

The advantage to using the PWM Controller as a signal conditioner is in the methods that are provided to command the PWM Controller. The PWM Controller has the ability to accept analog control signals or RS-232 ASCII character based commands. Typically in data acquisition and control systems, analog outputs (voltage or 0 to 20 mA) or serial ports are usually available. These systems may also possess digital I/O or possible timer / counter facilities, but, these resources may not be able to easily produce PWM signals.

An example of a data acquisition and control application is shown in figure A.1-1. This example illustrates both types of connections between the control system and the PWM Controller (both are not required).

In this application, a control system is constructed which uses a motor to drive a process. In this example, the motor is the device being developed, and, it requires a PWM signal at 100 Hz for commanding the motor speed. That is, the speed is directly proportional to the input signal duty cycle. The motor is to be controlled by a PLC (Programmable Logic Controller) which is also used to monitor the process. The PLC must monitor the process and control the motor speed accordingly. The PC shown in the system provides a user interface for the test operator and stores the test data and generates reports. This scenario represents a common development equipment architecture which may be found in industry today.

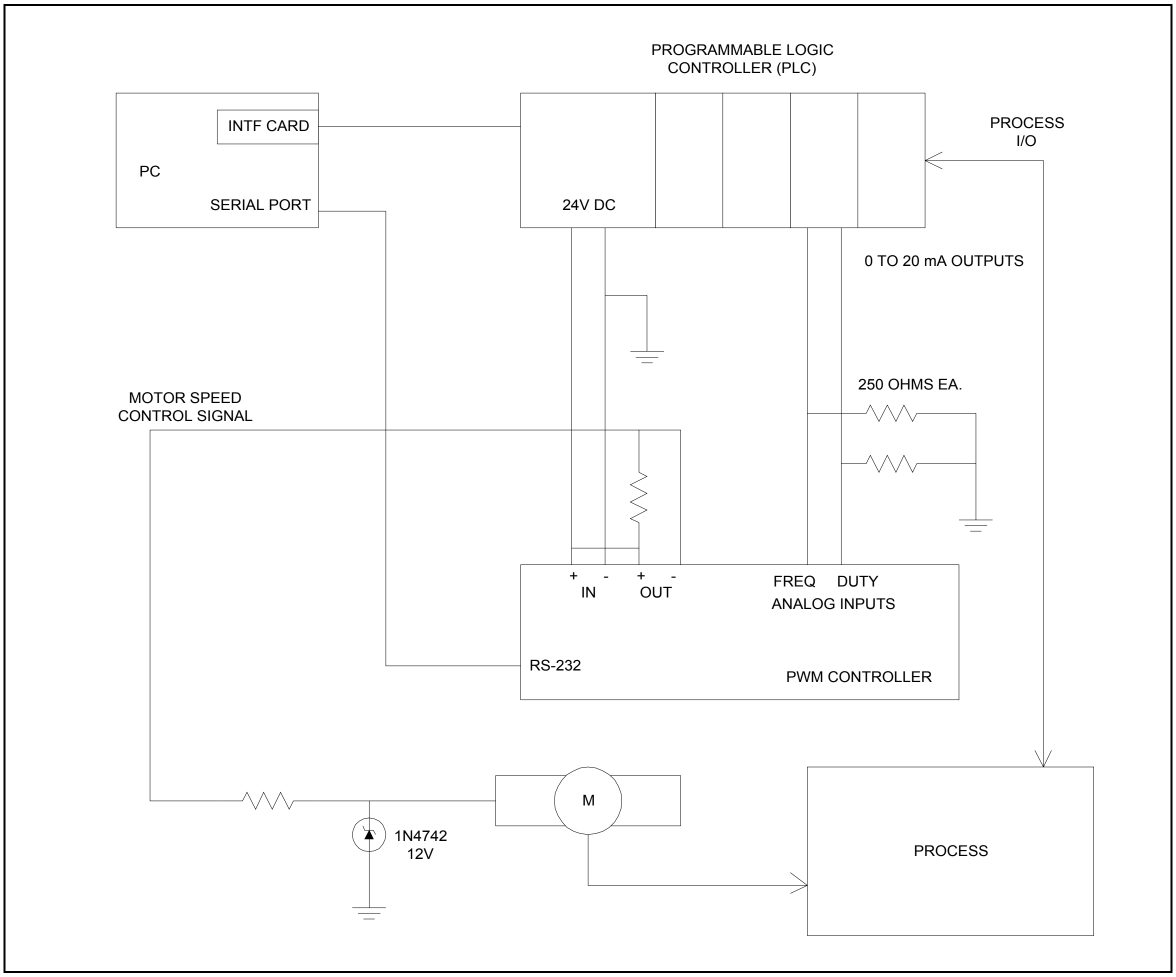

Figure A.1-1. PWM Controller - Signal Conditioning Example.

The PWM Controller supplies the PWM signal to the motor in the process. Two 0 to 20 mA output channels on the PLC, which are converted to voltage using the 250 ohm resistor, provide the control signal to the PWM Controller. Note that one output is fixed to 2.000 V to command a fixed frequency output at 100 Hz. This could also be done by hardwiring a fixed resistor combination from the power supply to the frequency input. The table below shows the signal translation from the PLC to the duty cycle output.

Current Output (mA)	Voltage to PWM Controller (V)	Duty Cycle Output (%)
0	0	0
0.16	0.040	1
3.2	0.800	10
8.0	2.000	50
16.0	4.000	100

Table A.1-1. Example, Current to Duty Cycle Conversion Data.

The power source used for the PWM Controller is the 24V DC power supply available on the PLC. In this application, the motor PWM control signal amplitude must be 12V (+/- 10%). The PLC 24V DC supply powers the PWM Controller and supplies load power. The 24V amplitude of the PWM signal generated is regulated down by the resistor, zener diode network which ultimately reduces the signal to the proper (12V) level for the motor speed control. By using this configuration, the need for adding an external power supply for the PWM Controller is avoided.

Note that the PC is also shown connected to the PWM Controller. If 0 to 20 mA outputs are not available in the PLC, the PC may be used to command the PWM Controller. In that scenario, the PC would need to receive the speed command information from the PLC, translate it into a PWM Controller command (for example: D 30 <CR>, for a 30.0% duty cycle), and transmit the command to the PWM Controller.

A.2 Using the PWM Controller with a Laptop PC and a PCMCIA Data Acquisition Card

The example below illustrates how a PC may be directly interfaced to the PWM Controller.

A currently popular architecture for data acquisition and control systems is a laptop PC which uses a multifunction PCMCIA data acquisition card. Because of the laptop PC and the versatility of the data acquisition card (analog and digital I/O), the configuration yields a very powerful, yet compact and portable controller and /or data system. The figure below (A.2-1) shows a PC with a data acquisition card which drives the PWM Controller. In this example, the PWM Controller drives a device requiring a PWM signal for control. The PC, through the PCMCIA card, monitors the system (for example temperatures, pressures, etc.) with its analog inputs, and provides analog outputs for frequency and duty cycle control. Software drivers (usually in C) are provided by the PCMCIA card supplier.

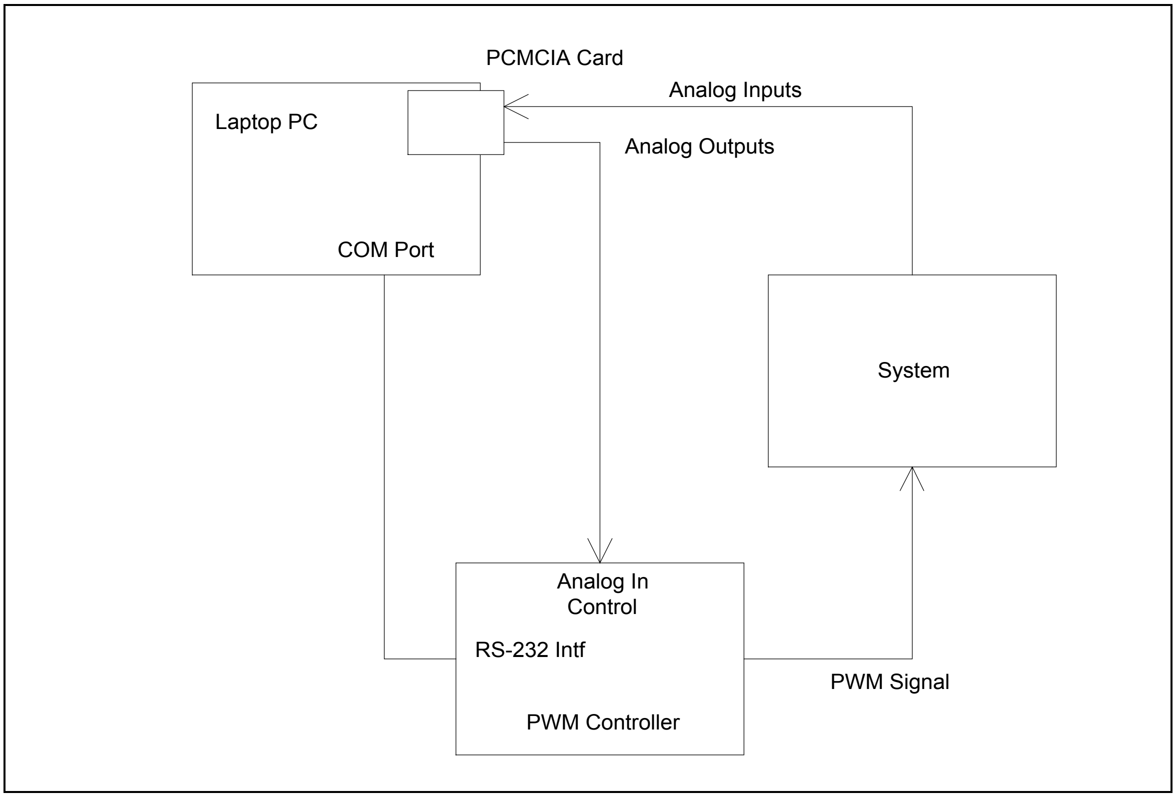

Figure A.2-1. PWM Controller PC / PCMCIA Interface Example.

Note that the PWM Controller may be directly connected to the PC via the serial port. The control software would need to interface with the PC COM port and send the PWM Controller the proper ASCII commands for setting the frequency and duty cycle (see the operations section of this manual).

A.3 Commanding the PWM Controller with PC Software

The following example C code commands the PWM Controller via the COM port on a PC. The example program demonstrates how a PC may communicate with the PWM Controller remote port command set. The software commands a test sequence of 5 different duty cycles at a fixed PWM frequency (a potential validation test on a solenoid). The duty cycle is changed every 5 minutes.

```
/*==============================================================*/
/*                                                              */
/* DEMO1.C                                                      */
/*                                                              */
/* DATE:  3/29/96                                               */
/*                                                              */
/* Description:  PWM Controller Demo Software                   */
/*  This program controls the PWMC via a PC serial port.        */
/*  A sample program changes the controller duty cycle          */
/*  for a durability test every 5 minutes.                      */
/*                                                              */
/*  This program assumes the use of PC COM2 port                */
/*   at 9600,N,8,1.                                             */
/*                                                              */
/*==============================================================*/

#include <stdio.h>
#include <dos.h>
#include <conio.h>
#include <time.h>

char            *cptr;

void main(void)
{

int             duty_index;
char            a;
time_t          t;
unsigned long   tmp;

printf("\nPWMC Demo - Durability Test Controller\n");
printf("Hit any key to stop\n\n");

/* init PWMC */
cptr = "F 100\n";       /* out freq fixed at 100 Hz */
sendcmd();
cptr = "P 0\n";         /* low polarity */
sendcmd();
cptr = "E\n";           /* enable output */
sendcmd();

duty_index = 0;
```

```
do
      {
      switch (duty_index)             /* set duty cycle */
            {
            case 0:
                  cptr = "D 10\n";
                  printf("Duty Cycle set to 10\n");
                  break;
            case 1:
                  cptr = "D 25\n";
                  printf("Duty Cycle set to 25\n");
                  break;
            case 2:
                  cptr = "D 50\n";
                  printf("Duty Cycle set to 50\n");
                  break;
            case 3:
                  cptr = "D 75\n";
                  printf("Duty Cycle set to 75\n");
                  break;
            case 4:
                  cptr = "D 90\n";
                  printf("Duty Cycle set to 90\n");
                  break;
            }

      sendcmd();                      /* send duty command */

      duty_index++;                   /* increment index */
      if (duty_index == 5)
            duty_index = 0;

      t=time(NULL);
      tmp=t;
      do                              /* time delay loop */
            {
            t=time(NULL);
            } while (t < tmp+300 && !kbhit());

      } while (!kbhit());

a = getch();

cptr = "S\n";           /* disable output */
sendcmd();

printf("\n\nEnd demo program.\n");

exit(0);

}
```

```
sendcmd()
{

#define COM2_DATA 0x02f8
#define COM2_STATUS 0x02fd
#define XMT_RDY 0x20
#define RCV_RDY 0x01

char    b;
int     com_stat;

/* send command */
b=0;
do
      {
      com_stat = inport(COM2_STATUS);
      if (com_stat & XMT_RDY)
            {
            b = *cptr++;
            outport(COM2_DATA,b);
            }
      } while (b != '\n');

/* get response, wait for the '*' prompt */
do
      {
      com_stat = inport(COM2_STATUS);
      if (com_stat & RCV_RDY)
            b = inport(COM2_DATA);
      } while (b != '*');

return;

}
```

Appendix B - Frequency / Duty Cycle Tables

The following tables provide timing data on the PWM output over the operating frequency range of the PWM Controller. Times are given for 1, 25, 50, and 75 % duty cycle of each frequency. Using the numbers provided in the table allow calculation of any duty cycle time, both on time and off time.

Frequency (Hz)	Period (msec)	75% Duty Cycle (msec)	50% Duty Cycle (msec)	25% Duty Cycle (msec)	1% Duty Cycle (msec)
1	1000.00	750.00	500.00	250.00	10.0000
2	500.00	375.00	250.00	125.00	5.0000
3	333.33	250.00	166.67	83.33	3.3333
4	250.00	187.50	125.00	62.50	2.5000
5	200.00	150.00	100.00	50.00	2.0000
6	166.67	125.00	83.33	41.67	1.6667
7	142.86	107.14	71.43	35.71	1.4286
8	125.00	93.75	62.50	31.25	1.2500
9	111.11	83.33	55.56	27.78	1.1111
10	100.00	75.00	50.00	25.00	1.0000
11	90.91	68.18	45.45	22.73	0.9091
12	83.33	62.50	41.67	20.83	0.8333
13	76.92	57.69	38.46	19.23	0.7692
14	71.43	53.57	35.71	17.86	0.7143
15	66.67	50.00	33.33	16.67	0.6667
16	62.50	46.88	31.25	15.63	0.6250
17	58.82	44.12	29.41	14.71	0.5882
18	55.56	41.67	27.78	13.89	0.5556
19	52.63	39.47	26.32	13.16	0.5263
20	50.00	37.50	25.00	12.50	0.5000
21	47.62	35.71	23.81	11.90	0.4762
22	45.45	34.09	22.73	11.36	0.4545
23	43.48	32.61	21.74	10.87	0.4348
24	41.67	31.25	20.83	10.42	0.4167
25	40.00	30.00	20.00	10.00	0.4000
26	38.46	28.85	19.23	9.62	0.3846
27	37.04	27.78	18.52	9.26	0.3704
28	35.71	26.79	17.86	8.93	0.3571
29	34.48	25.86	17.24	8.62	0.3448
30	33.33	25.00	16.67	8.33	0.3333
31	32.26	24.19	16.13	8.06	0.3226
32	31.25	23.44	15.63	7.81	0.3125
33	30.30	22.73	15.15	7.58	0.3030
34	29.41	22.06	14.71	7.35	0.2941
35	28.57	21.43	14.29	7.14	0.2857
36	27.78	20.83	13.89	6.94	0.2778
37	27.03	20.27	13.51	6.76	0.2703
38	26.32	19.74	13.16	6.58	0.2632
39	25.64	19.23	12.82	6.41	0.2564
40	25.00	18.75	12.50	6.25	0.2500

Frequency (Hz)	Period (msec)	75% Duty Cycle (msec)	50% Duty Cycle (msec)	25% Duty Cycle (msec)	1% Duty Cycle (msec)
41	24.39	18.29	12.20	6.10	0.2439
42	23.81	17.86	11.90	5.95	0.2381
43	23.26	17.44	11.63	5.81	0.2326
44	22.73	17.05	11.36	5.68	0.2273
45	22.22	16.67	11.11	5.56	0.2222
46	21.74	16.30	10.87	5.43	0.2174
47	21.28	15.96	10.64	5.32	0.2128
48	20.83	15.63	10.42	5.21	0.2083
49	20.41	15.31	10.20	5.10	0.2041
50	20.00	15.00	10.00	5.00	0.2000
51	19.61	14.71	9.80	4.90	0.1961
52	19.23	14.42	9.62	4.81	0.1923
53	18.87	14.15	9.43	4.72	0.1887
54	18.52	13.89	9.26	4.63	0.1852
55	18.18	13.64	9.09	4.55	0.1818
56	17.86	13.39	8.93	4.46	0.1786
57	17.54	13.16	8.77	4.39	0.1754
58	17.24	12.93	8.62	4.31	0.1724
59	16.95	12.71	8.47	4.24	0.1695
60	16.67	12.50	8.33	4.17	0.1667
61	16.39	12.30	8.20	4.10	0.1639
62	16.13	12.10	8.06	4.03	0.1613
63	15.87	11.90	7.94	3.97	0.1587
64	15.63	11.72	7.81	3.91	0.1563
65	15.38	11.54	7.69	3.85	0.1538
66	15.15	11.36	7.58	3.79	0.1515
67	14.93	11.19	7.46	3.73	0.1493
68	14.71	11.03	7.35	3.68	0.1471
69	14.49	10.87	7.25	3.62	0.1449
70	14.29	10.71	7.14	3.57	0.1429
71	14.08	10.56	7.04	3.52	0.1408
72	13.89	10.42	6.94	3.47	0.1389
73	13.70	10.27	6.85	3.42	0.1370
74	13.51	10.14	6.76	3.38	0.1351
75	13.33	10.00	6.67	3.33	0.1333
76	13.16	9.87	6.58	3.29	0.1316
77	12.99	9.74	6.49	3.25	0.1299
78	12.82	9.62	6.41	3.21	0.1282
79	12.66	9.49	6.33	3.16	0.1266
80	12.50	9.38	6.25	3.13	0.1250

Frequency (Hz)	Period (msec)	75% Duty Cycle (msec)	50% Duty Cycle (msec)	25% Duty Cycle (msec)	1% Duty Cycle (msec)
81	12.35	9.26	6.17	3.09	0.1235
82	12.20	9.15	6.10	3.05	0.1220
83	12.05	9.04	6.02	3.01	0.1205
84	11.90	8.93	5.95	2.98	0.1190
85	11.76	8.82	5.88	2.94	0.1176
86	11.63	8.72	5.81	2.91	0.1163
87	11.49	8.62	5.75	2.87	0.1149
88	11.36	8.52	5.68	2.84	0.1136
89	11.24	8.43	5.62	2.81	0.1124
90	11.11	8.33	5.56	2.78	0.1111
91	10.99	8.24	5.49	2.75	0.1099
92	10.87	8.15	5.43	2.72	0.1087
93	10.75	8.06	5.38	2.69	0.1075
94	10.64	7.98	5.32	2.66	0.1064
95	10.53	7.89	5.26	2.63	0.1053
96	10.42	7.81	5.21	2.60	0.1042
97	10.31	7.73	5.15	2.58	0.1031
98	10.20	7.65	5.10	2.55	0.1020
99	10.10	7.58	5.05	2.53	0.1010
100	10.00	7.50	5.00	2.50	0.1000
101	9.90	7.43	4.95	2.48	0.0990
102	9.80	7.35	4.90	2.45	0.0980
103	9.71	7.28	4.85	2.43	0.0971
104	9.62	7.21	4.81	2.40	0.0962
105	9.52	7.14	4.76	2.38	0.0952
106	9.43	7.08	4.72	2.36	0.0943
107	9.35	7.01	4.67	2.34	0.0935
108	9.26	6.94	4.63	2.31	0.0926
109	9.17	6.88	4.59	2.29	0.0917
110	9.09	6.82	4.55	2.27	0.0909
111	9.01	6.76	4.50	2.25	0.0901
112	8.93	6.70	4.46	2.23	0.0893
113	8.85	6.64	4.42	2.21	0.0885
114	8.77	6.58	4.39	2.19	0.0877
115	8.70	6.52	4.35	2.17	0.0870
116	8.62	6.47	4.31	2.16	0.0862
117	8.55	6.41	4.27	2.14	0.0855
118	8.47	6.36	4.24	2.12	0.0847
119	8.40	6.30	4.20	2.10	0.0840
120	8.33	6.25	4.17	2.08	0.0833

Frequency (Hz)	Period (msec)	75% Duty Cycle (msec)	50% Duty Cycle (msec)	25% Duty Cycle (msec)	1% Duty Cycle (msec)
121	8.26	6.20	4.13	2.07	0.0826
122	8.20	6.15	4.10	2.05	0.0820
123	8.13	6.10	4.07	2.03	0.0813
124	8.06	6.05	4.03	2.02	0.0806
125	8.00	6.00	4.00	2.00	0.0800
126	7.94	5.95	3.97	1.98	0.0794
127	7.87	5.91	3.94	1.97	0.0787
128	7.81	5.86	3.91	1.95	0.0781
129	7.75	5.81	3.88	1.94	0.0775
130	7.69	5.77	3.85	1.92	0.0769
131	7.63	5.73	3.82	1.91	0.0763
132	7.58	5.68	3.79	1.89	0.0758
133	7.52	5.64	3.76	1.88	0.0752
134	7.46	5.60	3.73	1.87	0.0746
135	7.41	5.56	3.70	1.85	0.0741
136	7.35	5.51	3.68	1.84	0.0735
137	7.30	5.47	3.65	1.82	0.0730
138	7.25	5.43	3.62	1.81	0.0725
139	7.19	5.40	3.60	1.80	0.0719
140	7.14	5.36	3.57	1.79	0.0714
141	7.09	5.32	3.55	1.77	0.0709
142	7.04	5.28	3.52	1.76	0.0704
143	6.99	5.24	3.50	1.75	0.0699
144	6.94	5.21	3.47	1.74	0.0694
145	6.90	5.17	3.45	1.72	0.0690
146	6.85	5.14	3.42	1.71	0.0685
147	6.80	5.10	3.40	1.70	0.0680
148	6.76	5.07	3.38	1.69	0.0676
149	6.71	5.03	3.36	1.68	0.0671
150	6.67	5.00	3.33	1.67	0.0667
151	6.62	4.97	3.31	1.66	0.0662
152	6.58	4.93	3.29	1.64	0.0658
153	6.54	4.90	3.27	1.63	0.0654
154	6.49	4.87	3.25	1.62	0.0649
155	6.45	4.84	3.23	1.61	0.0645
156	6.41	4.81	3.21	1.60	0.0641
157	6.37	4.78	3.18	1.59	0.0637
158	6.33	4.75	3.16	1.58	0.0633
159	6.29	4.72	3.14	1.57	0.0629
160	6.25	4.69	3.13	1.56	0.0625

Frequency (Hz)	Period (msec)	75% Duty Cycle (msec)	50% Duty Cycle (msec)	25% Duty Cycle (msec)	1% Duty Cycle (msec)
161	6.21	4.66	3.11	1.55	0.0621
162	6.17	4.63	3.09	1.54	0.0617
163	6.13	4.60	3.07	1.53	0.0613
164	6.10	4.57	3.05	1.52	0.0610
165	6.06	4.55	3.03	1.52	0.0606
166	6.02	4.52	3.01	1.51	0.0602
167	5.99	4.49	2.99	1.50	0.0599
168	5.95	4.46	2.98	1.49	0.0595
169	5.92	4.44	2.96	1.48	0.0592
170	5.88	4.41	2.94	1.47	0.0588
171	5.85	4.39	2.92	1.46	0.0585
172	5.81	4.36	2.91	1.45	0.0581
173	5.78	4.34	2.89	1.45	0.0578
174	5.75	4.31	2.87	1.44	0.0575
175	5.71	4.29	2.86	1.43	0.0571
176	5.68	4.26	2.84	1.42	0.0568
177	5.65	4.24	2.82	1.41	0.0565
178	5.62	4.21	2.81	1.40	0.0562
179	5.59	4.19	2.79	1.40	0.0559
180	5.56	4.17	2.78	1.39	0.0556
181	5.52	4.14	2.76	1.38	0.0552
182	5.49	4.12	2.75	1.37	0.0549
183	5.46	4.10	2.73	1.37	0.0546
184	5.43	4.08	2.72	1.36	0.0543
185	5.41	4.05	2.70	1.35	0.0541
186	5.38	4.03	2.69	1.34	0.0538
187	5.35	4.01	2.67	1.34	0.0535
188	5.32	3.99	2.66	1.33	0.0532
189	5.29	3.97	2.65	1.32	0.0529
190	5.26	3.95	2.63	1.32	0.0526
191	5.24	3.93	2.62	1.31	0.0524
192	5.21	3.91	2.60	1.30	0.0521
193	5.18	3.89	2.59	1.30	0.0518
194	5.15	3.87	2.58	1.29	0.0515
195	5.13	3.85	2.56	1.28	0.0513
196	5.10	3.83	2.55	1.28	0.0510
197	5.08	3.81	2.54	1.27	0.0508
198	5.05	3.79	2.53	1.26	0.0505
199	5.03	3.77	2.51	1.26	0.0503
200	5.00	3.75	2.50	1.25	0.0500

Appendix C - Forms

The following forms are provided for comments on the manual and the product in general, and, for returning the unit for service or upgrade.

Comments on the Manual

Applied Processor and Measurement, Inc. is committed to providing high quality equipment, that is easy to use, and value priced. Customer feedback on all facets of the product, including the product user manual, is an important element required to achieve our product goals.

Applied Processor and Measurement, Inc. welcomes and appreciates any comments or discrepancy reports that may be forwarded to us on the product manual. Send your comments (Mail, FAX, or E-mail) to the address provided on the front of this manual or in the Warranty / Service Section.

Document Title:________________________________ Document No.:_________________

Please categorize your report (check all applicable):

Comments / Suggestions _____ Discrepancy / Error _____

Report (use additional sheets if necessary) : ____

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Please rate the manual for the following (circle the appropriate rating):

	Excellent				Poor
Completeness	5	4	3	2	1
Accurate	5	4	3	2	1
Easy to Read	5	4	3	2	1
Easy to Find Information5	4	3	2	1	
Complexity	5	4	3	2	1

How often do you use the manual ? ____

Please provide the following:

Name: _______________________________________ Title: __________________________

Company: ____

Address / Department: ____

Address: ____

City: ______________________________ State: _________ Zip: _____________

Phone: _______________ FAX: _______________ E-mail: _____________________________

May we contact you ? Yes ______ No _____

Comments on the Product

Applied Processor and Measurement, Inc. is committed to providing high quality equipment, that is easy to use, and value priced. Customer feedback on all facets of the product including its features, operability, durability, value, and our customer service are all important elements required to achieve our company goals.

Applied Processor and Measurement, Inc. welcomes and appreciates any comments regarding the product, or our services including recommendations on additional features. Send your comments (Mail, FAX, or E-mail) to the address provided on the front of this manual or in the Warranty / Service Section.

Product Name:________________________________ Model No.:____________________

Comments (use additional sheets if necessary) : _____________________________________

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Please rate the product for the following (circle the appropriate rating):

	Excellent				Poor
Features	5	4	3	2	1
Ease of Operation	5	4	3	2	1
Durability	5	4	3	2	1
Value	5	4	3	2	1

Did this product meet your expectations ? Yes _____ No _____

Why ? ____

Did you have to call Applied Processor and Measurement, Inc. regarding this product ? Yes _____ No _____

Why ? ____

Comments on Service: ____

____

Please provide the following:

Name: _______________________________________ Title: ___________________________

Company: ____

Address / Department: ____

Address: ____

City: _______________________________ State: _________ Zip: _____________

Phone: _______________ FAX: _______________ E-mail: _____________________________

May we contact you ? Yes ______ No _____

Product Return

Please complete and return this form with your unit. You must obtain a Return Authorization number (see the Warranty / Service section of this manual for return instructions).

Product Name:________________________________ Model No.:____________________

Serial No.:____

Return Authorization Number: _______________________________

Reason for Return: Unit Defective _____ Software Upgrade _____ Customization _____

If the unit is being serviced:

Requested Disposition: Advise of Charges Before Repair ? Yes _____ No _____

Description of Problem / Notes (if applicable) : _______________________________________

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Contact Person:

Name: _______________________________________ Title: ___________________________

Company: ____

Address / Department: ____

Address: ____

City: _______________________________ State: _________ Zip: _____________

Phone: _______________ FAX: _______________ E-mail: ____________________________