RINEHART MOTION SYSTEMS LLC
7929 SW Burns Way, Suite B, Wilsonville, OR 97070 503.344.5085

AC Motor Controller for Electric and Hybrid Vehicles
Product Summary

The Rinehart Motion Systems LLC (RMS) PM Family of AC Motor Controllers are designed for on- and off-road Electric (EV) or Hybrid Electric (HEV) applications. The motor controller converts the DC power from the vehicle ESS (Energy Storage System / Battery) to the 3-phase AC required by the motor. These Traction drives are fabricated using a patented high heat flux thermal design approach that dramatically reduces the size and weight of the finished drive, and improves its life in the automotive environment. With extensive experience in automotive and military vehicle traction and power electronics applications, RMS has achieved a major breakthrough in integrating Motor Control into a vehicle.

RMS offers several different models within the PM Family of motor controllers to suit the DC bus voltage and motor current requirements of your specific vehicle. The PM Family has been designed to operate with many types of motors, including Induction Motors (IM) and Permanent Magnet motors (PMSM or IPM). Contact RMS for the latest list of motors supported by our controllers. The Drive can also be tuned to your new motor - contact the factory for more information.

The primary difference between models in the PM Family is the rated voltage and current (ultimate power output):

Controller Model	PM100DX	PM100DZ	PM100DXR *	PM150DX	PM150DZ
Maximum DC Voltage – operating	360 V	720 V	400 V	360 V	720 V
Maximum DC Voltage – non-operating	500 V	900 V	500 V	500 V	900 V
Motor Current Continuous	300 Arms	150 Arms	300 Arms	450 Arms	225 Arms
Motor Current Peak **	350 Arms	200 Arms	450 Arms	450 Arms	300 Arms
DC Bus Capacitance	440 µF	280 µF	440 µF	880 µF	560 µF
Size	See drawing	See drawing	See drawing	See drawing	See drawing
Weight	7.5 kg	7.5 kg	7.5 kg	10.7 kg	10.7 kg
Minimum Conductor Size	4 AWG			2 AWG	4 AWG***
Maximum Conductor Size	1 AWG			3/0 AWG	1 AWG
Minimum Cable O.D.	9.0 mm			11.0 mm	
Maximum Cable O.D.	16.5 mm			21.0 mm	

* The PM100DXR is only available for special applications (i.e. racing), use must be approved by RMS.

** Peak current is defined as a maximum of 30 seconds.

*** Depending on cable, it may be necessary to add additional sleeve to cable to meet the minimum Cable O.D. of the cable gland.

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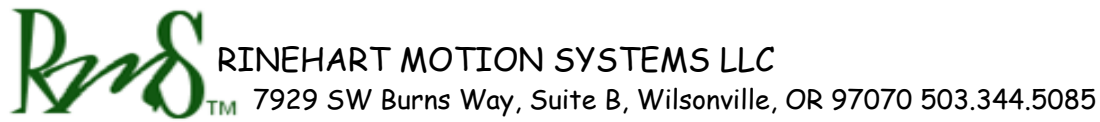
Power Production and Controller Ratings

The mechanical power that can be generated by any motor controller is highly dependent on the motor characteristics. It is possible to estimate the actual motor output power you can achieve in any specific system if certain motor characteristics are known. A common misconception is that Motor Current times DC Bus Voltage will give the motor power. THIS IS INCORRECT.

First, it is important to know the continuous and maximum (peak) motor current ratings. It is possible that the maximum motor current could be higher than the current rating of the motor controller. If so, then either a higher current controller can be considered or use the motor controller current limits in the below equations.

The next important item to understand is the maximum motor voltage. In many circumstances the maximum motor voltage is limited by the available battery voltage. The available motor voltage from the Drive output terminals is a function of the DC bus voltage:
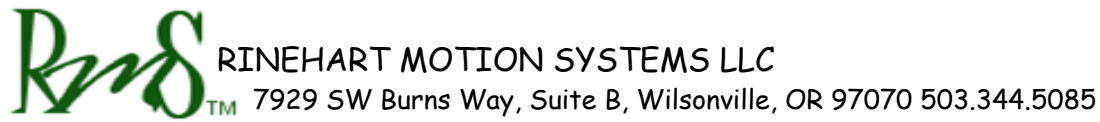
$$\text{Motor Voltage} = \frac{V_{DC}}{\sqrt{(2)}} \quad \text{line to line RMS}$$

For example, if the Battery pack voltage is 320V then the motor voltage the inverter can make can never exceed $226.27V_{RMSl-l}$. In practice the actual voltage is generally limited to ~95% of this value, so for design purposes the maximum motor voltage should be assumed to be 215.0 V_{RMSl-l}(max). As the motor speed varies, the Drive will vary its output voltage to deliver the required power – until it reaches this hard limit due to the battery voltage. You can't get any more. To go faster, the motor has to enter "field weakening", where the Drive adds current to defeat some of the permanent magnet field, so the motor output voltage is reduced and stays below the hard limit – in this case 215VAC. If the maximum motor rated current is 300 Arms, you still can't calculate how much mechanical power you can deliver without knowing the motor Power Factor and efficiency at that operating point.

It's not just how much current is flowing into the motor, but when it flows – its phase shift. Power Factor represents the 3-phase system phase shift that exists between the motor voltage and the motor current. The motor power factor varies from each different motor, motor type, and operating point. For this example assume a motor power factor of 0.768. Motor efficiency will also vary from motor to motor and over the speed/torque operating plane. Assume motor efficiency is 91.2%, typical of an SPM motor at peak load. We now have enough information to calculate the motor output power.

$$\text{Motor Power} = \sqrt{(3)} * Motor\ Voltage * Motor\ Current * Power\ Factor * Efficiency$$

For this example we get:

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$$78.2\,kW = \sqrt{3} * 215 * 300 * 0.768 * 0.912$$

The DC Input Current to the motor controller is based on the motor input power and the efficiency of the motor controller. The motor controller efficiency will vary depending on the load conditions. However, for most high power conditions a typical efficiency of the PM Family of controllers is 97%. The total system efficiency can be found by multiplying the motor efficiency by the controller efficiency. For this example we would multiply 91.2% with 97% giving a system efficiency of 88.5%. The DC input power can now be calculated as:

$$DC\_Power = P_{mech} / .885 = V_{batt} * I_{batt} = 88.36kW$$

To continue the example, the DC current would be 276 amps at 320V battery voltage (88.36kW/ V_{batt})

General Specifications for the PM Family

Description	Value
Short Circuit Protection	Yes
Hardware Over-current Protection	Yes
Vehicle System Power	9 .. 16V$_{DC}$ (12V Systems)
Operating Temperature Range – coolant water – no derating	-40 .. +80ºC
Isolation – High-Voltage to Low-Voltage	1000V$_{rms}$
Isolation – High-Voltage to Case	1000V$_{rms}$
Isolation – Low-Voltage to Case	50V
Operating Temperature Range – coolant water – derated output power	-40.. +105ºC
Non-Operating Temperature	-40 .. +115ºC
Storage Temperature	-55 .. +105ºC
Coolant Type	50/50 EGW
Coolant Flow Rate	8 – 12 LPM
Coolant Pressure Drop	0.2 bar for PM100xx
	0.25 bar for PM150xx
Maximum Coolant Pressure (above ambient)	1.4 bar
Operating Shock (ISO 16750-3, Test 4.2.2.2)	500 m/s^2 (50g), pending testing
Operating Vibration (ISO 16750-3, 4.1.2.4 Test IV)	27.8 m/s^2 (3g$_{rms}$), pending testing
Environmental Protection Class (see ISO 20653)	IP6K9K
EMC compatibility	IEC, pending testing

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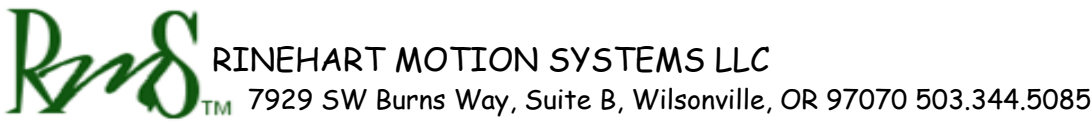
The PM Family of Motor Controllers comes with cable glands designed to accept shielded cable. Proper shielding and grounding of the motor controller cables is essential to control EMC that can effect motor operation and potentially other systems on the vehicle. The motor controller is designed with a wire clamping system that requires the use of a wire ferrule. Refer to the PM Family User's Manual on making the High Voltage Connections to the PM100.RMS recommends Champlain Cable type EXRAD XLE 1000V shielded power cables for use with our products. The size of the wire used depends on the application – the motor peak and continuous current and how long those peaks are expected to last. For reference a size versus ampacity (continuous current handling capability) chart is copied here:

Wire Size	Ampacity
4 AWG	190
2 AWG	255
1 AWG	293
1/0 AWG	339
2/0 AWG	390
3/0 AWG	451

Each controller contains a significant amount of DC bus capacitance. It is necessary for the user to provide a pre-charge circuit for this capacitance. The PM motor controller does not present any practical limits on how small or large the pre-charge current is. However, the user should take care to design the circuit so that if the controller were to fail shorted the pre-charge circuit is not damaged and cannot start a fire. Pre-charge circuit operation may be controlled by the internal software - refer to the PM100 User's Manual for more information.

Control Software

The PM Family of motor controllers comes with advanced motor control software developed by RMS. This software includes many features that are useful for control of an electric motor in an EV/Hybrid application. There is a rudimentary Vehicle Controller (simplistic VCU functionality) in the drive that may be enabled to operate the attached motor on the bench, or to drive a prototype vehicle around the parking lot in system integration. However, most safety sertified applications use the PM Drive as a CAN-based output node – a separate computer (the VCU) issues torque commands and reads feedback from the motor (and the battery management system, the driver inputs, etc) over the CAN serial port. For more information on the software refer to the PM100 User's Manual.

The PM Family of Drives can also be programmed with custom software, or with customer developed software. Contact RMS for more information.

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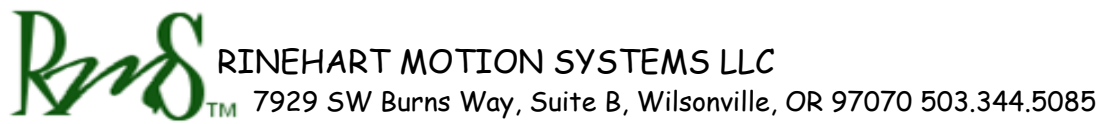
Hardware Description

The following section provides a brief description of the I/O hardware features of the PM family of motor controllers. To use these I/O features, please refer to the PM100 Users Manual.

Feature Summary

Feature	Generation 2[*]	Generation 3[*]
Analog Inputs (0 – 5V)	4	6
RTD Inputs	2xPT100, 2xPT100	2xPT100/PT1000, Selectable
Digital Inputs	6	8
High Side Outputs	2	4
Low Side Outputs	2	2
Resolver Interface	Yes	Yes
Quadrature Encoder Interface	Yes	Yes
Hall Effect Sensor Interface	No	Yes
CAN Interface	Yes	Yes
RS-232 Interface	Yes	Yes

* The PM150 family is implemented with Generation 3 Features.   The PM100 family is currently implemented with Generation 2 Features, The PM100 family is expected to change to Generation 3 in Spring of 2012.

Analog Inputs:

Intended for general analog signal sensing (0 – 5V).

RTD Inputs:

Used to sense temperature.

Digital Inputs:

Intended for general interface to the vehicle and for feedback from external contactors and switchgear as required in the application.   There are two types of inputs Switch To Ground and Switch To Battery.   Refer to the user's manual for more detail.

High-Current Digital Outputs:

High side outputs can be used for driving 12V loads.

Low-side Outputs:

Low side outputs can be used for driving 12V loads that switch the ground side of the load.

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CAN Interface:

There are two CAN2.0B compliant serial ports, capable of operation at 100k, 250k, 500k, and 1Mb/sec by software selection.   The CAN terminator for each port can be applied or opened under software control during setup or at any time.   EMI filtering for common-mode and differential-mode noise, and transient suppressors are used to improve the robustness of the serial I/O system.   Refer to the PM100 CAN Manual for more information on the protocol implemented by RMS.

RS-232 Serial Interface:

There is one RS-232 serial interface with EMI filtering.   This port can be used to set up and tune the controller, and to download controller software updates from a computer.   RMS offers a simple serial user monitor that runs on the PC to allow changing parameters, changing the I/O functionality to suit the application needs, and other user-selectable optimizations.

Encoder Interface:

For applications that use an incremental optical or magnetic encoder, there is a 5V interface to power the external encoder and to receive, level translate, and filter the signals from A, B and INDEX channels.   The sensor interface is designed to work with an open collector type sensor.   The maximum frequency of the interface is 50 kHz.   The DSP has specific hardware for wide dynamic range speed and angle calculation from the encoder data.

Resolver Interface:

A resolver can be used in place of the incremental encoder to determine machine rotor position and velocity.   The resolver is excited by a precision sinusoid, and the sine and cosine winding outputs are filtered for noise and presented to the DSP to be digitized at 12b resolution.   Due to the nature of the resolver interface the resolver excitation frequency is the same frequency as the PWM frequency.

Hall Sensor Interface:

A Hall Sensor Interface is provided for motors that use this type of position sensing.   The interface includes A,B,C channel inputs as well as providing 5V power for the sensor.   The sensor interface is designed to work with a open-collector type output.

Low-Voltage Signal Connector Interface:

The PM Family motor controllers use two connectors for the low-voltage signals (Tyco/AMP AMPSEAL family). The following connectors are used:

Connector	Connector Type	Mating Connector Type	Mating Contact Type
J1 (35 pin)	Tyco/AMP 776231-1	Tyco/AMP 776164-1	Tyco/AMP 770854-1
J2 (23 pin)	Tyco/AMP 776228-1	Tyco/AMP 770680-1	Tyco/AMP 770854-1

Note: It is extremely important for proper operation of the connector to utilize the recommended crimp tool from

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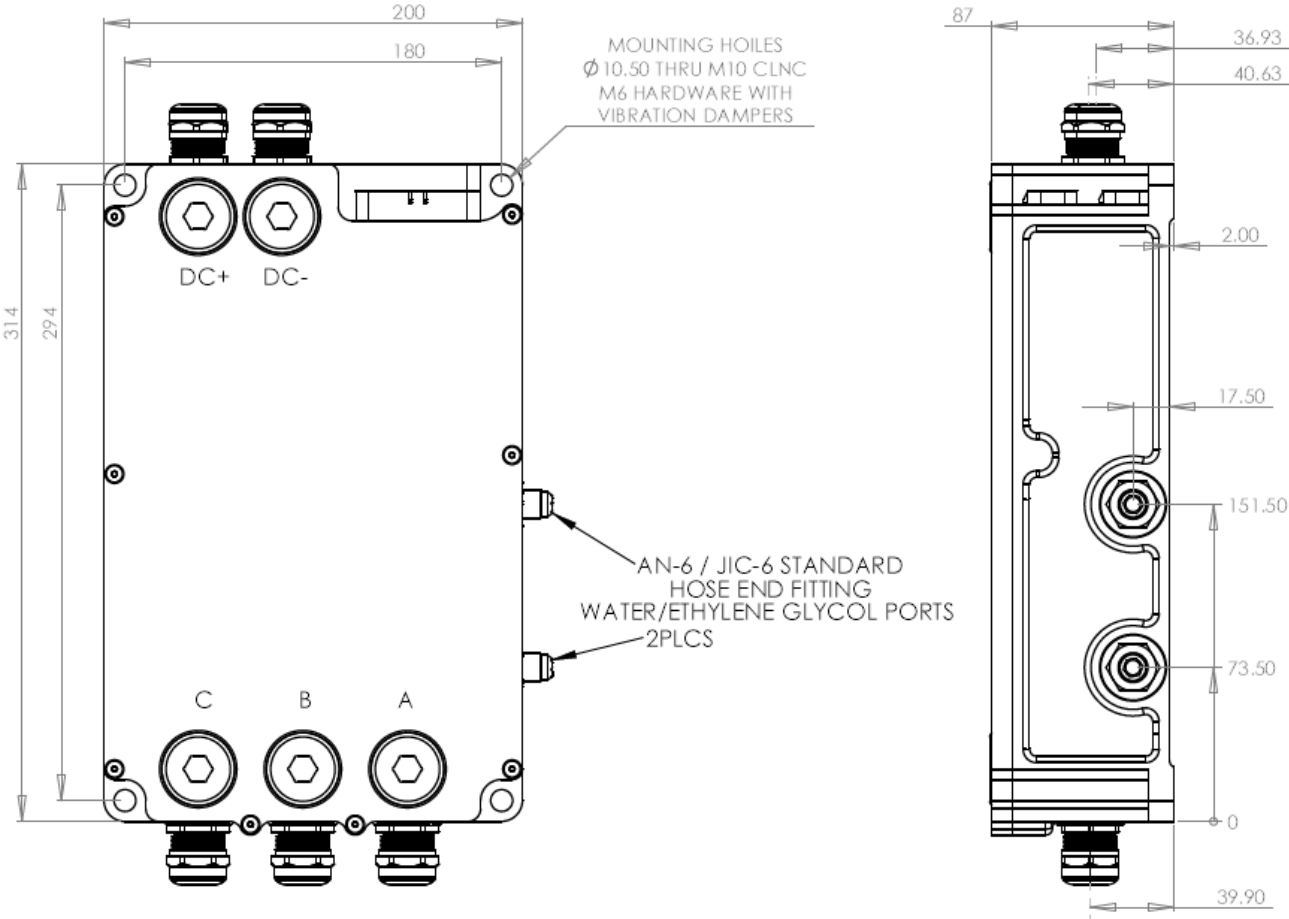7929 SW Burns Way, Suite B, Wilsonville, OR 97070 503.344.5085
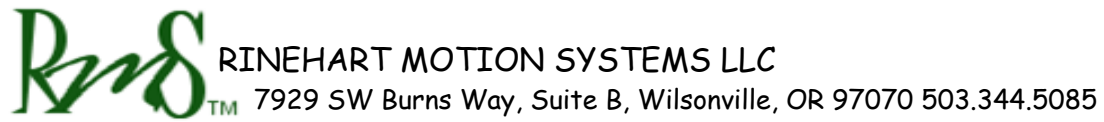
Tyco/AMP (Tyco/AMP part number 58529-1). A connector kit is available from RMS that includes the mating connectors and 60 contacts (RMS p/n G1-0001-01).
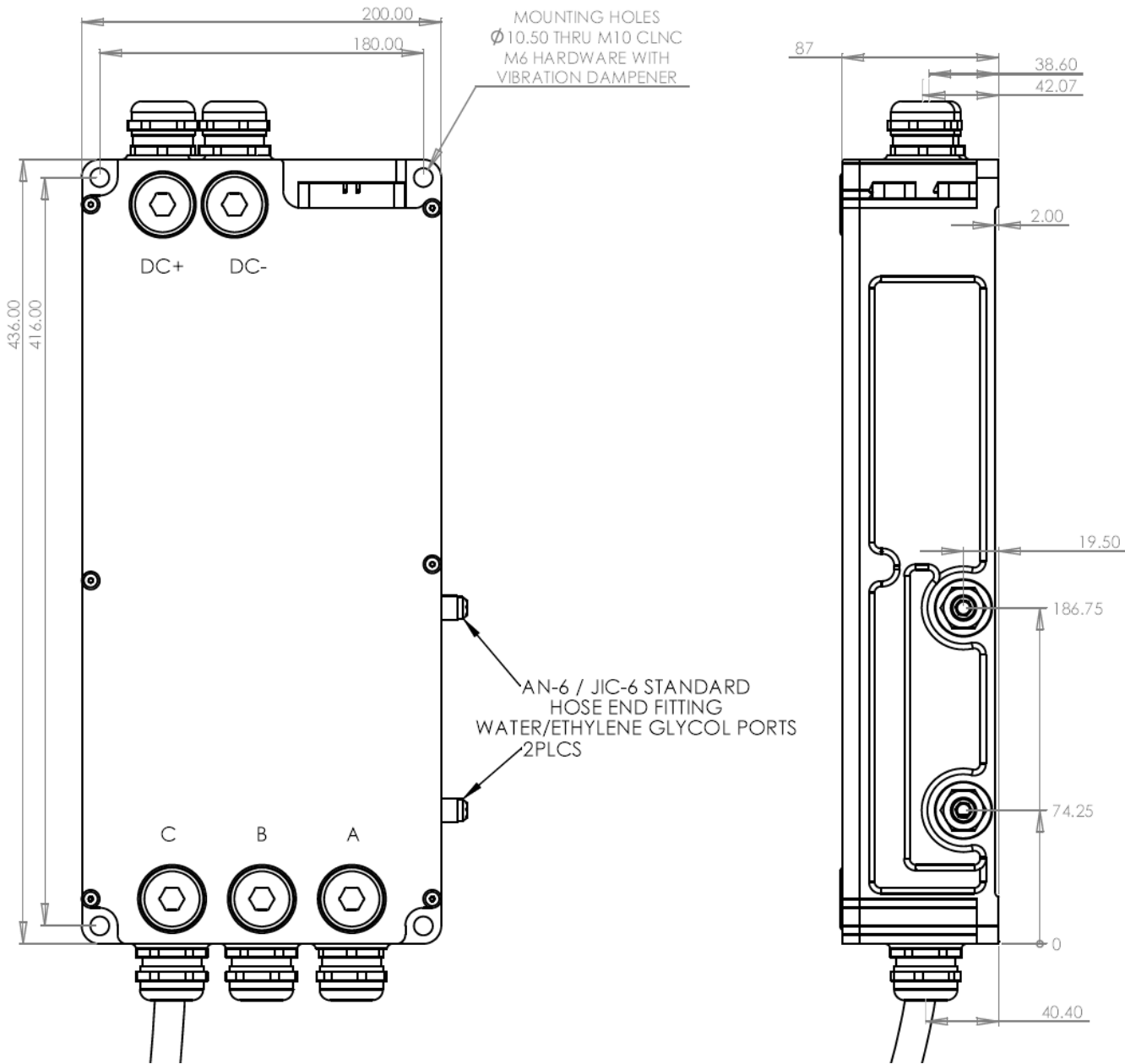
The AMPSEAL contact is designed to work with 16-20 AWG wire with an insulation diameter between 1.70 – 2.70 mm. Make sure that the wire used conforms to these requirements.
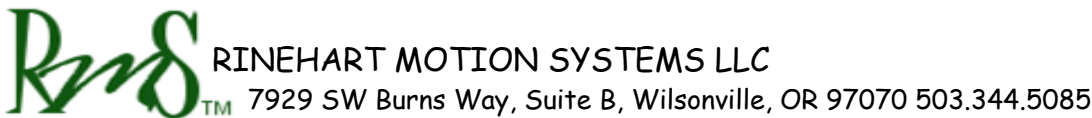
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Outline Drawings:

PM100 Package Outline:

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PM150 Package Outline

200.00

180.00

MOUNTING HOLES
Ø10.50 THRU M10 CLNC
M6 HARDWARE WITH
VIBRATION DAMPENER

87

38.60

42.07

DC+   DC-

2.00

436.00

416.00

19.50

186.75

AN-6 / JIC-6 STANDARD
HOSE END FITTING
WATER/ETHYLENE GLYCOL PORTS
2PLCS

74.25

C   B   A

0

40.40

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