M700

HYDRAULIC PUMP MOTOR CONTROLLER

INTERFACE MANUAL

CONTENTS

1 OVERVIEW

M700 is a high-power hydraulic pump controller that provides fully programmable control of DC series wound motors. It features microprocessor-based logic with programmable parameters and offers maximum flexibility for minimum cost. This means the controller can be tailored to the needs of specific applications. In addition to configuration flexibility, use of the programmer offers diagnostics and test capability. It is the ideal solution for hydraulic pump motor control on aerial work platform (AWP) equipment.

Fig. 1 M700-VR1 hydraulic pump motor controller.

The M700 controller offers superior operator control of motor speed and torque.

Controllable Power

- Pulse Width Modulation (PWM) control with programmable speed, acceleration rate, and current limit.
- Short duration boost capability (10 sec, 110% of 2 min current rating). Allows clearing of obstacles, climbing ramps.
- 16 kHz PWM frequency for near silent operation.
- High efficiency, silent operation. Operating costs, heat-sinking requirements, motor and battery losses reduced. Low-end torque, range, and battery life maximized.

Programmable and Flexible

- Fully programmable via Sensata PC programming software.
- Supports multiple throttle types and High Pedal Disable (HPD) options.
- LED output for easy system troubleshooting via flash codes.
- Fully programmable analog throttle input for precise speed control with a variety of signal sources.
- Programmable under voltage cutback caters to different battery types.
- CAN type input for throttle function
- Interlock function with a digital signal input that can be easily disabled/enabled by setting.
- Two-driver output with max 2A.

Robust Safety and Reliability

- Redundant hardware and software watchdog timers.
- MOSFET short-circuit protection functions.
- Programmable HPD function prevents controller operation if throttle is applied before key is turned on.
- Contactor fault detection: controller shuts down safety if the main contactor opens.
- Contactor protection functions minimize high current arcing to prevent contact pitting and thus prevent contactor weld failures.
- Undervoltage cutback and shutdown functions protect against low battery voltage, including low voltage caused by external loads.
- Electrical isolation to heat sink: 500VAC.
- Rugged housing meets IP54 environmental ratings.
- Full power operation over -40°C to 50°C environment temperature range.

Familiarity with the controller will help you install and operate it properly. We encourage you to read this manual carefully. If you have questions, please contact the Sensata service office nearest you.

2 INSTALLATION AND WIRING

MOUNTING THE CONTROLLER

The M700 controller can be oriented in any position and meets the IP54 ratings for environmental protection against dust and water. However, **the location should be carefully chosen to keep the controller clean and dry. If a clean and dry mounting location cannot be found, a cover must be used to shield the controller from water and contaminants.**

The controller's outline and mounting hole dimensions are shown in Figure 2. When selecting the mounting position, be sure to also take into consideration that access is needed at the end of the controller to plug the programming cable into its connector. To ensure full rated power, the controller should be fastened to a clean, flat metal surface with four 6 mm (1/4") diameter screws, using the holes provided. Although not usually necessary, a thermal joint compound can be used to improve heat conduction from the controller heatsink to the mounting surface. You will need to take steps during the design and development of your application product to ensure that its EMC performance complies with applicable regulations; suggestions are presented in Appendix A.

Fig 2 Mounting dimensions, M700-VR1 controller

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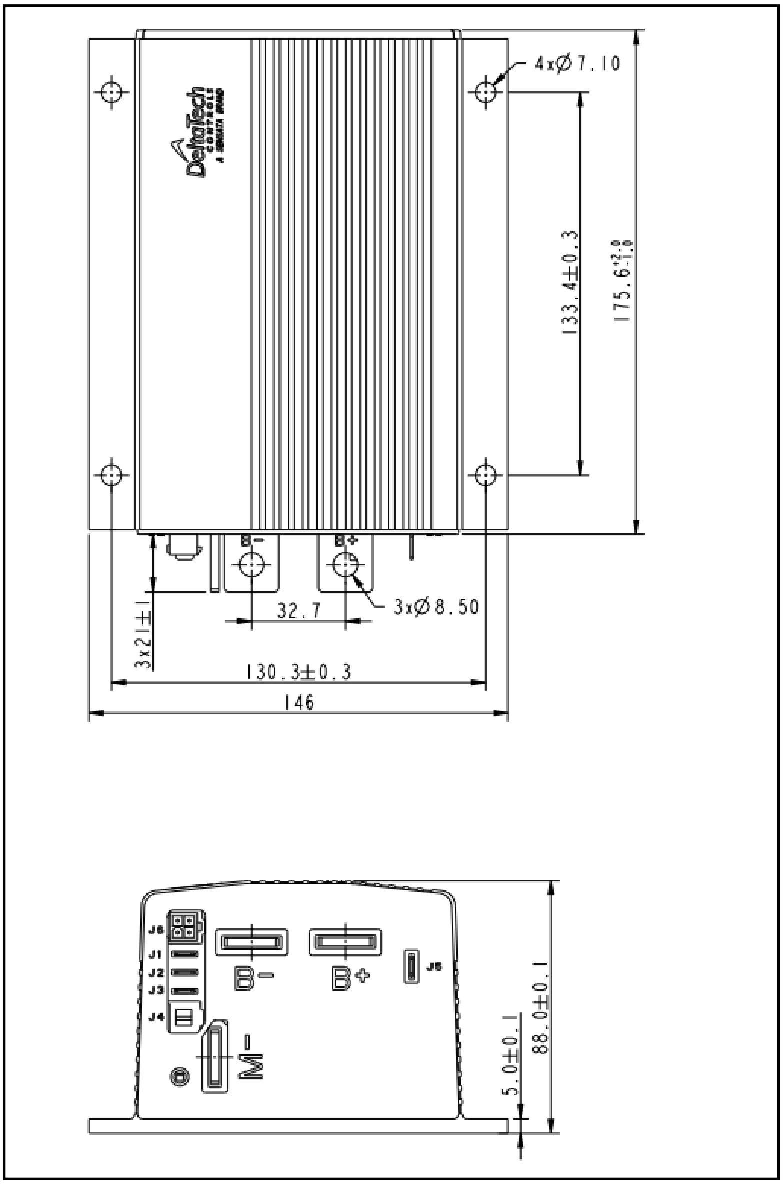


caution

Working on electrical systems is potentially dangerous. You should protect yourself against uncontrolled operation, high current arcs, and outgassing from lead acid batteries.

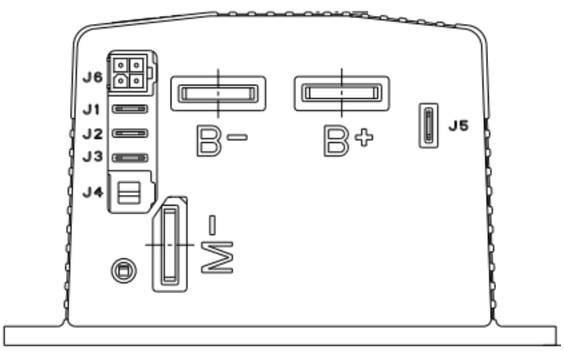
UNCONTROLLED OPERATION — Some conditions could cause the hydraulic pump system to run out of control. **Disconnect the motor or make sure the pump system has enough room to operate** before attempting any work on the motor control circuitry. Note: If the wrong throttle input signal type is selected with the programming device, the pump system may suddenly begin to operate.

HIGH CURRENT ARCS — Batteries can supply very high power, and arcs can occur if they are short circuited. Always open the battery circuit before working on the motor control circuit. Wear safety glasses and use properly insulated tools to prevent shorts.

LEAD ACID BATTERIES — Charging or discharging generates hydrogen gas, which can build up in and around the batteries. Follow the battery manufacturer’s safety recommendations. Wear safety glasses.

CONNECTIONS

The controller’s connectors are all conveniently located on one end:



High current connections

This controller has three high-current busbars: B+, B- and M-. The busbars are tin-plated solid copper.

Table 1 High Current Connections	
B+	Battery+ and motor armature
B-	B-
M-	Motor field (controller output)

Cables used for the battery and motor connections must be heavy enough to carry the high current required. A minimum size of 25 mm2 (#4 AWG) is recommended.

Connections to the controller busbars should be made with lugs suitable for the cable used, fastened by M8 bolts and nuts. **When tightening the bolts, two opposing wrenches should be used.** Failure to use the double-wrench technique could cause undue strain to be placed on the internal connections, and could also result in cracked seals around the busbars.

Low current connections

This controller has six low-current connections: four 6.35 mm push-on terminals (J1, J2, J3, and J5), and two 4-pin connectors (J4 and J6).

Table 2 Low Current Connections	
J1	Keyswitch
J2	Wire 1 of 2-wire throttle; Pot High of 3-wire.
J3	Wire 2 of 2-wire throttle; Pot Wiper of 3-wire throttle.
J4	4-pin connector: see Table 3.
J5	Reverse signal output / main contactor coil driver.
J6	4-pin connector: see Table 4.

For the control wiring, 0.75 mm2 (#18 AWG) vinyl insulated stranded wire is recommended.

The mating connector for J4 is a 4-pin Molex Mini-fit Jr. or equivalent. Either an external Status LED or a USB2UART programmer can be connected to J4. The pinout is as follows.

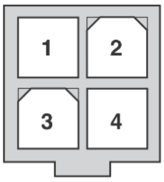


Table 3 J4 connector pinout		
PIN	PROGRAMMER	STATUS LED
J4-1	Data input from programmer (Rx).	Status LED enable.
J4-2	GND	GND
J4-3	Data output to programmer (Tx).	Status LED output.
J4-4	+12.7V	+12.7V

Note: When J4 is used for a Status LED, a jumper must be added between pins J4-1 and J4-4 as shown in the basic wiring diagram (Figure 3).

The mating connector for J6 is a 4-pin TE Mini-Universal MATE-N-LOK or equivalent. The pinout is as follows.

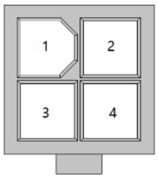


Table 4 J6 connector pinout	
PIN	PROGRAMMER
J6-1	Driver output
J6-2	Interlock
J6-3	CANL
J6-4	CANH

CONTROLLER WIRING: TYPICAL CONFIGURATION

Figure 3 shows the typical wiring configuration for most applications. The interlock switch is typically a seat switch, tiller switch, or foot switch, the interlock function can be disable in the setting. The throttle shown is a 3-wire pot; other types of throttles can also be used.

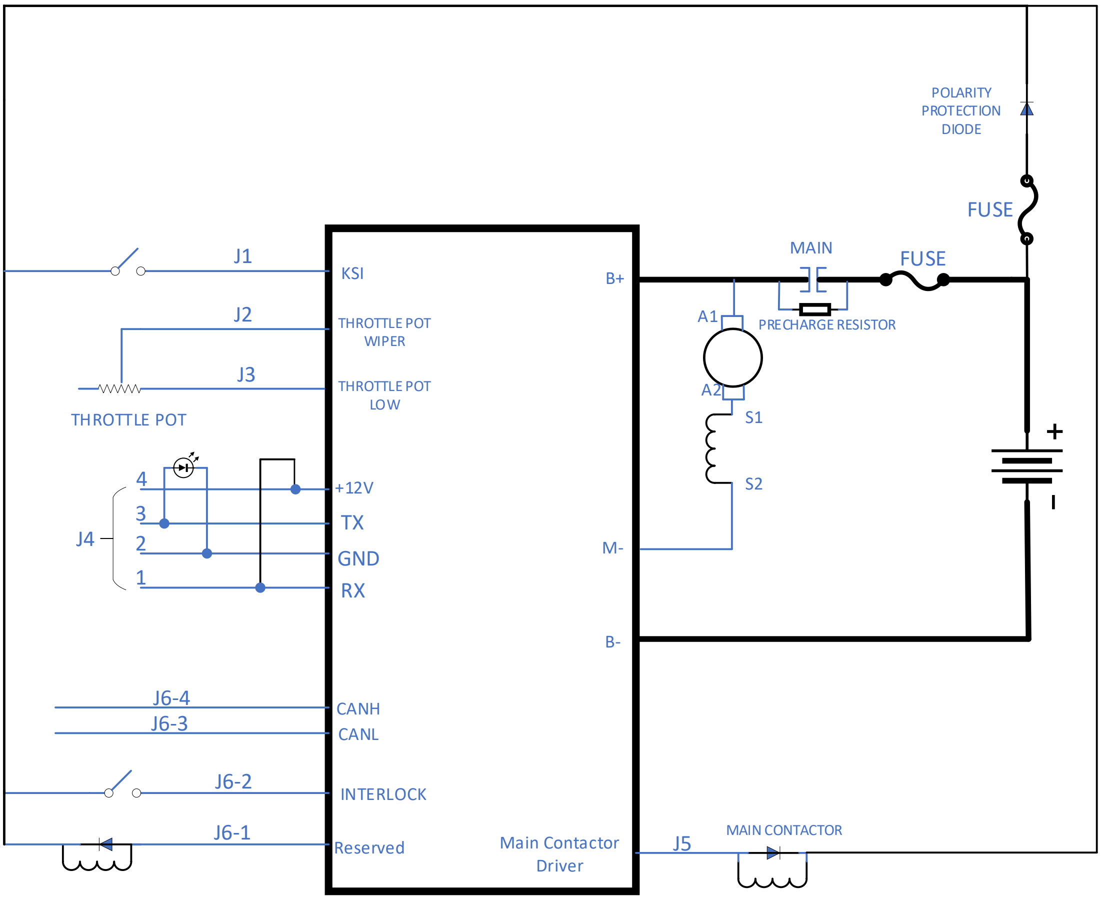


Fig.3 Typical wring diagram

KSI Wiring

The keyswitch input (KSI) circuit includes input from the keyswitch and from the various interlocks. The controller KSI is used to turn the controller on and off. KSI is turned on by connecting it to battery B+. Any positive voltage greater than about 16 volts will turn on the controller, but usually the full vehicle battery voltage is used. KSI draws up to 120 mA with the programmer connected.
In its simplest form, KSI is operated by a keyswitch that turns the vehicle off and prevents unauthorized use. The keyswitch should also turn off the main contactor This will act as a safety feature by removing power from the motor control system when the keyswitch is turned off.

Main Contactor

A main contactor should be used with the controller. Otherwise, the controller's fault detection will not be able to fully protect the controller and hydraulic system from damage in a fault condition. The main contactor allows the controller and motor to be disconnected from the battery. This provides a significant safety feature, because it means the battery power can be removed from the hydraulic system if a controller or wiring fault results in battery power being applied to the motor inappropriately.

The controller provides a low-side contactor coil driver (at J5) for the main contactor. The driver output is rated at 1 amp and is short-circuit protected. It is recommended that a coil suppression diode be included, as shown in the wiring diagrams. This protects the contactor coil driver from inductive voltage kickback spikes when the contactor is turned off.

Interlock Switch

The interlock switch, which is typically implemented as a seatswitch or a hand/foot activated deadman switch, provides a safety interlock to ensure that an operator is present in order for the system to run.

Circuitry Protection Devices

To protect the control circuitry from accidental shorts, a low current fuse (appropriate for the maximum current draw) should be connected in series with the battery feed to the keyswitch. Additionally, a high current fuse should be wired in series with the main contactor to protect the motor, controller, and batteries from accidental shorts in the power system. The appropriate fuse for each application should be selected with the help of a reputable fuse manufacturer or dealer. The standard wiring diagrams (Figure 3) show the recommended location for each fuse.

Throttle Wiring

Four throttle types can be used with this controller:

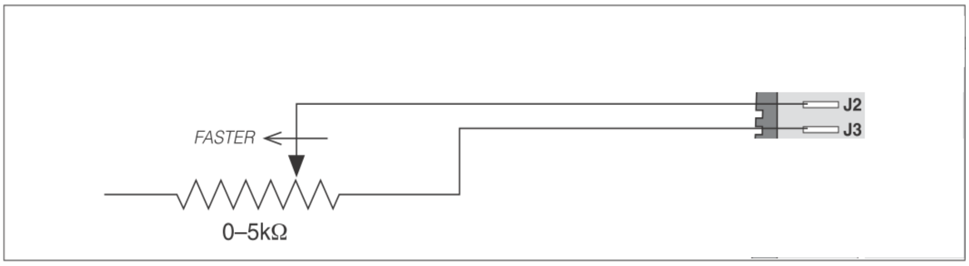
TABLE 5 WIPER INPUT: THROTTLE THRESHOLD VALUES

THROTTLE TYPE	PARAMETER	MINIMUM THROTTLE FAULT	MAXIMUM THROTTLE FAULT
0	0-5kΩ 2-wire potentiometer	-	5.5kΩ
1	5kΩ-0 2-wire potentiometer	-	5.5kΩ
2	0-5V Single-ended input	-	5.5V
3	CANOPEN command	-	1023

Throttle Type 0

Wiring for Type 0 throttles is simple: just connect the two wires to the J2 and J3 push-on terminals; it doesn’t matter which wire goes on which terminal. With Type 0 throttles, resistance increases as the applied throttle is increased. Mechanical pot boxes and foot pedals are Type 0 throttles. It doesn't matter which wire goes on which terminal, and the wires can be extended as required.

Fig 4 Wiring for 0–5k Ω throttle ("Type 0").



Some pot boxes have a built-in microswitch, eliminating the need to install a separate pedal actuated microswitch. It is important that a pedal microswitch be included in the circuit as shown in Figure 3 to allow the microcontroller a few milliseconds to boot up, run diagnostics and safety checks, and then be ready in standby before receiving the throttle signal.

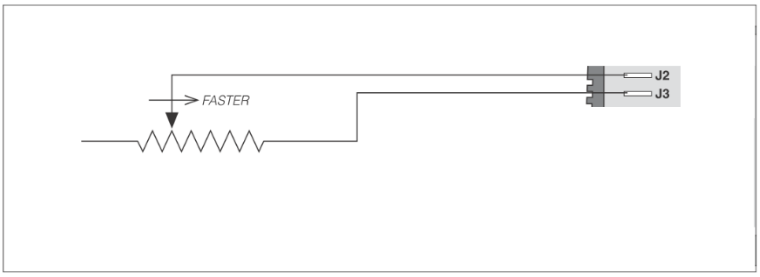
Any pot box that can provide a nominal 0–5kΩ output will work as a Type 0 throttle input.

If a pot box is used, it must be mounted so as to allow connection be-tween the pot box lever arm and the vehicle accelerator linkage. Use of a second return spring on the pedal, in addition to the pot box return spring, is required to prevent an uncontrollable full-on throttle input (which could happen if there was a single spring, and it broke). If the self-contained pot box spring is insufficient to return the pedal by itself, two additional pedal return springs must be used. It is also required that the accelerator pedal hit a mechanical stop at its full-on position just before (≈1 mm) the pot box lever hits its own full-on stop. This mechanical stop will prevent the pot box lever arm from bending if undue force is put on the pedal. Protection of the pot box from water and dirt will help avoid problems of corrosion and electrical leakage. After the pot box has been mounted, operation of the pot can be tested by measuring the resistance between the two wires with an ohmmeter. With the pedal not applied, the resistance should be less than 50 ohms. As the pedal is applied, the resistance should rise smoothly until it reaches a value between 4500 and 5500 ohms. Values below 4500 ohms may cause a reduction in efficiency and top speed; however, you still can get top speed by lowering the Throttle Max setting. Values above 5500 ohms indicate a defective pot box and will cause controller shutdown.

Throttle Type 1

Wiring for Type 1 throttles is the same as for Type 0 throttle; again, it doesn't matter which wire goes on which terminal. With these throttles, resistance is in an inverse relationship to applied throttle; that is, resistance decreases as applied throttle is increased.

Fig 4 Wiring for 5k–0 Ω throttle ("Type 0").



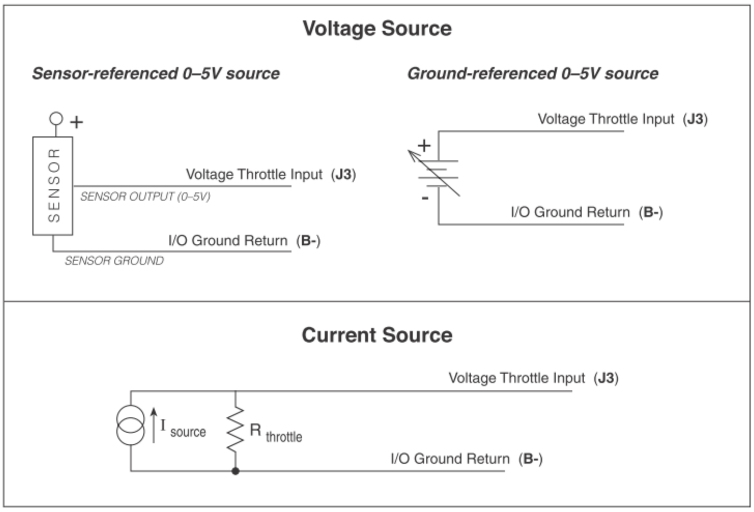
Throttle Type 2

With Type 2 throttles, the controller looks for a voltage signal at J3. Zero throttle request corresponds to 0 V and full throttle request to 5 V. A variety of devices can be used with this throttle input type, including voltage sources, current sources, and electronic throttles. The wiring for each is slightly different, as shown in Figure 10, and they have varying levels of throttle fault protection.

When a voltage source is used as a throttle, it is the responsibility of the OEM to provide appropriate throttle fault detection. For ground referenced 0–5V throttles, the controller will detect open breaks in the wiper input but cannot provide full throttle fault protection. To use a current source as a throttle, a resistor must be added to the circuit to convert the current source value to a voltage; the resistor should be sized to provide a 0–5V signal variation over the full current range. It is the responsibility of the OEM to provide appropriate throttle fault detection.

There are many electronic foot pedals on the market; for wiring, consult the instructions that are provided with the foot pedal.

Fig 5 Wiring for type 2 throttle



Throttle Type 3

Communicates with ECU and other devices via CAN. Main microcontroller of this controller can send controller's state and the measure values to other devices. The communication protocol should follow CANOpen protocol.

M700-VR1 will set as slave station, and support NMT, PDO and Emergency message.

1. Common
   - Baud rate: Configurable, default value is 250kbps (Max speed), and it is adjustable.
   - ID format: Standard ID (11bit).
   - Node type: M700-VR1 is a slave node.
   - Node ID: Configurable, default value is 1.
2. PDO
   - TPDO1 (Slave→Master, COB-ID=0x180+Node-ID, length=8)

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Status word 1 Lo	Status word 1 Hi	Throttle Lo	Throttle Hi	Battery Lo	Battery Hi	Heatsink temperature Lo	Heatsink temperature Hi
Unsigned 16 Bit 0: interlock input status Bit 1: drive 1 output status Bit 2: drive 2 output status Bit 3-15: reserved		Unsigned 16 0-1023: 0-100%		Unsigned 16 0-3600: 0-36.0V		Unsigned 16 0-150: --25-+125°C	

   - RPDO1 (Master→Slave, COB-ID=0x200+Node-ID, length=8)

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Control word Lo	Control word Hi	Throttle reference Lo	Throttle reference Hi	reserved	reserved	reserved	Reserved
Unsigned 16 Bit 0: interlock enable Bit 1: drive 1 enable Bit 2-15: reserved		Unsigned 16 0-1023: 0-100%					

3. NMT
   - NMT Module Control (Master→Slave, COB-ID=0x000, length=2)

Byte 0	Byte 1
NMT type	Node ID
0x01: start node 0x02: stop node 0x80: enter pre-operational 0x81: reset node 0x82: reset communication	0: broadcast >0: special node

- NMT Node Guarding Request (Master→Slave, COB-ID=0x700+Node-ID, remote frame)
- NMT Node Guarding Response (Slave→Master, COB-ID=0x700+ Node-ID, length=1)

Byte 0
Node Status
Bit 0-6: 0-boot up, 4-stopped, 5-operational, 127-pre-operational Bit 7: toggle bit

4. Emergency Object

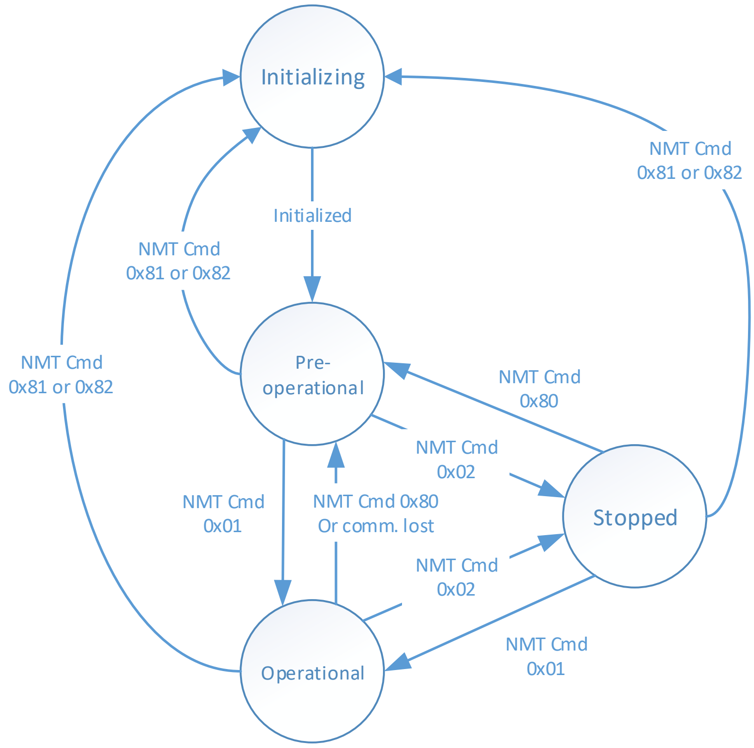
- Emergency Object (Slave→Master, COB-ID=0x080+Node-ID, length=8)

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Error code Hi	Error code Lo	reserved	reserved	reserved	reserved	reserved	reserved
Unsigned 8 High digit of error code	Unsigned 8 low digit of error code						

5. Sequence

- M700-VR1 should design 4 states for CANOpen communication: Initializing, Pre-operational, Operational, Stopped. State machine of CANOpen communication is shown as below:
- M700-VR1 changes state after received NMT Module Control frame.
- When M700-VR1 change state from initializing to pre-operational, it should send NMT Node Guarding Request frame actively. (node status is 0)
- In all states, M700-VR1 send NMT Node Guarding Response frame after received NMT Node Guarding Request frame. (Toggle bit 7 every time)
- In all states, M700-VR1 send Emergency Object once when any fault happened.
- Only in Operational state, M700-VR1 executes command in RPDO1, and send TPDO1 frame after received RPDO1 frame.

Fig 6 CANopen communication sequence



6. Error Handle
   - In operational state, if M700-VR1 not receive RPDO1 for 200ms, it will return to pre-operational state and clear all command.

3 PROGRAMMABLE PARAMETERS

The M700-VR1 programmable parameters allow the pump system's performance characteristics to be customized to fit the needs of individual applications or system operators. Programming can be done with a UART2USB adapter and PC APP.

- Voltage
  - Rating Voltage
  - Under Voltage Cutback
  - Under Voltage Cutback Rate
  - Under Voltage Cutback Off
  - Over Voltage
- Current
  - Max Current Limitation
  - Continue Current Limitation
- Speed
  - Accel Rate

- Quick Start
- Max Speed
- Throttle
  - Throttle Type
  - Throttle Deadband
  - Throttle Max
  - Throttle Map
- Misc
  - HPD
  - Boost
  - Main Contactor Driver
  - Contactor Pull In
  - Contactor Holding
  - Contactor Protection
  - Contactor Open Delay
  - Interlock
- CAN
  - CAN ID
  - CAN Baud Rate

The individual parameters are presented as follows in the parameter charts:

VOLTAGE MENU			
PARAMETER	ALLOWABLE RANGE	DEFAULT VALUE	DESCRIPTION
Rating Voltage	24V 36V	24	Set this parameter to match the battery pack of your vehicle
Under Voltage Cutback	50-100(%)	80	The controller's circuitry requires a minimum battery voltage to function properly. When battery voltage drops, reducing the controller's output to the motor allows the battery to recover. The parameter sets the threshold voltage below which controller output will start to be reduced. The programmed value is a percentage of the battery voltage.
Under Voltage Cutback Rate	0-50(A/0.1V)	5	This is a proportional value. Use the current voltage minus the cutoff voltage and then the ratio to the current output current

Under Voltage Cutback Off	50-100(%)	75	The Under Voltage Cutoff parameter sets the voltage at which controller output will be cut off completely. The programmed value is a percentage of the battery voltage. The Under Voltage Cutoff parameter can only be set to values smaller (lower) than the programmed Under Voltage Cutback.
Over Voltage	2500-3000 (Battery Voltage*100)	2800	The Over Voltage parameter sets the voltage at which controller will stop run to protect the circuit from high voltage. It is the highest voltage at that rating voltage.

CURRENT MENU

PARAMETER	ALLOWABLE RANGE	DEFAULT VALUE	DESCRIPTION
Max Current Limitation	0-3000(setting current*10)	1500	Max Current Limitation parameter sets the max current that the software allows the controller's output

SPEED MENU

PARAMETER	ALLOWABLE RANGE	DEFAULT VALUE	DESCRIPTION
Accel Rate	2-30(100ms)	10	The Accel Rate defines the time it takes the controller to accelerate from 0% output to 100% output when full throttle is applied. Larger values represent a longer acceleration time and therefore a gentler start. For faster starts, adjust the Accel Rate to a smaller value.
Quick Start	2-30(100ms)	10	When the throttle is moved from zero rapidly, the quick start feature is activated. The Quick Start acceleration rate then replaces the normal acceleration rate as set by the Accel Rate parameter). The Quick Start parameter can only be set to values smaller (faster) than the programmed Accel Rate.

Max Speed	0-1000(percentage*10)	1000	Defines the maximum requested motor speed at full forward throttle, as % PWM. Partially-applied throttle is scaled proportionately; e.g., 40% applied throttle corresponds to a request for 40% of the programmed Max Speed value. Example: if Max Speed is set to 80%, a 40% applied forward throttle corresponds to a 32% request (0.80*0.40=0.32).

THROTTLE MENU

PARAMETER	ALLOWABLE RANGE	DEFAULT VALUE	DESCRIPTION
Throttle Type	0:0-5K 1:5K-0 2:0-5V 3:CANOPEN	0:0-5k	The M700-VR1 controllers accepts a variety of throttle inputs. The Throttle Type parameter can be programmed as follows: 0: 2-wire potentiometer, 0–5kΩ input 1: 2-wire potentiometer, 5kΩ–0 input 2: single-ended 0–5V input
Throttle Deadband	10-500 (percentage*10)	200	The Throttle Deadband parameter defines the neutral deadband as a per-centage of the full throttle range. Increasing the Throttle Deadband setting will increase the neutral range. This parameter is especially useful with throttle assemblies that do not reliably return to a well-defined neutral point, because it allows the deadband to be defined wide enough to ensure that the controller goes into neutral when the throttle mechanism is released.
Throttle Max	100-1000 (percentage*10)	800	The Throttle Max parameter defines the percentage of throttle movement at which 100% output is requested. Decreasing the Throttle Max setting reduces the full stroke necessary to produce full controller output. This parameter allows reduced-range throttle assemblies to be accommodated.

Throttle Map	0-100(%)	50	The Throttle Map parameter modifies the vehicle's response to the throttle input. Setting Throttle Map at 50% provides a linear output response to throttle position. Values below 50% reduce the controller output at low throttle settings, providing enhanced slow speed maneuverability. Values above 50% give the vehicle a faster, more responsive feel at low throttle settings. The Throttle Map value is the controller output at half throttle, as a percentage of the Max Speed. Half throttle is the mid point of the throttle's active range, which is the range from zero output (at the Deadband setting) to 100% output (at the Throttle Max setting).

THRTL DEADBAND

The Throttle Deadband parameter defines the pot wiper voltage range the controller interprets as neutral. Increasing the throttle deadband setting increases the neutral range. This parameter is especially useful with throttle assemblies that do not reliably return to a well-defined neutral point, because it allows the deadband to be defined wide enough to ensure that the controller goes into neutral when the throttle mechanism is released.

Examples of deadband settings (30%, 10%, 0%) are shown in Figure 6 for throttle types 0 through 3, using a nominal 5kΩ–0 potentiometer (where applicable).

The programmer displays the throttle deadband parameter as a percentage of the nominal wiper voltage range and is adjustable from 4% to 90%, in 1% increments. The default deadband setting is 10%. The nominal wiper voltage range depends on the throttle type selected.

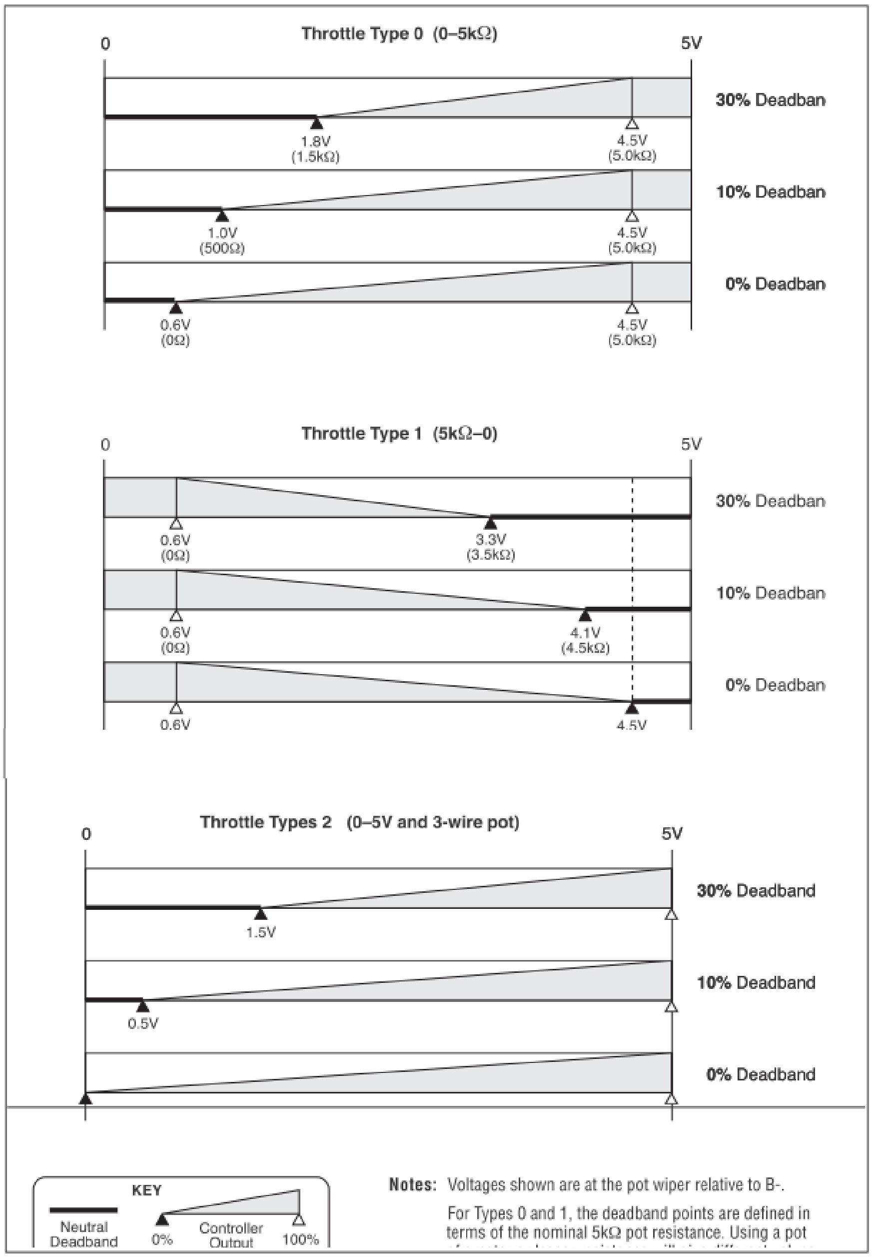


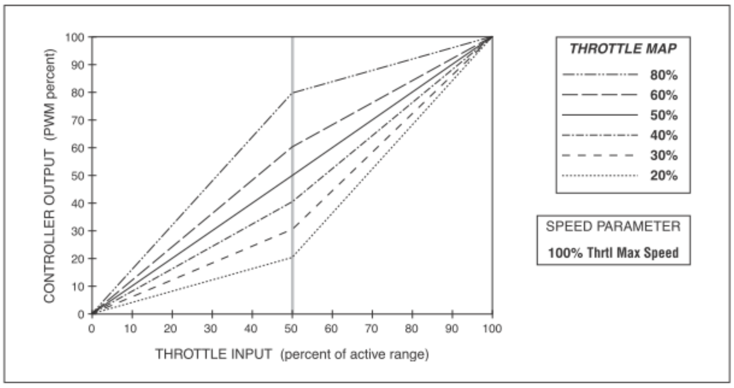
Fig. 6 Effect of adjusting the throttle deadband parameter

THROTTLE MAP

The Throttle Map parameter modifies the response to the throttle input. This parameter determines the controller output for a given mount of applied throttle. Setting the throttle map parameter at 50% provides a linear output response to throttle position. Values below 50% reduce the controller output at low throttle requests, providing enhanced slow speed control. Values above 50% give the function a faster, jumpier feel at low throttle requests.

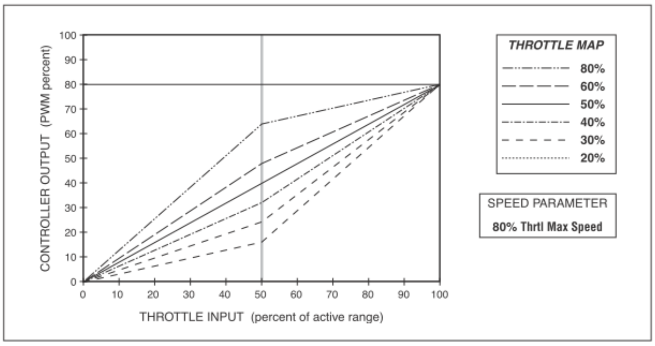
The throttle map can be programmed in 5% increments between 20% and 80%. The number refers to the controller output at half throttle, as a percentage of the throttle's full active range. The throttle's active range is the voltage or resistance between the 0% output point (throttle deadband) and the 100% output point (throttle max). For example, if maximum speed is set at 100%, a throttle map setting of 50% will give 50% output at half throttle. The 50% setting corresponds to a linear response. Six throttle map profiles (20, 30, 40, 50, 60, and 80%) are shown as examples in Figure 7, with the maximum speed set at 100%.

Fig. 7 Throttle maps for controller with maximum speed set at 100%



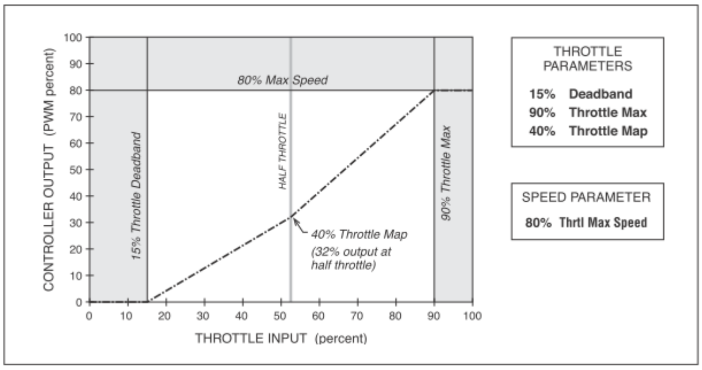
Lowering the max speed limits the controller's output range. Throttle map profiles with the max speed reduced from 100% to 80% are shown in Figure 8. The throttle map is always a percentage of the controller's output range. So, in these examples, the throttle map is a percentage of the 0–80% output range; a 40% throttle map setting will give 32% output at half throttle (40% of 80% =32%). Controller output will begin to increase as soon as the throttle is rotated out of its normal neutral range (deadband). Controller output will continue to increase, following the curve defined by the throttle map setting, as the throttle input increases and will reach maximum output when the throttle input enters the upper deadband (crosses the throttle max threshold).

Fig.8 Throttle maps for controller with maximum speed set at 80%



The throttle map operates within the window established by the Throttle Max Speed, Throttle Deadband, and Throttle Max parameters, as shown below in Figure 9. Throttle Max Speed defines the controller's output range, while Throttle Deadband and Throttle Max define the throttle's active range. These three parameters, together with the Throttle Map parameter, determine the controller's output response to throttle demand.

Fig. 9 Influence of various parameters on controller output response to throttle demand



MISCELLANEOUS PARAMETERS			
PARAMETER	ALLOWABLE RANGE	DEFAULT VALUE	DESCRIPTION
HPD	Disable/Enable	Disable	By preventing the vehicle from being turned on with the throttle applied, the HPD feature ensures the vehicle starts smoothly and safely. To start, the controller must receive an input to KSI before receiving a throttle input. In addition to providing routine smooth starts, HPD also protects against accidental sudden starts if problems in the linkage (such as bent parts or a broken return spring) give a throttle input signal to the controller even with the throttle released. When programmed enable, the HPD feature is enabled. This is required for full throttle protection. When programmed disable, the HPD feature is not enabled.
Boost	Disable/Enable	Disable	In situations where the controller detects that the motor is about to stall, the boost feature provides a short burst of extra torque by briefly applying a current higher than the rated current. This can be useful for occasionally getting the vehicle out of a pothole or over an obstacle. Setting the Boost parameter Enable enables the boost feature. If the Boost parameter is set to Disable, the controller's output is limited to its rated current.
Main Contactor Driver	Disable/Enable	Disable	The Main Contactor Driver parameter determines the signal input at the controller's J5 terminal; see basic wiring diagrams, Figures 3. Disable= Main Contactor Driver function is invalid; Enable= Main Contactor Driver function is active;
Contactor Pull In	16-24(v)	24	The Main Contactor Pull-in Voltage parameter allows a high initial voltage when the contactor driver first turns on, to ensure contactor closure. After the controller detects that the contactor is closed, this peak voltage will be applied for 0.1 second to ensure a reliable close; the voltage will then drop to the programmed contactor holding voltage.

Contactor Holding	16-24(v)	20	The Contactor Holding Voltage parameter allows a reduced average voltage to be applied to the contactor coil once it has closed. The holding voltage must be set high enough to hold the contactor closed under all shock and vibration conditions it will be subjected to.
Contactor Protection	Disable/Enable	Disable	The Contactor Protection parameter can be used to protect the tips of main contactor from possible damage due to high current arcs. If the Contactor Protection parameter is programmed Enable, when the controller detects the throttle is released (within the throttle deadband) it will immediately cut off the PWM output, and because the current is cut off quickly the contactor tips will be opened with no high current arcs. Similarly, when contactor is open, the controller will lock the PWM output so that when the contactor starts to close again, there is no current on the tips. If programmed Disable, this protection is lost. However, the PWM will decrease at the set deceleration rate instead of abruptly, resulting in a smoother stop—which may be desired in some applications.
Contactor Open Delay	0-60(s)	0	The Contactor Open Delay defines the time delay before the main contactor drops out after there has been no active throttle signal. Setting Main Drop Delay = 0 means the main contactor never drops out; it does not mean there is no delay.
Interlock	Disable/Enable	Disable	Input from operator-present switch, tied to B+

CAN PARAMETERS			
PARAMETER	ALLOWABLE RANGE	DEFAULT VALUE	DESCRIPTION
Baud Rate	250k 125K 100K 50K	250K	This parameter sets the CANopen Baud rate for the communication.
CAN ID	0-120	2	This parameter sets the CAN ID.

4 MONITOR MENU

Through its Monitor menu, the programmer provides access to real-time data during vehicle operation. This information is helpful during diagnostics and troubleshooting, also adjusting programmable parameters.

MONITOR MENU		
VARIABLE	DISPLAY UNITS	DESCRIPTION
Heatsink Temp	°C	Heatsink Temperature
Throttle	%	Throttle request, as percentage of full throttle.
Duty Cycle	%	Controller's PWM output, as percentage of programmed Max Speed.
Cap Voltage	V	Voltage of controller's internal capacitor bank at B+ busbar.
KSI Voltage	V	Voltage of controller's KSI input.
Fault information	/	Show the fault information, if no fault this will be null.
Main Contactor Status	/	Show the Main Contactor status if it is active.
Motor Current	A	Motor output current value.

Note: All the monitor parameters should be used a general USB2UART adaptor connecting to PC and Sensata PC APP should be used.

All mostly this monitor menu is not used on the vehicle, unless this vehicle has a display. This not means the monitor menu is not useful, it is necessary when the vehicle is initialized and when the controller is troubleshooting.

5 DIAGNOSTICS AND TROUBLESHOOTING

The M700-VR1 controller provides diagnostics information to assist technicians in troubleshooting pump system problems. The diagnostics information can be obtained by connecting to PC by USB3UART adaptor or the fault codes issued by the optional Status LED. Refer to the troubleshooting chart for suggestions covering a wide range of possible faults.

PC APP DIAGNOSTICS

The APP presents complete diagnostic information in plain language. Faults are displayed in the Faults Menu (in the troubleshooting chart), and the status of the controller inputs/outputs is displayed in the Monitor Menu.

Accessing the Fault History Menu provides a list of the faults that have occurred since the fault history file was last cleared. Checking (and clearing) the fault history file is recommended each time the vehicle is brought in for maintenance.

Table 5 TROUBLESHOOTING CHART				
LED CODES		PC APP DISPLAY	EXPLANATION	POSSIBLE CAUSE
0,1	■ ¤	/	Controller operational; no known faults	/
1.1	¤ ¤	EEPROM fault	EEPROM fault Note: Usually can be cleared by modifying any parameter value in the Program Menu	1. EEPROM data lost or damaged. 2. EEPROM checksum error.
1,2	¤ ¤¤	MOSFET short fault	MAIN MOSFET shorted	MOSFET shorted
1,3	¤ ¤¤¤	Over current	Motor output over current	Motor shorted or over current
1.4	¤ ¤¤¤¤	Throttle wiring fault	Throttle wiring wrong	Throttle wiring does not match the Throttle type setting
2,1	¤¤ ¤	Under voltage cutoff	Under voltage cutoff	Battery voltage<VOLTAGE CUTOFF setting
2,3	¤¤ ¤¤¤	HPD lock fault	HPD sequencing error	Throttle signal is active when the controller startup
2,4	¤¤ ¤¤¤¤	Throttle fault	Wiper signal out of range	Throttle signal is out of range
3.1	¤¤¤ ¤	Coil short/driver fault	Coil short/driver fault	Main contactor coil short
3,2	¤¤¤ ¤¤	Main weld fault	Main contactor welded.	1Main contactor struck closed 2 Main contactor coil short
3.3	¤¤¤ ¤¤¤	Main driver fault	Main contactor coil open	1 Main contactor coil open 2 Main Contactor Driver parameter setting wrong
3,4	¤¤¤ ¤¤¤¤	Main contactor DNC	Main contactor did not close	1 Main contactor driver loose 2 Main contactor did not close
4,1	¤¤¤¤ ¤	Undervoltage cutback	Undervoltage cutback	Battery voltage<VOLTAGE CUTBACK setting

4,2	¤¤¤¤ ¤¤	Over voltage	Over voltage	Battery voltage> OVER VOLTAGE setting
4,3	¤¤¤¤ ¤¤¤	Thermal cutback	Thermal cutback	1 Heatsink temperature>85℃ or <-25℃ 2 Thermal detection circuit fault
4,4	¤¤¤¤ ¤¤¤¤	Over Temperature, more than 120℃	Over Temperature, more than 120℃	1 Heatsink temperature>120℃ 2 Thermal detection circuit fault
5.1	¤¤¤¤¤ ¤	Pre-charge failed	Pre-charge failed	1 Pre-charge circuit failure 2 External short or leakage between B+ and B-
5.2	¤¤¤¤¤ ¤¤	Sample circuit fault	Sample circuit fault	Current sample circuit fail

LED DIAGNOSTICS

During normal operation, with no faults present, the Status LED flashes steadily. If the controller detects a fault, a 2-digit fault code is flashed until the fault is corrected. For example, code “2,3”—HPD lock fault—appears as:

¤¤ ¤¤¤ (2 , 3)	¤¤ ¤¤¤ (2 , 3)	¤¤ ¤¤¤ (2 , 3)

LED CODES		EXPLANATION
LED off	▬	No power or defective controller
Solid on	▭	Controller or microprocessor fault
0,1	■ ¤	Controller operational; no known faults
1.1	¤ ¤	EEPROM fault
1,2	¤ ¤¤	MOSFET short fault
1,3	¤ ¤¤¤	Over current
1.4	¤ ¤¤¤¤	Throttle wiring fault
2,1	¤¤ ¤	Under voltage cutoff
2,3	¤¤ ¤¤¤	HPD lock fault
2,4	¤¤ ¤¤¤¤	Throttle fault
3.1	¤¤¤ ¤	Coil short/driver fault
3,2	¤¤¤ ¤¤	Main weld fault
3.3	¤¤¤ ¤¤¤	Main driver fault
3,4	¤¤¤ ¤¤¤¤	Main contactor DNC

4,1	¤¤¤¤ ¤	Undervoltage cutback
4,2	¤¤¤¤ ¤¤	Over voltage
4,3	¤¤¤¤ ¤¤¤	Thermal cutback
4,4	¤¤¤¤ ¤¤¤¤	Over Temperature, more than 120℃
5.1	¤¤¤¤¤ ¤	Pre-charge failed
5.2	¤¤¤¤¤ ¤¤	Sample circuit fault

Note: Only one fault is indicated at a time. Faults are not queued up. Refer to the troubleshooting chart (Table 5) for suggestions about possible causes of the various faults.

6 MAINTENANCE

There are no user serviceable parts in the M700-VR1 controller. No attempt should be made to open, repair, or otherwise modify the controller. Doing so may damage the controller and will void the warranty.

It is recommended that the controller be kept clean and dry that its fault history file be checked and cleared periodically.

CLEANING

Periodically cleaning the controller exterior will help protect it against corrosion and possible electrical control problems created by dirt, grime, and chemicals that are part of the operating environment and that normally exist in battery powered systems.

caution

When working around any battery powered system, proper safety precautions should be taken. These include, but are not limited to proper training, wearing eye protection, and avoiding loose clothing and jewelry.

Use the following cleaning procedure for routine maintenance. Never use a high-pressure washer to clean the controller.

1. Remove power by disconnecting the battery.
2. Discharge the capacitors in the controller by connecting a load (such as a contactor coil) across the controller's B+ and B- terminals.

3. Remove any dirt or corrosion from the power and signal connector areas. The controller should be wiped clean with a moist rag. Dry it before reconnecting the battery.
4. Make sure the connections are tight.

FAULT HISTORY

The PC APP and USB2UART adaptor can be used to access the controller's fault history. The APP will read out all the faults that the controller has experienced since the last time the fault history file was cleared. The faults may be intermittent faults, faults caused by loose wires, or faults caused by operator errors. Faults such as contactor faults may be the result of loose wires; contactor wiring should be carefully checked. Faults such as startup lockout or overtemperature may be caused by operator habits or by overloading.

After a problem has been diagnosed and corrected, it is a good idea to clear the diagnostic history file. This allows the controller to accumulate a new file of faults. By checking the new fault history file at later date, you can readily determine whether the problem was indeed fixed.

APPENDIX A
VEHICLE DESIGN CONSIDERATIONS
REGARDING ELECTROMAGNETIC COMPATIBILITY (EMC)
AND ELECTROSTATIC DISCHARGE (ESD)

ELECTROMAGNETIC COMPATIBILITY (EMC)

Electromagnetic compatibility (EMC) encompasses two areas: emissions and immunity. Emissions are radio frequency (RF) energy generated by a product. This energy has the potential to interfere with communications systems such as radio, television, cellular phones, dispatching, aircraft, etc. Immunity is the ability of a product to operate normally in the presence of RF energy.

EMC is ultimately a system design issue. Part of the EMC performance is designed into or inherent in each component; another part is designed into or inherent in end product characteristics such as shielding, wiring, and layout; and, finally, a portion is a function of the interactions between all these parts. The design techniques presented below can enhance EMC performance in products that use Sensata motor controller.

Emissions

Signals with high frequency content can produce significant emissions if connected to a large enough radiating area (created by long wires spaced far apart). Contactor drivers and the motor drive output from controller can contribute to RF emissions. Both types of output are pulse width modulated square waves with fast rise and fall times that are rich in harmonics. (Note: contactor drivers that are not modulated will not contribute to emissions.) The impact of these switching waveforms can be minimized by making the wires from the controller to the contactor or motor as short as possible and by placing the wires near each other (bundle contactor wires with Coil Return; bundle motor wires separately).

For applications requiring very low emissions, the solution may involve enclosing the controller, interconnect wires, contactors, and motor together in one shielded box. Emissions can also couple to battery supply leads and throttle circuit wires outside the box, so ferrite beads near the controller may also be required on these unshielded wires in some applications. It is best to keep the noisy signals as far as possible from sensitive wires.

Immunity

Immunity to radiated electric fields can be improved either by reducing overall circuit sensitivity or by keeping undesired signals away from this circuitry. The controller circuitry itself cannot be made less sensitive, since it must accurately detect and process low level signals from sensors such as the throttle potentiometer. Thus, immunity is generally achieved by preventing the external RF energy from coupling into sensitive circuitry. This RF energy can get into the controller circuitry via conducted paths and radiated paths.

Conducted paths are created by the wires connected to the controller. These wires act as antennas and the amount of RF energy coupled into them is generally proportional to their length. The RF voltages and currents induced in each wire are applied to the controller pin to which the wire is connected. The controller includes bypass capacitors on the printed circuit board's throttle wires to reduce the impact of this RF energy on the internal circuitry. In some applications, additional filtering in the form of ferrite beads may also be required on various wires to achieve desired performance levels.

Radiated paths are created when the controller circuitry is immersed in an external field. This coupling can be reduced by placing the controller as far as possible from the noise source or by enclosing the controller in a metal box. The controller is enclosed by a heatsink that also provides shielding around the controller circuitry, while others are partially shielded or unshielded. In some applications, the vehicle designer will need to mount the controller within a shielded box on the end product. The box can be constructed of just about any metal, although steel and aluminum are most commonly used.

Most coated plastics do not provide good shielding because the coatings are not true metals, but rather a mixture of small metal particles in a non-conductive binder. These relatively isolated particles may appear to be good based on a dc resistance measurement but do not provide adequate electron mobility to yield good shielding effectiveness. Electroless plating of plastic will yield a true metal and can thus be effective as an RF shield, but it is usually more expensive than the coatings.

A contiguous metal enclosure without any holes or seams, known as a Faraday cage, provides the best shielding for the given material and frequency. When a hole or holes are added, RF currents flowing on the outside surface of the shield must take a longer path to get around the hole than if the surface was contiguous. As more "bending" is required of these currents, more energy is coupled to the inside surface, and thus the shielding effectiveness is reduced. The reduction in shielding is a function of the longest linear dimension of a hole rather than the area. This concept is often applied where ventilation is necessary, in which case many small holes are preferable to a few larger ones.

Applying this same concept to seams or joints between adjacent pieces or segments of a shielded enclosure, it is important to minimize the open length of these seams. Seam length is the distance between points where good ohmic contact is made. This contact can be provided by solder, welds, or pressure contact. If pressure contact is used, attention must be paid to the corrosion characteristics of the shield material and any corrosion-resistant processes applied to the base material. If the ohmic contact itself is not continuous, the shielding effectiveness can be maximized by making the joints between adjacent pieces overlapping rather than abutted.

The shielding effectiveness of an enclosure is further reduced when a wire passes through a hole in the enclosure; RF energy on the wire from an external field is re-radiated into the interior of the enclosure. This coupling mechanism can be reduced by filtering the wire where it passes through the shield boundary.Given the safety considerations involved in connecting electrical components to the chassis or frame in battery powered vehicles, such filtering will usually consist of a series inductor (or ferrite bead) rather than a shunt capacitor. If a capacitor is used, it must have a voltage rating and leakage characteristics that will allow the end product to meet applicable safety regulations.

The B+ (and B-, if applicable) wires that supply power to a control panel should be bundled with the other control wires to the panel so that all these wires are routed together. If the wires to the control panel are routed separately, a larger loop area is formed. Larger loop areas produce more efficient antennas which will result in decreased immunity performance.

Keep all low power I/O separate from the motor and battery leads. When this is not possible, cross them at right angles.

ELECTROSTATIC DISCHARGE (ESD)

Sensata motor controllers contain ESD-sensitive components, and it is therefore necessary to protect them from ESD (electrostatic discharge) damage. Most of these control lines have protection for moderate ESD events but must be protected from damage if higher levels exist in a particular application.

ESD immunity is achieved either by providing sufficient distance between conductors and the ESD source so that a discharge will not occur, or by providing an intentional path for the discharge current such that the circuit is isolated from the electric and magnetic fields produced by the discharge. In general, the guidelines presented above for increasing radiated immunity will also provide increased ESD immunity.

It is usually easier to prevent the discharge from occurring than to divert the current path. A fundamental technique for ESD prevention is to provide adequately thick insulation between all metal conductors and the outside environment so that the voltage gradient does not exceed the threshold required for a discharge to occur. If the current diversion approach is used, all exposed metal components must be grounded. The shielded enclosure, if properly grounded, can be used to divert the discharge current; it should be noted that the location of holes and seams can have a significant impact on ESD suppression. If the enclosure is not grounded, the path of the discharge current becomes more complex and less predictable, especially if holes and seams are involved. Some experimentation may be required to optimize the selection and placement of holes, wires, and grounding paths. Careful attention must be paid to the control panel design so that it can tolerate a static discharge.

MOV, TVS, or other devices can be placed between B- and offending wires, plates, and touch points if ESD shock cannot be otherwise avoided.

APPENDIX B
PROGRAMMING DEVICES

Sensata provides an APP than can run on PC, that can read information and parameters from the controllers. The customer should use a USB2UART adaptor to connect PC and the controller. This adaptor is general and can be buy from the market or design by self. The controller provides a 4-pin connector J4 to match the adaptor.

This figure shows the connection between the PC and M700-VR1. The terminal for this connection cable should match the J4 connector (Table 3).

The customer can adjust the parameters referring the application and monitor the information from the controller.

PROGRAMMER FUNCTIONS

Programmer functions include:

COM setting— set the COM number and the Baud rate.

Parameter adjustment — provides access to the individual programmable parameters.

Monitoring — presents real-time values during vehicle operation; these include all inputs and outputs.

Diagnostics and troubleshooting — presents diagnostic information, and also a means to clear the fault history file,

Programming — allows you to update the system software.

APPENDIX C
SPECIFICATIONS

SPECIFICATIONS: M700-VR1 CONTROLLER

Nominal input voltage	24 V and 36V
PWM operating frequency	15.6 kHz
Electrical isolation to heatsink	500 VAC (minimum)
KSI Input current (no Contactors engaged)	100 mA
Logic input current	< 2 mA
Status LED output current (max.)	< 2 mA
Throttle types	2-wire rheostats: 0–5kΩ, 5kΩ–0 Voltage throttles: 0–5V CANopen
Operating ambient temperature range	-40°C to 50°C
Storage ambient temperature range	-40°C to 85°C
Package Environmental rating	IP54
Dimensions (L×W×H)	173×146×77mm
Weight	2.5kg
Regulatory compliance	Designed to The requirements Of EN 12895 and EN 61000 *Note: Regulatory compliance of the complete vehicle system with the controller installed is the responsibility of the OEM.*

MODEL NUMBER	NOMINAL BATTERY VOLTAGE	CURRENT RATING		
		2MINUTE	5MINUTE	1HOUR
M700-VR1	24/36V	300A	250A	150A

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