WaveSculptor Motor Controller Datasheet

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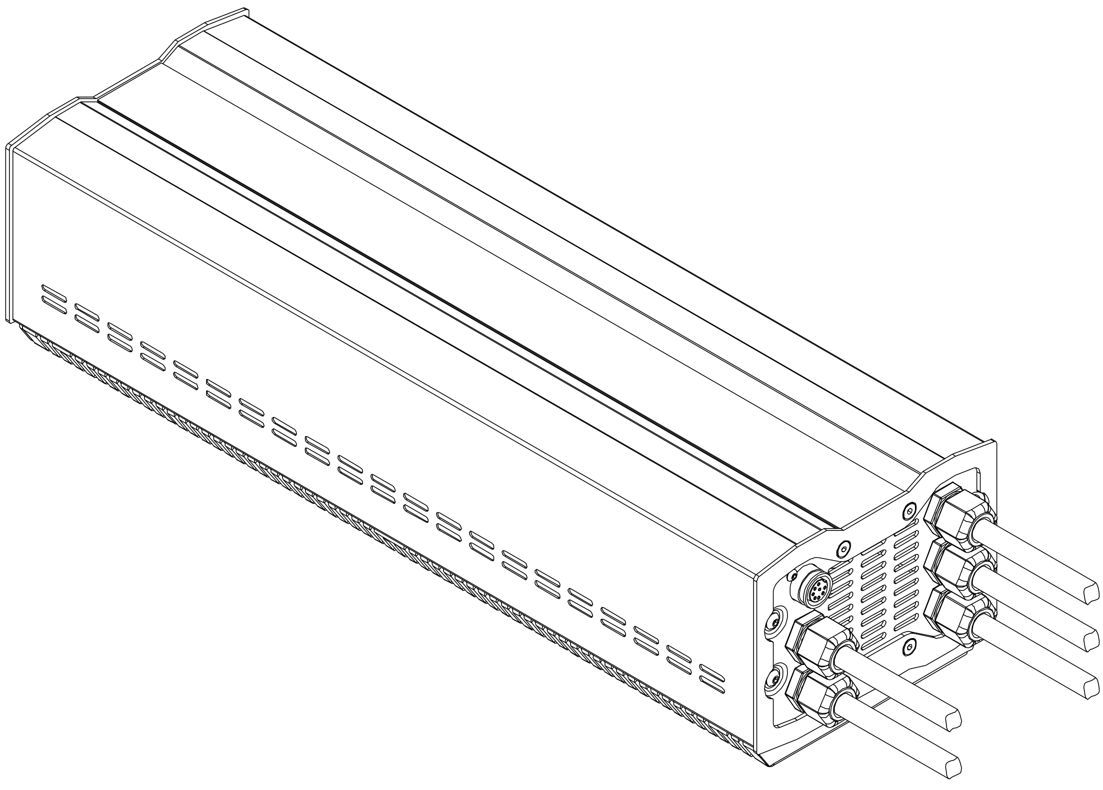
1 INTRODUCTION

This document describes the electrical specifications, performance and properties of the Tritium WaveSculptor Motor Controller.

For more details on communications and programming, please refer to the relevant specification documents available on the Tritium website.

For more details on mechanical positioning and mounting, wiring and precharge, and network configuration, please refer to the engineering reference documents available on the Tritium website.

Operating the controller beyond the limits specified in this document will result in the voiding of the controller warranty, and any repairs required will be at the owners expense. Tritium accepts no responsibility for events caused as a result of operating the controller beyond the limits specified in this document.



2 DC BUS

The DC bus connection provides power to the controller during normal (motoring) operation, and accepts power from the controller during regenerative braking operation. It is expected to be connected to a battery pack through a precharge circuit and a fuse.

Continuous voltage minimum:	0	V	(Note 1)
Continuous voltage maximum:	160	V	
Peak voltage maximum:	165	V	(Note 2)
Peak current maximum (drive):	122	A	(Note 3, 4)
Peak current maximum (regen):	-122	A	(Note 3, 4)

Notes:

1. The WaveSculptor control electronics operate from low-voltage DC supplied along the CAN bus cable, not from the high-voltage DC bus. Therefore, the supply to the main power stage (via the DC bus) has no operating minimum voltage.
2. The WaveSculptor uses 200V MOSFETs as the power switching elements. Exceeding this voltage across the device for even a short interval (nanoseconds) will result in catastrophic failure of the motor controller. The WaveSculptor contains sufficient internal capacitance, and sufficiently rapid detection circuitry, such that it can protect itself against a self-imposed worst-case situation during normal operation. This situation is regenerative braking at full current, at maximum continuous bus voltage, and having the DC bus connection broken or removed. This situation can occur as a result of the DC bus protection contactor opening, the battery fuse blowing, or a loose connection in the vehicle wiring. Operating with higher DC bus voltages than the continuous voltage maximum could result in this self-protection mechanism failing to shut down the controller in time, resulting in the destruction of the controller.
3. The peak current rating of the DC bus is related to the worst case drive situation, which is driving at full current and full speed. In this case, the bus current will be $\sqrt{3} / \sqrt{2}$ * RMS motor current maximum (100A) giving a peak current of 122A DC. The equivalent factors apply for regenerative braking. Although the controller is capable of processing this bus current, the motor impedance will limit the current at high speed, therefore limiting the bus current. Refer to the TRI50.019 Motor Impedance document for more information on this topic.
4. The maximum DC bus current can be limited by the WaveSculptor under software control, and is adjustable dynamically via a command on the CAN bus during operation to anywhere between 0 and 100% of full current. This feature can be used to limit the current capability and sizing of battery packs, battery wiring, and battery fusing and contactors.

3 MOTOR POWER

The WaveSculptor uses two output drive modes. Below around 10km/h (for a 0.5m wheel with hub motor) it provides a six-step square-wave output to begin rotating the motor, using motor position sensors for feedback. Once the motor is moving, the WaveSculptor switches to sensorless control mode, and provides a space-vector modulated sine-wave output.

Peak motor current maximum:	100	A_{rms}	(Note 5)
Output voltage maximum (at max DC bus):	110	$V_{rms\ line\text{-}line}$	
Motor phase inductance minimum:	50	µH	(Note 6, 8)
Motor resistance minimum:	0	Ω	(Note 7, 8)
Sensorless engage frequency:	2.5	Hz	(Note 9)
Sensorless disengage frequency:	1.75	Hz	(Note 9)

Notes:

5. The peak motor current is software controlled and may be limited to lower values via the configuration / setup utility if required. Continuous motor current is limited by thermal performance of the controller and depends on external factors such as ambient temperature and airflow.
6. The WaveSculptor requires a minimum amount of inductance in each motor phase to properly regulate current. Not providing this inductance may result in an out-of-regulation condition of the motor current control loop, possibly resulting in an undesired self-protection shutdown, or failure of the controller. Please ensure that both the motor inductance, and any external inductors (if used), are still providing at least the minimum required inductance, even at full rated current, and at elevated temperatures.
7. As long as the minimum inductance per phase requirement is met, the WaveSculptor will regulate current and operate successfully into a shorted connection.
8. The WaveSculptor can report inductance and resistance present on it’s output when running the configuration / setup program. This will provide a figure for the complete output circuit, including motor, external inductors (if any), wiring, and connectors. This can be used to verify these values meet the datasheet requirements, but only for low current operation.
9. This is a mechanical rotational frequency, not an electrical motor frequency. Other conditions must also be met before the sensorless control system engages. Please refer to document TRI50.017 Algorithms for more information on this topic.

4 MOTOR SENSE

The WaveSculptor requires three sensors from the motor to give position feedback while in six-step drive mode. It also measures the motor temperature for both telemetry data and motor protection, if desired.

Sensor power supply output minimum:	12	V	(Note 10)
Sensor power supply output maximum:	16	V	
Sensor power supply output regulated:	5	V	(Note 10)
Sensor power supply current maximum:	50	mA	
Sensor power supply isolation:	400	V	(Note 11)
Sensor input phase offset:	±10	°	(Note 12, 13)
Temperature sensor:	10	kΩ	(Note 14)

Notes:

10. The WaveSculptor provides an isolated voltage supply to operate the motor position sensors and motor temperature sensor. This supply is an unregulated supply operating from the internal controller operating voltage of 15V. It may vary under load conditions between the specified values. As a factory build option, this supply voltage may also be set to a regulated 5V output. The higher voltage supply will provide a more noise-immune signal path for the motor position sensors. Please check with your motor supplier for the acceptable operating voltage of the position sensors used in your motor.
11. The sensor output supply, position inputs, and temperature input, have an isolation barrier between them and both the DC bus and the CAN bus voltages.
12. Motor position sensors should be aligned such that the phase angle offset between each sensor's output changing state, and the zero-crossing point of it's approprate motor phase, is no more than the specified maximum. This implies that the sensors are 120° offset (electrically, per motor pole) from each other under ideal conditions.
13. The polarity and arrangement of the position input signals does not matter. The WaveSculptor detects relative alignment of position signals to motor phases, as well as the polarity of each input, when the Phasorsense algorithm is run during motor controller configuration and setup. The WaveSculptor can store this information for multiple motors, thus allowing motor changes in your vehicle without having to re-run the configuration program. Please refer to the communications and programming specification documents for more information.
14. The WaveSculptor expects a 10kΩ (at 25°C) NTC thermistor embedded in the motor to detect motor temperature. The beta and logarithmic fit constants (available in the thermistor datasheet) can be programmed into the WaveSculptor during configuration / setup to exactly match the temperature response of your thermistor.

5 EFFICIENCY

To estimate an operating point efficiency of the WaveSculptor, refer to the efficiency maps below. These two plots are generated using a DC bus voltage of 160V and 90V respectively, and operating with a CSIRO 'surface' type motor. The motor efficiencies are not included in the plot.

For Illustration 1, using typical solar car with a mass of 275kg and a wheel radius of 250mm, the maximum values on each axis will correspond to a speed of 135km/h and an accelleration of 0.16g.

The efficiency (in percent) is shown using the red lines, and the power being processed by the WaveSculptor using the green lines (in kW). As an example, a car may operate at 100 rads/s motor velocity and 40 Nm of torque. The graph shows that at this point, the WaveSculptor will be processing just over 4 kW of power at 98% efficiency.

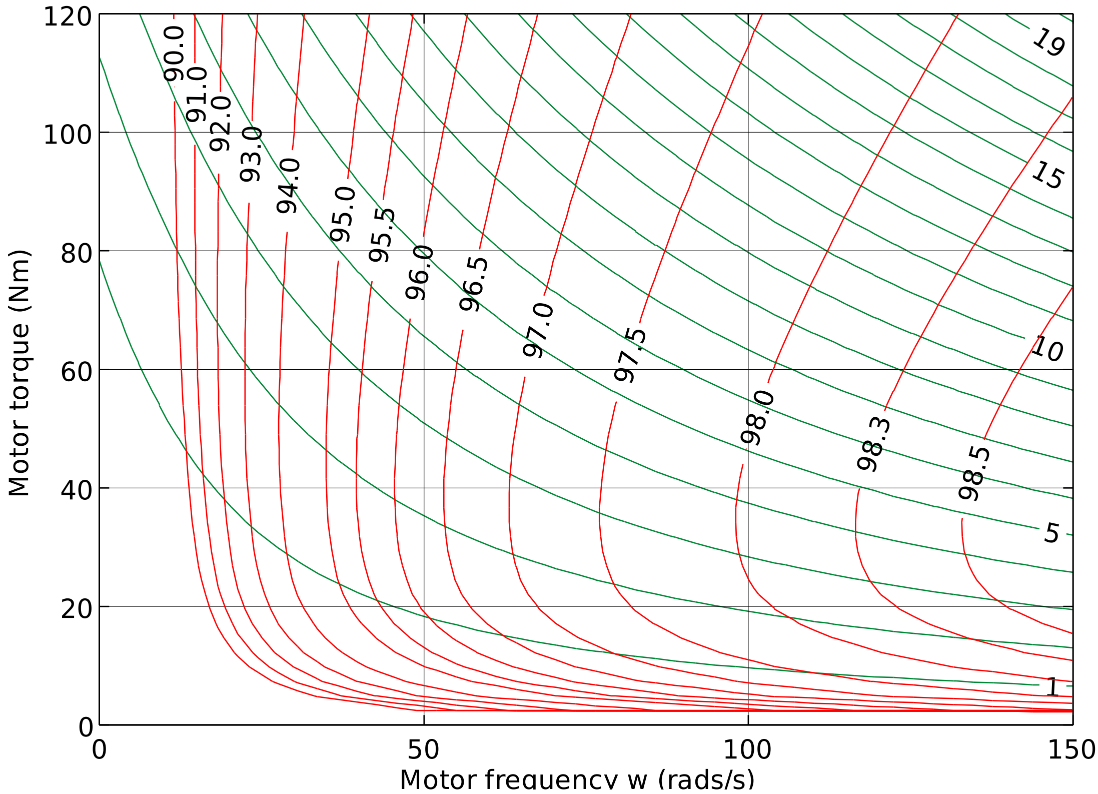


Illustration 1: Predicted efficiency map of the WaveSculptor controller with a 160V DC bus

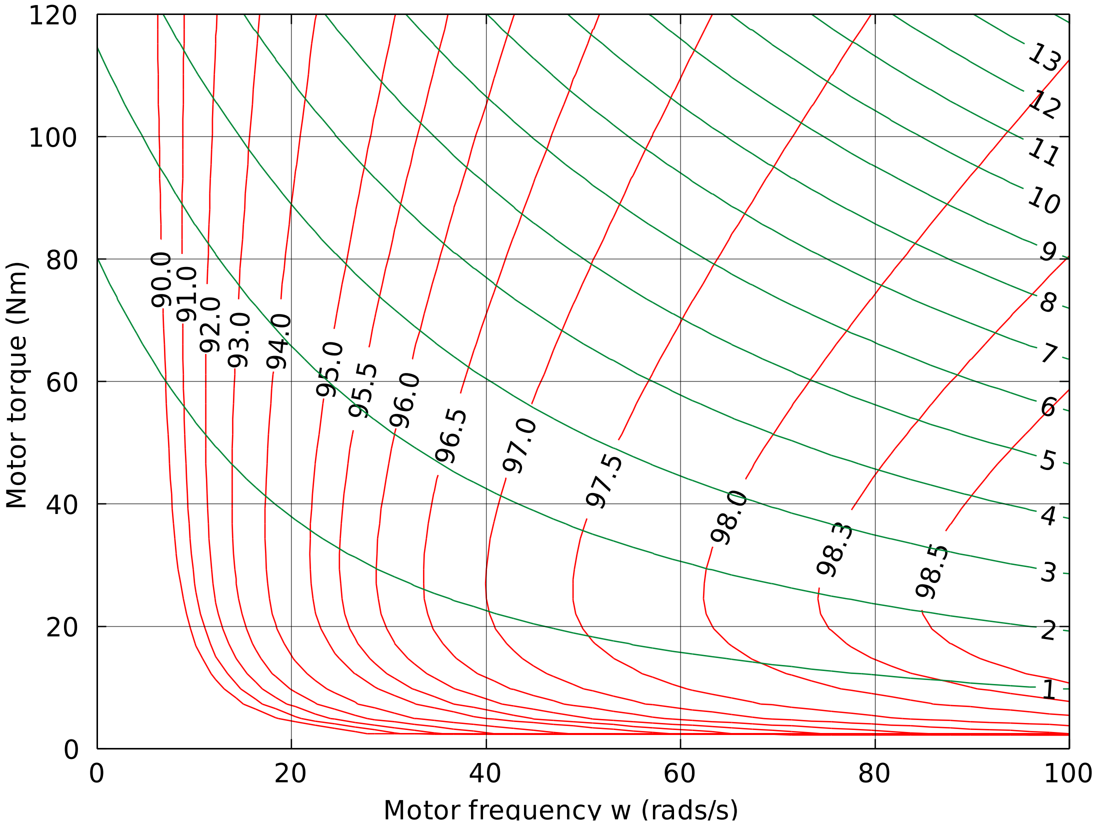


Illustration 2: Predicted efficiency map of the WaveSculptor controller with a 90V DC bus

These efficiency maps were generated using an accurate mathematical model of the WaveSculptor's power stage. The parameters used in this model have been experimentally obtained.

6 OPERATING POWER & COOLING

The peak output power from the WaveSculptor is limited by internal hardware restrictions, as detailed in previous sections. However, the average power capability of the controller is limited by thermal performance, and as such, is affected by conditions external to the controller such as ambient temperature and airflow.

The WaveSculptor has internal fans to provide forced cooling for the main heatsink and other power components requiring cooling. These fans operate at whatever speed is required to keep the controller within acceptable operating limits. Therefore, providing cooler input air to the controller will result in a lower operating speed for these fans, giving lower power consumption for the controller. Careful consideration should be paid to the position and ventilation of the WaveSculptor controller(s) in your vehicle.

Peak power output:	20.0	kVA	(Note 15)
Continuous power output at 30°C ambient:	7.00	kVA	(Note 16)
Continuous power output at 40°C ambient:	5.25	kVA	(Note 16)
Continuous power output at 50°C ambient:	3.50	kVA	(Note 16)

Notes:

15. Maximum software current limit multiplied by maximum DC bus voltage limit.
16. The controller is thermally limited to maintain its heatsink temperature below 85°C.

7 CONTROL & TELEMETRY INTERFACE

The WaveSculptor receives commands, and transmits telemetry values, using a CAN bus connection. No other interface is provided. Low-voltage DC power must be provided along the CAN bus cable to operate the control electronics of the WaveSculptor.

CAN bus supply voltage minimum:	9	V	(Note 17)
CAN bus supply voltage maximum:	15	V	(Note 17)
CAN bus supply voltage nominal:	13.8	V	(Note 18)
CAN bus supply power maximum:	24	W	(Note 19)
CAN bus supply power with fans off:	6	W	(Note 19)
CAN bus data rate maximum:	1000	kbps	(Note 20)
CAN bus isolation:	400	V	(Note 21)

Notes:

17. The CAN bus power supply is used directly to operate the cooling fans in the WaveSculptor. Variations in this supply will affect maximum cooling performance. All cooling and power throughput testing has been performed using a 12V DC voltage on the CAN bus power connection. Providing a higher voltage (up to the specified maximum) will result in increased cooling performance.
18. Tritium recommends providing the CAN bus supply with 13.8V, using a DC/DC converter and a backup lead-acid battery. This arrangement, when properly implemented, gives a supply that can tolerate failures and still operate the controller successfully.
19. The majority of the operating power consumed by this bus is used to operate the cooling fans in the WaveSculptor. Supplying the WaveSculptor with lower temperature ambient air will result in lower power operation of the fans, and reduced power consumption from the CAN bus supply.
20. The data rate used for CAN bus activity is set using during configuration and setup of the controller. Factory default for all Tritium devices is 1000 kbits per second.
21. The CAN bus data connection and power supply are isolated from the high-power DC bus to this continuous voltage rating. Please refer to the isolation section in the Wiring Engineering Reference document (available on the Tritium website) regarding recommended earthing and connection practices.

8 MECHANICAL

The WaveSculptor controller is mounted into position using a lightweight detachable tray. All dimensions in this section are with the controller mounted in position on a horizontal surface. For full details regarding positioning and fixing of the WaveSculptor, please refer to the Mechanical Engineering Reference document available on the Tritium website.

WaveSculptor enclosure length:	457	mm	(Note 22)
WaveSculptor enclosure width:	146	mm	(Note 22)
WaveSculptor enclosure height:	110	mm	(Note 22)
WaveSculptor mass:	4	kg	(Note 23)
Motor Phase and DC bus cable length:	250	mm	(Note 24)

Notes:

22. Dimensions do not include attached cabling and connectors.
23. Weight includes mounting tray, attached cables, and connectors.
24. Length is approximate. Tritium can supply controllers with custom length cables if necessary.

9 REVISION RECORD

REV	***DATE***	***CHANGE***
1	6 December 2006	Document creation (JMK)
2	2 January 2007	Minor revisions (DAF)
3	8 January 2007	Modified efficiency map text (DAF)
4	23 February 2007	Revised efficiency map as a result of further testing (DAF)
5	20 April 2007	Added 90V efficiency map (DAF), Formatting (JMK)
6	14 December 2007	Updates to: bus current note 4, sensorless engage frequencies, operating power & cooling note 16 (DAF)