REACTION WHEEL

10 mNms RW-0.01 & 30 mNms RW-0.03

Interface Control Document

Rev. 2.0, August 3, 2021
Sinclair Interplanetary

components@rocketlabusa.com
rocketlabusa.com

ROCKETLAB

1. Revision Notes

This revision of the document contains the following changes relative to the previously released version:

- This document was formed by merging the following documents
  - 10 mNm-sec Mechanical ICD Revision 1.4
  - 30 mNm-sec Mechanical ICD Revision 1.3
  - 4V Reaction Wheel Electrical ICD Revision 1.2

2. Scope

This document describes the mechanical and electrical interfaces for the 10 mNm-sec and 30 mNm-sec reaction wheels built by Sinclair Interplanetary. This document is relevant to the following part number forms:

- RW-0.01-xx-xxxxx-x-x-x
- RW-0.03-xx-xxxxx-x-x-x

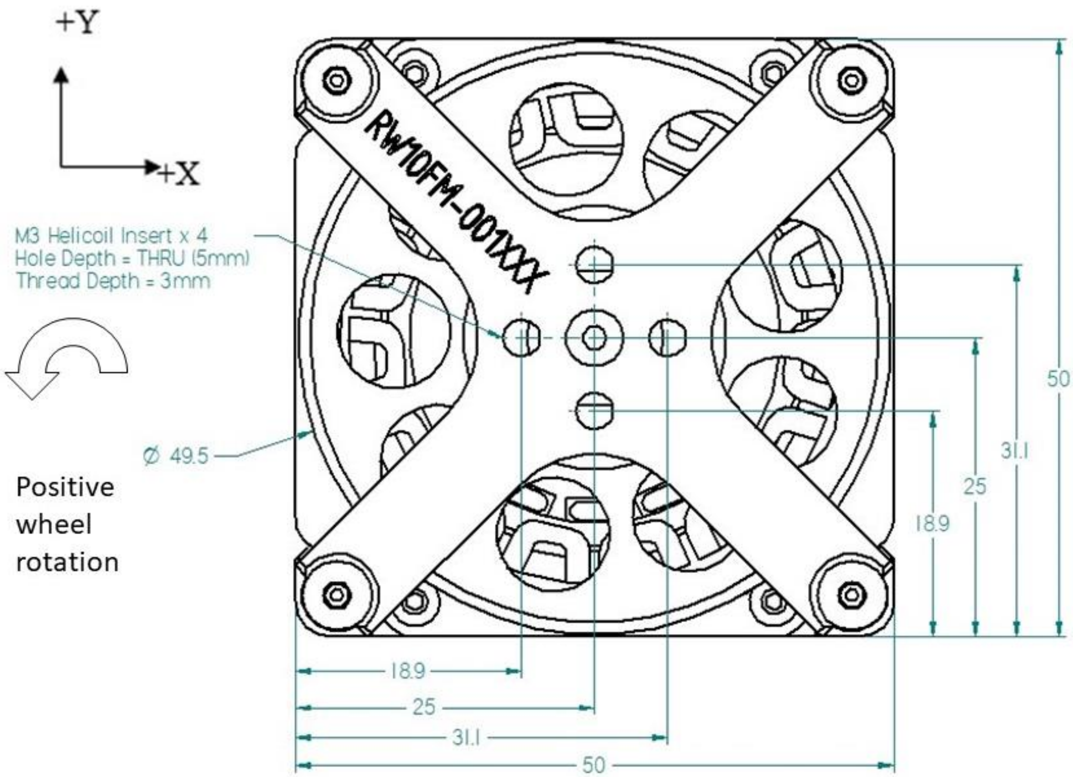
For additional interface definitions see:

- Reaction Wheel NSP Application
- NSP Packet Protocol

3. Mechanical

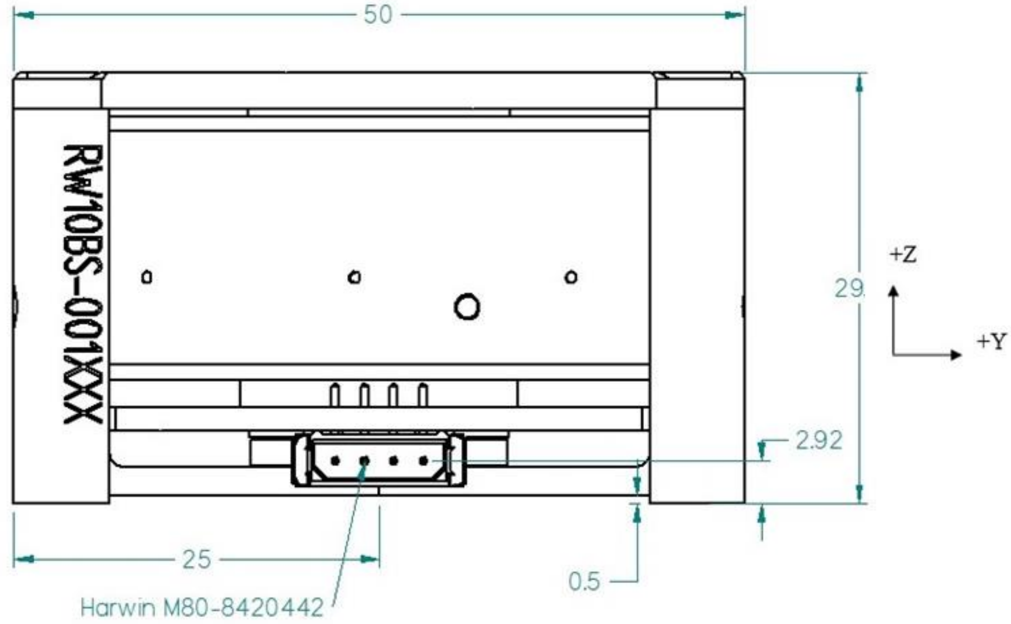
3.1. RW-0.01 Drawings

3.1.1. Top View

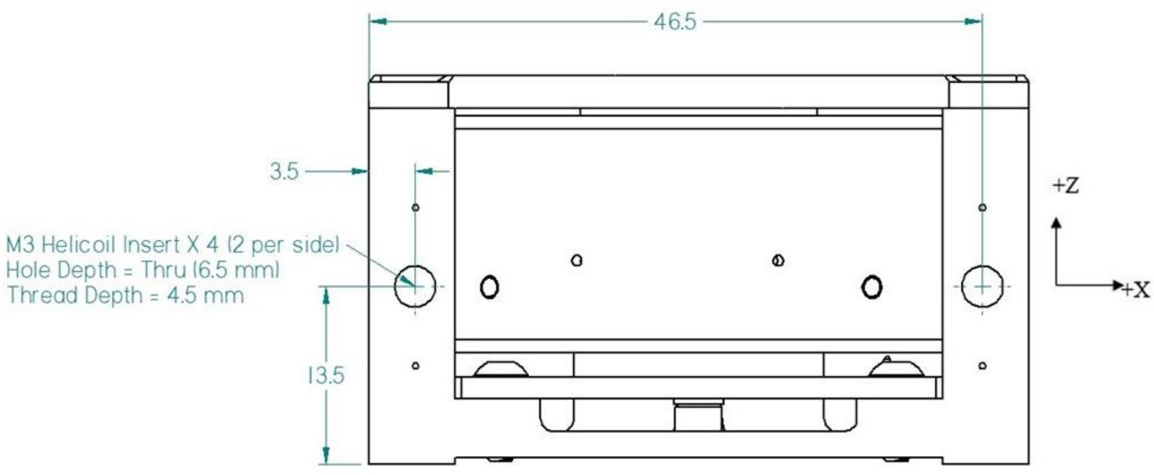


The X and Y axes are defined as shown in the figure. The Z-axis (illustrated in the following figures) completes the right-handed set. The rotation arrow shows the direction of wheel rotation that is considered positive speed. Rotation in the opposite direction is considered negative wheel speed.

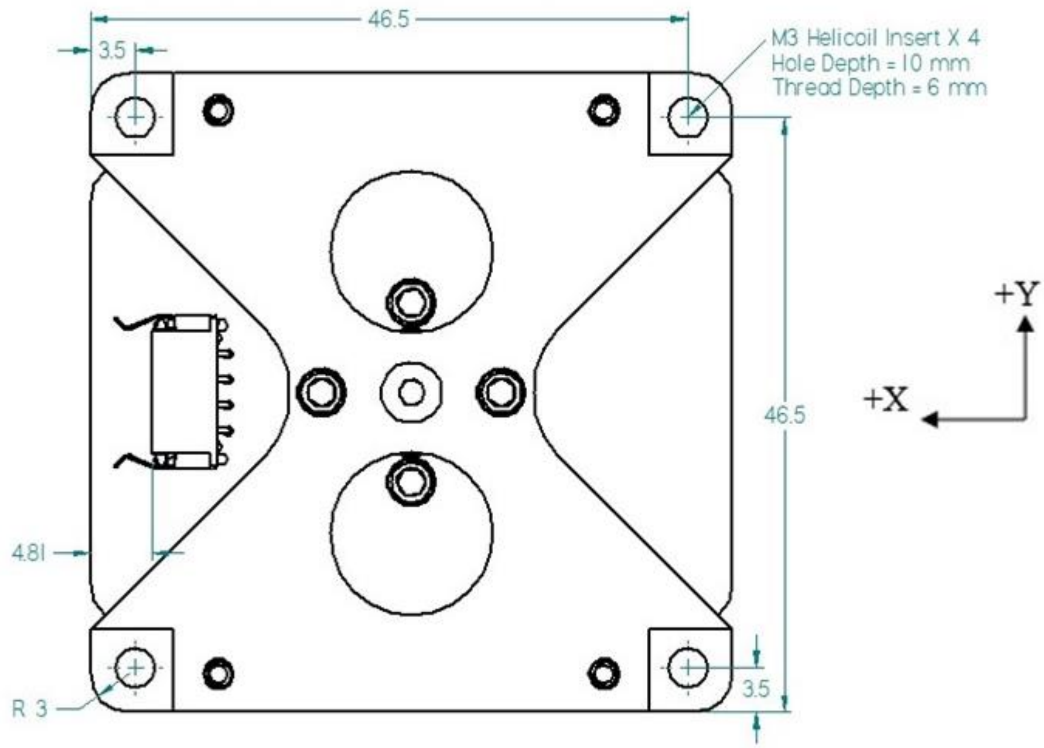
3.1.2. Side View



3.1.3. Front View

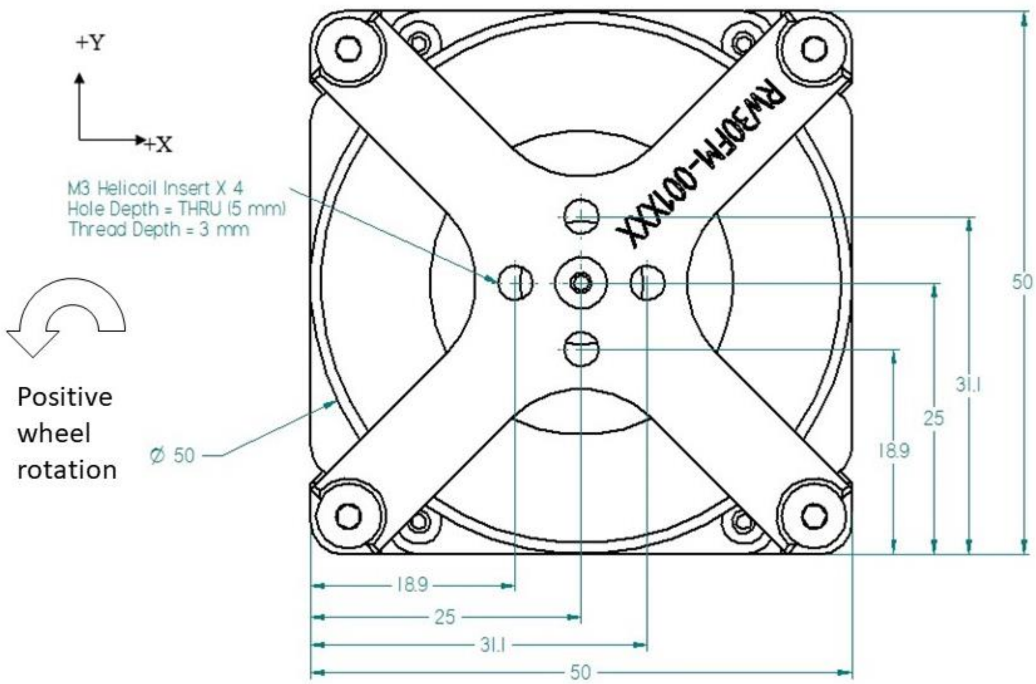


3.1.4. Bottom View



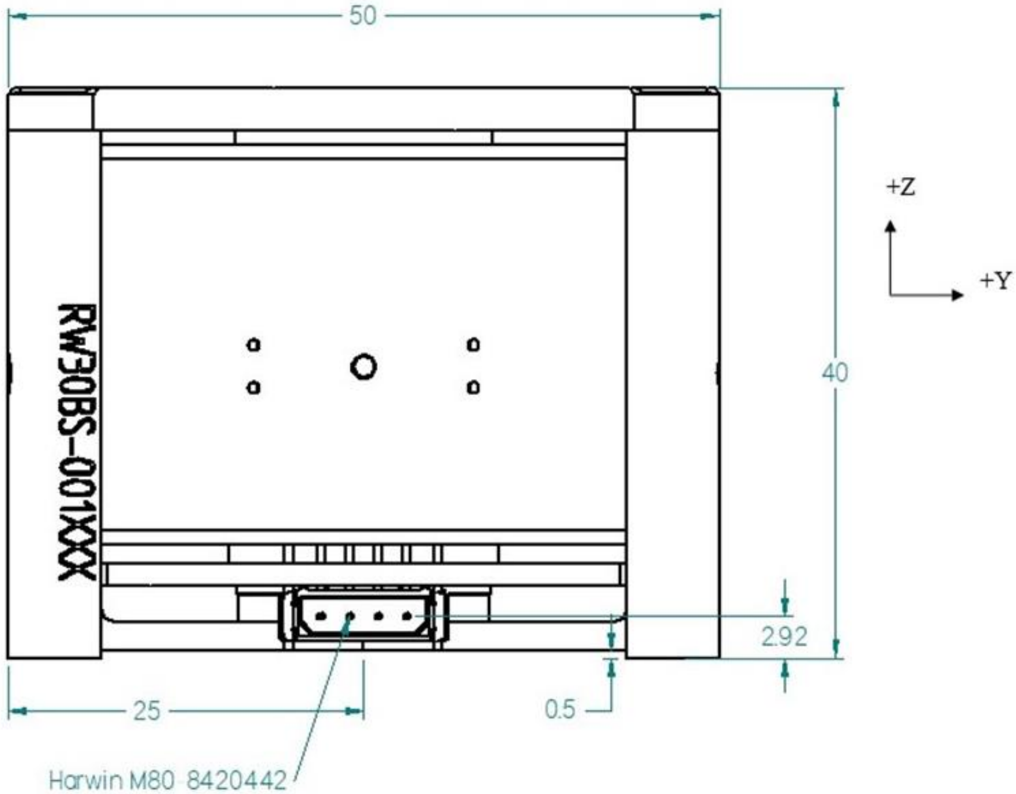
3.2. RW-0.03 Drawings

3.2.1. Top View

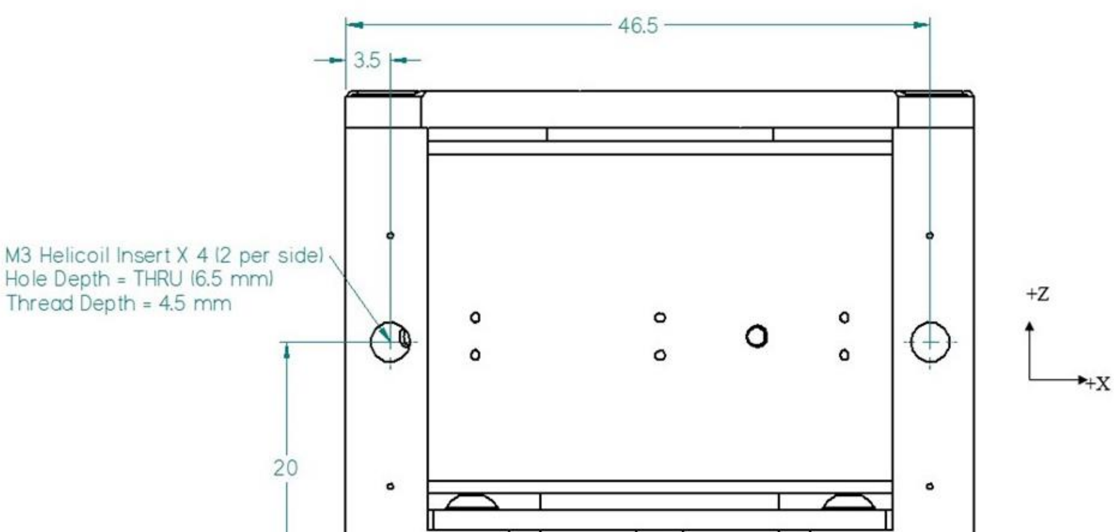


The X and Y axes are defined as shown in the figure. The Z-axis (illustrated in the following figures) completes the right-handed set. The rotation arrow shows the direction of wheel rotation that is considered positive speed. Rotation in the opposite direction is considered negative wheel speed.

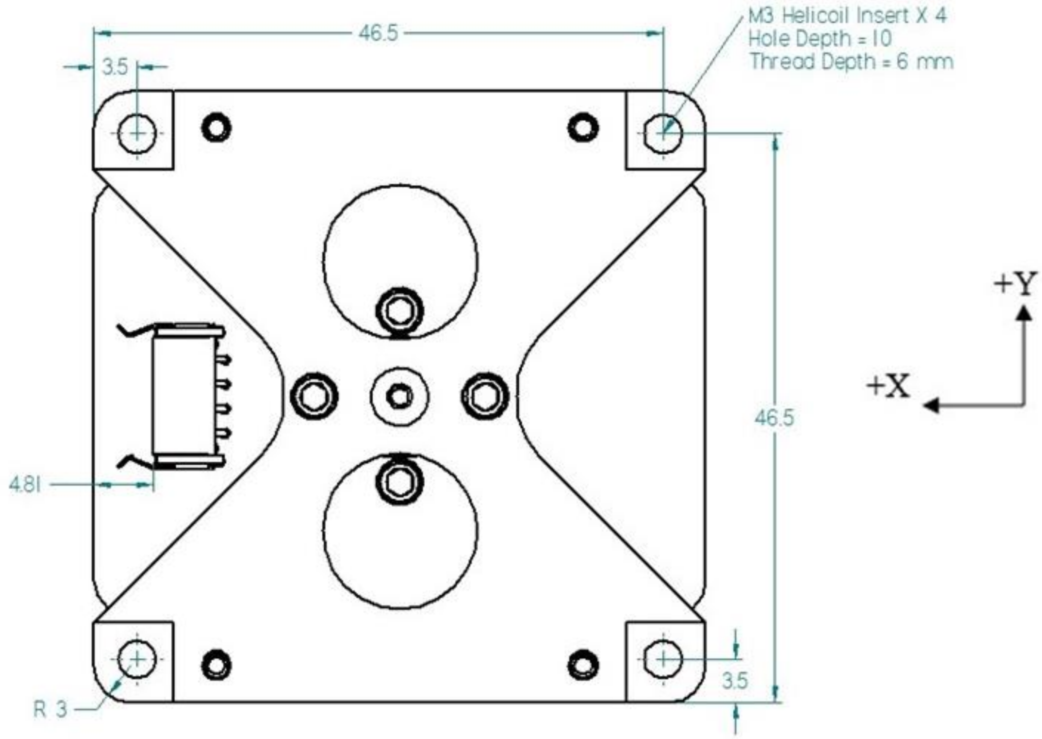
3.2.2. Side View



3.2.3. Front View



3.2.4. Bottom View



3.3. Materials

The following materials are used as structural elements in the reaction wheel.

- Aluminum 6061-T6, with yellow chemical film coating, for primary structural elements
- Nitronic 60™ (UNS S21800) stainless steel helical inserts for all internal threads
- Windform LX 2.0 composite polymer as an insulator in the motor
- Windform XT 2.0 composite polymer as a magnet positioner in the rotor
- Samarium Cobalt, with nickel overplate, in the rotor magnets
- Stainless Steel 416, for the bulk of the rotor

All of the materials and processes for the wheel have been selected for compatibility with high vacuum and low outgassing requirements.

3.4. Mounting

The wheel has mounting points on the bottom, front, back, and top surfaces. This flexibility allows the customer to mount a number of orthogonal wheels to a plate while reducing the need for additional brackets. All mounting holes are threaded for M3x0.5. The wheel mounting points provide mechanical, thermal and electrical bonding paths.

The bottom mounting points may be used alone, as the four widely-spaced holes provide a solid anchor for the wheel. Alternatively, a combination of the top and front or back holes can be used to securely mount the wheel.

Be careful when using the front or back mounting points that the spacecraft structure does not interfere with the rotor. In the RW-0.03, the rotor diameter reaches all the way to the edge of the wheel footprint, so it cannot be simply mounted to a flat plate. Some form of standoff is required. In the RW-0.01, there is only 0.5 mm of clearance between the rim of the rotor and the edge of the wheel footprint. If mounting to a plate it must be flat, or some sort of standoff will be required.

3.5. Mass Properties

The mass of the complete RW-0.01 is 122 grams. The mass center is on the spin axis, 16.0 mm in the +Z direction above the base.

The mass of the complete RW-0.03 is 185 grams. The mass center is on the spin axis, 20.0 mm in the +Z direction above the base.

3.6. Magnetic Properties

The rotor is contains a 10-pole magnet array on its inner surface. The stainless steel of the rotor prevents the vast majority of the field lines from leaving the wheel. The large number of poles means that the field decays very quickly with increasing distance. There is no dipole moment, and so no unwanted attitude torques upon the spacecraft.

3.7. Pressure Environment

The reaction wheel is designed to operate in the vacuum of space, and in the atmosphere of a terrestrial laboratory environment. The bearings are lubricated with space-grade grease and will give many years of service on-orbit. This lubricant is not moisture sensitive, and is not degraded by atmospheric operation.

The wheel has not been designed to operate through critical pressure, and has not been tested for coronal discharge. For safety it should be unpowered while the host spacecraft is attached to the launch vehicle.

3.8. Vibration and Shock Environment

The reaction wheel has been designed to be compatible with the vibration and shock environment of most launch vehicles. Please contact the factory for further details.

The total vibration lifetime of the wheel bearings is limited. The user must be careful not to over-test flight wheels during unit-level or spacecraft-level acceptance testing. Test plans should be designed so that the sum of the acceptance testing plus the actual launch vibration does not exceed the duration of the qualification tests.

3.9. Contamination Environment

This wheel is not hermetically sealed, and so great care must be taken to avoid contamination of the electronics and the bearings by dust and debris. It should be bagged when not used, and handled only in a clean-room environment.

4. Thermal

4.1. Thermal Environment

Operating Temperature	-40 ºC to +75 ºC
Survival Temperature	-40 ºC to +85 ºC

The temperature is defined as the temperature of the base plate in the nominal mounting configuration.

Note that the motor magnets are high-temperature samarium-cobalt and are at no risk of demagnetization from reasonable spacecraft temperatures.

4.2. Thermal Interface

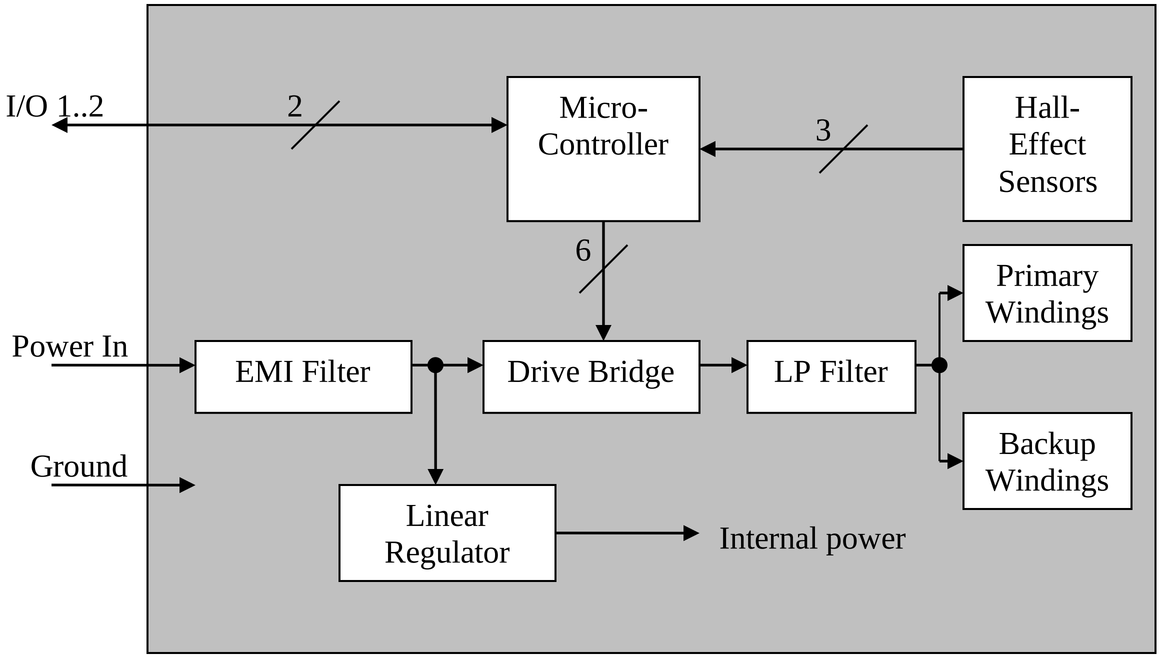
The thermal interface to the spacecraft is through conduction. There are 4 mounting feet, with a total surface area of 130 mm^2. The contact material is aluminum 6061-T6, with yellow chemical film coating.

There is no convective thermal interface. Radiation is not considered a significant thermal interface. The reaction wheel rotor is thermally isolated, as conduction through the bearings is minimal.

In normal operation, the maximum heat load from the reaction wheel is 1.0 W.

5. Electrical

5.1. Block Diagram



5.2. Principle of Operation

The motor is a three-phase brushless design with redundant windings. Unregulated spacecraft power passes through the front-end EMI filter and into the drive bridge. Here it is chopped by a 350 kHz PWM waveform. The LP (low pass) filter smoothes the PWM, leaving only the DC drive components that pass on to the motor. Backup windings are wired in parallel with the primary.

Three Hall-effect sensors detect the position of the rotor magnets. This data is processed by a microcontroller where it is used for commutation and for speed estimation. The microcontroller controls the three current-mode half-bridges allowing it to set the motor torque.

Two I/O signals from the microcontroller are carried on the electrical connector. The command and telemetry interface is implemented using these signals. The details of this interface depend on which onboard software load the customer has requested.

5.3. Connector

The connector is a Harwin Datamate M80-8420442. This is a 4-pin single row plug with retention latches.

Mating Connector Part Number	Comments
M80-8450445 (Digikey 952-1184-ND)	Receptacle connector takes wires 24-28 AWG. Special crimp tooling required.
M80-8400401	Through-hole connector with SnPb termination,

	suitable for flex circuit.

Care must be taken when demating the connector as the retention latches are delicate. If they are treated well they will positively retain a mating connector without any need for staking.

If customer access to crimp tooling is problematic, Sinclair Interplanetary can pre-terminate wires or prepare harnesses on a special order basis.

5.4. Connector Saver

Reaction wheels are provided with connector savers to protect the flight connectors from unnecessary mate/demate cycles during testing. These savers are fabricated from short lengths of Teflon wire and Harwin Datamate crimp plug and socket connectors. The connector saver should be removed prior to final integration with the spacecraft.

5.5. Pinout

The connector has the following pin assignments:

Pin	Type	Signal
1	Digital I/O	IO/2
2	Power	Power In
3	Digital I/O	I/O1
4	Power	Ground

5.6. Grounding

The default factory option is RF multipoint grounding, whereby the chassis is connected to the internal electronics ground via 4 x 10 nF capacitors (50 V rated), and one 1 MΩ resistor. Upon request, wheels can be furnished with complete isolation between chassis and electronics. Alternatively, wheels can be supplied with low-impedance DC connection between chassis and electronics.

5.7. Signals

5.7.1. Ground

Ground is the reference used for all other signals.

5.7.2. Power In

Absolute Maximum Voltage	0 to +7.0 V (see note)
Operating Voltage	+3.5 V to +6.0 V
Fault Protection	6 V TVS

The Power In signal provides power to the all of the wheel circuits. It is intended to be compliant with busses that are regulated from either a single cell Li-ion battery or two triple-junction GaAs solar cells.

A transient voltage suppressor (TVS) is included for fault protection. This part is rated for a standoff voltage of 6 V, and at this voltage it does not impact the circuit. At 6.67 V it may begin to conduct up to 10 mA. At a maximum voltage of 10.3 V it conducts a clamping current of 58.3 A. It will also conduct if a negative voltage is applied to the Power In signal.

High (or negative) voltages must not be applied for long durations from low impedance sources or the TVS will overheat and become damaged. It is intended to absorb capacitive discharges, load dumps, and other short-lived phenomena. A power of 600 W may be applied for no longer than 1 msec.

5.7.3. I/O[1..2]

Absolute Maximum Voltage	-0.5 to 5.5 V
Input Low Voltage	0.9 V max
Input High Voltage	2.1 V min
Output Low Voltage	0.7 V max, 3 mA external load
Output High Voltage	2.3 V min, 3 mA external load
Pull-up	120 kΩ nominal to +3.0V
ESD Protection	5.6 V Zener
Power-off impedance	High

The use of the I/O signals is dependent on the software running in the wheel. They may be configured as digital inputs or open-drain or push-pull outputs.

I/O1 and I/O2 may be driven above the internal +3.0 V rail, though they must always respect the absolute maximum limits.

5.8. Connections

The connections made to the I/O pins depend on the communication option specified in the part number:

Part Number	Communications
RW-x.xx-4-ASYNC-x-x-x	Asynch Serial with NSP
RW-x.xx-4-I2C-x-x-x	I2C with NSP

Signals are assigned to I/O pins as follows:

Signal	ASYNC	I2C
I/O1	Transmit	SDA
I/O2	Receive	SCL

Using the Asynch Serial and I2C options a number of devices may share a common data bus, and each requires a unique address to identify it. However, the small

4-pin connector does not allow any additional signals for addressing. Instead, each wheel has an NSP address programmed into it in the factory. The user must take care not to put two wheels with the same NSP address on the same bus.

The asynchronous option configures the UART in the following way. Note that the wheel's master oscillator is not crystal driven and so there can be some variation in actual baud rates.

Data Bits per Byte	8
Parity	None
Stop Bits	1
Nominal Baud Rate	57600 bps
Actual Output Rate	56338 bps to 58685 bps
Permissible Input Rate	56000 bps to 59000 bps

Using the I2C option, connections SDA and SCL are open-drain digital lines. The internal pull-up device will be turned on for each line, but this pull-up is weak. It is recommended that the user install an additional pull-up resistor to ensure fast transitions.