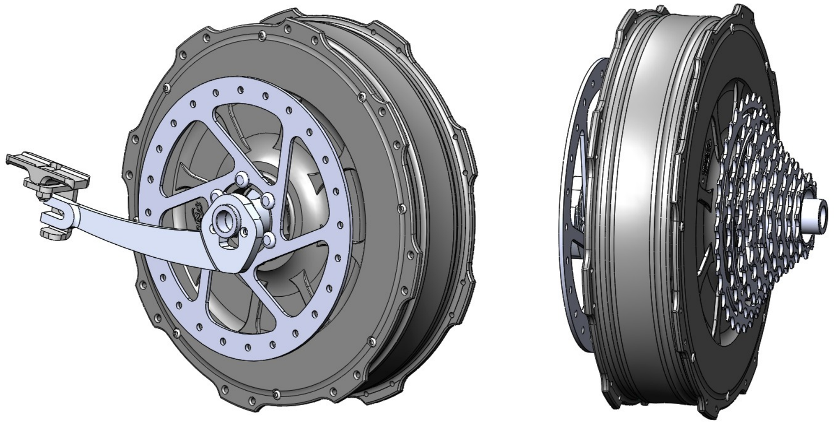
The Grin All-Axle Motor
Rear V3 Model

Owner's Manual – *Rev 0*



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1 Introduction

Thank you for purchasing the universal V3 Rear All-Axle hub motor from Grin Technologies. This efficient and robust direct drive hub motor can provide years of ebike joy on almost any bicycle platform.

Features of the Rear All-Axle motor include:

- Light weight for its power class (4.25 kg vs typical 6-7 kg)
- Compatible with almost all thru-axle and quick release dropouts
- Integrated torque arm for secure installation
- Waterproof L1019 controller connector for hall and phase leads
- Embedded thermistor for motor temperature sensing
- Built in PAS and torque sensor in freehub
- Capable of over 80 Nm peak torque, and 30-40 Nm continuous
- Made in Vancouver, Canada

2 Components

In addition to the hub motor itself, the motor package may include additional hardware such as disc spacers, axle end caps, axle extenders, cassette gears, and of course, a torque arm. These are identified below:

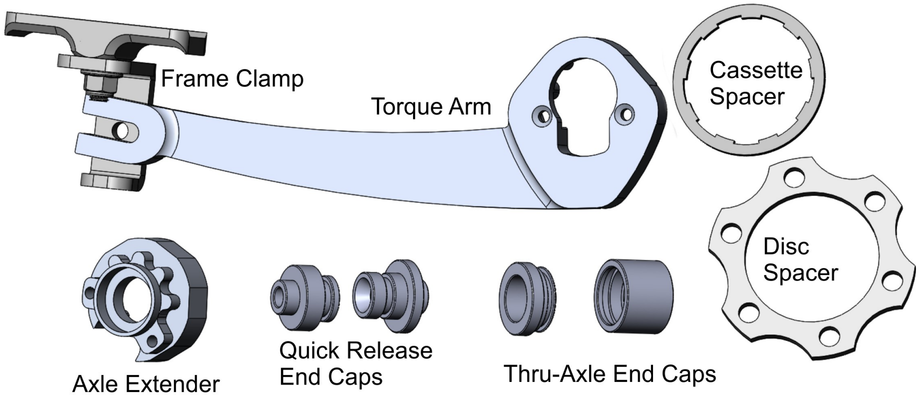


Figure 1: Depending on the adapter kit purchased with your motor, various end caps and spacers may be present to properly align the motor with your bike frame.

2.1 Disc Spacer

A variety of disc spacers from 1mm to 20mm in thickness are used to position the disc rotor in the correct alignment for an ISO disc caliper. In most cases, that is 15.5mm inside the left dropout face of the bike.

2.2 Axle Extenders

The 145, 157, and 160/167mm adapter kits also include an axle extender which increases the effective axle length on the disc side of the hub.

2.3 Axle End Caps

The axle end caps fit either inside or over each end of the axle and provide the necessary termination for either quick release or thru-axle dropouts. Note that the left side and right side end-caps are different and are not interchangeable.

2.4 Cassette and Spacer

The motor purchased with Shimano HG freehub option includes a 1.5mm cassette spacer. This spacer is required when using mountain bike standard 8, 9, 10, or 11 speed cassettes. It is omitted when wider road bike cassettes are used instead.

2.5 Torque Arm

The torque arm is a pivotal part of the motor system that transmits all of the motor torque safely to the bicycle frame without putting any spreading force on the dropouts. It uses a snug splined and lobed interface that can withstand tremendous spinning force from the axle, with virtually no play when the torque direction alternates during regenerative braking.

2.6 Frame Clamp

The swiveling frame clamp provides a versatile attachment point for the torque arm to connect with the bicycle chainstay via a pair of hose clamps. Once the frame clamp is installed, it can stay in place allowing the torque arm to detach with just a single fastener.

3 Installation

The rear All-Axle motor mounts to a bicycle just like a regular bike wheel, but you may first need to install the associated hardware components if they are not already mounted.

3.1 *Axle Extender (145, 157, and 160mm adapters only)*

Fit the axle extender (if provided) over the left side of the axle, and tuck the motor wire into the channel of the extender. This extender is only used on adapters for the extra wide dropout standards, and will be held in place by the two torque arm screws.

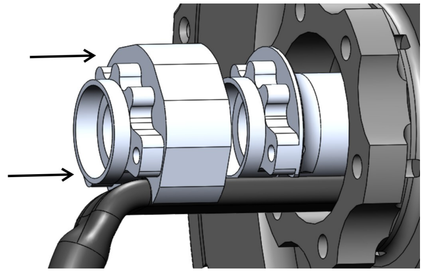


Figure 2: Axle Extender is only used on 145mm (tandem bike), 157mm (superboost), and 160mm (Santana) adapter kits.

3.2 *Disc and Disc Spacer*

If the bike uses disc brakes, install the disc rotor over the included disc spacers before you install the torque arm. Spacers less than 5mm thick just go under the disc rotor, while spacers 9mm and are fastened with a separate set of screws (provided).

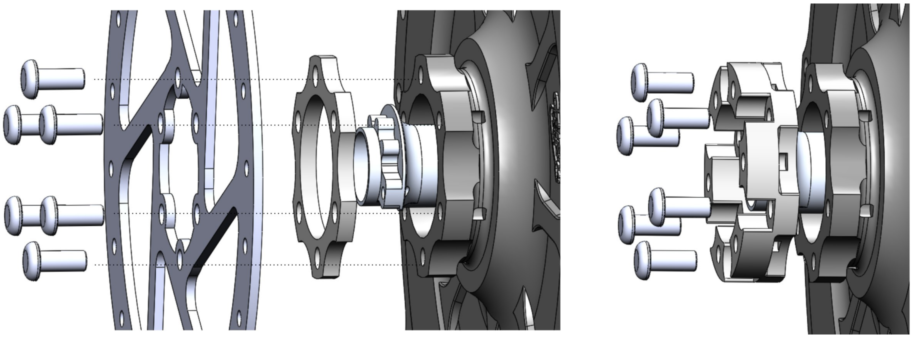


Figure 3: Narrow disc spacers (left) fit behind rotor. Wider spacers (right) bolt independently to motor, and present separate threaded holes for disc bolts.

The disc rotor screws should be fastened to 7 Nm of torque using a T25 torx driver.

3.3 Torque Arm

Next, with the disc rotor and (optional) axle extender installed, feed the motor cable through the center of the torque arm and secure the torque arm with the supplied M3 screws. These screws do not transmit torque, rather they simply hold the torque arm in position.

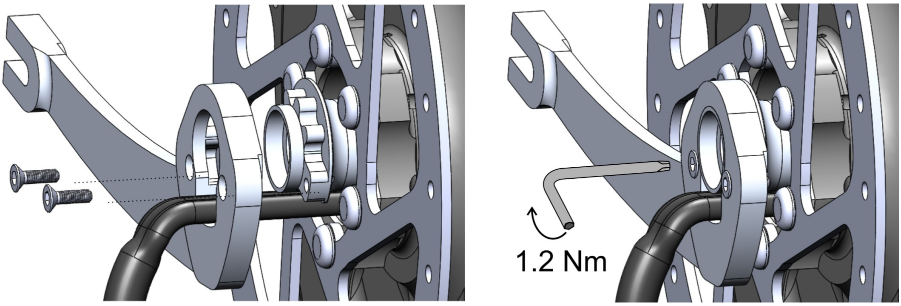


Figure 4: Pass cable through the torque arm first. The L1019 connector just fits through the round opening. Tighten the two M3x10 screws to 1.2 Nm. Longer screws are provided when an axle extender is present.

3.4 Axle End Caps

Insert the left and right side end caps into or over the axle. These pieces are held snug with a small O-ring to provide sufficient friction that they stay in place when the wheel is removed from the bike.

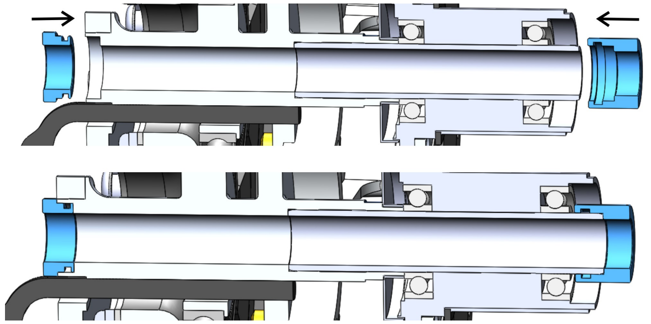


Figure 5: Left side thru-axle end-caps fit inside axle, while the right side slides over the axle .

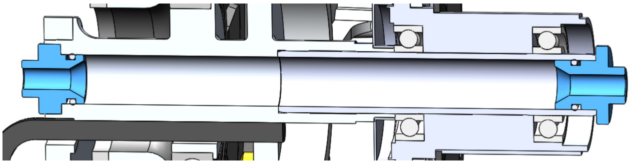


Figure 6: Both left and right side quick-release inserts fit inside axle bore, but they have different widths and diameters.

3.5 Cassette

Finally slide the cassette gear cluster over the freehub driver and tighten the cassette lockring until it is snug. If you are using a mountain standard Shimano cassette then a 1.5mm spacer is required to make the stack height long enough. Without the spacer in place, the cassette will not sit snug and will have play.

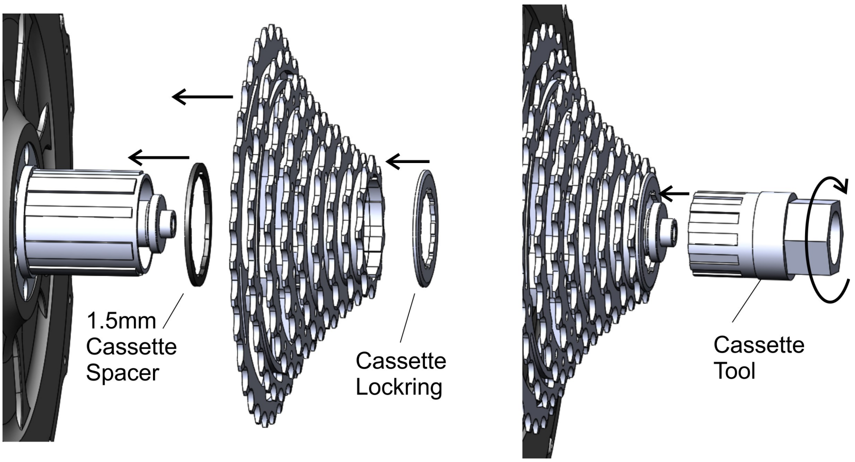


Figure 7: A 1.5mm spacer is required behind mountain cassettes, but should be left out with the wider road cassettes. A bicycle cassette tool is required to tighten lockring.

3.6 Wheel Insertion

The completed hub motor can now be dropped into the bicycle frame exactly like any other bicycle wheel. Carefully place it into the frame, getting the derailleur out of the way and aligning the disc rotor between the brake calipers, then loosely secure the quick release or thru-axle spindle.

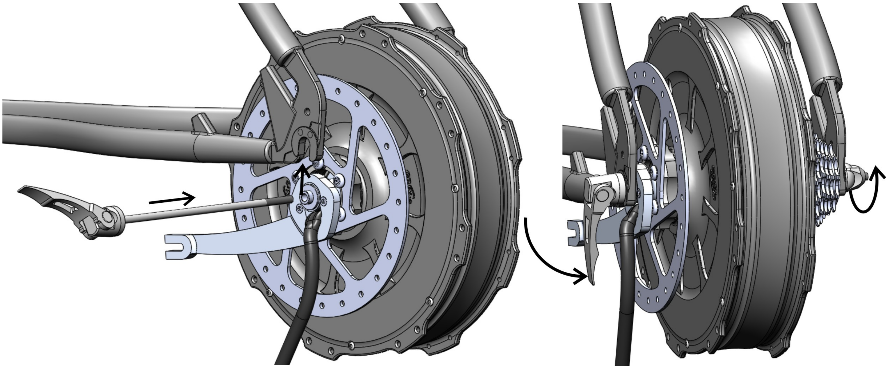


Figure 8: Install hub with torque arm facing forward, using QR skewer or thru-axle. Ensure that cable exits down and out of dropout slot without getting pinched.

3.7 Attaching the Frame Clamp

The frame clamp attaches to the left chainstay with two hose clamps. A piece of rubber sleeving can be cut to length and slipped over the hose clamp band to make this hardware more discreet.

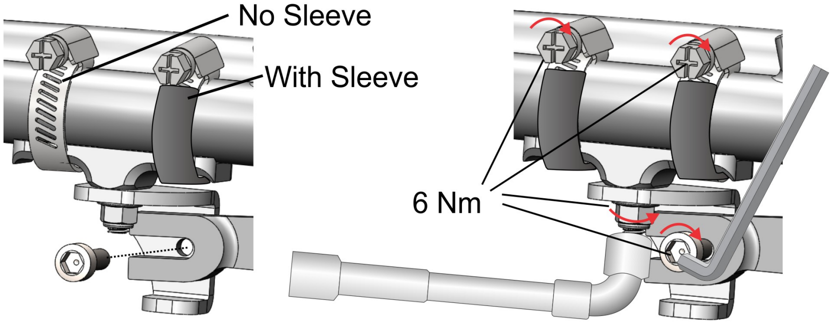


Figure 9: Frame Clamp installed to chainstay. Once aligned, all fasteners should be tightened to 6Nm. Rubber sleeve can be cut to size and slipped over hose clamps.

Align the frame clamp with the torque arm and tighten up both the M5 nut and the hose clamp bands using the included socket wrench. Tighten the M5 bolt linking the torque arm to the frame clamp with a 5mm Allen Key. With the torque arm now oriented, you can fully tighten the thru-axle or quick release.

When removing the wheel in the future, simply loosen the single M5 bolt linking the torque arm to the frame clamp and the torque arm will slide out.

4 Controller Hookup

If you have a Phaserunner or Baserunner controller from Grin terminated with an L1019 plug, these parts simply plug together.

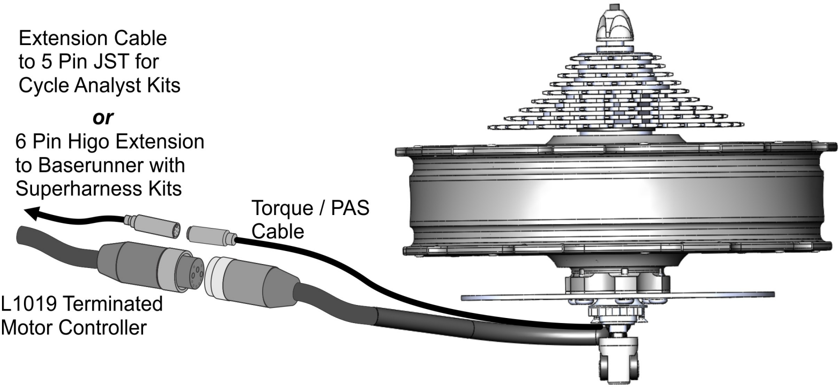


Figure 10: Connectors. Torque/PAS cable hookup is independent of motor plug.

The hookup of the 6 pin torque sensor is optional and depends on your kit style. With a Cycle Analyst based kit, a 140cm Higo to JST extension cable connects the motor torque sensor to the CA3 on the handlebar. With a Superharness kit from Grin, the 6 pin signal connects directly to the Phaserunner or Baserunner motor controller with a shorter (24 or 44cm) Higo extension cable.

The details of configuring your motor controller and/or Cycle Analyst are covered in their respective manuals. If you are using a third party motor controller, then it is up to you to either terminate your controller with a matching plug or cut off the L1019 plug and solder on connectors that match your controller.

Grin does not provide installation support for third party controller integration. All necessary information for you to figure that out is in this document.

5 Power and Speed Capabilities

The Rear All-Axle motor is available in 3 different winding speeds to achieve the required performance over a range of battery voltages, wheel diameters and target cruising speeds.

Motor SKU	Name	Turns	Kv
M-AA2705R	Fast Winding	5T	12 rpm/V
M-AA2706R	Standard Winding	6T	10 rpm/V
M-AA2708R	Slow Winding	8T	7.5 rpm/V

Table 1: The three winding speed options. Note that most ebike hub motors spin at 7-8 rpm/V, the “Slow Winding” is not actually that slow.

5.1 No-Load Speed Table

The *unloaded* speed for each winding at different wheel diameters is summarized in Table 2. This is the no-load speed it will spin at with the wheel off the ground; actual cruising speed will be 10-30% less than this depending on the vehicle loading. Please use Grin's online motor simulator tool to better understand the effect of vehicle type, hill grade, and rider weight on the fully loaded speed.

Battery Voltage	Slow (8T) Wind		Standard (6T) Wind		Fast (5T) Wind	
	20”	26”	20”	26”	20”	26”
36V	26 kph	34 kph	34 kph	45 kph	41 kph	54 kph
48V	34 kph	45 kph	46 kph	60 kph	55 kph	72 kph
52V	37 kph	49 kph	50 kph	65 kph	60 kph	78 kph

Table 2: This is how fast a given system will spin at full throttle with the wheel lifted off the ground and facing no resistance. The actual speed under any kind of load will always be less than this and is fully detailed on our Motor Simulator web app.

In general the faster windings are used in smaller wheel diameters or lower voltage batteries, while the slower windings are better suited to larger rims or higher voltage packs. But there is nothing stopping you from doing fast motors in big wheels or slow motor winds in small wheels if that provides the performance you want.

5.2 Winding Speed vs Torque

Note that a faster motor winding does not mean a lower torque motor. That is a very common misconception. All 3 motor windings can produce the same torque and power, but a faster wind motor needs more phase amperage to reach that torque. It is only when your *motor controller* is limiting the phase current that you will see more torque from the slower motor wind.

5.3 Short Term and Continuous Power

The power output capability of an electric motor depends on both how fast the motor is spinning and how long it needs to run for. Table 3 summarizes the output power the All-Axle hub can sustain both continuously and over a 5 minute period when the maximum allowable core temperature is defined (somewhat arbitrarily) at 110C. This table assumes a 20C ambient air temperature and that the motor has a passing airflow consistent with being in a 26” diameter wheel.

Wheel Speed	Continuous Power		5 Minute Power	
	Dry	w/Statorade	Dry	W/Statorade
100 rpm	*250 W*	*340 W*	*500 W*	*575 W*
200 rpm	*560 W*	*785 W*	*1040 W*	*1235 W*
300 rpm	*900 W*	*1275 W*	*1590 W*	*1830 W*
400 rpm	*1250 W*	*1840 W*	*2110 W*	*2420 W*

Table 3: The motor power capability depends heavily on the motor speed. That's why it is better to characterize motors by their torque capability than their power output.

As long as the control system is setup to measure the motor temperature and rollback power when it gets too hot, there is little harm in pushing high watts through the motor.

Be aware that the L1019 connector can also become a bottleneck, especially with fast motor windings. While it can handle 80-90A for short times, the plug risks melting if it is used for long periods above 55 amps.

5.4 Official Rated Power

As both the designer and manufacturer of this motor, Grin has full discretion over its official power rating. For the EU and Eurasia, we define the rated motor power as the maximum continuous output before thermal rollback in a worst case scenario of a slow 100 rpm hill climb. As per Table 3, this is 250 watts.

For Canada, we define the rated motor power as the maximum continuous output in a more modest hill climb at just under 200 rpm wheel speed. As per Table 3, that is 500 watts.

For the USA, we define the rated motor power as the general continuous power capability at 20 mph cycling speeds (~250 rpm), which is 750 watts.

6 Statorade Injection

As shown in Table 3, motor performance at high loads is increased significantly by the addition of 8mL of Statorade ferrofluid which helps conduct heat from the stator core to the motor ring. If you routinely see core temperature exceeding 100 C, we highly recommend using Statorade to extend the usable power window before thermal rollback.

Statorade is injected into the motor from a small M3 screw located on the right side plate. Add Statorade with a syringe tip with the hole on the bottom so that the fluid flows directly downwards and into the rotor magnets and avoids flowing over the motor bearings and torque sensor.

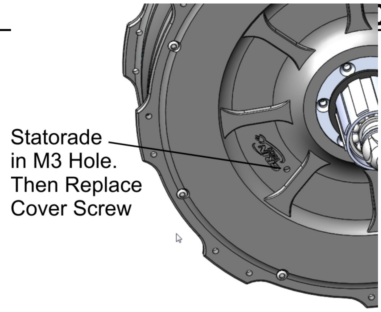


Figure 11: Statorade Fill Port

7 PAS / Torque Sensor

The integrated cassette PAS sensor allows a conversion to have full pedal assist controls without the need for a separate pedal sensor on the crankset or bottom bracket.

7.1 Sensor Models

Grin provides 3 options for the pedal sensing freehub

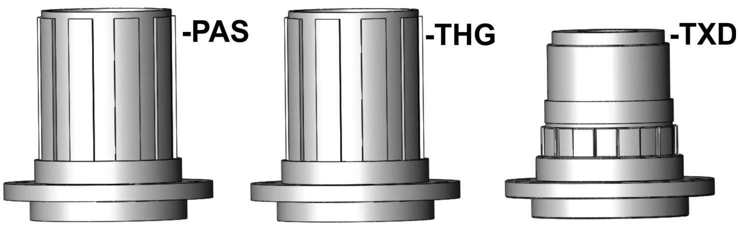


Figure 12: PAS only sensor and default Torque sensor both use industry standard Shimano HG cassette freehub drivers. For high end drivetrains, a torque sensing model with the SRAM XD driver is also available.

-THG: This is the default option that uses a Shimano HG road compatible freehub and has both cadence and torque signals. The longer road size freehub body allows both road cassettes and mountain cassettes with a spacer.

-TXD: For higher-end systems we provide a SRAM-XD cassette driver. The 11 and 12 speed XD cassettes are available in massive gear range with a small 10T cog and are popular for use in 1x drivetrains. The 10T cog option is useful with fast ebikes to provide a comfortable pedal cadence even at high speeds.

-PAS: This is a lower cost option that is mechanically identical to the THG model but only includes an integrated PAS signals without a torque sensor. The torque signal voltage does not change with pedal pressure when this sensor is installed.

7.2 PAS Signal Levels

The PAS sensor output is a 2 wire quadrature signal with 9 full pulses per cassette rotation. This allows for the downstream system to distinguish between forwards and backwards pedaling, and allows advanced features such as reverse pedal regenerative braking.

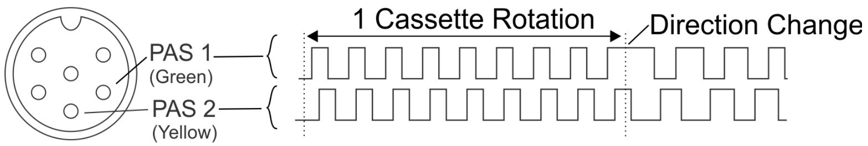


Figure 13: Pedal sensor signals illustrating one full rotation (9 pulses) and then a change to pedaling backwards.

Note: It should not be wired up to a controller that expects just a 1 wire PAS signal without additional signal conditioning, or else rolling the bike backwards will also trigger PAS power.

7.3 Torque Signal Levels

The torque signal is an analog voltage that sits nominally at 0.8V and increases linearly with applied pedal torque.

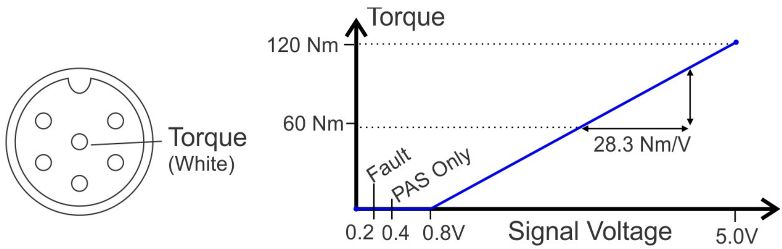


Figure 14: Torque Sensor Signal Voltage.

While this can be used in a pinch as a substitute for a throttle signal in most motor controllers, we recommend only using it in a setup that properly identifies it as a torque signal and can control motor behavior accordingly. For safety it should only respond to the torque signal when a valid pedal RPM is detected as well.

A torque signal of 0.4V indicates that a PAS only sensor is installed, while a signal of 0.2V indicates a communication fault with the sensor.

7.4 PAS Power

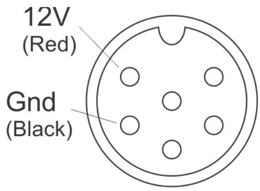


Figure 15: Sensor can operate from 6V-16V

The torque sensor runs off its own 12V nominal power source that is completely isolated electronically from the hall sensor circuit on the motor's L1019 plug. This configuration makes it easy to have fully independent systems for measuring the rider input and powering the motor.

7.5 Differences between Crank and Wheel Sensors

Because the torque sensor is on the wheel and not on the cranks, both the RPM and the torque seen by the sensor are also scaled by your bicycle gear ratio which has some effect on the expected behavior.

In high gears a large torque on your cranks will result a small torque on the sensor, while in low gears even a modest pedal force and result in a high torque on the sensor. For simple control schemes that simply amplify this signal, the apparent 'assist level' will vary with what gear you are in.

Similarly, the RPM detected by the device will not mirror your pedal RPM.

Generally we recommend telling the control device (Cycle Analyst or Baserunner/Phaserunner) that it has 20-30 pulses per rotation, which results in RPM values that are closer to typical crank RPMs.

8 Service and Maintenance

Direct drive hub motors can be run for many years with no need for any scheduled maintenance. Frequent exposure to salty conditions can cause corrosion / pitting of aluminum metal over time, but this does not affect your motor's performance. The cassette gears should be periodically cleaned of gunk and the area around the chain kept well lubricated as with any bicycle hub.

If the motor does need to be opened up for service (e.g. ball bearing replacement, torn cable repair), the motor must to be unlaced from the rim first. See Grin's disassembly video for further details. Attempting to remove the right side plate without first unscrewing the 6 screws on the freehub assembly will almost certainly rip the internal wiring of the torque sensor.

9 Additional Points

9.1 Wheel Lacing

The All-Axle motor uses 32 paired spoke holes, which results in the spokes having a tangential angle even in a 0 cross 'radial' lacing pattern. There is no need to cross the spokes with this hub.

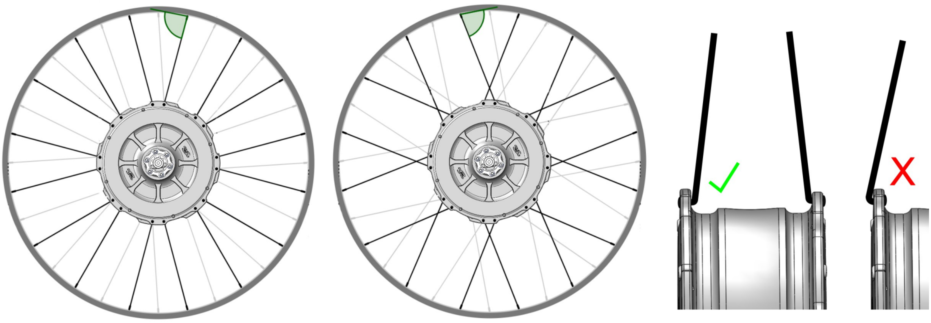


Figure 16: 0 Cross (left) is recommended, but for 24" and larger 1 cross (middle) is OK too. Even if dishing optimization suggests otherwise, lace both left and right side spokes with elbows in.

The side plates of the all-axle motor are counter-bored for the spokes to be laced with the elbows in, head out. This detail is important, as wheel builds with the spoke elbows out can put enough bending moment on the flange to cause the side plate to bow outwards, resulting in axle play.

9.2 Disc Caliper Clearance

Some hydraulic disc calipers are especially wide and may not fit between the rotor and the motor's side plate. The exact amount of clearance available depends on the disc spacer used with the adapter set.

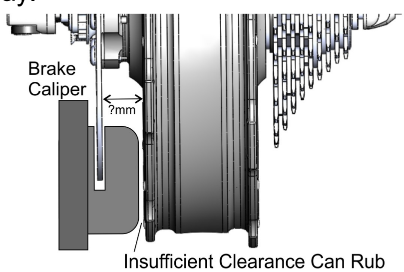


Figure 17: Illustration of Caliper Space.

A summary of the expected caliper room for each of the motor adapter sets is presented in the table below.

Table 4: Disc Spacer and Clearance Details for Each Adapter Kit (142x12 has two options*).

Adapter Kit	Actual Axle Length	Disc Spacer Used	Max Caliper Width
135x9 QR	138 mm	1.5 mm	19.5mm
142x12 TA*	143.5 / 145*	None / 1.5mm	18 mm / 19.5 mm*
145x9 QR	146.5 mm	9 mm	>25mm
148x12 TA	148 mm	4 mm	22 mm
157x12 TA	157 mm	13 mm	>25mm
160x9 QR	160 mm	9 mm	>25mm
167x12 TA	167 mm	9 mm	>25mm

9.3 Temperature Limits and Thermal Rollback

The temperature required to actually burn the enamel off the motor windings and cause permanent damage is very high, over 180 C, but allowing the motor to get close to this value is not recommended as the efficiency and performance plummet well before then. It is best to keep the motor core under 110-120C, which provides significant headroom from actual damage and ensures that the outside shell of the motor is not uncomfortably hot.

In order to automatically scale back power as the motor heats up, the controller system must respond to the motor thermistor which is a 10K NTC with a 3450 Beta constant. The table below shows the expected thermistor resistance at different temperatures.

Table 5: Thermistor Resistance Table.

Temperature	NTC Resistance	Voltage with 5K Pullup
0 C	28.9 kOhm	4.26 V
25 C	10.0 kOhm	3.33 V
50 C	4.08 kOhm	2.25V
75 C	1.90 kOhm	1.37 V
100 C	1.13 kOhm	0.82 V
125 C	0.70 kOhm	0.49 V

9.4 Regenerative Braking

Direct drive motors can regeneratively brake extremely well and can produce the same braking force as acceleration force. The integrated torque arm can safely handle the alternating back and forth torque on the axle.

Regen can greatly reduce the wear rate of your mechanical brake pads and can take over 90% of braking duties. We highly recommend taking advantage of this feature and adding regen control to your system. The supported regen control options for Grin's three kit styles are summarized in the table below

Table 6: Regen Brake Control Modes with Grin Kits.

Regen Mode	Barebones Kit	Superharness Kit	CA3 Kit
Digital Brake Lever	Supported	Supported	Supported
Digital Lever +Throttle	No	Supported	Supported
Analog Lever	No	Supported	No*
Bidirectional Throttle	No	Supported	No*
Backwards Pedal	No	No	Supported
Speed limit	No	No	Supported
Assist Buttons	No	No	Supported

***Support anticipated in future firmware releases.**

Information on configuring the regen behavior is supplied with the motor controller and/or Cycle Analyst.

9.5 Anti-Theft Quick Release

For those concerned about motor security, many anti-theft quick release skewers are available on the open market.

9.6 Horizontal Dropouts

The standard torque arm is designed for vertical dropouts, and will damage the cable with horizontal dropouts. A separate torque arm option specific to horizontal dropouts with a sideways rather than downwards cable exit is planned for the future.

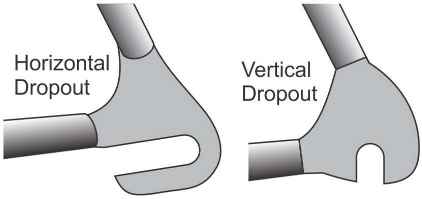
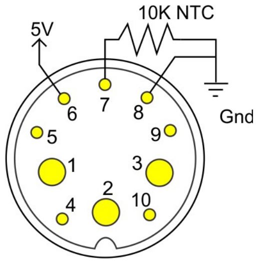


Figure 18: Currently only vertical dropouts (right) are supported. Horizontal slots will crush the cable.

10 Specifications

10.1 Electrical - Pinout

 **Male L1019 Cable**	1 = Blue Phase .... 2 = Yellow Phase .... 3 = Green Phase .... 4 = Green Hall .... 5 = Wheel Speed .... 6 = Hall Power (5-15V OK) .... 7 = Thermistor (10K B3450) ..... 8 = Hall Gnd .... 9 = Yellow Hall .... 10 = Blue Hall	**Blue** **Yellow** **Green** Green White Red Grey Black Yellow Blue
Male Higo MiniB Cable	1 = Programming Pin .... 2 = PAS 1 Signal .... 3 = PAS 2 Signal .... 4 = Gnd .... 5 = 12V Power .... 6 = Torque Signal	Blue Green Yellow Black Red White

10.2 Electrical - Motor

Winding	**5T (Fst)**	**6T (Std)**	**8T (Slw)**
Grin SKU	M-AA2705	M-AA2706	M-AA2708
Motor Kv	12 rpm/V	10 rpm/V	7.5 rpm/V
Motor Ki (Inverse of Kv)	0.79 Nm/A	0.95 Nm/A	1.28 Nm/A
Resistance (Phase to Phase)	268 mΩ	145 mΩ	100 mΩ
Inductance (Phase to Phase)	680 uH	380 uH	260 uH
Maximum Torque*	80 Nm for up to 1 minute		
Continuous Torque to 110C**	30 Nm standard, 40 Nm with Statorade		
Motor Hysteresis Drag	0.6 – 0.7Nm Typ.		
Motor Eddie Current Drag	0.0005 Nm/rpm		
Rated Power (EU/UK/Au/NZ)	250Watts (100 rpm, no statorade)		
Rated Power (Canada)	500 Watts (190 rpm , no statorade)		
Rated Power (USA)	740 Watts (250 rpm, with statorade)		
Rated Power (Your Location)	You tell us, we'll laser it!		
Motor Hall Power	5V-12V DC		
Hall Signal Level	Open Collector, pull-up required on controller		
Hall Timing	120 degree, 8 degree offset		
Thermistor	10K NTC. 3450 Beta. Ground Referenced		

*Maximum peak torque is typically limited by controller phase current.

**Continuous torque depends on passing air velocity and ambient temperature.

10.3 Electrical – Torque Sensor

Torque Sensor Power Draw	24 mA at 12V
PAS Sensor Signal	0-5V Quadrature Encoded (2 wire)
PAS Sensor Poles	9 Pulses / Rotation
Torque Voltage Offset	0.7-0.9V
Torque Voltage Scale	28.3 Nm/V (or 35 mV/Nm)

10.4 Mechanical

Spoke Flange Diameter	214 mm
Spoke Flange Spacing	53 mm
Spoke Size Compatibility	13g (2.0mm) or 14g (1.8mm)
Spoke Holes	32, paired with 21mm between each
Dishing Offset	Depends on adapter set
Motor Diameter	226mm (flange), 212mm (rotor)
Motor Width	54.5mm
Weight (motor only)	4.25 kg
Cable Length	26cm to end of connector

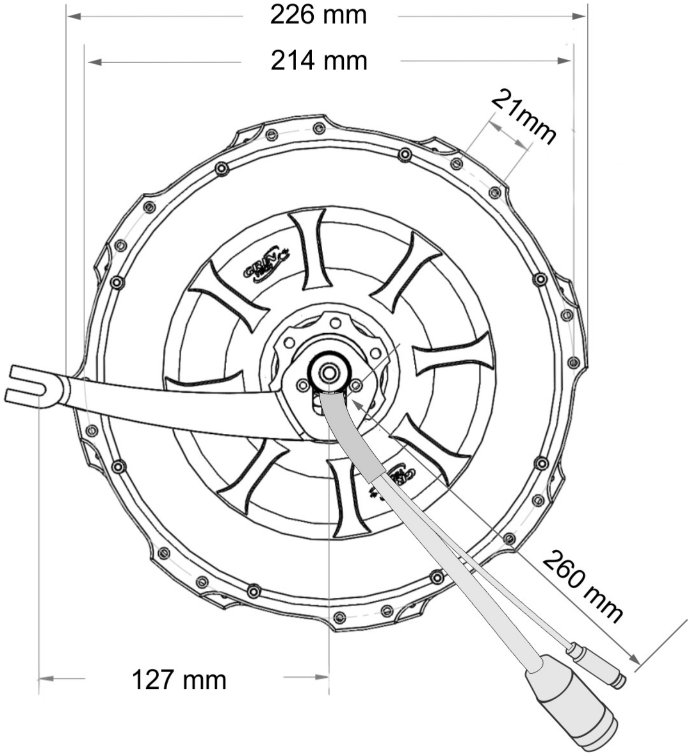


Figure 19: Mechanical Drawing.