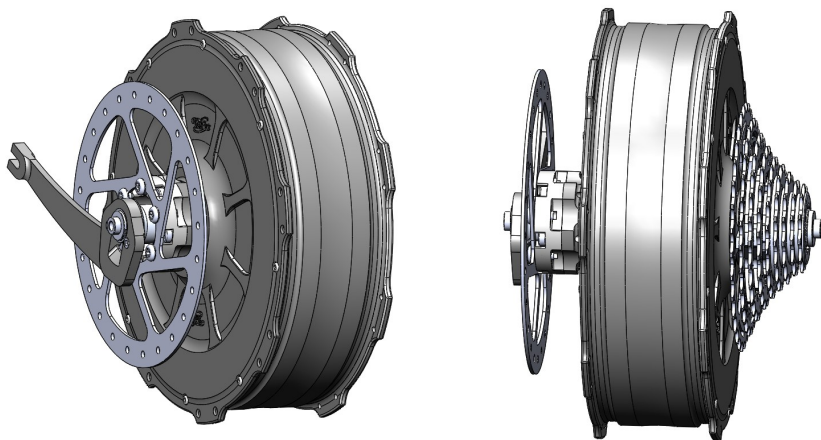# *The Grin All-Axle Motor*
Fat (45mm) Rear Model

Owner's Manual – *Rev0*

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1   Introduction

Thank you for purchasing the V3 Fat Rear All-Axle hub motor from Grin Technologies. This efficient and robust direct drive hub motor can provide years of ebike joy on your fat tire bicycle project.

Features of the Fat Rear All-Axle motor include:

- Light weight for its power class (6.25 kg vs typical 9-11 kg)
- Compatible with both quick release and thru-axle dropouts
- Compatible with 170/177mm (4") and 190/197mm (5") frame spacing
- Integrated torque arm fully secures axle against any rotation
- 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 120 Nm peak torque, and 40-60 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:
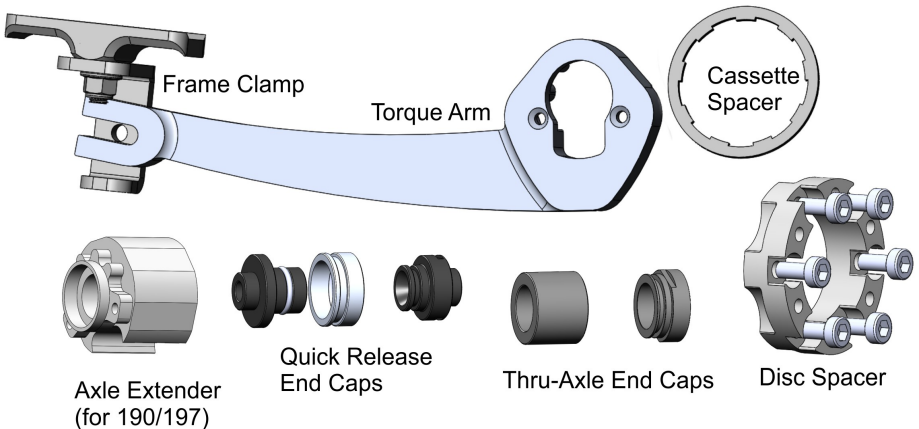

Figure 1: Depending on the adapter kit purchased with your motor, various end caps and spacers will be present to properly align the motor with your bike frame.

2.1 Disc Spacer

The 170mm kits use a 15mm disc spacer and the 190mm kits have a 35mm spacer to position the disc rotor in the correct alignment for an ISO disc caliper, ie 15.5mm inside the left dropout face of the bike.

2.2 Axle Extenders

The 190/197mm adapter kits also include a 20mm 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 on the 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. The quick release end-cap includes a sleeve that must be fit over the axle to retain the cassette.
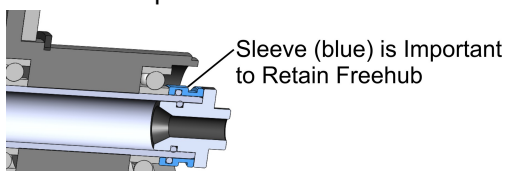
Sleeve (blue) is Important to Retain Freehub

Figure 2 Sleeve Holds Freehub from Sliding Out

2.4 Cassette and Spacer

The motor purchased with Shimano HG freehub option includes a 1.5 mm 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 (190/197mm adapters only)

Fit the 20mm axle extender over the left side of the axle, and tuck the motor wire into the channel of the extender. It is tight and may need to be tapped on, and will be held in place by the two extra long torque arm screws.
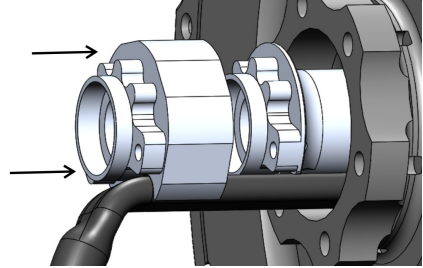

Figure 3: Axle Extender is only used on 190/197mm 5" tire fatbikes

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.
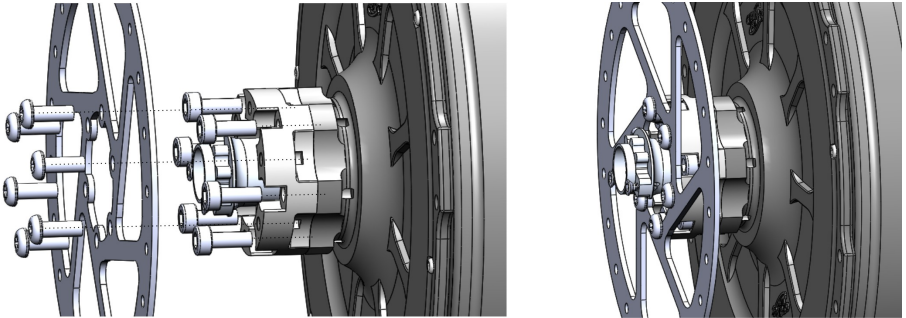
Figure 4: The disc spacers bolt independently to motor, and present separate threaded holes for disc bolts.

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 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.
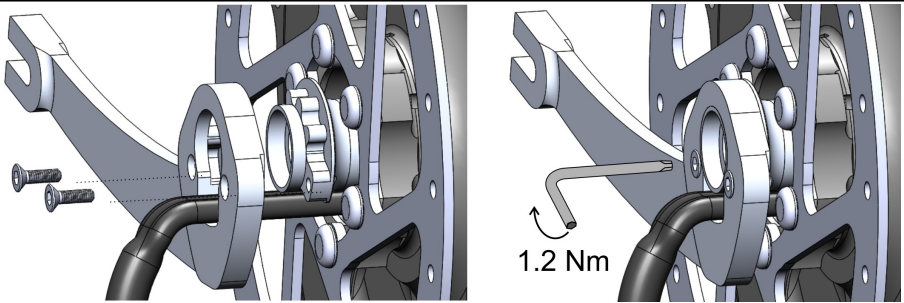
Figure 5: Pass cable through the torque arm first. The L1019 connector just fits through the round opening. Tighten the two M3x10 screws to 1.2 Nm. Longer screws are provided when an axle extender is present.

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.
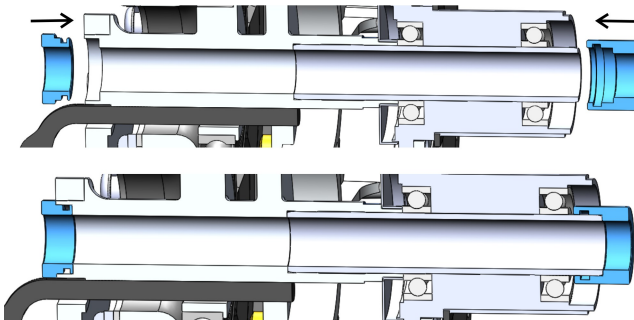

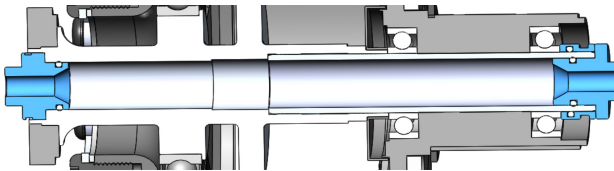**Figure 6: Left side thru-axle end-caps fit inside axle, while the right side slides over the axle .**

Figure 7: 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 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.

1.5mm Cassette Spacer

Cassette Lockring
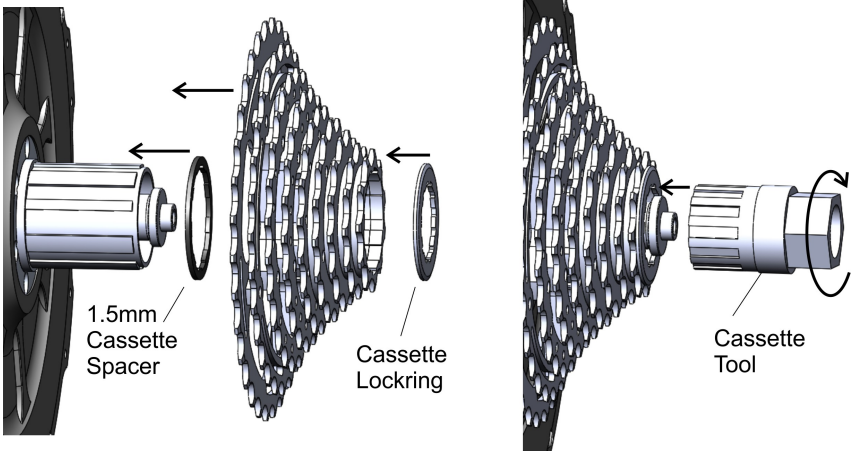
Cassette Tool

Figure 8: 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 9: 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.

No Sleeve

With Sleeve

6 Nm

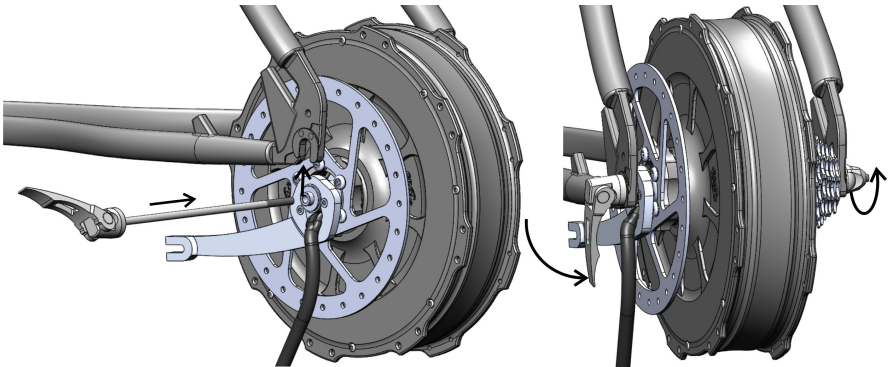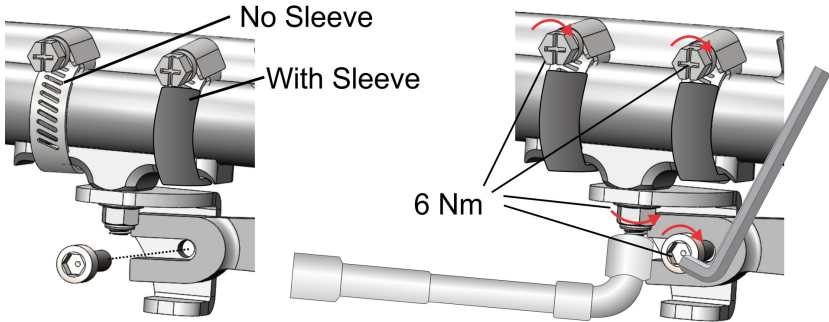**Figure 10: Frame Clamp installed to chainstay. Once aligned, all fasteners should be tightened to 6Nm. Rubber sleeve can be cut to size and slipped over hose clamps.**

3.8 Securing the Torque Arm

Align the frame clamp with the torque arm so that they connect on the natural plane of the torque arm.
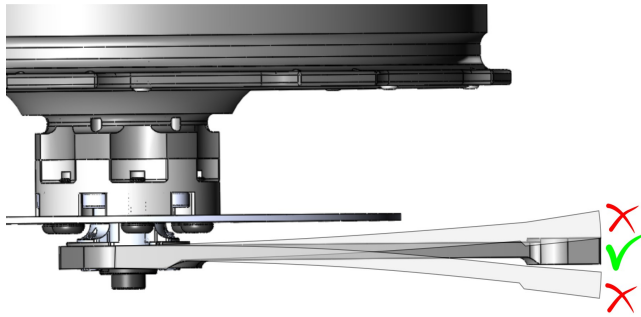
Figure 11: Torque Arm must not be flexed in or out

Important: if your frame geometry does not allow the torque arm to sit flat on the plate, then use spacers or reposition hardware so that it does. Do not force the arm to flex in or out, as this may put unnatural stress concentrations on the arm's spline interface leading to fatigue failure.

Once aligned, 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.

Extension Cable to 5 Pin JST for Cycle Analyst Kits

or

6 Pin Higo Extension to Baserunner with Superharness Kits

Torque / PAS Cable

L1019 Terminated Motor Controller

Figure 12: 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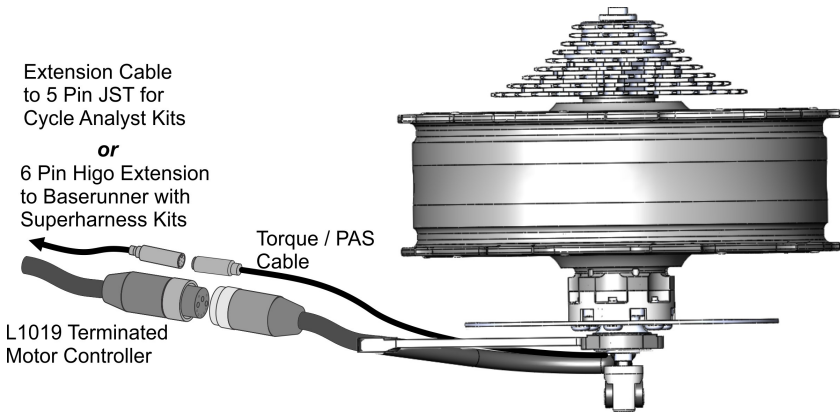 Higo to JST extension cable connects the motor torque sensor to the CA3 on the handlebar. With a Superharness kit from Grin, the 6 pin signal connects directly to the Phaserunner or Baserunner motor controller with a shorter (24 or 44cm) Higo extension cable.

The details of configuring your motor controller and/or Cycle Analyst are covered in their respective manuals, though key parameters are summarized in Appendix A. 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 Fat Rear All-Axle motor is available in 2 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-AA4504R	Standard Winding	4T	9.0 rpm/V
M-AA4505R	Slow Winding	5T	7.2 rpm/V

Table 1: The two winding speed options.

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 (5T) Wind		Standard (4T) Wind	
	20"	**26"**	**20"**	**26"**
36V	24 kph	31 kph	30 kph	39 kph
48V	32 kph	42 kph	40 kph	53 kph
52V	35 kph	42 kph	43 kph	56 kph
72V	48 kph	62 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 winding is used in smaller wheel diameters or lower voltage batteries, while the slower winding is better suited to larger rims or higher voltage packs.

5.2   Winding Speed vs Torque

Note that a faster motor winding does not mean a lower torque motor. However, it does mean that a higher phase current is required to achieve a given torque, and the current handling capability of the L1019 connector will become a bottleneck to high currents.

We recommend the slow motor winding if maximizing the peak motor torque output is a primary goal. Alternatively, cutting off and replacing the L1019 plug with a higher current connector will allow similarly high torques with the standard speed winding.

5.3   Short Term and Continuous Power

The power output capability of an electric motor is highly variable and depends on both how fast the motor is spinning and how long it needs to run for. Table 3 summarizes the estimated output power the Fat 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 20" diameter wheel.

Wheel Speed	Continuous Power		5 Minute Power	
	Dry	w/Statorade	Dry	W/Statorade
70 rpm	*250 W*	*600 W*	*600 W*	*660 W*
100 rpm	*370 W*	*840 W*	*860 W*	*950 W*
200 rpm	*840 W*	*1600 W*	*1700 W*	*1950 W*
300 rpm	*1330 W*	*2500 W*	*2600 W*	*3000 W*
400 rpm	*2200 W*	*3400 W*	*3500 W*	*4100 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 power levels through the motor.

Note that this table is based on the motor itself and does not include limitations that may come from the L1019 connector or the controller. The 5 minute power ratings involve phase currents that exceed 60-70 amps and will potentially melt the L10 plug, likely well before the motor itself becomes overheated.

5.4   Official Rated Power

As both the designer and manufacturer of this motor, Grin has full discretion over the ill-defined concept of an official power rating, which can be any point on the previous table.

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 70 rpm (approx 10 kph) 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 120 rpm wheel speed, which is 500 watts.

For the USA, we define the rated motor power as the general continuous power capability at 15 mph cycling speeds (~180 rpm), which is 750 watts.

6   Statorade Injection

As shown in Table 3, motor thermal performance at high loads is increased significantly by the addition of 10mL 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 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.
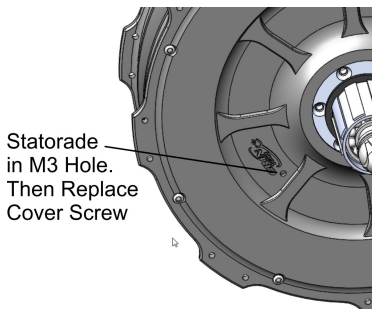
Statorade in M3 Hole. Then Replace Cover Screw

Figure 13: 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
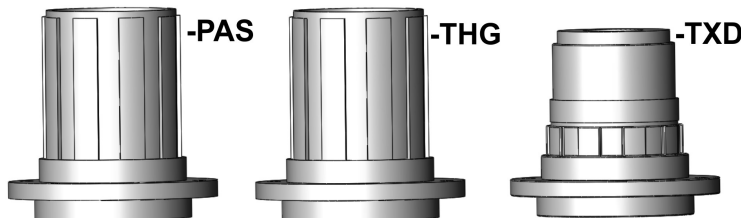
-PAS   -THG   -TXD

Figure 14: 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 XDR 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-XDR cassette driver. The 11 and 12 speed XD and XDR 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.
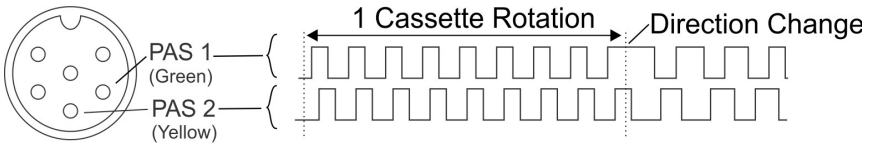

Figure 15: Pedal sensor signals illustrating one full rotation (9 pulses) and then a change to pedaling backwards.

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.
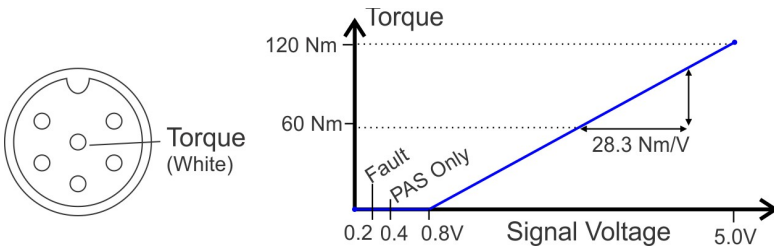

Figure 16: Torque Sensor Signal Voltage.

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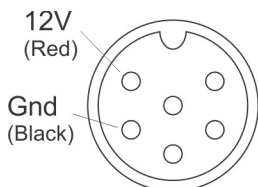
The torque sensor runs off its own 12V nominal power source that is completely isolated electronically from the hall sensor circuit on the motor's L1019 plug. This configuration makes it easy to have fully independent systems for measuring the rider input and powering the motor.

Figure 17: Sensor can operate from 6V-16V

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 but will be scaled by your gearing.

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.
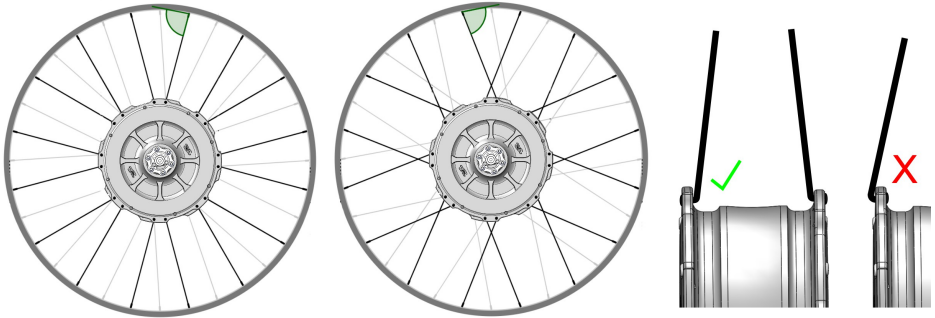

Figure 18: 0 Cross (left) is recommended, but for 24" and larger 1 cross (middle) is OK too. Even if dishing optimization suggests otherwise, lace both left and right side spokes with elbows in.

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 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 should 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 4: 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

9.3   Regenerative Braking

Direct drive motors can produce a powerful regen braking force, equal to the forwards torque for acceleration. The integrated torque arm will safely handle transmission of torques in both directions.

We highly recommend taking advantage of this feature and adding regen control to your system, as it greatly reduces the wear and maintenance on your mechanical brakes, and increases your range as well. The supported regen control options for Grin's three kit styles are summarized in the table below

Table 5: 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.

9.4   Anti-Theft Quick Release

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

9.5   Horizontal Dropouts

The standard torque arm is designed for vertical dropouts but can accommodate a number of horizontal and diagonal dropouts too.

When installing with non-vertical dropouts, ensure that the cable can route under the lower dropout bar without getting pinched. If it will get pinched, you can either file or grind away the metal on your frame to
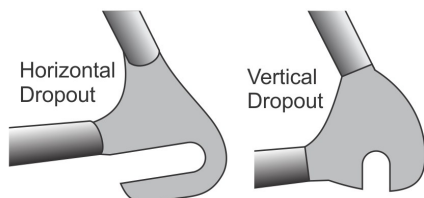

Figure 19: Vertical dropouts (right) are supported. Attention is required with horizontal dropouts to avoid crushing the cable.

leave a channel for the wire, or use a spacer on the axle insert to increase the axle OLD. Cable damage from installation is repairable but is not covered by warranty, so pay attention to this detail.

9.6 Funny Noises

The Fat All-Axle motor has been optimized for weight savings and is generally 3kg lighter than comparable generic motors. However, that optimization means that the motor shell is much thinner and prone to amplifying small innocuous sounds that may be present in the motor which are of no consequence.

Do not be concerned if you hear small noises from the motor when running unloaded, when actually seated on a bicycle it will be quite silent.

10 PAS System Settings

10.1 Recommended CA3 PAS Settings

If the motor is installed with the torque sensor plugged into a V3 Cycle Analyst, we recommend installing the V3.2x Cycle Analyst firmware which has wheel torque sensor mode and using the following parameters. This will average the torque over 3 full wheel rotations and provide accurate readout of human watts.

PAS Config Settings	Preset 1
Pedaling Torque Threshold	5 Nm
Off the Line Torque Threshold	15 Nm
PAS Assist Mode	Torque
Assist Start Level	0 W
Assist Scale Factor	4.00 W/HW
Torque Assist Averaging	27 Poles
Start Threshold	0.30 sec/pole
Stop Threshold	0.19 sec/pole

Temperature Settings	Preset 1
Temperature Sensor Type	NTC b=3450
Threshold Temperature	110.0 ℃
Max Temperature	120.0 ℃

PAS Device Settings	Preset 1
PAS Poles	27 Pulses/Rev
PAS Signal Type	2-Wire
PAS Direction Polarity	5V = Forward
Device Sensor Type	Wheel TRQ
Torque Scale	28.3 Nm/V
Zero Torque Offset	0.80 V
Torque Fault Voltage	4.98 V

Pedal Regen Settings	Preset 1
Backpedal Regen Mode	Position
Backpedal Regen Max Steps	18 Poles
Backpedal Regen Engage Steps	4 Poles

Figure 20: PAS Device and Configuration, requires CA3.2 Firmware

10.2 Recommended Superharness Controller Settings

If the motor is setup with the PAS sensor plugged directy into a Phaserunner or Baserunner controller using the Superharness and 3rd party display, we recommend the following PAS setup parameters. These can also be loaded automatically by choosing "All-Axle Trq/PAS" from the Pedal Sensor Presets dropdown.

Figure 21: Suggested PAS Setup in Phaserunner or Baserunner device for kits using Grin Superharness and 3rd party displays

Note that the torque sensor is configured as a bottom bracket sensor using half the Nm/V as actual, but also with left crank only symmetry. This is required to achieve the best smoothing effect due to a limitation in ASI's firmware only allowing a maximum of 18 pulses / rotation.

11 Specifications

11.1 Electrical - Pinout

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

11.2 Electrical - Motor

Winding	4T (Standard)	5T (Slow)
Grin SKU	M-AA4504	M-AA4505
Motor Kv	9 rpm/V	7.2 rpm/V
Motor Ki (Inverse of Kv)	0.79 Nm/A	0.95 Nm/A
Resistance (Phase to Phase)	102 mΩ	155 mΩ
Inductance (Phase to Phase)	240 uH	330 uH
Maximum Torque*	120 Nm for up to 1 minute	
Continuous Torque to 110C**	40 Nm Dry, 60 Nm with Statorade	
Motor Hystersis Drag	1.0 – 1.2 Nm Typ.	
Motor Eddie Current Drag	0.0008 Nm/rpm	
Rated Power (EU/UK/Au/NZ)	250Watts (70 rpm, no statorade)	
Rated Power (Canada)	500 Watts (120 rpm , no statorade)	
Rated Power (USA)	750 Watts (180 rpm, no statorade)	
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.

11.3 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)

11.4 Mechanical

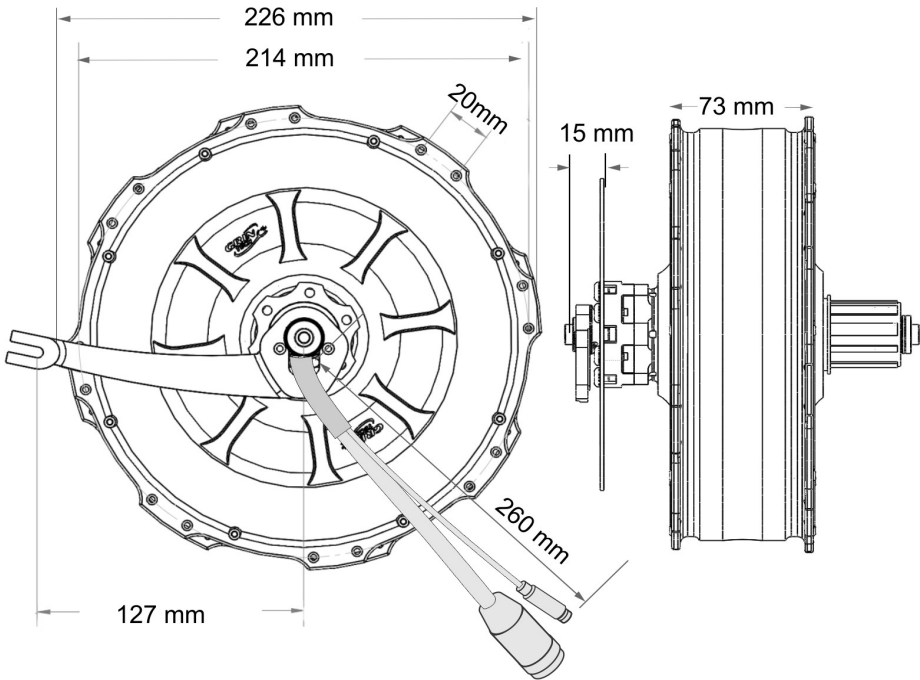|	
Spoke Flange Diameter	214 mm
Spoke Flange Spacing	53 mm
Spoke Size Compatibility	13g (2.0mm) or 14g (1.8mm)
Spoke Holes	32, paired with 21mm between each
Dishing Offset	Depends on adapter set
Motor Diameter	226mm (flange), 212mm (rotor)
Motor Width	72.5mm
Weight (motor only)	6.25 kg
Cable Length	26cm to end of connector

Figure 22: Mechanical Drawing. Fullly detailed drawings with all the various axle adapters available as separate .pdf download