CANCoder User's Guide

Revision 1.4

Cross The Road Electronics

www.ctr-electronics.com

Table of Contents

TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your CTRE products. To this end, we will continue to improve our publications, examples, and support to better suit your needs.

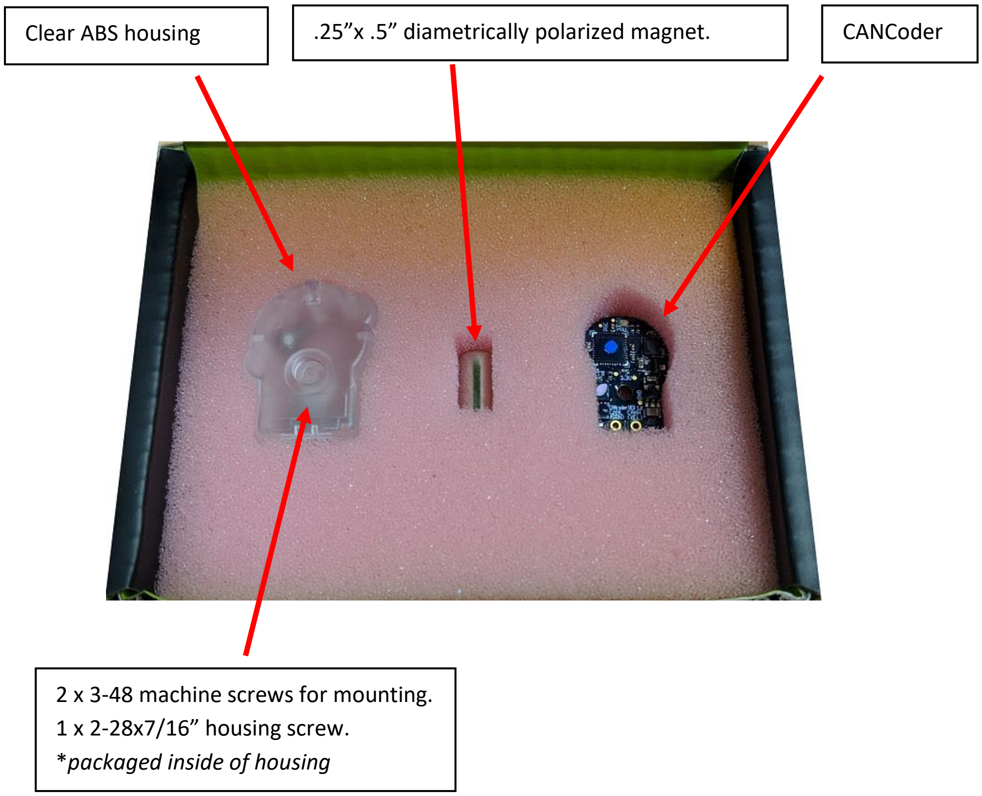
If you have any questions or comments regarding this document, or any CTRE product, please contact support@crosstheroadelectronics.com

To obtain the most recent version of this document, please visit www.ctr-electronics.com.

1. Device description

The CTR CANCoder is a rotary sensor that can be used to measure rotational position and velocity. The device senses the magnetic field of a diametrically polarized magnet to determine rotational position with 12 bit precision. The device is capable of providing a relative position measurement and an absolute position measurement simultaneously over the CAN bus.

1.1. Kit Contents



1.2. Features

- Tri-color LED indicator for magnetic field strength and CAN connectivity
- Conformal coating helps protect against foreign body debris (FOD)
- Built in ESD protection diodes
- Measures both absolute and relative positioning.

1.3. Electrical Specifications

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Tamb	Ambient temperature		-40		+85	°C
Isupp	Supply Current	DC supply 12.0V		50	60	mA
Vdd	Supply voltage		6.0	12.0	16.0	V
ESD Rating						
	ESD Protection Contact Discharge				±30	kV
	ESD Protection Air-Gap Discharge				±30	kV
Resolution						
CPR	Counts per revolution			4096		
Output						
Vmax	Rotational Velocity				15000	RPM

1.4. Magnet Specification

Parameter	Condition	Value	Unit
Length	±0.004	.500	INCH
Diameter	±0.004	.250	INCH
Material	Grade N42	NdFeB	
Plating		Nickel	
Magnetization Direction		Diametrical	
Weight		.106	OUNCE
Surface Field		6898	GAUSS
Max Operating Temperature		176°	F
Br_{max} (Residual Induction)		13200	GAUSS
BH_{max} (Maximum Energy Product)		42	MGOe

1.5 General Specification

Parameter	Condition	Max	Unit
Discrepancy between Absolute Position and Regular Position.[1]	CANCoder is still when booting	0.1	degrees
	CANCoder is rotating < 60 RPM	1.44	degrees

Note 1: CANCoder is configured to boot to absolute position

1.6. LED States

The CANCoder features a tri color LED that indicates magnetic field strength and CAN bus health. This feature can be used to confirm proper magnet distancing and proper CAN bus wiring. The table below shows the possible color states and their respective magnetic field strength.

LED Color	LED Brightness	CAN Bus detection	Magnet Field Strength	Description
Off	---	---	---	CANCoder is not powered/ plugged in. Check power cabling to the CANCoder.
Yellow/Green	**Bright**	---	---	Device is in boot-loader, most likely because field-upgrade failed in middle of event. Inspect CAN bus wiring and re-field-upgrade using Phoenix Tuner. If device has valid firmware, turn device off, wait 10 seconds, and turn device on to boot strap it.
Red/Green	**Bright**	---	---	Device has Phoenix Pro firmware and is unlicensed. Either connect this device to a Phoenix Pro licensed CANivore, apply a Phoenix Pro device license, or change firmware to use Phoenix v5.
Slow Red Blink	**Bright**	CAN bus has been lost. (Section 1.5.1)	---	Check CAN Bus health and connection to the CANCoder. If the goal is simply to test magnet placement, wait 8 seconds and use the dim rapid blink LED patterns.
Rapid Red Blink	*Dim*	CAN bus never detected since boot (Section 1.5.1)	Magnet is out of range (<25mT or >135mT).	
Rapid Yellow Blink	*Dim*	CAN bus never detected since boot (Section 1.5.1)	Magnet in range with *slightly* reduced accuracy (25-45mT or 75-135mT).	
Rapid Green Blink	*Dim*	CAN bus never detected since boot (Section 1.5.1)	Magnet in range (between 45mT – 75mT).	
Rapid Red Blink	**Bright**	CAN bus present	Magnet is out of range (<25mT or >135mT).	
Rapid Yellow Blink	**Bright**	CAN bus present	Magnet in range with *slightly* reduced accuracy (25-45mT or 75-135mT).	
Rapid Green Blink	**Bright**	CAN bus present	Magnet in range (between 45mT – 75mT).	

1.6.1. Dim Rapid-Blink LED

In a typical setup, if the CAN bus is not healthy, the CANCoder will **slow blink red**, regardless of the magnet field strength. This is ideal in most circumstances because a wiring/CAN-bus issue must be addressed first for successful operation.

However it may be useful to indicate the magnet field strength during prototyping / hardware-bring up, even if CAN-bus is not wired. If CANCoder does not detect CAN bus for 8 seconds after boot, LED state will transition from **slow blink red** to the **dim rapid-blink patterns** for Magnet Strength. This allows magnet placement to be verified without requiring a CAN bus. If CAN bus is detected at any time, CANCoder will leave and **never** re-enter the dim LED mode without a full power cycle.

1.6.2 LED Behavior on Boot

Immediately when CANCoder powers up, it will hold solid orange LEDs to indicate it has begun operation.
Following that, it will do one of the following depending on its initialization strategy:

1. Boot to Zero (relative mode) – CANCoder will immediately begin blinking according to the LED table in section 1.6
2. Boot to Absolute – CANCoder will go solid red LED as it seeds its position register to the absolute position. If the magnet is too far away the LED will be solid red for up to 500ms.[1]

Note 1: This applies for CANCoder firmware > 22.0.1

2. Installation

Proper alignment of the magnet, rotary shaft and encoder is necessary to ensure reliable performance. The magnet should be placed at the end of a rotary shaft so that the magnet, shaft and encoder are coaxial. The encoder will tolerate some eccentricity, however steps should be taken to ensure that the magnet is concentric to the shaft and encoder. If a nonferrous shaft is used it is recommended that an adhesive is used to keep the magnet from rotating inside the rotary shaft. A press fit may be used to avoid this, however the magnet material is brittle and can be damaged if a tight press fit is required.

Although similar to the CTRE "Magnetic Encoder", the CANCoder requires CAN bus and power leads to be wired to the CANCoder circuit board. This is also covered in the sections below.

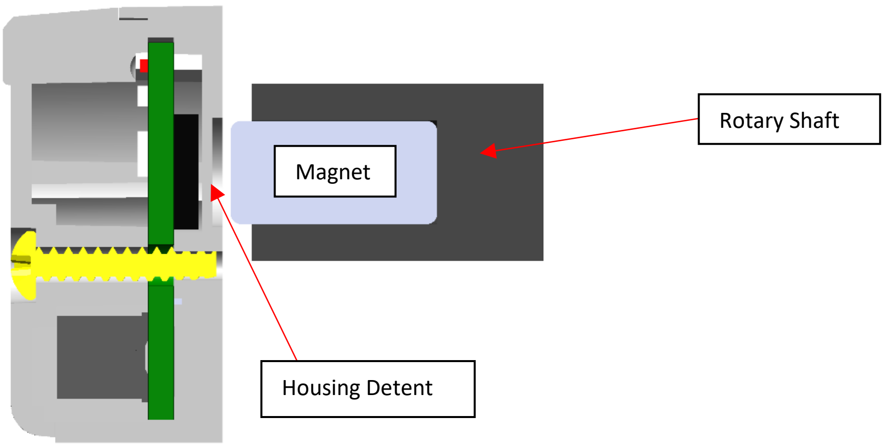
2.1. Magnet Placement

The typical distance "Z" between the magnet and the housing detent, as illustrated in Figure 2.1, is .75mm (.030) to 1.5mm (.059"). The table below shows the relationship between LED color and magnet Z distance.

LED color	Minimum distance from detent	Maximum distance from detent "Z"
Rapid Red Blink	NA	>2.95mm (.116")
Rapid Yellow Blink	0.0mm	2.95mm (.116")
Rapid Green Blink	.75mm (.030")	1.5mm (.059")

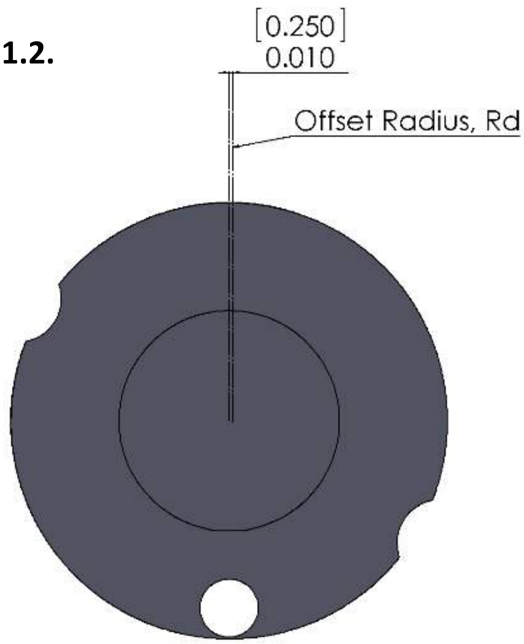
This table assumes the use of supplied magnet. If a different magnet is used, the LED may be used to determine correct distancing.

Figure 2.1.1.



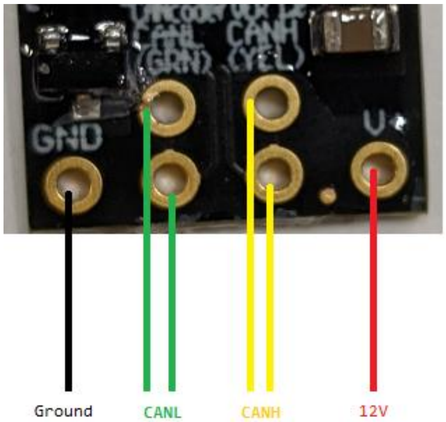
The magnet's center axis must be aligned within an offset radius Rd of 0.25mm (.009") from the defined center of the encoder housing, see Figure 2.2. This is the recommendation from the silicon manufacturer. The ideal application would have the magnet, rotary shaft and encoder all coaxial. However, the encoder will function without any noticeable performance loss if this tolerance cannot be held.

Figure 2.1.2.



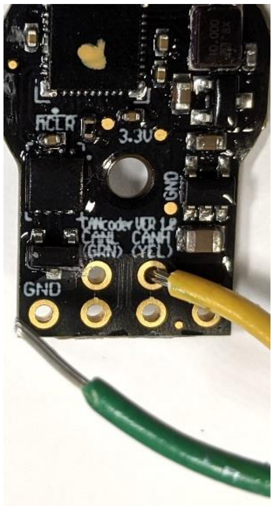
2.2. Wiring

The CANCoder printed circuit board features six through-holes to make soldering easier.



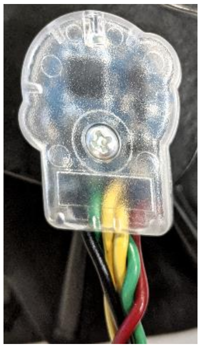
Note the CAN H and CAN L lines each have two through-holes. This allows two CAN bus pigtails, each with a CANH/CANL pair.

Strip ~20 AWG wire and pass through the 100mil through-hole.



Tin the exposed portion of the wire-lead, until solder hole completely fills with solder. Cut the excess lead with diagonal cutters.

Once all six wires are solder in, the should package with the enclosure, see image below for reference.



2.3. Encoder Mounting

The encoder should be mounted to a surface that is rigid and in a fixed position relative to the magnet and rotary shaft. A center hole is not required provided the material the encoder is mounted to has a relative magnetic permeability similar to air (~1.0). Aluminum and most plastics meet this requirement.

2.4. Confirming Proper Installation

When properly installed, the LED should be **green**. A **yellow** LED is acceptable however there is less tolerance to mechanical deviation that may cause the Z distance to change, as this state is farther away from ideal. The LED should remain **green** through the shafts full range of motion and speed. If the LED transitions or "blips" a color other than **green**, confirm that the mechanical relationship between the encoder, shaft and magnet are consistent. This can be done through manual movement of the components until the cause is isolated. Determine whether the problem is shaft end play, encoder mounting or magnet installation.

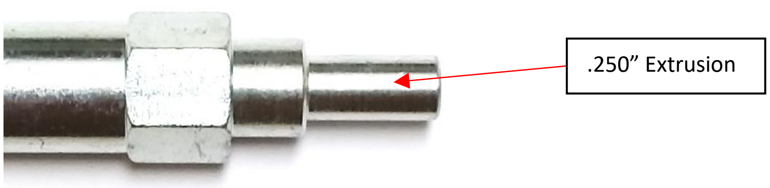
3. Modifications to COTS Components

There are several companies that make commercial off the shelf, or COTS, transmissions and gear boxes. Some of these components contain interfaces for optical or shaft type encoders. This section describes modifications of two COTS transmissions, the AndyMark Toughbox Mini (am-0654) and the VEX PRO Single Speed Double Reduction gearbox (217-2454). Both gearboxes require modification to the output shaft.

3.1. AndyMark Toughbox Mini (am-0654)

The output shaft of the Toughbox Mini features a .250” diameter extrusion located at the housing side of the gearbox Figure 3.1. This extrusion needs to be removed before boring the pocket that will house the magnet. The recommended tools for this procedure are: lathe, .250” drill bit, dial calipers, parting tooling and a cutting tool for facing off the end of the shaft. A hacksaw or cutoff wheel may be used in place of the parting tool. This user manual is not intended to be a substitute for proper training and use of machinery. A lathe can be the most dangerous piece of machinery in a shop. Please exercise caution and follow recommended safety procedures for your particular piece of equipment. The shaft pictured is from a CIMple box. The procedure for both the Toughbox Mini and CIMple box are the same.

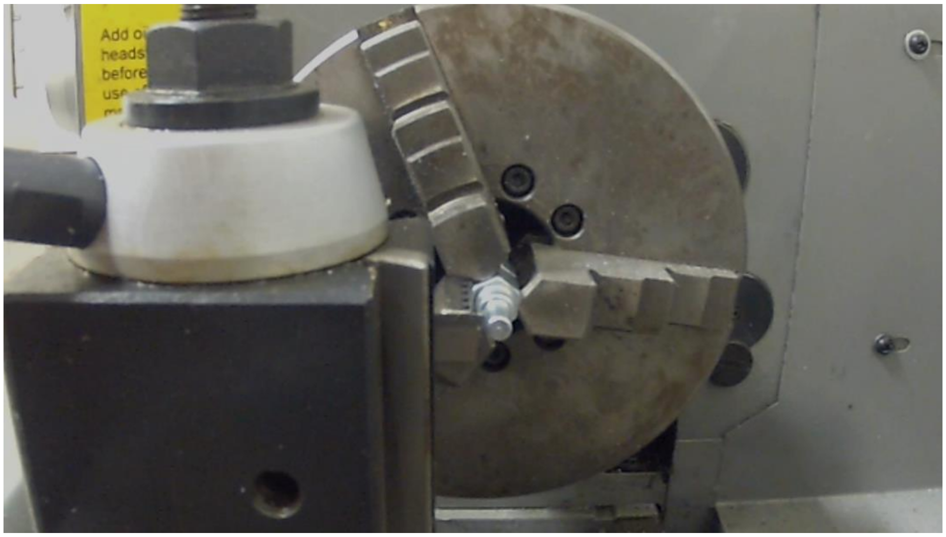
Figure 3.1.



3.1.1. Extrusion removal

The first step is to remove the .250” extrusion from the output shaft. Figure 3.1.1 illustrates how a parting tool and a lathe can be used for this task. Completely remove the extrusion so that only a small portion of the .250” diameter is remaining (about ~.020” - .050”).

Figure 3.1.1.



3.1.2. Facing Off the Shaft End

Once the Extrusion has been removed, the end of the shaft will need to have a smooth even surface. This will make the following steps go smoother. Using a facing tool, turn the face of the shaft down until it is smooth and all of the remaining .250" extrusion is removed. Figure 3.1.2.1 illustrates the tooling used for this step. Figure 3.1.2.2 shows what the shaft should look like after this step has been completed.

Figure 3.1.2.1.

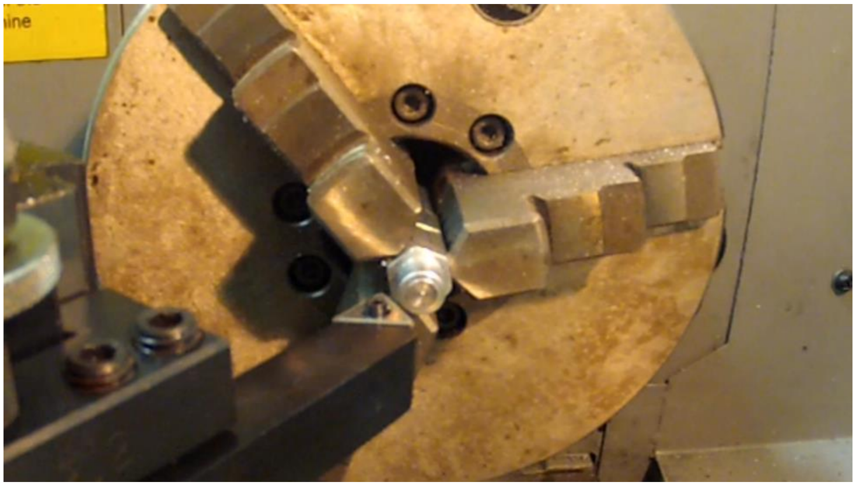
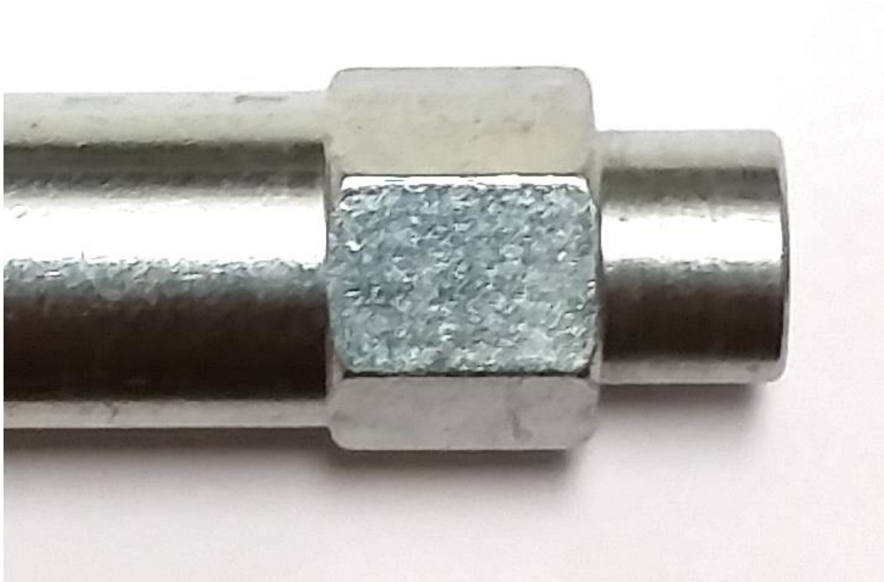


Figure 3.1.2.2.

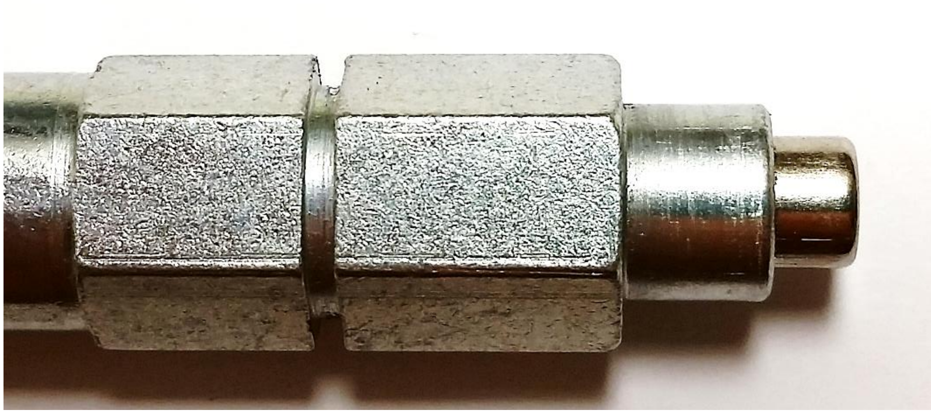


3.1.3. Boring the Magnet Pocket

After the shaft has been faced, a pocket will need to be bored to house the magnet. The depth of this pocket is determined by the distance the encoder is located from the magnet. For the stock mounting location the pocket should be deep enough so the magnet is flush with the outside of the plastic housing after assembly. A bore depth of ~ .350" should be sufficient. This of course is dependent on how much material was removed during step 3.1.2. A centering drill should be used to start the hole prior to boring with a .250" drill. If the hole is bored too deep, shims may be placed inside the pocket to correct the over bore. The goal is the make the final seated depth of the magnet so that the face is flush with the encoder housing (not the detent). Figure 3.1.3.1 shows the final hole being bored with a .250" drill. Figure 3.1.3.2 shows the output shaft with all the necessary modifications and magnet installed.

Figure 3.1.3.1.

Figure 3.1.3.2.



3.1.4. Mounting the Encoder

After the shaft has been completely modified, the encoder housing should be mounted using the two supplied 3-48 machine screws (Figure 3.1.4.1). Next place the encoder inside the housing (Figure 3.1.4.2). Insert the data cable (sold separately) then place the housing cover and secure it with the supplied 2-28 x 7/16" screw (Figure 3.1.4.3). DO NOT OVER TIGHTEN THE 2-28 SCREW AS THIS MAY RESULT IN PERMANENT DAMAGE TO THE HOUSING. HAND TIGHTEN UNTIL RESISTANCE IS FELT.

Figure 3.1.4.1.

Figure 3.1.4.2.

Note – Image shows a CTRE Mag Encoder, however CANCoder mounting is identical.

Figure 3.1.4.3.

Note – Image shows a CTRE Mag Encoder, however CANCoder mounting is identical.

3.1.5. Verifying Magnet Placement.

Once the CANCoder has been installed, magnet placement should be verified. A properly distanced magnet should result in a **green** LED at all speeds and positions. This test only requires the CANCoder to be powered. Wait 8 seconds after boot if CAN bus is not wired (to use the dim-rapid LED pattern - Section 1.5.1). Verify the LED is **green**. If the LED is **yellow** the encoder will still perform with a small reduction in accuracy. If the LED is **red**, the magnet is either too close or too far away from the encoder. Using the supplied magnet, the LED should only be **red** if the magnet is too far away. This is only true when the encoder is mounted in its supplied housing. Increase or decrease the magnet distance until the LED is **green**. Once magnet position is confirmed, the magnet should be secured using Loctite or epoxy. Loctite/Epoxy is usually not necessary for steel shafts.

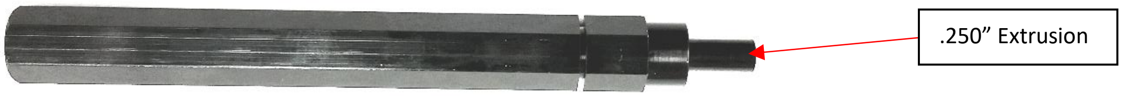
Figure 3.1.5.

Note – Image shows a CTRE Mag Encoder, however CANCoder also displays color LED indicating magnet field strength.

3.2. VEX PRO Single Speed Double Reduction Gearbox (217-2454)

The output shaft of the VEX pro Gearbox has a .250" diameter extrusion located at the housing side of the gearbox Figure 3.2. This extrusion needs to be removed before boring the pocket that will house the magnet. The recommended tools for this procedure are: lathe, .250" drill bit, dial calipers, parting tooling and a cutting tool for facing off the end of the shaft. A hacksaw or cutoff wheel may be used in place of the parting tool. This user manual is not intended to be a substitute for proper training and use of machinery. A lathe can be the most dangerous piece of machinery in a shop. Please exercise caution and follow recommended safety procedures for your particular piece of equipment.

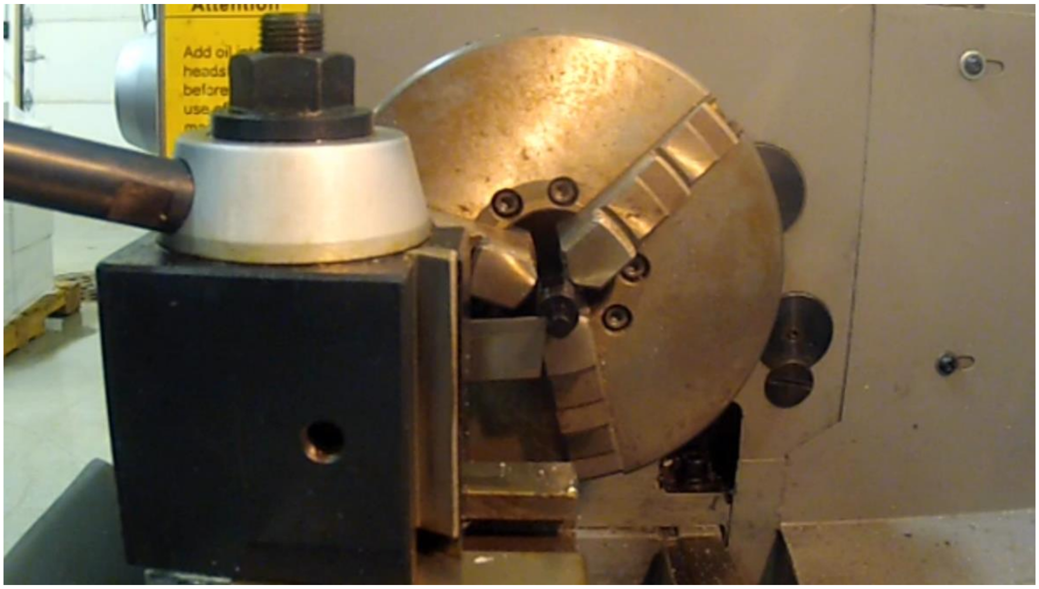
Figure 3.2.



3.2.1. Extrusion removal

The first step is to remove the .250" extrusion from the output shaft. Figure 3.2.1 illustrates how a parting tool and a lathe can be used for this task. Completely remove the extrusion so that only a small portion of the .250" diameter is remaining (about ~.020" - .050").

Figure 3.2.1.



3.2.2. Facing Off The Shaft End

Once the Extrusion has been removed, the end of the shaft will need to have a smooth even surface. This will make the following steps go smoother. Using a facing tool, turn the face of the shaft down until it is smooth and all of the remaining .250" extrusion is removed. Figure 3.2.2.1 illustrates the tooling used for this step. Figure 3.2.2.2 show's what the shaft should look like after this step has been completed.

Figure 3.2.2.1

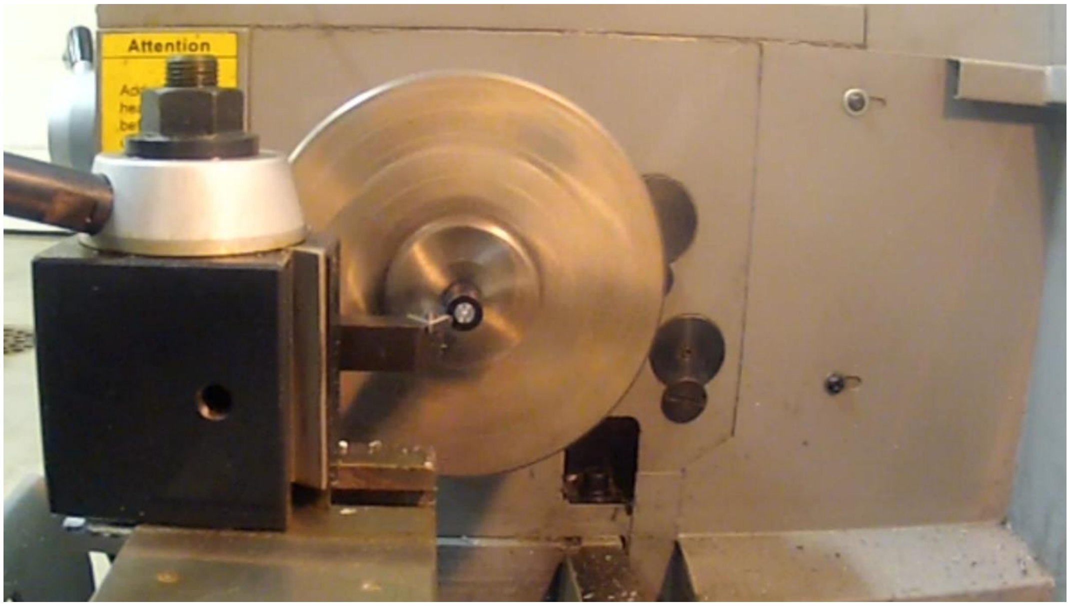
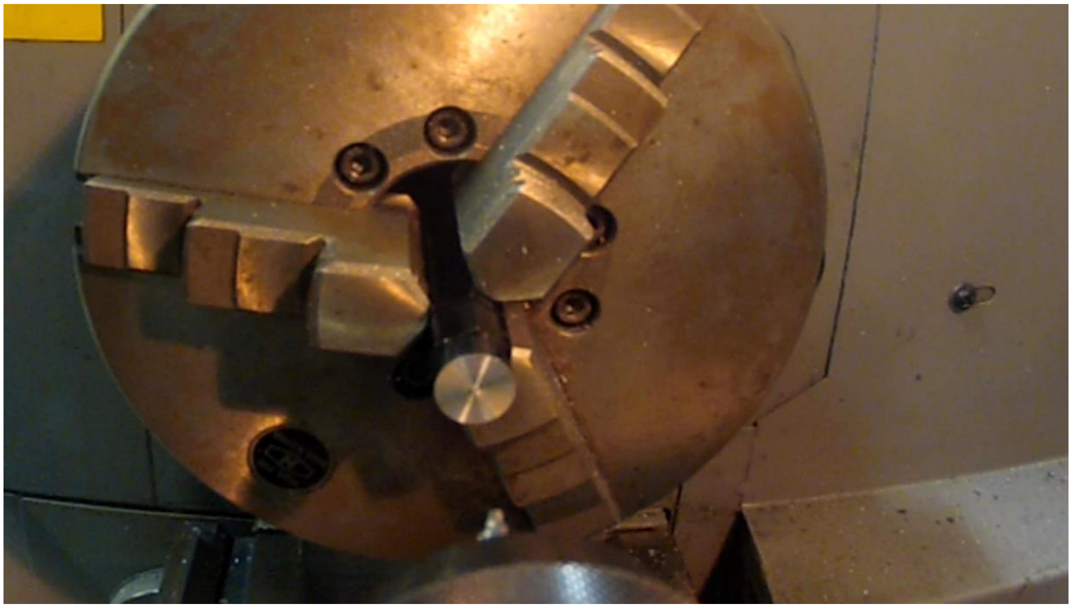


Figure 3.2.2.2

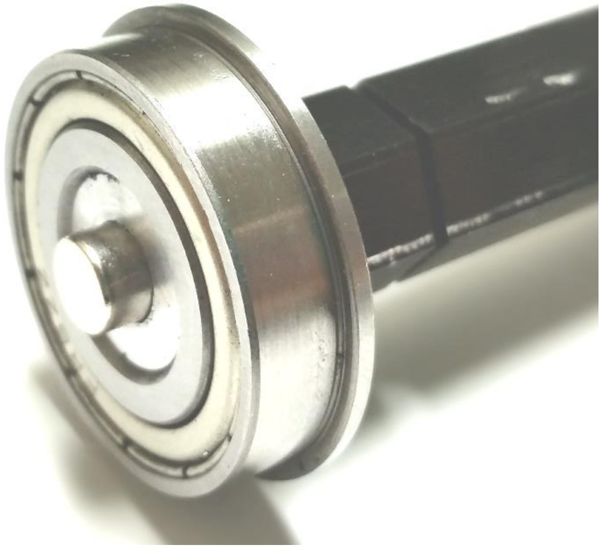


3.2.3. Boring the Magnet Pocket

After the shaft has been faced, a pocket will need to be bored to house the magnet. The depth of this pocket is determined by the distance the encoder is located from the magnet. For the stock mounting location the pocket should be deep enough so the magnet is flush with the outside of the gearbox plastic housing after assembly. A bore depth of ~ .380" should be sufficient. This of course is dependent on how much material was removed during step 3.2.2. A centering drill should be used to start the hole prior to boring with a .250" drill. If the hole is bored too deep, shims may be placed inside the pocket to correct the over bore. The goal is to make the final seated depth of the magnet so that the face is flush with the encoder housing (not the detent). Figure 3.2.3.1 shows the final hole being bored with a .250" drill. Figure 3.2.3.2 shows the output shaft with all the necessary modifications and magnet installed.

Figure 3.2.3.1

Figure 3.2.3.2



3.2.4. Mounting the Encoder

After the shaft has been completely modified, the encoder housing should be mounted using the two supplied 3-48 machine screws (Figure 3.2.4.1). Next place the encoder inside the housing (Figure 3.2.4.2). Insert the data cable (sold separately) then place the housing cover and secure it with the supplied 2-28 x 7/16" screw (Figure 3.2.4.3). DO NOT OVER TIGHTEN THE 2-28 SCREW AS THIS MAY RESULT IN PERMANENT DAMAGE TO THE HOUSING. HAND TIGHTEN UNTIL RESISTANCE IS FELT.

Figure 3.2.4.1

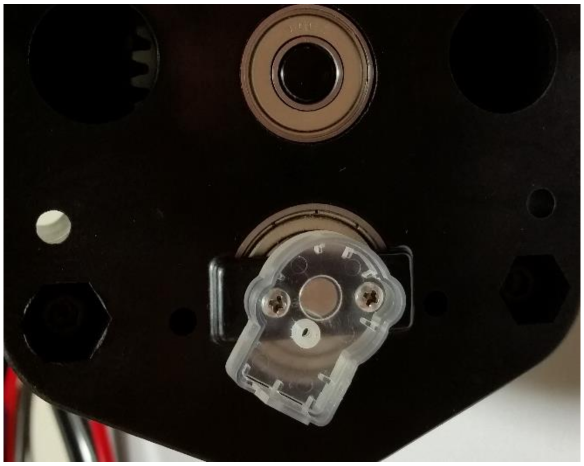
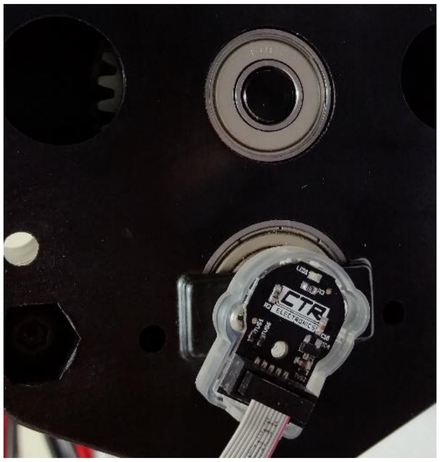
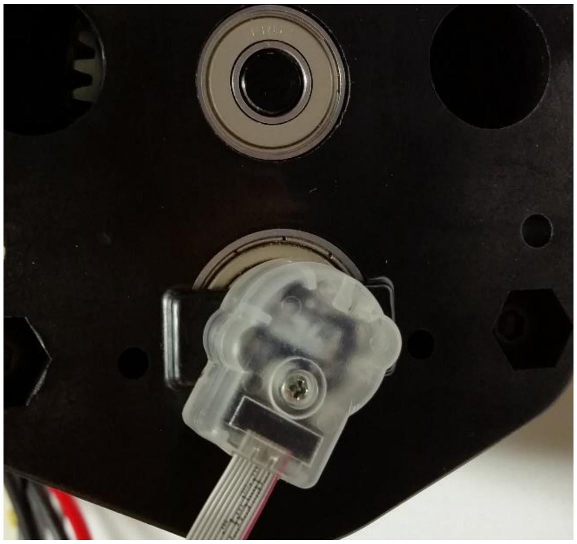


Figure 3.2.4.2



Note – Image shows a CTRE Mag Encoder, however CANCoder mounting is identical.

Figure 3.2.4.3



Note – Image shows a CTRE Mag Encoder, however CANCoder mounting is identical.

3.2.5. Verifying Magnet Placement.

Once the Encoder has been installed, magnet placement should be verified. A properly distanced magnet should result in a **green** LED at all speeds and positions. This test only requires the CANCoder to be powered. Wait 8 seconds after boot if CAN bus is not wired (to use the dim-rapid LED pattern - Section 1.5.1). Verify the LED is **green**. If the LED is **yellow** the encoder will still perform with a small reduction in accuracy. If the LED is **red**, the magnet is either too close or too far away from the encoder. Using the supplied magnet the LED should only be **red** if the magnet is too far away. This is only true when the encoder is mounted in its supplied housing. Increase or decrease the magnet distance until the LED is **green**. Once magnet position is confirmed, the magnet should be secured using Loctite or epoxy.

Figure 3.2.5.1

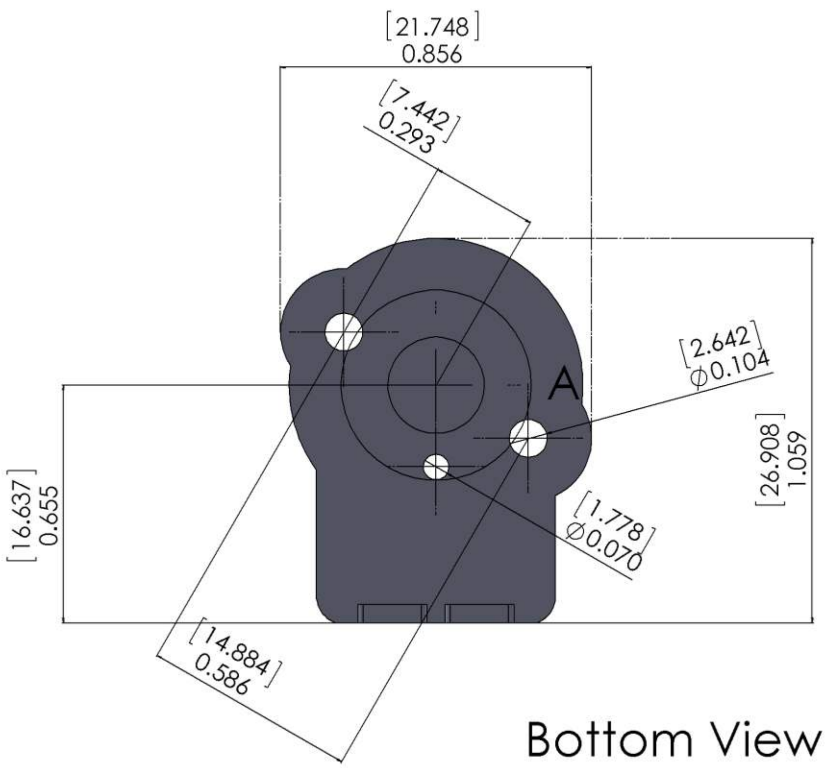
Note – Image shows a CTRE Mag Encoder, however CANCoder also displays color LED indicating magnet field strength.

4. FAQ

4.1. Is there a way to tell if the sensor is present/powered?

To determine visually if the sensor is powered and functioning, check the built-in LED, see Section 1.5.

5. Mechanical Drawings



6. Errata

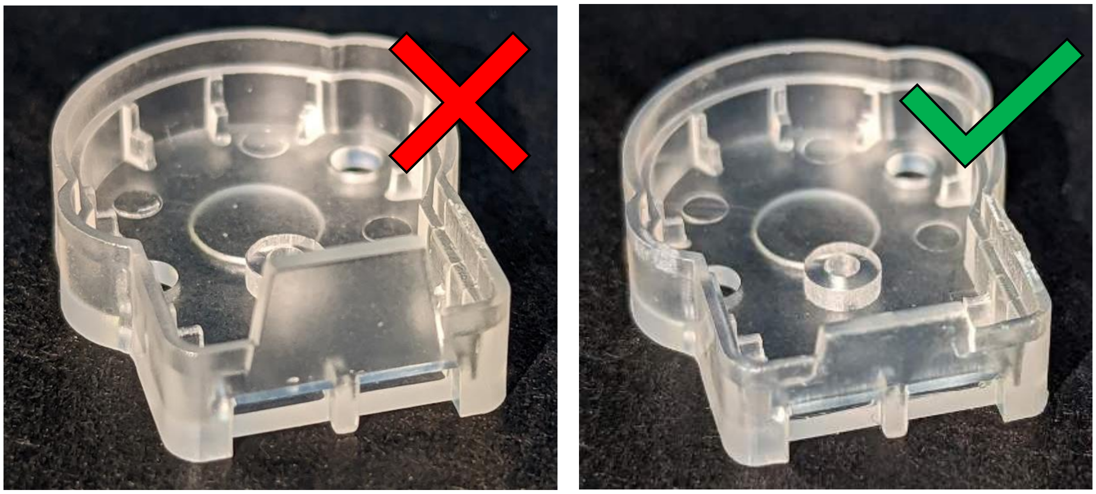
6.1. Fix for Too-Long Housing Tab

Some units in Fall of 2022 include a housing that has a tab that is too long.
This prevents wires from passing through the housing as intended.

Fix:

If the housing included with your CANcoder has a too-long tab (as shown on the left of Figure 6.1.1), use diagonal cutters to cut the tab to the length shown on the right of Figure 6.1.1.

Figure 6.1.1: Bad vs Good CANcoder Housing



7. Revision History

Revision	Date	Description
1.0	02-Dec-2019	Initial Creation.
1.1	23-Jan-2020	Added Max RPM
1.2	31-March-2022	Added general specifications & LED Boot behavior
1.3	03-Nov-2022	Added Errata Section
1.4	13-Feb-2023	Added Phoenix Pro unlicensed LED state