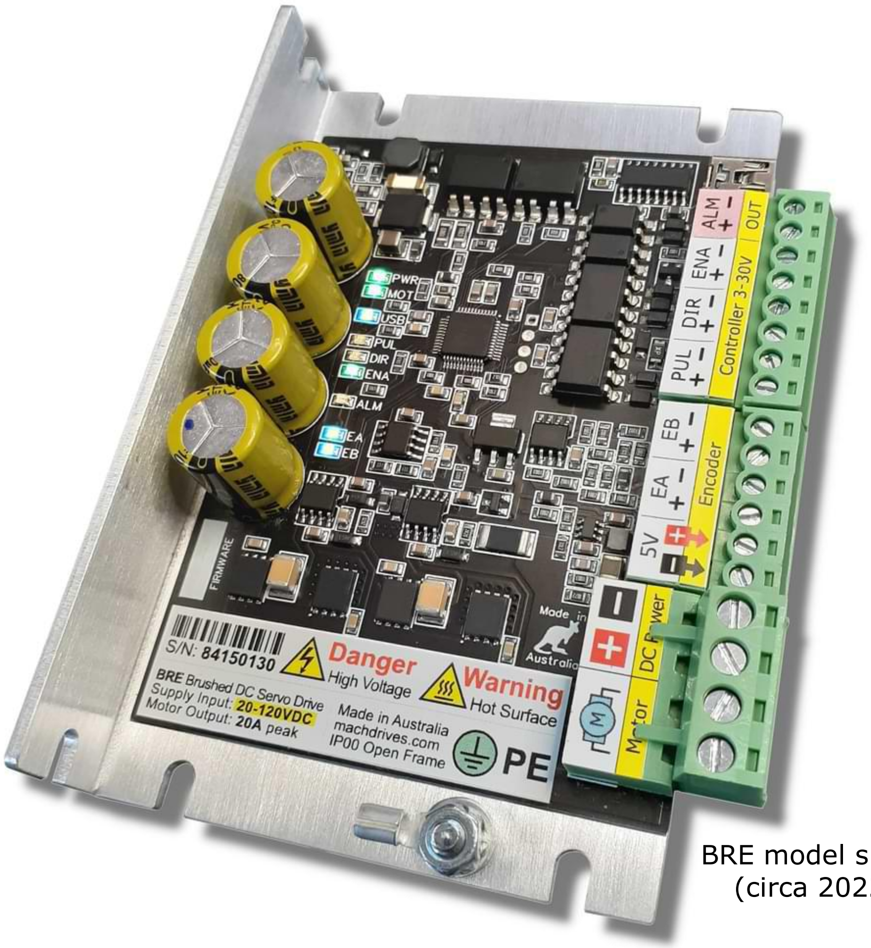
BRD	BRE	BRF
20-80V 20A	20-120V 20A	20-160V 20A

Open Frame

Brushed DC Servo Drives



BRE model shown
(circa 2022).

User Manual

www.machdrives.com

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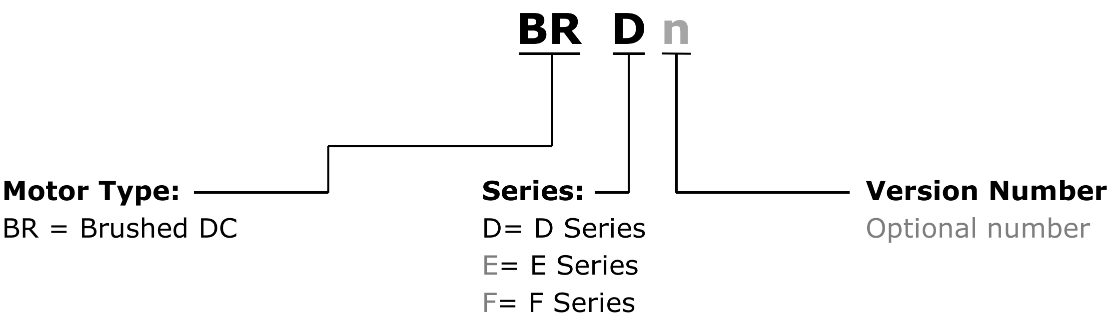
Product Identifier



Document Revision History

Document Name: BRDEFUM

Version	Date	Details
1.0	14-Jul-2022	Initial Release

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CONTENTS

1.0 SAFETY

The following symbols are used in this manual.

WARNING:
This information is needed to avoid a safety hazard that may cause bodily injury or death.

CAUTION:
This information is necessary for preventing damage to this product or other equipment.

HOT SURFACE:
This information is to advise where hot surfaces may be present during device operation.

1.1 Warnings

- Installation and operation of this product involves the use of software, firmware, electronics and documentation. Software and firmware can contain bugs, electronic components can fail and documentation can contain errors. Such defects can cause electrical or mechanical hazards that could result in property or equipment damage, personal injury or death. Electrical and mechanical hazards are also present during normal installation and operation of this product and associated equipment. You and any associated third parties shall be suitably qualified or experienced to access such risks and ensure this product is installed and operated safely in accordance with your local regulations and industry best practice.

- While every care has been taken in preparation of this manual, it may still contain errors or omissions. Where the contents of this manual differ from, or conflict with your local regulations or industry best practice, then your local regulations or industry best practice shall prevail. If in any doubt please contact Machdrives support for clarification before proceeding.

- This product can only be operated from an isolated DC power source. Never connect it directly to the mains supply or through a non-isolated source such as an auto-transformer.

- This product must always be connected to a protective earth ground (PE) before applying power. Failure to earth this product could present an electrocution hazard.

- Always ensure motor power is removed from this device by a mechanical or electromechanical means before placing any body parts in the path of connected machinery. Never solely rely on electronics or firmware for safety.

- Never touch power circuitry or connect/disconnect power or motor connections while power is applied.

- Power cables can carry high voltage even when the motor is stationary. Remove power before touching conductors.

- After removing power wait at least 5 minutes for any stored charge to be dissipated before touching. If in any doubt confirm safe voltage levels with a meter before proceeding.

1.2 Cautions

- The DC power source applied to this product must never exceed the specified maximums. Allow suitable margins for supply voltage increases during deceleration and braking. Exceeding maximums can damage the product and void warranty.

- Never reverse the polarity of the DC power source. Reversing the power source can damage the product and void warranty.

- The power source must be able to supply the expected maximum current. Exceeding the capacity of switch mode power sources can result in them "hiccuping", causing the drive to reset .

- The control connections, USB, power and earth are all electrically isolated from each other inside the drive for maximum noise immunity. Avoid ground loops or damage to the drive that can result by connecting the different sections of the drive together.

- Never unplug the drive power connector while the drive is under power. The motor inductance can cause arcing and damage to the connector contacts. Connector arc damage is NOT covered under warranty.

1.3 Hot Surfaces

- This product may contain hot surfaces. Exercise care when touching during or after operation. If elevated temperatures are present, additional cooling such as forced air circulation may be required.

1.4 Standards and Conformance

This product has been designed and constructed to comply with IEC/EN 61800-5-1 as defined below.

- This product is classified as an industrial Basic Drive Module (BDM) and sale and installation is restricted to machine builders and other suitably qualified or experienced persons. This is not a consumer product.
- Protective Class I - Must be installed in a suitable protective earthed metal cabinet.
- Over voltage category II - Must be connected to an isolated DC power supply.
- Operation in pollution degree 1 or 2 environment only.
- Altitude < 2000m.
- The machine builder is responsible for designing the system with suitable safety devices and disconnects.
- The machine builder is responsible for ensuring the complete system and all auxiliary equipment, cabling and motors comply with appropriate local electrical safety regulations and EMI requirements.
- The machine builder shall be suitably qualified or experienced in assessing EMI requirements to install appropriate EMI filtering if deemed necessary to ensure compliance.

1.5 Warranty

This product is warranted to be free of material defects and workmanship and conform to the published specifications.

This product is warranted for a period of 12 months from the date of sale. Products replaced under warranty are covered under the original warranty period.

Physical damage or operation of the product outside of the published specifications is not covered by warranty. Connector arc damage from plugging/unplugging the drive power connector while under power is not covered by warranty.

All warranty claims must obtain a Return Material Authorization (RMA) number before returning the product. Defective products will be repaired or replaced at the manufacturer's sole discretion. The customer is responsible for the cost of returning the product to the manufacturer. The manufacturer is responsible for the cost of returning the product to the customer by standard shipping service.

No other warranties, expressed or implied, including a warranty of merchantability and fitness for a particular purpose, extend beyond this warranty.

2.0 INTRODUCTION

Thank you for choosing Machdrives for your new project. We want your experience to be a positive one, so please contact us at *support@machdrives.com* if you have any questions about this product or its use.

This user manual describes the Machdrives BRD, BRE and BRF series servo drives and their commissioning as part of a CNC machine or similar system. Please read all sections carefully to ensure the best performance of your drive and your system as a whole.

2.1 Drive Description

Machdrives BRD, BRE and BRF series servo drives are designed for use with brushed DC servo motors and step/direction CNC control software such as Mach3, UCCNC and LinuxCNC. These drives are open frame, giving excellent value for money and are designed to be installed in an enclosed metal control cabinet.

All three models are identical except for the input voltage range, with the BRD requiring 20-80VDC, the BRE 20-120VDC, and the BRF requiring 20-160VDC.

The drive needs to be powered with an isolated DC power supply, and internally generates the other voltages required for operation, as well as the 5V supply to power the encoder.

The drive is configured and tuned using Machdrives Tuna software via USB. This Windows based software can be downloaded for free from https://www.machdrives.com/app/tuna.zip

2.2 Drive Features

2.2.1 Advanced Control Algorithm

- Supports modified PI-D (PIV) algorithm.
- 32 bit ARM CPU with double precision floating point motion calculations.
- Command smoothing for smoother and quieter operation.
- Velocity and acceleration feed-forward for higher accuracy trajectory tracking.
- Stiction (static friction) compensation reduces positioning errors on move starts and stops.
- Supports all combinations of metric and imperial hardware. Automatic calculation of electronic gearing and step multiplying with no loss of precision.
- Abnormal condition detection like following error and encoder faults.

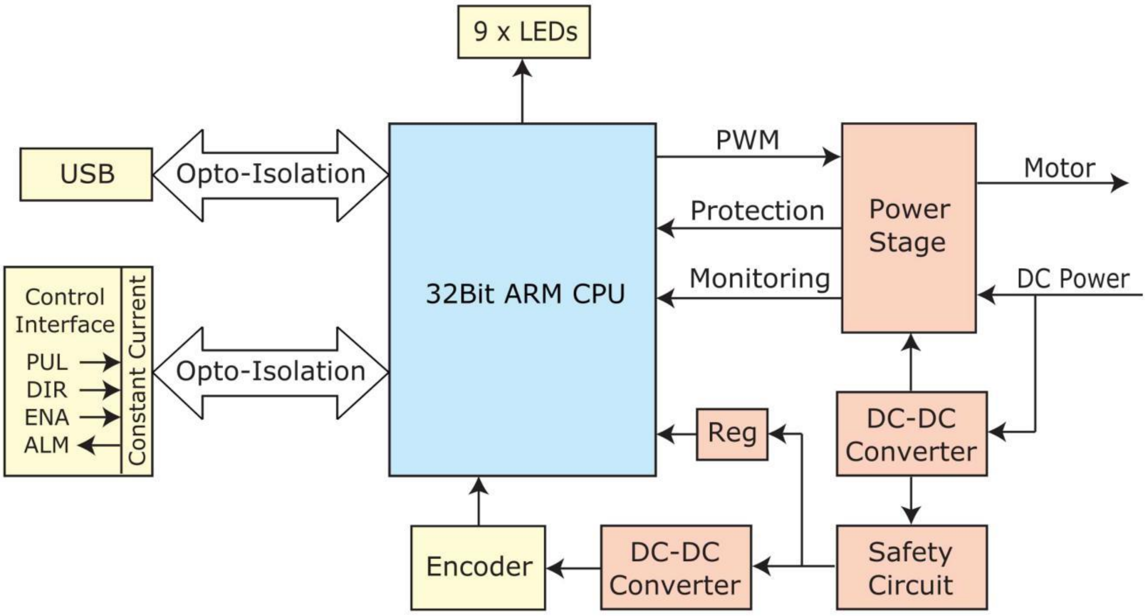
2.2.2 Easy Setup and Operation

- Standard step and direction interface supports popular CNC software and motion controllers.
- Supports CNC controllers from 3VDC to 30VDC without needing series resistors.
- Flexible wall or base mounting "L" chassis open frame design.
- Pluggable screw connectors for easy installation.
- 5V encoder power up to 150mA provided internally by the drive.
- Accepts differential, single ended and open collector encoders.
- Isolated controller and USB interface eliminates ground loop issues.
- Easy drive commissioning with free Machdrives Tuna software for Windows via USB.
- Nine LED indicators show drive states without multimeters or oscilloscopes. Signals too fast or short to be seen are "shifted" into the visible range.
- Compact - light weight design at 115 x 74 x 20mm and 115 grams (4oz).
- In-built waveform generator creates tuning waveforms such as trapezoid and S-profile.
- Real time parameter updating with automatic saving.
- Six channel scope with pan and zoom for easy waveform analysis.
- Digital readouts on command and motor positions.
- Real time statistical motor position error analysis and charting over multiple time intervals.
- Ability to assign drive axis names and connect multiple drives at the same time.

2.2.3 Advanced Power Stage

- Ultra high efficiency MOSFET bridge. Typical applications do not require a dedicated heat-sink. Steel control cabinet wall mounting is normally sufficient.
- Silent operation. No singing or dithering.
- Detection and logging of eight different alarm conditions.
- Optional power saving mode significantly reduces drive and motor losses with no effect on performance.
- Over voltage protection and monitoring.
- Output short circuit protection.
- Intelligent overload protection.
- Thermal protection and monitoring.
- High efficiency internal DC-DC converters with negligible losses and spread-spectrum frequency for reduced EMI.

2.3 Drive Architecture



2.4 Drive Models

The BRD, BRE and BRF models are identical except for voltage rating. The BRD has a maximum input voltage of 80VDC, the BRE 120VDC, while the BRC can accept up to 160VDC.

Dimensions and mounting holes are identical between the models.

	Input Voltage	Output Current	Dimensions
BRD	20 - 80VDC	20A peak	115x74x20mm
BRE	20 - 120VDC	20A peak	115x74x20mm
BRF	20 - 160VDC	20A peak	115x74x20mm

3.0 INSTALLATION

This chapter covers the physical installation of the drive and cable connections as well as the installation of the USB driver and Tuna software.

3.1 Unpacking the Drive

Your BRD/BRE/BRF drive is shipped in anti-static wrapping and, like all electronic devices, can be damaged or degraded by static electricity. Avoid wearing synthetic clothing like nylon and polyester and discharge any static electricity by touching an earthed metal object before unpacking the drive. Where possible wear natural fibers like cotton and an anti-static wrist strap during installation.

Unpack your drive and confirm model and quantities are correct as ordered. Inspect the drive for any visible damage. Contact Machdrives support if any issues are discovered. Do not attempt to install a damaged drive.

Take note of the model and serial number of the drive. These are located on the main PCB label, underneath the barcode. The serial number is in the format “S/N: XXXXXXXX”. This number is required for any warranty claims.

3.2 Environmental Requirements

To ensure safe and reliable operation of your drive, it is important that it is installed in an appropriate environment.

Ambient temperature:	0°C to 40°C (32°F to 104°F)
Altitude:	Maximum 2,000m (6,000 ft)
Humidity:	90% maximum - non condensing
Atmosphere:	No explosive or corrosive gases
Contamination:	No wood dust, plasma cutting dust, metal chips etc.

3.3 Installing the Tuna Software

Tuna is a Windows base application that allows the drive to be configured and tuned via USB. Tuna is compatible with Windows XP, 7, 8.x, 10 and 11.

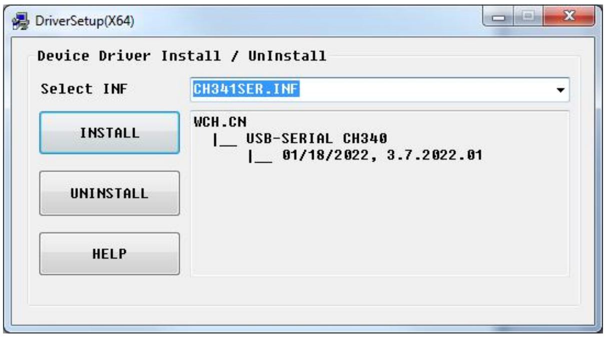
The Tuna application can be downloaded from https://machdrives.com/app/tuna.zip

Extract the appropriate install file from the .zip and follow the prompts to install the software.
You will need to read and accept the End User Licence Agreement (EULA) before the software can install.

Detailed information on using the Tuna application is available in the Tuna user manual that can be downloaded from https://machdrives.com/pdf/tuna.pdf

3.4 Installing the USB drivers

The WCH CH340 USB driver should automatically install on most systems with internet access. If not, it can be downloaded and installed from https://machdrives.com/app/ch341ser.zip
The USB driver supports Windows XP, Vista, Win7, 8.x, 10 and 11, both 32 and 64 bit and is Microsoft WHQL Certified.

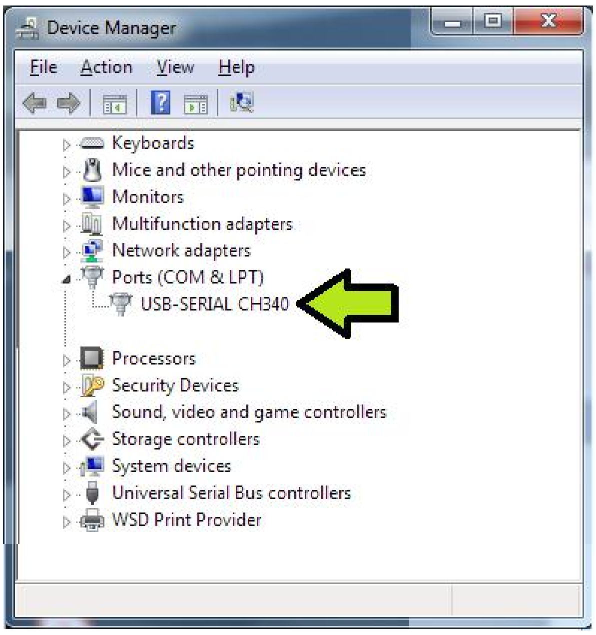


Follow the prompts to install the driver.
Whether the Tuna application is installed or open has no effect on the driver installation.

When the driver is installed correctly and the USB is connected, it will show in "Devices and Printers" and will also appear in the "Device Manager" under "Ports (COM & LPT)" as shown in the picture on the right.

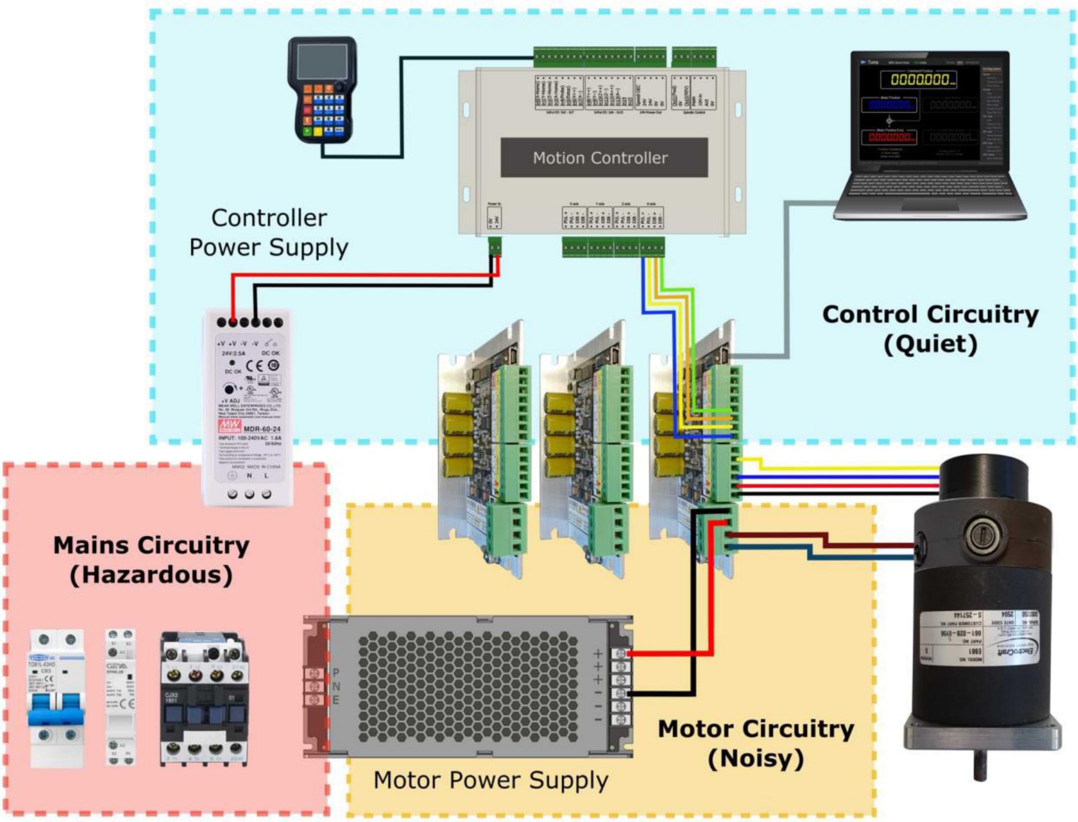
Note: The driver will only show up while the USB cable is plugged into the drive. When the cable is removed the entries will be hidden.

Once the drive is connected to the PC via the USB cable and the Tuna application is open, the blue “USB” LED on the drive will illuminate to indicate that a successful data link has been established.



3.5 Planning your Layout

Your BRD/BRE/BRF drive is designed to allow easy layout and separation of power and control signals for maximum reliability and noise immunity. The controller and USB interfaces are located on the top of the drive, allowing noise sensitive components and wiring to be routed above the drive, well away from motor noise. The power and motor connections are placed at the bottom, allowing noisier cabling to be routed below the drive. The suggested layout shown below allows good physical separation of control and power signals, without cable cross over or noise coupling between the two circuits. The control circuitry must also be powered from a separate isolated power supply to prevent any conducted interference from the motor circuitry.



3.6 Mounting the Drive

Your BRD/BRE/BRF drive generates a small amount of heat during normal operation that must be dissipated away. The two main ways to dissipate heat are through conduction to the surface it is mounted to, and convection by air passing over the drive.

The drive should preferably be end mounted vertically (wall mounted) on a thermally conductive surface such as an aluminum base plate or metal control cabinet using two screws spaced at 106mm. This allows both conduction and convection cooling of the drive to occur.

The drive may alternatively be base mounted on a thermally conductive surface using four screws on a 51mm x 106mm square. When base mounting, ensure adequate air flows are available over the drive.

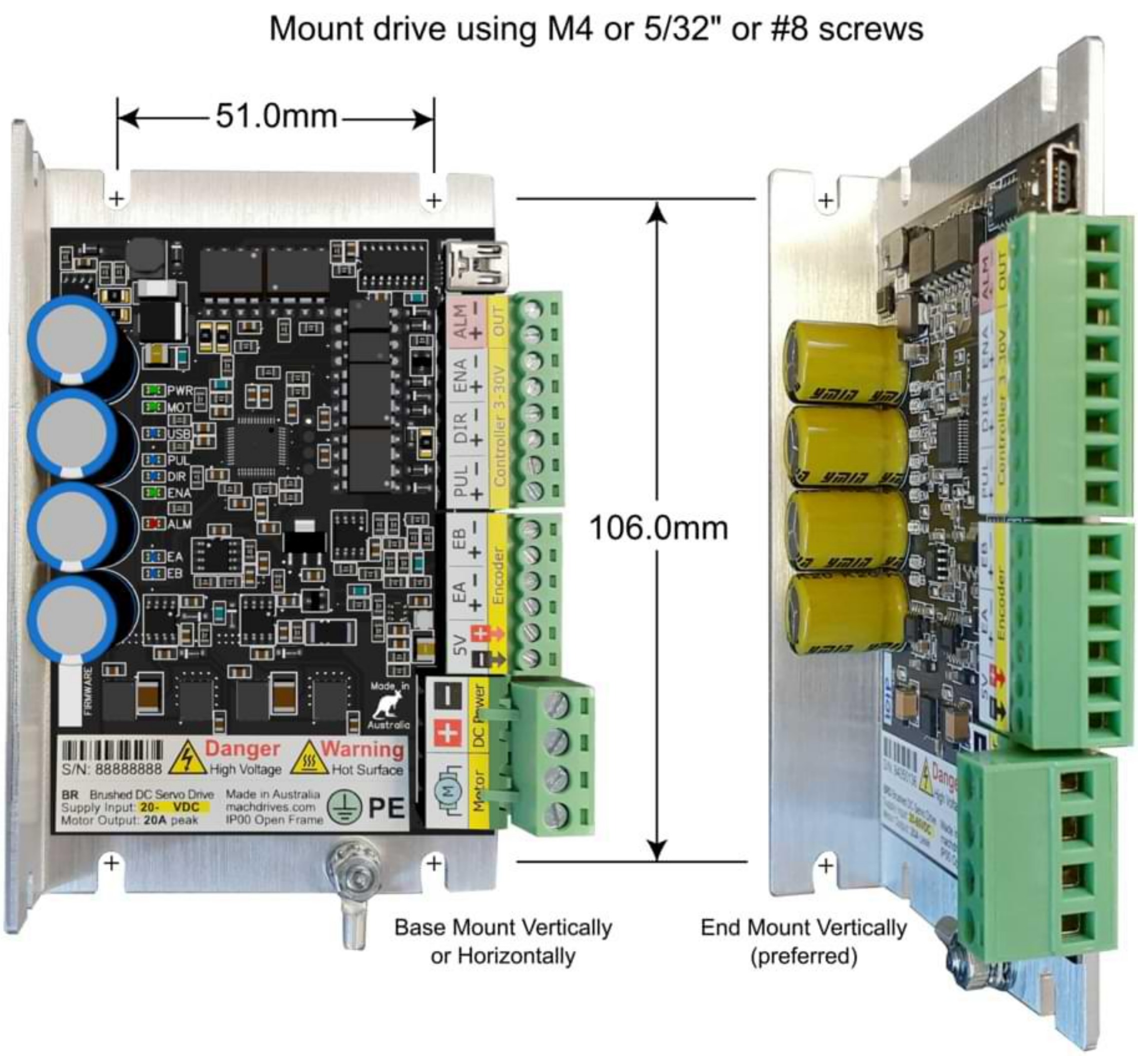
The drive should not be mounted on a poor thermal conductor such as Bakelite or fiber board.

If the drive is installed in an enclosed space, make sure heat does not build up, and take additional steps as required, such as forced air cooling.

For typical applications such as a small CNC mill or router, vertical end mounting on a steel control cabinet wall will normally provide sufficient heat dissipation. For more demanding applications a small heat sink or aluminium base plate may be required.

Remember the operating life of all electronic devices is adversely effected by temperature. Aim for the best cooling practical for your installation to maximize operational life.

Note: Your local electrical regulations may also impose requirements that affect your installation, such as mounting the drive in a locked and earthed metal cabinet.

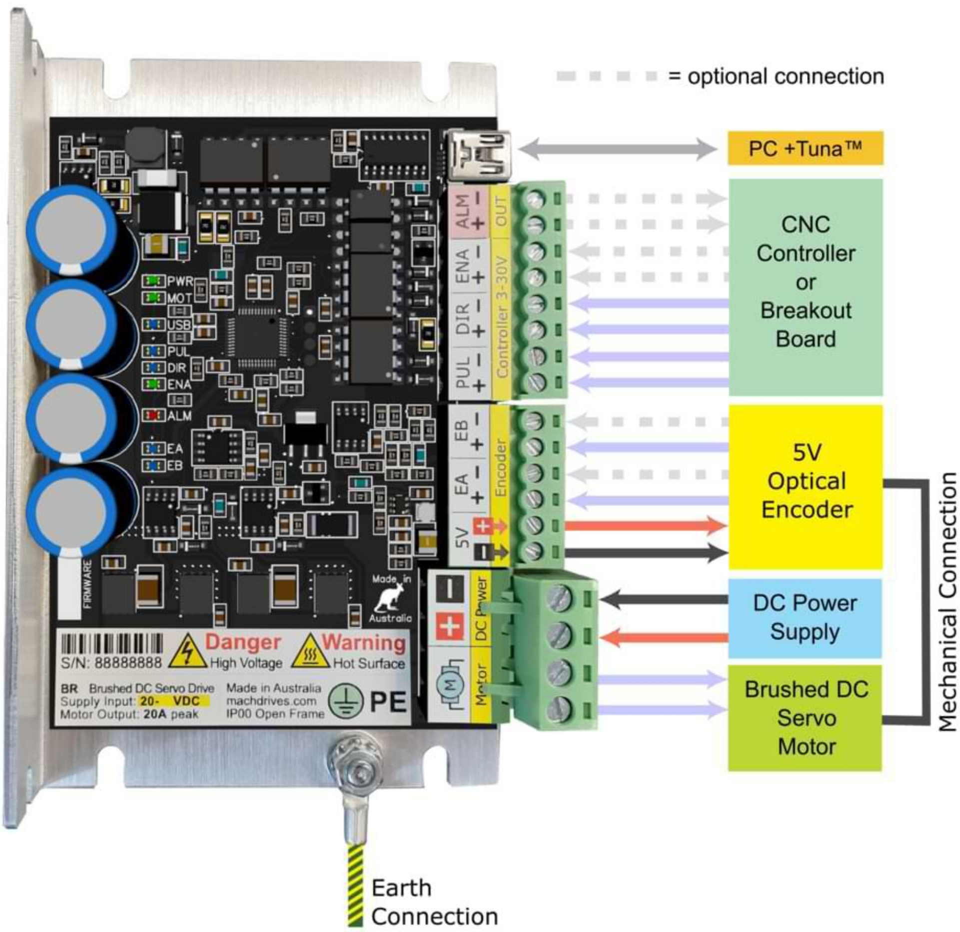


BRD/BRE/BRF Mounting Hole Locations

3.7 Connecting the Drive

3.7.1 Connection Overview

The drive has connectors for a DC power supply, a brushed DC servo motor, an optical encoder and a CNC controller or breakout board. Additionally there is a USB port for drive setup and tuning. Once configured, the USB connection is not required for normal drive operation.

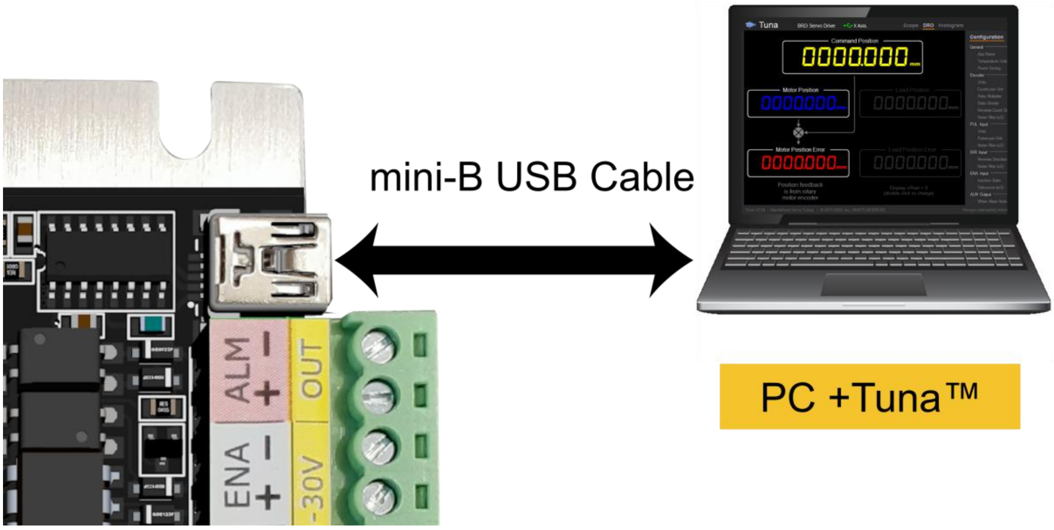


3.7.2 Earth Connection

IMPORTANT: This drive must NOT be operated without a protective earth connection. The earth serves a dual function of EMI reduction and safety under fault conditions. A M4 earthing stud is provided along with a solder/crimp connector and associated washers and nut. It is recommended that the protective earth terminal (PE) is connected to low impedance earth with a 2.5mm^2 (14 AWG) wire. The earth wire should be as short as practical to minimize inductance. Additionally the metal surface the drive is mounted to, such as the control cabinet, should also be earthed.

3.7.3 USB Connection

A mini-B USB cable is required for the drive to communicate with the Machdrives Tuna application. The USB circuitry is opto-isolated from all other drive circuitry, providing maximum noise immunity and eliminating grounding issues between the drive and host computer. As the USB cable is only required for setting up and tuning the drive, one cable is sufficient for multiple drives.



It is important that a good quality shielded USB cable is used with the shield connected to the metal shells at both ends as specified by the USB standard. A properly constructed cable should give reliable connection between the drive and the Tuna software. If in doubt, check both end shells and the braided shield for continuity with a multimeter.

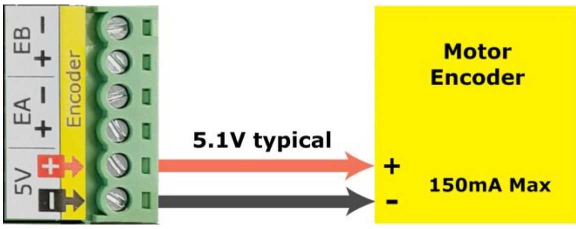
Avoid joining cables or use adapters or extenders. Keep the cable as short as practical with a 1.5m (5ft) cable being ideal.

Example of a suitable cable. A quality Molex brand shielded mini-B to USB A cable.

3.7.4 Encoder Connection

Your BRD/BRE/BRF drive will work with all common incremental quadrature encoder types, including single ended TTL, differential line drive, and open-collector output.

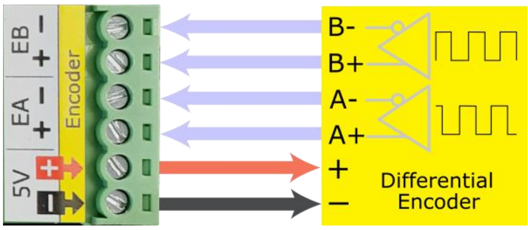
Encoder Power



The drive supplies the necessary power for the encoder and an external supply is not required. Terminal voltage at the drive is typically 5.1V to allow for a small drop in the encoder cable. The drive can supply up to a maximum of 150mA.

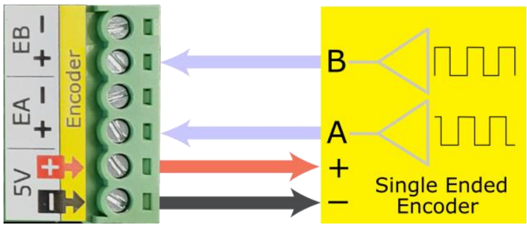
Do NOT connect an external 5V supply to the drive 5V terminals. This may result in damage to the drive. Do NOT connect the 5V supply to any device other than the encoder. This may cause ground loops and erratic operation.

Differential Line Drive Encoders



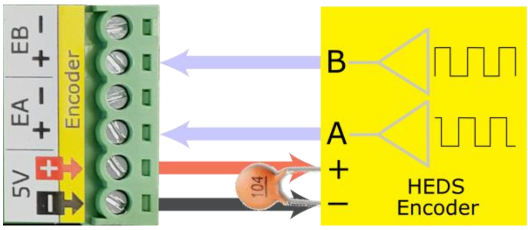
Connect all six wires of a differential line drive encoder as show. If your encoder also has index signal outputs, then leave these unconnected, making sure to insulate them against accidental connection.

Single Ended Encoders



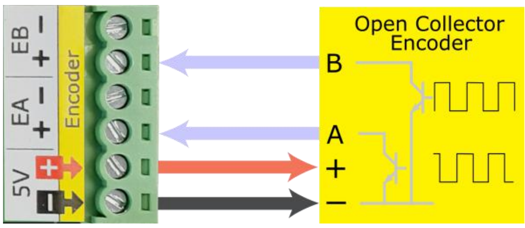
Connect all four wires of a single ended encoder as shown. Leave the EA- and EB- terminals open. Do not connect them to ground as the floating inputs are biased correctly inside the drive.

HEDS Encoders



Connect all four wires of a HEDS encoder as shown. Leave the EA- and EB- terminals open. Connect a 0.1uF (104) decoupling capacitor across the encoder 5V power supply pins as close to the encoder body as practical.

Open Collector Encoders



Connect all four wires of an open collector as shown. Leave the EA- and EB- terminals open. The drive contains internal 2K7 pull-ups on the EA+ and EB+ terminals, so external pull-ups are not required.

To get the best performance from your drive we recommend using a good quality, high resolution optical encoder with 2500PPR being the current de facto standard. Quadrature encoders count on both the rising and falling edges of the A and B channels, resulting in a resolution four times the stated PPR value. The Machdrives ELD-2500 encoder will therefore generate 10,000 counts per revolution.

Use good quality shielded cable where possible and connect the shield to a convenient earth point at the drive end. Leave the shield at the encoder end unconnected and insulate with heatshrink tubing to prevent accidental shorts. Route the wires well away from motor cables.

Basic operation can be checked by slowly turning the shaft and observing the blue flashing EA and EB LEDs. The Tuna DRO screen can be used to verify distance and direction once the drives electronic gearing has been configured. See appendix A "Electronic Gearing" for more information.

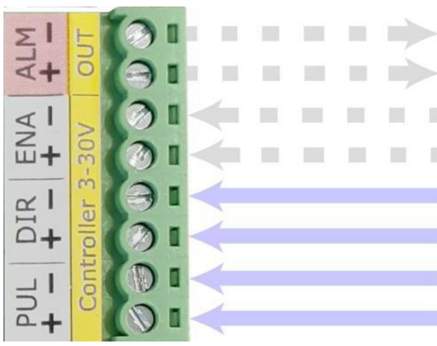
Digital filtering on the encoder inputs can be configured through the Tuna application. The default value of 1µs works well to eliminate noise in most situations.

Note: We only recommend using optical encoders with your BRD/BRE/BRF drive. Magnetic or capacitive encoders like the AMT102-V from CUI use an on-board ASIC chip to interpolate position. The small calculation delay can result in a position lag under acceleration and an overshoot during deceleration. While these encoders work well on standard PID servo drives, your BRD/BRE/BRF drive uses advanced features like velocity and acceleration feed-forward that require real-time encoder data to function optimally. During testing of the AMT102-V encoder with our drives we found that data lag increased with encoder resolution, resulting in the tuning difficulties, rough operation and poor tracking at encoder settings over 500PPR.

3.7.5 Controller Connection

Overview

The Controller Interface allows you to control the drive using popular Step/Direction CNC control software such as Mach3, UCCNC, LinuxCNC or similar. Additionally the drive can be directly connected to motion controllers such as Masso, Centroid, Digital Dream and many more. The drive receives PUL (pulse), DIR (direction) and ENA (enable) signals from the controller and sends back the ALM (alarm) signal.



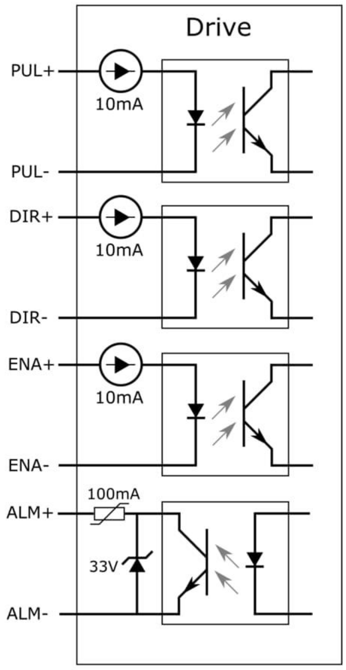
Simplified Internal Diagram

The PUL, DIR, ENA and ALM signals are all opto-isolated, with both the positive and negative connections accessible, giving maximum wiring flexibility and noise immunity.

The PUL, DIR and ENA inputs each feature a high speed 10mA constant current regulator, as well as having reverse polarity protection. This enables the inputs to be directly connected to controllers with logic levels ranging from 3V to 30VDC, without needing additional series resistors.

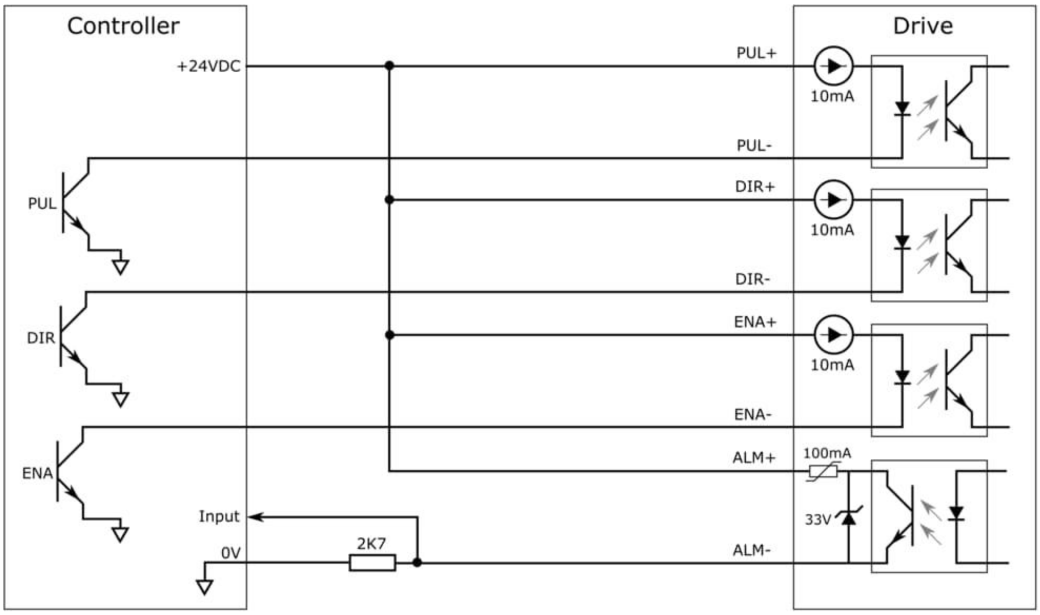
The ALM output can also be interfaced to logic ranging from 3V to 30VDC, and can sink up to 100mA. The ALM output features reverse polarity, short circuit and transient over-voltage protection, allowing direct driving of inductive loads such as relays.

The controller interface wide voltage range allows easy connection of 3.3V micro controller systems, 5V breakout boards or industry standard 24V motion controllers.



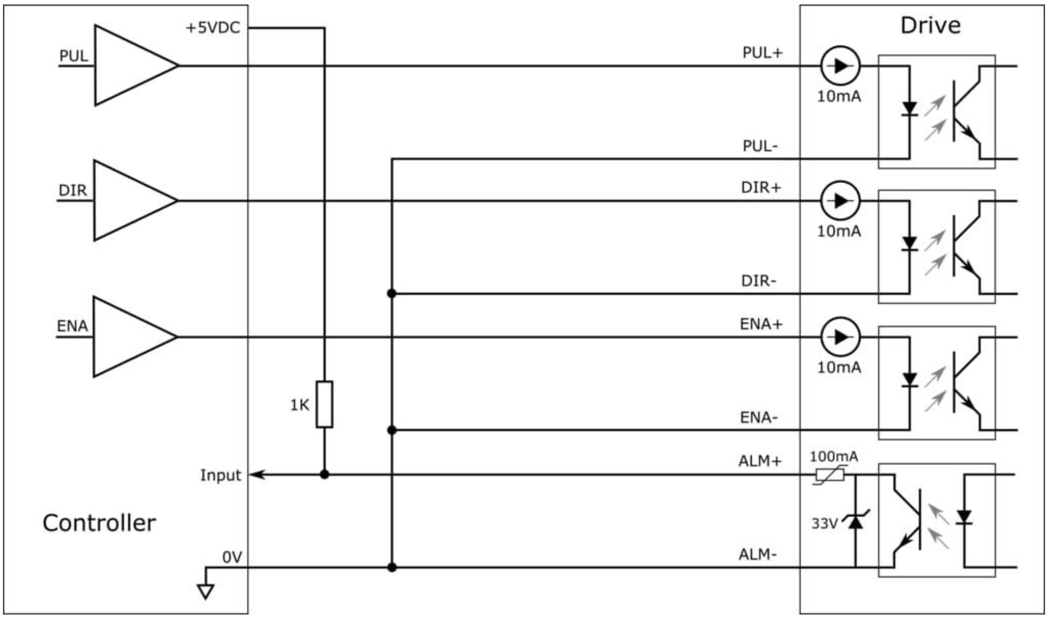
Controller Connection - Common Anode Example

Connection to controllers with a common anode configuration is as shown below. This example shows a typical 24VDC motion controller with open collector outputs .



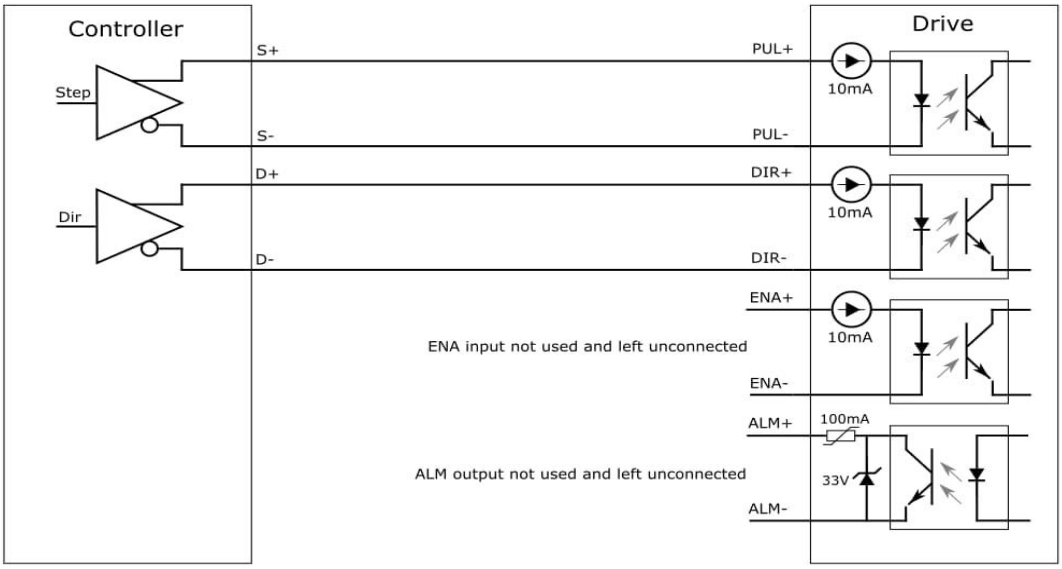
Controller Connection - Common Cathode Example

Connection to controllers with a common cathode configuration is as shown below. This example shows a typical 5VDC breakout board with buffer driver outputs.



Controller Connection - Differential Drive Example

Connection to controllers with differential Step and Dir outputs, such as a Masso controller, is as shown below. In this example the optional ENA and ALM features are not used and are left unconnected.



3.7.6 Controller Connection Details - PUL Input

A step occurs on the active rising edge of the PUL input signal, i.e. when the PUL+ input goes positive with respect to the PUL- input. Software like Mach3 then holds the signal high for 1-5µs before returning it low again, ready for the next step. The state of the PUL input is displayed on the blue “PUL” LED. When correctly configured the LED should normally be OFF, and flash ON when a step is received. If the PUL LED is normally ON then the controllers active high/active low setting for the step signal needs to be inverted.

3.7.7 Controller Connection Details - DIR Input

The active/inactive state of the DIR input controls the forward/reverse direction of the motor. The actual motor direction is also dependant on controller settings and motor wiring. The DIR signal must not change state at the same time as the PUL transition occurs or the step direction will be indeterminate. It is recommended that the DIR signal change leads the PUL signal by at least 5µs. DIR signal input operation can be verified by observing the state of the blue “DIR” LED.

3.7.8 Controller Connection Details - ENA Input

The ENA input allows enabling and disabling of the drive. This input can be controlled by the CNC controller/breakout board, or can be left unconnected so the drive is enabled automatically at power up. The advantage of controlling the signal is it allows the controller to disable all axes simultaneously, if required, such as during an alarm condition. Alarms can be cleared by toggling the enable line, however if the ENA input is not used, then alarms are cleared by cycling the drive power. The enabled state of the drive is displayed on the green “ENA” LED. If the controller attempts to enable the drive while an alarm condition still persists, such as over temperature, then the green “ENA” LED will flash to show that an enable request has been received but has been refused.

3.7.9 Controller Connection Details - ALM Output

The ALM output allows alarm conditions to be communicated back to the CNC controller so machine motion can be stopped during abnormal events. The ALM output can be configured in Tuna to be either high or low impedance when an alarm condition is active. The output can sink up to 100mA in the low impedance state. As this is an open collector output, connection to a controller input usually requires a pull-up or pull-down resistor as appropriate. See connection diagrams above. The alarm state of the drive is displayed on the red “ALM” LED. For user safety, the ALM output will not automatically clear and requires explicit user action to do so. This is done by toggling the enable line, if connected, otherwise cycling the drive power is required. There are eight different conditions that can raise an alarm. Alarm codes are flashed on the red “ALM” LED, additionally the last 5 alarms are displayed on the Tuna monitoring tab.

3.7.10 Power Connection

Power supply voltages can be hazardous. Read the safety section at the beginning of this manual before proceeding.

Your BRD/BRE/BRF drive requires an isolated DC power supply (PSU) of at least 20VDC. Supply voltage is normally determined by the rating of the motors. Allow enough margin for the voltage to rise under motor deceleration without exceeding the maximum voltage. Supply voltage can lift by 10 to 20V or more, depending on the PSU. Typical PSU voltages for 80V drives are 36V to 65V, and for 120V drives are 60V to 100V. 160V drives are often used with PSU voltages in the 90 to 130V range. The PSU should be able to supply the full 20A peak per drive during acceleration, although average current requirement is much lower.

The supply can be a switching or linear type. If using a switching type, make sure it can handle the current required without tripping out or "hiccuping". If using a linear type, make sure the ripple voltage is sufficiently low at maximum current. To reduce ripple, increase the power supply capacitance. High ripple voltage will result in increased drive bus capacitor temperature and reduced life expectancy.

Drives may use individual power supplies or preferably share the same larger power supply. Connect each drive directly to the power supply. Do not daisy chain drives together. Use heavy gauge wire and twist positive and negative together, or use shielded power cable and earth the shield at both ends.

Keep the power cables between the drive and the power supply as short as possible. If this is not possible then additional capacitance will need to be placed near the drive to counteract the lead inductance.

Connect the wires to the drives power terminals, and route all power cables well away from control cables. **Double check that the power supply positive and negative are the correct way around, as incorrect polarity can destroy the drive.**

Never unplug the drive power connector while the drive is under power. The motor inductance can cause arcing and damage to the connector contacts. **Connector arc damage is NOT covered under warranty.**

Place any power on/off switch on the AC side of the power supply. Do not place a switch on the DC bus supply side as opening it while the drive is running could damage the drive.

3.7.11 Motor Connection

Motor voltages can be hazardous. Read the safety section at the beginning of this manual before proceeding.

Connect the drive to the motor using shielded motor cable and connect the shield to earth at both ends.

Use a metal saddle to clamp the shield around 360 degrees to an earth plane. Avoid long wire pigtails between the shield and earth as lead inductance reduces the shields effectiveness.

Connect the wires to the drive motor terminals and route the cable well away from any control cables.

If required, common mode noise can be further reduced by passing the two motor wires together several times through a toroidal ferrite core, before screwing into the connector. Do not pass the earth wire or shield through the core and do not use a powered iron toroid.

3.7.12 Avoiding Ground Loops

One of the most common problems that leads to erratic and unreliable machine operation is incorrect grounding, resulting in motor noise being coupled back into control circuity. Here are a few simple rules to help ensure a reliable system.

- Use separate isolated power supplies for the motor and the controller. Do not use a regulator off the motor PSU to provide controller power. Do not use a multiple output PSU to provide both motor and controller power.
- Use a 2 pin PSU to provide controller power, such as a Meanwell HDR-15-24, or a 2 pin wall adapter. This guarantees that any earth noise on the motor PSU cannot be coupled back into the controller via the power supply common earth connections.
- Make sure all connections from the drives controller connector only return to the motion controller or breakout board. A common mistake we see here is when wiring the controller in the common cathode configuration, the PUL-, DIR-, ENA- and ALM- wires are connected together and returned to the negative terminal of the motor PSU instead of the control PSU or the motion controller negative power terminal.
- If using electrically "noisy" DC components such as relays, contactors, alarms, pumps etc, do not power these from the motion controllers PSU, but instead use a separate PSU to keep the noise isolated from control power supply lines.
- If using a VFD spindle, consider powering the VFD off a separate outlet that runs back to the switchboard via a different circuit breaker from the outlet that powers the rest of the control cabinet. Always use a shielded cable for the connection from the VFD to the spindle and ensure the shield is earthed at both ends.

4.0 CONFIGURATION

Configuring your drive is done through the Machdrives Tuna application for Windows. The drive is connected to the PC via a Mini-B USB cable. Make sure the drive is powered on by applying power to the DC power terminals.

4.1 General Configuration

General drive settings are used to set the axis name, temperature units and power saving mode.

Parameter	Description
Axis Name	Assign an axis letter to the drive. This replaces the COM port number in the Tuna application title bar and Windows task bar. This helps identify which drive is connected when configuring multiple drives.
Temperature Units	The drive temperature on the monitoring tab can be displayed in either Celsius or Fahrenheit.
Power Saving:	Determines how the power stage behaves when the drive is enabled yet the motor is stationary. In most applications, power saving will reduce drive and motor heating. This is also useful where the machine finishes operations while unattended (lights-out machining).
Disabled	No power saving. The power stage remains on when motor is stationary.
Enabled	Enables relaxed power saving. This allows the motor shaft to relax due to ball screw torsion or belt stretch when power is removed. The drive will still restart instantly when a command is received or the motor shaft moves off the relaxed position.

4.2 Encoder Configuration

The encoder parameters are used to configure the motor encoder.

Parameter	Description
Units	Select the units that the encoder counts are defined in. For example with an encoder driving an imperial ball screw this would be "Inches"
Counts per Unit	Enter how many encoder counts occur when moving 1 full "Unit" as defined above. See Appendix A "Electronic Gearing" for a detailed explanation and calculation examples.
Ratio Multiplier Ratio Divider	These two parameters allow an exact fractional ratio to be applied to the "Counts per Unit" without any rounding or loss of precision. See Appendix A "Electronic Gearing" for a detailed explanation.
Reverse Count Direction	Verify on the DRO screen that when the axis moves in the positive direction the encoder count increases. Change this setting if necessary to get the correct behavior. See Reversing Count Direction for details.
Noise Filter (µs)	This is a digital filter that eliminates electrical noise picked up on the encoder inputs. This sets the minimum time in microseconds that the encoder line can change state and still be accepted as a valid signal. Any signal transitions shorter than this time are considered noise glitches and are ignored. Set interval according to maximum encoder pulse rate. The default of 1µs works well in most cases.

4.3 PUL Input Configuration

Configuring the PUL Input informs the drive of the step distance and applies noise filtering.

Parameter	Description
Units	Select the units that the command step pulses are defined in. This is the same as the native units setting in your CNC controller software. i.e. Mach3. Customers in the USA will generally use inches, while others using the metric system will generally prefer to work in millimeters.
Pulses per Unit	Enter how many command pulses it takes to move 1 full "Unit" as defined above. See Appendix A "Electronic Gearing" for a detailed explanation and calculation examples.
Noise Filter (µs)	This is a digital filter that eliminates any electrical noise picked up on the PUL inputs. The value sets the minimum time in microseconds that the PUL input can change state and still be accepted as a valid signal. Any signal transitions shorter than this time are considered noise glitches and are ignored. Mach3 typically outputs step pulses 1-5µs wide, so the default of 0.5µs works well in this case.

4.4 DIR Input Configuration

Configuring the DIR Input controls the motor direction and applies noise filtering.

Parameter	Description
Reverse Direction	Reverses the direction of the command movements received from the CNC controller. See Reversing Count Direction for more details.
Noise Filter (µs)	This is a digital filter that eliminates any electrical noise picked up on the DIR inputs. The value sets the minimum time in microseconds that the DIR input can change state and still be accepted as a valid signal. Any signal transitions shorter than this time are considered noise glitches and are ignored. The default value is 1.0µs.

4.5 ENA Input Configuration

Configuring the ENA Input controls how the drive is enabled and applies noise filtering.

Parameter	Description
Unconnected State	Determines the drives enable state when the ENA input is left unconnected, or is connected but unpowered (inactive).
Drive Enabled	The drive will be enabled when the ENA input is unconnected/inactive.
Drive Disabled	The drive will be disabled when the ENA input is unconnected/inactive.
Debounce (ms)	This is a digital filter that eliminates any electrical noise or switch bounce on the ENA input. This value sets the minimum time in milliseconds that the ENA input can change state and still be accepted as a valid signal. Any signal transitions shorter than this time are considered noise glitches and are ignored. The default value is 50ms.

4.6 ALM Output Configuration

Configuring the ALM Output determines the output state when an alarm condition is active.

Parameter	Description
When Alarm Active	Determines the ALM output state when an alarm condition is active.
Low Impedance	The ALM output will be in a low impedance state (closed circuit) when an alarm condition is active.
High Impedance	The ALM output will be in a high impedance state (open circuit) when an alarm condition is active.

5.0 TUNING

Tuning your drive is done through the Machdrives Tuna application for Windows which can be downloaded from https://www.machdrives.com/app/tuna.zip.

A tuning video for our brushed DC servo drives is available on our Machdrives channel. https://www.youtube.com/watch?v=y4bAE6wqcuI

The objective of tuning a single encoder system is to get the motor shaft to follow the commanded position as accurately as possible. The motor should be tuned while connected to the machine as the drivetrain characteristics will affect the tuning parameters.

5.1 PID Parameters

The following parameters are used for tuning single encoder systems.

Parameter	Description
Proportional Gain	This is the Proportional gain, the "P" element in PID.
Integral Gain	This is the Integral gain, the "I" element in PID.
Differential Gain	This is the Differential gain, the "D" element in PID.
Velocity Feedforward	The Velocity Feedforward value is used to eliminate position error under constant velocity.
Acceleration Feedforward	Acceleration Feedforward is used to eliminate position error under acceleration.
Stiction Compensation	Stiction Compensation eliminates errors at the beginning of moves.

5.2 Checklist

For successful tuning the following items must be correct. Check them and correct any deficiencies before proceeding.

- "PUL Input" parameters set correctly on Configuration tab. (See Appendix A for details.)
- "Encoder" parameters set correctly on Configuration tab. (See Appendix A for details.)
- The encoder is checked by manually moving the axis and checking that the DRO value moves by the correct amount, and in the correct direction.
- "Power Saving" is disabled on Configuration tab - General section.
- Machine axis is positioned in center of travel.
- Set "Following Error" on the Tuning tab to the number of command steps for two revolutions of the motor. E.g. If step input is set to 200 steps/mm and the axis moves 5mm for one motor rotation, then set the following error to 200 x 5 x 2 = 2000 steps.

5.3 Tuning the Velocity Loop

The velocity loop must be tuned first. The objective is to get the motor velocity to follow the command velocity as closely as possible with good stability and damped overshoot. This loop is tuned with a square velocity waveform, which exposes any instabilities, making tuning easier.

1. Set all PID parameters on the Tuning tab to Disable or zero (with the exception of "Following Error").
2. Set the Wave Generator parameters on the Tuning tab as follows:
    a. **Pulse Polarity:** Positive
    b. **Distance:** Number of command steps for one motor revolution. This will be half the value entered in "Following Error".
    c. **Velocity:** Enter the value that gives the "Feed Rate" that you will most commonly use during machining operation. An example of a typical feed rate for a mill is 600mm/min (metric) or 25 in/min (imperial).
    d. **Acceleration Time:** Set to zero. This is important as it generates the required square velocity profile.
    e. **Pause Time:** 250ms
    f. **Repeat:** Yes
3. Set the "Command Source" drop-down under the scope display to "Wave Generator"

WARNING: The following steps will power the motor and result in machine motion. Make sure all personnel are clear of the machine and a method of shutting off machine power is available and close to hand if required.

4. Apply motor power to the drive and check the green “PWR” LED is ON.
5. Check the drive is enabled and the green “ENA” LED is ON. Check the green “MOT” LED is also ON, if not check “Power Saving” is “Disabled”. When all three green LEDs are ON the power stage is now ready to drive the motor.
6. On the Velocity grid, tick the "Command" and "Motor" traces. Clear all other traces. Only the Velocity grid should now be showing.
7. Press the Sweep "START" button and set both trace scales to the same value with waveforms visible. If the "START" button is grayed out then the drive is not enabled.
8. Start increasing the "Proportional Gain" first, then the "Differential Gain", while referring to the example traces below. Keep adjusting only these two values until a well tuned velocity loop is obtained.

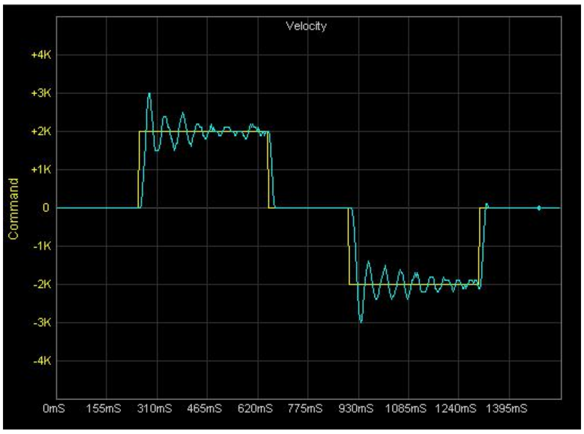
If the drive faults out and the motor trace moves in the wrong direction, remove motor power and reverse the **motor wires**. DO NOT reverse the + and - power wires by mistake!

If the drive starts current limiting during tuning, (ALM LED single flash when accelerating), then stop and reduce the Wave Generator velocity by half, then start the tuning again.

Command Velocity: Yellow
Motor Velocity: Blue

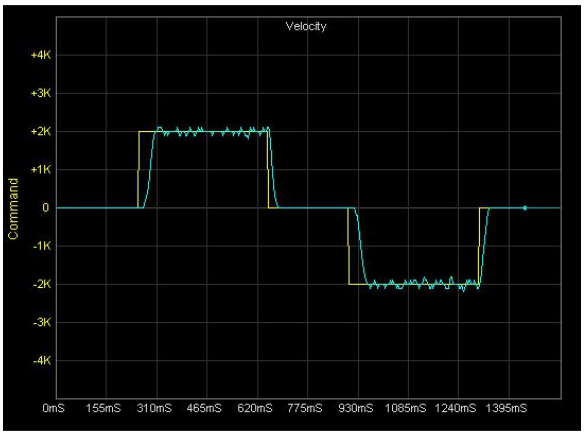
Start increasing the "Proportional Gain ", the waveform will begin to become unstable with overshoot and ringing as shown.

Next, use the "Differential Gain" to dampen out the oscillations.



Command Velocity: Yellow
Motor Velocity: Blue

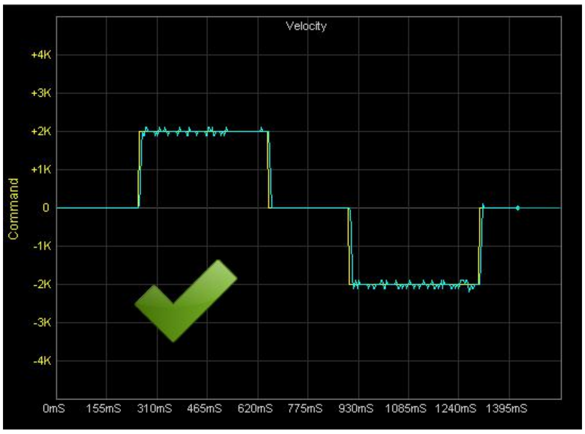
Increasing the "Differential Gain" dampens the ringing and stabilizes the waveform as shown. Only use the minimum amount of Differential to achieve this. Too much Differential will start rounding off the leading edge and slow the response.
Next, increase the "Proportional Gain" to speed up the rising and falling edges.



Command Velocity: Yellow
Motor Velocity: Blue

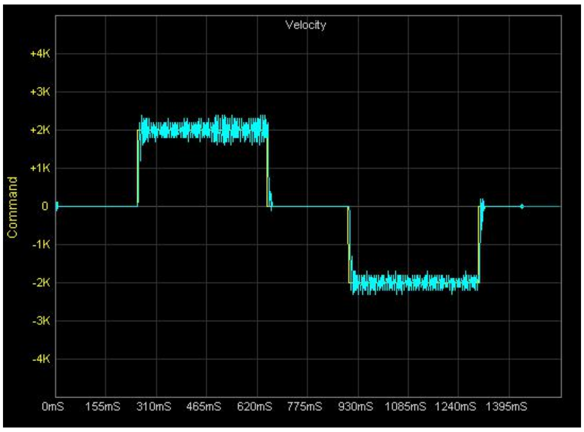
Keep increasing the "Proportional Gain" and adjusting the "Differential Gain" to keep the response square with minimum overshoot or rounding off the leading edge.

This waveform shows a well tuned Velocity loop with fast and stable tracking of the commanded velocity. Tuning of the velocity loop is now complete.



Command Velocity: Yellow
Motor Velocity: Blue

If the response starts to become noisy or difficult to stabilize, the gains are too high. Listen to the motor while tuning and watch the traces for noise starting to appear.
This trace shows the gains set much too high. The motor will sound rough or gritty. Reduce gains until the motor movement is smooth and quiet again.



5.4 Tuning the Position Loop

The position loop should be tuned with a waveform as close to your typical machining waveform as possible. This step must follow after tuning the velocity loop.

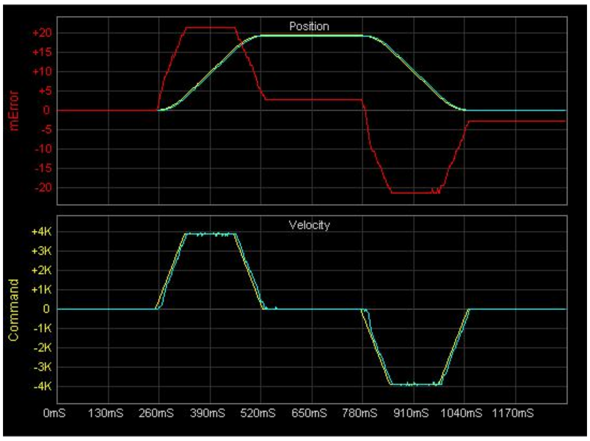
1. The Wave Generator on the Tuning tab should be configured as follows to give a trapezoid velocity profile and an S-profile for position.
    a. **Pulse Polarity:** Positive
    b. **Distance:** Number of Command steps for one motor revolution. This will be half the value entered in "Following Error".
    a. **Velocity:** Adjust this value so the calculated "Feed Rate" shows the value that you will most commonly use during normal machine operation. An example of a typical feed rate for a mill is 600mm/min (metric) or 25 in/min (imperial).
    c. **Acceleration Time %:** Adjust this value so the calculated "Acceleration" value matches the acceleration set in your CNC controller software. In Mach3 this is on the "Motor Tuning" screen. An example of a typical acceleration setting for a mill is 250mm/s/s (metric) or 10 in/s/s (imperial).
    d. **Pause Time:** 250ms
    e. **Repeat:** Yes
2. Set the "Command Source" drop-down under the scope display to "Wave Generator".

WARNING: The following steps will power the motor and result in machine motion. Make sure all personnel are clear of the machine and a method of shutting off machine power is available and close to hand if required.

3. Apply motor power to the drive and check the green “PWR” LED is ON.
4. Check the drive is enabled and the green “ENA” LED is ON. Check the green “MOT” LED is also ON, if not check “Power Saving” is “Disabled”. When all three green LEDs are ON the power stage is now ready to drive the motor.
5. On the Velocity grid tick the "Command" and "Motor" traces. On the Position grid tick the "Command", "Motor" and "mError" traces. Clear all other traces. Both grids should now be showing.
6. Press the Sweep "START" button. If the "START" button is grayed out then the drive is not enabled.

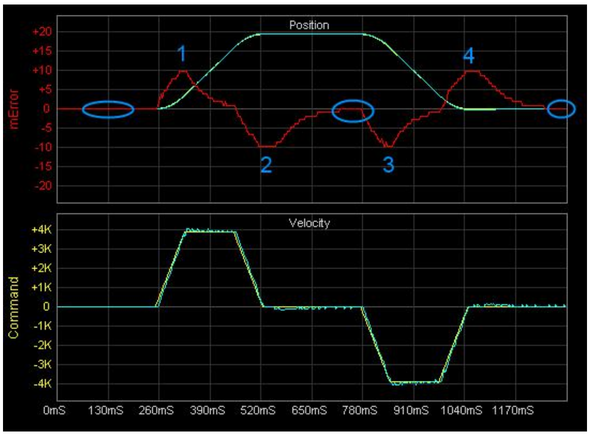
The scope waveforms should look similar to this. Adjust the scale of each trace as appropriate. The red motor position error may be different as "Integral Gain" is set to zero and the position trace is floating.

Check that "Velocity Feedforward", "Acceleration Feedforward" and "Stiction Compensation" are also set to zero.



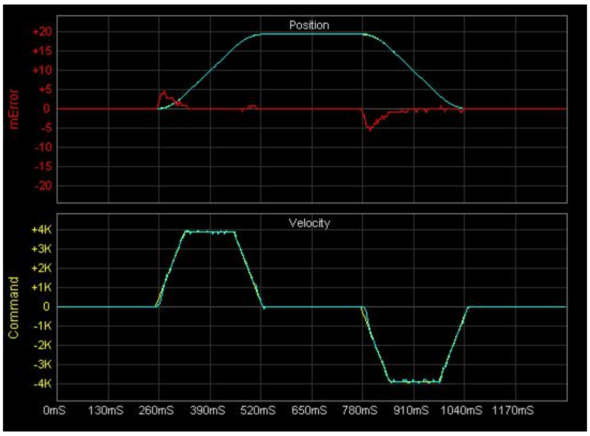
Command Position: Yellow
Motor Position: Blue
Motor Position Error: Red

Increase the "Integral Gain" parameter until the error trace touches the zero line at the start, middle and end of the sweep as shown. This removes any position offset.
Do not increase it any more at this stage as it will mask the effect of the "Velocity Feedforward" adjustment.



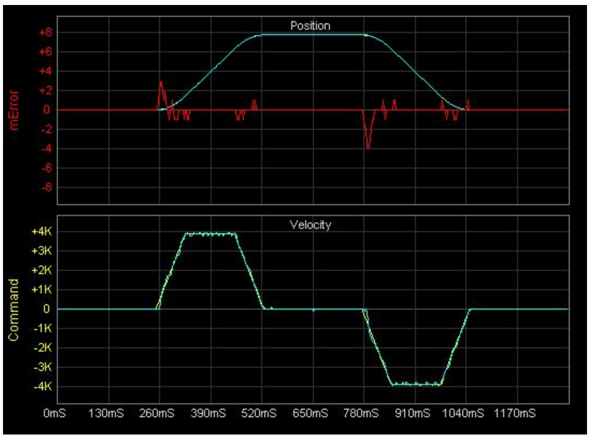
Command Position: Yellow
Motor Position: Blue
Motor Position Error: Red

Now increase the "Velocity Feedforward" parameter to eliminate bumps 2 and 4 in the previous image. If the parameter is too high, the bumps will invert and start appearing on the other side.
When adjusted correctly, the two bumps should be substantially removed as shown.



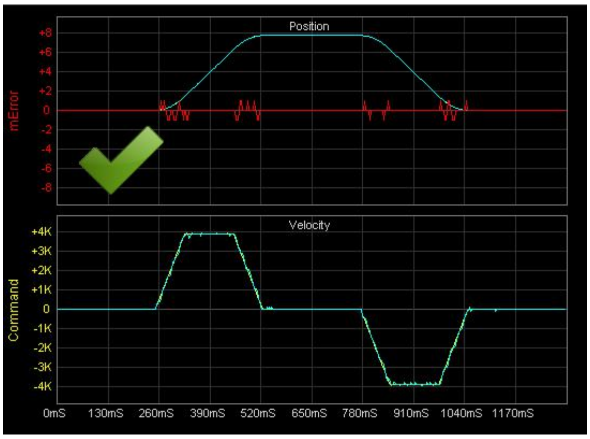
Command Position: Yellow
Motor Position: Blue
Motor Position Error: Red

Adjust the error trace scale to make the remaining error more visible.
Now increase the "Integral Gain" parameter to reduce the remaining error.
If the motor becomes noisy or oscillations start appearing on the velocity traces, then the Integral value is too high. Reduce again until the motor and traces are smooth and quiet.



Command Position: Yellow
Motor Position: Blue
Motor Position Error: Red

Now use the "Stiction Compensation" to eliminate any spikes at the start of each move. Too much compensation will invert the spikes. Use "Acceleration Feedforward" to remove any remaining bumps during motor acceleration and deceleration. Too much will invert the bumps. When all errors are reduced as much as possible, the traces should look similar to this.



7. After tuning is complete, reduce the "Following Error" to a smaller value e.g. 200, and set "Power Saving" to "Enabled" if desired.
8. Set the "Command Source" back to "Step/Dir Inputs" so the drive can be commanded from your CNC Controller software such as Mach3.

In this example the “PUL Input” “Pulses per Unit” was set to 200 steps/mm, so each step is 0.005mm or 0.0002". Much of the move is executed with zero steps error and the bulk of the remainder falls in the +/- 1 step range (+/-0.005mm).

This tuning example was done on a low end milling machine, and results should be typical for most users. If there is one secret to obtaining great results it is to use a high resolution optical encoder on the motor, having 10 (or more) times the command step resolution. This test used a glass 2,500 line (10,000 count) motor encoder set to 2000 counts/mm.

5.5 Fine Tuning

This is just one way to tune a servo drive. There are many other methods. You can try adjusting the parameters after tuning to see the effect it has on positioning accuracy. If movements become noisy or gritty sounding, reduce the gains until moves are smooth and quiet again.

You can also monitor and fine tune the drive while running normal G-Code. Check the "Command Source" drop-down is set to "Step/Dir Inputs" and the sweep is running.

6.0 MONITORING

The Monitoring tab on the Tuna application can be used to check drive health including voltages and temperatures, as well as recent fault conditions and operating hours.

"Last" values are dynamic and updated continuously.
"Session High" values are from when the drive was last powered up.
"All Time High" values are permanent and cannot be cleared.

"Hours Drive on" records total time the drive has been on, even if the power stage is off.
"Hours Motor on" records total time the power stage has been on and powering the motor. Turning on power saving will affect this value.

The last five faults are listed with "Fault Last" being the most recent and "Fault Last -4" the oldest. Existing faults are shuffled back when a new fault occurs and the oldest fault drops off.

7.0 ALARM CODES

Alarm codes can be used to identify which alarm has just occurred. An alarm condition will stop the drive and the ALM LED will flash a number of times, corresponding to the code as listed below. The last five faults can also be viewed on the Monitoring tab in the Tuna application.

Code	Name	Description
1	Current Limiting	A single flash under motor acceleration indicates the drive is current limiting. Reduce the acceleration setting in your CNC controller until current limiting ceases. **This does not stop the drive or raise an alarm**.
2	Over Voltage	The motor power supply voltage has exceeded the drive rating. During deceleration the motor pushes power back into the PSU lifting the supply voltage. Reduce the acceleration setting in your CNC controller or add an external brake resistor circuit.
3	Over Temperature	The drive is too hot. Mount the drive on an aluminium heat sink or improve air flow over the drive.
4	Under Voltage	The motor power supply voltage dropped under the minimum drive rating while the motor was running. This can happen if your power supply is under-rated and trips out or “hiccups” under acceleration.
5	Short Circuit	A short circuit was detected at the motor terminals. Check wiring or possible motor fault.
6	Overload	The motor was overloaded. Can happen after sustained current limiting from crashing into a fixture or hard stop.
7	Encoder No Signal	No encoder is detected. This could be a faulty or disconnected encoder or cable.
8	Encoder Channel	Only one encoder channel is detected.This could be a faulty encoder or an encoder wire connection issue.
9	Following Error	The difference between the commanded position and the motor encoder position has exceeded the value specified in the "Following Error" parameter. This value is expressed as Step pulses.

8.0 LED INDICATORS

Your BRD/BRE/BRF drive has 9 LED indicators whose function is detailed below.

LEDs	Notes
PWR	ON indicates that DC power is present on the + and - terminals.
MOT	ON indicates that the power stage is on and power is being supplied to the motor. This is useful when the power saving functionality is enabled.
USB	ON indicates the drive is communicating with the Tuna application via USB.
PUL	Normally OFF and flashes ON when a step has been received. Steps occur on the positive transition on the signal.
DIR	Indicates step direction as configured in the Tuna application.
ENA	ON indicates the drive is enabled. Flashing indicates the user is trying to enable the drive but a persistent alarm condition, such as over-temperature, is preventing it.
ALM	Flashes fault codes or when current limiting. See Alarm Codes for more details.
EA	Indicates the state of the encoder EA input signals. ON= high, OFF = low
EB	Indicates the state of the encoder EB input signals. ON= high, OFF = low

9.0 SPECIFICATIONS

Value	Min	Typical	Maximum
Electrical			
DC Power Supply (BRD/BRE/BRF)	20VDC		80/120/160VDC
Standby Current - Motor Off		35mA	
Motor Current Limit		20A peak	
Heat sink Temperature			68°C (154°F)
Encoder Supply Voltage		5.1V	
Encoder +5V Supply Current			150mA
Encoder Frequency (counts)			2MHz
PUL Input Frequency			2MHz
PUL/DIR/ENA Voltage	3VDC	5V, 24V	30VDC
PUL/DIR/ENA Current		10mA	
ALM Output Voltage		5V, 24V	30VDC
ALM Output Current			100mA
Compliance	Designed and constructed to comply with IEC/EN 61800-5-1		
Classification	Basic Drive Module (BDM)		
Protective Class	I		
Over Voltage Category	II		
Mechanical			
Length	115mm (4.5")		
Width	74mm (2.9")		
Height	20mm (0.8")		
Weight	115g (4oz) with connector plugs		
Material	PCB on aluminum base plate.		
Environmental			
Ambient Temperature	0°C (32°F)		40°C (104°F)
Humidity			90%RH
Atmosphere	No explosive or corrosive gases		
Contamination	No wood dust, plasma cutting dust, metal chips etc.		
Altitude			2,000m (6,000 ft)
Pollution Degree	I or II		
Ingress Protection	IP00		

10.0 FAQ

This chapter answers some questions we have been frequently asked.

10.1 How can I contact you?

Our contact details are listed in the front of every user manual under the section "Contact".
For support it is preferred if you use our support email address *support@machdrives.com* While we can also answer questions through the eBay message system, it is more restrictive, not allowing files, attachments and external links to be sent. Additionally using email allows a message trail to be created by continually replying to the same message.

10.2 Why did eBay charge me tax when I am an international customer?

As of 1st October 2019, the USA introduced a new Internet Sales Tax that requires 34 states to collect tax on internet sales. This impacts some of our USA customers, depending on state. The tax is collected by eBay on transactions through our eBay store and is outside our control. If customers wish they can opt to buy from us directly by contacting sales on *sales@machdrives.com*

10.3 Why was I charged import tax?

When importing goods from overseas you may be required to pay import tax or duty. Import tax rates vary considerably between countries and are collected by your government before releasing the goods to you. It is the importer's responsibility to check with their customs department *before importing* to see if any import charges apply. For example orders sent to the USA typically do not attract import charges if the value is under USD $800. Other regions like the UK attract VAT on imports regardless of the value.

10.4 Where is the serial number?

The serial number is located on the colour label on the PCB. It is under the barcode and is of the format "S/N: XXXXXXXX". Values hand written on the board like "101P" are the firmware revision number.

10.5 Why won't the USB drivers install?

If the USB driver has problems installing then go to "Device Manager" (not Devices and Printers) and expand the "Ports (COM & LPT)" and see if there is an entry with a warning or error sign. If so right click and select "Uninstall" then before clicking OK tick the box marked "Delete the driver software for this device". Next right click on "Ports (COM & LPT)" and select "Scan for hardware changes"
If after all this you still cannot get the driver to download then your PC policy settings my be stopping it. To check open "Devices and Printers" (not device manager). Find your PC at the top under "Devices", right click the icon with your computer name and select "Device Installation Settings". Make sure driver download is set to "Automatic". If you had to change it then go back to the first step and try again.

10.6 Why are the PUL and DIR signals not working?

If the PUL and DIR LED’s are both solid on and don’t flash when jogging the controller, this is normally because the Step and Direction pins are set to “Active Low” in your CNC controller instead of “Active High”. When configured correctly the PUL LED should be normally OFF and only *flash* ON when a step is received.

10.7 Why are the encoder LED's not flashing?

If the EA and EB encoder LED’s are not flashing when rotating the encoder shaft, here is a simple test to narrow down the problem.

Check 1) Remove the wires from the EA and EB terminals and confirm both EA and EB LEDs are ON
Check 2) Touch a jumper wire from the 5V- encoder terminal to the EA+ terminal and check the EA LED goes OFF.
Check 3) Touch a jumper wire from the 5V- encoder terminal to the EB+ terminal and check the EB LED goes OFF.

If all three checks pass then the drive is reading both encoder inputs correctly. If the LEDS don't flash when you connect your encoder, then either the encoder is wired incorrectly, it is the wrong type or it is faulty.

10.8 Are my existing encoders suitable?

The drive will work with all common incremental quadrature encoder types, including single ended TTL, differential line drive, and open-collector output. Higher resolution encoders are required to get the best performance from features like Velocity feed-forward that result in higher tracking accuracy.

Here are some common encoder wire configurations.

An eight wire encoder is normally differential with index as follows. +5V, 0V, A+, A-, B+, B-, I+, I-
A four wire encoder is normally single ended as follows. +5V, 0V, A, B
A five wire encoder is normally single ended with index as follows. +5V, 0V, A, B, I
A six wire could be differential without index +5V, 0V, A+, A-, B+, B- or single ended with shield +5V, 0V, A, B, I, shield
Any of the above can be used with the BRD/BRE/BRF drives.

Connection Rules....
1) Connect up +5V and 0V wires to the drives respective 5V + and - terminals.
2) Connect A(single ended) or A+(differential) to the EA+ terminal.
3) Connect B(single ended) or B+(differential) to the EB+ terminal.
4) Connect A- and B- wires to their respective EA- and EB- terminals.
5) Do not connect up index wires. BRD/BRE/BRF drives do not use the index.

Note: The Index is not always labeled "I" can also be "R" or "Z" or "C"
If your encoder has a model number on it you can try googling to find data on the wire colours.

10.9 Where can I find suitable servo motors?

Brushed DC servo motors are now an older technology so it can be a challenge to find a supplier of new motors, however there is normally a good supply of used motors available online from places such as eBay.

New motors: Leadshine make a range of motors in smaller sizes. Typical models are the DCM50202A-1000 (50W), DCM50205D-1000 (80W) and the DCM50207-1000 (120W). These are widely available, including from Ocean Controls in Australia and American Motion Tech in the US. Larger motors in the 150W to 600W range are available online from companies such as CNC4PC in the US and CNCDrive in the EU.

Used motors: Two of the most commonly available brands are ElectroCraft for smaller size, and SEM for the larger sizes. A typical ElectroCraft model is the E661, and common SEM motors are the MT30 range such as the MT30M4-59.

10.10 Where can I find a suitable power supply?

When converting on older machine it will usually have a large linear power supply. This can often be re-purposed by replacing the old bus capacitors and reducing the voltage by removing some turns off the transformer secondary.
A custom linear power supply can be built from a large transformer, bridge rectifier and capacitors, a popular source in the USA for parts and complete units is from eBay seller “antek-inc”.
Switching power supplies are widely available online, but it can be challenging to find them in larger sizes. One solution is to repurpose a data center PSU such as the Cisco WS-CAC-2500W. This is a 2500W model and outputs 42VDC at up to 55A and surplus units can often be found for under $100.

Mains supply voltage can be lethal. Do not attempt to repair or modify mains equipment unless you are suitably experienced to perform the work safely and in compliance with local regulations.

10.11 What power supply voltage can I use?

When choosing a power supply voltage, remember that when the motor decelerates it acts as a generator and pushes power back into the PSU. This lifts the supply voltage, often by 10-20V or more. Therefore an 80V drive *cannot* be used with an 80V power supply. Typical PSU voltages for 80V drives are in the 36V to 65V range, and 160V drives range from 90V to 130V.
A braking resistor circuit can be used if the supply voltage is close to the drive maximum, however it is not normally required if an appropriate supply voltage is chosen.

Mains supply voltage can be lethal. Do not attempt to repair or modify mains equipment unless you are suitably experienced to perform the work safely and in compliance with local regulations.

10.12 My existing PSU voltage is 160V, can I still use it?

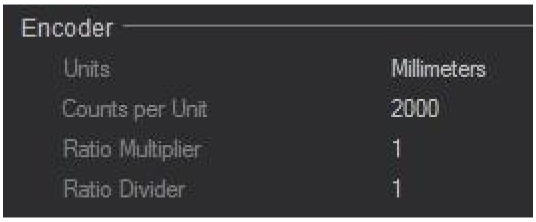
This is a common problem when retrofitting an older CNC machine with a new control system. Existing PSU voltages are often too high at around the 160VDC level.
As these supplies typically use a large mains transformer, the output voltage can be reduced by simply unwinding some turns off the transformer secondary. This assumes the secondary is wound on the outside, over top the primary, which is usually the case.
The secondary winding should be adjusted to give the desired DC voltage divided by 1.414.
Therefore to obtain a 120 VDC power supply the transformer secondary voltage should be adjusted to 120/1.414 = approx 85 VAC.
Additionally it is good practice to replace the old electrolytic capacitors as they dry out over time resulting in high ripple on the DC output when under load.

Mains supply voltage can be lethal. Do not attempt to repair or modify mains equipment unless you are suitably experienced to perform the work safely and in compliance with local regulations.

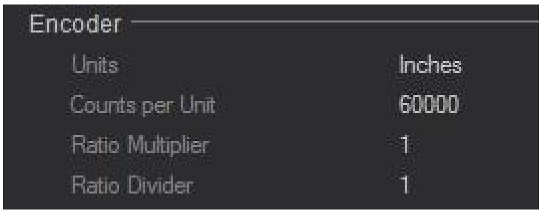
10.13 How do I calculate the encoder "Counts per Unit" parameter?

The encoder "Units" and "Counts per Unit" parameters tell the drive how many counts it will receive from the encoder for every millimeter (or inch) of axis travel. Choosing the correct "Units" depends on the mechanics of the axis transmission, not your preferred units for working. For example if the axis uses a metric ball screw then the "Units" will be set to millimeters. Conversely if the ball screw has an imperial pitch like 5tpi then the encoder counts are most accurately expressed if "Units" are set to inches.

Example 1: A RF45 mill has a motor with a 2,500PPR encoder direct driving a 5mm pitch ball screw. As the encoder is quadrature it will output four times the PPR value per revolution. Therefore one revolution of the encoder will generate 2500x4 = 10,000 counts. As one ball screw revolution will move the axis 5mm the drive will receive 10,000/5 = 2,000 counts for every millimeter of travel.



Example 2: A Bridgeport mill has a motor with a 1,000PPR encoder and a 3:1 belt reduction on to a 5tpi ball screw. As the encoder is quadrature it will output 1000x4 = 4,000 counts per revolution. The encoder will require three turns (12,000 counts) for 1 turn of the ball screw. Therefore 12,000 counts will move the axis 1/5 inch, so to move the axis one inch will require 12,000x5 = 60,000 counts.



For more details and information regarding the relationship between the Encoder and PUL Input settings, please see Appendix A "Electronic Gearing".

10.14 How do I calculate the PUL Input "Pulses per Unit" parameter?

The PUL Input "Units" and "Pulses per Unit" parameters tell the drive how many pulses it will receive from the CNC Controller for every millimeter (or inch) of commanded movement. Choosing the correct "Units" depends on your preferred units for working. Customers in the USA will generally have their controller set up to work in inches, while those from other countries will normally prefer millimeters.

The "Pulses per Unit" value can in theory be set to almost any value and the next time the drive is enabled it will recalculate the correct electronic gearing ratio. However choosing the optimum value is a balancing act, trading off step resolution for tracking accuracy and ease of tuning. Calculating the electronic gearing ratio that will give the best performance for your system is covered in more detail in Appendix A "Electronic Gearing"

If you change your drive "Pulses per Units" setting it is important to remember to change your CNC Controller settings to match.

10.15 Why did the drive fault out?

The drive can detect eight different types of alarm conditions, so the first step is to find out what type of alarm has occurred. The last five alarms are listed on the Tuna monitoring tab. Additionally the current alarm can be determined by counting the number of flashes on the drives red ALM LED. The flash codes and details of what causes each alarm is detailed in section 7.0 of the user manual "Alarm Codes".

10.16 How do I send you a screen shot of the Tuna settings?

A screen shot is not the same as taking a photo of the screen with your phone. To take a screen shot make sure the Tuna application is selected (click on it) then hold down the Alt key and press the Print Screen key. An image of the Tuna app is now in your copy buffer. You can now paste this image directly into an email, or paint or Word etc.

10.17 How do I rapidly change the parameter values like in the video?

To nudge a parameter up or down , *single click* the parameter row so it is highlighted darker gray and an orange triangle marker appears on the right side. Now use the "+" and "-" keys. Holding the key down enables the keyboard auto-repeat for rapid changes. Any of the the "+" and "-" keys on the keyboard will work including the number pad regardless of Num Lock state.

Nudging will *not* work if you are in data entry mode with the cursor in the orange data entry box, this mode is only for typing in parameter values directly.

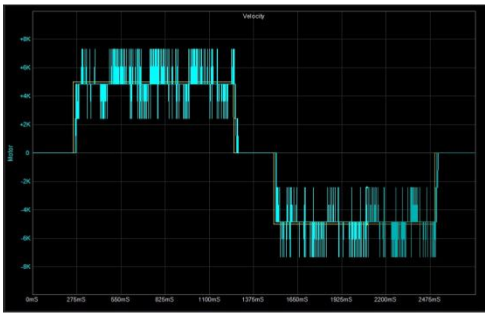
10.18 Why is the motor not moving?

The motor will not move or have any holding torque until you start the tuning process and begin increasing the PID gains. For safety reasons the drive is shipped with all the PID parameters set to zero. Before attempting to tune the drive make sure you have successfully completed the steps in the installation and configuration sections of the user manual.

10.19 Why doesn't the motor have any holding torque?

The motor will not move or have any holding torque until you start the tuning process and begin increasing the PID gains. For safety reasons the drive is shipped with all the PID parameters set to zero. Before attempting to tune the drive make sure you have successfully completed the steps in the installation and configuration sections of the user manual.

10.20 Why do my Tuna traces not look like the ones in the manual/video?



If your traces are low resolution and jagged like the picture on the right, this is normally because your electronic gearing ratio is set too low, or you have a low resolution encoder, or often both.
For more information regarding choosing an optimal electronic gearing ratio for your system, please see Appendix A "Electronic Gearing".

10.21 Can I use the drive on a rotary axis (A axis)?

Yes, you can use the drive to control a rotary positioning axis (turn table), but not a rotary speed axis like a spindle motor on a mill or lathe.
The trick is just to set the PUL Input and Encoder to the same units ie: "millimeters" and pretend it says "degrees". Now set the encoder "Counts per Unit" to the number of counts per degree and set the PUL Input "Pulses per Unit" to your controllers steps per degrees. For good performance the encoder value should be several times higher than the command value. For more information regarding choosing an optimal electronic gearing ratio for your system, please see Appendix A "Electronic Gearing".

10.22 Can I use the drive to control a lathe spindle motor?

No, you cannot use the drive to control the speed of a continuously rotating motor like the spindle motor on a lathe.
The reason is that the position variable is stored in a signed 32 bit integer so if you "move" continuously in one direction for more than approx 2 billion steps the position counter will overflow and become invalid. While this is a huge distance for a position axis it can easily be reached on a continuous rotation spindle application.

10.23 Why am I getting current limiting on rapids?

The drive will flash the red ALM LED if the motor current reaches the 20A current limit during motor acceleration. Intermittent current limiting is not a problem, but tracking accuracy is reduced while the current limit is in effect. To prevent current limiting reduce your CNC controller acceleration setting until the limiting ceases. High "Stiction" and "Acceleration Feedforward" values can also increase the likelihood of current limiting.

10.24 My drive is not working. Any suggestions?

Building a servo based system is quite a technical undertaking, and it can be daunting working out where to start when things are not working as expected. The key is to break the problem down into small manageable pieces and work through them in order until the issue is found.
The user manual is logically laid out with the following three main sections that should be completed in order.

1) Installation
2) Configuration
3) Tuning

1) Installation covers mounting and connecting up the drive, getting the Pulse and Direction signals working, being able to Enable and Disable the drive from your controller. Checking the encoder's LEDs flash when the shaft is rotated etc.

2) Configuration is setting all the configuration parameters via the Tuna software. This entails such things as calculating the correct Encoder and PUL Input unit values, and verifying everything is configured and functioning correctly via the Tuna DRO tab.

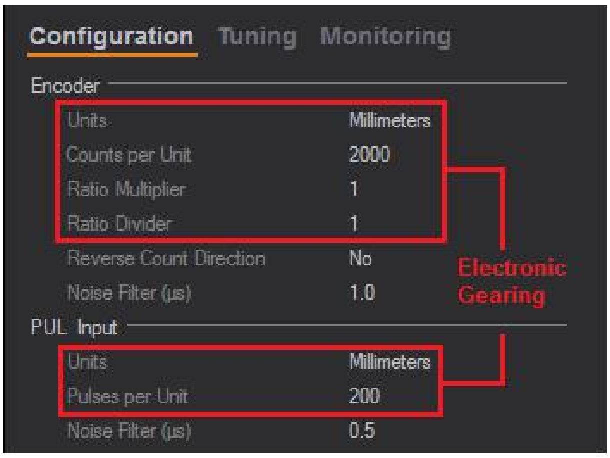
3) Tuning is done in two parts, tuning the velocity loop must be done first, then tuning the position loop.

Customers are often eager to see the motor running and wonder why it is not working when they are still in the installation step and have not yet configured or tuned the drive. It is important that all three steps are completed in order, as each step builds on the previous steps. Unfortunately there is no short cut to just quickly "get the motor running".

If after following all the advice in the manual you still have questions you can contact us on support@machdrives.com and we will be happy to help out.

11.0 APPENDIX A: ELECTRONIC GEARING

The main function of a servo drive is to receive commanded trajectories from a CNC controller, then move the machine axis to match those paths as closely as possible. The drive receives the command information in the form of digital pulses over the PUL and DIR control lines. The encoder sends pulses back to the drive over the EA and EB inputs, indicating the actual position of the axis. The drive needs to be configured so it knows how many pulses represent an inch (or millimeter) of travel for both the command input and the encoder feedback.



The command input is configured by the PUL Input "Units" and "Pulses per Unit" parameters on the Tuna "Configuration" tab, while the encoder is configured by the Encoder "Units", "Counts per Unit", "Ratio Multiplier" and "Ratio Divider" parameters (see picture above).

The encoder parameter values are determined by the encoder resolution as well as the axis mechanics such as belt reduction ratio and ball screw pitch. As the values are determined by hardware there is only one correct value for the encoder parameters.

The PUL Input parameter values must match the step configuration setting in your CNC controller, but as long as they do there is a wide range of possible values that will work.

The ratio of the encoder to step pulses is known as electronic gearing ratio. As the encoder values are fixed by hardware the ratio can only be manipulated by changing the PUL Input settings in both the drive and the CNC controller.

The electronic gearing ratio has important implications on how the drive performs and how easy it is to tune. To get maximum benefit from advanced features like feed-forward and stiction compensation the drive needs to receive multiple encoder pulses for every step pulse so it can extract meaningful velocity and acceleration information. Ratios of less than 5:1 are not ideal, ratios around 5:1 are OK, but a ratio up around 10:1 (or more) will give the best results.

Choosing the best PUL Input values is a trade off. Higher PUL Input values result in a higher step resolution but poorer trajectory tracking and increased tuning difficulty. Lower PUL Input values result in easier tuning and better tracking but lower step resolution. The optimum value is always a balance of resolution and tracking performance resulting in the most accurate axis performance.

11.1 Calculating the Encoder Parameters

The encoder "Units" and "Counts per Unit" parameters tell the drive how many counts it will receive from the encoder for every millimeter (or inch) of axis travel. Choosing the correct "Units" depends on the mechanics of the axis transmission, not your preferred units for working. For example if the axis uses a metric ball screw then the "Units" will be set to millimeters. Conversely if the ball screw has an imperial pitch like 5tpi then the encoder counts can most accurately be expressed if the "Units" is set to inches.

The encoder parameter values are determined by your hardware and cannot be arbitrarily set.

Example 1: A RF45 mill has a motor with a 2,500PPR encoder direct driving a 5mm pitch ball screw. As the encoder is quadrature it will output four times the PPR value per revolution. Therefore one revolution of the encoder will generate 2500x4 = 10,000 counts. As one ball screw revolution will move the axis 5mm, the drive will receive 10,000/5 = 2,000 counts for every millimeter of travel.

Encoder	
Units	Millimeters
Counts per Unit	2000
Ratio Multiplier	1
Ratio Divider	1

Example 2: A Bridgeport mill has a motor with a 1,000PPR encoder and a 3:1 belt reduction on to a 5tpi ball screw. As the encoder is quadrature it will output 1000x4 = 4,000 counts per revolution. The encoder will require three turns (12,000 counts) for 1 turn of the ball screw. Therefore 12,000 counts will move the axis 1/5 inch, so to move the axis one inch will require 12,000x5 = 60,000 counts.

Encoder	
Units	Inches
Counts per Unit	60000
Ratio Multiplier	1
Ratio Divider	1

Example 3: A router has a motor with a 1,024PPR encoder and a 2:1 belt reduction on to a 0.375" pitch ball screw. As the encoder is quadrature it will output 1024x4 = 4,096 counts per revolution. The encoder will require two turns (8,192 counts) for 1 turn of the ball screw. The required number of turns of the ball screw to move 1 inch is 1/0.375 = 2.6666666667. This number is repeating, so rounding it will produce inaccuracies. The solution to avoid rounding is to use the "Ratio Multiplier" and "Ratio Divider" parameters. As a fraction 0.375 can be expressed as 3/8, therefore 1/0.375 = 8/3. Set the "Counts per Unit" to 8,192 and the "Ratio Multiplier" to 8 and the "Ratio Divider" to 3.

Encoder	
Units	Inches
Counts per Unit	8192
Ratio Multiplier	8
Ratio Divider	3

11.2 Calculating the PUL Input Parameters

The PUL Input (command) "Units" and "Pulses per Unit" parameters tell the drive how many pulses it will receive from the CNC Controller for every millimeter (or inch) of commanded movement. Choosing the correct "Units" depends on your preferred units for working. Customers in the USA will generally have their controller set up to work in inches, while those from metric countries will normally prefer millimeters.

The "Pulses per Unit" value can in theory be set to almost any value and the next time the drive is enabled, or powered on, it will recalculate the correct electronic gearing ratio. Higher values result in a higher step resolution but poorer trajectory tracking and increased tuning difficulty. Lower values result in easier tuning and better tracking but lower step resolution. The "Pulses per Unit" value must match that of your CNC controller and if one is changed the other must also be changed to match.

The PUL Input value is a trade off between tracking performance and step resolution and must match your CNC controller settings.

Example 1: An Australian customer has a converted mill where the encoder parameters have been calculated to be 2,000 counts per millimeter as per section 12.1 above. The customer uses the metric system and has their CNC controller native units set to millimeters. A common mistake here is to also set the Pulse Input to 2000 steps/mm in the belief that a higher resolution means a more accurate machine. This would give a step resolution of 0.0005mm which is much smaller than the actual accuracy of the machine. In addition to not improving the machine accuracy, the low encoder to step ratio results in poorer tracking performance and more difficult tuning.

By choosing their Pulse Input to give an encoder to step ratio of 10:1, the step resolution is 2000/10 = 200 steps per millimeter or 0.005mm resolution. This is a realistic value in line with actual machine accuracy, giving good resolution, good tracking performance and easy tuning.

Don’t mistake resolution for accuracy. A C7 ball screw is accurate to within +/-0.05mm per 300mm. Setting a step resolution of 0.0005mm will not make it more accurate!

Example 2: An American customer has a Bridgeport mill with low resolution 200PPR encoders and a 3:1 belt reduction on to a 5mm pitch ball screw. They correctly calculate their encoder parameter to be 480 counts per millimeter. They want to set their PUL Input resolution to 5000 steps per inch. To calculate what the resulting encoder to step ratio would be they need to compare using the same units. As there are 25.4 millimeters per inch the encoder to step ratio would be (480x25.4) / 5000 = 2.43:1 This is much lower than the ideal of 10:1.

The no cost option is to reduce the PUL Input down to 2000 steps per inch. This gives an encoder to step ratio of 6.1:1 and a step resolution of half a thou. Neither are great but it is a good compromise for balanced performance given the low encoder resolution.

A better option would be to upgrade the encoder to a 1000PPR model. This would give an encoder parameter of 2,400 counts per millimeter, and setting the step resolution to the desired 5000 steps per inch would now yield an encoder to step ratio of (2,400x25.4) / 5000 = 12.2:1. Now, with a great step resolution and encoder to step ratio, the drive will be easy to tune and give excellent tracking performance.

11.3 Verifying the electronic gearing settings.

Before tuning the drive it is important to verify the electronic gearing parameters have been set correctly. This can be done on the Tuna DRO screen by comparing the distance displayed with the actual distance the axis travelled when manually moved a predetermined amount.

The electronic gearing is recalculated whenever the drive is powered on or enabled. Remember to toggle the enable after changing any of the electronic gearing

The test should check the distance with moves in both the positive and negative direction. Use a dial gauge or similar to measure the actual distance travelled. The DRO display can be zeroed by toggling the drive's enable line.
If the axis is displaying the correct distance travelled but in the wrong direction then see section 12.4 below.

11.4 Reversing Count Direction.

Both the DIR Input and Encoder parameters have an option to "Reverse Count Direction" The correct sequence for reversing things (if required) is as follows.

1) Test the encoder direction with the DRO screen before tuning as outlined above in section 12.3 above. If the DRO displays the wrong direction then change the encoder "Reverse Count Direction" parameter so the display reads correctly.
2) Start tuning, if the blue trace heads in the opposite direction to the yellow trace and the drive faults out with a following error, then reverse the motor wires (NOT THE POWER WIRES!).
3) Once tuning is complete, switch the "Command Source" back to "Step/Dir Inputs" and jog the axis with your CNC controller. If the axis moves in the wrong direction then change the "DIR Input" "Reverse Direction" parameter to change movement to the correct direction.