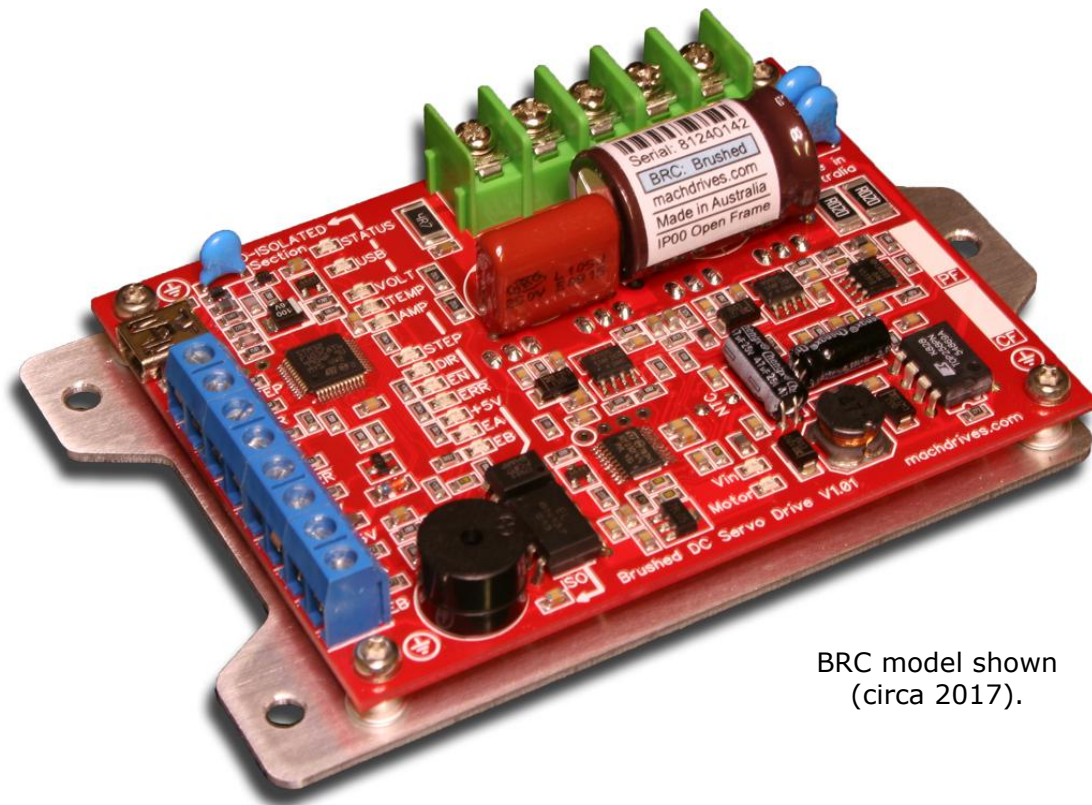

BRB
20-80V 20A

BRC
20-150V 20A

Open Frame Brushed DC Servo Drives



BRC model shown
(circa 2017).

User Manual

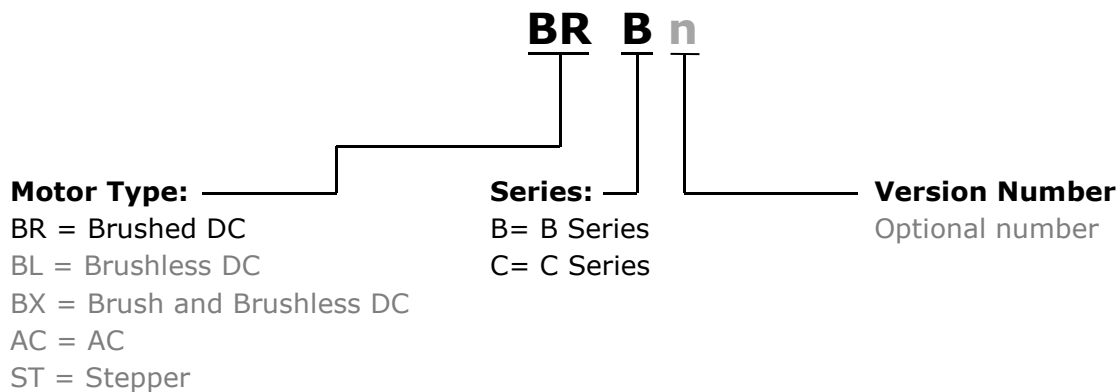
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Product Identifier



Document Revision History

Document Name: BRBBRCM

Version	Date	Details
1.1	17-Mar-2017	Initial Release
1.2	22-May-2017	Discontinued the full height variants and made the low profile variants standard. Added information to USB driver installation instructions.
1.3	17-Dec-2019	Major update based on two years of support questions. Added information to most sections. New F.A.Q. section. New Appendix on calculating Electronic Gearing with examples.

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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 earth ground 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 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 "hiccupping", causing the drive to reset .
- The control ground, power ground and earth are all electrically isolated from each other in the drive. Read and understand section 3.4.9 on "Grounding and Earthing" to avoid ground loops or damage to connected equipment.



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 time of installation, or 18 months from time of shipment, whichever comes first. 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.

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

Both models are identical except for the input voltage range, with the BRB requiring 20-80VDC and the BRC requiring 20-150VDC. Standard height and a low profile variants are also available on both models. See section 2.5 for details.

The drives must be powered with an isolated DC power supply to drive the motor, and a small 5V DC isolated supply for the control circuitry and encoders.

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

2.2 Drive Features

2.2.1 Advanced Control Algorithm

- Supports modified PI-D (PIV) algorithm.
- Dedicated 32 bit ARM control board CPU with double precision floating point motion calculations.
- Command velocity improvement with glitch filter, sliding filter and noise filter.
- Frequency and 1/T command velocity estimation with automatic transition.
- Velocity and acceleration feed forward with time shifting.
- Stiction (static friction) and reversal compensation.
- 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 saturation, following error and encoder fault.

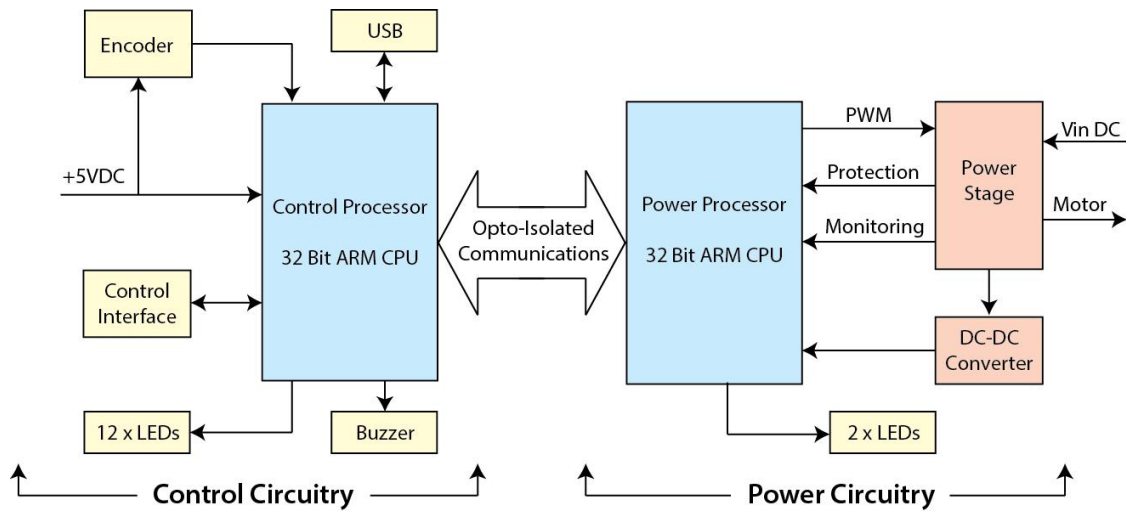
2.2.2 Easy Setup and Operation

- Standard step and direction input supports popular CNC programs like Mach3.
- All PC interface signals are isolated from power circuitry.
- Easy drive commissioning with free Machdrives Tuna software for Windows via USB.
- 14 LED indicators show all I/O states without multimeters or oscilloscopes. Signals too fast or short to be seen are "shifted" into the visible range.
- In-built waveform generator creates tuning waveforms such as trapezoid and S-profile.
- Easy parameter configuration. Values can be keyed in directly or + and - keys can be used for live "nudging" of tuning values.
- 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.
- Automatic saving of values.
- Ability to assign drive axis names and connect multiple drives at the same time.

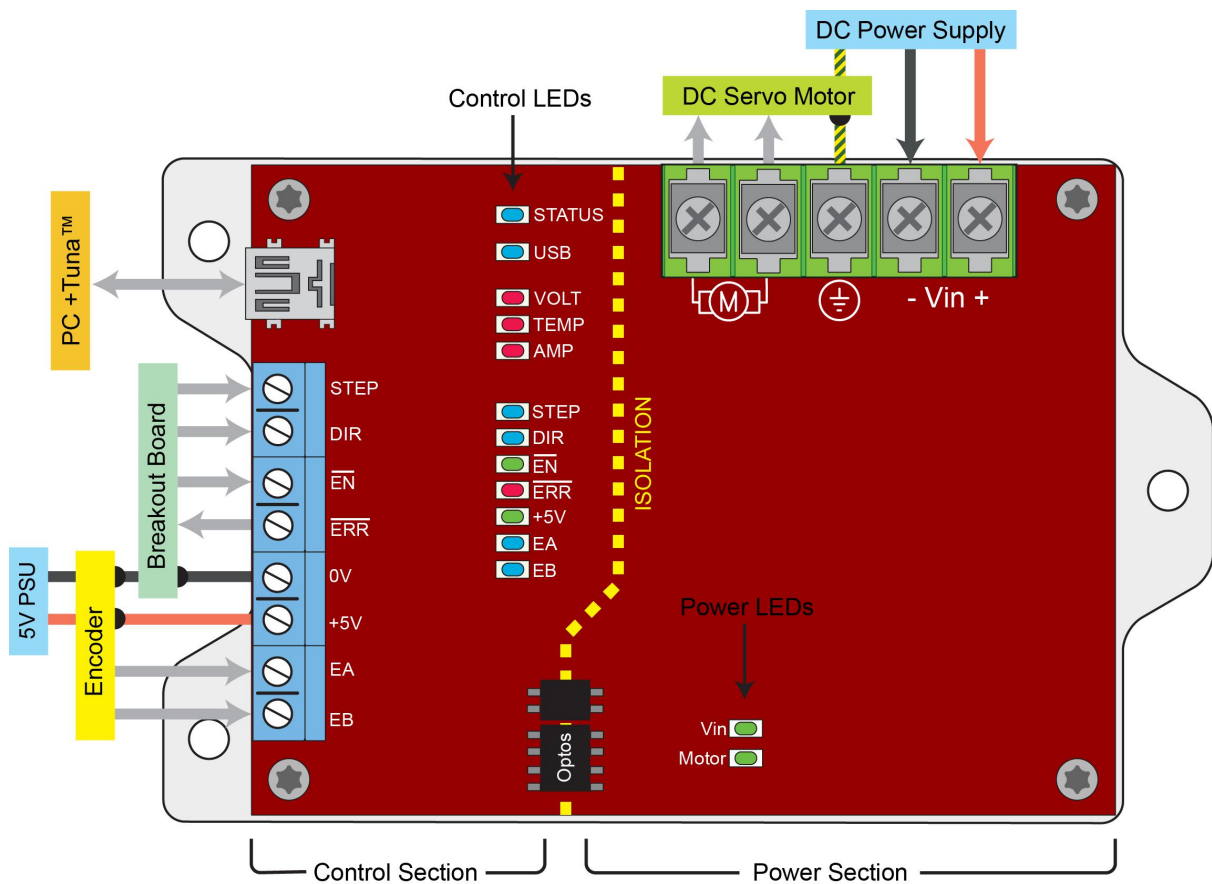
2.2.3 Advanced Power Stage

- Under and over voltage monitoring and alarms. User adjustable current limit from 5 to 20A. Current limiting alert.
- High efficiency MOSFET bridge. Typical applications do not require a dedicated heatsink. Steel control cabinet wall mounting is normally sufficient.
- Dedicated 32 bit ARM CPU for power stage.
- Silent operation. No singing or dithering.
- Optional power saving mode significantly reduces drive and motor losses with no effect on performance.
- Output short circuit protection.
- Intelligent overload protection.
- Snubber circuits for EMI reduction.
- Thermal monitoring of heatsink with audible warning and shutdown.
- High efficiency DC-DC converter supplies power stage with negligible losses and spread-spectrum frequency for reduced EMI.
- Power stage is isolated from control circuitry and earth.

2.3 Drive Architecture



2.4 Drive Layout and Connection Diagram

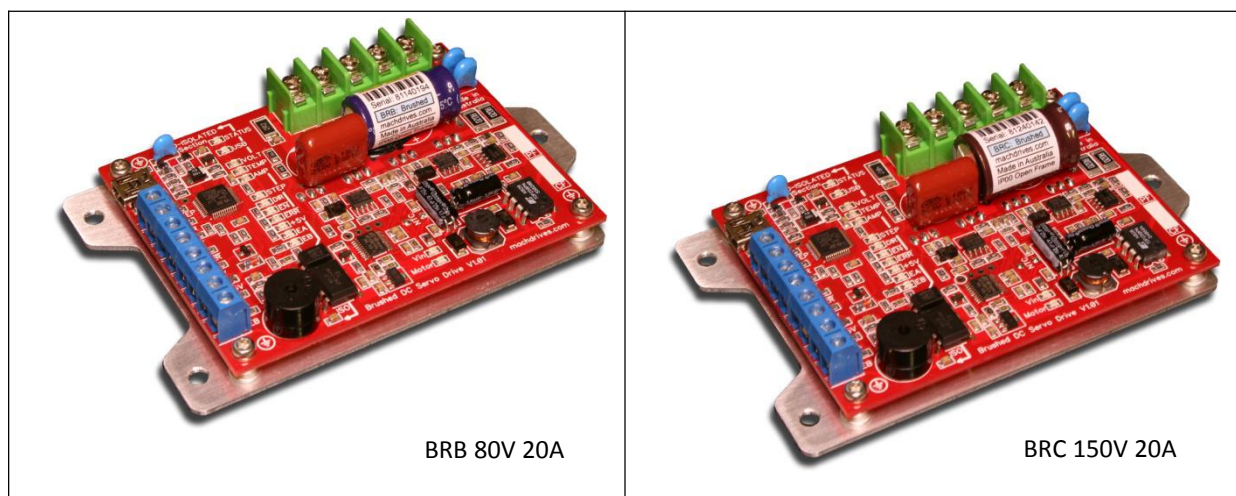


2.5 Drive Models

The BRB and BRC models are identical except for voltage rating. The BRB has a maximum input voltage of 80VDC, while the BRC can accept up to 150VDC.

Dimensions and mounting holes are identical between models and variants except for height, which is detailed in the table below.

	Input Voltage	Output Current	Height
BRB	20 - 80VDC	20A peak	21.7mm
BRC	20 - 150VDC	20A peak	24.2mm



3.0 INSTALLATION

This chapter covers the physical installation of the drive and cable connections.

3.1 Unpacking the Drive



Your BRB/BRC 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 serial number of the drive. This is located on the main bus capacitor label, underneath the barcode. This number is required to obtain your drive's unique activation code.

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 Mounting the Drive



Your BRB/BRC drive generates heat during normal operation that must be dissipated away. The two main ways to dissipate heat are through the surface it is mounted to, and convection by air passing over and through the drive.

The drive should be mounted vertically (wall mounted) on a thermally conductive surface such as an aluminum base plate or metal control cabinet. This allows both conduction and convection cooling to occur.

The drive may also be mounted horizontally on a thermally conductive surface if adequate air flows are available over the drive.

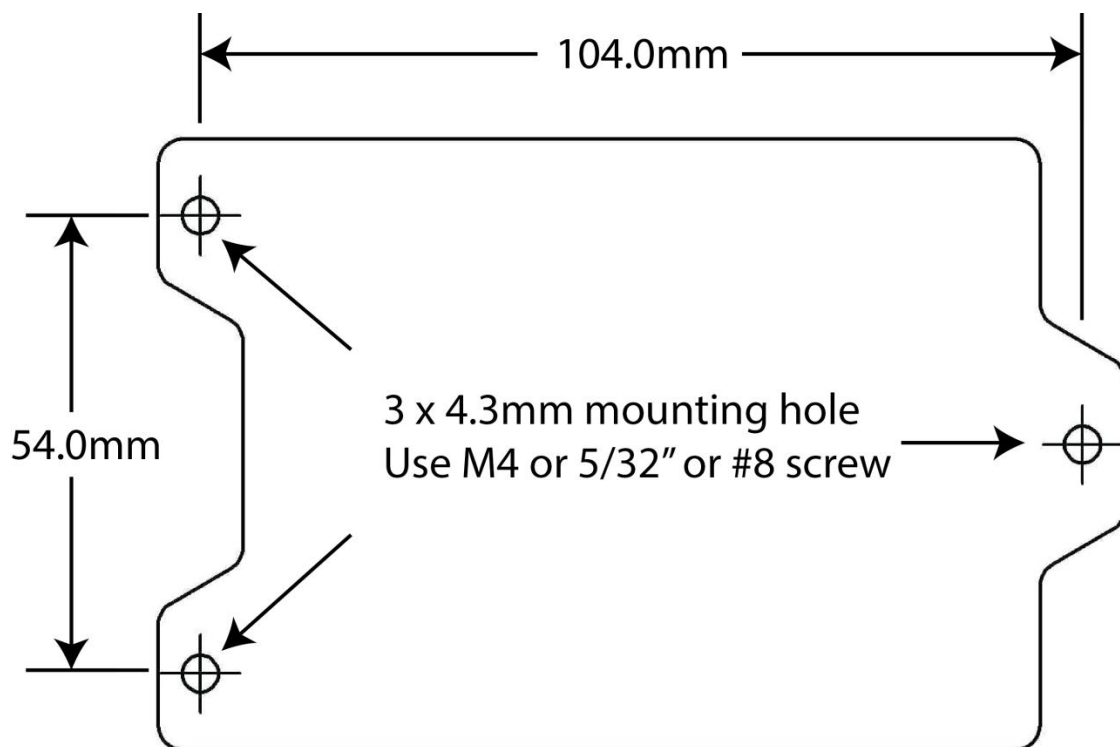
The drive should not be mounted on a poor thermal conductor such as Bakelite or fiber board.

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, mounting on a steel control cabinet wall will normally provide sufficient heat dissipation. For more demanding applications a small heatsink 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.



BRB/BRC Mounting Hole Locations (not actual size)

3.4 Connecting the Drive

3.4.1 Earth Connection



IMPORTANT: This drive must NOT be operated without an earth connection. It is recommended that the earth terminal is connected to low impedance earth with a 12 gauge wire, preferably no longer than 75mm (3 in). Additionally the metal surface the drive is mounted to must also be earthed.

3.4.2 USB Connection

A mini-B USB cable is required for the drive to communicate with the Machdrives Tuna application. Make sure the PC has internet connection before plugging in the drive for the first time. This will enable it to find and install the correct USB driver automatically. As the USB cable is only required for setting up the drive, one cable is sufficient for setting up and tuning a multiple drive system.



It is important that a good quality shielded USB cable is used with the shield connected to the metal shells at both ends as required by the USB standard. During testing, several low cost "shielded" USB cables were purchased online and most were found to be faulty with the shield not connected.

A properly constructed cable should never drop the connection between the drive and the Tuna software. If in doubt check both end shells for continuity with a meter, then strip the sleeve from a small section in the middle of the cable and check the braided shield to end shells for continuity as well.

Do not join multiple 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.

3.4.3 +5V Control Supply Connection

A small isolated +5VDC power supply is required to power the drive control circuitry and the encoder. The same PSU can power multiple drives, with a 5V 1A unit being sufficient for a three drive system.

Connect the power supply positive to the +5V terminal and the negative (or return) to the 0V terminal.

Do not use the PC internal 5V supply as this can cause return currents to flow in any data cables connected to the PC.

Do not use a supply sharing a common ground with the motor power circuitry, as this will connect the control ground and power ground together.

Do not use a power supply that has either output connected to earth. The best way to avoid this is to use a PSU with a 2 pin mains connection like a 5V wall adapter or a 5V DIN rail PSU such as the Meanwell HDR-15-5.

Route the 5VDC cable well away from motor cables and twist together or use shielded cable for maximum noise immunity. If using a shielded cable, earth the shield at both ends.



Examples of suitable 2 wire 5V isolated power supplies.

3.4.4 Encoder Cable Connection

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

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 shown will therefore generate 10,000 counts per revolution.



Connect your encoder's power wires to the drives +5V and 0V terminals taking care to ensure the correct polarity. Connect the encoder A and B outputs to the EA and EB input terminals respectively. If using a differential encoder, connect the A+ and B+ outputs as above, and leave the A- and B- outputs unconnected.

Encoders with open collector output can be directly connected as the drive contains internal 2K7 pull-up resistors to +5V on the EA and EB inputs.

If using a HEDS encoder, be sure to wire a 0.1uF (104) decoupling capacitor across the +5V and 0V pins of the encoder as close to the encoder body as possible.

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.

The +5V supply must be present before the encoder can operate. Basic operation can be checked by slowly turning the shaft and observing the 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.

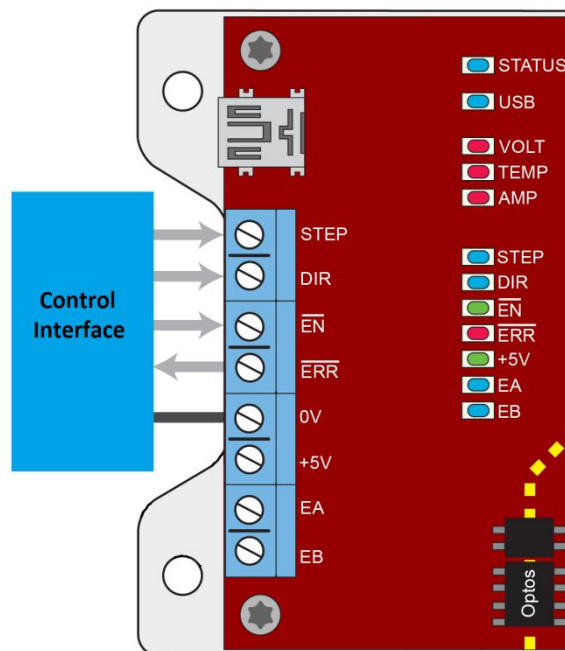
Digital filtering on the encoder inputs can be configured through the Tuna application. The default value of 4uS works well to eliminate noise in most situations.



Note: We only recommend using optical encoders with your BRB/BRC 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 BRB/BRC 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.

3.4.5 Control Interface Connection

The Control Interface allows you to control the drive using popular Step/Direction CNC control software such as Mach3/4, LinuxCNC or similar. The drive receives STEP, DIR (direction) and \overline{EN} (enable) signals from the controller and sends back the \overline{ERR} (error) signal.



Signals with lines above the name such as \overline{ERR} are active low. This means the condition has occurred when the signal goes low (in this case an error condition). Signals without lines above are active high.

All the control Interface signals are isolated from the drive power circuitry, so additional opto-isolation is not required. These signals are normally connected to the CNC controller via a breakout board such as the Machdrives BBC breakout board. The control signals are of the 5V TTL type with the 0V terminal being the common reference point. Both the STEP and DIR inputs have 4k7 pull-down resistors to 0V while the \overline{EN} input has a

4k7 pull-up resistor to +5V.

Use shielded cable if possible and connect the shield to a convenient earth point near the drive. Leave the shield at the breakout board end unconnected, and insulate with heatshrink to prevent accidental shorts. Route the wires well away from motor cables.

STEP: A step occurs on the low to high transition of this input. Software like Mach3 then holds the signal high for 1-5uS before returning it low again, ready for the next step.

DIR: A low level on this input means steps move the axis in the positive direction, and a high level in the negative direction. The direction signal must not change state at the same time as the step transition occurs or the step direction will be indeterminate.

\overline{EN} : This enable input is active low, and all drives should have this line connected together. A high to low transition will enable the drives if no alarm conditions are present, otherwise the enable request will be ignored and the \overline{ERR} output will be activated. A high level, or leaving the terminal open, will disable the drive. The \overline{EN} input must be controlled and cannot simply be wired to 0V. For testing a switch may be connected between the \overline{EN} and 0V terminals. Closing the switch will pull the enable input low, while opening the switch will allow the internal pull-up to disable the drive.

\overline{ERR} : This error output is active low, and all drives should have this line connected together. The drive will pull this line low if an alarm condition occurs. While this is an output, drives

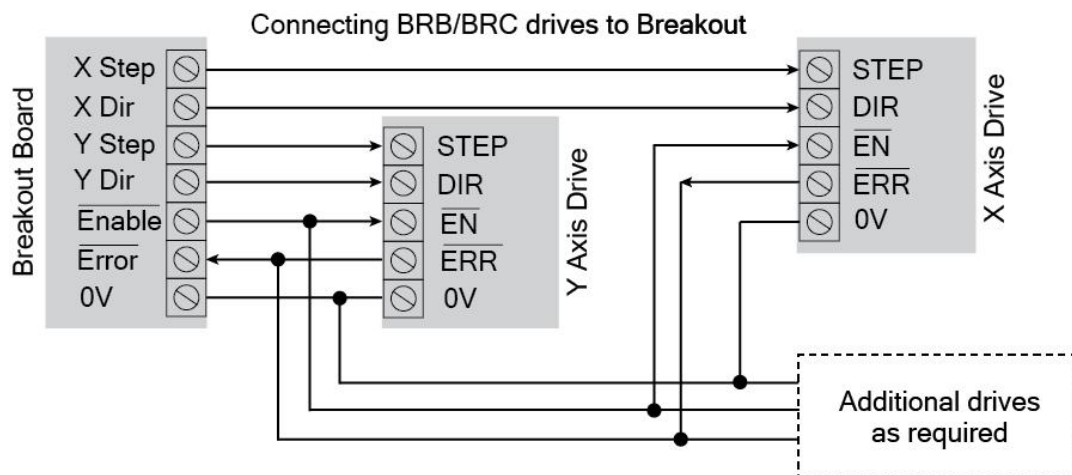
can also detect if it is pulled low by another drive, and will also stop and raise an external error alarm. The $\overline{\text{ERR}}$ output can sink a maximum of 50mA and is short circuit protected.

0V: This is the control ground, and all drives should have this line connected together. This terminal should also be connected to the negative (return) of the 5V control power supply and the 0V (return) wire of the encoder.



Do not connect the control ground to the power ground used by the motors as this will bypass the safety isolation and may pose an electrocution hazard or damage connected equipment.

The easiest way to connect your BRB/BRC drives to a PC is using the Machdrives BBC breakout board as shown below. These breakouts have the correct signal levels and polarities and can connect up to six drives directly.



3.4.6 Power Connection



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

Your BRB/BRC 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. Typical PSU voltages for BRB based systems are 36V to 65V, and for BRC systems are 80V to 120V. The PSU should be able to supply the full 20A peak per drive, or maximum current limit as configured in the Tuna application.

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 "hiccupping". 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 barrier strip connector using spade terminal connectors, 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.**

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.

3.4.7 Motor Connection



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

While your BRB/BRC drive incorporates EMI reduction features, the motor outputs can still be a source of interference if not properly connected.

Always 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 pigtailed between the shield and earth as lead inductance reduces the shields effectiveness.

Connect the wires to the barrier strip connector using spade terminal connectors, and route all motor cables well away from 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 on to the barrier strip connector. Do not pass the earth wire or shield through the core and do not use a powered iron toroid.

3.4.8 Grounding and Earthing

Your BRB/BRC drive has three electrically isolated circuits for safety, to eliminate ground loops and to provide a high level of noise immunity. There is no connection between these sections inside the drive.

- The "Power Ground" is the Vin negative (return) terminal on the barrier strip connector. This is the ground for the power stage that controls the motor, and can contain motor switching noise.
- The "Control Ground" is the 0V terminal on the Control Interface. This is a quiet ground and is only used for control signals.
- The "Earth" is the center terminal on the barrier strip connector. This is connected to the drive's metal base plate for safety and EMI shielding.

Do not connect the power ground, control ground or earth together, or share any power supplies or other circuitry between them.

After your system is completely wired up, turn off all power then verify with a meter that the two grounds and earth are all isolated from each other. Note: It is normal and acceptable for your PC to connect the control ground and earth together inside the computer power supply. Unplug any data cables connecting the PC to the system for the purpose of this test. If any connection is found, isolate the cause and rectify it before operating the system.

4.0 CONFIGURATION

Configuring your drive is done through the Machdrives Tuna application for Windows. The drive is connected to the PC with a Mini-B USB cable. It is possible to configure the parameters and activate the drive with only the USB cable connected, no other power is required. However other circuitry such as the encoder will not function until the 5VDC supply is connected.

4.1 Installing the Tuna Software

The Tuna application for Windows can be downloaded from <https://machdrives.com/tuna.aspx>. There is a choice of two different downloads. They are the same program but use different versions of the .Net framework.

- Tuna for Windows XP. This uses the .Net 2.0 framework for older PC's
- Tuna for Windows 7, 8.x, 10. This uses the .Net 4.0 framework for newer PC's

Install the software. **On newer versions of Windows you need to right click the .exe and select "Run as administrator"**. Note: You must extract the .exe file from the downloaded .zip file before attempting to install it or the "Run as Administrator" option will not be displayed.

You will need to read and accept the EULA before installing the software.

4.2 Installing the USB drivers

Your drive appears as a Virtual COM Port to Windows and needs a VCP driver to communicate.

Make sure the PC has internet connection before connecting the USB cable for the first time. The drive does not need power or any other cables connected. The PC will automatically download and install the correct driver. This may take a few minutes.

If there is no internet connection the first time the drive is plugged in, Windows will not install the drivers on subsequent connections. You will then need to open Device Manager/Ports and find the USB Serial Device and uninstall it before trying again. Note: the device will only be listed if the USB cable is connected to the drive.

Whether the Tuna application is installed or open has no effect on the driver installation.

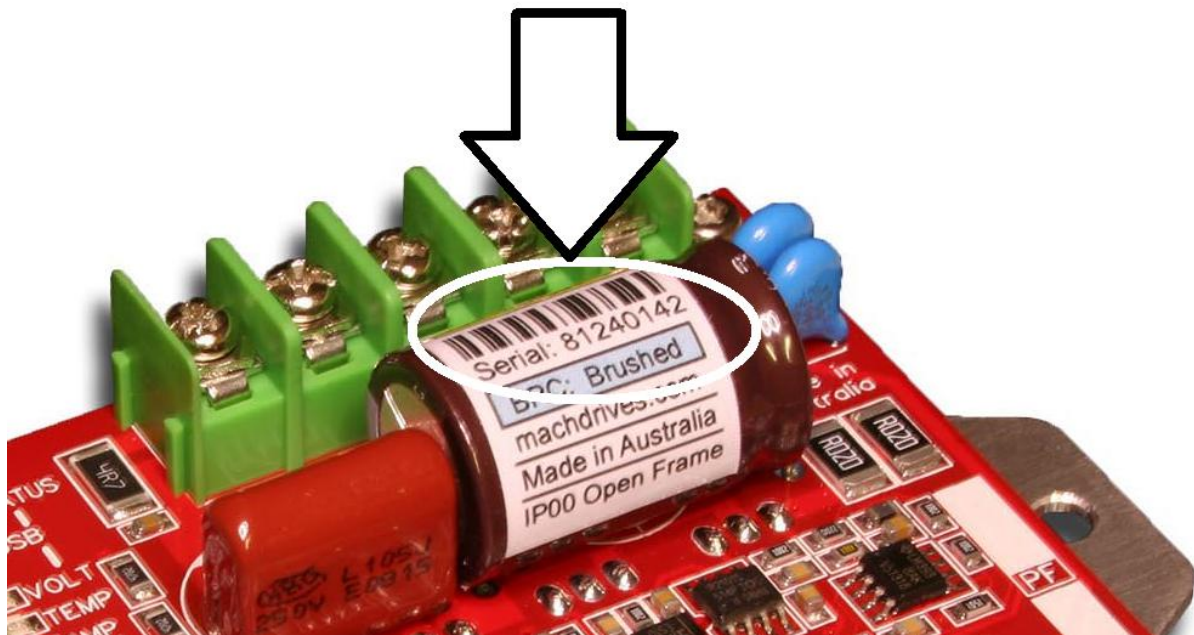
If the drivers do not download automatically check your Windows setting under "Devices and Printers", right click the icon with your computer name and select "Device Installation Settings". Make sure driver download is set to "Automatic".

If you are installing the software on a PC where internet connection is not available then please contact us on support@machdrives.com for a driver install package.

4.3 Activating the Drive

Your drive requires a one-time activation before it is fully functional. Activation is a security feature designed to prevent fraud and piracy. This helps us keep our product prices low and guarantees you receive a genuine Machdrives product.

To activate your drive send the serial number to support@machdrives.com and request the activation code.



The serial number is in the format "Serial: nnnnnnnn" and is located under the barcode as shown.

You will receive back a 24 character code in the format: DGLH-LXMI-LWXU-MFEI-HIHG-FZXD
Every code is unique and will only work in the drive with the supplied serial number.

Open the Tuna application and plug the USB cable into the drive. A rapid flashing USB LED verifies the driver is installed and USB communications are active. An orange key will appear on the title bar. Click the key and paste the code in the dialog box exactly as supplied, then click OK. The key will disappear and you will receive a confirmation that the drive has been activated. If the code is entered incorrectly three times, the Tuna application will need to be restarted before it can be attempted again.

You will normally receive the activation code within a few hours of requesting it. Remember we may be in a different time zone to you. While you are waiting you can still install and configure the drive. You can also tune it by setting the command source to "Wave Generator". This uses the internal motion profile generator as the command source. The drive cannot however be commanded from the Step/Direction interface until it has been activated.

OEM and established volume customers can elect to have the drives shipped pre-activated.

4.4 Step/Dir (Command) Configuration

Configuring the Step/Dir Inputs informs the drive of the step distance and applies filtering and command conditioning.

Parameter	Description
Units	Select the units that the command steps 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 most other countries will prefer to work in millimeters.
Counts per Unit	Enter how many command steps it takes to move 1 full "Unit" as defined above. See Appendix A "Electronic Gearing" for a detailed explanation and calculation examples.
Reverse Count Direction	When set to "No", a low on the Direction input causes steps to move the axis in the positive direction. When set to "Yes", this is reversed. Changes to this parameter take effect the next time the drive is enabled.
Glitch Filter	This removes discrete jumps in the command velocity information from non-deterministic operating systems like Windows.
Sliding Filter	This removes jitter in the command velocity information from non-deterministic operating systems like Windows.
Noise Filter (uS)	This is a digital filter that eliminates electrical noise picked up on the step input. This sets the minimum time in microseconds that the step 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 1-5uS wide, so the default of 0.5uS works well in this case.

4.5 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	These two parameters allow an exact ratio to be applied to the "Counts per Unit" without any rounding or loss of precision. For example if your axis has 333.33 (repeating) counts per mm, you would set units to "Millimeters", "Counts per Unit" to 1000 and then apply a ratio of 1/3 by making "Units Multiplier"= 1 and "Units Divider"=3.
Ratio Divider	
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.
Noise Filter (uS)	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 4uS works well in most cases.

4.6 Sound and LED Configuration

Allows users to disable drive buzzer audio and LED indicators.

Parameter	Description
Audio Notifications	Enable or disable all audio notifications. These are as follows: <ul style="list-style-type: none"> • Short beep on power up. • Short beep on enabling the drive. • Short beep on disabling the drive. • Short beep on current limit.
Audio Alarms	Enable or disable all audio alarms. These are as follows: <ul style="list-style-type: none"> • +5V supply too low or too high. • Trying to enable the drive when a fault condition still exists. • Error output activation. • External error. (Another drive has pulled the Error line low). • Motor voltage is too low or too high. • Motor overload. • Motor short circuit. • Heatsink temperature too high. • Following error limit exceeded. • Encoder fault. • Activation error. Trying to run the drive from the Step/Dir inputs before it has been activated.
LEDs Enable:	
<i>All</i>	All LED indicators are operational.
<i>Power and Status Only</i>	Only power and status LED indicators are operational. All others are off.
LED Brightness	Sets the brightness of the 12 control LEDs. Adjustable from 25 to 100%.

4.7 Miscellaneous Configuration

Miscellaneous drive settings.

Parameter	Description
Drive Axis	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.
Current Limit	Sets the maximum current the drive will deliver to the motor before current limiting. Normally left at maximum setting of 20A.
Temperature Units	Temperatures 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).
<i>Disabled</i>	No power saving. The power stage remains on when motor is stationary.
<i>Enabled</i>	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.

5.0 TUNING

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



A tuning video for BRB/BRC drives is available on our Machdrives channel.

<https://www.youtube.com/watch?v=y4bAE6wgcui>

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.

- "Step/Dir 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.
- 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 $200 \times 5 \times 2 = 2000$ 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 little 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" dropdown 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 Vin LED is on.
5. Enable the drive by pulling the Enable pin down to 0V. The drive will give one short beep and the Enable LED will be on. Check the Motor LED located by the power connector is 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.
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.

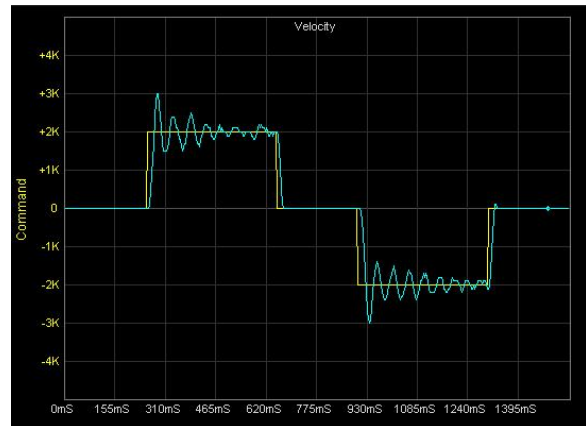
If the drive faults out and the motor trace moves in the wrong direction, remove motor power and reverse the motor wires. DO NOT reverse the Vin power wires by mistake.

If the drive starts current limiting during tuning, then stop and reduce the Wave Generator velocity by half, then start the tuning again.

Command Velocity: Yellow
Motor Velocity: Blue

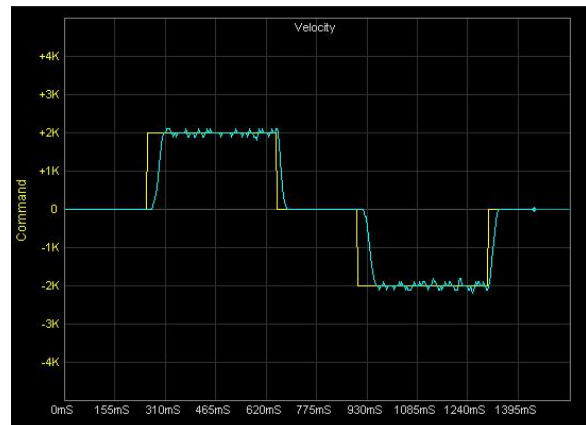
Start increasing the "Proportional Gain", the waveform will begin to become unstable with overshoot and ringing as shown.

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

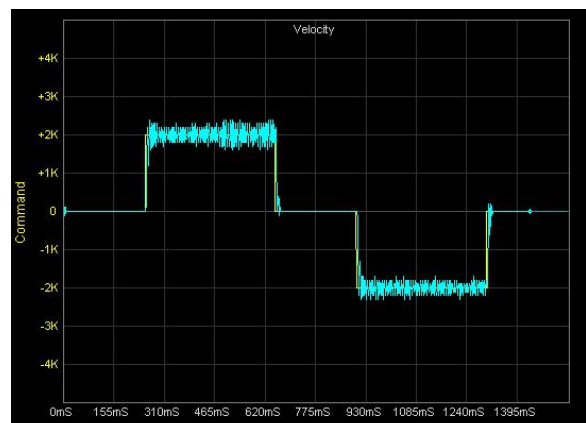
Keep increasing the "Proportional Gain" and adjusting the "Differential Gain" to keep the response square with minimum overshoot or rounding off the leading edge.

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".

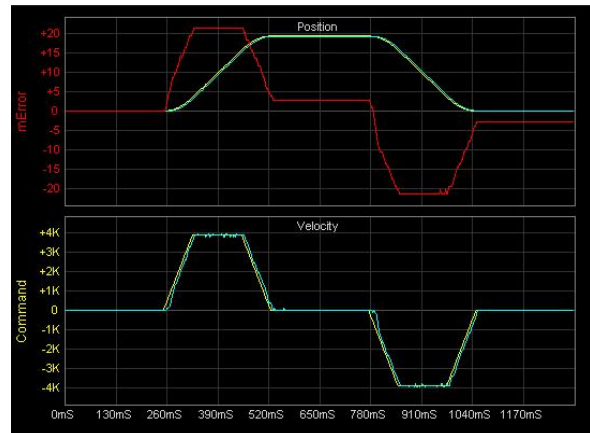


WARNING: The following steps will power the motor and result in machine motion. Make sure all personnel are clear of the machine and a method of shutting off machine power is available and close to hand if required.

3. Apply motor power to the drive and check the green Vin LED is on.
4. Enable the drive by pulling the Enable pin down to 0V. The drive will give one short beep and the Enable LED will be on. Check the Motor LED located by the power connector is 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.

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.

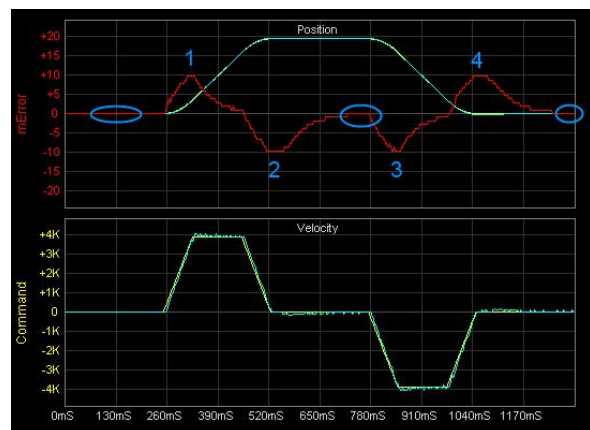
Check that "Velocity Feedforward", "Acceleration Feedforward" and "Stiction Compensation" are also set to zero.



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.

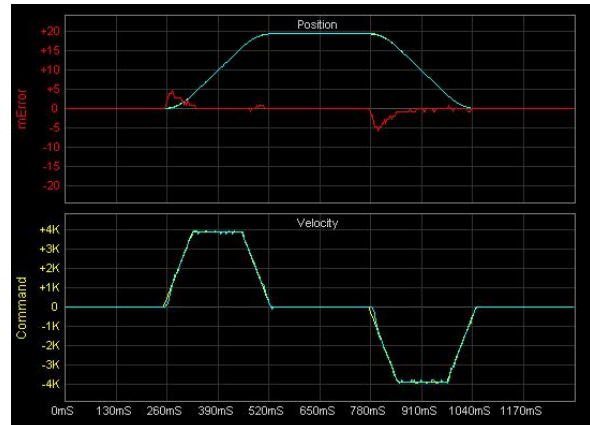
Do not increase it any more at this stage as it will mask the effect of the "Velocity Feedforward" adjustment.



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.

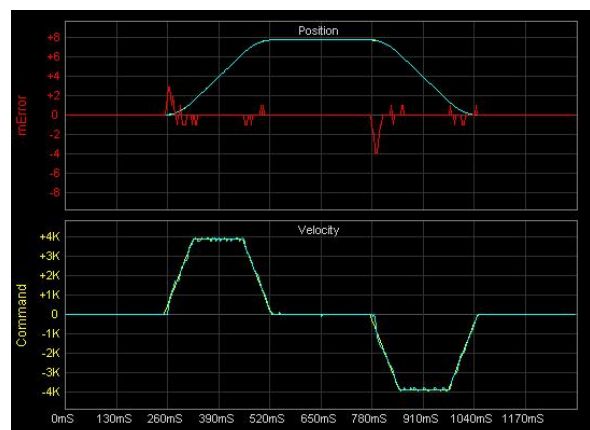


Command Position: Yellow
Motor Position: Blue
Motor Position Error: Red

Adjust the error trace scale to make the remaining error more visible.

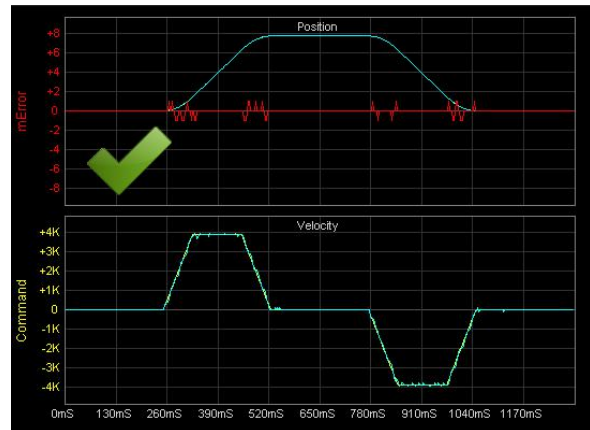
Now increase the "Integral Gain" parameter to reduce the remaining error.

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. Both "Glitch" and "Sliding" filters can be enabled on the Configuration tab.

In this example the Command Steps/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 moves 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" dropdown 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 FAULT CODES

Fault codes can be used to identify which fault has just occurred. A fault condition will stop the drive and sound one long beep. The Status 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	External Error	Another drive has experienced a fault and has pulled the Error line low. This drive will stop and signal an external error condition.
2	+5V Low	The +5V control voltage is too low.
3	+5V High	The +5V control voltage is too high.
4	Following Error	The difference between the commanded position and the motor or load encoder position has exceeded the value specified in the "Following Error" parameter. This value is expressed as Step pulses.
6	Motor Voltage Low	The Vin motor supply voltage is too low.
7	Motor Voltage High	The Vin motor supply voltage is too high.
8	Motor Overload	The motor was overloaded. Can happen after sustained current limiting.
9	Motor Short Circuit	An electrical short circuit has occurred on the motor terminals.
10	Heatsink Temp	The heatsink is too hot. Improve cooling.
13	Encoder Count	The encoder count is outside the range of expected values. This could be a faulty or disconnected encoder or cable.
14	Activation Error	The user tried to run an un-activated drive from the Step/Dir inputs. Activate the drive or run the drive from the internal Wave Generator.

8.0 LED INDICATORS

Your BRB/BRC drive has 14 LED indicators to simplify set up and diagnosis without needing to use meters or oscilloscopes.

LED flashes that are too fast to be seen, like step pulses are "stretched" into the visible range. The stretching only applies to the LED, the source signals themselves are not affected.

LEDs	Notes
Vin	Indicates the motor power is present on the + and - terminals.
Motor	Indicates that the power stage is on and power is being supplied to the motor. This is useful for showing power saving functionality.
STATUS	Flashes fault codes. See section 7.0 for more details. Solid "ON" when drive running.
USB	Solid "ON" when USB connected, flashing when transferring data.
VOLT	When illuminated indicates an abnormal voltage.
TEMP	When illuminated indicates a high heatsink temperature.
AMP	When illuminated indicates current limiting, overload or short circuit.
STEP	A flash indicates a step has occurred. Steps occur on the positive transition on the signal.
DIR	Indicates step direction as configured in the Tuna application.
$\overline{\text{EN}}$	Indicates an active $\overline{\text{Enable}}$ input when illuminated.
$\overline{\text{ERR}}$	Indicates an active $\overline{\text{Error}}$ output when illuminated.
+5V	Solid "ON" indicates a good +5VDC supply. "OFF" with short flash "ON" indicates an under voltage condition. "ON" with short flash "OFF" indicates over voltage condition.
EA	Indicates the state of the encoder A input signal. ON= high, OFF = low
EB	Indicates the state of the encoder B input signal. ON= high, OFF = low

9.0 ALARMS AND NOTIFICATIONS

Progressive "Volt" and "Temp" alarms warn operators of abnormal conditions before they shut down the drive and stop machine operations. Alarm thresholds are defined as follows:

Reset Limit: The condition returns into the normal range and the alarm is reset.

Beep Limit: The corresponding alarm LED starts flashing and the buzzer starts beeping.

Tone Limit: The corresponding alarm LED turns "ON" and the buzzer issues a continuous tone.

Shutdown Limit: The corresponding alarm LED stays "ON" and the drive shuts down.

Alarm	Reset Limit	Beep Limit	Tone Limit	Shutdown Limit
Vin Supply (BRB/BRC)	80/150VDC	83/160VDC	86/170VDC	90/180VDC
Heatsink Temperature	66C	69C	72C	75C

"Amp" alarms are instant and can be either an Overload or Short Circuit. Current limiting is a notification only and issues a short beep while the drive continues operating. Sustained current limiting can cause an overload condition and drive shutdown.

Audible notifications and alarms can be turned off if desired on the Configuration tab of the Tuna application.

10.0 SPECIFICATIONS

Value	Min	Typical	Maximum
Electrical			
Vin Supply (BRB/BRC)	20VDC		80VDC/150VDC
Vin Supply Current - Motor Off		15mA	
Motor Current Limit - User	5A	20A	20A
Heatsink Temperature			68°C (154°F)
+5V Control Voltage	4.5VDC	5.0VDC	5.5VDC
+5V Current - No Encoders		50mA	
Encoder Frequency (counts)			2MHz
Encoder Voltage		5.0V	
Step Frequency			2MHz
Control Interface Logic Low Input	-0.3V		+0.8V
Control Interface Logic High Input	+2.6V		+5.3V
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	114mm (4.5")		
Width	72mm (2.8")		
Height	See section 2.4 for details.		
Weight	95g (3.4oz)		
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		

11.0 FAQ

This chapter answers some questions we have been frequently asked.

11.1 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.

11.2 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.

11.3 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.

11.4 Where is the serial number?

The serial number is located on the colour label on the main bus capacitor. It is under the barcode and is of the format “Serial: nnnnnnnn” For a picture showing the location please see section 4.3 “Activating the Drive”. Values hand written on the board like “106P1” are firmware revision numbers and are *not* required to activate the drive.

11.5 Why do I have to activate the drive?

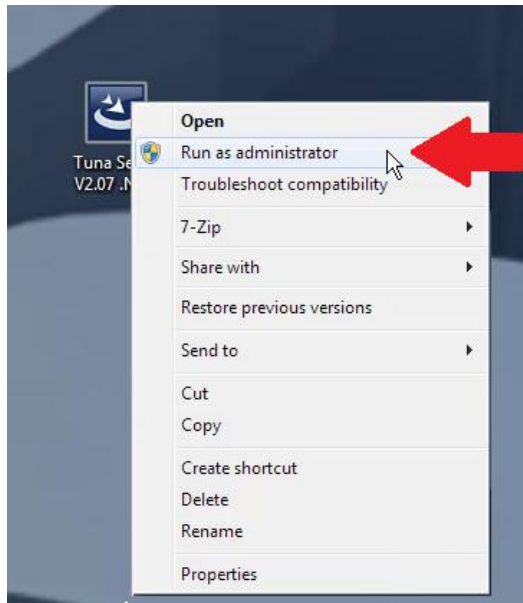
Drive activation serves several important functions, the main two are fraud prevention and anti-piracy.

As we are an online business, fraud is something we must always be aware of. Fraud is a cost that businesses must factor into their selling price, so eventually honest customers end up paying more because of it. The activation code prevents the common *Item Not Received* fraud, and to date has been very successful in this regard. This has allowed us to keep our product prices low, benefiting everyone.

Piracy of intellectual property and counterfeit products allow companies to sell cheap knock-offs as they don’t have to bear the cost of developing a product or supporting it. Machdrives motor drivers

have a unique ID code locked in the silicon that assures our customers they have received a genuine product.

11.6 Why don't I have permission to install the Tuna application?



Later versions of Windows require explicit user permission when installing .exe files, even if you are already an administrator. This is to prevent malware from installing software on your machine in the background. The install file that is downloaded from our website is a .zip file. You must extract the .exe file from the .zip file *before* attempting to install it or the "Run as administrator" option will not be available and the install will fail with lack of permission.

The sequence to install the Tuna application is...

- 1) Download the Tuna Setup.zip file from our website.
- 2) Extract the .exe file from the .zip file to the desktop.
- 3) Right click the .exe file and select "Run as administrator".

11.7 Why won't the USB drivers install?

In the handful of cases where customers have encountered driver install issues we have found the following steps have resolved the problem.

- 1) Check you have an internet connection on your PC (open browser etc)
- 2) With the drive unplugged open "Devices and Printers" (not device manager). When you plug the drive in watch the bottom "Unspecified" Group to see what appears.
- 3) Plug in the drive. If nothing appears in the unspecified group then you probably have a cable or USB port problem, try another cable. If the driver is not installed you will see "Machdrives Series Servo Drive" If you single click this to highlight it you should see a message in the lower part of the window that says "Software is Installing for this device" Note this can take up to 5 minutes. The most common problem here is not waiting long enough. Make a cup of coffee.
- 4) When the drive has installed successfully the name in "Devices and Printers" will change to "STMicroelectronics Virtual COM Port". Installation was successful. You are done.
- 5) If after 10 minutes the drive has still not installed 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"
- 6) If after all this you still cannot get the driver to download then your PC policy settings may 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 step 2 and try again.

11.8 Why are the Step and Dir signals not working?

If the Step 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 Step LED should be normally OFF and only *flash* ON when a step is received.

11.9 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 0V terminal on the blue terminal block to the EA terminal and check the EA LED goes OFF.

Check 3) Touch a jumper wire from the 0V terminal on the blue terminal block 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.

11.10 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 BRB/BRC drives.

Connection Rules....

- 1) Connect up +5V and 0V wires to their respective terminals.
- 2) Do not connect up index wires. BRB/BRC drives do not use the index.
- 3) Connect A(single ended) or A+(differential) to the EA terminal.
- 4) Connect B(single ended) or B+(differential) to the EB terminal.
- 5) Do not connect the A- and B- wires. Insulate or shrinkwrap them to prevent shorts.

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.

11.11 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.

11.12 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.

11.13 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 BRB based systems are in the 36V to 65V range, and BRC systems range from 80V to 120V.

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.

11.14 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 $120/1.414 = \text{approx } 85 \text{ VAC}$.

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.

11.15 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 $2500 \times 4 = 10,000$ 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 $1000 \times 4 = 4,000$ 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 $12,000 \times 5 = 60,000$ counts.

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

For more details and information regarding the relationship between the Encoder and Step count settings, please see Appendix A “Electronic Gearing”.

11.16 How do I calculate the Step “Counts per Unit” parameter?

The Step (command) “Units” and “Counts 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 “Counts 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 “Count per Units” setting it is important to remember to change your CNC Controller settings to match.

11.17 Why did the drive fault out?

The drive can detect eleven different types of fault conditions, so the first step is to find out what type of fault has occurred. The last five faults are listed on the Tuna monitoring tab. Alternatively the fault can be determined by counting the number of flashes on the drives status LED. The flash codes and details of what causes each fault is detailed in section 7.0 of the user manual “Fault Codes”.

11.18 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.

11.19 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.

11.20 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.

11.21 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.

11.22 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".



11.23 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 Step/Dir 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 step (command) "Counts 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".

11.24 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.

11.25 Why am I getting Amp alarm beeps on rapids?

The drive will beep and flash the red Amp LED if the motor current reaches the 20A current limit, or a lower limit if set by the user. Intermittent current limiting is not a problem, but tracking accuracy is reduced while the current limit is in effect. To prevent current limiting the drive limit current should be set to 20A and your CNC controller acceleration setting should be reduced until beeping ceases. High "Stiction" and "Acceleration Feedforward" values can also increase the likelihood of current limiting. Audio notifications, including the current limit beep, can be disabled on the configuration tab if desired.

11.26 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 Step 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 Step 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.

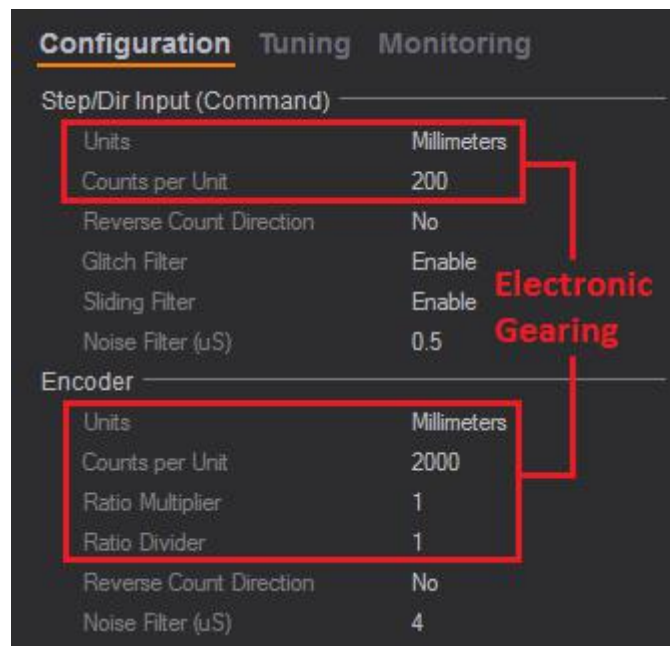
Customers are often eager to see the motor running and wonder why it is not working when they are still in the installation step and have not yet configured or tuned the drive. It is important that all three steps are completed in order, as each step builds on the previous steps. Unfortunately there 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.

12.0 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 Step and Direction 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 Step “Units” and “Counts 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.

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 step 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 Step 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 feedforward 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 step parameter values is a trade off. Higher step values result in a higher step resolution but poorer trajectory tracking and increased tuning difficulty. Lower step 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.

12.1 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 $2500 \times 4 = 10,000$ 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 $1000 \times 4 = 4,000$ 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 $12,000 \times 5 = 60,000$ 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 $1024 \times 4 = 4,096$ 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

12.2 Calculating the Step Parameters

The Step (command) “Units” and “Counts 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 “Counts 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. Higher step values result in a higher step resolution but poorer trajectory tracking and increased tuning difficulty. Lower step values

result in easier tuning and better tracking but lower step resolution. The “Counts per Unit” value must match that of your CNC controller and if one is changed the other must also be changed to match.



The step 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 Step parameter 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 step resolution 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.

Step/Dir Input (Command)	
Units	Millimeters
Counts per Unit	200
Reverse Count Direction	No



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 Step 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 $(480 \times 25.4) / 5000 = 2.43:1$. This is much lower than the ideal of 10:1.

The no cost option is to reduce the Step parameter 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 5000 steps per inch would now yield an encoder to step ratio of $(2,400 \times 25.4) / 5000 = 12.2:1$. Now, with a great step resolution and encoder to step ratio, the drive will be easy to tune and give excellent tracking performance.

12.3 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 enabled. Remember to toggle the enable after changing any of the electronic gearing parameters.

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.

12.4 Reversing Count Direction.

Both the Step 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 Step/Dir "Reverse Count Direction" parameter to change movement to the correct direction.