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# BRA Series

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## 20A 150V Brushed DC Dual Encoder Servo Drive



## User Manual

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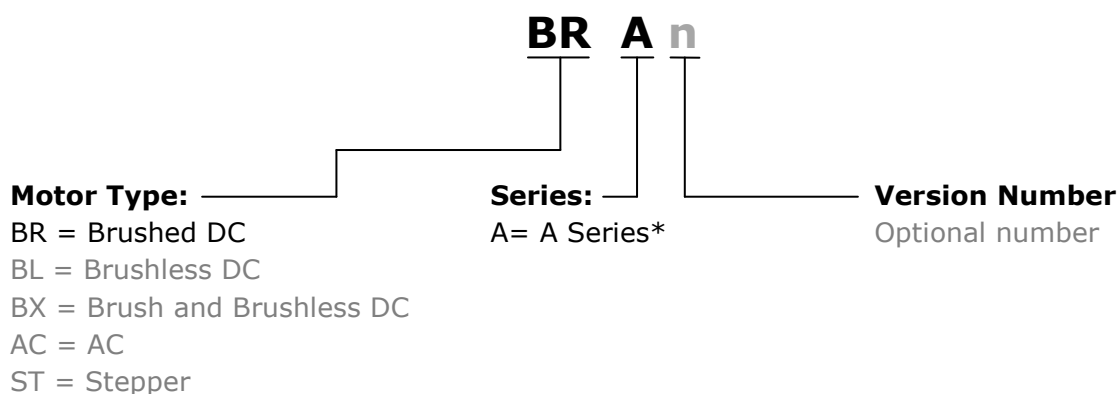
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## Product Identifier



\*A Series: Enclosed IP1X, Dual Encoder, 20-150VDC, 20A

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## Document Revision History

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Version	Date	Details
1.1	09-Jan-2017	Initial Release

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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 cause 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 or 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 still may 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 supply of 150VDC max.
- 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 — and 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 support if you have any questions about this product or its use.

This user manual describes the Machdrives BRA series servo drive and its 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

Your Machdrives BRA series servo drive is a digital dual encoder servo drive for use with brushed DC servo motors and step/direction CNC control software such as Mach3. In addition to the normal motor encoder, the BRA drive can optionally use a second encoder on the load to provide an exceptionally high level of point-to-point and trajectory tracking accuracy. The second encoder is normally realized as quadrature linear glass scales.

The drive must be powered with a 20 to 150VDC isolated supply to drive the motor, and a small 12V DC isolated supply for the control circuitry.

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](http://machdrives.com/tuna.aspx)

### 2.2 Drive Features

#### 2.2.1 Dual Encoder Support

- Supports single or dual incremental encoder operation up to 2MHz count rate.
- Supports single ended or differential encoder types . True differential operation with RS485 standard line driver chips.
- All encoder inputs are isolated from power circuitry.
- User adjustable digital noise filtering.
- High efficiency DC-DC converter provides up to 250mA per encoder at 5V.
- Extremely high positional accuracy in dual encoder mode. Typical results are point-to-point positioning error  $\pm 0.5$  encoder counts and less than  $\pm 1.5$  encoder counts full trajectory tracking error at the tool, measured as per ISO 230-2  $\pm 2$  Sigma error deviation.

#### 2.2.2 Advanced Control Algorithms

- Supports modified PI-D (PIV) algorithm for single encoder, and modified cascade algorithm for dual encoder.

- 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.
- Fast settle feature stops dead on exact encoder count without dithering or deadband.
- 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.

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### 2.2.3 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.
- 20 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. Key in values directly or use plus and minus keys for live "nudging" of tuning values.
- Eight channel scope with pan and zoom for easy waveform analysis.
- Digital readouts on command, motor and load positions.
- Real time statistical position error analysis and charting over multiple time intervals.
- Automatic saving of values.
- Assign drive axis names and connect multiple drives at the same time.

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### 2.2.4 Advanced Power Stage

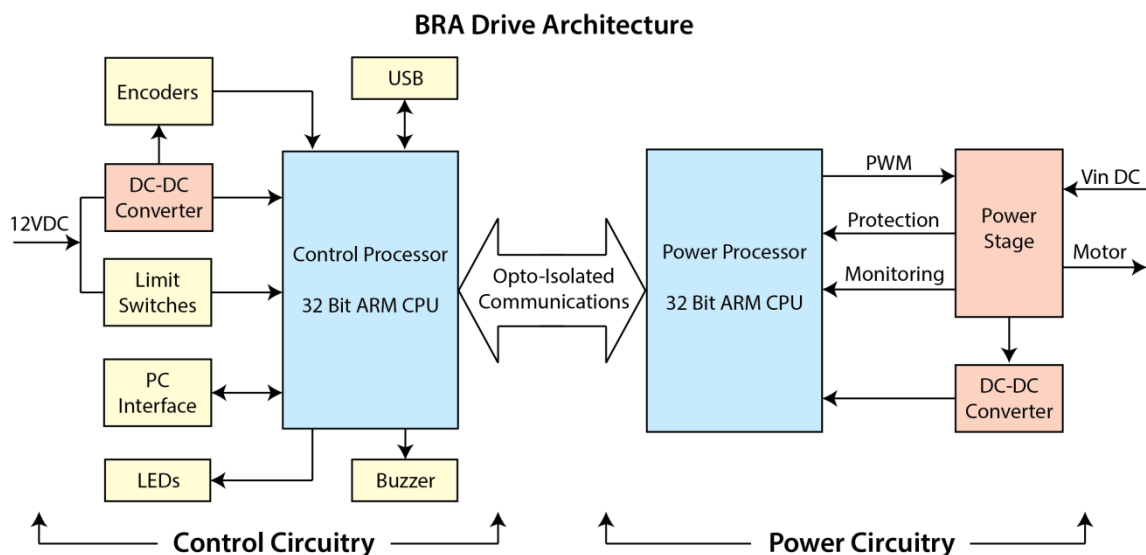
- DC bus voltage from 20 to 150VDC. Under and over voltage monitoring and alarms. User adjustable current limit from 5 to 20A. Current limiting alert.
- High efficiency MOSFET bridge with low Rds ON resistance. Typical applications require no additional heatsink or cooling.
- Dedicated 32 bit ARM CPU for power stage.
- Silent operation. No singing or dithering.
- Optional power saving mode significantly reduces drive and motor losses with no effect on performance.
- Dual di/dt output filter inductors reduce EMI and increase SOA under fault conditions.
- Four quadrant short circuit detection protects against motor to motor, motor to negative and motor to positive supply faults.

- Progressive overload protection shuts down within 0.4mS to 2 sec depending on severity of overload condition, while eliminating nuisance tripping.
- Snubber circuits across each MOSFET for reduce di/dt and switching stress. Additional snubbers on motor power rails.
- Independent thermal monitoring of heat sink, output inductors and main filter capacitors 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.

### 2.2.5 Limit/Home Switch Support

- Supports direct connection of mechanical or NPN inductive proximity switches.
- Supports normally open (NO) or normally closed (NC) operation.
- Limit switch inputs are isolated from power circuitry.
- Intelligent jogging off limits, but not into them.
- Homing off limit switches or combined with encoder index pulse for precision homing to within 1 encoder pulse.
- User adjustable digital noise filtering.

## 2.3 Drive Architecture



## 3.0 INSTALLATION

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

### 3.1 Unpacking the Drive



Your BRA 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.

Each drive also comes with three green plug-in terminal block connectors as follows.

- 2 pin +12VDC connector
- 4 pin Limit Switch connector
- 6 pin PC Interface connector

Additionally motor and power cables require crimp spade connectors, and the encoders require DB9 male connectors. These are not supplied.

Take note of the serial number of the drive. This is located on the label on the side of the drive as shown. 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 BRA drive generates heat during normal operation that must be dissipated away. The two main ways for this to happen is conduction through the surface it is mounted to, and convection by air passing over and through the drive housing.

The preferred mounting option is for the drive to 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 good air flows are available over the drive.

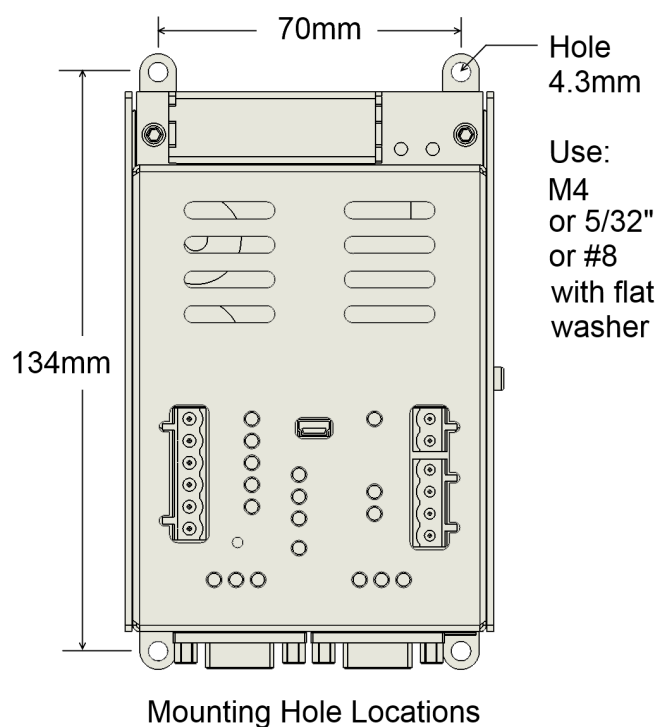
If the drive is to be mounted vertically to a poor thermal conductor such as Bakelite or fiber board, then the drive must be mounted off the surface with spacers by at least 2cm (1 inch) to allow airflow over the back surface of the drive.

The drive should not be mounted horizontally on a poor thermal conductor as neither conduction nor convection cooling is effective.

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.

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



## 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 a copper earth bar with a short braided strap no longer than 75mm (3 in).

### 3.4.2 USB Connection

A mini-B USB cable is required to use 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.



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 different 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 shell for continuity as well.

### 3.4.3 +12V Control Supply Connection

A small isolated 12VDC power supply is required to power the drive control circuitry and its internal DC-DC converter that provides the encoder power. The same PSU can power multiple drives, with a 12V 1A unit being ideal for a three drive system.

Do not use the PC internal 12V supply as this can cause return currents to flow in any data cables connected to the PC.

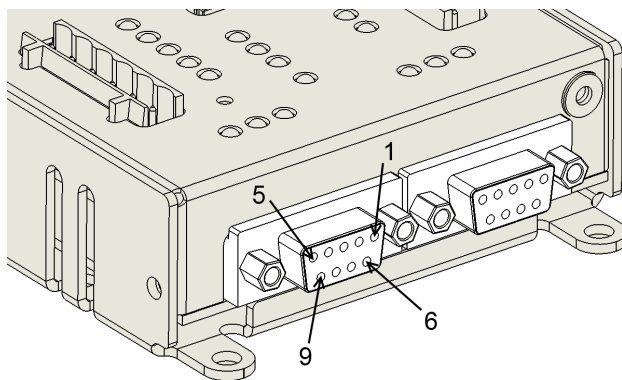
Do not use a supply sharing a common ground with the motor power circuitry, as this will connect the control ground and power ground together.

Route the 12VDC cables 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.

### 3.4.4 Encoder Cable Connection

Using the correct type of encoder and cable is necessary to ensure trouble free, reliable encoder operation. Your BRA drive has two DB9 female sockets and requires DB9 male plugs on the encoder cables. The motor encoder must always be connected. The load encoder is only required when the drive is configured in dual encoder mode. Encoders can have single ended or differential (line drive) output. The output type is configured through the Tuna application.

- Use good quality cable with a braided copper shield.
- Use 24, 26 or 28 AWG multi-stranded wire, 24 AWG is preferred.
- Used shielded twisted pair cable when connecting differential encoders.
- Make sure the shield is connected to the earth pin or the metal D shell at the drive end.
- Do not connect the shield at the motor end. Trim off any loose strands and cover with heatshrink to avoid shorts inside the encoder.
- Route the encoder cables well away from motor cables.
- When connecting single ended encoders, leave the A-, B- and Z- pins unconnected.



Pin	Description
1	A-
2	0V encoder supply
3	B-
4	Earth (Shield)
5	Z-
6	A+
7	+5V encoder supply
8	B+
9	Z+

When using dual encoders it is important that the motor encoder has a higher effective resolution than the load encoder. A ratio of around 10:1 produces excellent results. A typical configuration with direct drive of a 5mm pitch ball screw is: Linear glass scales 0.005mm resolution and a 2500 line (10,000 count) encoder on the motor. This gives 200 counts/mm on the load and 2000 counts/mm on the motor.



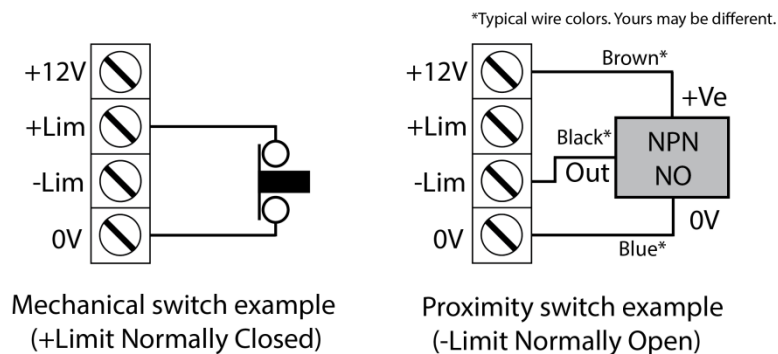
**Note:** Only use optical encoders with your BRA drive. Magnetic or capacitive encoders like the AMT102-V from CUI use an onboard ASIC chip to calculate position. This produces a lag under acceleration, then overshoots as pulses are added to bring the position back to the correct count. While these encoders work well on standard servo drives, your BRA drive tracks position extremely accurately and this behavior is faithfully transferred into machine motion, producing inaccurate and rough operation. This effect is particularly noticeable in dual encoder mode due to the high tracking speed of the velocity loop.

### 3.4.5 Limit Switch Connection

Your BRA drive includes built-in limit switch circuitry to provide intelligent management of home and limit switches.

Use twisted pair cable or shielded cable if possible. If using shielded cable, connect the shield to a convenient earth point near the drive. Leave the shield at the switch end unconnected and insulate with heatshrink to prevent accidental shorts.

Mechanical or NPN inductive proximity switches can be directly connected as shown. Both normally open (NO) or normally closed (NC) types are supported, and can be configured through the Tuna application.



### 3.4.6 PC Interface Connection

The PC Interface allows your PC to control the drive using Step/Direction CNC control software such as Mach3 or similar. The drive receives Step, Direction and  $\overline{\text{Enable}}$  signals from the PC and sends back  $\overline{\text{Error}}$  and  $\overline{\text{Limits}}$  signals.

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

All PC Interface signals are isolated from the drive power circuitry, so additional opto-isolation is not required. These signals are normally connected to the PC via a breakout board such as the Machdrives 4 axis BBA breakout board.

Use shielded cable where 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 signal. Software like Mach3 then holds the signal high for 1-5 $\mu$ s before returning it low again, ready for the next step.



**Dir:** A low level 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.

**Enable:** This input is active low, and all drives should have this line connected together. A low level will enable the drives if no alarm conditions are present, otherwise the  $\overline{\text{Error}}$  output will be activated and the enable request will be ignored.

**Error:** This 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 stop and raise an external error alarm. This output has short circuit current limiting and can sink a maximum of 20mA.

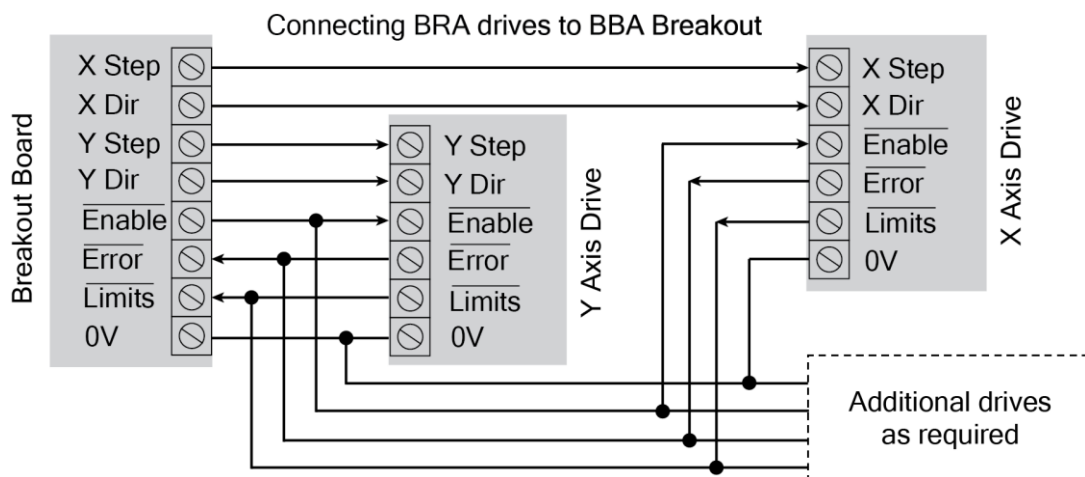
**Limits:** This output is active low, and all drives should have this line connected together. The drive will pull this line low if a limit switch is activated. When the output is deactivated depends on how limits are configured in the Tuna application. This output has short circuit current limiting and can sink a maximum of 20mA.

**0V:** This is the control ground, and all drives should have this line connected together.



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 BRA drives to a PC is using the Machdrives BBA breakout board as shown below. The BBA has the correct signal levels and polarities and can connect up to four drives directly.



### 3.4.7 Power Connection



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

Your BRA drive requires an isolated DC power supply (PSU) of at least 20VDC. Supply voltage is normally determined by the rating of the motors. Choose a voltage the same or slightly higher than the motors rated voltage. Allow enough margin for the voltage to rise under motor deceleration without exceeding the maximum voltage of 150VDC. 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 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 as opening it while the drive is running could damage the drive.

### 3.4.8 Motor Connection



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

While your BRA drive incorporates multiple 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.

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#### 3.4.9 Grounding and Earthing

Your BRA 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 black negative 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 connections on the PC Interface, Limit switches, 12V input and encoders. This is a quiet ground and is only used for control signals.
- The "Earth" is the green center terminal on the barrier strip connector. This is connected to the drive's metal case and the encoder metal shells 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 encoders and limit switches will not function until the 12VDC 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 and install as administrator. You will need to read and accept the EULA before installing the software.

### 4.2 Installing the USB drivers

Your BRA 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.

### 4.3 Activating the Drive

Your drive requires a one-time activation before it is fully functional. Activation ensures that only the correct person receives and commissions the drive, and that you have received a genuine Machdrives product.

To activate your drive send the serial number and your order number to [support@machdrives.com](mailto:support@machdrives.com).

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. 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 should receive the activation code within one business day of requesting it. 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.

#### 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 steps are defined in. This is the same as your native units setting in Mach3. For example if you want 200 steps per millimeter, then set this to "Millimeters" and "Counts per Unit" to 200.
Counts per Unit	Enter how many steps it takes to move 1 full "Unit" as defined above. For example if you want 200 steps per millimeter, then set "Units" to "Millimeters" and "Counts per Unit" to 200.
Reverse Count Direction	When set to "No", a low on the Direction input causes steps to the move the axis in the positive direction. When set to "Yes", this is reversed.
Glitch Filter	This removes discrete jumps in the command velocity information from non-deterministic operating systems like Windows. In single encoder mode this may have little effect. In dual encoder mode this should be "Enabled" for acceptable results.
Sliding Filter	This removes jitter in the command velocity information from non-deterministic operating systems like Windows. In single encoder mode this may have little effect. In dual encoder mode this should be "Enabled" for acceptable results.
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 motor encoder parameters are always visible. The load encoder parameters are only visible when the PID algorithm is set to "Dual Encoder" on the Tuning tab.

Parameter	Description
Output Type	This configures the RS485 differential amplifiers for "Single Ended" or "Differential" input signals. It is important that this correctly matches the encoder output type.
Units	Select the units that the encoder counts are defined in. For example with 0.005mm linear glass scales this would be "Millimeters". With a motor 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. For example if 200 counts per millimeter, then set "Units" to "Millimeters" and "Counts per Unit" to 200.
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 defaults of 4uS for the motor encoder, and 16uS for the load encoder work well in most cases.

## 4.6 Limits/Home Configuration

Determines how the limit switches behave

Parameter	Description
Mode:	
<i>Disabled</i>	Limit switch inputs are ignored and can be left unconnected. $\overline{\text{Limits}}$ output is always inactive.
<i>Switches Only</i>	$\overline{\text{Limits}}$ output goes active when either limit switch activates, and goes inactive when both limit switches are inactive.
<i>Switches + Motor Index</i>	$\overline{\text{Limits}}$ output goes active when either limit switch activates, and goes inactive when a motor encoder index pulse occurs, if both limit switches were inactive.
<i>Switches + Load Index</i>	$\overline{\text{Limits}}$ output goes active when either limit switch activates, and goes inactive when a load encoder index pulse occurs, if both limit switches were inactive.
Switch Polarity	
<i>Normally Open</i>	Limit switch is open for normal operation and pulled down to 0V when a

	limit is reached.
<i>Normally Closed</i>	Limit switch is closed (pulled down to 0V) for normal operation and opens when a limit is reached.
Noise Filter (mS)	This is a digital filter that eliminates electrical noise picked up on the limit switch lines. This sets the minimum time in milliseconds that the limit switch lines 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. Longer values give better noise immunity, shorter values allow homing at faster speeds. The default value of 20mS works well in most cases.
Limit Raises Error:	
	<i>Yes</i> In addition to activating the <u>Limits</u> output, the drive also activates the <u>Error</u> output and stops the drive with fault code 5.
	<i>No</i> The drive only activates the <u>Limits</u> output. It relies on the CNC control software to stop the drive. Use this setting with Mach3 to allow homing and jogging off limits.

#### 4.7 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"> <li>• Short beep on power up.</li> <li>• Short beep on enabling the drive.</li> <li>• Short beep on disabling the drive.</li> <li>• Short beep on <u>Limits</u> output becoming active.</li> <li>• Short beep on <u>Limits</u> output becoming inactive.</li> <li>• Short beep on current limit.</li> </ul>
Audio Alarms	Enable or disable all audio alarms. These are as follows: <ul style="list-style-type: none"> <li>• +12V supply too low or too high.</li> <li>• Trying to enable the drive when a fault condition still exists.</li> <li>• Error output activation.</li> <li>• External error. (Another drive has pulled the Error line low).</li> <li>• Motor voltage is too low or too high.</li> <li>• Motor overload.</li> <li>• Motor short circuit.</li> <li>• Temperature too high from heatsink, bus capacitors or output inductors.</li> <li>• Following error limit exceeded.</li> <li>• Encoder fault.</li> <li>• Activation error. Trying to run the drive from the Step/Dir inputs before it has been activated.</li> <li>• Trying to jog into a limit switch instead of away from it.</li> </ul>
LED Indicators:	
	<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.

## 4.8 Misc 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>Strict</i>	Recommended for dual encoder configuration. Power is removed from the power stage when the motor is stationary and restored instantly when a command is received or the load moves off the commanded position.
<i>Relaxed</i>	Recommended for single encoder configuration. Similar to strict, but allows the motor shaft to relax due to ballscrew 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 - SINGLE ENCODER SYSTEMS

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

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 - Single Encoder

The following parameters are used for tuning single encoder systems.

Parameter	Description
Algorithm	Single Encoder (PI-D): The drive uses a modified PI-D (PIV) algorithm in the Ideal(dependant) format. This algorithm only uses the motor encoder. The load encoder will be ignored if connected.
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 - Single Encoder

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.
- "Motor Encoder" parameters set correctly on configuration tab.
- The motor 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.
- Set "Algorithm" on the Tuning tab to "Single Encoder".

### 5.3 Tuning the Velocity Loop - Single Encoder

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 no 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"), and check Algorithm is set to "Single Encoder".
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 half the "Feed Rate" that you will most commonly use during machining operation.
  - 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: Cyan

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

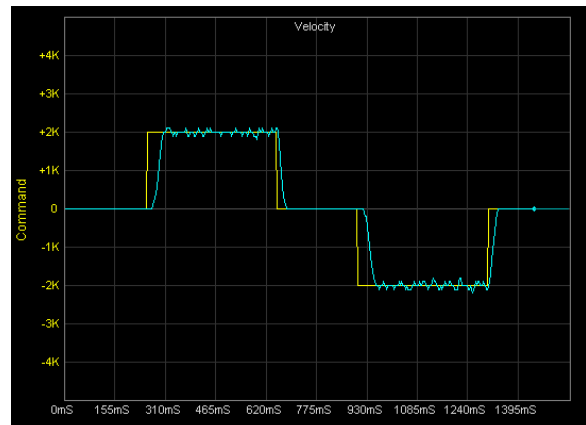
Next, use the "Differential Gain" to dampen out the oscillations.



Command Velocity: Yellow  
Motor Velocity: Cyan

Increasing the "Differential Gain" removes the overshoot 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: Cyan

Keep increasing the "Proportional Gain" and adjusting the "Differential Gain" to keep the response square without overshoot or rounding off the leading edge.

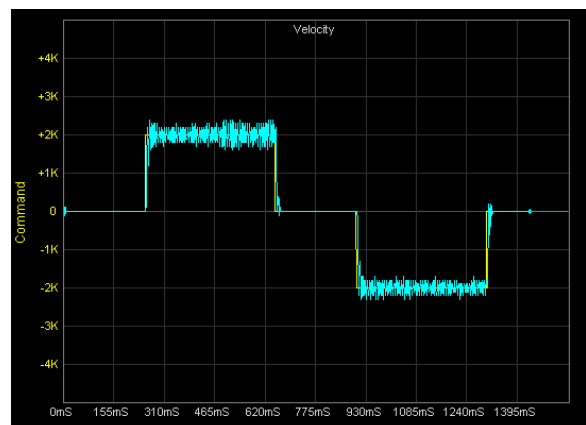
This waveform shows a well tuned Velocity loop with fast and stable tracking of the commanded velocity. Tuning of the velocity loop is now complete.



Command Velocity: Yellow  
Motor Velocity: Cyan

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 - Single Encoder

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".
  - c. **Velocity:** Adjust this value so the calculated "Feed Rate" shows the value that you will most commonly use during normal machine operation.
  - d. **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. If you have not yet determined this value for your machine then set this parameter to 50%.
  - e. **Pause Time:** 250mS
  - f. **Repeat:** Yes
2. Set the "Command Source" dropdown under the scope display to "Wave Generator"

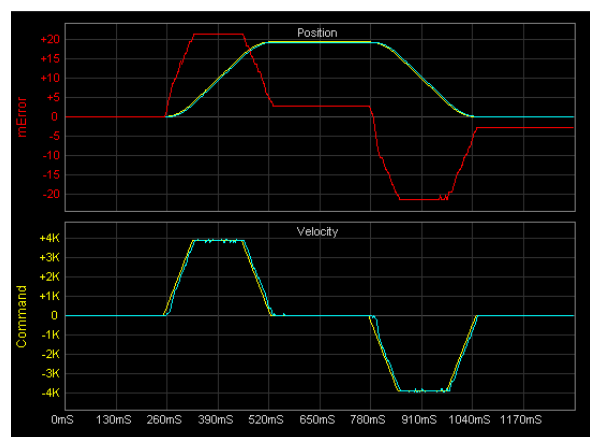


**WARNING:** The following steps will power the motor and result in machine motion. Make sure all personnel are clear of the machine and a method of shutting off machine power is available and close to hand if required.

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.

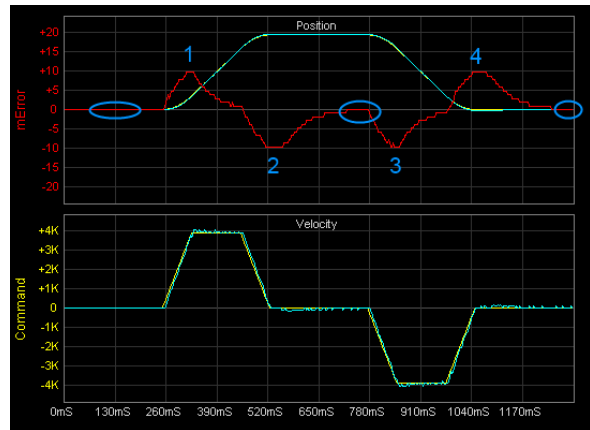
The scope waveforms should look similar to this. Adjust the scale of each trace as appropriate. The red motor position error may be different as "Integral Gain" is set to zero and the position trace is floating.

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



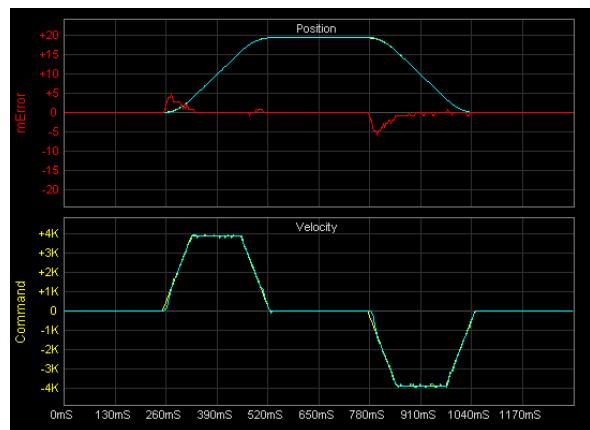
Command Position: Yellow  
 Motor Position: Cyan  
 Motor Position Error: Red

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.



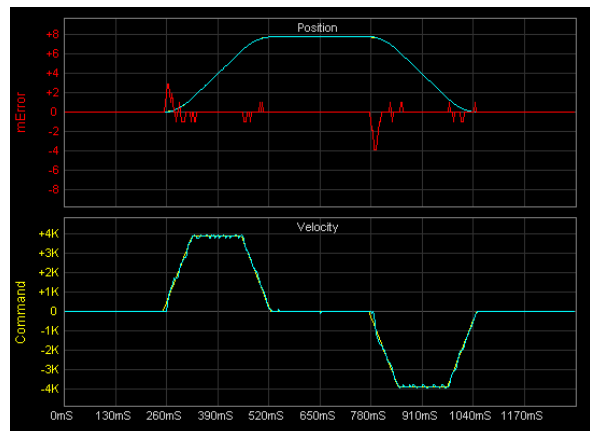
Command Position: Yellow  
 Motor Position: Cyan  
 Motor Position Error: Red

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.



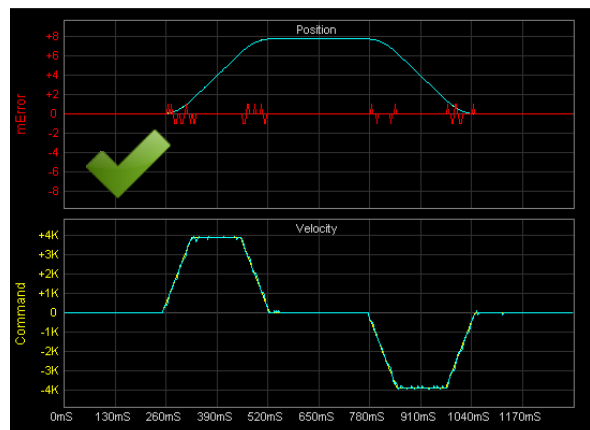
Command Position: Yellow  
 Motor Position: Cyan  
 Motor Position Error: Red

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: Cyan  
 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 "Relaxed" 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.

Remember with single encoder systems the servo drive is trying to maintain zero position error on the motor shaft. Downstream errors such as belt stretch, lead screw pitch error, backlash and thermal expansion are not compensated for. To obtain truly accurate positioning, add a linear glass scale and configure the drive in dual encoder mode.

## 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 TUNING - DUAL ENCODER SYSTEMS

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

The objective of tuning a dual encoder system is to get the load (tool, table etc) to follow the commanded position trajectory as accurately as possible. The motor must be tuned while connected to the machine, and feedback from both encoders is required.

**It is essential that your CNC controller software such as Mach3 has backlash compensation disabled when operating the drive in dual encoder mode.**

### 6.1 PID Parameters - Dual Encoder

The following parameters are used for dual encoder systems.

Parameter	Description
Algorithm	Dual Encoder (Cascade): The drive uses a modified cascade P-PI algorithm, with the optimum "Velocity Feedforward" automatically applied while tuning. This algorithm requires both the motor and load encoders.
Proportional Gain	This is the "P" element in the Velocity loop.
Integral Gain	This is the "I" element in the Velocity loop.
Proportional Gain2	This is the "P" element in the Position loop.
Velocity Feedforward	The velocity feedforward value is used to eliminate position error under constant velocity. This is optimized automatically.
Acceleration Feedforward	Acceleration feedforward is used to eliminate position error under acceleration.
Fast Settle	Reduces the time taken to bring the position error to zero when stopped.
Stiction Compensation	Stiction compensation eliminates errors at the beginning of moves.
Following Error	The maximum allowable difference between the commanded position and the motor or load position, specified in command steps. Exceeding the limit stops the drive.

### 6.2 Checklist - Dual Encoder

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.
- Both "Motor Encoder" and "Load Encoder" parameters set correctly on Configuration tab.
- Encoder functionality 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" disabled on configuration tab.
- Machine axis 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.
- Set "Algorithm" on the Tuning tab to "Dual Encoder".

### 6.3 Tuning the Velocity Loop - Dual Encoder

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 no 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"), and check Algorithm is set to "Dual Encoder".
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 half the "Feed Rate" that you will most commonly use during machining operation.
  - 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 "Integral Gain" first, then the "Proportional Gain", while referring to the example traces below. Keep adjusting only these two values until a well tuned velocity loop is obtained.

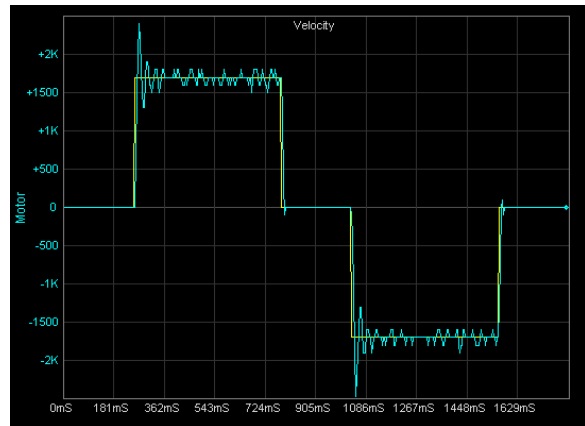
If the drive faults out and the motor trace moves in the wrong direction, remove motor power and reverse the motor wires. DO NOT reverse the Vin power wires by mistake.

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



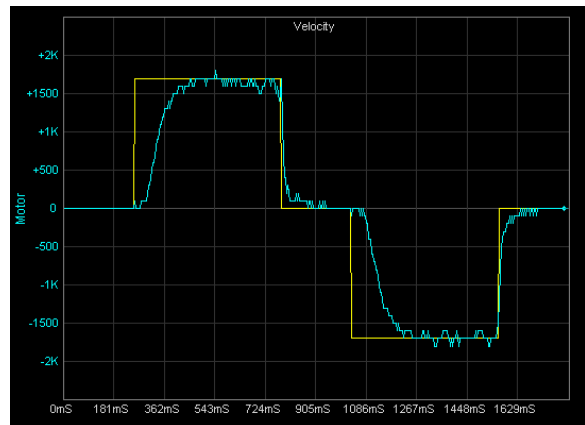
Command Velocity: Yellow  
 Motor Velocity: Cyan

The ratio of "Integral" to "Proportional" has too much "Integral".  
 The response is becoming unstable with overshoot and oscillation on the leading edge.  
 Increase the "Proportional" gain if possible. If the response becomes noisy, then reduce the "Integral" gain until the ratio is correct.



Command Velocity: Yellow  
 Motor Velocity: Cyan

The ratio of "Integral" to "Proportional" has too much "Proportional".  
 The response is sluggish with a slow rise time on the leading edge.  
 Increase the "Integral" gain if possible. If the response becomes noisy, then reduce the "Proportional" until the ratio is correct.



Command Velocity: Yellow  
 Motor Velocity: Cyan

The ratio of "Integral" to "Proportional" is correct, but both gains are too low.  
 The leading edge is lagging the commanded value and the tracking on the top and bottom of the waveforms is loose.  
 Increase both gains to tighten up the response while keeping the stability.  
 Back off the gains if the response starts to become noisy or difficult to stabilize.



Command Velocity: Yellow  
 Motor Velocity: Cyan

A well tuned Velocity loop.  
 Fast and stable tracking of the commanded velocity.  
 Quick rise and fall times with no overshoot.  
 Tight tracking on top and bottom of waveforms.  
 Tuning of the Velocity loop is complete.



## 6.4 Tuning the Position Loop - Dual Encoder

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".
  - c. **Velocity:** Adjust this value so the calculated "Feed Rate" shows the value that you will most commonly use during normal machine operation.
  - d. **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. If you have not yet determined this value for your machine then set this parameter to 50%.
  - e. **Pause Time:** 250mS
  - f. **Repeat:** Yes
2. Set the "Command Source" dropdown under the scope display to "Wave Generator"



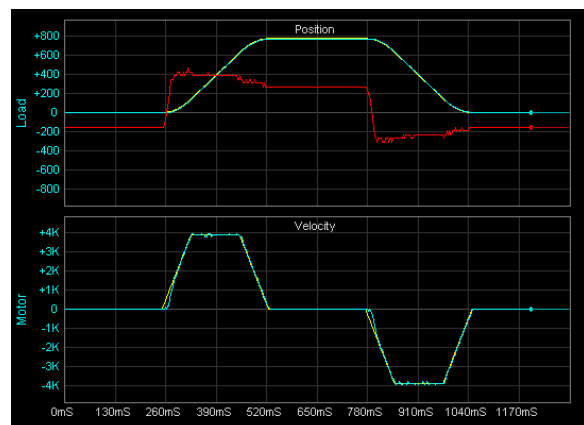
**WARNING:** The following steps will power the motor and result in machine motion. Make sure all personnel are clear of the machine and a method of shutting off machine power is available and close to hand if required.

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", "Load" and "IError" 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.

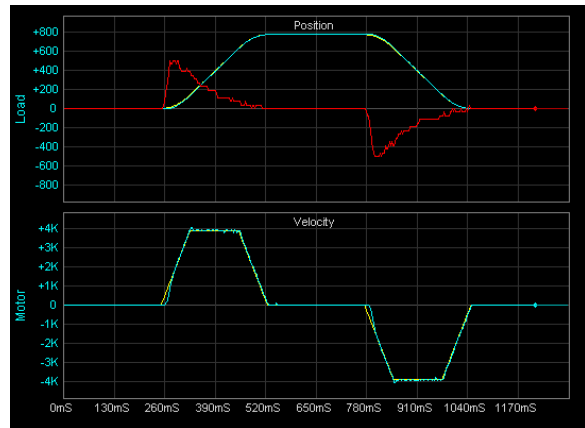
The red load position error may be different as "Proportional Gain 2" is set to zero and the position is floating.

Check that "Acceleration Feedforward" and "Stiction Compensation" are also set to zero and "Fast Settle" is Disabled.



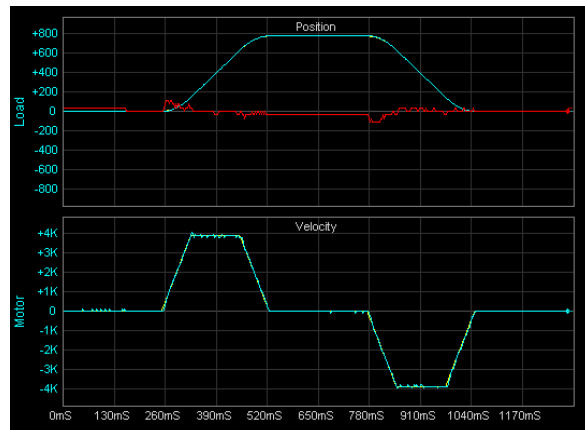
Command Position: Yellow  
 Load Position: Cyan  
 Load Position Error: Red

Start increasing the "Proportional Gain 2" parameter and the error will come to zero at the start, middle and end of the sweep where the motor is stationary.



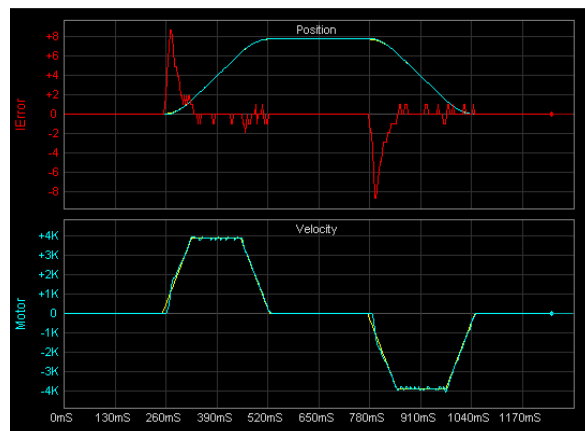
Command Position: Yellow  
 Load Position: Cyan  
 Load Position Error: Red

Keep increasing the "Proportional Gain 2" parameter and the error will keep reducing. When the error gets too small to see clearly, adjust the "IError" trace scale to make it easily visible again. If the motor starts sounding rough or the traces start getting noisy then reduce the "Proportional Gain 2" parameter until motion is smooth and quiet again.



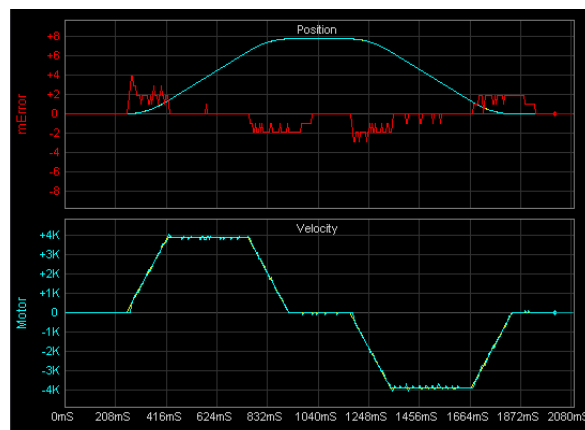
Command Position: Yellow  
 Load Position: Cyan  
 Load Position Error: Red

After the "Proportional Gain 2" setting has been optimized there may be a spike left at the start of one or both moves as shown. Use the "Stiction Compensation" parameter to eliminate this. If the spike starts inverting then the parameter value is too high. Adjust until any remaining error is symmetrical about the zero line.



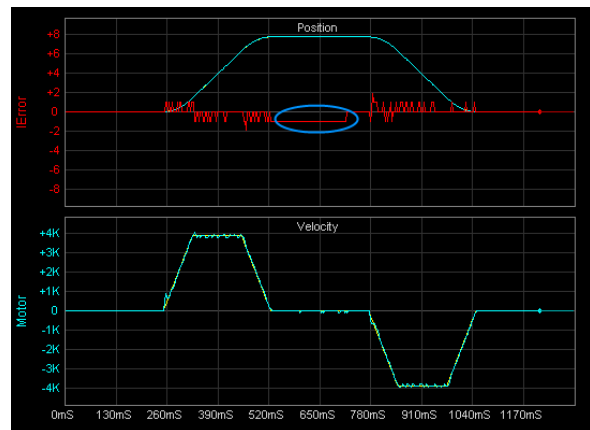
Command Position: Yellow  
 Load Position: Cyan  
 Load Position Error: Red

After the "Proportional Gain 2" setting has been optimized there may be four bumps left as shown where the command accelerates and decelerates. Use the "Acceleration Feedforward" parameter to eliminate this. If the bumps start to invert then the parameter value is too high. Adjust until any remaining error is symmetrical about the zero line.



Command Position: Yellow  
 Load Position: Cyan  
 Load Position Error: Red

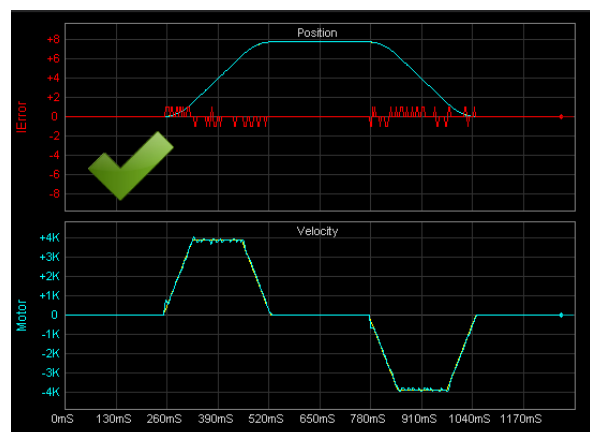
After the "Proportional Gain 2" setting has been optimized the "Fast Settle" parameter can be enabled. This helps eliminate any delay (as shown) in removing the last few counts of position error.



Command Position: Yellow  
 Load Position: Cyan  
 Load Position Error: Red

After all PID parameters are set correctly the load position error should be small as shown.

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).



7. After tuning is complete reduce the "Following Error" to a smaller value e.g. 200, and set "Power Saving" to "Strict" 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, and check its backlash compensation is disable. Check both "Glitch" and "Sliding" filters are enabled on the Configuration tab.

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 effective resolution of the load encoder. This test used a glass 2,500 line (10,000 count) motor encoder and a 0.005mm resolution linear glass scale on the table. The motor encoder setting was 2000 counts/mm and the load encoder 200 counts/mm. The Command Steps/Unit was also set to 200 steps/mm.

## 6.5 Fine Tuning - Dual Encoder

This is just one way to tune a servo drive. You can try adjusting the parameters after tuning to see the effect it has on positioning accuracy. If moves become noisy or gritty sounding then 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.

## 7.0 MONITORING

The Monitoring tab on the Tuna application can be used to check on 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.

## 8.0 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	+12V Low	The +12V control voltage is too low.
3	+12V High	The +12V 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.
5	Limit Activated	A limit switch was activated while the "Limit Raises Error" parameter was set to "Yes"
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.
11	Bus Capacitor Temp	The bus capacitor is too hot. The power supply ripple voltage is probably too high. Add additional bus capacitance close to the drive.
12	Inductor Temp	The output inductors are too hot. This could indicate an overload, or the motor inductance is too low, or cooling is insufficient.
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.

## 9.0 LED INDICATORS

Your BRA drive has 20 LED indicators (18 on the control module and 2 on the power module) 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 and index 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.
+12V	Solid "ON" indicates a good +12VDC supply. "OFF" with short flash "ON" indicates an under voltage condition. "ON" with short flash "OFF" indicates over voltage condition.
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.
Enable	Indicates an active $\overline{\text{Enable}}$ input when illuminated.
Error	Indicates an active $\overline{\text{Error}}$ output when illuminated.
Limits	Indicates an active $\overline{\text{Limits}}$ output when illuminated.
Limit+	Indicates an active Limit+ switch when illuminated.
Limit-	Indicates an active Limit- switch when illuminated.
Encoders	Indicates the state of the encoders A, B and Index lines.
Alarms	When illuminated indicates an abnormal temperature, voltage or current condition.

## 10.0 ALARMS AND NOTIFICATIONS

Your BRA drive features progressive "Volt" and "Temp" alarms to 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 Motor Supply	150VDC	160VDC	170VDC	180VDC
Heatsink Temperature	66C	69C	72C	75C
Capacitor Temperature	80C	85C	90C	100C
Inductor Temperature	105C	110C	115C	120C

"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.

## 11.0 SPECIFICATIONS

Value	Min	Typical	Maximum
<b>Electrical</b>			
Vin Supply Voltage	20VDC		150VDC
Vin Supply Current - Motor Off		15mA	
Motor Current Limit - User	5A	20A	20A
Heatsink Temperature			68°C (154°F)
Capacitor Temperature			84°C (183°F)
Inductor Temperature			109°C (228°F)
+12V Control Voltage	10VDC	12VDC	14VDC
+12V Current - No Encoders		50mA	
+12V Current - Dual Encoders		145mA	
Encoder Frequency (counts)			2MHz
Encoder Supply Voltage		5.0V	
Encoder Current (each)			250mA
Step Frequency			2MHz
Logic Low Input	-0.3V		+0.8V
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		
<b>Mechanical</b>			
Length	142.7mm (5.6")		
Width	89.8mm (3.5")		
Height	29.3mm (1.2")		
Weight	258g (9.1oz)		
Material	Black powder coated aluminum. Epoxy screen printing.		
<b>Environmental</b>			
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	IP1X		