BEAST

Bene's Advanced Stepper Drive

High power driver for stepper motors

improved, digital version

Installation manual

Brief product description

The "BEAST" is a powerful and compact stepper motor output stage for applications in CNC and automation technology. With its wide range of adjustable phase current from 1.8 to 1 0A, it can be used for all common two-phase motors from 56mm (NEMA23) to 11 0mm (NEMA42) flange size.

The output stage is constructed with discrete MOSFETs. The high supply voltage range up to 80V offers significant advantages over most integrated power stage ICs at higher speeds and more safety margin against damage from voltage spikes. An integrated short-circuit protection makes the electronics insensitive to the most common errors.

Microstep control and a new type of continuous sinusoidal commutation significantly reduces noise and resonance at low speeds. Active damping also prevents vibrations at high speeds and enables very high speeds that cannot be achieved with low-cost solutions.

Targeted circuit measures such as optical decoupling of all control signals and limited edge steepness of the circuit breakers (Active Slope Control) ensure maximum interference immunity and minimum interference emission. This increases reliability and helps you to comply with EMC regulations. Of course the device also complies with the latest RoHS regulations.

1 Safety Instructions

The BEAST stepper motor output stage may only be installed and commissioned by qualified personnel. Please read the operating instructions carefully and follow all instructions exactly. Improper installation or operation of the device can cause damage to the electronics or the machine and can result in dangers to the health of the operating personnel. The system manufacturer, who assembles the power amplifier and other components to form the overall system, and the system operator are responsible for compliance with the legal regulations.

Caution: Danger to life! The device can be operated with voltages up to 80V. In the event of a fault, voltage peaks of up to 100V may occur briefly. If you operate the system with more than 60V, the installation and commissioning may only be carried out by a trained electrician or must be approved by such an electrician. No liability is accepted for damage or injury resulting from disregard of safety regulations or improper use.

Always use a power supply unit with potential separation (no autotransformer or variac)! The machine, motor and housing must be grounded in accordance with regulations.

2 System requirements

To obtain a functional drive system, the following components are required in addition to the BEAST power amplifier:

1. A two-phase stepper motor with a rated current between 1.8 and 10A. Three- or five-phase motors or high-impedance motors from printers and disk drives are not suitable.
2. A power supply unit for the voltage supply. with an output voltage between 24 and 80V. Stabilization is not absolutely necessary. More detailed selection criteria are given in chapter 3.2.
3. A signal source for the step and direction signal to control the power amplifier. This can be a PC with appropriate software, an external CNC control (e.g. USB-CNC), or for test purposes also a frequency generator.

2.1 Recommended motors

The table below lists some recommended combinations with motors from Benezan Electronics. The applications mentioned above only represent an approximate selection. If you wish a more precise calculation of the drives, please contact Benezan Electronics.

Motor Type	Dimensions	Phase current	Operating voltage	Application
HS56-0818	56 x 56mm	1,8A	30..48V	Miniature machines,Pick&Place, Pen plotter
HS56-1442	56 x 76mm	4,0A	36..50V	smaller milling machines in aluminium profile-Design
HS60-2150	60 x 90mm	5,0A	48..55V	
HS86-3263	86 x 78mm	6,0A	48..70V	Milling machines for metalworking, larger portal machines
HS86-5880	86 x 118mm	8,0A	60..80V	
HS86-8588	85 x 156mm	9,0A	70..80V[1]	

The BEAST power amplifier also works together with many motors from other manufacturers. Please note, however, that under certain circumstances full performance may not be achieved.

————————————————— 1 with Big-BEAST up to 160V

3 Installation

3.1 Assembly

The output stage is designed for mounting on a 35mm DIN rail ("top-hat rail"). Hook the power amplifier into the rail with the terminal side facing up, then press the bottom side with the control connection firmly onto the rail until it snaps into place. Alternatively, it can also be mounted from the rear side with M3 screws or spacer bolts on a mounting plate. Since the output stage becomes more or less hot during operation depending on the motor current, the following rules must be observed during installation:

- Make sure that there is free air circulation. The distance to other devices, housing wall, cable ducts, etc. should be at least 2 cm on all sides.

- If possible, the heat sink should be mounted vertically with vertical fins.

- For horizontal mounting and motor current >4A, for vertical mounting >6A or at an ambient temperature >40°C, forced cooling (fan) is required.

- With a motor current >8A forced cooling is always necessary.

3.2 Power supply connection

The supply voltage must be between 24 and 80V. A stabilized power supply is not necessarily necessary, an unregulated power supply consisting of transformer, rectifier and filter capacitor is completely sufficient. Please note, however, that the voltage range must be maintained even with mains and load fluctuations (usually ±10%).

The maximum current with which the power supply unit is loaded is approx. 2/3 of the motor current. However, the permanent load is lower in most applications. For the operation of 3 motors with 4A each, for example, a power supply unit with 3 x 4A x 2/3 = 8A peak current and about 5A continuous load capacity is sufficient. An electrolytic capacitor with about 1000µF per A motor current is recommended to keep voltage fluctuations caused by mains hum and short load changes small. A little more won't hurt either, but the capacitor should not be too big either, otherwise the current peaks in the rectifier and transformer will be too big.

Connect the positive pole of the power supply to terminal 1 (labelled 24..80V DC) and the negative pole to terminal 2 (labelled Power Ground). **Caution,** wrong polarity can damage the power amplifier, especially if the power supply does not have a fast fuse or current limiter

If necessary, several BEAST power amplifiers can be operated in parallel on one power supply unit. Please note please ensure that the negative connection (Power Ground) is connected to the heat sink and therefore automatically to the housing (potential earth) is connected. The connecting cables between the power supply unit and the power amplifiers should be laid in a star shape and as short as possible, i.e. each power amplifier should have its own direct connection to the power supply unit.

3.3 Motor connection

The output stage is suitable for the operation of two-phase motors. These usually have four or eight connections. For motors with eight connections, two windings can be connected in parallel or in series. The following formula can be helpful as a decision aid - serial or parallel: The supply voltage should be in the range of 10 to 25 times the rated motor voltage. If the nominal voltage is not given, it can be calculated by multiplying the winding resistance by the nominal current. Example:

Motor data: 8 connections, 0.8Ω per winding, rated current 3A per winding, 6A parallel
parallel connection 2x0.8Ω gives 0.4Ω * 6A = 2.4V Series connection: 2x0.8Ω gives 1.6Ω
* 3A = 4.8V
Line voltage 48V = 20 x 2.4V = 10 x 4.8V

In this case both types of connection would be possible. However, parallel connection allows higher speeds, and is therefore usually preferred.

Motors with 6 terminals can also be used, but this is not recommended as these are mostly older models designed for unipolar operation with obsolete power amplifiers. Old motors, which can usually be recognized by their round, cylindrical housing, are not designed for microstep operation and exhibit increased vibration and reduced torque.

Connect one winding of the motor to terminals 3 and 4 (A-B), the second winding to terminals 5 and 6 (C-D). The polarity and sequence is irrelevant for the function, but determines the direction of rotation of the motor. If the motor turns in the wrong direction, this can be corrected by reversing the polarity of one (not both) of the windings.

Caution, never disconnect the terminal connection to the motor or power supply unit when the power supply unit

is switched on. The output stage is protected against interruption of the motor cable. However, a rotating motor acts like a generator when switched off and returns energy to the output stage. It cannot absorb the energy if the connection to the power supply has been disconnected and may be damaged. Furthermore, the contacts of the connectors are affected by sparking.

3.4 Settings

The phase current is selected with the rotary coding switch "Current Set". No measuring device and no external components are required, only a screwdriver. The phase current corresponds to the maximum current through a winding or the magnitude value of the current vector (i.e. not the rms value) according to the following table:

Switch position	Phase current	Switch position	Phase current
0	1,8A	8	5,0A
1	2,0A	9	5,5A
2	2,4A	A	6,0A
3	2,8A	B	6,5A
4	3,2A	C	7,0A
5	3,6A	D	8,0A
6	4,0A	E	9,0A
7	4,5A	F	10,0A

Switch No.	Meaning
1	Resolution: 1/5, 1/10, 1/20, 1/40 Microstep
2	
3	automatic current reduction
4	Waveform sine + harmonic

Attention Be sure to set the correct phase current before switching on the power supply. Too high a current - even for a short time - can damage the motor. If you do not need the full torque of the motor, you can also set a slightly lower current. This significantly reduces heat generation. However, do not set less than 70% of the rated current, otherwise the motor may not run smoothly.

The BEAST output stage has a current reduction which can either be automatic or controlled by an input signal. With automatic current reduction, the phase current is reduced to approx. 66% of the set maximum value if no step signal has been received for longer than approx. 0.6s. This reduces the losses and thus the heating of the motor to less than half, while still sufficient torque is available to hold the position

With heavy loads, such as CNC metalworking, the automatic current reduction is not recommended, because otherwise, with straight lines parallel to the axes, the non-moving axis may lose steps when lateral forces are applied. To avoid this, the explicit current reduction via the input signal should be selected here. The control then only activates the current reduction if *all* Axles stationary.

The Piano DIP switches have the following assignment (pressing down activates the option):
Switch No. 3 activates the automatic current reduction. If it is pressed, the power stage automatically reduces the current to 66% of if no step has been executed for more than 0.6s. If it is switched off, the current reduction is activated via the input of the RJ45 socket.

Switch #4 is used to adjust the waveform of the motor current. Some motor types do not have an exact sine wave but a waveform slightly distorted in the direction of a triangle. The optimal waveform can be determined experimentally, and leads to a reduction of vibrations in certain speed ranges.

Switches 1 and 2 (left) are used to set the resolution. The following combinations are possible.

Switch position (down = 1)		Resolution Microstep	Steps/revolution at 1,8°/step
V V	0 0	1/5	1000

V W	0 1	1/10	2000
W V	1 0	1/20	4000
W W	1 1	1/40	8000

3.5 Status display

The output stage indicates the current status with 3 LEDs. The meaning of the possible combinations is listed in the following table:

Colour combination	Meaning	Cause
-	switched off	Operating voltage too low or sleep mode
green	Operation, full current	-
yellow	Operation, current reduction	no step signal or current reduction signal
red	Overvoltage	Braking energy too high or power supply unsuitable
flashing red	Overheating	Ambient temperature too high or ventilation impeded
red/yellow flashing	Overcurrent	Short circuit, wrong connection or motor defective
flashing yellow	Current too low	no motor connected or motor cable interrupted

3.6 Signal connections

The step and direction signals are connected to the RJ-45 socket marked "Command Input". The power amplifiers can be connected directly to the Benezan Electronics breakout board with standard Ethernet patch cables (1:1, no crossover or X!). The wire colours apply when using standard Cat5 Ethernet patch cables (e.g. from Reichelt). Pin 1 is located on the side of the housing corner.

BEAST RJ-45 socket		Wire colour
8	Status output -	brown
7	Status output +	white/brown
6	Step Input +	green
5	Direction entrance -	white/blue
4	Direction entrance +	blue
3	Step Input -	white/green
2	Current reduction -	orange
1	Current reduction +	white/orange

If you are not using a breakout board with compatible RJ45 jacks, you can connect the power amplifier as follows:
- All negative inputs are connected to ground and the positive inputs are driven with a TTL or CMOS signal
- All positive inputs are connected to +5V or +3.3V and the negative inputs are driven by a low-active driver (or open collector).
- Positive and negative inputs are controlled with complementary drivers (RS422). The status output is conductive in normal operation (+ and - connected), interrupted in case of error message. If the negative output is connected to ground, an open-collector signal with 0=Ok and 1=error is obtained at the positive output.
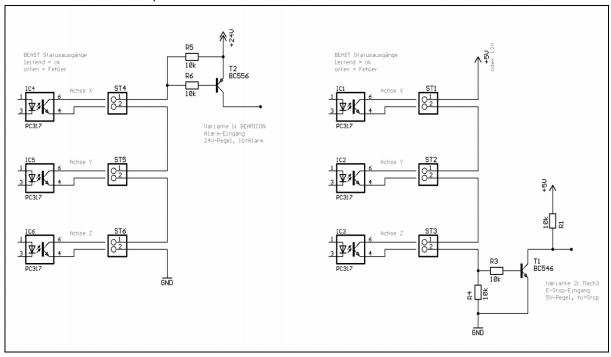
The step signal reacts to the positive edge, i.e. when pin 3 becomes positive with respect to pin 6. When changing direction, a distance of min 2µs should be kept to the preceding and following positive edge.

The current reduction is active (66%) when voltage is applied to the input. If no or automatic lowering is desired, the input can be left open.

3.7 Stop on error

For machines with several axes, it is essential to provide a circuit that informs the central control about possible error states of individual axes and ensures controlled stopping of all axes triggers. With milling machines, for example, damage to the workpiece and the machine can occur if only one axis and the others would drive on. If the BEAST power amplifiers are connected to a suitable breakout board, the status outputs of all axes are automatically linked and switched to the alarm input of the controller. If other controllers are used, a small external circuit is necessary.

The figure above shows two circuit examples, one for 24V level (e.g. PLC systems) and one for 5V level (PC parallel port, Mach3 without breakout board or from another manufacturer). The status outputs of the BEAST output stages are connected in series. A fault in at least one output stage, the interruption of a cable or a power failure will certainly lead to an alarm message to the control system.

The pull-up resistor R1 can be omitted in most cases because it is already internally integrated in the parallel port of the PC. This means that in most cases no external 5V supply is necessary. Up to 5 axes can be connected in series.

3.8 Sleep mode

In order to ensure a safe stop, e.g. in case of an emergency stop or open safety doors, it is often necessary to disconnect the motors from the power supply. A shutdown via software or a (non-redundant) enable signal is not sufficiently safe. However, if the supply voltage is switched off completely, the disadvantage is that the current microstep position is lost and the motor jumps to the next full step when it is switched on again. As a result, a reference run would be necessary after each emergency stop or door opener, which takes time and is an unnecessary source of error.

With the BEAST power amplifier this problem can be circumvented with the sleep mode. When the supply voltage is reduced to 12V, the motor is de-energized, but the processor remains active and keeps the current position. When the full operating voltage is switched on again, no steps are lost and work can be continued without reference run.

It is recommended to connect a fuse (<1A) and a diode in series in the positive lead of the 12V power supply. This protects the 12V power supply from the higher operating voltage. It also ensures that regardless of the correct function of the power stage, the motor cannot start unintentionally in sleep mode, as increased current consumption causes the fuse to blow.

4 New features

The present version of the BEAST power amplifier has been improved once again.

- With the exception of the connectors and switches, all components - even the power transistors - are 100% SMD-assembled. This increases reliability and improves heat dissipation.

- The resolution is selectable from 1/5 to 1/40 microstep. This means that the output stage can also be used for applications in which the step frequency is limited by the software or which require extreme resolution (e.g. camera tracking).

- The waveform is switchable between pure sine and sine with harmonic content. This reduces the vibrations of some engine types.

- The engine noise at standstill has been reduced.

- The resonance damping has been improved, the sometimes rough running no longer occurs with some engine types and certain frequencies.

- The output stage detects interruptions in the motor cable. In case of cable breakage, the system can be switched off in a defined manner.

- The resonance damping can no longer be switched off, and the direction of rotation can no longer be reversed by a switch (if necessary, reverse the polarity of the motor winding).

- Sleep mode prevents step loss in case of emergency stop

(see3.8).

4.1 Compatibility

Of course, the new version is compatible with earlier versions. If you replace BEAST power amplifiers in an existing system, set the DIP switches to a resolution of 1/10 microstep (switch no. 1 off, switch no. 2 pressed). Set the automatic current reduction (switch no. 3) in the same way as the previous one, and set the waveform to pure sine wave (switch no. 4 off). If you have used the direction of rotation reversal with the old power amplifier, you must now do this by reversing the polarity of the direction signal in the control software or by reversing the polarity of a motor winding.

It is no longer necessary to adjust the motor size or switch off the resonance damping, because the damping automatically adapts to the motor.

5 Technical data

5.1 Absolute limit values

The following parameters must not be exceeded under any circumstances to prevent damage to the device:

Parameters	min.	max.	Unit
Operating voltage	-0.5	+100	V
Storage temperature	-40	+85	°C
Operating temperature	-20	+70	°C
Voltage at signal inputs	-6	+6	V
Voltage at status output	-5	+30	V
Current at status output		20	mA
Potential difference between supply voltage and Signal inputs (optical coupler)	-100	+100	V

5.2 Electrical connection values

Parameters	min.	max.	Unit
Operating voltage	+24	+80	V
Current consumption without motor		50	mA
Ambient temperature	0	+50	°C
Level logical 0 for signal inputs	-5	+0.8	V
Level logic 1 for signal inputs	+3	+5.5	V
Current consumption signal inputs at +5V	4	12[2]	mA
Current consumption signal inputs at +3.3V	3	6	mA
Pulse width for step signal	2		µs
Setup time Direction signal valid until step[3]	2		µs
Level logical 0 for status output		0.8	V
Crotch frequency	0	200	kHz
Delay time automatic current reduction	0.5	0.7	s
Threshold over temperature	70	85	°C
Current control accuracy	-10	+10	%
Wire cross section for terminals	0.5	2.5	mm²
Number of microsteps per full step	5, 10, 20, 40		-
Microsteps/revolution for standard motor[4]	1000, 2000, 4000, 8000		-

5.3 Dimensions

Parameters	typ.	Unit
Length (incl. clamps)	112	mm
Height (without top-hat rail)	63	mm
Width	48	mm

---

2 This is the maximum current that flows when 5V is applied directly. A normal CMOS driver (e.g. 74HC245) with 8mA driver power is still sufficient to drive the input at 4.5V.

3 Step is executed on rising edge, i.e. transition from logical 0 to logical 1

4 Standard motor: 1 ,8°/full step, 200 full steps/revolution