PiezoDrive
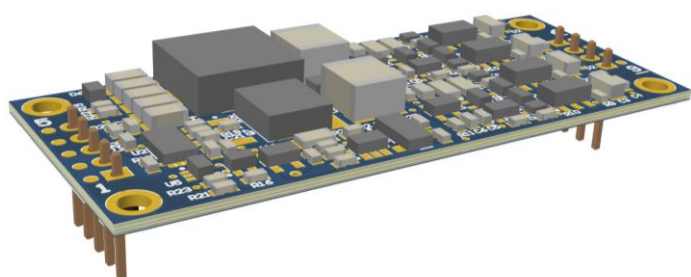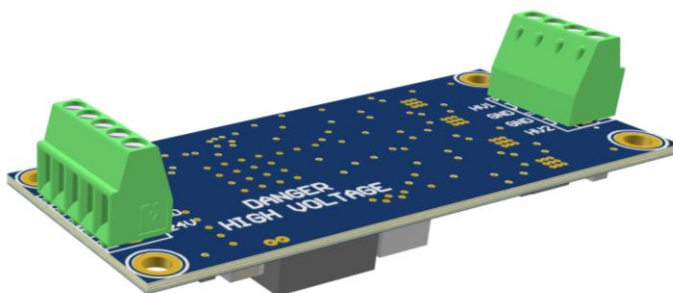
BD300, BD250, BD200, BD150

Dual Channel Drivers for Piezo Bender Actuators

Hardware Version V5

BD300-PCB

BD300-Screw

The BD300 family of miniature driver modules contain a high-voltage power supply and two linear amplifier channels. The individual channels can drive piezoelectric actuators up to +300V, or can be combined for a single +/-300V output. An inverting option also allows these modules to drive two and three wire piezoelectric bender actuators.

The 3V input range, fast response, and high peak current suits applications including high speed valves, robot actuators, non-resonant piezo motors, and motion control applications.

The BD300 modules include comprehensive overload protection and are available with screw terminals or PCB mounting pins.

Voltage Ranges

Variant	Output Voltage	Differential Output	Gain	Peak Current	RMS Current
BD300	300 V	+/-300 V	101	50 mA	11 mA
BD250	250 V	+/-250 V	83.6	59 mA	13 mA
BD200	200 V	+/-200 V	67.7	73 mA	16 mA
BD150	150 V	+/-150 V	51.0	95 mA	21 mA

Operation
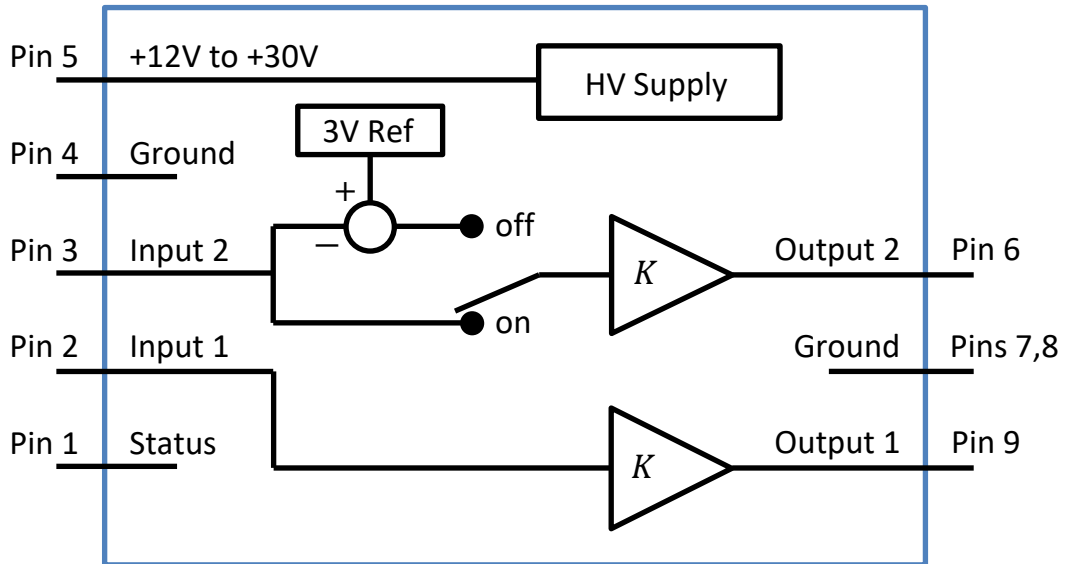
The modules contain a high voltage DC-DC converter and two linear amplifier channels. A 0V to 3V input applied to channel 1 will produce a 0V to full range output. Channel 2 can be switched between a non-inverting configuration (on) which is identical to channel 1, or an inverting configuration (off), which is useful when driving three wire benders or creating a single differential output.

Application Example: Independent Channels
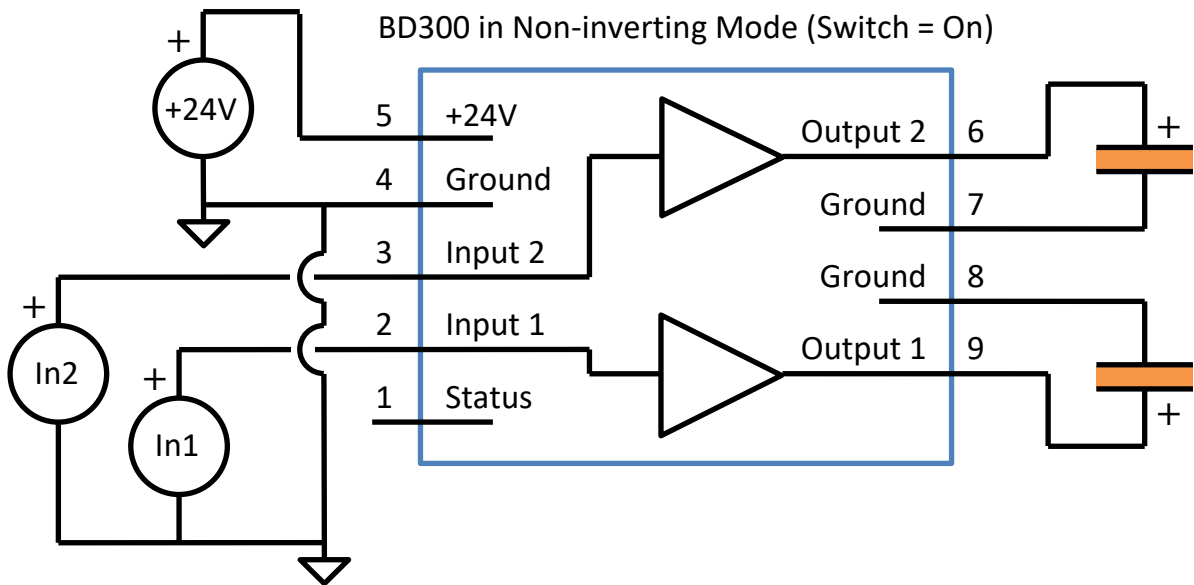
In this example, two 0V to 3V input signal sources produce a 0V to full-range output on two independent loads. It is recommended to connect the power supply directly to Pin 5 and 4 via twisted pair cable (if using screw terminals).

Application Example: +/-200V Series Poled Bender
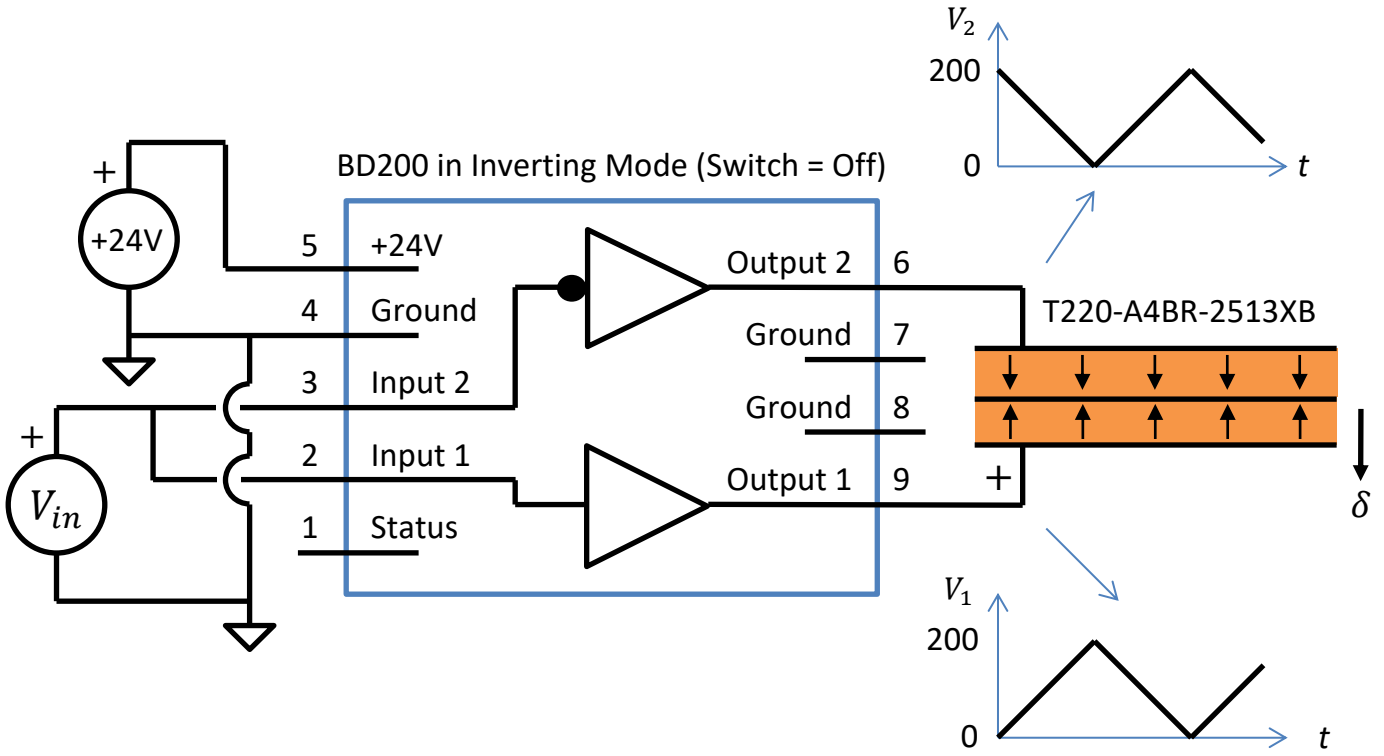
This example shows a series poled bender driven in the "two-wire" configuration [1]. A 0V to 3V input signal produces +/-200V output. Note that the load is driven differentially and cannot be connected to ground. Channel 2 is configured in the inverting mode by setting the switch to "off". The voltage at output 1 is $V_1 = KV_{in}$, and the voltage at output 2 is $V_2 = K(3 - V_{in})$, where $K = 67.7$ for the BD200. Therefore, the voltage across the load is

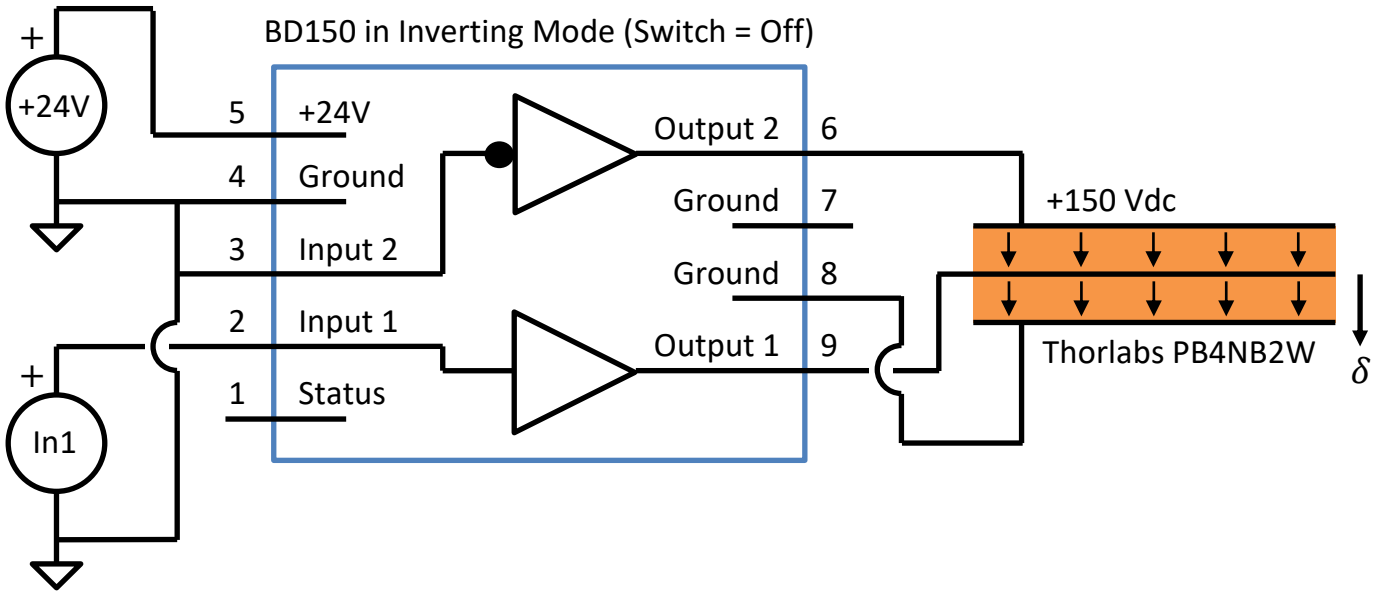$$V_{Load} = V_1 - V_2 = 2K(V_{in} - 1.5)$$

Therefore, a 0V input produces -200V across the load, 1.5V input produces 0V across the load, and 3V produces +200V across the load.

When the output voltage is positive, the actuator bends downward. The deflection δ is

$$\delta = 2K(V_{in} - 1.5)\frac{\delta_{pp}}{V_{pp}}$$

where δ_{pp} is the peak-to-peak displacement of the bender, and V_{pp} is the maximum peak-to-peak voltage. For example, $\delta_{pp} = 1.048$ mm, and $V_{pp} = 360$ for the T220-A4BR-2513XB actuator (www.piezo.com).

Application Example: +150V Three-wire Parallel Poled Bender

BD150 in Inverting Mode (Switch = Off)

Pin	Name
5	+24V
4	Ground
3	Input 2
2	Input 1
1	Status

Output 2 — 6
Ground — 7
Ground — 8
Output 1 — 9

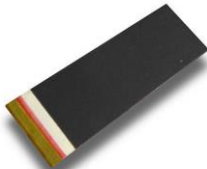+150 Vdc

Thorlabs PB4NB2W

δ

This example shows a parallel poled bender driven in the "biased unipolar" or "three-wire" configuration [1]. The +150V bias voltage is achieved by configuring channel 2 in inverting mode and grounding the input.

A zero volt input results in +150V across the top piezo layer and maximum upward deflection. A +3V input results in +150V across the bottom piezo layer and maximum downward deflection. The deflection δ can be represented by

$$\delta = \frac{V_{in} - 1.5}{3} \, \delta_{pp}$$

where δ_{pp} is the peak-to-peak displacement of the bender. Examples of compatible actuators are listed below:

Actuator	Part Number	Bias Voltage	Amplifier
	PiezoDrive BA6020	+150V	BD150
	Thorlabs PB4NB2W	+150V	BD150
	Noliac CMBR02 (see note 1)	+200V	BD200

Note 1: The recommended +100V and -100V bias voltages can be replaced by +200V and 0V

Application Example: Two-wire Parallel Poled Bender

V_2

150

0

t

$V_2 - V_1$

+150

−150

BD150 in Inverting Mode (Switch = Off)

5	+24V
4	Ground
3	Input 2
2	Input 1
1	Status

Output 2   6
Ground   7
Ground   8
Output 1   9

+24V

In1

+
−

BA6020

δ

V_{in}

3

1.5

0   t

V_1

150

0   t
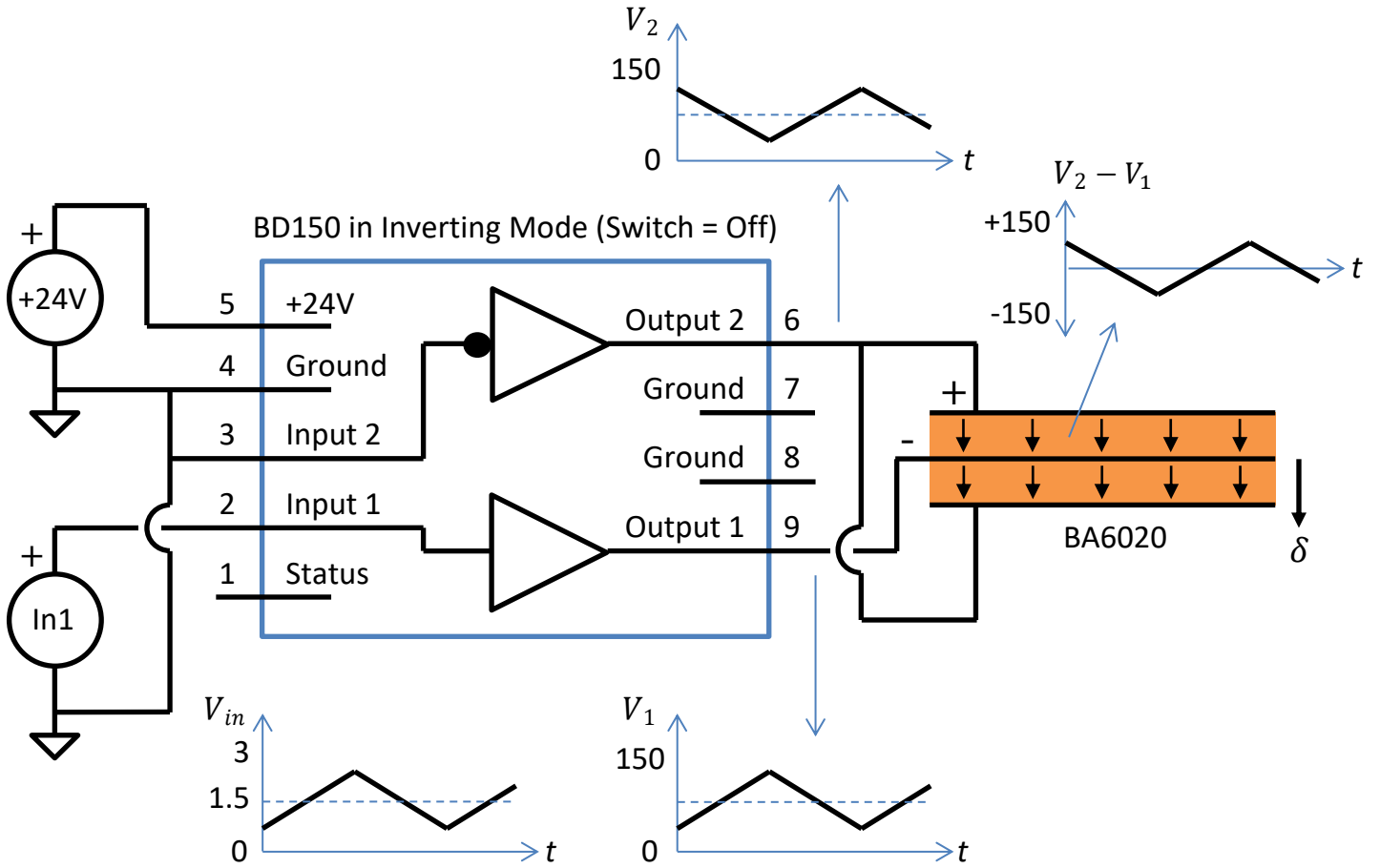
To avoid negative electric fields, parallel poled benders are usually driven in the three-wire configuration described in the previous example. However, parallel poled benders can also be connected in a two-wire configuration and driven with a bipolar signal, as shown in this example.

The negative electric field limit of common piezoelectric materials is -400V/mm to -500V/mm. A value of -300V/mm can used as a conservative choice which provides an additional safety factor. For example, the thickness of each layer in a BA6020 actuator is 0.3mm so the maximum negative voltage across each layer is -90V. If the thickness is not known, use 60% of the recommended positive voltage (which is based on a positive electric field limit of +500V/mm typically recommended by bender manufacturers). For example, the BA6020 has a recommended positive voltage of +150V per layer, so each layer can be connected in parallel as shown above, and driven with +/-90V.

In the schematic, the voltage at output 1 is $V_1 = KV_{in}$, and the voltage at output 2 is $V_2 = K(3 - V_{in})$, where $K = 51$ for the BD150. The voltage across the top layer is

$$V_{top} = V_2 - V_1 = 3K - 2KV_{in}$$

Therefore, a 0V input results in +153V across the top layer, a 1.5V input results in 0V across both layers, and a 3V input results in -153V across the top player. The voltages across the bottom layer are equal but inverted.

Since a 1.5V input results in zero volts across each layer and zero deflection, it is convenient to define the input source as a 1.5V offset and additional voltage V_x which is proportional to deflection, that is

$$V_{in} = 1.5 + V_x$$

Where the full-scale range of V_x is +/-1.5V. With this substitution, the voltage across the top layer becomes $V_{top} = -2KV_x$ and the effective voltage gain is

$$\frac{V_{top}}{V_x} = -\frac{V_{bot}}{V_x} = -2KV_x$$

The deflection δ can then be written

$$\delta = \frac{2V_x}{3} \frac{3K\delta_{pp}}{V_{pp}}$$

Where δ_{pp} is the peak-to-peak displacement of the bender and V_{pp} is the maximum voltage. Either the three-wire specifications, or two-wire specifications can be used.

With a maximum negative voltage of $V_{neg} = -\alpha V_{pos}$, the maximum peak amplitude of V_x is

$$|V_x| = \frac{V_{neg}}{2K} = \frac{\alpha V_{pos}}{2K}$$

where α represents the ratio of maximum negative to maximum positive voltage $\alpha = |V_{neg}/V_{pos}|$. For the BA6020 and many other bimorph benders $\alpha = 0.6$, i.e. 60%. Therefore, the maximum input voltage with a BA6020 actuator and BD150 is

$$V_{in} = 1.5 \pm \frac{V_{neg}}{2K} = 1.5 \pm 0.88$$

Since the maximum peak-to-peak amplitude of V_x is $2|V_x|$, the maximum peak-to-peak deflection in the two-wire configuration $\delta_{pp,2w}$ is

$$\delta_{pp,2w} = \frac{4\alpha V_{pos}}{6K} \frac{3K\delta_{pp}}{V_{pp}} = 2\alpha\delta_{pp}$$

This above simplification makes use of the fact that $V_{pos} = V_{pp}$ in the three-wire configuration. Therefore, the deflection in the two-wire configuration is increased by a factor of 2α. When $\alpha = 0.6$, approximately 20% more deflection and force can be expected from the BA6020 in the two-wire configuration compared to the three-wire configuration. If α is chosen more conservatively to be 0.5, the deflection in the two-wire configuration is identical to the three-wire case.

Note: Multilayer actuators such as the Noliac CMBR02 use a much higher positive electric field and are not suited to a two-wire configuration unless a much smaller negative voltage is used, i.e. $\alpha = 0.15$. Ceramic insulated multilayer benders are best suited to the three wire configuration.

Other Specifications

Specification	Value	Notes
Input voltage range	0V to 3V	
Input impedance	10 $k\Omega$, 5 $k\Omega$	Channel 1 is 10 $k\Omega$, Channel 2 is 5 $k\Omega$
Minimum output voltage	< 3 V	Output voltage does not reach zero
Over-current protection	Peak and RMS	Includes direct short circuit
Thermal protection	70 C	Disabled when PCB temp > 70 C
Power supply	+12 V to +30 V	+24 V recommended
Supply power	5W	Maximum average power under full load
Small signal bandwidth	20 kHz	Measured with 80% full range voltage
Slew rate	12 V/us	
Output noise	<1% of full range	E.g. < 3 Vpp for BD300
Status pin voltage	0.6 V	< 0.5 V signals a thermal overload
Temperature range	0 C to +50 C	
Humidity	Non-condensing	
Dimensions	60 x 25.4 mm	2.3 x 1 inch
Height	8 mm	Total height required for PCB mount version
Weight	11 g	

Output Current

The peak and average current limit specifications are listed in "Voltage Ranges". The RMS current limit defines the maximum frequency that is achievable with a capacitive load, which is discussed in "Power Bandwidth".

The peak current can be drawn for up to five milliseconds before the RMS current limit engages. This allows fast step changes with capacitive loads. The output voltage slew rate is:

$$\frac{\Delta V_o}{\Delta t} = \frac{i_{pk}}{C_L}$$

Where i_{pk} is the peak current limit, C_L is the load capacitance, ΔV_o is the change in output voltage, and Δt is the time interval. For example, a voltage change of ΔV will require a slewing time of $\Delta t = \Delta V_o C_L / i_{pk}$.

Power Bandwidth

The power bandwidth is the maximum frequency periodic signal that can be reproduced without distortion. The online power bandwidth calculator determines the maximum operating frequency and required power for a given load capacitance. The calculator includes the effects of current limit, slew-rate, and signal bandwidth.

The calculator does not include the time-constant of the peak current limit, and therefore may become inaccurate when the power bandwidth is below 50 Hz.

BD300 Power Bandwidth Calculator

Input Parameters			
Module Part Number		BD300	V
Load Capacitance (effective)	C	0.1	uF
Output Voltage (peak to peak)	Vpp	300	V
Frequency (optional)	f	10	Hz

Results		
Maximum Average Current	Iav,max	0.005 A
Load RMS current	Irms	0.001 A
Load Average Current	Iav	0.000 A
Input Supply Power	P	0.590 W

Maximum Frequency (Power Bandwidth)	
Sine Wave	167 Hz
Triangle Wave	167 Hz
Square Wave	83 Hz
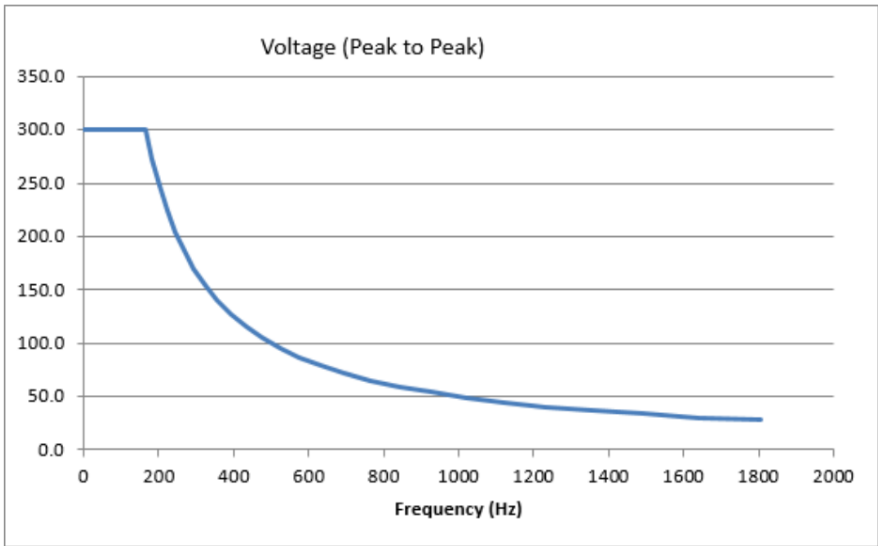
Signal Bandwidth and Settling Time

With a load capacitance below 10 nF, the small signal bandwidth of the BD300 modules is 20 kHz. The rise-time with a step input is approximately 20 us.

With a load capacitance above 10 nF, the bandwidth and rise-time are effected by the output impedance, current limit, and voltage slew-rate. For periodic signals, refer to the online calculator above. For step-response rise times, refer to "Output Current".
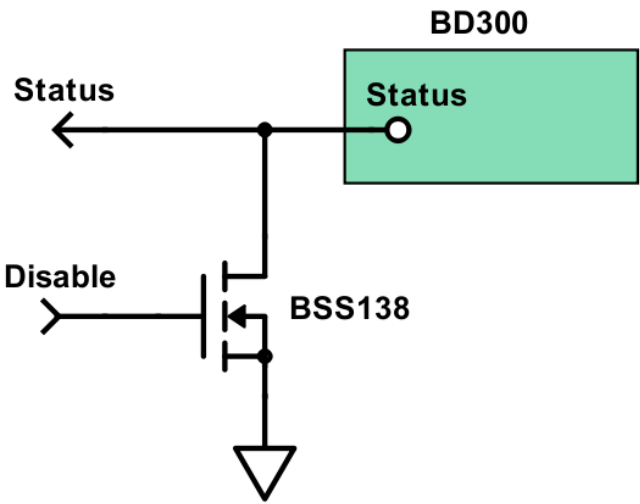
Heat Dissipation

When driving capacitive loads, the heat dissipation of the module is equal to the required supply power calculated by the online calculator. The worst case is approximately 5W which may require some enclosure ventilation for passive convection. The PCB temperature can be monitored by measuring the voltage on the test point labelled "Temp". The temperature in degrees C is

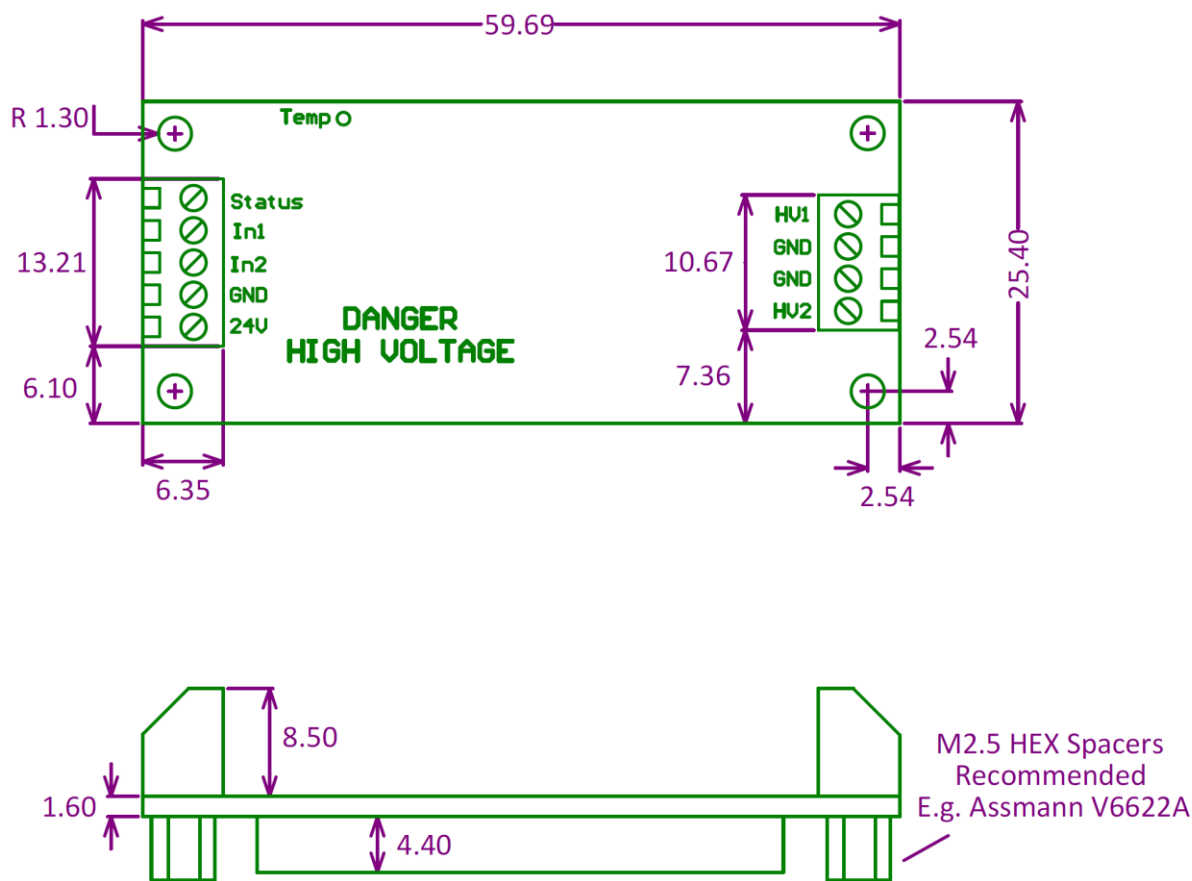$$T = \frac{V_{temp} - 0.550}{1.96 \times 10^{-3}} + 25$$

Status Pin

In normal operation, the status pin voltage is 0.6V. If the voltage drops below 0.5V, this indicates that the PCB temperature is above 70C and the power supply has been temporarily disabled.
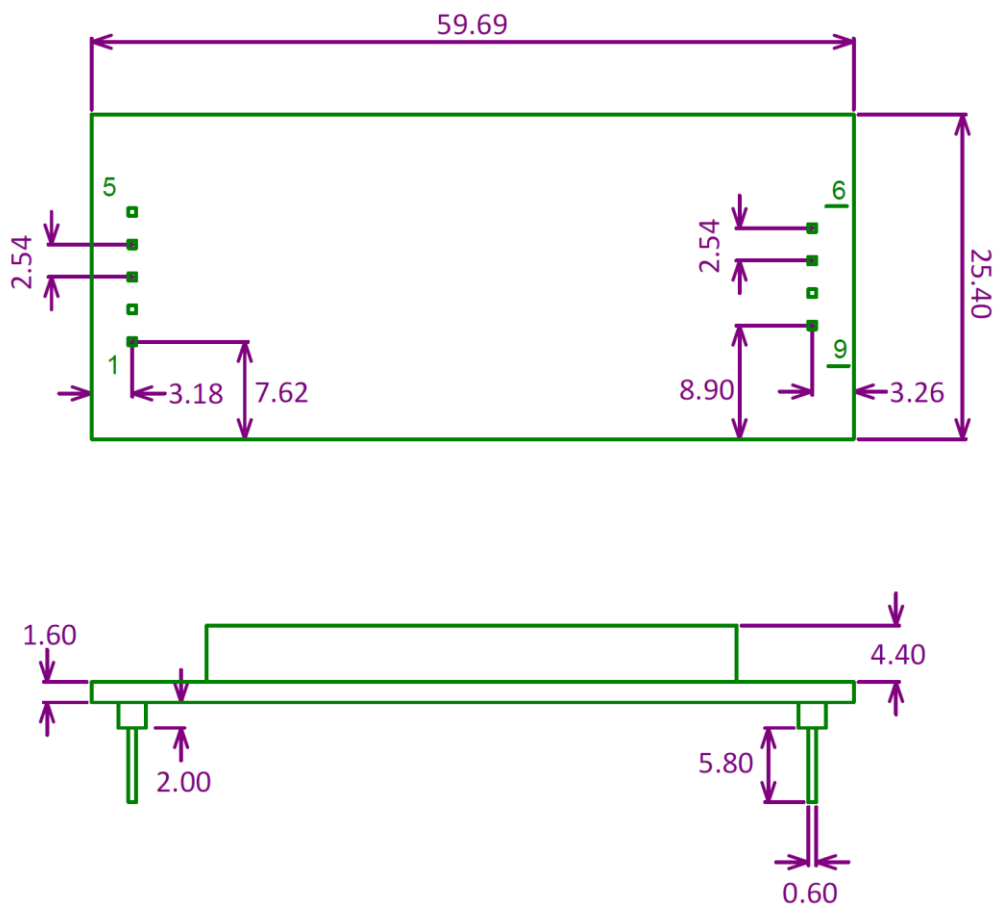
The status pin can also be pulled low to disable the high-voltage power supply. For example, by using the circuit below:

Dimensions BD300-Screw (mm)

59.69

R 1.30

Temp O

Status
In1
In2
GND
24V

HV1
GND
GND
HV2

13.21

10.67

25.40

DANGER
HIGH VOLTAGE

6.10

7.36

2.54

6.35

2.54

8.50

1.60

4.40

M2.5 HEX Spacers
Recommended
E.g. Assmann V6622A

Dimensions BD300-PCB (mm)

59.69

5

6

2.54

2.54

25.40

1

9

3.18   7.62

8.90

3.26

1.60

4.40

2.00

5.80

0.60
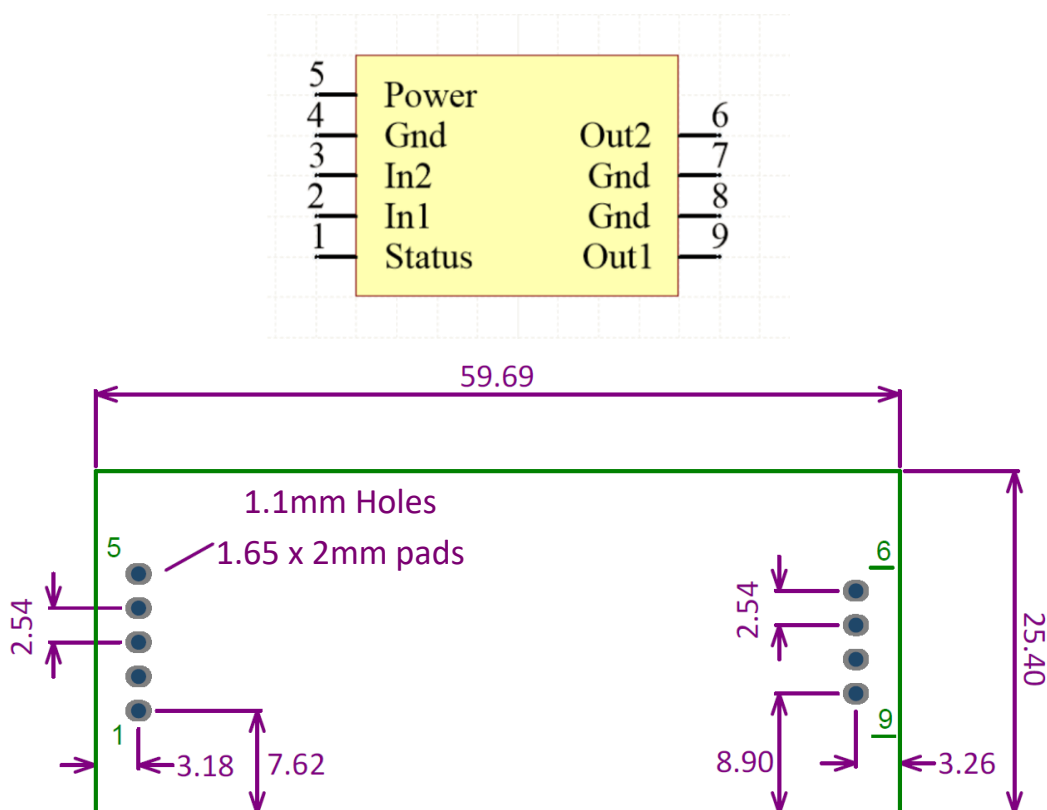
PCB Footprint

An Altium schematic and footprint library is available for [download](). The recommended schematic symbol and footprint are:

Pin	Left		Right	Pin
5	Power			
4	Gnd	Out2		6
3	In2	Gnd		7
2	In1	Gnd		8
1	Status	Out1		9

Footprint dimensions:
- 59.69 (overall width)
- 25.40 (overall height)
- 1.1mm Holes
- 1.65 x 2mm pads
- 2.54 (pin spacing, left)
- 2.54 (pin spacing, right)
- 3.18
- 7.62
- 8.90
- 3.26

High Voltage Safety Warning

This product produces potentially lethal voltages up to 330 Vdc.

Observe Low-Voltage (as per ANSI C84.1-1989) safety precautions, e.g.

- Use an observer trained in low-voltage rescue
- Do not operate with exposed conductors
- Use appropriate signage

References

[1]   A New Electrical Configuration for Improving the Range of Piezoelectric Bimorph Benders; S. A. Rios, A. J. Fleming; Sensors and Actuators A: Physical, 2015.

Revision History

Date	Revision	By	Changes
21/01/21	R6	KB	Temperature range update