



Bel amp

High Performance Discrete Op Amp
with Voltage and Current Outputs

Low noise and distortion
High output current
High impedance JFET input

FEATURES

- Current or voltage output
- Very low noise (4.5nV/√Hz)
- Low distortion (0.0001%)
- 100mA peak limited output current
- Wide power supply range (+5V to ±20V)
- Stable with 0.01μF load
- High input impedance JFET
- Low input bias current (100pA)
- Low output impedance (<10mΩ at 1kHz)
- 4.2mA supply current
- Unity gain stable
- No phase reversal
- Small footprint vertical version available

APPLICATIONS

- Audio preamps, mixers
- Phono preamps
- Microphone preamps
- High resolution D/A and A/D converters
- Headphone amps
- Power amp input stage
- Precision measurement systems
- Biometric sensors
- Transducer interface
- Cable driver

DESCRIPTION

Bel amp is a custom discrete op amp developed for amplification of low level signals such as audio from a phono cartridge or microphone, for medical or biometric applications, and as an interface for transducers such as headphones, cable drivers, MEMs or piezoelectric sensors, etc.

Combined with low input noise, it delivers the optimum in clean, low level signal boost. With its high impedance JFET inputs, Bel amp can be tailored to match specific requirements for most applications.

Both current and voltage outputs are available, so Bel amp can be used as either a trans-conductance or trans-impedance amplifier, or in a dual configuration as a low distortion amp with 50+dB gain and ultra low distortion.

Current up to 100mA is available from the MOSFET boosted output, with internal current limit circuitry to prevent over-current damage.

Bel amp can be easily retrofit into existing systems or designed into new systems for maximum performance. Both a horizontal and vertical PCB version are available for ease of upgrading and for mechanical design convenience.

[Contact Belleson](#) for more information.



Figure 1: Horizontal mount



Figure 2: Vertical mount

Absolute Maximum Ratings

Parameter	Conditions	Value	Units
Supply voltage	Unipolar Bipolar	40 ± 20	V
Input voltage maximum	Above V_{cc+} , below V_{ee-}	0.5	V
Peak input current	V_{in} beyond input voltage maximum	1.0	mA
Output short circuit current	Continuous within 0.5W power dissipation	110	mA
Operating temperature		-25→70	°C

Operation at these limits is not guaranteed. Operation beyond these limits may result in irreversible damage.

Pin Connections

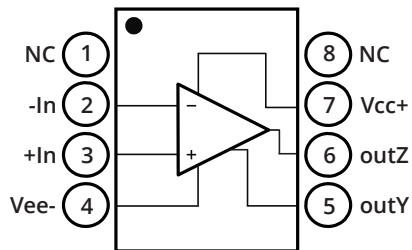


Figure 1: Pin connections

Typical Performance Characteristics

$T_A = 25^\circ\text{C}$, $V_{CC+} = 16\text{V}$, $V_{EE-} = -16\text{V}$, $R_L = 2\text{k}\Omega$ to 0V or mid-supply

Parameter	Description	Conditions	MIN	TYP	MAX	Units
THD	harmonic distortion, <i>outZ</i> , inverting mode	gain=-1, voltage@ <i>outZ</i> $V_{in} = -V_O = 3V_{RMS}$, 1kHz		0.0001		%
				-120		dB
	harmonic distortion, <i>outZ</i> , non-inverting mode	gain=+1, voltage @ <i>outZ</i> $V_{in} = V_O = 3V_{RMS}$, 1kHz		0.0002		%
				-115		dB
	harmonic distortion, <i>outY</i> , gain=45dB with $R_{outY} = 5\text{k}\Omega$	differential $V_{in} = 2\text{mV}_{pp}$, 1kHz		0.01		%
				-80		dB
Noise	input voltage noise, rms	20Hz – 20KHz		430		nV_{RMS}
	input voltage noise density e_n	1kHz		4.5		$\text{nV}/\sqrt{\text{Hz}}$
	input current noise	20Hz – 20KHz		0.5		$\text{pA}/\sqrt{\text{Hz}}$
V_{os}	input offset voltage	After trim		100	250	μV
I_b	input bias current			-100		pA
I_{os}	input offset current (1*)			(1*)		
	Input voltage range		-16		13.50	V
Y	Transconductance, pin 5	Current out per differential v_{in}		11		mA/V
C_{in}	input capacitance			25		pF
PSRR	power supply rejection	60Hz		110		dB
CMRR	common mode rejection	$V_{in} = 10\text{mV}$, DC-1kHz	120	130		dB
I_{sc}	Short circuit current	positive or negative	80	100	125	mA
Z_{out} <i>outZ</i>	impedance, voltage output	below 1kHz			1	$\text{m}\Omega$
		20kHz		5		
Z_{out} <i>outY</i>	impedance, current output	20Hz	10,000			$\text{k}\Omega$
		1kHz	750			
		20kHz	38			
A_{vol}	equiv open loop voltage gain	Accounts for internal feedback		124	120	dB
SR	Slew rate	gain=1		± 4		$\text{V}/\mu\text{sec}$
GBW	gain-bandwidth-product			7		MHz
I_{cc}	idle supply current	inputs at mid-supply, $2\text{k}\Omega$ load terminated to mid-supply		4.2	5	mA
C_L	load capacitance	gain > -1, +2		0.01		μF
		gain = +1 (2*)		50		pF

Notes

(*1) input offset current is negligible

(*2) adding 50pF from *outY* to ground gives +1 gain stability to 0.01 μF

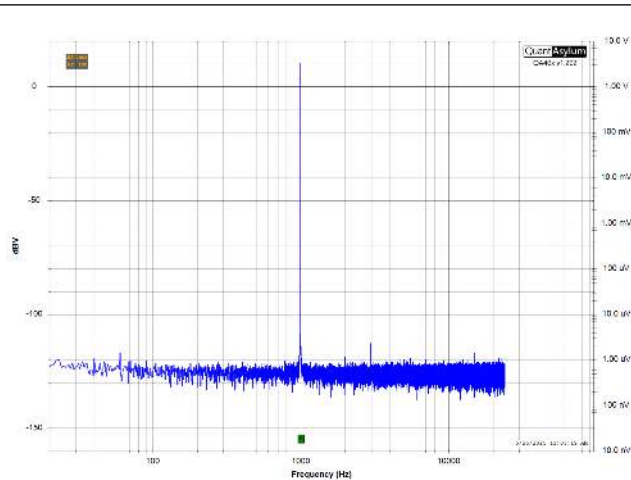


Figure 1: Distortion, unity gain inverting, 3Vrms

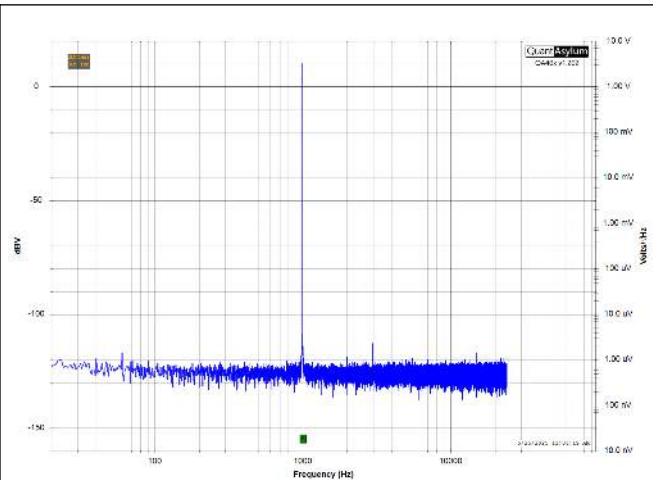


Figure 2: Distortion, unity gain non-inverting, 3Vrms

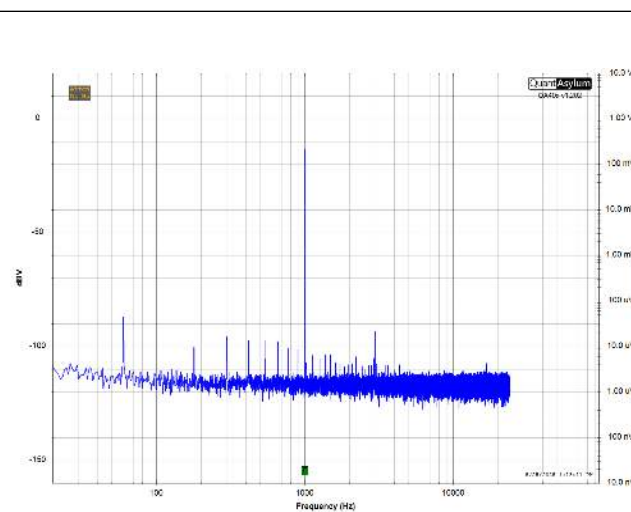


Figure 3: Differential in, current out at 54dB gain

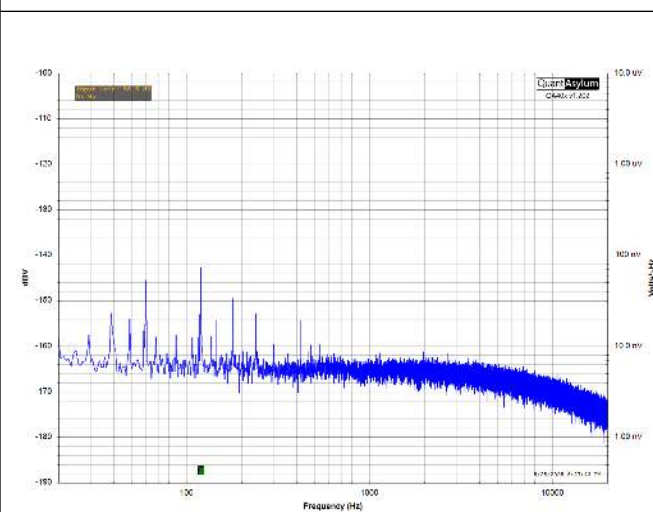


Figure 4: Input noise, inputs grounded

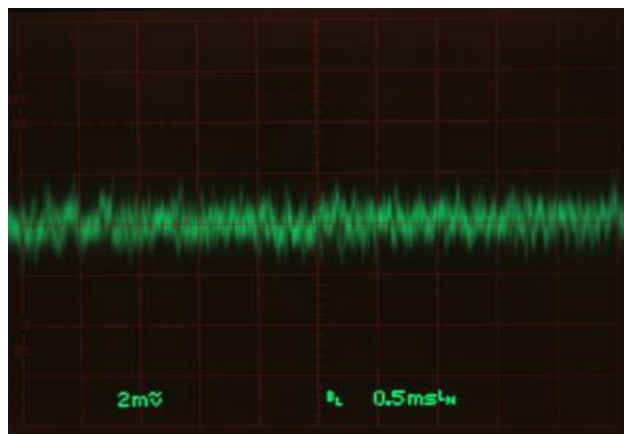


Figure 5: Noise, 20MHz bandwidth, vertical scale $\approx 3\mu\text{V}/\text{div}$

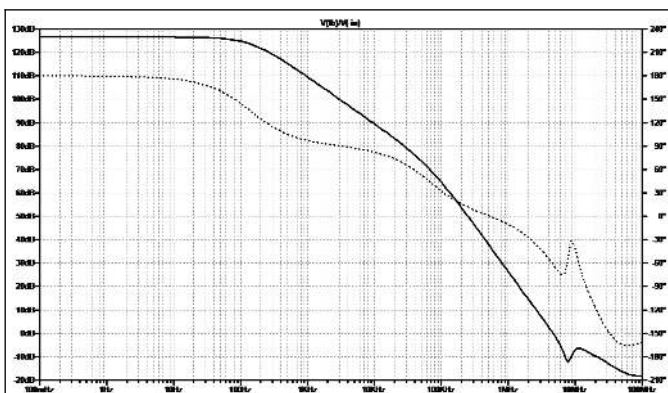


Figure 6: Full open loop gain

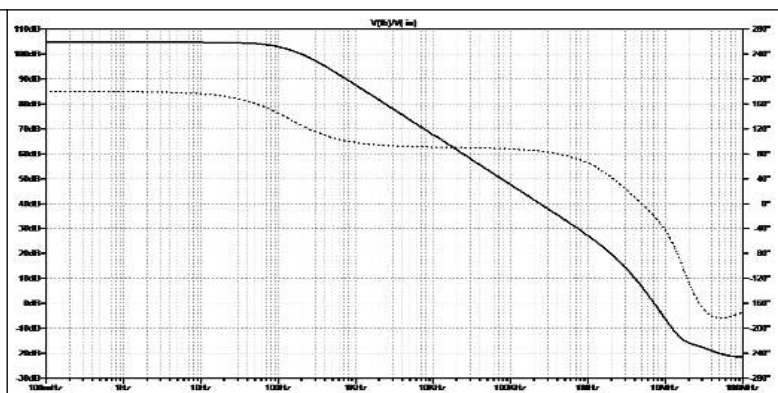


Figure 7: Forward open loop gain with stage 1 feedback



Figure 8: Power supply rejection (PSRR) vs. frequency

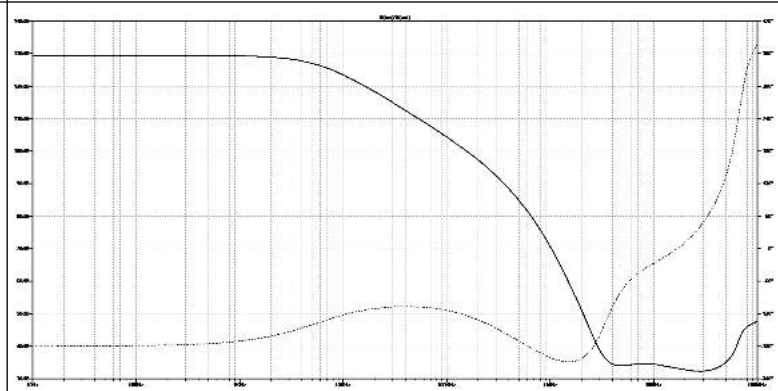


Figure 9: CMRR vs frequency

Circuit Description

More than a “standard” op amp, Bel amp uses a unique complementary feedback pair (CFP) with the low noise and high input impedance of JFET input and the high gain typical of bipolar (BJT) input op amps. Emitter feed-back for the PNP reduces stage one distortion. Coupling this CFP stage to a folded cascode current mirror of VAS keeps all nodes at a DC bias voltage, keeping distortion low by reducing effects of voltage variable junction capacitance. The cascode voltage is fixed with a low impedance (0.5Ω) reference bias point.

A trim pot is available to balance the input stage halves and reduce 2nd harmonic distortion in transconductance mode, or to trim offset voltage in standard op amp mode. It is factory adjusted for lowest offset voltage prior to shipment.

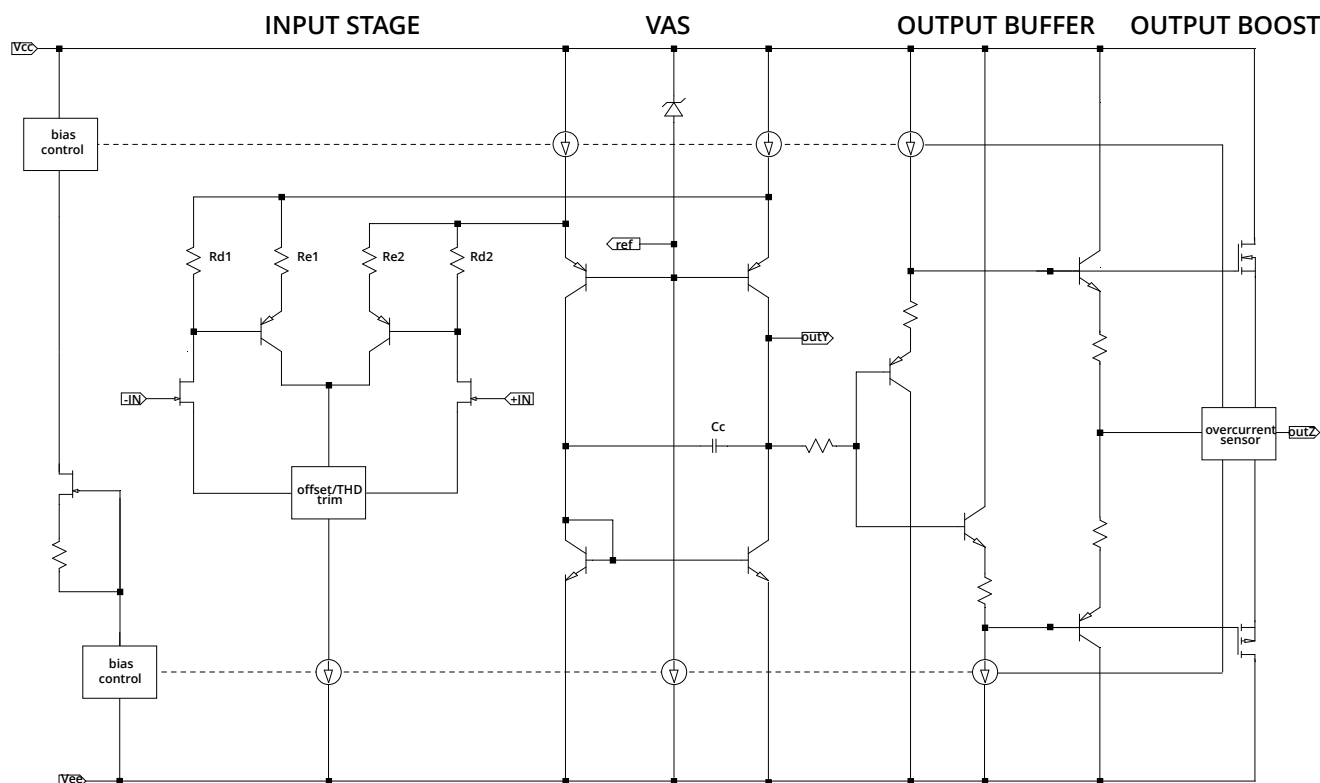


Figure 1: Bel amp simplified schematic. $Re1,2$ give local feedback, $Rd1,2$ set forward stage gain

VAS node *outY* is brought to pin 5 to allow Bel amp to be used in current output mode as a low distortion transconductance amp for low level input signals. In more typical transimpedance mode, this pin can also be connected to additional capacitance to enhance stability. (See *Application Information* following.) Maximum current is $\pm 1.5\text{mA}$, but distortion rises rapidly above $\pm 400\mu\text{A}$. As an output, *outY* is typically terminated into a resistance between $2\text{k}\Omega$ and $10\text{k}\Omega$ to convert to a voltage.

Pin 6, *outZ*, is a standard low impedance op amp voltage output. Driven with a boosted unity gain “diamond buffer”, a bipolar output delivers the first 5 to 10mA of output current, then an output boost stage, made from matched complementary high current MOSFETs, engages to provide additional current up to 100mA, with low output impedance to drive capacitive loads up to 10nF.

A protection circuit monitors output current and shuts off output drive when peak current reaches 100mA.

Application Information

Use as a voltage output op amp

As a standard op amp, Bel amp has excellent performance characteristics across the audio spectrum and beyond. With 9MHz unity gain bandwidth and 124dB peak open loop gain (see figure 5),

High input impedance and low noise make it great for sensors such as thermocouples, IR sensors, biological, acceleration, pressure or other MEMs sensors. Combined with low distortion over the audio frequency band and stable, high current output, Bel amps are great for professional and consumer audio products.

Using Bel amp as a standard op amp typically means in a feedback loop, with 2k Ω or higher resistor load, as in figures 1 and 2. C_c should be, depending on gain, between 10pF and 33pF. R_f is part of the op amp load, and is typically 2k Ω or higher.

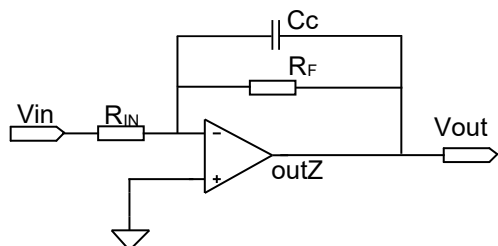


Figure 1: Inverting op amp

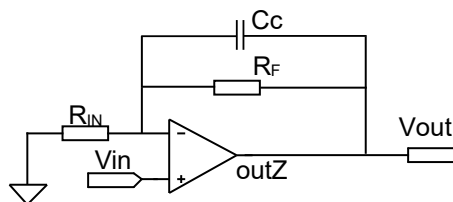


Figure 2: Non-inverting op amp

Stability considerations for voltage output

In inverting mode, and in non-inverting mode with a gain of 2 or more, the circuit is stable with up to 0.01 μ F capacitance, so driving coaxial cables is not a problem. If non-inverting gain of 1 is needed, adding 100pF between pin 5 (outY) and ground gives this same stability for higher capacitance loads.

Use as a current output amplifier

Bel amp's stage 1 has, as noted in the circuit description, internal feedback and special circuitry to keep distortion low when used "open loop" with current output from *outY*. Thus pin 5 can be terminated into a resistor and used as a high gain, fully differential high impedance input amplifier for low level signals from sensors and transducers such as moving coil or moving magnet phono cartridges, guitar pickups, microphones, biomedical pickups, etc.

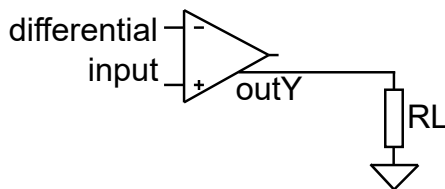


Figure 3: Differential input high gain low distortion transducer amp

This circuit has about 50dB gain with $R_L=7.5\text{k}\Omega$ and distortion near 0.01% if output current is kept below about $\pm 300\mu\text{A}$. Distortion increases as voltage at *outY* approaches maximum possible node voltages ($\approx 2\text{V}$ from rails).

Note that, when inputs are both floating, as when a differential transducer is connected across them, they will float to around 55% of the positive rail, or 70% of a single supply rail.

A high gain, low distortion amplifier for low level signals

For even better performance, Bel amp can be used in tandem with a standard op amp as seen in figure 4. By terminating *outY* into the summing junction of a transimpedance amplifier, the output current from the transconductance stage is fixed at virtual ground due to the feedback of stage 2. Thus node *outY* is at constant voltage, which reduces distortion further.

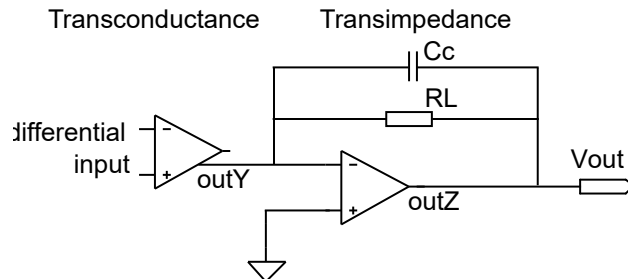


Figure 4: Two Bel amp 50dB ($RL=7k5$) gain stage with all internal voltage nodes held constant up to the output stage of the second op amp.

Distortion reduction tweak

Second harmonic distortion is caused primarily by mismatched currents in two halves of the first stage of an op amp. Bel amp provides a trim-pot to allow 2nd harmonic distortion to be reduced down to the noise level by using a distortion analyzer. The trim-pot is visible in the photos of page 1.

Offset voltage reduction tweak

In voltage output mode, this same trim-pot allows offset voltage to be nulled. Clockwise increases the offset voltage. With both inputs grounded, offset voltage will measure near zero, use a "tweaker" screwdriver to adjust it to your requirements. It is factory adjusted to be within $\pm\frac{1}{2}mV$ prior to shipping.

In figure 4, highest DC accuracy and lowest distortion can be set by injecting a low distortion differential sine wave into the transconductance amp and measuring distortion at *Vout*. Adjust the trim-pot on the first op amp for least 2nd harmonic distortion. Then ground both differential inputs and, with a five or six digit voltmeter, adjust the transimpedance op amp's trim-pot to set *Vout* as close to 0V as you desire. *This assumes bipolar power supplies are used. If using unipolar supplies, set Vout to mid-supply.*

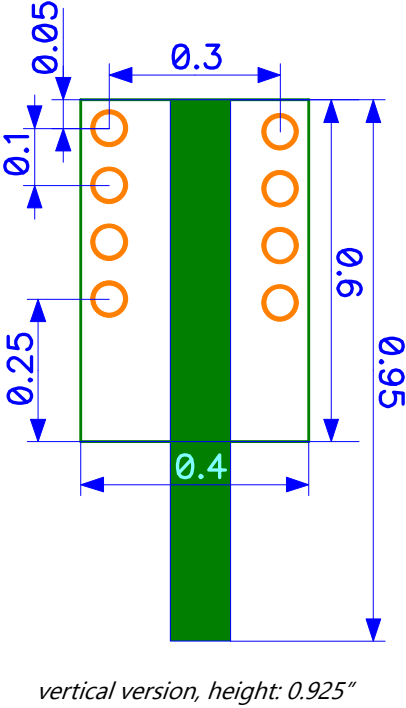
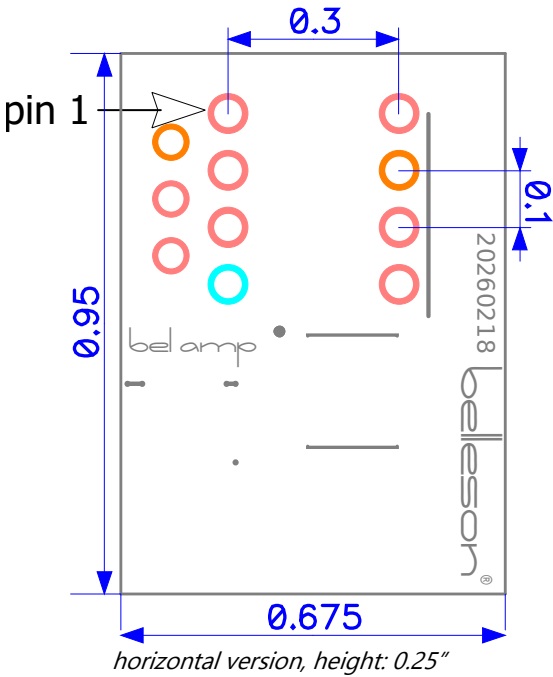
Power supply rails and output voltage range

Bel amp operates from $\pm 20V$ down to $\pm 2.5V$, or unipolar 40V to 5V. With 2V overhead required for *Vout*, a 5V power supply range restricts linear operation to about $\pm 1.5V$ output swing. Within this range, distortion remains very low, at about 0.0001%.

Input Voltage Range

When used in as a non-inverting voltage output op amp, input voltage must be constrained within approximately 1.5V below the positive power supply voltage to prevent phase reversal due to current flowing into the JFET gate. This is a temporary effect while input voltage is above range and does not cause damage to the Bel amp. It can, when used in a closed loop control system, cause a circuit to latch in the wrong state.

Mechanical Specifications



Dimensions in inches

Legal Information

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