Model 252AP
Discrete Operational Amplifier

The Sonic Imagery Labs Model 252AP is a high performance discrete operational amplifier designed for professional audio applications and areas where ultralow noise and low distortion is required. The 252AP is best suited for use in circuits with medium to high source impedances and with microphone input transformers with high turns ratios (> 1:4).

The Model 252AP is a modern re-engineering of the classic 2520 discrete op-amp. It was designed as an enhanced higher performance upgrade replacement with a focus on superior AC and DC performance. The pinouts conform to the 2520/990 package, allowing direct replacement.

The all-discrete SMT design is similar to the API2520 basic topology but has been redesigned to use an ultra-precision differential super-matched input transistor pair specifically designed to meet the requirements of ultra-low noise and ultra-low THD audio systems. A variant (252AP-ULN) is also available for ultra damn low noise applications. (0.560nV/rtHz at 1kHz) Unlike the original API2520 design, the 252AP can incorporate two precision matched pair transistors as the differential input stage. A total of 4 matched devices, for ultra-ultra low noise applications. These devices are selected by the manufacturer at final test to Sonic Imagery Labs noise, Vos, Ic and Vbe matching specifications.

Features:
- Ultra Low Total Harmonic Distortion, 0.0003 THD+N @ 1kHz
- Ultra Low Noise 0.89nV/rtHz typical@1Khz Rs=150 Ω
- High Current Output Drive (250mA peak)
- +26dBu Output Levels (into 600 ohms)
- Standard Gain Block Footprint
- Operates over ±10V to ±28V supply rails
- Much lower output offset voltage than existing counterparts
- Lower input leakage current than existing counterparts
- Particular emphasis on audio performance
- Designed, assembled and produced in the USA
- 3 Year Warranty

Applications:
- Low Impedance Line Amplifiers and Drivers
- Active Filters and Equalizers
- Summing/Mixer Amplifiers
- High Performance Microphone Preamplifiers
- High Performance A/D and D/A front end Preamplifier
- High Performance D/A I-V convertors
- High Current Buffer Amplifier

DC perfomance is easily a magnitude better than previous counterparts. With an offset voltage of better than ±35uV (at Av1) and input leakage better than <30nA, the Sonic Imagery Labs Model 252AP is well suited for DC coupled audio applications in which output offset errors cannot be tolerated.

In addition to the enhanced input stage, and unlike the original API2520 devices, the Sonic Imagery Labs 252AP uses precision temperature stable power supply independent current sources. Supply independent current sources allow the bias of the input and matched pair differential VAS stage to remain locked at the optimum operating point regardless of power supply voltage.

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Sonic Imagery Labs
P.O. Box 20494
Castro Valley, California 94546
P:(510)728-1146 F:(510)727-1492
www.sonicimagerylabs.com

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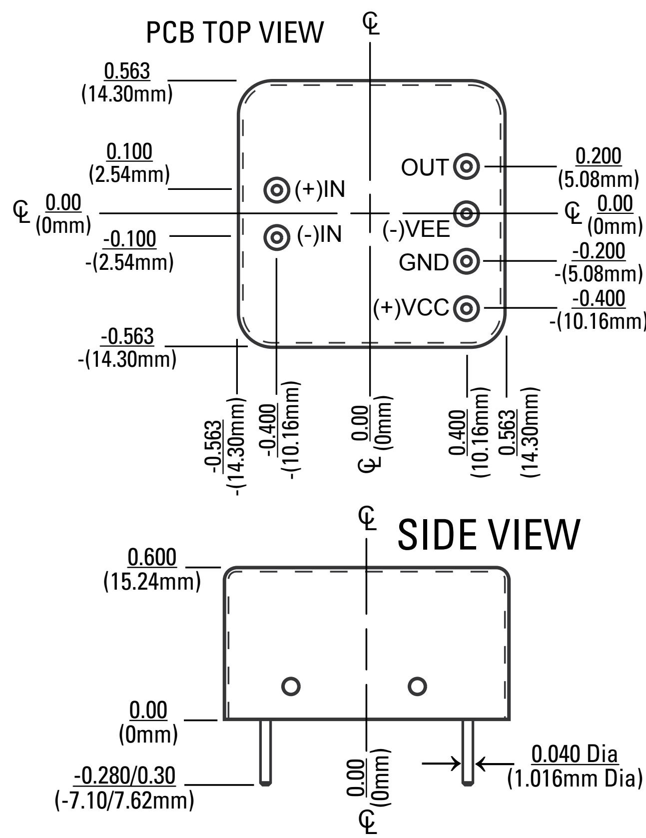
Another feature not found in the original API2520 design is the addition of matched pair active current loads which gives the Model 252AP differential input and VAS stage it's outstanding (PSRR) power supply noise rejection ratio performance.

The Sonic Imagery Labs 252AP can be operated from ±10V to ±24V power supplies. The redesigned input stage circuitry provides outstanding common-mode rejection and maintains low input bias current over its wide input voltage range, minimizing distortion. The 252AP is unity-gain stable and provides outstanding dynamic behavior over a wide range of load conditions.

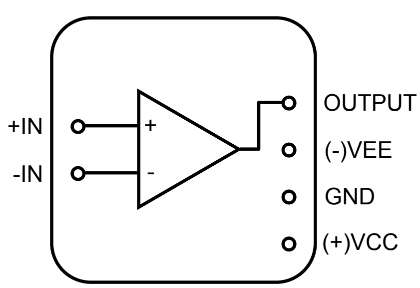
Integrated power transistor heatsinks coupled to a anodized aluminum enclosure keeps the Sonic Imagery Labs 252AP operating within a wide safe operating area (SOA) and does not suffer from Beta droop when driving heavy loads. Each amplifier is individually fully tested and meets or exceeds published specifications.

Package Diagram:



Connection Diagram:

Top View



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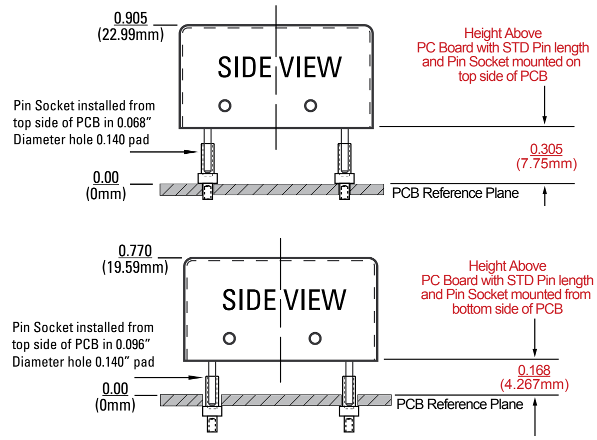
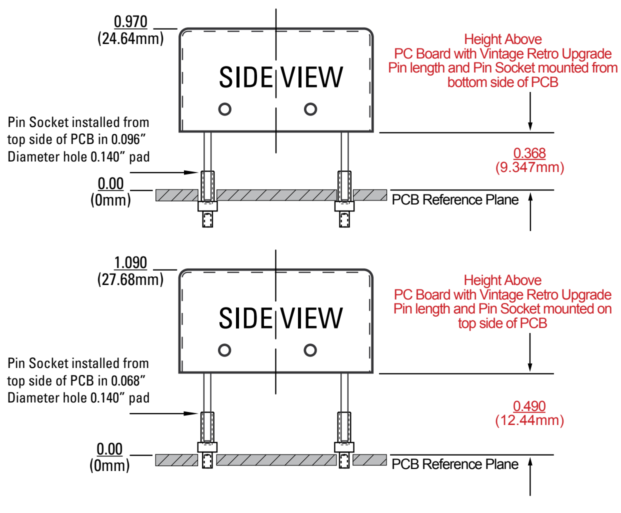
If the user is upgrading or replacing vintage or retro-clone gear, take note of the pin length required for your particular application. Older gear typically used modules with 0.480 to 0.510 inch long 0.040 pins. Sonic Imagery Labs offers this longer pin length variant at no additional charge. See the Model 990Enh-Ticha and 995FET-Ticha Mechanical Options Application Note AN-18 for additional mechanical details.

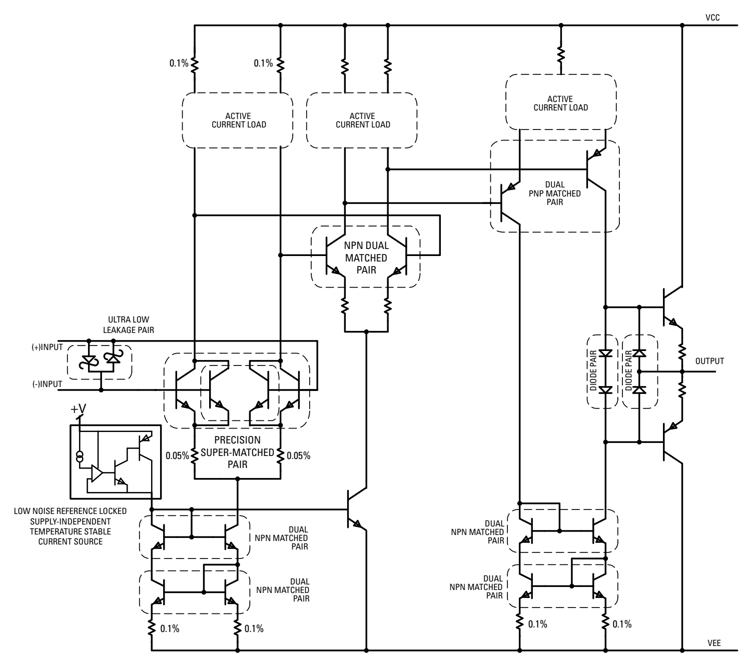


DETAIL A. (Above) Standard pin length height specifications and mounting options for Sonic Imagery Labs Model 252AP opamp module.



DETAIL B. (Above) Vintage or retro gear upgrade pin length variant height specifications and mounting options for Sonic Imagery Labs Model 252AP opamp module.

Refering to the aforementioned mechanical diagrams, the user has additional height options if it is required to mount the Sonic Imagery Labs 252AP over tall components. The use of pin sockets is the prefered mounting method to a PCB. These sockets are commonly available through electronic component distributors. Many types of sockets for 0.040" diameter pins are available from several manufacturers. Sonic Imagery Labs uses and stocks the sockets from Mill-Max. The mechanical specifications shown here are using Mill-Max pin socket **Part Number 0344-2-19-15-34-27-10-0.**



Simplified Schematic of the Model 252AP

Recommended Operating Conditions:

Positive Supply Voltage	VCC	+10V to +25V
Negative Supply Voltage	VEE	-10V to -25V
Signal Current (inverting mode)	Iin	35nA to >200 uA

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only; the functional operation of the device at these or any other conditions above those indicated in the operational sections is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

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Castro Valley, California 94546
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Absolute Maximum Ratings

Supply Voltage	VCC-VEE	58V
Differential Input Voltage	V_{ID}	13.9Vrms (+25dBu) @ unity gain
Input Voltage Range	V_{IC}	±13V
Operating Temperature Range	T_{OPR}	-40~85°C
Storage Temperature Range	T_{STG}	-60~150°C

DC Electrical Characteristics (Ta=25°C, Vs=±24V unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{OS}	Input Offset Voltage	R_S=0Ω Av=Unity	-	0.022	0.035	mV
I_{OS}	Input Offset Current	-	-	1	5	nA
I_B	Input Bias Current	-	50	<200	-	nA
A_{VOL}	Voltage Gain (open loop)	-3dB @ 33Hz	118	120	122.5	dB
V_{OM}	Output Voltage Swing	Vs=±24V R_L=600Ω Av=10	44	46	-	Vpp
V_{OM}	Output Voltage Swing	Vs=±24V R_L=75Ω Av=10	40	44.5	-	Vpp
V_{CM}	Input Common-Mode Range	R_L=600Ω	±12	±12.5	-	V
CMRR	Common-Mode Rejection Ratio	-	80	95	-	dB
PSRR	Power Supply Rejection Ratio	-	88	100	-	dB
I_Q	Supply Current	Vo=0, inputs gnd, Vcc=24V	15.9	16.5	17	mA
		Vo=0, inputs gnd, Vee=24V	16.0	16.9	17.5	mA

AC Electrical Characteristics (Ta=25°C, Vs=±24V unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
SR	Slew Rate	R_L=600Ω	15	16	17	V/uS
SR	Slew Rate	R_L=75Ω	14	15	16	V/uS
GBW	Gain Bandwidth Product	10kHz to 100kHz	-	>40		MHz
	Maximum Peak Output Drive Current		-	250		mA

Design Electrical Characteristics (Ta=25°C, Vs=±24V, Rs=25Ω, 20Hz-20Khz BW unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
THD	Distortion+Noise	R_L =600Ω Unity Gain @1kHz	-	0.00045	-	%
THD	Distortion+Noise	R_L =600Ω 20dB Gain inverting @1kHz	-	0.0003	-	%
THD	Distortion+Noise	R_L =600Ω 20dB Gain non-invert @1kHz	-	0.00034	-	%
e_n	Input Refered Noise Voltage	Input Rs=150Ω	-	890	1050	pV√ Hz
i_n	Input Refered Noise Current		-	<1.0	-	pA√ Hz
PBW	Power Bandwidth	Large-signal BW R_L =600Ω	-	>185	-	kHz
f_U	Unity Gain Frequency	Small-signal BW at unity gain (ft)		13.5		MHz
Zin	Input Impedance	Noninverting Input		>10M		Ω

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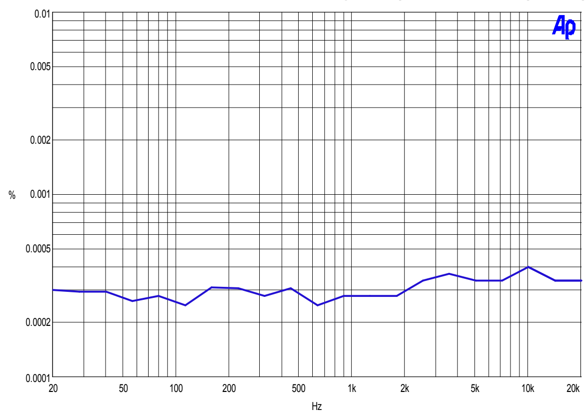
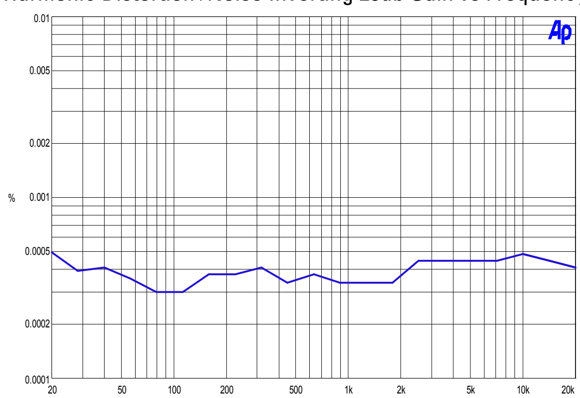
THD+N Characteristics (Ta=25°C, Vs=±24V, 1.0Vrms input, Rs=25Ω, Rl=10K, 20Hz-20Khz BW unless otherwise noted)

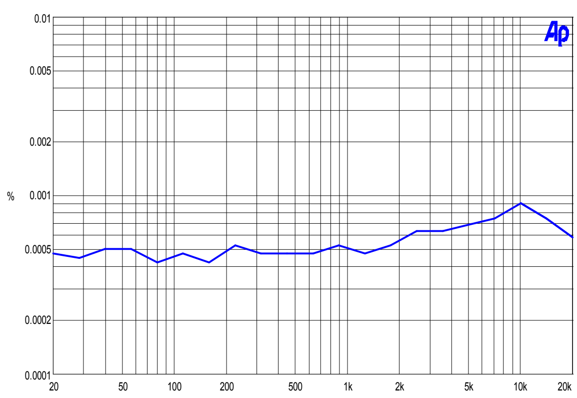
Total Harmonic Distortion+Noise Inverting Unity Gain vs Frequency



Total Harmonic Distortion+Noise Inverting 20db Gain vs Frequency

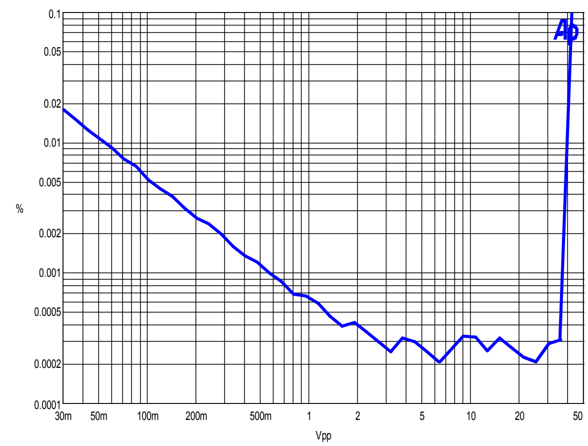


Total Harmonic Distortion+Noise Non-Inverting 20db Gain vs Frequency



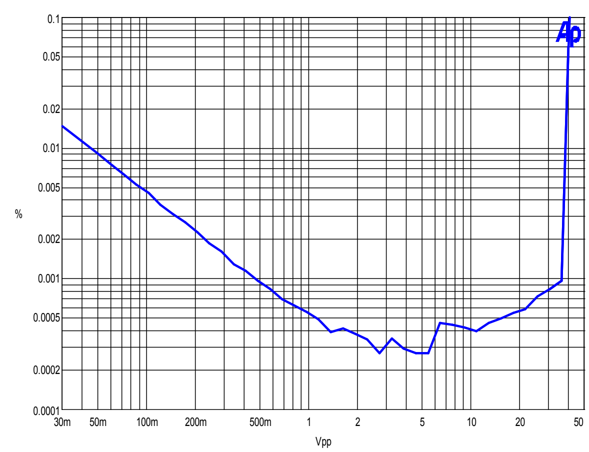
THD+N vs Amplitude (Ta=25°C, Vs=±24V unless otherwise noted)

Total Harmonic Distortion+Noise Inverting Unity Gain vs Output Amplitude



THD+N vs Amplitude (Ta=25°C, Vs=±24V unless otherwise noted)

Total Harmonic Distortion+Noise Non-Inverting 6dB Gain vs Output Amplitude



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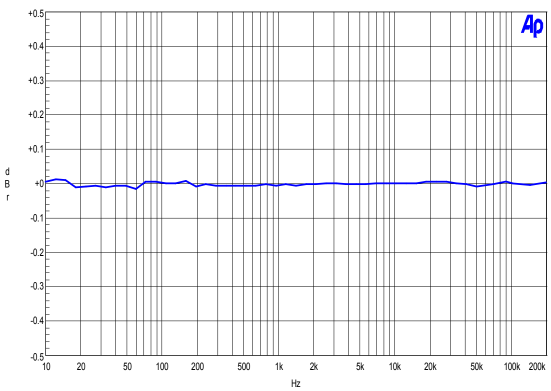
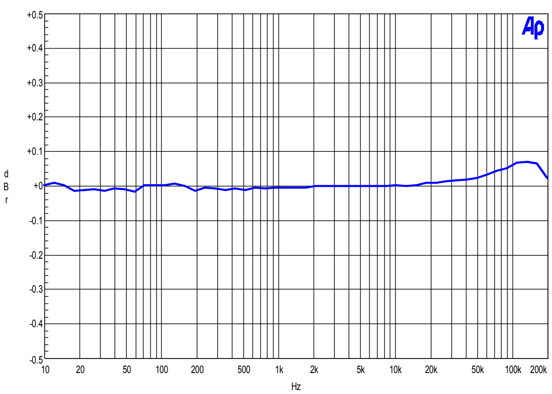
Gain Accuracy vs Frequency (Ta=25°C, Vs=±24V unless otherwise noted)

0dB (Av=1) Inverting gain vs Frequency

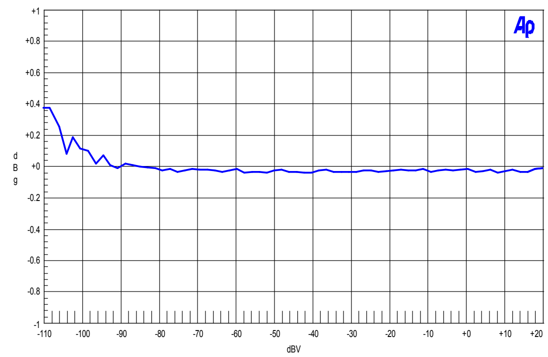


6dB (Av=2) Non inverting gain vs Frequency

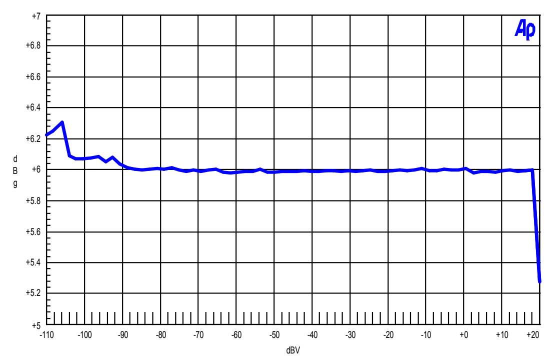


Linearity vs Amplitude (Ta=25°C, Vs=±24V unless otherwise noted)

0dB (Av=1) Inverting gain vs Amplitude

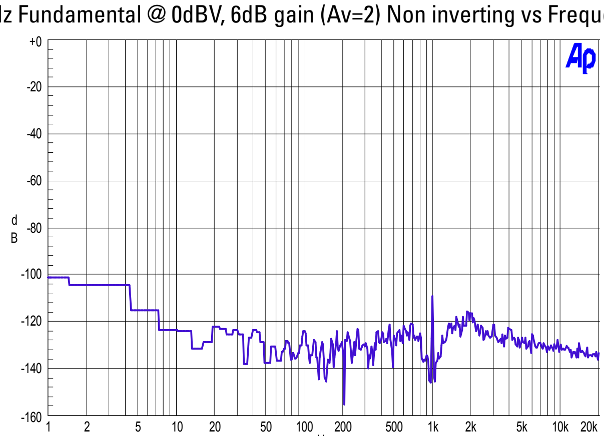


6dB (Av=2) Non-inverting gain vs Amplitude



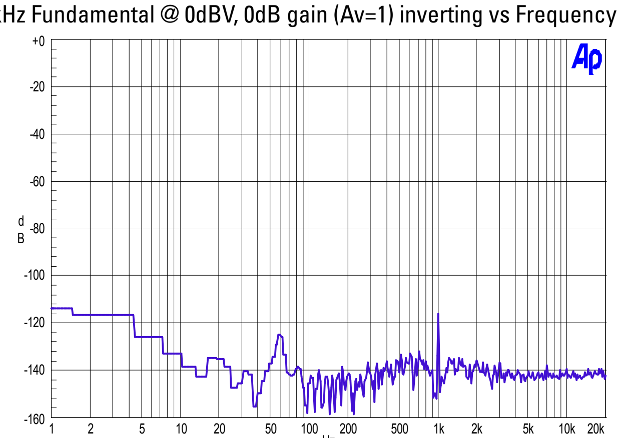
THD Residual+N Characteristics (Ta=25°C, Vs=±24V, 1Vrms input, Rs=25 Ω Rload=100K Ω unless otherwise noted)

1kHz Fundamental @ 0dBV, 6dB gain (Av=2) Non inverting vs Frequency



THD Residual+N Characteristics (Ta=25°C, Vs=±24V, 1Vrms input, Rs=25 Ω Rload=100K Ω unless otherwise noted)

1kHz Fundamental @ 0dBV, 0dB gain (Av=1) inverting vs Frequency



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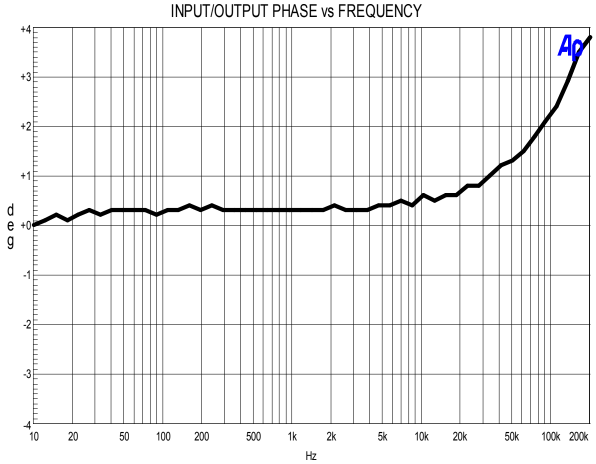
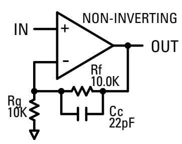
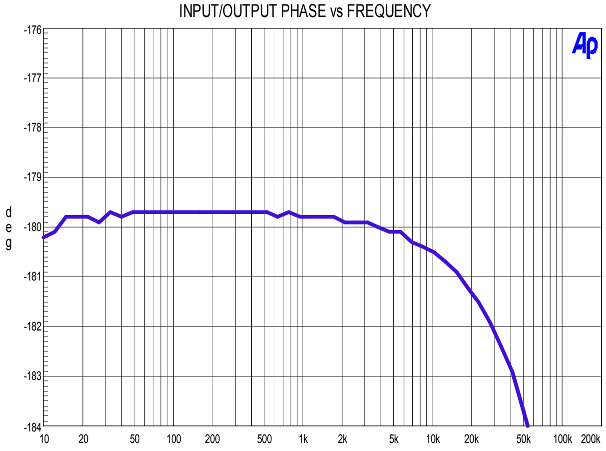
Input-Output Phase Characteristics (Ta=25°C, Vs=±24V, 1Vrms input, Rs=25 Ω Rload=100K Ω unless otherwise noted)

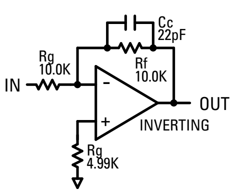
Non inverting input 6dB gain (Av=2) vs Frequency





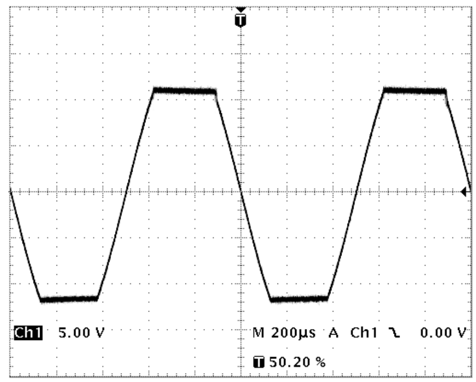
Inverting input 0dB gain (Av=1) vs Frequency





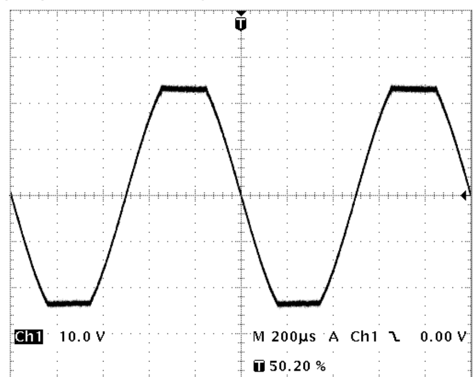
Input Overdrive Response Ta=25°C, Vs=±12V RL=100KΩ Cc=22pF

15Vpp Input Non-Inverting Av=2



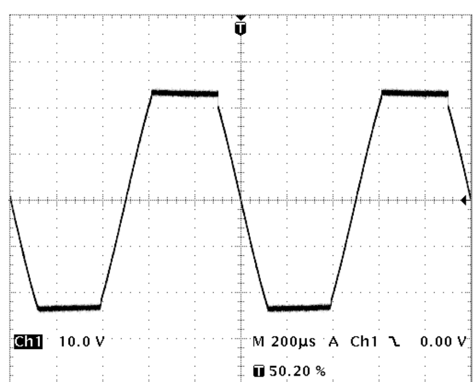
Output Clipping Response Ta=25°C, Vs=±24V RL=100KΩ Cc=22pF

300mVpp Input Non-Inverting Av=100



Output Hard Clipping Response Ta=25°C, Vs=±24V RL=100KΩ Cc=22pF

700mVpp Input Non-Inverting Av=100



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www.sonicimagerylabs.com

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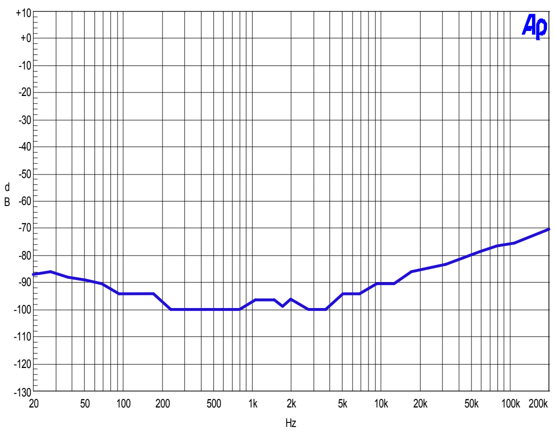
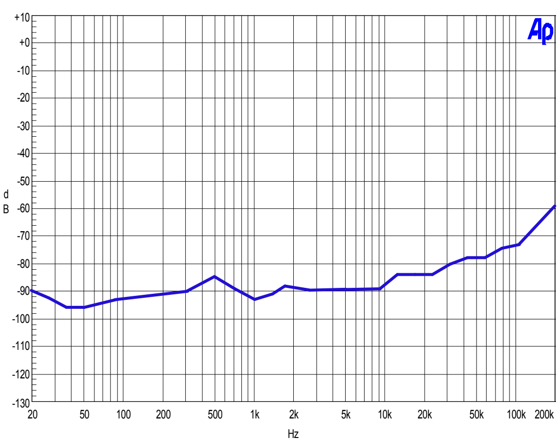
Power Supply Rejection Ratio Characteristics (Ta=25°C, Vs=±24V, Rs=0 Ω to Gnd Rload=10K Ω unless otherwise noted)

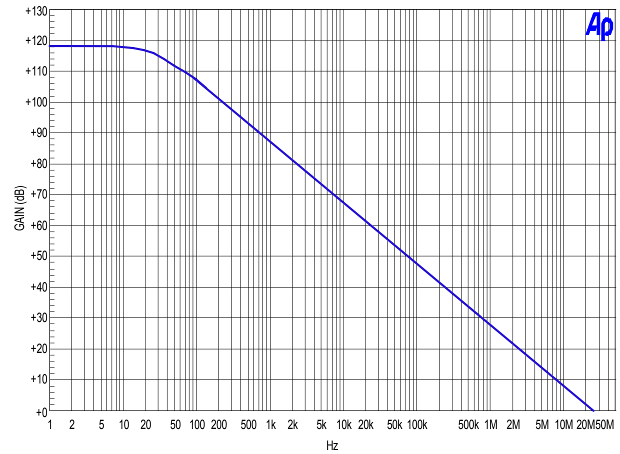
Non inverting, Unity gain (Av=1) vs Frequency, Positive Supply



Non inverting, Unity gain (Av=1) vs Frequency, Negative Supply

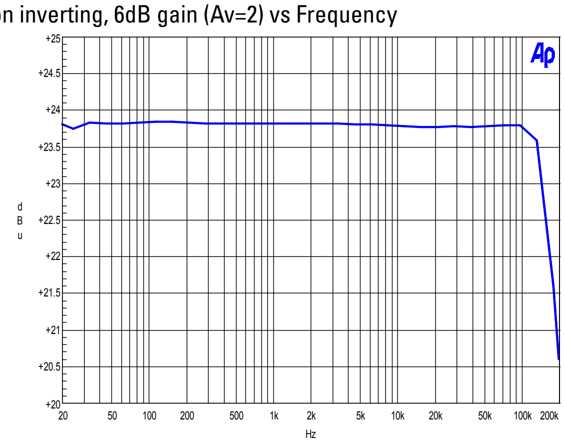


Open Loop Frequency Response (Ta=25°C, Vs=±24V, Rload=100K Ω unless otherwise noted)

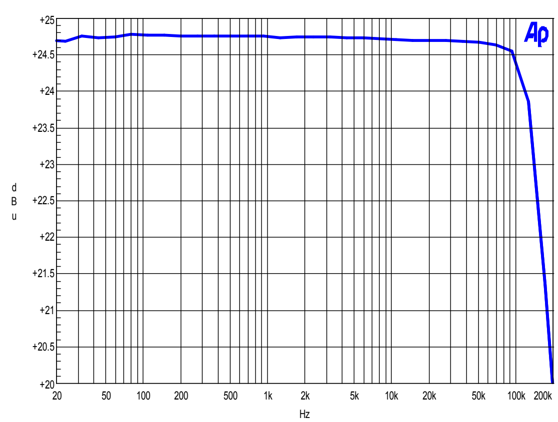


Full Power Frequency Response (Ta=25°C, Vs=±24V, Rload=600 Ω unless otherwise noted)

Non inverting, 6dB gain (Av=2) vs Frequency



Non inverting, 20dB gain (Av=10) vs Frequency



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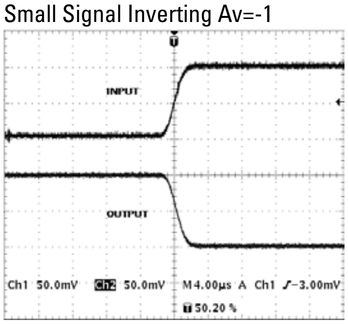
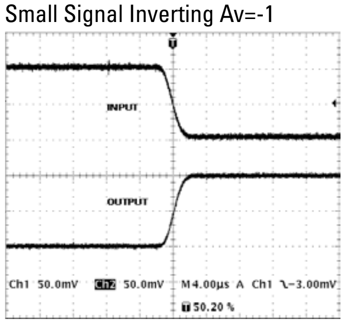
Pulse Response Ta=25°C, Vs=±24V RL=600Ω Cc=22pF

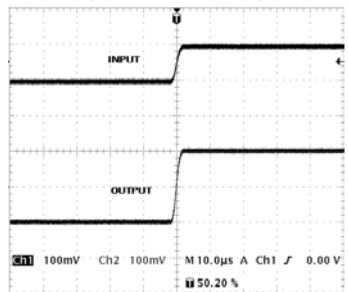
Small Signal Inverting Av=-1



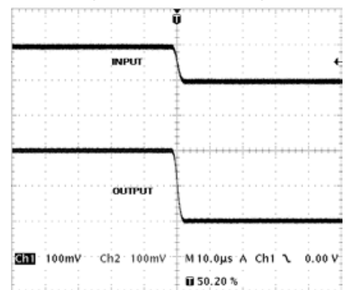
Small Signal Inverting Av=-1



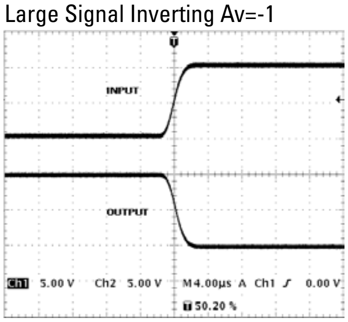
Small Signal Non-Inverting Av=2



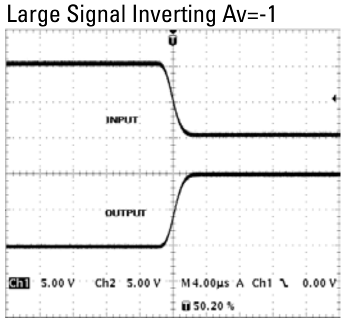
Small Signal Non-Inverting Av=2



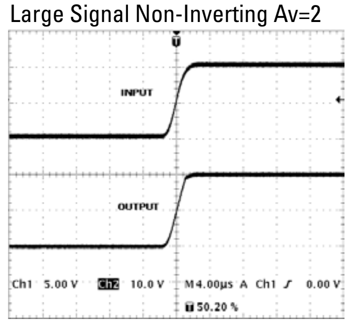
Large Signal Inverting Av=-1



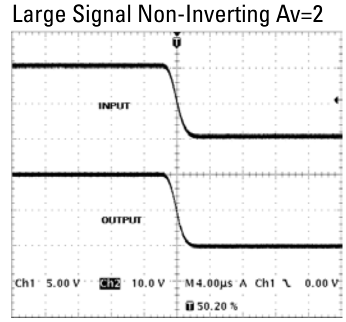
Large Signal Inverting Av=-1



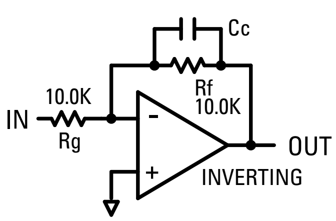
Large Signal Non-Inverting Av=2



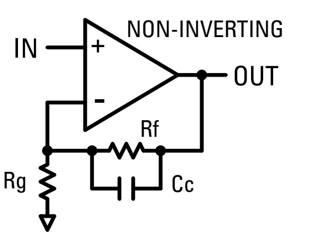
Large Signal Non-Inverting Av=2



Pulse Response Test Setup



Pulse Response Test Setup



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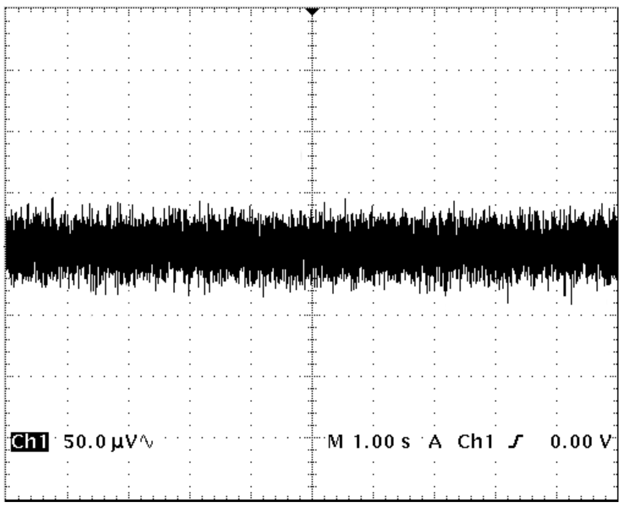
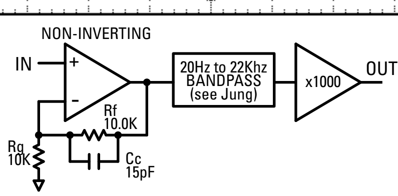
Broadband Noise Characteristics (Ta=25°C, Vs=±24V, Rs=150 Ω to gnd, Rload=10K Ω unless otherwise noted)

Non inverting, 6dB gain (Av=2) 22Hz to 22kHz NBW vs Time





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Discrete Operational Amplifier

Application Notes

Low leakage film capacitors with high-quality dielectric (polypropylene or COG-NPO ceramic) should be used. Low-ESR power supply bypass capacitors with a small resistance in series with the power supply rails are essential for low noise operation. Precision low noise 1% metal film resistors should always be used. Since these components can represent high impedance, lead length and trace lengths should be minimized. Surface mount components do not suffer temperature gradients errors and parasitics as leaded componets and are highly recommended. Assembled circuits and PCB's should be carefully cleaned of flux residue to prevent leakage paths or other spurious behavior. The 252AP and the 99X family of opamps are lowest noise discrete operational amplifiers available, but poor layout, grounding or system architecture can defeat this advantage.

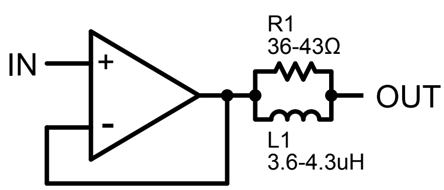

Figure 1. Isolating capacitive loads from disturbing feedback loop stability with an inductor. The non-inductive resistor avoids resonance problems with load capacitance by reducing Q.

The 252AP is normally stable with resistive, inductive or smaller capacitive loads. Larger capacitive loads interact with the open-loop output resistance to reduce the phase margin of the feedback loop, ultimately causing oscillation.

With loop gains greater than unity, a feedback compensation capacitor across the feedback resistor will aid stability. In all cases, the op amp will behave predictably only if the supplies are properly bypassed, ground loops are controlled and high-frequency feedback is derived directly from the output terminal of the opamp.

So-called capacitive loads are not always capacitive. A high-Q capacitor in combination with long leads or PCB traces can present a series-resonant load to the op amp. In practice, this is not usually a problem; but the situation should be kept in mind.

Large capacitive loads (including series-resonant) can be accommodated by isolating the feedback amplifiers loop from the load as shown in **Figure 1**. The inductor gives low output impedance at lower frequencies while providing an isolating impedance at high frequencies.

The resistor flattens the Q of series resonant circuits formed by capacitive loads. A low inductance resistor is recommended. Optimum values of L and R depend upon the feedback gain and expected nature of the load, but are not critical.

Typical Applications

Figure 2 shows a simple traditional transformer input mic preamp, with a fixed gain of 40dB (Av=100). The Jensen JT-115K-E mic input transformer is perfectly suited for this application.

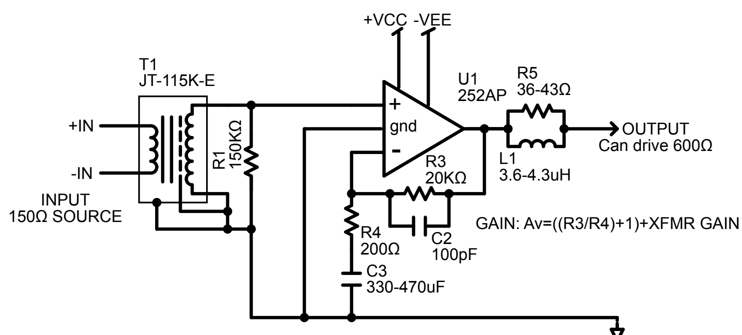

Figure 2. Transformer input mic preamp

R1 provides termination for the input transformer and ground reference for the 252AP amplifier. The step up nature of the transformer provides additional voltage gain. R3 and R4 set ac voltage gain of the 252AP op-amp. Whereas, R3/R4+1=Av, 20logAv=Gain_dB. Other values can be chosen depending on gain desired. C2 provides phase-lead compensation and sets the upper frequency BW cutoff point. C3 keeps the DC gain of the 252AP at unity so that a small difference between the DC volatges at the inputs will not produce large offset voltages at the output. The value of C3 also establishes low frequency cutoff.

Sonic Imagery Labs
P.O. Box 20494
Castro Valley, California 94546
P:(510)728-1146 F:(510)727-1492
www.sonicimagerylabs.com

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Typical Applications (continued)

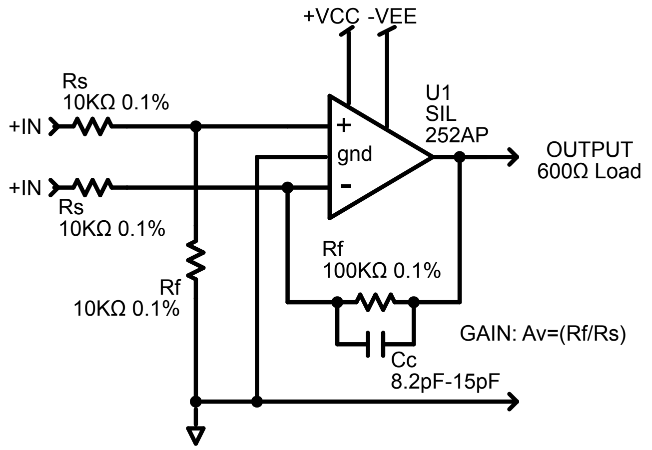

Figure 3. Balanced transformerless amplifier.

The circuit shown in **FIGURE 3.** illustrates a classic balanced instrumentation amplifier. By incorporating precision 0.1% or better resistor matching for Rs and Rf, common mode rejection ratios of greater than 90dB are easily obtainable. Gain is 20db, and is set by Rf/Rs. Input impedance is 20KΩ. Other impedances are obtained by simply scaling the values shown. Equivalent input noise (EIN) approaches -129dBm, 20Hz-20kHz, unweighted. The value of Cc, the feedback compensation capacitor, sets the high frequency cutoff point. With Cc set to 10pF, frequency response is +0 -0.25dB over a DC to 20kHz bandwidth.

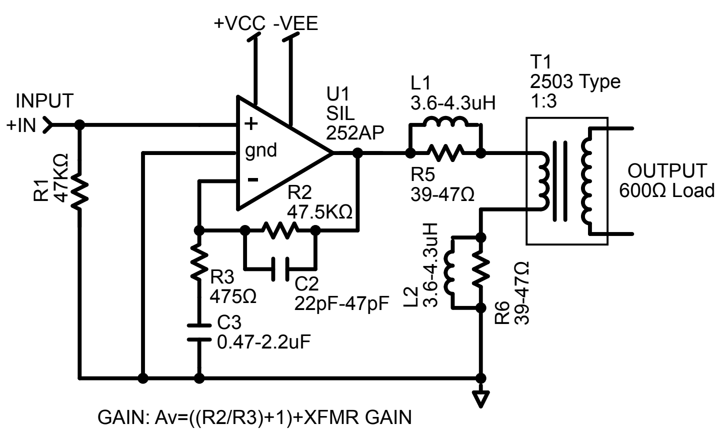

Figure 4. Line Amplifier

The circuit shown in **FIGURE 4.** is the traditional line amplifier or balanced cable driver. The 1:3 transformer provides about 9dB of voltage gain. Amplifier gain is 40db with the values shown, and is set by ratio of Rf/Rs+1. Input impedance is 47KΩ as set by R1. Equivalent input noise (EIN) approaches -128dBm, 20Hz-20kHz, unweighted. The value of C3 sets the low frequency cutoff. With C3 set at 0.47uF the -3db point is about 22Hz. The value of Cc, the feedback compensation capacitor, sets the high frequency cutoff point. With Cc set to 47pF, frequency response is +0 -0.5dB over a 30Hz to 20kHz bandwidth.

As the Sonic Imagery Labs 252AP easily can operate with ±24V supply rails, power outputs of over +30dBm into 600Ω is possible. The dominant source of distortion for this circuit is the output transformer. At 1Khz, THD is typically better than 0.01% at +18dBm output. Distortion will rise rapidly at lower frequencies due to the transformer and the nature of magnetics and materials involved. This distortion phenomenon is basic to all audio transformers, to one degree or another. It is lessened (but not eliminated) in the higher quality transformers, such as nickel-core types.

In practice, there are some factors that tend to mask the seriousness of the lower frequency/rising distortion/output level phenomenon. First, rarely will maximum audio levels ever be seen at 10-100Hz ranges. However, if the lowest possible distortion possible independent of level and frquency is desired, then some additional effort will be needed to be expended on making a transformer driver circuit more sophisticated.

Werner Baudisch[1] developed a very effective driver technique for the linearization of tranformer distortion. The technique involves the use of a drive amplifier, connected to the transformer primary in a direct manner. The amplifier uses conventional negative feedback for gain stabilization. In addition, a primary sensing resistance develops a voltage sample proportional to primary current, and the voltage thus derived is also fed back to the amplifier. This second feedback path is positive feedback, so the arrangement is known as a mixed feedback driver[2].

Sonic Imagery Labs
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Typical Applications (continued)

This technique of the mixed feedback driver can be used to advantage to integrate a line driver with the transformer primary within a feedback loop, which cancels the majority of the objectionable distortion. In practice, with careful driver adjustment it is possible to reduce the distortion of the transformer plus the driver amplifier almost to that of the driver stage itself, operating without the transformer. The beauty of the principle is that the inherent floating transformer operation is not lost, and is still effectively applied in a highly linear mode. Due to the action of the mixed feedback, the transformer primary resistance is effectively cancelled, thus appreciably lowering the net secondary output impedance.

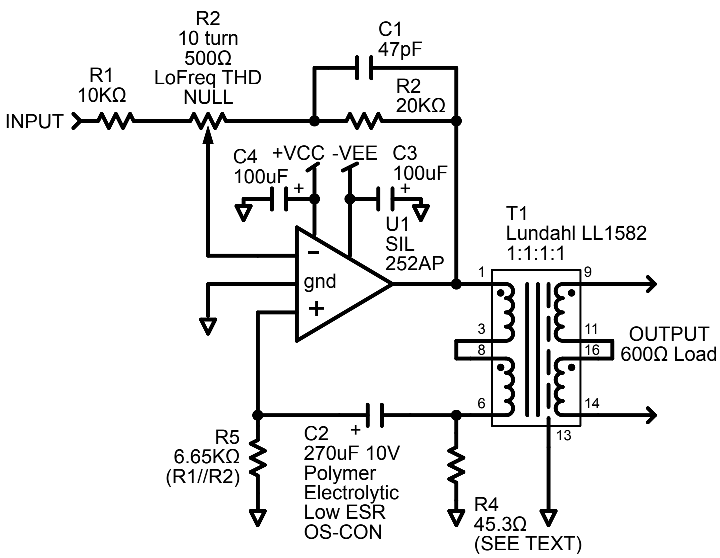

Figure 5. Basic single ended input mixed feedback transformer driver amplifier.

The circuit of **FIGURE 5.** is a basic, single-ended mixed feedback driver using a Lundahl LL1582 transformer as T1, and a Sonic Imagery Labs 252AP as the driver amplifier. The transformers have two 1:1 primaries, as well as two 1:1 secondaries. As used, both primaries are connected in series, and the T1 net voltage transfer is unity. To enable correct mixed feedback operation, two key ratios within the circuit must be set to match. One ratio is between the net T1 primary resistance, Rprimary and sample resistor R4 and the other is R2 and R1. This relationship is:

Rprimary/R4 = R2/R1 Eq. 1-1

It is important to note that Rprimary is the total effective DC resistance of T1. As used here, two series 45Ω primaries are used, so Rprimary is 90Ω. Gain of the driver circuit is established as in a standard inverter, or the R2-R1 ratio. For a gain of 2X, R2 is then simply 2 times R1, i.e., 20KΩ and 10KΩ. R4 may then be selected as:

R4 = R1 /R2 * RPRIMARY Eq. 1-2

With the R1/R2 ratio of 0.5, this makes R4 simply 1/2 Rprimary, or in this case 45Ω.

Note the value of R1 is critical, thus the VIN source impedance must be low (<10Ω). This and other subtleties are effective performance keys. One is the sensitivity of the ratio match described by Eq. 1-1. Only when trimmed optimally will the lowest frequency THD be minimum. Thus a multi-turn film trimmer R3 is used to trim out the various tolerances and the winding resistance of T1. Further, the positive feedback path is AC-coupled via C2. This provision prevents DC latchup, should positive feedback override the negative. However, a simple time constant of say, 8ms (corresponding to 20Hz) is not sufficient for lowest low frequency THD. To counteract this, the C2-R5 time constant is set quite long (~1.8 seconds), which enables lowest possible 20Hz THD. With the Sonic Imagery Labs 252AP for U1, distortion is lowest, as it is also with an OS-CON polymer capacitor for C2. A larger value ordinary aluminum electrolytic can also be used for C2 with a penalty of somewhat higher distortion performance. Alternately, Sonic Imagery Labs 99XEnh series of opamps can also be used for U1.

With the Sonic Imagery Labs 252AP input op amp used for U1, the maximum DC at the T1 primary is essentially the amplifier Vos times the stage's 3x noise gain, or <1mV. Since the Sonic Imagery Labs 252AP can also dissipate 750mW, operating supplies at ±18Vto ±24V help keep the offset change with temperature as low as possible and provide maximum headroom and dynamic range.

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Typical Applications (continued)

Lab THD measurements of the circuit illustated in FIGURE 5 were made using a Lundahl LL1582. The performance of this feedback driver is shown in FIGURE 6. for successive output levels of 0.5, 1, 2, and 5Vrms into a 600Ω load. Comparison of this data in FIGURE 6. to the LL1582 THD data shows the utility of the distortion reduction; it is decreased by orders of magnitude. More importantly, the level dependence with decreasing frequency is also essentially eliminated.

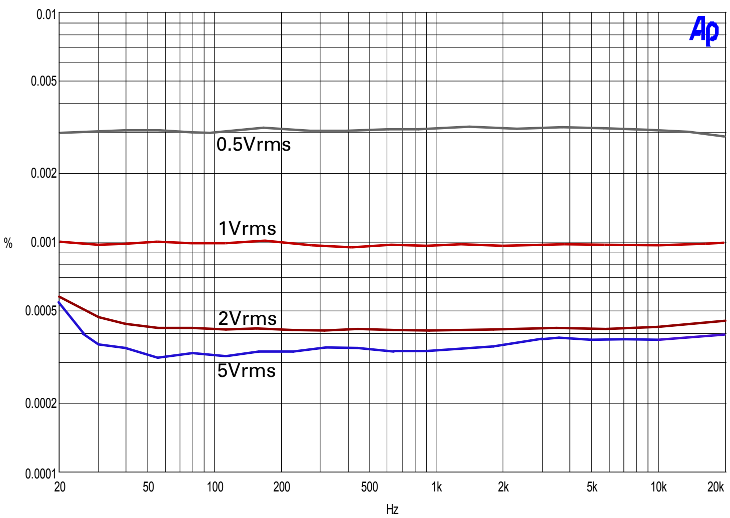

Figure 6. Driver circuit with Lundahl LL1582 transformer and the SIL252AP, THD+N (%) vs. frequency (Hz), for Vout= 0.5, 1, 2, 5Vrms, R_L=600ohm

These data do in fact represent almost an ideal THD+N pattern; the distortion level is flat with frequency, and it decreases with increasing output level. An extremely slight increase in THD+N can just be discerned at 20Hz in the 5V curve.

REFERENCES: AUDIO LINE DRIVERS

1. Werner Baudisch, "Schlatungsanordnung mit Verstarker mit Ausgangubartrager," German Patent DE2901567, issued July 24, 1980.

2. Per Lundahl, "Mixed Feedback Drive Circuits For Audio Output Transformers," Lundahl Transformers, Norralje, Sweden, http://www.lindahl.se

PCB Sockets for 252AP and 99X Series

It is highly recommended that the user not solder the pins directly to the mating printed circuit board. Overheating the pin creates a cold solder joint at the other end. Permanant soldering of the pin prevents easy removal of the module. Lastly, soldering prevents one from servicing components which may lie underneath the module.

Many types of sockets for 0.040" diameter pins are available from several manufacturers. Sonic Imagery Labs uses and stocks the sockets from all three listed manufacturers below. These sockets can be soldered or swaged in your printed circuit board. Additionally, users can purchase a set of six from Sonic Imagery Labs online.

Mill-Max **Part Number 0344-2-19-15-34-27-10-0**
190 Pine Hollow Road,
PO Box 300
Oyster Bay NY 11771

Wearnes Cambion Ltd **Part Number 450-3756-02-03**
Peverial House
Mill Bridge, Castleton
Hope Valley S33 8WR
United Kingdom

Concord Electronics Corp **Part Number 09-9035-2-03**
33-00 47th Ave, Level 1A
Long Island City, NY 11101

Sonic Imagery Labs
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Castro Valley, California 94546
P:(510)728-1146 F:(510)727-1492
www.sonicimagerylabs.com

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P:(510)728-1146 F:(510)727-1492
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