Balanced Trasformerless Mic Preamp with the Sonic Imagery Labs 996VP-LZ Amplifier

The circuit shown in FIGURE 1. represents the Sonic Imagery Labs Model 996VP-LZ transformerless microphone pre-amp in its fully optimized form. The design is capable of direct tranformerless amplification of both dynamic and phantom powered condenser type microphones, whose output impedances range from 40 to 600 ohms. Performance specifications described are for standard 150 ohm microphones used in most professional broadcast and recording studio applications.

Advantages

The advantages of this balanced amplifier circuit may not be obvious at first glance. While having a professional audio input transformer is the standard go to solution when high common mode rejection of noise is needed, transformers are large, expensive, saturate at high input levels and can color the program materials sound. This is not always a bad thing and has become a part of the tool box for the audio landscape. The most critical aspect of a pre-amp is its ability to reject common mode noise found on the input balanced lines. Input transformers do this well and this accounts for there ubiquitousness. The circuits presented in this application note approach and in some cases can surpass transformer input performance with the added benefits of cost reduction, simpler support circuitry, more spectral purity and wider dynamic range without the color produced by input and output transformers. By using the Sonic Imagery Labs Model 996VP-LZ as the input gain block, the designer also can take advantage of the 996VP-LZ's balanced output and create a fully balanced system through out. This balanced topology would provide an additional lowering of the noise floor by 6dB. Using monolithic IC devices to achieve this requires 2 to 4 opamps, 8 to 12 super matched resistors and a dual ganged precision matched potentiometer to set gain. As dual precision matched potentiometers are somewhat unobtainium, building a preamp with monolithic devices in this manner quickly becomes problematic in regards to circuit complexity and CMRR performance.

Circuit Description

The microphone input is supplied with +48V DC phantom power, in the industry accepted manner by R1 and R2. These resistors should be 6.81KΩ 1% or better matched and at least 1/2W 2512 size. If leaded resistors are used the designer should be aware of thermal gradiants causing resistive mismatch due to self heating and poor temperature coefficients. Precision here is required for minimum generation of non-common mode hum from the phantom power supply from getting into the input stage. Low pass filter produced by R17 and C4 also aids in removing phantom power noise.

Input Capacitors

Capacitors C1 and C2 serve to isolate the +48V DC phantom power from the Sonic Imagery Labs 996VP-LZ inputs. To obtain the highest quality preamp, polypropylene low leakage capacitors should be used for C1 and C2. Although 22uF value may appear a low value for coupling a 150Ω source, it should be noted that the frequency response is determined by: Freq3db=(1/2πXcC)*2 wherein Xc equals 100KΩ differential input impedance of the Sonic Imagery Labs 996VP-LZ amplifier. This calculates out to be about 0.14Hz for a 22uF capacitor. The capacitors will increase the noise figure of the amplifier at sub-audio frequencies - a point of essentially no concern in reality. Larger values would reduce this effect but would become prohibitive in terms of size, cost, leakage currents and hum induction.

Input Protection

R4, R5 and Z1 thru Z4 form an input protection circuit to protect the 996VP-LZ input stages from high voltage surges which may be produced when connecting and disconnecting microphones from the input. These components must not be ignored when the system is phantom powered, or permanent damage may result to the input stage of the 996VP-LZ. The circuit shown clamps each leg to ±6.8V maximum potential. The circuit has no effect on program material below +21dBV. If diode clamps to the power supply rails are used instead, it should be determined that these rails can absorb the potential discharge from C1 and C2 without damage and that no overshoot, ringing or spikes are present during a discharge event. There are many other circuit topologies for input protection and are always worth exploring depending on the application specific needs of the designer and the enviroment the circuit will be used in.

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De-Thump Circuitry

The input stage of the 996VP-LZ is DC coupled, and should be offset to zero volts differential, if rapid gain changes are to be made with R14. If the input is not zero offset, large magnitude level shifts (thumps) will will heard, especially when adjusting in the higher gain portions of R14. The circuit of R11 and R12 provide this correction/ adjustment. R18, R19, C5 and C6 form filters to prevent supply rail noise from entering the input stage. De-thumping may alternatively be accomplished by inserting a large value capacitor in series with R13. For audio applications this may be somewhat impractical since a low frequency roll off will be introduced at:

Freq roll= $1/2\pi XcC$ wherein Xc equals R13+R14 at the selected gain. At 60dB gain setting a 6800uF capacitor would be required for a 1dB roll off at 20Hz.

EMI/RF Suppression

Capacitor C3, together with R3//R4 and R5//R6, provides additional EMI/RF suppression by limiting the input bandwidth to about 200kHz. C3 also serves to add additional stability with capacitive or inductive elements from various input sources. The circuit is typically stable with C3 as low as 560pF, in which case the bandwidth is extended beyond 1Mhz.

Gain Setting

The 996VP-LZ gain is set by the ratios of R15, R16, R13 and R14 and is determined by the formula:

DiffGain=1+(R15+R16 / R13+R14)

The maximum gain is set by R13, while the minimum gain is established by R14 (a pot, fader, or stepped resistor ladder). It should be noted that, for thermal noise purposes, R13 and R14 are effectively in series with the microphone and must be kept as low in resistance as possible. For instance, at the gain point where R13+R14 equal the microphones impedance of 150Ω, the noise figure is necessarily degraded by 3dB. With the values shown, this occurs at a gain of approximately 18dB. Fortunately, at this low circuit gain, the actual output noise figure is of no consequence in achieving ultra low noise performance. Indiscriminately raising the values of R13, 14, 15 and 16 can, however, bring the noise performance into an area of degradation.

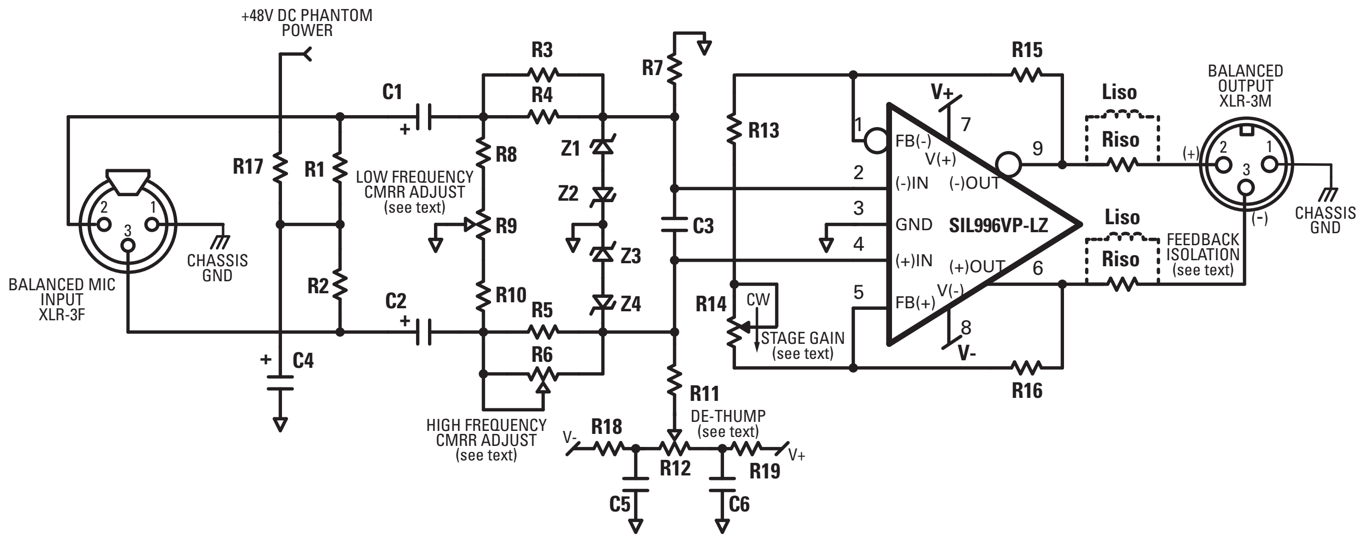

FIGURE 1. Balanced Input Balanced Output Transformerless Preamp and Cable Driver. See page 4 for Bill of Materials and component values.

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Gain Set Potentiometer/ Fader

A higher value potentiometer can be substituted for R14, allowing lower minimum gains (below unity Av<1) with resultant higher allowable input levels (to +21dBV with 6.8V zener clamps). The practical limitation however is a loss of adjustability at the high gain end. The problem area here is the resolution of the pot in the 0Ω to 10Ω region. Because of this, linear taper potentiometers are simply not very practical. Better alternatives would be:

A. A reverse compound audio taper potentiometer
B. A switchable 2 pot scheme, 1KΩ high gain/10KΩ low gain
C. A switchable resistor in parallel with potentiometer
D A stepped resistor ladder where in the designer sets gain steps

Output Riso and Drive Capability

The 996VP-LZ output stage provides nearly rail to rail output voltage. Output levels of +28dBu differential are easily obtainable and are not limited by gain setting dependency. Unlike the original Valley People Trans-Amp-LZ, the Sonic Imagery Labs 996VP-LZ output driver stage has been redesigned specifically to source and sink large amounts of current without degrading the output drivers linearity. The resistors Riso serve to isolate the feedback loop from reactive elements that might degrade the feedback loops performance. The addition of Riso in series with the output insures stability with capacitive and inductive loads. This allows the Sonic Imagery Labs 996VP-LZ to drive headphones, transformers and balanced cabling directly and remain stable. Additionally, 996VP-LZ is also protected against short-circuit and thermal overload events. Load impedances as low as 75Ω can be driven directly. Additional high frequency stability can be achieved by adding a 3.9uH inductor in parallel with Riso in high frequency wide bandwidth applications.

Achieving the Extreme

Extreme common mode noise and hum rejection requires careful balancing of the common mode paths. This is particularly true with the circuit configured for phantom power capability, as the series elements R3//R4, R5//R6, C1 and C2 are capable of introducing errors in the magnitude of signals reaching the Sonic Imagery Labs 996VP-LZ inputs.

Achieving the Extreme (continued)

It must be noted that an error in magnitude as small as 0.01% between signal levels on the two inputs can reduce the achievable common mode rejection ratio to 80dB. Such an error can be introduced, at 60Hz, by a 3% mismatch of C1 and C2, unless compensated for. In the circuit shown in FIGURE 1., two CMRR trim pots are provided (R6, R9) which serve the following function:

A. R9 corrects mismatch error produced by C1 and C2.
B. R6 corrects mismatch error produced by R3//R4 and R5, together with the small CMRR error of the 996VP-LZ itself.

Properly adjusted, the circuit provides CMRR's well in excess of 100dB (typically 115 to 125dB), thoughout the audio range, with excellent CMRR extending into the RF region for wideband scientific applications. Making resistors R15 and R16 0.1% tolerance devices will allow trimming CMRR to 128dB.

Adjustment and Set Up

Although the trims may certainly be adjusted with test equipment, a faster and sometimes more effective method, simply involves a signal source (audio oscillator or synthesized signal source) and monitor speaker set up.

Procedure:

1. Set R6, R9 and R12 to center range.
2. Set R14 to minimum gain position
3. With phantom power supply off, short or tie the two microphone terminals (pins2 and 3 of XLR) together and apply 1kHz, at -10dBv level to the shorted inputs.
4. Adjust R14 between gain settings while adjusting R12 for minimum "thump" if present.
5. Set audio source to 60Hz, adjust R9 for minimum output.
6. Set audio source to 1kHz, adjust R6 for minimum output.
7. Repeat steps 4-7, if needed.
8. Seal trim pots with GLPT or fingernail polish for vibration resistance.

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Transformerless Microphone Preamp with Cable Drive (FIGURE1.)
GAIN = 10dB to 60dB
MAX INPUT = +18dBv
MAX OUTPUT = +28dBv @ 600Ω
MIN LOAD = 75Ω
MAX SUPPLY ±18V
Noise Figure at 60dB = <0.4dB (EIN = -132.5dBv re: 0.775V
Noise Figure at 30dB = <2.5dB (EIN = -128dBv re: 0.775V
THD+N = Below 0.005% at any setting below clip (20Hz-20kHz)
BW = 2Hz to 160kHz any setting
Slew Rate = 20V/uS
CMRR = Trimmable to exceed 110dB

PARTS LIST
U1 = SIL996VP-LZ Operational Amplifier
Z1-Z4 = 6.8V/500mW ZENER DIODE
C1, C2 = 22uF 63V Polypropylene low leakage
R1, R2 = 6.81KΩ 1% 1/2W FP
R3 = 100Ω 1%
R4, R5 = 10Ω 1%
R6 = 1KΩ 10 turn trimpot
R7, R11 = 1MegΩ 1%
R8, R10 = 68.1KΩ 1%
R9, R12 = 50KΩ 10 turn trimpot
R13 = 2.21Ω 1%
R14 = 1KΩ reverse audio taper pot (see text)
C3 = 2200pF to 5600pF (4700pF in test circuit) NPO/C0G type
R15, R16 = 2.21KΩ 1% (0.1% to achieve 128dB CMRR)
C5, C6 = 0.1uF
C4 = 220uF 63V Low ESR Tantalum or Electrolytic type
R17 = 100Ω 1% 1/2W FP
R18, R19 = 221Ω 1%
Riso = 39.2Ω 1% 1/2W
Liso Option = 3.9uH Inductor

NOTES:
Decouple power supply connections with 10uF 25WVDC minimum Low ESR Tantalum or Electrolytic types. The 996VP-LZ has additional decoupling (0.1uF and 4.7uF) on board. Resistors can be 1/4W or 1/8W Metal Film leaded or 1206 SMD Type (recommended) unless otherwise specified.

Additional Applications
In addition to to simply having a balanced differential output, the designer can also add a parallel functioning unbalanced single ended output as well and, still maintain outstanding audio performance specifications.

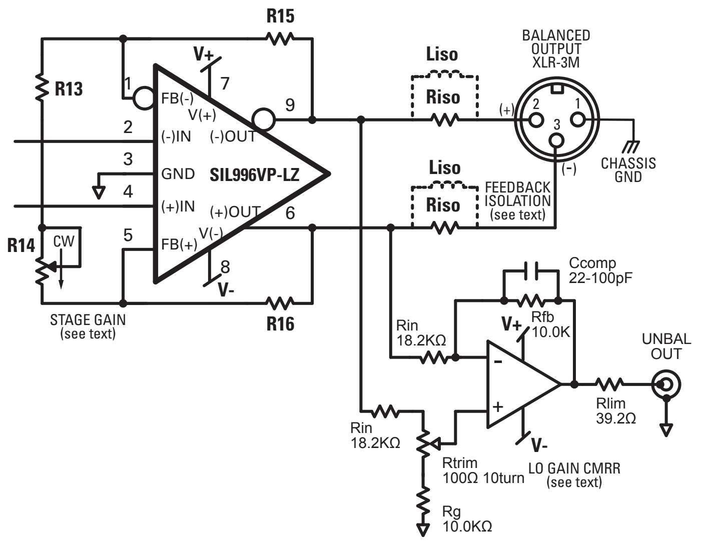

FIGURE 2. Additional Unbalanced Output Option

Shown in FIGURE 2. above, the 996VP-LZ circuit from FIGURE 1. produces a differentially opposed output, it's maximum voltage output swing is 6dB greater, for a given input plus gain than a single ended amplifier. Since the 996VP-LZ can produce an output swing of +28dBV before clipping, a loss amounting to 5.2dB is designed into the gain structure of the single ended circuit, in order to equalize the clipping points and maximize the signal to noise characteristics of the total circuit. Rtrim is added to correct for tolerance mismatch of Rin, Rg and Rfb. This is a 1kHz trim step that can be added before STEP 6 of the aforementioned procudure in this application note on page 3. Adjust Rtrim for minimum 1kHz at SE output of circuit. Higher output swings can be realized by using a higher voltage compliant amplifier operating on higher supply voltages (I.E. ±24V), and omitting the 5.2dB loss. The Sonic Imagery Labs models 992Enh, 990Enh, 995FET devices suit this application well. In this case, Rin would should be changed to 10.0KΩ.

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Additional Applications (continued)

The Sonic Imagery Labs 996VP-LZ is perfectly suited as a current to voltage converter for most commercially available high resolution audio DACs. As shown in FIGURE 3. the Sonic Imagery Labs 996VP-LZ can be configured as a true balanced differential current to voltage amplifier by simply grounding its input terminals and treating its feedback terminals as virtual ground current summing junctions. In this application, coupling capacitors Cin are required to prevent differences in bias voltages present at the +FB and -FB points of the 996VP-LZ to cause DC currents to flow through the sources. Modern current output DACs usually have differential outputs, to achieve high common-mode rejection and reduce the even-order distortion products. Fullscale output currents in the range of 0.5 mA to 30 mA are common. In many cases, both true and complementary current outputs are available. The differential outputs can drive the opamp directly. This method will often give better distortion performance at high frequencies than simply taking the output signal directly from one of the DAC current outputs and grounding the other. Resistors Rbw and Cbw form a low pass filter to remove high frequency DAC switching and alias noise from passing thru to the next stage or output.

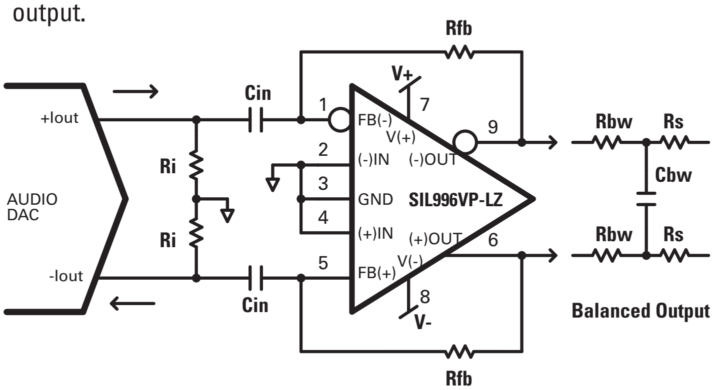

FIGURE 3. Direct interface with differential current output digital to analog converters

Driving the virtual ground of the Sonic Imagery Labs 996VP-LZ op amp minimizes any distortion due to nonlinearity in the DAC output impedance. In fact, most high resolution DACs of this type are factory trimmed using an I/V converter in this manner. 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% or better, metal film resistors should always be used. Since these components can represent high impedance, lead length and trace lengths should be minimized. Assembled circuits and PCB's should be carefully cleaned of flux residue to prevent leakage paths or other spurious behavior.

Additional Applications (continued)

The Sonic Imagery Labs 996VP-LZ can be configured as a true balanced differential voltage amplifier with final gain set by Rg as illustrated in FIGURE 4.

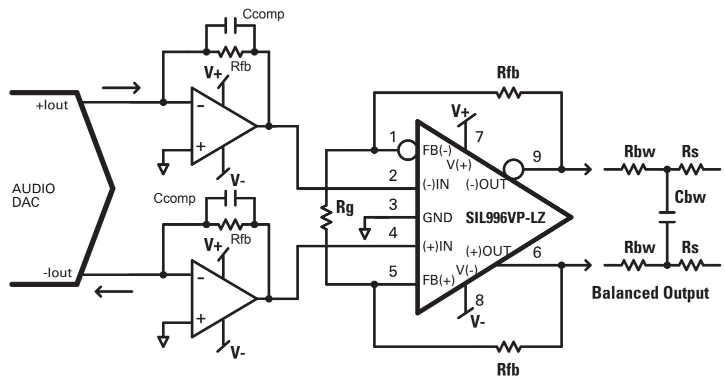

FIGURE 4. The 996VP-LZ being driven by external I-V convertors. The 996VP-LZ acts as a true differential voltage amplifier interface with current output digital to analog converters that may have large BPZ offset current.

The Sonic Imagery Labs 996VP-LZ can also accommodate differential voltage output digital to analog converters. This can be accomplished either by the current summing method as shown in FIGURE 5 shown below or by the differential voltage amplifier topology.

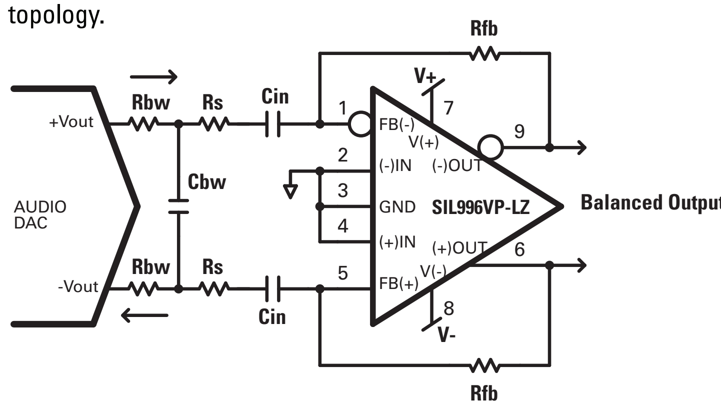

FIGURE 5. The 996VP-LZ being driven by a differential voltage output digital to analog converter.

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Additional Applications (continued)
Given the information thus far regarding balanced interfaces, it does not take much of a technical leap to see that the Sonic Imagery Labs 996VP-LZ is also perfectly suited as a driver for commercially available high resolution audio analog to digital convertors. As shown in in FIGURE 4. the Sonic Imagery Labs 996VP-LZ can be configured as a true balanced differential interface to directly drive most modern ADCs.

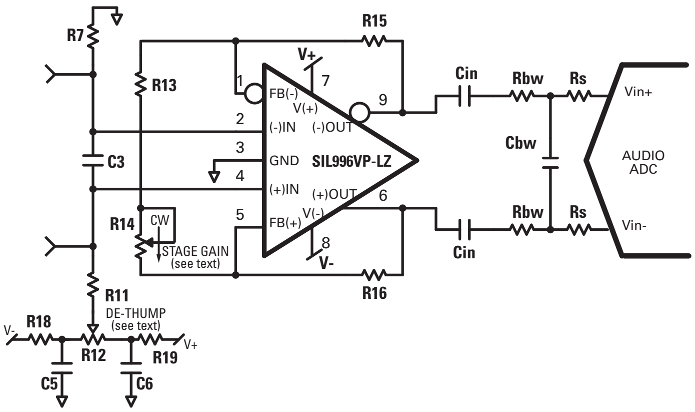

FIGURE 4. Direct interface with modern balanced analog to digital converters

Resistors R15//R16 and Cin form a low frequency high pass pass filter and prevents any DC offset from being digitized into the program material. Essentially a DC block and rumble filter. Resistors Rbw//Rs and Cbw set the high frequency roll off point. It is essentially the input anti-alias filter. Setting this to around 21-23kHz insures high frequency harmonics of the program material from producing alias noise in the digital domain.

With the advent of new 32 bit sampling ADCs for professional audio becoming available, Sonic Imagery Labs also offers the 996VP-LZ UULN option. This option pushes the 996VP-LZ's equivalent input noise into the 390-480pV√Hz region. This type of noise performance is a technical must have for these types of analog to digital convertors.

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PCB Sockets for 996VP-LZ OpAmp

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 contact Sonic Imagery Labs and purchase a set of nine.

PCB Sockets for 996VP-LZ OpAmp

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

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