Digital Gain Control with Sonic Imagery Labs 312A Discrete VCA Amplifier

Richard Ian Doporto
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November 2013

The 312A VCA module is a very high performance device offering wide range exponential control of gain and attenuation with very low audio program signal distortion. The 312A VCA module is a powerful and versatile building block with applications ranging from radio AGC, compressors, limiters, expanders, to microprocessor controlled faders. Its application is merely limited to the designers imagination.

The circuits within this application note feature the Sonic Imagery Labs Model 312A to provide the essential function of voltage-controlled amplifier (VCA). In many cases, a fully analog signal path provides the least compromise to sonic integrity, and ultimately delivers the best sounding audio program material. What is often needed, however, are methods for varying the gain and other parameters of the analog circuitry, under digital or microprocessor control.

A high performance, exponential-control, Voltage Controlled Amplifier (VCA), and a low cost Digital-to-Analog Converter (DAC) will provide to the designer the best combination of sound quality, control range, and control resolution.

The analog signal path provides the highest possible dynamic range, and avoids such common digital artifacts as pot noise, spectral spreading, digital feedthrough, and digital DSP idle noise, and eliminates the need for an expensive high-resolution Analog-to-Digital Converter (ADC).

The exponential gain control of the VCA means that the equal step sizes of an ordinary DAC will translate to gain increments which are of uniform size in decibels. As a result, an inexpensive DAC of relatively low precision (8 to 14 bits) will provide the gain range and resolution required for any application.

While digital signal processing has grown in popularity in recent years, there are significant advantages to using an all-analog signal in professional audio equipment. These include: No digital artifacts such as digital feedthrough and spurious idle tones; No need for an expensive, high-resolution Analog-to-Digital Converter (ADC).

At the same time, designers want to take advantage of the convenience, programmability and recall afforded by modern microcontrollers. The use of a DAC to manipulate the gain of an exponentially-controlled Voltage Controlled Amplifier (such as the Sonic Imagery Labs Model 312A) is a near-perfect solution to the problem of digital gain control of analog signals, and provides additional advantages over other approaches.

• Wide dynamic gain range, with equal decibel gain steps

An ordinary linearly-controlled gain element will provide gains that increase in equal, but linear, increments. The result is a gain range that is both severely restricted and whose gain steps, when viewed on a decibel scale, vary widely and inefficiently from one end of its gain range to the other. An exponentially-controlled VCA's linear-in-dBs control port characteristic, on the other hand, results in much more efficient use of a DAC's dynamic range. By using an inexpensive 8-14bit DAC, setting the gain scaling and offset, the designer can easily control a VCA range that spans 120 dB.

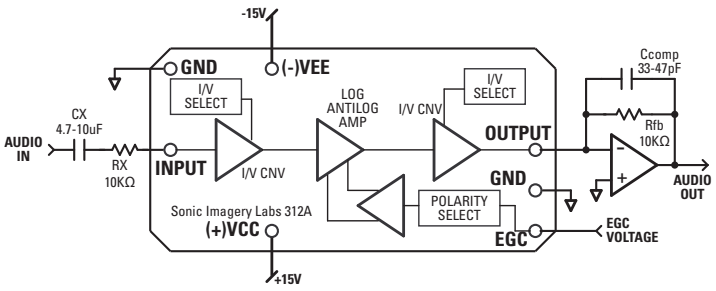

FIGURE 1. Basic connections for current-in and current out mode of operation.

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High Performance Digital Gain Control Application:

Digital gain control with no artifacts can be implemented with the Sonic Imagery Labs Model 312A, an 8-bit DAC and a smoothing filter, as shown in **Figure 2.** Sonic Imagery Labs VCAs are 2-quadrant multipliers with a linear signal input and an exponential gain-control input. With the use of a DAC, one channel will generate the VCA's EGC control signal.

Op amp U2 acts as a control voltage buffer, and sets the control voltage offset. Since this circuit drives the EGC control port with the Sonic Imagery Labs 312A VCA configured with negative polarity control,

$Gain_{dB} = -EGC/Kc$

where EGC is the voltage at the control port, and Kc (the control voltage constant) is equal to 50 mV/dB. If it is required to compensate the VCA's gain against variations in extreme temperature, R1 can be a +3300ppm PTAT type.

The DAC in **Figure 2.** is a generic, serial 8-bit DAC which can typically be purchased relatively easily and at low cost.

Unlike the case where analog audio is passing directly through the DAC, the output of this DAC can, and should, be filtered to create continuous transitions between gain settings at the VCA's control port. The parallel combination R2 and R3 in conjunction with Cfilt results in TIMEconstant of around 7mS. This combination has proven to provide good audible results in fader-type applications, though the designer should feel free to experiment and find the filter characteristic that suits the project's needs.

The DAC output varies from 0 to 4.096 volts, which is scaled by the control voltage buffer to be

$4.096\ V \bullet (R1/R2+R3) = EGC_{range}$

When this voltage is divided by the VCA's control voltage constant, the resulting gain control range in decibels is:

EGC_{range}/Kc = VCAcontrol in dB

R4 is used to offset the gain control signal by +20.0 dB to allow the VCA's gain to be varied from -80 dB to +20 dB in steps of 0.39 dB.

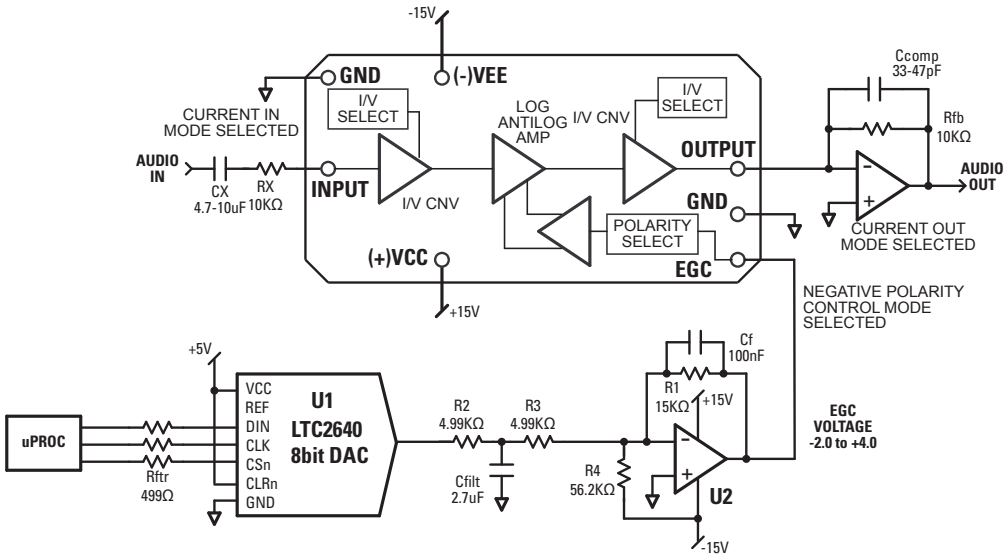

FIGURE 2. Basic 8Bit DAC-controlled VCA

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November 2013

High Resolution Digital Gain Control Application:

FIGURE 3. illustrates a 14bit DAC (U1) driven by a SPI digital port from a microcontroller. A low cost precision 2.5V reference sets the DAC output voltage range. In this case the output of the DAC is 0 to 2.5V. Any reference will work as long as final EGC voltage is scaled and offset appropriately for the gain/attenuation range required. Scaling and offset is performed by U2. Any low noise precision op-amp can perform this duty.

Slewing rate of DAC step changes can be controlled by placing a capacitor across R1. This reduces the bandwidth of the U1. The parallel combination R2 and R3 in conjunction with Cfilt results in TIMEconstant of around 7mS.

This is generally a good idea as noise and spurious signal at the output of U1 will modulate the program material passing through the Sonic Imagery Labs 312A VCA module.

Using the values shown in **FIGURE 3**., the Model 312A VCA-EGC module has a gain range of +44dB at 2.2V and -84dB at -4.2V. With a 14 bit DAC, each DAC step is equivalent to a 0.007dB change in gain/attenuation.

Other bit resolution DACs, voltage references and scaling operational amplifier circuits can be implemented depending on the final application and needs of the designer.

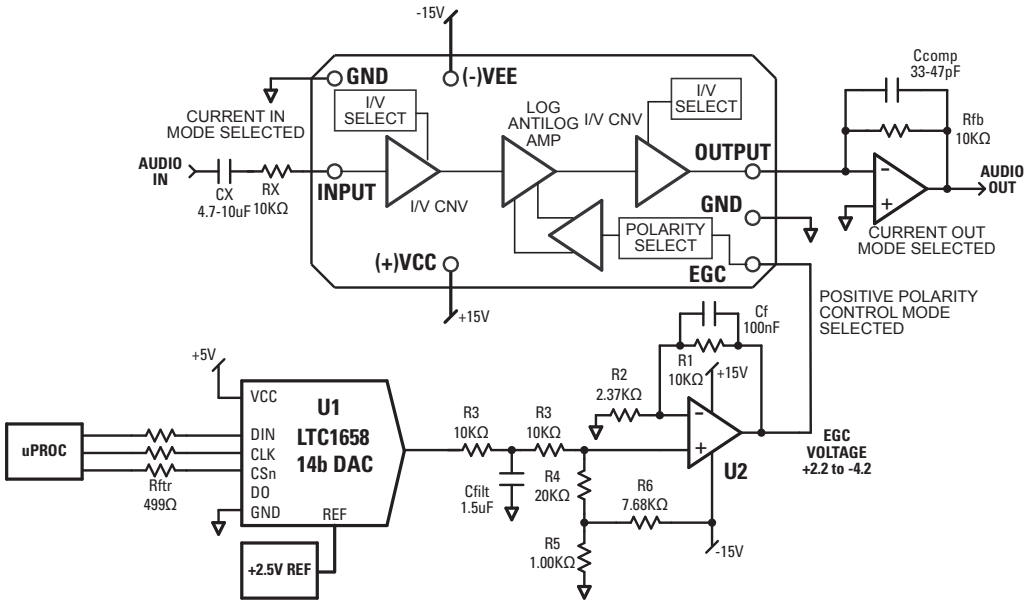

FIGURE 3. High resolution 14Bit DAC-controlled VCA

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Digital Gain Control Application:

When designing digitally-controlled analog circuits, Sonic Imagery Labs 312A VCA-EGC provide a simple, high performance means to realize a wide variety of precision dynamic elements.

Isolation of the digital and analog signals is easily maintained since the analog signal never has to traverse circuitry referenced to digital ground. The ability to add a smoothing filter to the controlling DAC's output enables switching noise and artifact-free gain control, while "zipper noise" and "spectral splatter" are all but eliminated due to the resultant continuous nature of the gain changes.

Sonic Imagery Labs Model 312A VCA provides additional versatility and performance opportunities as a result of their ability to do double-duty, with a single component acting as both gain control and effects processor.

System architecture is simplified since exponentially-controlled VCAs at different gain levels can have their gain incremented as a group in like dB steps (as a result of the VCA's linear-in-decibel control port function) by simply adding the same integer to each VCA's DAC. The overall simplicity and sensibility of VCAs make them the designers choice where digital control of analog signal is desired.

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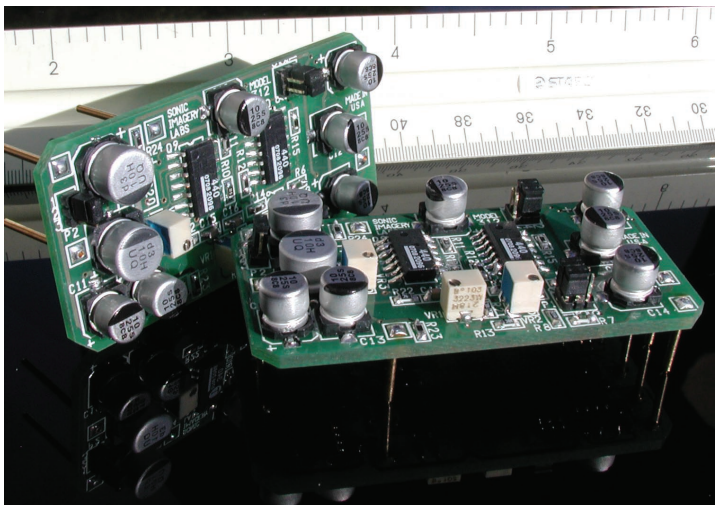
Model 312A Discrete Voltage Controlled Amplifier Module

PRODUCT BRIEF

The Model 312A voltage controlled amplifier is a high-performance voltage controlled amplifier or electronic gain control (VCA-EGC) designed for audio or instrumentation applications where low distortion, low noise, low control-voltage feed through and exceptional gain control characteristics are of primary importance. The 312A approaches immeasurably small intermodulation and total harmonic distortion independent of gain, input, or output levels. The 312A has been designed using precision matched pair discrete SMD component technology, resulting in outstanding performance, high reliability, temperature stability and wide dynamic range. It is pinned out for industry compatibility.



The gain versus control voltage characteristics of the 312A are an exponential function (20db/volt) allowing the designer to easily and accurately program the gain in decibels. The all discrete VCA core boasts a gain-bandwidth product of better than 50Mhz, resulting in full audio bandwidth at 60dB of gain without slew rate distortion error.

The Model 312A can be shunt jumper configured to be a current in-current-out, voltage in-current-out device, voltage in-voltage-out or current in-voltage-out device. Additionally, the gain control input of the Model 312A can be shunt jumper configured to allow either positive or negative (inverting or non-inverting) gain control voltage to control the device.

The Model 312A VCA-EGC module can be utilized in voltage controlled automation consoles, filters, gates, compressors, oscillators, test instrumentation, radio AGCs and any other signal modifier circuits where voltage controlled amplification is required.

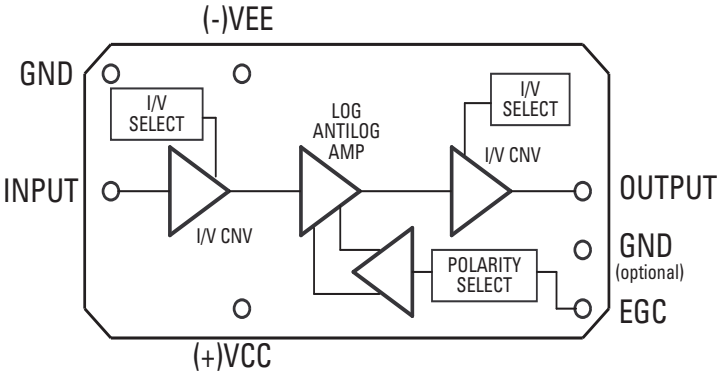
Features:

- Ultra Low Total Harmonic Distortion, 0.005 THD+N @ 1kHz
- Ultra Low Noise <4.4nV/rtHz typical
- Wide Dynamic Range >100dB typical
- Wide Gain Range
- Simplified Standard Retro/Upgrade Footprint
- Operates over ±12V to ±16V supply rails
- Low Control-Voltage Feedthrough
- I-In, I-Out or V-In, V-Out Selectable Operation
- Selectable Gain Control Operation (pos/neg)
- Particular emphasis on audio performance
- Designed, assembled and produced in the USA
- 3 Year Warranty

Applications:

- Voltage Controlled Faders and Panners
- Voltage Controlled Filters and Equalizers
- Gates and Expanders
- Compressors and Limiters
- Voltage Controlled Oscillators
- Automatic Gain Control (AGC)

Connection Diagram (Top View)



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Model 995FET-Ticha Discrete Operational Amplifier

PRODUCT BRIEF

The 995FET-Ticha is a high performance discrete operational amplifier designed for professional audio applications and areas where ultra-low noise and extremely low distortion is required. A true matched monolithic FET input stage is incorporated to provide superior sound quality and speed for exceptional audio performance. This, in combination with high output drive capability and excellent dc performance, allows use in a wide variety of demanding applications. In addition, the 995FET's wide output swing, allows increased headroom, making it ideal for use in any audio circuit.

The 995FET-Ticha can be operated from ±10V to ±24V power supplies. Input cascode circuitry provides excellent common-mode rejection and maintains low input bias current over its wide input voltage range, minimizing distortion. The 995FET discrete op amp is unity-gain stable and provides excellent dynamic behavior over a wide range of load conditions.

The all-discrete design uses an ultra-precision differential matched FET pair specifically designed to meet the requirements of ultra-low noise and ultra-low THD audio systems. In addition to the enhanced input stage, the 995FET uses high performance temperature stable current sources, dual matched pair temperature stable current mirrors and an enhanced low distortion high performance Class-A output driver stage.

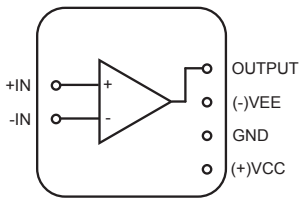
Features:

- Ultra Low Total Harmonic Distortion, 0.00055 THD+N @ 1kHz
- Ultra Low Noise, 1.1nV/rtHz
- High Current Output Drive (250mA into 75 ohms)
- +26.5dBu Output Levels (into 600 ohms)
- Standard Gain Block Footprint
- Operates over ±10V to ±24V supply rails
- Lower output offset voltage than existing counterparts
- Lower input leakage current than existing counterparts
- Class A Output Drive
- Particular emphasis on audio performance
- Designed, assembled and produced in the USA
- 3 Year Warranty

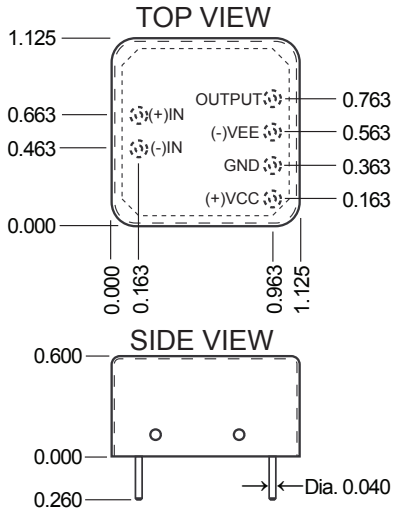
Applications:

- High Input Impedance Line Amplifiers and Drivers
- High Input Impedance Buffer
- Active Filters and Equalizers
- Summing/Mixer Amplifiers
- High Performance High Input Impedance Microphone Preamplifiers
- High Performance A/D front end preamplifier
- High Performance D/A back-end driver

Connection Diagram:



Package Diagram:



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Model 990Enh-Ticha Discrete Operational Amplifier

PRODUCT BRIEF

The 990Enh-Ticha is a high performance discrete operational amplifier designed for professional audio applications and areas where ultra-low noise and low distortion is required. It was designed as an enhanced specification upgrade replacement. The pinouts conform to the 990/2520 package, allowing direct replacement. See **Table 1.** below for additional discrete opamps which can be upgraded. Complete specifications datasheet for the 990Enh-Ticha can be downloaded from www.sonicimagerylabs.com

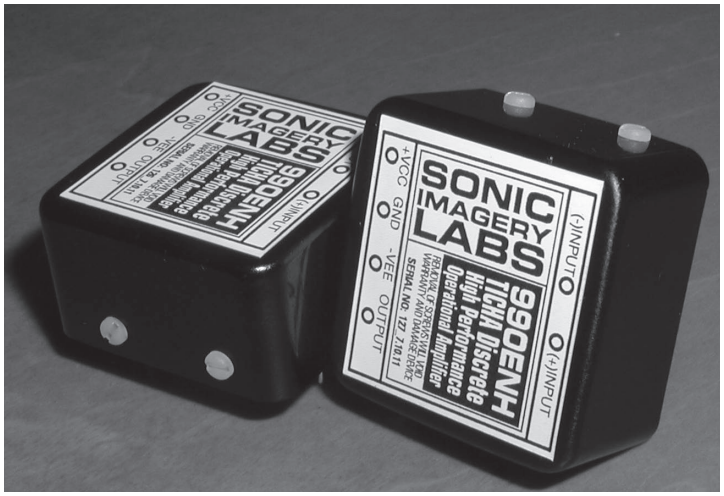
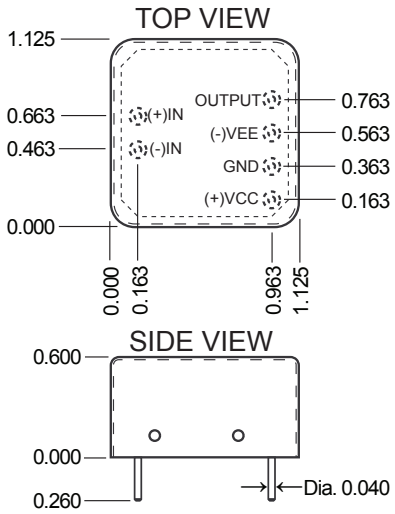


Table 1. Compatible Upgrade Table

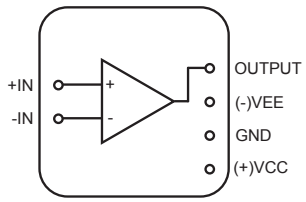
The Model 990Enh-Ticha can be used to upgrade and/or replace these obsolete or end-of-life discrete operational amplifiers. This list is by no means comprehensive. Contact Sonic Imagery Labs for additional information.

Jensen JE990 Series
Automated Processes Inc. API-2520, 2520H, 2525
John Hardy Co. 990A-990C
FiveFish Studios DOA series
Avedis Audio 1122
Seventh Circle Audio SC10, SC25, SC99
Sound Skulptor SK25, SK99, SK47
Yamaha NE80100, NE80200
TOA PC2011
ProTech Audio Model 1000
Purple Audio KDJ3, KDJ4
Modular Devices 1731, 1757
Modular Audio Products (MAP) 5000 Series, 1731 1731A
Melcor 1731
JLM Audio 99V
Inward Connections SPA690
BTI OA400
FAX Audio FA-100
Analog Devices 111

Package Diagram:



Connection Diagram:



Features:

- Ultra Low Total Harmonic Distortion, 0.00045 THD+N @ 1kHz
- Ultra Low Noise <1nV/rtHz (890pV/rtHz typical)
- High Current Output Drive (250mA into 75 ohms)
- +25dBu Output Levels (into 600 ohms)
- Standard Gain Block Footprint
- Operates over ±10V to ±24V supply rails
- 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

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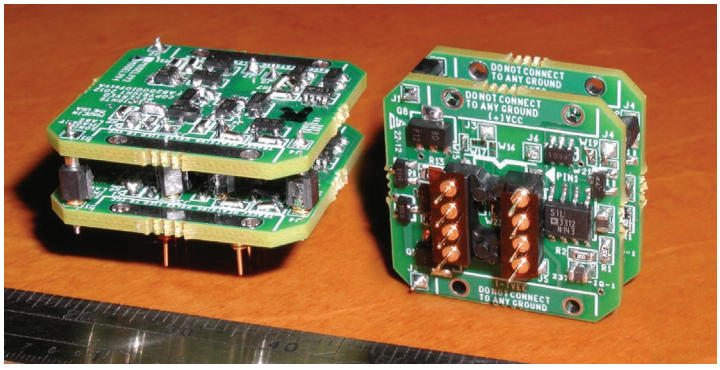
Model 994Enh-Ticha Dual Matched Discrete Operational Amplifier

PRODUCT BRIEF

The 994Enh-Ticha is a dual high performance discrete operational amplifier designed for professional audio applications and areas where ultralow noise and low distortion is required. It was designed as an enhanced upgrade replacement universal dual op-amp gain block. The pinouts conform to the standard 8 pin dual in-line monolithic IC package, allowing direct replacement.

The all-discrete SMT design utilizes an ultra-precision differential matched monolithic transistor pair specifically designed to meet the requirements of ultra-low noise and ultra-low THD audio systems. In addition to the enhanced input stage, the 994Enh-Ticha uses high performance temperature stable current sources, dual matched pair temperature stable current mirrors, dual matched pair active current loads and an enhanced low distortion Class-A output driver stage. Each amplifier is matched for noise, offset and distortion to within 0.1% of each other and both amplifiers meet or exceed published specifications over temperature and operating voltage range.

Because of the 994Enh high current drive capability, supporting circuitry impedances can be scaled down within the application circuit. This can reduce the overall system noise, without increased distortion.



The 994Enh-Ticha op amp is a true bipolar op amp and behaves as such. It does not require a flying ground lead as do other designs on the market. Because the 994Enh is a true op amp, It can also be operated in single supply applications as long as external biasing has been implimented correctly.

See Also:

Sonic Imagery Labs **Model 992Enh-Ticha**- Discrete Op Amp DIP8
Sonic Imagery Labs **Model 995FET-Ticha**- FET Discrete Op Amp 990/2520
Sonic Imagery Labs **Model 990Enh-Ticha**- Discrete Op Amp 990/2520

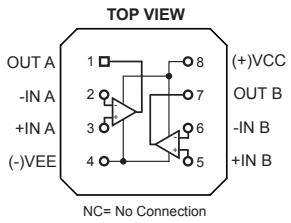
Features:

- Ultra Low Total Harmonic Distortion, 0.00045 THD+N @ 1kHz
- Ultra Low Noise 0.89nV/rtHz typical
- High Current Output Drive (100mA into 600 ohms @ ±24V supply)
- +26dBu Output Levels (into 600 ohms @ ±24V supply)
- Standard 8 pin DIP Footprint
- Operates over ±7.5V to ±24V supply rails
- 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

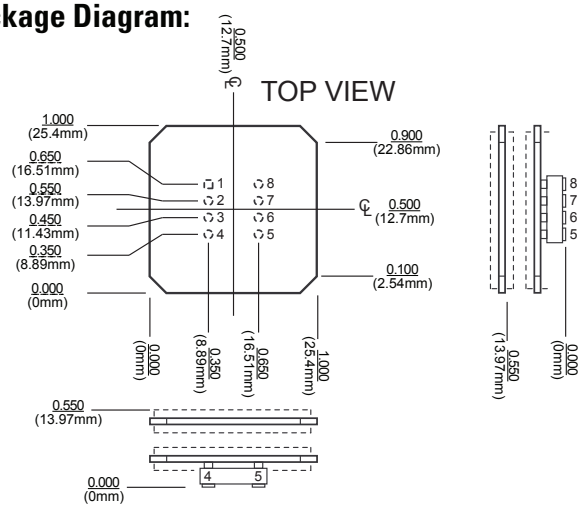
Applications:

- 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

Connection Diagram:



Package Diagram:



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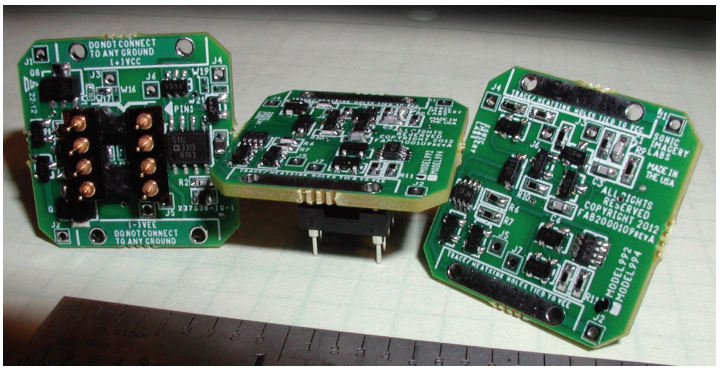
Model 992Enh-Ticha
Discrete Operational Amplifier

PRODUCT BRIEF

The 992Enh is a high performance discrete operational amplifier designed for professional audio applications and areas where ultralow noise and low distortion is required. It was designed as an enhanced upgrade replacement universal op-amp gain block. The pinouts conform to the standard 8 pin dual in-line monolithic IC package, allowing direct replacement.

The all-discrete SMT design utilizes an ultra-precision differential matched monolithic transistor pair specifically designed to meet the requirements of ultra-low noise and ultra-low THD audio systems. In addition to the enhanced input stage, the 992Enh-Ticha uses high performance temperature stable constant current sources, dual matched pair temperature stable current mirrors, dual matched pair active current loads and an enhanced low distortion Class-A output driver stage.

Because of the 992Enh high current drive capability, supporting circuitry impedances can be scaled down within the application circuit. This can reduce the overall system noise, without increased distortion.



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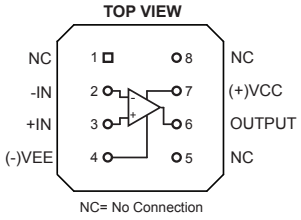
See Also:
Sonic Imagery Labs **Model 994Enh-Ticha**- Dual Discrete Op Amp DIP8
Sonic Imagery Labs **Model 995FET-Ticha**- FET Discrete Op Amp 990/2520
Sonic Imagery Labs **Model 990Enh-Ticha**- Discrete Op Amp 990/2520

Features:
- Ultra Low Total Harmonic Distortion, 0.00045 THD+N @ 1kHz
- Ultra Low Noise 0.89nV/rtHz typical
- High Current Output Drive (100mA into 600 ohms @ ±24V supply)
- +26dBu Output Levels (into 600 ohms @ ±24V supply)
- Standard 8 pin DIP Footprint
- Operates over ±7.5V to ±24V supply rails
- 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

Connection Diagram:



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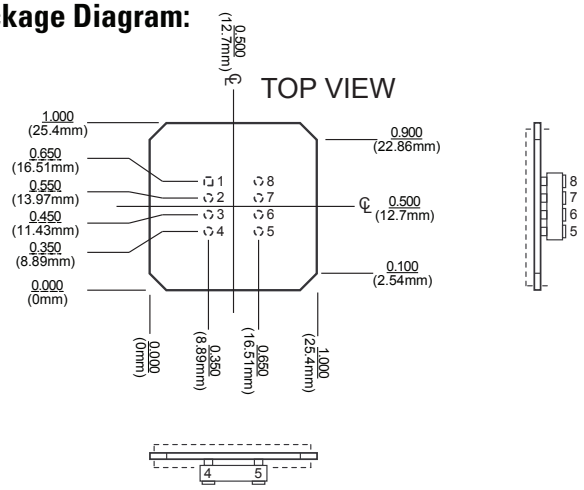

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