

Professional Audio Products Datasheet

High Performance Audio Electronics

Model 995FET-Ticha High Performance Discrete Operational Amplifier

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

The 995FET-Ticha can be operated from $\pm 10V$ to $\pm 24V$ 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 SMT 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-Ticha uses high precision temperature stable power supply independent current sources. Supply independent current sources allow the bias to remain locked at the optimum operating point regardless of power supply voltage.

Dual matched pair temperature stable current mirrors, dual matched pair active current loads give the Model 995FET-Ticha it's outstanding power supply rejection performance. The enhanced low distortion Class-A output driver stage can sink or source 250mA allowing this module to drive transformers easily.

Features:

- Ultra Low Total Harmonic Distortion, 0.00048 THD+N @ 1kHz
- Ultra Low Noise, 1.1nV/rtHz
- High Current Output Drive (250mA)
- +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







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Integrated power transistor heatsinks coupled to a anodized aluminum enclosure keeps the 995FET-Ticha operating within a wide SOA (safe operating area) and does not suffer from Beta droop when driving transformers or low impedance loads. Each amplifier is fully tested and meets or exceeds published specifications.

Because of the 995FET-Ticha 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 and provides higher headroom compliance performance.

The 995FET-Ticha discrete opamp was designed as an enhanced upgrade replacement for the Millennia Media Series MM-99, MM990, Forssell Technologies JFET-993, JFET-992, or similar FET based op-amp gain blocks. The pinouts conform to the 990/2520 package type, allowing direct replacement.

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.

For a BJT based discrete opamp version with this architecture, see the Sonic Imagery Labs Model 990Enh-Ticha datasheet. Sonic Imagery Labs also can provide a variation of this model that can operate down to $\pm 4.5V$ for low power, low voltage applications. Contact us and ask about the Model 995LV-Enh-Ticha.



DETAIL A. (Above) Standard pin length height specifications and mounting options for Sonic Imagery Labs Model 990Enh-Ticha opamp module.

Recommended Operating Conditions:

Positive Supply Voltage	VCC	+10V to +24V
Negative Supply Voltage	VEE	-10V to -24V
Signal Current (inverting mode)	lin	1nA to >500 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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Absolute Maximum Ratings

Supply Voltage	VCC-VEE	52.5V
Differential Input Voltage	V _{in}	14.5Vrms (+25.4dBu) @ unity gain
Input Voltage Range	Vic	±12.5V
Power Dissipation Max	Pn	7.5W Max
Operating Temperature Range	T	-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	Тур	Max	Units
V_{OS} I_{OS} I_{B} A_{VOL} V_{OM} V_{OM} V_{CM} $CMRR$ $PSRR$ I_{Q}	Input Offset Voltage Input Offset Current Input Bias Current Voltage Gain (ac open loop) Output Voltage Swing Output Voltage Swing Input Common-Mode Range Common-Mode Rejection Ratio Power Supply Rejection Ratio Supply Current	$R_{s}=0\Omega \text{ (shorted)}$ 3dB@28Hz $Vs=\pm 24V R_{L}=600\Omega \text{ Av}=10$ $Vs=\pm 24V R_{L}=75\Omega \text{ Av}=10$ $R_{L}=600\Omega$ Vo=0, inputs gnd, Vcc=+24V Vo=0, inputs gnd, Vee=-24V	- 400 108 41 38 ±12 - 15 22	1.0 200 500 110 42 38.5 ±12.5 90 110 17 24	2.5 - 600 112 - - - - 19 27	mV pA dB Vpp Vpp V dB dB mA mA

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

Symbol	Parameter	Conditions	Min	Тур	Max	Units
SR SR GBW	Slew Rate Slew Rate Gain Bandwidth Product Maximum Peak Output Drive Current	R_{L} =600Ω R_{L} =75Ω 10kHz to 100kHz R_{L} =75Ω	21 19.7 - 250	22 20.5 45 260	23 21	V/uS V/uS MHz mA

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

Symbol	Parameter	Conditions	Min	Тур	Max	Units
THD	Distortion+Noise (Inverting Unity)	R ₁ =600Ω Gain=1 @1kHz 1Vrms		0.00048		%
THD	Distortion+Noise (Non-Inverting 6dB)	R ₁ =600Ω Gain=2 @1kHz 1Vrms		0.00035		%
THD	Distortion+Noise (Non-Inverting 20dB)	$R_1 = 600\Omega$ Gain=10 @1kHz 1Vrms		0.0003		%
e	Input Refered Noise Voltage	Input shorted to ground		<1.2		nV√ Hz
i ["]	Input Refered Noise Current	-		<5		pA√ Hz
Ρ̈́BW	Power Bandwidth	Large-signal BW $R_1 = 600 \Omega$		>200		kHz
f _u	Unity Gain Frequency	Small-signal BW at unity gain (ft)		>10		MHz
Zin	Input Resistance	Noninverting Input		>20M		Ω
Zin	Input Resistance	Inverting Input		>20M		Ω
Cin	Input Capacitance	Each Input		20pF		C
1						



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

Total Harmonic Distortion+Noise Inverting 0dB (Av=1) versus Frequency (1Vrms (0dBV)In, R_{LOAD} 600 Ω , 22Hz-22kHz BW)



Total Harmonic Distortion+Noise Non-Inverting 6dB (Av=2) versus Frequency (1Vrms (0dBV)In, R_{10an} 600 Ω , 22Hz-22kHz BW)







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Non-Inverting Condition Rload = 75 Ω, Gain= 40dB Rload = 75 Ω, Gain= 20dB Rload = 600 Ω, Gain= 40dB

0.0011% 0.00062% 0.00095%

Total Harmonic Distortion+Noise, Non-Inverting, Rload=75 $\Omega,$ +24dBu output, 40dB gain verses Frequency



Total Harmonic Distortion+Noise, Non-Inverting, Rload=75 Ω , +24dBu output, 20dB gain verses Frequency



Total Harmonic Distortion+Noise, Non-Inverting, Rload=600 $\Omega,$ +24dBu output, 40dB gain verses Frequency





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THD+N Large Signal Performance (20kHz, Vs=±24V,

+24dBu Voutput, Rload variant, Gain variant as noted below)

Inverting Condition	
Rload = 75 Ω , Gain= 40dB	0.00098%
Rload = 75 Ω , Gain= 20dB	0.00080%
Rload = 600 Ω , Gain= 40dB	0.00095%

Total Harmonic Distortion+Noise, Inverting, Rload=75 $\Omega,$ +24dBu output, 40dB gain verses Frequency



Total Harmonic Distortion+Noise, Inverting, Rload=75 Ω , +24dBu output, 20dB gain verses Frequency



Total Harmonic Distortion+Noise, Inverting, Rload=600 Ω , +24dBu output, 40dB gain verses Frequency



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

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







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





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Linearity vs Amplitude (Ta=25°C, Vs=±24V unless otherwise noted) Non-Inverting Av=2 (R_{L0AD} =600 Ω)



Inverting Av=1 (R_{LOAD}=600 Ω)



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



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THD Residual+N Characteristics (Ta=25°C, Vs= \pm 24V, 0dBV input, Rs=600 Ω Rload=10K Ω unless otherwise noted)

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



Broadband Noise Characteristics (Ta=25°C, Vs=±24V, Rs=0 Ω to gnd, Rload=10K Ω unless otherwise noted)



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Rs=600 Ω Rload=10K Ω unless otherwise noted)

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



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





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



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



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Pulse Response Test Setup



Pulse Response Test Setup



Overdrive/Clipping Response Inverting







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Application Notes

These are op amps with JFET input devices. These JFETs have large reverse breakdown voltages from gate to source and drain and have low leakage high performance diode clamps across the inputs internally. Adding clamps shown in Figure 1. externally is not recommended. The inputs also do not have gate resistors to ground. This allows the user to tailor the input impedance to the application. See Figure 1. below for a simplified input schematic.



Figure 1. Simplified diagram of FET differential input stage.

Whenever there is a risk, either of input signals exceeding the voltages on the supplies, or of signals being present prior to powerup of the op-amp, the terminals at risk should be protected with diodes (preferably fast low-forward-voltage Schottky diodes) to prevent damage from occurring. Current-limiting resistors may also be needed to prevent the diode current from becoming excessive (see Figure 2). This protection circuitry can cause problems of its own. Leakage current in the diode(s) may affect the error budget of the circuit (and if glass-encapsulated diodes are used, their leakage current may be modulated at 60 or 120 Hz due to photoelectric effects if exposed to ambient lighting, thus contributing hum as well as dc leakage current); Johnson noise in the current-limiting resistor may worsen the circuit's noise performance; and bias current flowing in the resistor may produce an apparent increase in offset voltage. All



Figure 2. Simplified protective circuitry of FET differential input stage.

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A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground sets the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately six times the expected 3 dB frequency a lead capacitor (Ccomp in Figure 3.) should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.



Figure 3. Feedback compensation should be placed from the output to the input of the op amp.

The 995FET-Ticha Opamp is a high gain wide bandwidth device and the designer should analyze the application carefully to ensure operational success. The value of this capacitor is dependant on the value of feedback resistor chosen. Since correct compensation is important for optimum ac performance, it follows that no more compensation should be used than necessary to ensure adequate stability. However, there is a difference between the inverting and non-inverting configurations in the required compensation values if all other values are the same. Figures 4 and 5 demonstrates the effects of the feedback compensation on setting the upper frequency -3dB bandwidth.



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Application Notes (continued)

The non-inverting unity gain of 1 (+0dB) is considered the worst case insofar as compensation requirements are concerned, since there is no attenuation in the feedback path. As a rule of thumb, when the opamp is stabilized for this condition (β =1), it will be stable for all feedback conditions since there can be no more than 100% feedback.



Figure 4. Various Ccomp values across Rf=10K in the noninverting opamp configuation circuit shown in Figure 3.



Figure 5. Various Ccomp values for across Rf=10K in the inverting opamp configuation circuit shown in Figure 3.

Less compensation is necessary when β is less than unity, or feedback is less than 100%. Therefore, the compensation capacitance required for unity gain stability for the inverting stage of Figure 3 is one half of that required for the noninverting stage with the same resistor values.

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Application Notes (continued)

The 995FET-Ticha discrete opamp 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 capacitor across the feedback resistor will aid stability as discussed previously. 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.

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 amplifier from the load as shown in **Figure 6**. The inductor gives low output impedance at lower frequencies while providing an isolating impedance at high frequencies.



Figure 6. Isolating capacitive loads with an inductor. The non-inductive resistor avoids resonance problems with load capacitance by reducing Q.

The resistor kills 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.

A 100 ohm resistor in series with the output is recommended when driving reactive loads, transformers, or where the output has the possibility of shorting to ground. The 995FET-Ticha opamp has the ability sink or source 250mA of current and the resistor aids in current limiting during short circuit conditions.



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Application Notes (continued)

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 in signal paths and feedback loops. Since these components can represent high impedance, and are susceptible to "pickup" and other noise sources, 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.

PCB Sockets for 995FET-Ticha 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 purchase a set of six from Sonic Imagery Labs online.

Mill-Max 190 Pine Hollow Road, PO Box 300 Oyster Bay NY 11771	Part Number 0344-2-19-15-34-27-10-0
Wearnes Cambion Ltd Peverial House Mill Bridge, Castleton Hope Valley S33 8WR United Kingdom	Part Number 450-3756-02-03
Concord Electronics Corp 33-00 47th Ave Level 1A Long Island City, NY 11101	Part Number 09-9035-2-03

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