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SECTION V

APPLICATIONS FOR AMPLIFIERS IN AUDIO

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INTRODUCTION

Today, IC amplifiers are available which perform many of the tasks required within audio systems. Many of these functions can be performed by standard op amps, although not always with optimum performance.

Audio circuit performance requirements can often be demanding in terms of very low noise, very high current and/or voltage outputs, and low signal distortion. While standard amplifiers exist which excel in all of these areas, some functions may need higher levels of system integration to make them performance and cost effective to the audio designer. Some cases in point are described in the sections following, under audio line drivers and receivers.

Another factor strongly influencing audio circuit design is the concept of the *universal* single/dual audio op amp readily available at low cost. Quite often however the only critical specification qualifying such devices is simply and solely their low cost. Frequently other IC devices might be available which can meet or exceed performance in one or more key areas, but don't get due consideration because of entrenched standards.

Audio, like many other electronic design areas, needs full and thoughtful regard of many issues for the most effective device selection. Distortion under load must be low, common mode rejection must be high, power consumption must be reasonable, and a minimum of related components should be required.

Fortunately, a wide variety of very high performance IC amplifiers are available to meet these audio demands. Some of them are designed specifically for audio application requirements, such as balanced input/output interfacing, very low voltage noise, high output currents, etc. Others achieve one or more of these objectives through the use of standard IC devices, in topologies most useful to audio requirements. The circuits following illustrate examples of both of these design approaches in high performance audio applications, with characterization data accompanying them to aid assessment.

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A LOW NOISE MICROPHONE PREAMPLIFIER WITH DC SERVO OUTPUT

The SSM-2017 audio preamplifier chip is a versatile differential input IC with an input voltage noise of less than $1nV/\sqrt{Hz}$, and low distortion. The gain of the device is set via one external resistor, R_g, and it is adjustable over a range of 1-1000 times. Differential inputs of the SSM-2017 allow balanced input signal operation, and the single-ended output signal of the device appears between the output and reference terminals. It operates from dual power supplies of ±22V or less, and drives loads of 2kΩ or more.

Figure 5.2 is an application which employs the best advantages of the SSM-2017, combined with the OP-275 dual bipolar/JFET op amp. Although this circuit is labeled a microphone preamp (an application for which it is well suited) the gain range over which it operates and relative ease of output interfacing make it general purpose as well.

A HIGH PERFORMANCE AUDIO COMPOSITE LINE DRIVER STAGE

IC op amps of various types are often used as simple non- inverting gain stages to drive output lines. Typically, such line driver stages operate with voltage gains of 5-10 times (14-20 dB), work from medium-to-high impedance sources, and may drive difficult loads (600Ω or less, paralleled with several nF of capacitance). Ideally these goals are achieved with minimum non-linearity, providing low distortion operation over the full audio range.

However, this line stage has some requirements which basically conflict; it must drive low Z loads, but it cannot distort in doing so. It must operate with stability from medium to high Z sources, with minimal changes in DC offset, noise, and distortion as the source impedance changes (for example, operating from a level control). Unfortunately, high output currents can evoke thermal feedback in an op amp IC. When present, this result can also be a problem for both DC and low frequency AC signals.

A family of op amps with general specifications meeting these goals is the FET input category. Better quality FET op amps have good DC specs, namely low offset voltage. In addition, they have input bias currents of just a few pA (low enough that DC current related errors are generally negligible for source resistances below a megohm). The combination of these attributes makes net DC errors low enough that an entire line driver stage can be DC coupled. Sadly though, while many good to excellent FET input op amps exist, very few have outstanding audio performance driving 600Ω (or lower) loads.

For ±10V peak signals (7Vrms), a 600Ω load requires ±17mA. However, this Ohm's law criterion is too simplistic. Actually, these levels must be delivered with low levels of total harmonic distortion (THD), preferably 0.001% (10ppm) or less over the audio range. When lower full scale distortion is desired, and/or lower impedances must be driven, the optimum IC choice becomes more challenging.

COMPOSITE AMPLIFIERS TO THE RESCUE

Fortunately, the technique of combining the best aspects of two different amplifiers into a single composite amp structure produces real dividends for a line driver. A high performance FET input IC can be used as the input stage, combined with a high current, wide band output stage. This allows the positive features of two dissimilar ICs to be exploited, with each optimized for their respective input and output tasks.

Figure 5.18 shows this low distortion composite amplifier, using a cascade of two amplifier ICs. Two gain stages are used, U1 and U2, with individual performance selected as follows.

In the topology shown, stage U1 provides the bulk of the overall amplifier open loop gain and determines the basic input characteristics. With U1 loaded as shown, by only the high impedance input (+) of U2, it has virtually zero drive requirements. This helps to maximize linearity. Stage U2 provides primarily a high current output, but it also provides additional voltage gain via local feedback.

With this topology, individual U1/U2 ICs can be selected for unique input or output performance advantages. These are characteristics not available in one device, or, even when available, not cost effective.

LOW DISTORTION COMPOSITE AMPLIFIER

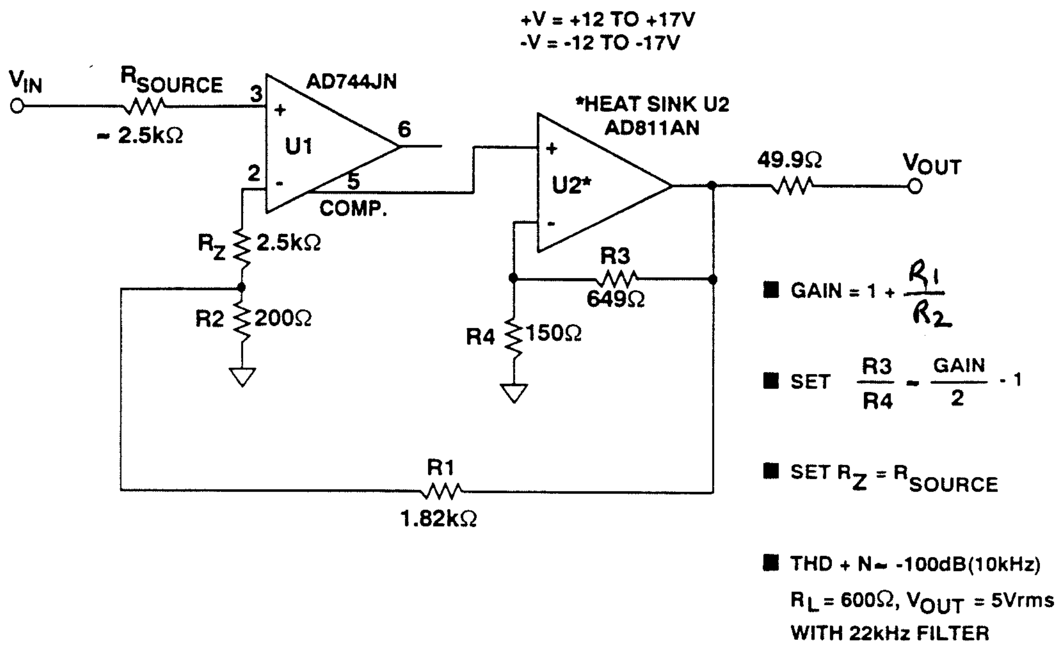

Figure 5.18

CIRCUIT DESCRIPTION

In this application U1 is an AD744, a high SR, fast settling FET input op amp with a basic THD of 0.001% below 10kHz (See Figures 16 and 20 of AD744 data sheet.) Note however, that since this characterization data is for a standard gain-of-10 follower, the net performance of the AD744 in this composite amplifier is appreciably better. This is due to several topology dependent factors.

One factor is that the U1 stage operates unloaded, which removes any output current related distortion within this stage. Another key point is that the overall gain bandwidth and SR of U1 are boosted, by a factor equal to the voltage gain of U2 (G2). For example, a 75V/μs SR in stage U1 becomes 75V/μs times G2, assuming the SR of U2 is appreciably higher (discussed further below).

A third ingredient which can lower frequency dependent distortion products is the use of input impedance compensation, which ideally balances both the R and C components seen at the input amp's two inputs (See the AD743 data sheet for a more detailed discussion of input impedance compensation in FET input op amps.) If used, this compensation serves to minimize the non-linear effects of FET input amplifier common mode capacitance. To implement this in Figure 5.18, an optional feedback resistance Rz is added, between R_1-R_2 and U1's (-) input. Rz is simply made equal to the nominal source impedance, Rsource (Rsource is shown here as the equivalent source resistance typical of a 50kΩ level control, operating at a low nominal level). For the performance tests below, Rz was not used.

U2 in this application is an AD811AN, a high performance transimpedance amplifier. While designed primarily for video use, the AD811's key specs are a SR 2500V/μs, a bandwidth of 120 MHz, and 100mA of output current. These factors greatly enhance this circuit, by providing both high and linear load current capability. Simultaneously, since U2 operates with local feedback and is also a transimpedance amplifier, its own bandwidth remains essentially high and constant as the U2 local gain changes. With the AD811 used for U2, this has the effect of making the stage transparent to overall operation in terms of bandwidth and SR limitations. There still remains the potential for loading effects in U2. But, as U2 in this instance is designed for low video distortion driving low impedance loads, this likelihood is minimal.

DESIGN FACTORS

The design as shown in Figure 5.18 operates at an overall voltage gain "G" of 10, set by R_1 and R_2 as in a conventional non inverting amplifier, or:

$$G = 1 + (R_1/R_2)$$

The individual stability requirements of U1 and U2 must also be met by the design. In this case U1 is stable at a gain G1, which is 2 (or more), therefore U2's gain G2 should be made equal to

$$G2 \leq G/(G1)$$

In the design process, by first considering G and G1, stage two gain G2 is made to satisfy the overall stability requirement. Here, with a G1 of 2, G2 becomes 10/2 or 5, and R_3/R_4 are then selected for a ratio of (G/G1)-1 to provide this.

It is important to note that because U2 is a transimpedance amplifier, local feedback resistor R_3 has a preferred value for stability purposes; here the value is 649Ω. The designer should fix R_3 at 649Ω, then set U2 stage gain via R_4, as:

$$R_4 = \frac{649\Omega}{(G/G1)-1}$$

(Note: R_4/R_3 are not as critical to gain as R_1/R_2, and they can be more loosely specified).

MEASURED PERFORMANCE

With these design and device selection factors, the composite amplifier performance is remarkable for its modest complexity. For a typical audio load of 600Ω, THD+N at an output level of 5Vrms is on the order of 10 ppm (-100dB) for frequencies below 20kHz, as shown in Figure 5.19. Note that lower operating levels may appear to have higher distortion, but will actually be more limited by the noise of the AD744.

In terms of operating hints, maximum output will be a function of the power supplies, and can approach 10Vrms with supplies of about ±17V supplies (both devices are rated for a maximum of ±18V). For supply voltages of ±12 or more however, a clip-on heat sink is recommended for U2, such as the Aavid 580100. For low impedance loads, the supplies should be well bypassed with large electrolytics, returned to the load common point.

Note that the general principles of this composite amp can be used for other devices in the U1/U2 positions, with different factors of optimization. For example, for lowest voltage noise from high Z sources, an AD745 (or AD743) device will be useful at U1.

COMPOSITE LINE AMPLIFIER THD + N PERFORMANCE, V_{out} = 5V rms, R_{load} = 600Ω, 22kHz Filter

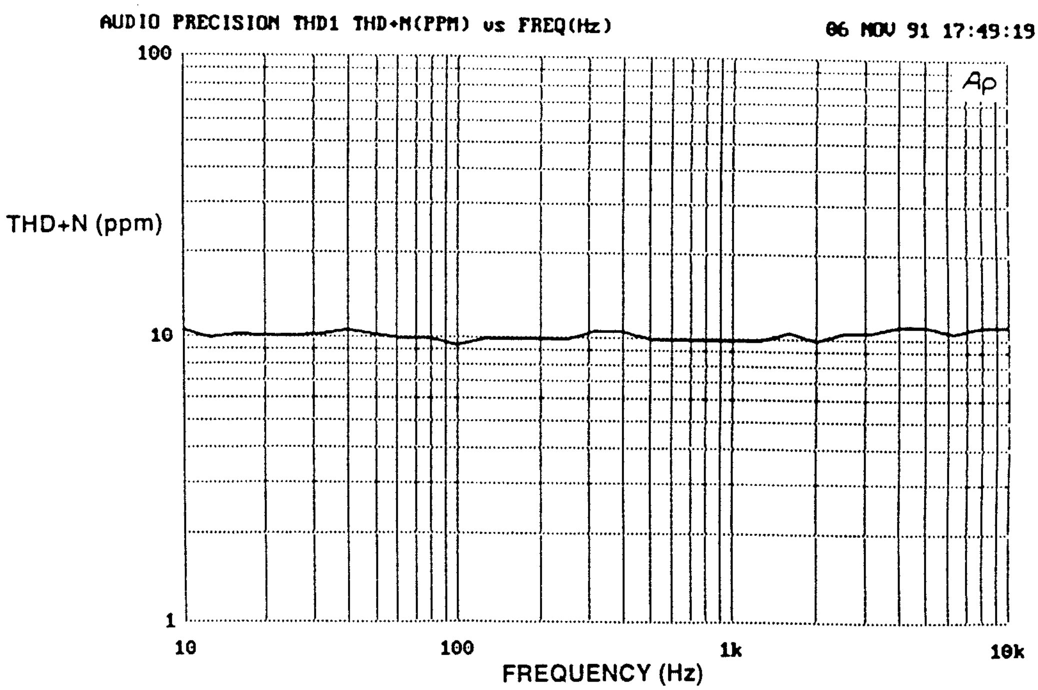

Figure 5.19

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[2]Walter G. Jung, **Audio IC Op Amp Applications, 3rd Edition**, 1987, Howard W. Sams.