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The Sight & Sound of Information

Audio Applications

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High Power Configurations with IC Amplifiers

Bridge Transformer Less (BTL) and Parallel Amplifier (PA) Configurations

$$P_O = V_O(p\text{-}p)^2/8R_L = I_O(p\text{-}p)^2R_L/8$$

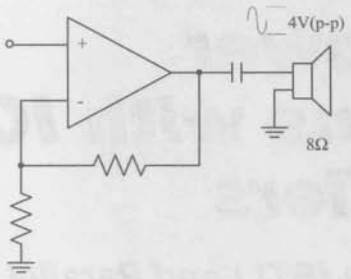
The maximum amount of ac (sine wave) power that can be delivered to a given resistive load RL is limited either by the maximum voltage swing available from the amplifier output or (less likely) the maximum current swing the amplifier can deliver. The interdependence of these quantities is illustrated by the simple expressions given below where VO(p-p) is the output voltage swing and IO(p-p) is the output current swing.

$$\text{Power} = VO(p\text{-}p)^2/8RL = IO(p\text{-}p)^2RL/8$$

For most audio amplifiers, voltage swing is largely dependent on the supply voltage or the semiconductor process breakdown voltage, whichever is lower. For a given load the maximum current (and output power) is determined by this voltage swing. The amplifier current capability usually depends on the design topology and the size of the output transistors. Normally I/C audio amplifiers are designed with specific loads and supply voltages in mind, but when an audio system designer wants more power but is constrained by a (lower) supply voltage, conventional approaches do not always work.

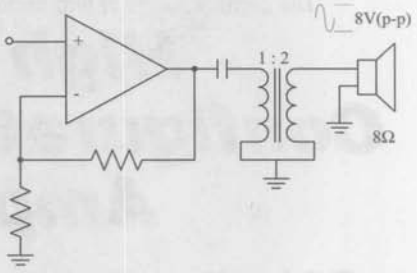
Increasing the Load Power

Conventional



Power = $\frac{4^2}{64}$ = 0.25 Watts

Transformer Drive

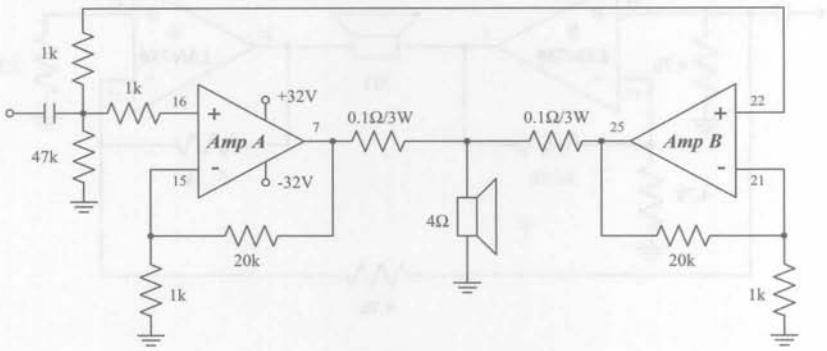


Power = $\frac{8^2}{64}$ = 1.0 Watts

The introduction of portable entertainment equipment was one of the earliest trends that made working with low supply voltages voltages important, and many transistor radios used transformer coupled speakers. As shown here, even a modest turns ratio of 1:2 will double the swing across the loudspeaker with a four times increase in power. Unfortunately, particularly when much higher power outputs are required, the expense, bulk and radiated field of the transformers start to make this approach unattractive. Also, note that in the example above, the load presented to the amplifier is increased by the square of the turns ratio, to 2Ω instead of 8Ω, and the amplifier has to deliver peak currents that are four times higher. Nothing is for free, and the higher output power is achieved at the expense of higher amplifier internal power dissipation.

Solution #1: The PA Configuration

Using The LM4780 Stereo Audio Power Amplifier



The low cost and ease of use of modern high power audio amplifiers make it very practical to apply different topologies to replace transformer drive.

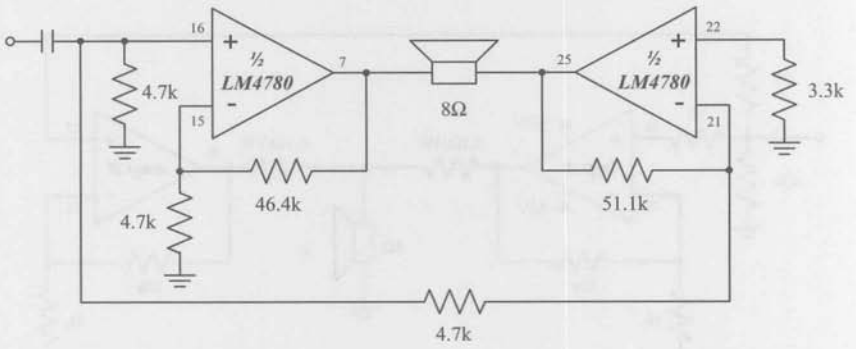
Where the amplifier and speakers are provided together to make a complete system, the speaker impedance can be lowered to 4Ω or even 2Ω to get the required increase in power output. Nevertheless, on large systems, the increased current to drive these loads can easily cause excess power dissipation in the power amplifier, or the peak current can actually exceed that available from the amplifier output transistors. A solution to this problem is to employ two similar amplifiers connected in parallel across the speaker.

In the case of a 4Ω load, each amplifier is matched in gain (use 1% resistors to set the gain) and so delivers only half the load current required for the speaker. As far as each amplifier is concerned, the effect is the same as driving an 8Ω load, so the internal peak current and power dissipation are the same as for an 8Ω load, yet the power output is actually into a 4Ω load.

To further ensure good matching between the amplifiers, dual amplifiers, such as the LM4780, are easily available. This power amplifier is a new Overture® series two channel amplifier, the LM4780, which can deliver 60 Watts/channel into 8Ω loads. These amplifiers also feature a smooth transition fade in/out mute. They are available in 27 pin TO-220 style packages with a package θ_{JC} of 0.80C/Watt. The design shown here can deliver 100 Watts into a 4Ω load on 32V supply rails. This is 2X the power that could be delivered to an 8Ω load with the same power supply voltage.

Note: While dual, or stereo, amplifiers can solve the matching and output current requirements, since both amplifiers are in the same package, the total internal power dissipation will be the same as for a single amplifier driving the actual 4Ω load. Where dissipation and heat sinking remain an issue, two physically separate amplifiers should be used. In that case the power dissipation per amplifier is the same as that for an amplifier driving an 8Ω load.

Solution #2: The BTL Amplifier



When both terminals of the speaker are available (one side is NOT connected to ground) another approach is available, also using a dual amplifier in place of a single. While there are a number of different ways to connect the BTL or Bridged Transformer Less (also known as Bridge Tied Load) amplifier, all the ways will have one thing in common. In the absence of a differential drive source, one amplifier will be driven non-inverting, while the other will be driven inverting. The big advantage to this configuration is that the power output can be up to 4X that of an amplifier driving a single ended load from the same supply voltage.

In the absence of an ac signal the outputs of both amplifiers will be at the same potential, in this case 0Vdc, and the load is connected between the outputs. This means that the large coupling capacitor for a single-ended load has been eliminated. When an ac signal is applied and the output of the left hand amplifier swings positive, the output of the right hand amplifier will swing negative by the same amount. Ideally the left hand amplifier output can swing almost to the positive supply rail so that the total positive swing across the the load is twice the positive supply voltage. Similarly the maximum negative swing across the load will be almost twice the negative supply voltage. Since the power delivered to the load is proportional to the square of the voltage swing across the load, the power is increased by almost 4X. The word almost is used because in the real world the amplifier output will not be able to swing all the way to the supply rail. Headroom is required for the output stage transistors and this can be several volts when low distortion is important.

Note: Although the load is 8Ω, as far as each amplifier is concerned it is driving a 4Ω load and power dissipation per amplifier should be calculated assuming RL = 4Ω.

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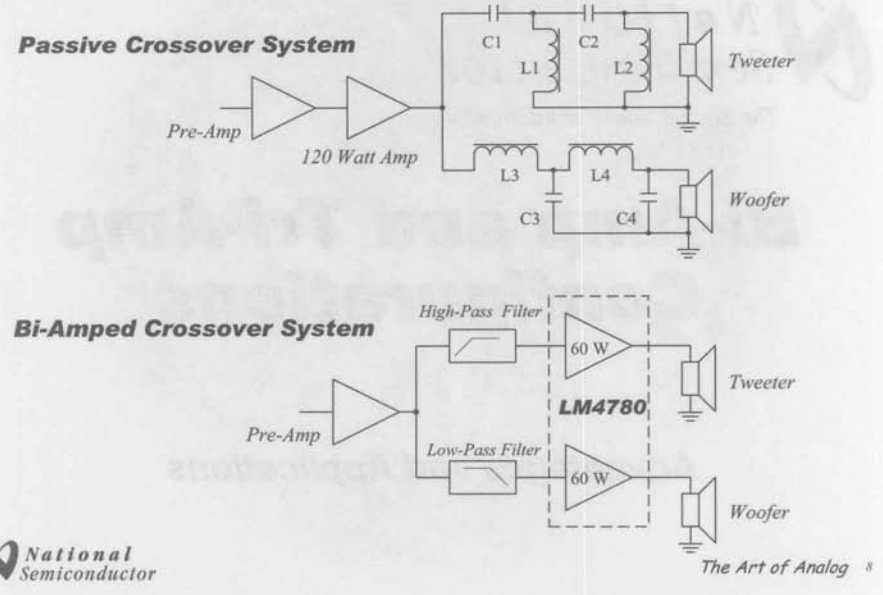
Bi-Amp and Tri-Amp Configurations

Advantages and Applications

Yet another solution to obtaining increased audio power is to provide separate amplifiers to drive each speaker in a loudspeaker enclosure. This is known as Bi-Amping or Tri-Amping.

Bi-Amping

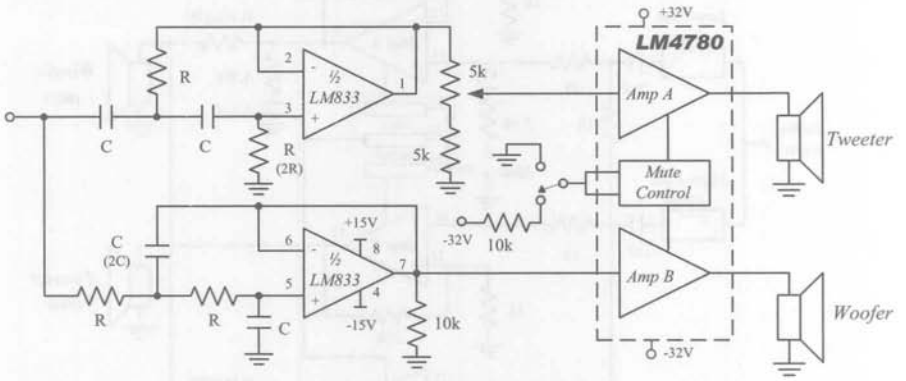


Because of the difficulty in manufacturing a single speaker capable of reproducing the entire audio spectrum, most Hi-Fi speaker enclosures have multiple speakers,where each speaker is designed to cover only one section of the frequency band. Since the power amplifier delivers the entire range of frequencies, separation of the audio signal is done with passive high-pass and low-pass filters, known as crossover networks. These networks have to handle high power levels and are composed of relatively large (and expensive) inductors and capacitors.

Crossover networks are difficult to design and even more difficult to tweak. They present a different load to the power amplifier than would be presented by the speaker alone and they consume power that would otherwise go to the speaker. Nevertheless, the presence of the crossover network inside the speaker enclosure means that almost any power amplifier designed to drive the nominal speaker impedance can be connected to any speaker enclosure with that impedance.

An alternative (for the go-it-alone audio enthusiast) is to provide separate power amplifiers for each speaker within the enclosure. In a bi-amp system one channel would handle the signals at the low end of the audio spectrum (the woofer), and a second channel would handle the signals at the high end (the tweeter). Separation of the signal frequencies occurs between the pre-amplifier output and the power amplifier inputs as shown above.

Bi-Amped LM4780 With Active Crossover Network



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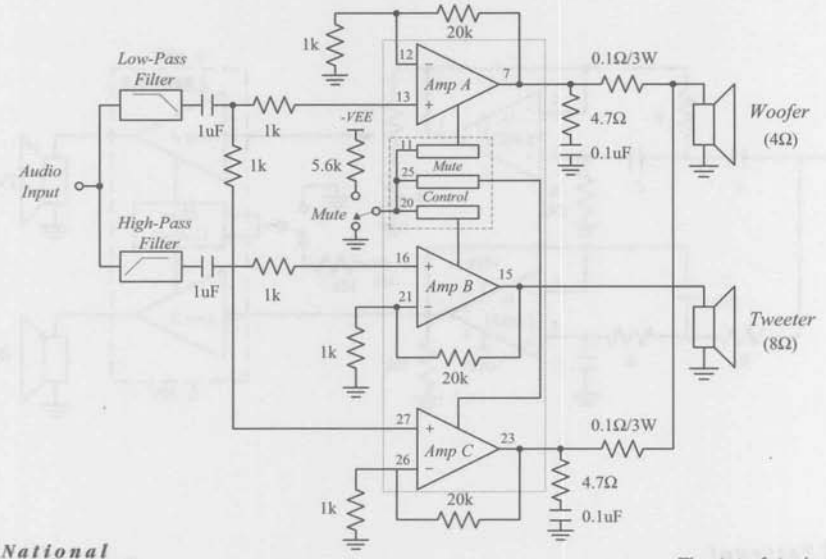
The audio signals passing through the crossover network are now line level signals from the pre-amplifier and the cumbersome passive networks can be replaced with active crossover networks. Here we are showing active 2nd order low-pass and high-pass filters using the LM833 dual audio amplifier. These filters are of the all pass type so the combined overall voltage response will be flat, and the crossover frequency $Fc = 1/2\pi RC$. Increasing the roll off rate in the stop band to 24dB/octave is done by simply cascading two 2nd order filters, the crossover frequency now being given by $1/2\pi RC\sqrt{2}$. A quad op-amp, the LM837, can be substituted for the LM833 but lower power supply voltages will be needed. Notice that the output of the high-pass section has a trim pot to set the output level. This is because woofers have a generally lower efficiency than midranges and tweeters and the pot can be used to set up an overall acoustically flat response.

Bi-Amping With the LM4781



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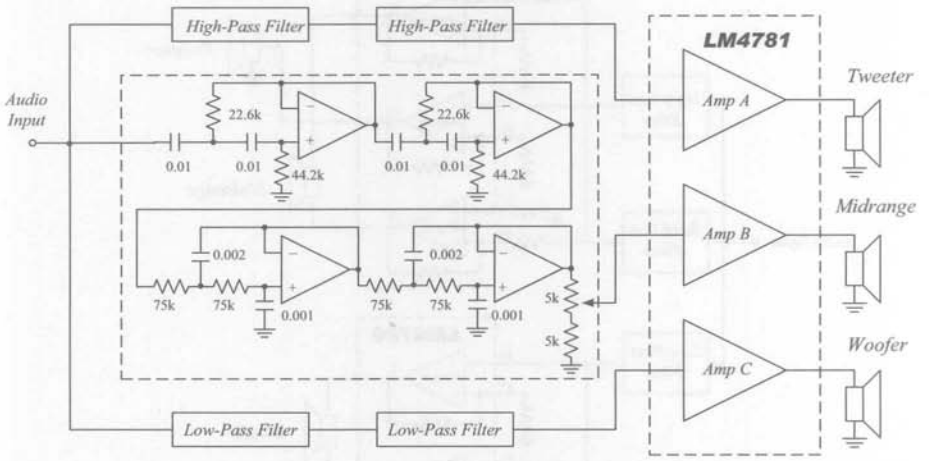
Although the audio frequency range is generally accepted to be between 20Hz and 20kHz, the energy in music signals is not evenly distributed over this range. In fact, for most music programmes, 70% of the energy occurs at frequencies below 700Hz. Less than 10% occurs at frequencies above 3.5kHz. This suggests that in a bi-amped system the woofer amplifier needs to be able to handle more power than the tweeter amplifier, or put another way, the tweeter channel needs less power than the woofer channel.

Shown above is yet another new Overture® amp, the LM4871. This is a three-channel amplifier, each amplifier capable of delivering 35Watts/channel into 8Ω loads. Here we are showing channels 1 and 3 driving the 4Ω woofer in parallel, and channel 2 driving the 8Ω tweeter.

Tri-Amping



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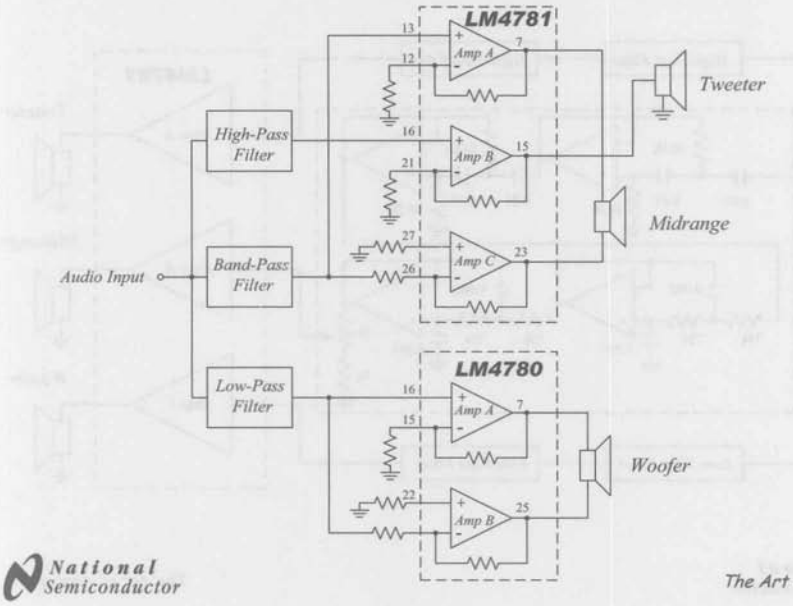
Three channel power amplifiers make it very easy to implement a three-way system. Now the audio spectrum is divided into three sections, a woofer amplifier driven through a low-pass filter, a midrange amplifier driven through a band-pass filter, and a tweeter amplifier driven through a high-pass filter. Although the crossover frequencies are different from the two-way system, the high and low-pass sections are designed as before, with the band-pass section formed by cascading a high-pass and a low-pass section.

Choosing the crossover frequencies depends on how adventuresome you feel. If the speakers come with a passive crossover, or are a matched set with recommended crossover frequencies, then you won't go too far wrong with staying with those frequencies. If you have the means to measure the individual driver characteristics, then go for it. In general terms the cone diameter is a good guide to the upper end of frequencies that the driver is good for. If the diameter divided by the acoustic wavelength at the highest frequency the driver is expected to reproduce with a flat response is less than or equal to 1, the crossover frequency will be in the right range. For a two-way system the crossover will be in the range of 800Hz to about 2kHz. A three-way system can have crossovers as low as 100Hz and as high as 4Khz. In the system shown here, fourth order filters are used with the component values in the filter network for crossover frequencies at 500Hz and 3kHz.

Using the LM4781 provides all the power amplifiers for a single three-way enclosure in one package, but does not take advantage of the reduced power requirements for the midrange and tweeter section.

Tri-Amping



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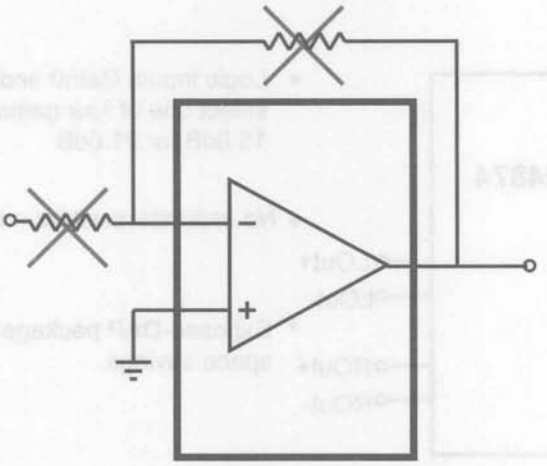
This design is a combination of the BTL and single ended configurations. The LM4870 is used to drive the woofer in BTL mode, amplifiers 1 and 3 of the LM4871 drive the midrange in the BTL mode, and amplifier 2 drives the tweeter in the single ended mode.

External Resistors Waste Board Space and Increase Cost



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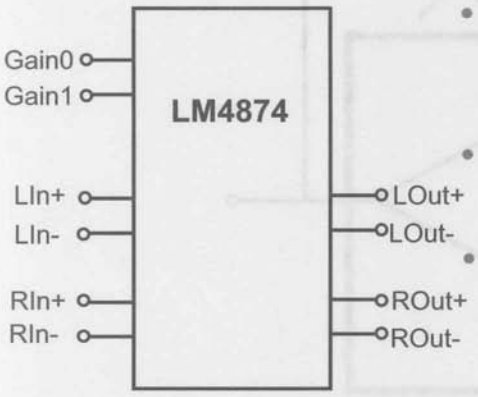
Many audio amplifiers require external resistors in order to set the gain. However, these resistors take up valuable board space and increase both cost and assembly time.

LM4874 – No External Gain-Setting Resistors Needed!



- Logic inputs Gain0 and Gain1 select one of four gains: 6dB, 10dB, 15.6dB, or 21.6dB
- No external resistors = space savings
- Exposed-DAP package – further space savings

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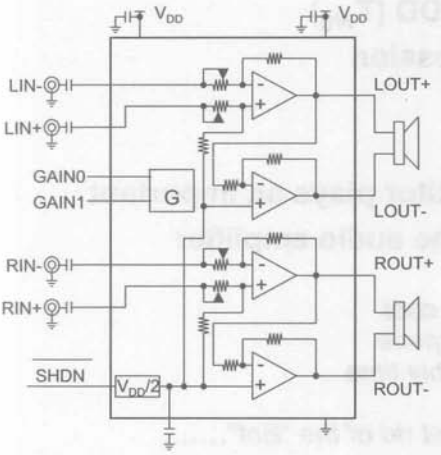
The LM4874 provides a solution to these issues because its gain is set without any external resistors. The LM4874 features four fixed, internally set, BTL voltage gains: 6dB, 10dB, 15.6dB, and 21.6dB. Select one of the four gains by applying a logic level signal to the Gain0 (MSB) and Gain1 (LSB) digital inputs.

LM4874 – 2.1W Differential Input, BTL Output Stereo Audio Amplifier With Selectable Gain and Shutdown



- BTL Output Power of 2.1W (R_L = 3Ω), 1.9W (R_L = 4Ω), 1.2W (R_L = 8Ω) [V_{DD} = 5.0V, THD+N = 1%]
- Micropower shutdown current = 0.1μA
- PSRR = 62 dB, at 1kHz, V_{DD} = 5.0V
- Exposed-DAP package – high thermal efficiency
- Applications: notebook computers, PDAs, portable electronic devices

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The LM4874 also features pseudo-differential stereo inputs and BTL outputs. Operating on a single 5V supply, the LM4874 delivers 1.2W, 1.9W, or 2.1W of output power to an 8Ω, 4Ω, or 3Ω BTL load, respectively, with less than 1% THD+N. Other features include an active-low micropower shutdown mode input, thermal shutdown protection, and improved "click and pop" suppression. The LM4874 is designed for notebook and other handheld portable applications.

The Reference Bypass Capacitor:

- **Filters out noise on the input node**
- **Affects charging time to ½VDD (T_{WU})**
- **Provides click & pop suppression**
- **Improves PSRR**

- **The reference bypass capacitor plays an important role in the performance of the audio amplifier**
- **But.....**
  - *It adds to system cost*
  - *Takes up board space*
  - *Increases assembly time*

Too bad we can't get rid of the "But".....

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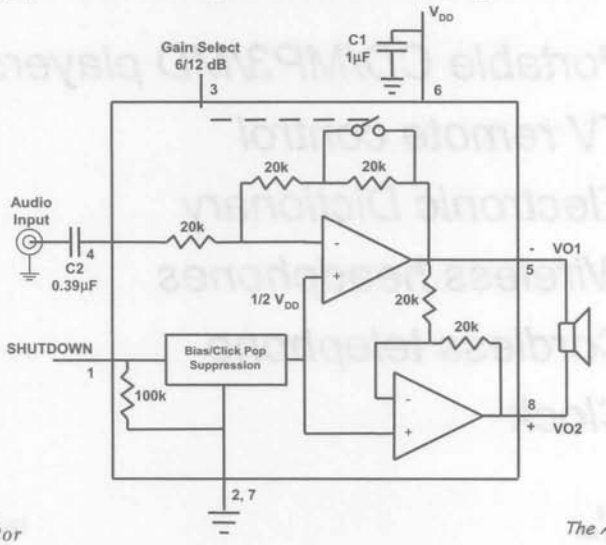
The reference bypass capacitor affects audio amplifier performance by the following ways:

1. Filters out noise on the input node. Along with an input resistor, the reference bypass capacitor forms a low-pass filter to minimize noise.
2. The size determines charging time to ½VDD (Wake Up Time, T_{WU}); the larger the capacitor the lower the slope at which charging occurs.
3. Click & Pop suppression is also determined by the size of the reference bypass capacitor; larger capacitances provide more resistance to sudden voltage changes.
4. The higher PSRR can be achieved with increasing capacitance but it comes at a cost of a longer wake up time.

Introducing the LM4906! Getting Rid of the "But"..... No Reference Bypass Capacitor Required!



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The LM4906 is the first Boomer® power amplifier that does not require an external reference bypass capacitor.
A new patented technology eliminates the need for the capacitor, resulting in a quick wake-up time (T_{WU}) , great PSRR specification, board space savings, and less assembly time.

The LM4906 requires only two capacitors (input capacitor and supply bypass capacitor), and has an internal gain (6dB or 12dB) setting pin.

Key Specifications:
V_{DD} = +3V
PSRR: 71dB @ 217 Hz; 73dB @ 1kHz
P_O = 390mW, R_L = 8Ω, BTL
T_{WU} = 4ms

V_{DD} = +5V
PSRR: 67dB @ 217 Hz; 70dB @ 1kHz
P_O = 1W, R_L = 8Ω, BTL
T_{WU} = 5ms

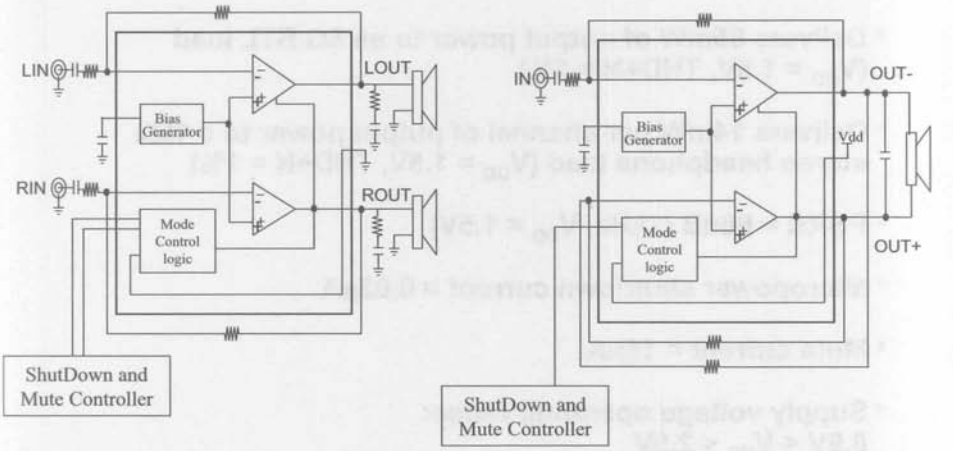
Applications:
Portable computers
Desktop computers
Multimedia monitors

Portable Consumer Audio Devices Operating on a Single Cell Battery

- *Portable CD/MP3/MD players*
- *TV remote control*
- *Electronic Dictionary*
- *Wireless headphones*
- *Cordless telephone*
- *Clock*

Most audio amplifiers suitable for portable devices operate between 3V to 6V. However, there are several portable consumer audio devices (as listed above) that only require a single cell battery, 1.5V, as the power source.

LM4916 Provides a Single-Cell Battery Solution



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The LM4916 is an audio power amplifier which operates on a 1.5V supply, therefore making it an ideal solution for portable, single-cell, audio products. The unity gain stable LM4916 features two modes of operation, a stereo headphone mode and a mono BTL speaker mode. It is capable of driving an 8W load in mono BTL mode and 16W in stereo headphone mode. The LM4916 also features a low current mute mode.

LM4916 – Mono 85mW BTL Output, 14mW Stereo Headphone Audio Amplifier

- Delivers 85mW of output power to an 8Ω BTL load (V_{DD} = 1.5V, THD+N = 1%)
- Delivers 14mW per channel of putput power to a 16Ω stereo headphone load (V_{DD} = 1.5V, THD+N = 1%)
- PSRR = 66dB (1kHz, V_{DD} = 1.5V)
- Micropower shutdown current = 0.02μA
- Mute current = 15μA
- Supply voltage operating range: 0.9V < V_{DD} < 2.5V

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Operating on a single 1.5V supply, the mono BTL mode delivers 85mW into an 8 Ω load at 1% THD+N. In Single Ended stereo headphone mode, the amplifier delivers 14mW per channel into a 16Ω load at 1% THD+N. Additionally, the LM4916 features a low-power consumption shutdown mode, a low-current mute mode, "click and pop" suppression circuitry, and thermal shutdown.

The LM4921 Stereo Headphone Power DAC

- *Stereo headphone amplifier and DAC in one package!*
- *CD quality 16-bit power DAC*
- *Standard I²S input*
- *Perfect for MP3 and cell Phone audio systems*
- *Outstanding PSRR*
- *32 Step stereo volume control (SPI interface)*
- *+2.6V to +5V operation*
- *P_O = 26mW @ V_{DD} = 3V*
- *Outstanding THD+N*
- *Space-saving, 20 bump, micro SMD package*

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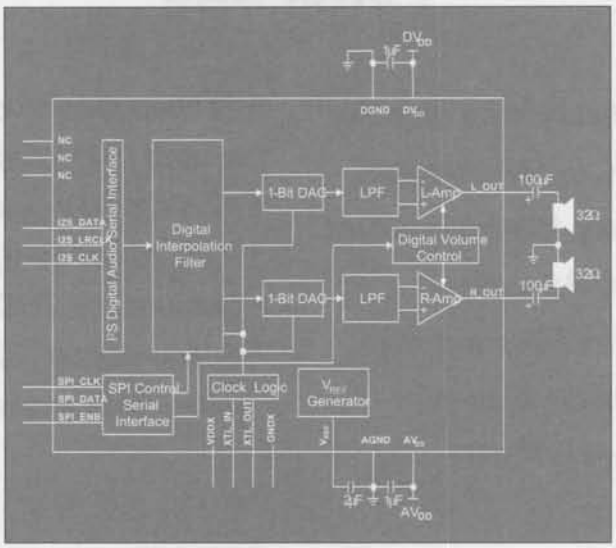
In today's demanding portable audio applications where features, size and cost are paramount, the LM4921 Power DAC is a perfect fit. In previous audio systems for portable handheld devices the DAC, Volume control and power amplifiers were in different packages which took up valuable space.. The new LM4921 combines a 16-bit resolution, stereo, I²S input, digital-to-analog converter (DAC) with a 1W per channel, stereo headphone, audio power amplifier. This new part saves both system design and board layout time while providing a simple to use, industry standard interface. National's industry proven 20 bump micro SMD package also saves valuable board space.

The LM4921's 16-bit/CD quality resolution provides a quality listening experience on a par with any portable devices in the market. The LM4921's superior 0.05% THD+N into a standard headphone load (32Ω) at 13mW makes the LM4921 suitable for any music or voice band applications.

The LM4921 Stereo Headphone Power DAC



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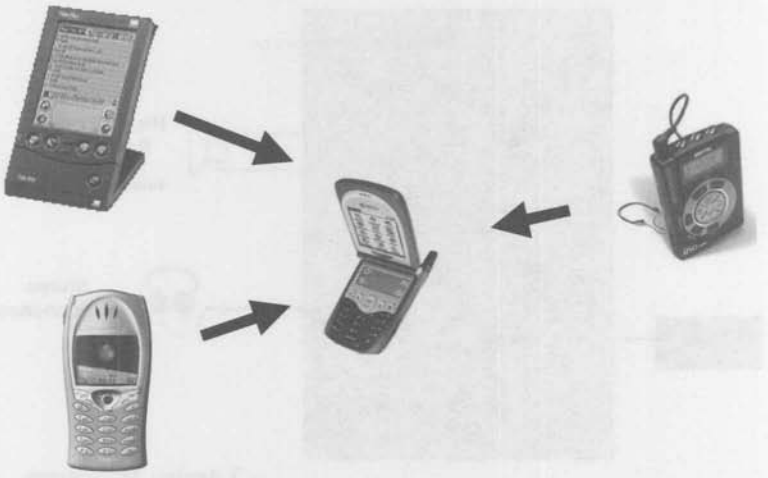
The LM4921 is primarily designed for demanding applications in mobile phones, PDAs and other portable communication device applications. The LM4921 features an I2S serial interface for the digital audio information and a 16-bit SPI serial interface for internal register control and communication. The LM4921 also features a programmable 32-step (1.5 dB per step) digital volume control accessed through the same easy-to-use SPI interface. The necessary clock signal can be externally generated or internally generated using an external crystal. It is, therefore, ideally suited for mobile phone and other low-voltage applications where minimal power consumption is a primary requirement. The LM4921 also features a low-power-consumption shutdown mode and an internal thermal shutdown protection mechanism.

PDA/handset Convergence and Audio Integration



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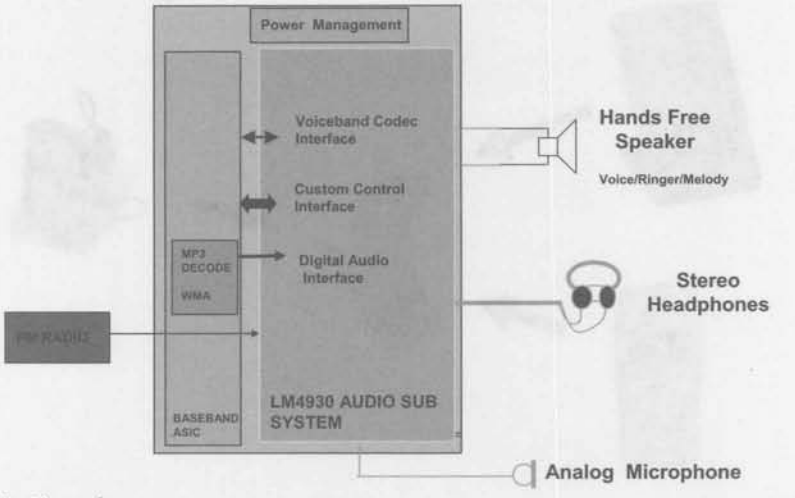
Today, the cellular handset is more than just a phone. It has quickly evolved into becoming a multimedia device, combined with the functionality of a phone, PDA organizer, and MP3/FM player. With all the increased features and demands required for today's handset, the audio amplifier solution for handsets has become increasingly complex.

Multiple Interface Audio Solution



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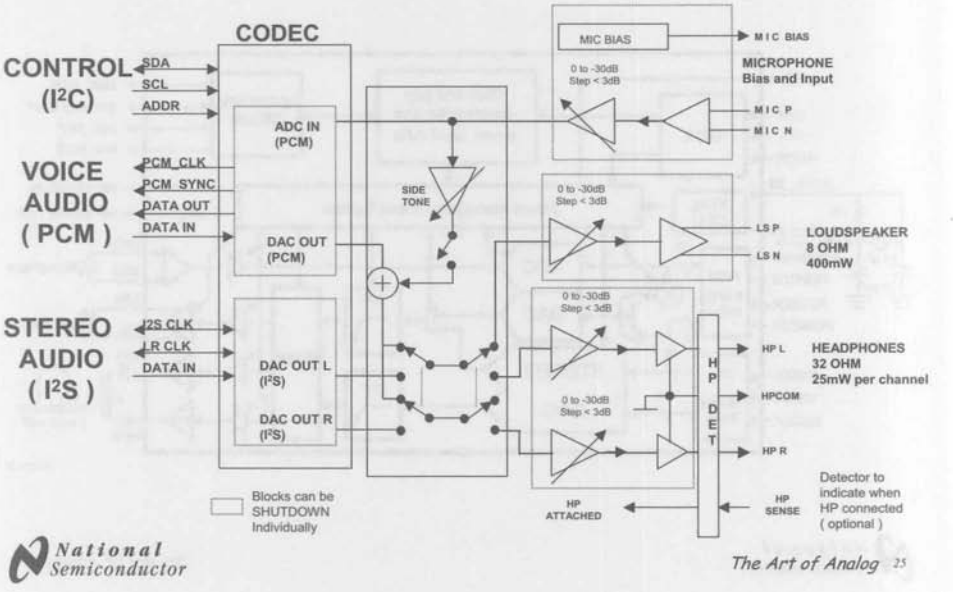
This diagram depicts the role of an audio subsystem in a cellular environment. The audio subsytem must be able to handle multiple audio interfaces, for voice data as well as high quality music from an MP3 decoder. Currently most solutions require a separate voice band codec and audio DAC to handle both voice and music data. The LM4930 integrates both the voice band codec and audio DAC, as well as the power amps required to drive both a hands-free speaker and stereo headphones into a single audio sub-system solution. An analog microphone input with ADC and full gain control of all inputs and outputs completes the system.

This system incorporates multiple audio modes where Voice or Audio may be sent to the mono output or the stereo headphone output, or even both at the same time! Full mixing and sidetone control are also integrated.

LM4930 PCM, I²S, I²C Interfaces



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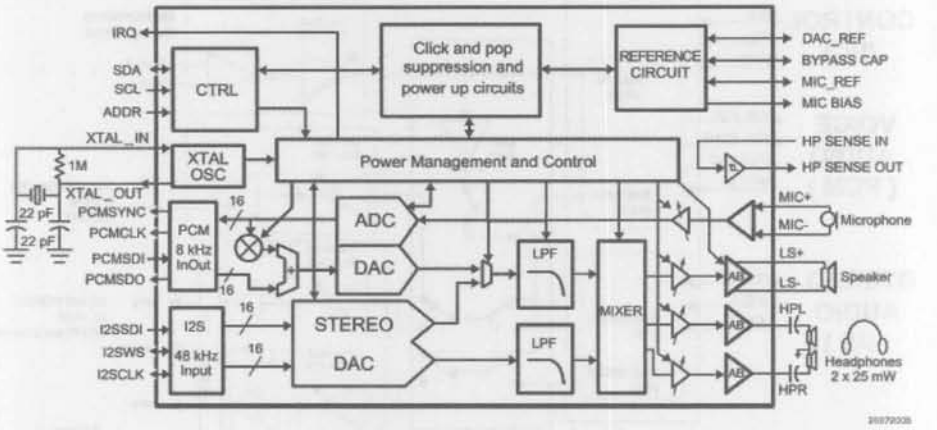
The LM4930's 48kHz DAC uses a standard I²S digital audio interface for stereo music playback. The integrated 8kHz voice band codec uses a standard PCM digital audio interface for voice data. The LM4930 also features an I²C compatible control (two-wire) interface to program both the voice band codec and audio DAC. For instance the LM4930 can be programmed to be either I²S master or slave mode. The PCM interface is master only. The I²C compatible interface can also program the LM4930 into different output modes as well as different volume control settings.

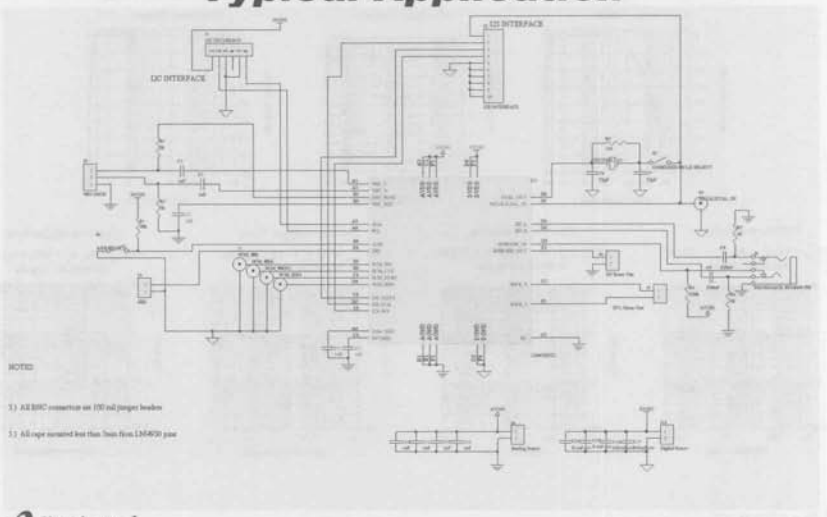
Audio Sub-System



Now integrated onto one IC:

- LM4930ITL, 36 bump micro SMD package
- All on same I^2C control bus
- Minimum amount of board space consumed (3.2mmx3.4mm)
- Reduced RF susceptibility system wide
- Enhanced power management and system-wide integrated click/pop reduction
- Minimum of external components
- Integrated filtering and mixing

LM4930 Audio Sub-System Typical Application



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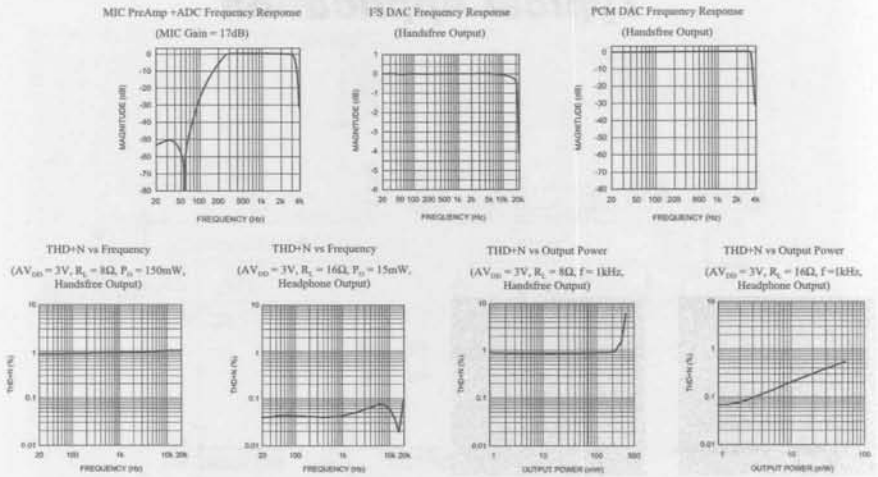
This shows the typical application circuit as given on the Reference Design Board. Note the small number of external components compared to separate system components. As an integrated system, the LM4930 enjoys many advantages vs. separate components: the single control bus reduces layout and system complexity, the small size and integrated traces reduces RF susceptibility system-wide, the integrated shutdown control reduces "click and pop" transients system-wide, low external component count, and best of all – small footprint (just 3.2mmx3.4mm in the 36-bump micro SMD package).

An external clock (Y1) option is shown in this diagram. The LM4930 is intended to be run off the 12.288MHz master clock of the baseband IC or micro controller.

LM4930 Performance



The performance of the LM4930 is also in line with the rest of the boomer family. The top curves show frequency response for the MIC preamp +ADC stage, the I²S DAC, and the PCM DAC. The frequency response for the MIC section is obviously affected by external cap values, but is near flat from 300-3kHz. The I²S 16-bit DAC is near flat out to 20KHz – dropping only 0.4dB from 5kHz to 20kHz. The PCM DAC is also flat out to about 3kHz.

THD+N and Output Power for the internal BTL mono amp and single-ended stereo headphone amps are also excellent. THD+N is relatively flat for both the BTL out and the headphone out. The BTL output is capable of driving an 8 ohm load to 300mW with less than 2% THD+N. The headphone output has improved THD+N, with almost 50mW of power being delivered to a 16 ohm load at less than 0.5% THD+N.

History of Boomer® Amplifiers

- **Boomer amplifiers originally featured:**
  - *CMOS technology*
  - *BTL output(s)*
  - *5V supply operation*

National Semiconductor

From their inception, National's Boomer® audio amplifiers have taken advantage of a computer's available 5V power supply and rail-to-rail operation made possible by CMOS technology.

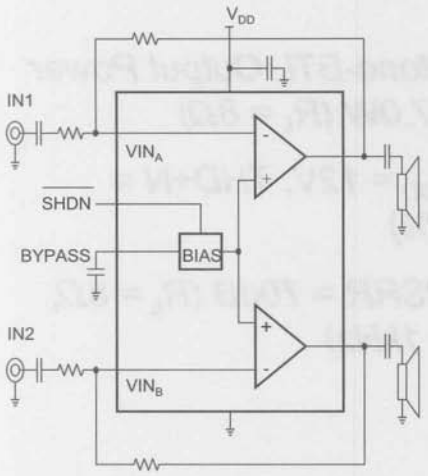
Modern Technology is Moving Away From 5V Supplies

- *Boomer® amplifiers now need to be powered by a 12V supply*

- *Want to retain superior performance of traditional Boomer amplifiers*

In many applications, a 1.8V digital supply is replacing the 5V supply, thus leaving a 12V analog supply to power audio circuitry. This creates a need for a new type of Boomer that maintains the superior performance of the previous generation of Boomers while powered by a 12V supply.

LM4950 – 7W Mono-BTL or 3.1W Stereo Audio Power Amplifier

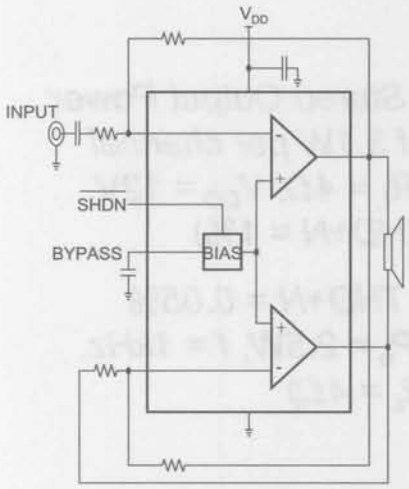


- *Stereo Output Power of 3.1W per channel (R_L = 4Ω, V_{DD} = 12V, THD+N = 1%)*
- *THD+N = 0.05% (P_o = 2.5W, f = 1kHz, R_L = 4Ω)*

National Semiconductor

The LM4950 fills the need for a high performance audio amplifier that is also powered by a 12V supply. External resistors gives customers the option of setting the gain in either stereo SE or mono-BTL mode. In stereo mode, the LM4950 delivers an output power of 3.1W per channel (RL = 4Ω, THD+N=1%). It also has a THD+N of 0.05% at an output power of 2.5W (f = 1kHz, RL = 4Ω).

LM4950 – 7W Mono-BTL or 3.1W Stereo Audio Power Amplifier



- *Mono-BTL Output Power of 7.0W (R_L = 8Ω)*
- *V_{DD} = 12V, THD+N = 10%)*
- *PSRR = 70dB (R_L = 8Ω, f = 1kHz)*

National Semiconductor

In mono-BTL mode, the LM4950 delivers an output power of 7.0W (RL = 8Ω, THD+N=10%) and has a PSRR of 70dB (RL = 8Ω, f = 1kHz).