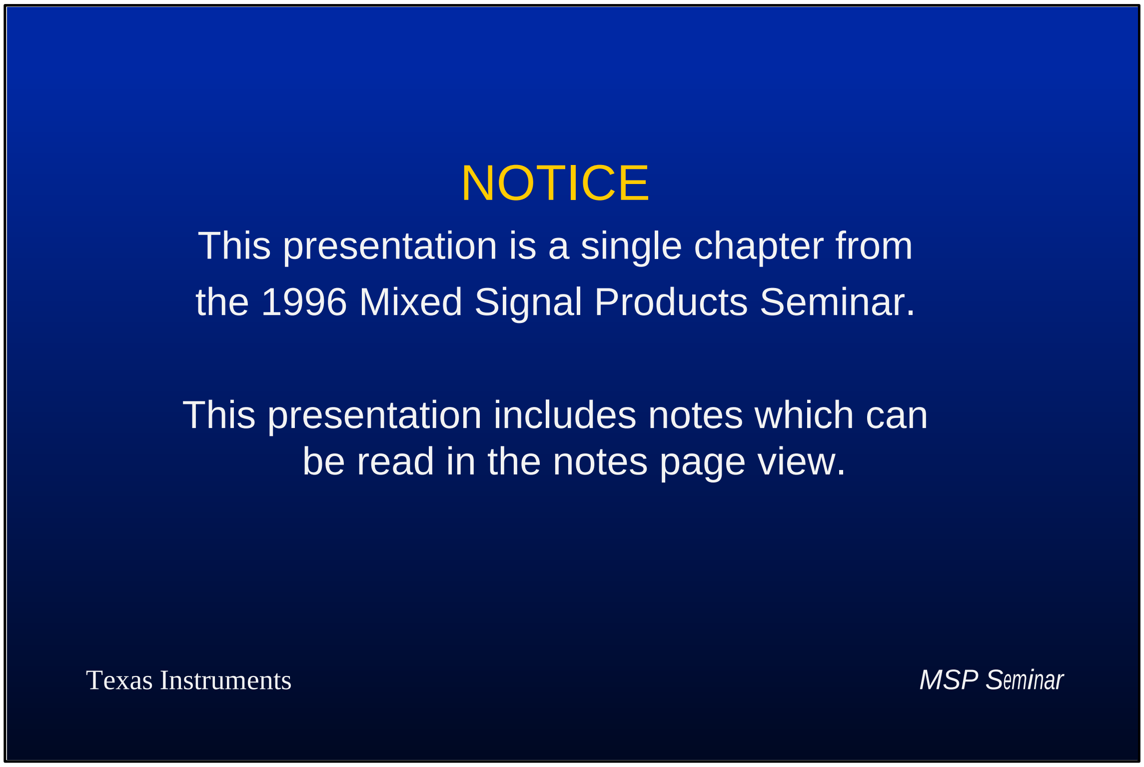
*Section 1*

# *SIGNAL CONDITIONING*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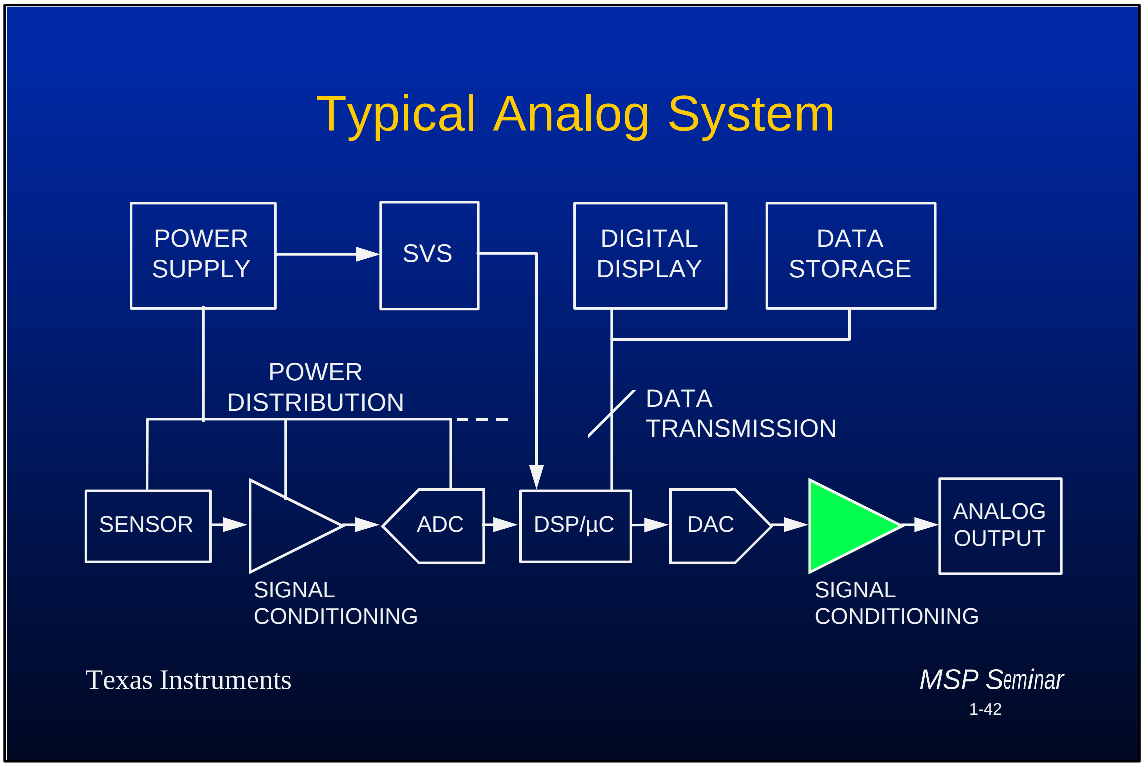


*Figure 1-42 Typical Analog System*

## Output Signal Conditioning

Next we will consider signal conditioning requirements for output transducers. Specifically, we will examine audio power amplifiers for PC sound systems.

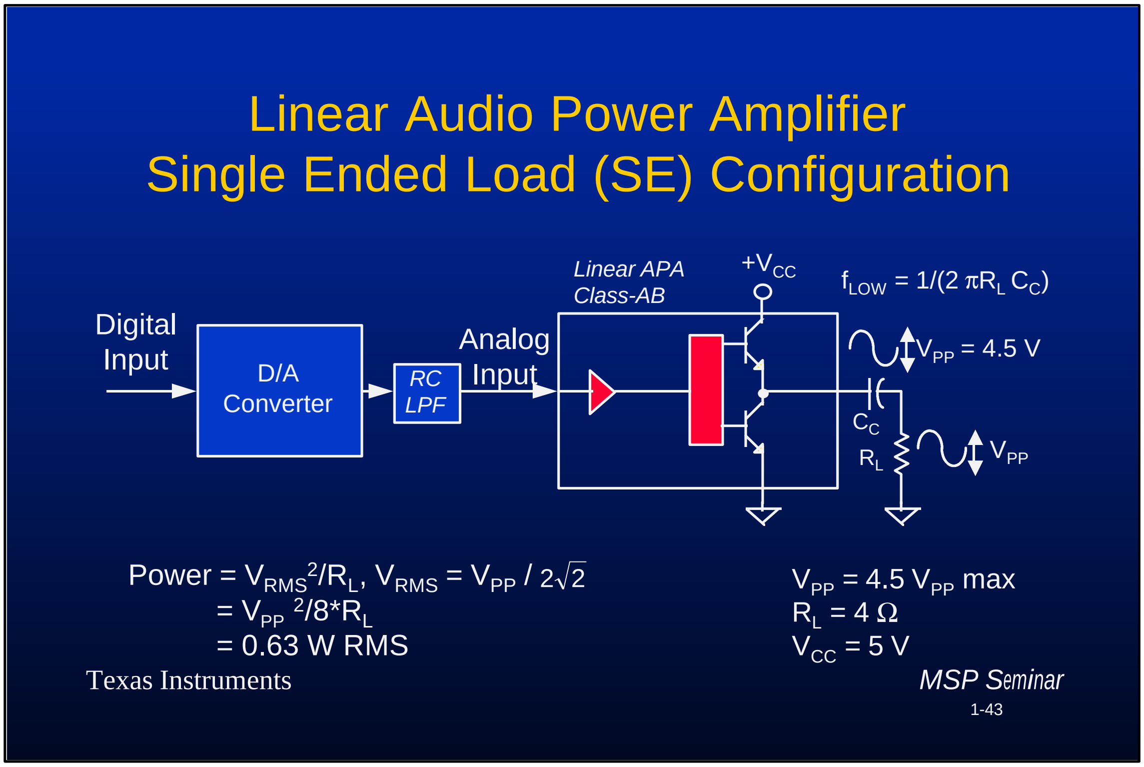


*Figure 1-43   Linear Audio Power Amplifier  Single Ended Load (SE) Configuration*

## Audio Power Amplifiers

Audio Power Amplifiers (APA) are a special type of Operational Amplifier optimized to drive low impedance loads, typically speakers or headphones, at frequencies from 20 to 20 kHz. In the diagram you see a representation of a typical computer audio output channel employing the most common type of APA, the Class AB linear amplifier.  From the title you can see that we call it Single Ended, this refers to the fact that the amplifier drives only one end of the load while the other is typically connected to ground.

In the diagram the D/A Converter accepts digital sound data from the Sound Chip or other source and converts it into a linear representation of the original sound waveform.  The RC Low Pass Filter removes conversion noise from the D/A output and provides an analog waveform to the APA.

In terms of power provided to the load the equation is straight forward if you remember to convert the Voltage to an RMS value by dividing the peak-to-peak number by $2\sqrt{2}$or 2.83. Then it is just Vrms$^2$/ R.  Also remember that when determining the peak power capability of an amplifier that most APAs can not approach the supply rails or distortion is significantly increased.  So, for a +5 volt supply into a 4 Ω  speaker we get about 4.5 Volt maximum peak-to-peak swing which translates into 1.59 volts RMS (quite a difference in peak vs rms power if you happen to forget to make the conversion).  Plugging the numbers into the equation you get 0.63 W of RMS power into a 4 Ω load from a  +5 Volt power supply.  If you change the speaker to an 8 Ω type then you get half the power - down to .32 Watts - whereas if you change the load to 2 Ω then you could expect 1.26 Watts of power into the load.  Not all amplifiers however can handle 4 or 8 Ω loads, be sure to check the specifications of the candidate devices.

Another way of providing more power into the load rather than lowering the impedance of the speaker is a technique called “bridging.”

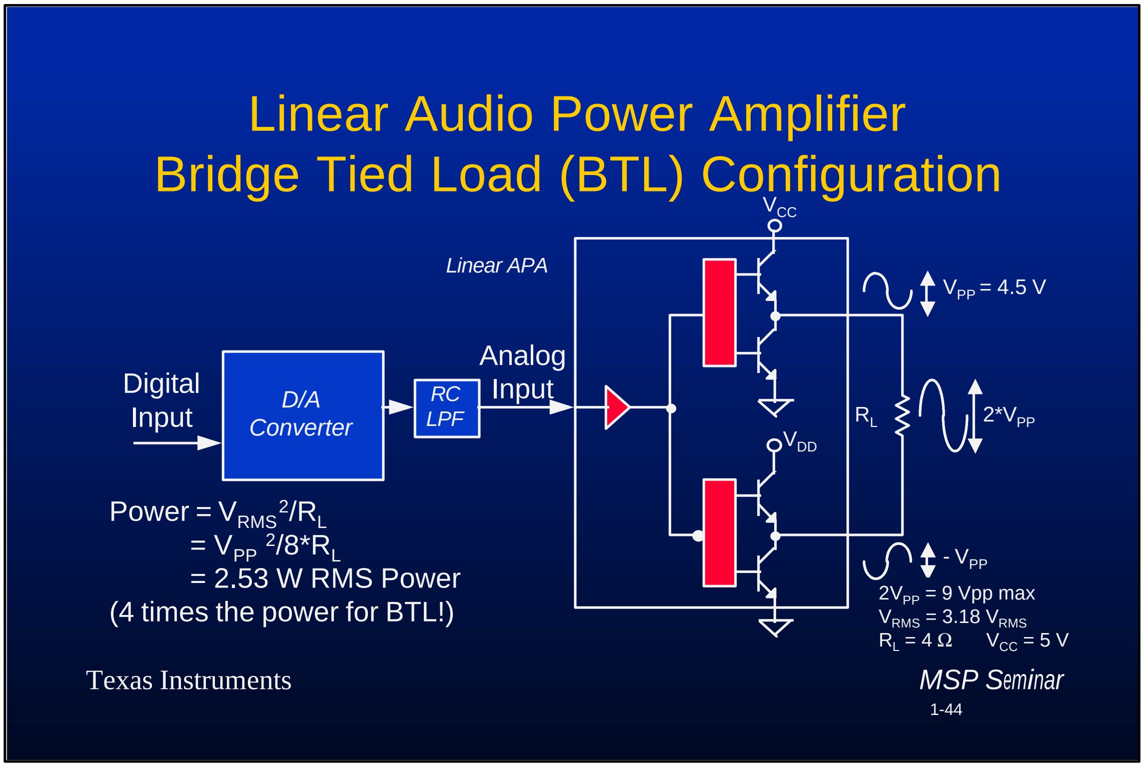


*Figure 1-44 Linear Audio Power Amplifier Bridge Tied Load (BTL) Configuration*

## Bridge-Tied Load (BTL) Configuration

In this diagram we see a linear APA in a Bridge Tied Load (BTL) configuration. A BTL amplifier actually consists of two linear amplifiers driving both ends of the load differentially. There are several potential benefits to this configuration but for now let us consider power to the load. The differential drive to the speaker means that as one side is slewing up the other side is slewing down and vice versa. This in effect doubles the available voltage swing on the load. When you the plug twice the voltage into the power equation, where voltage is squared, then you get 4 times the output power from the same supply rail and load impedance.

In a typical computer sound channel running from 5 V supplies, bridging raises the power into a 4 Ω speaker from .63 watts to 2.5 Watts. In sound power that's a 6 dB improvement - that's loudness you can really hear. There are also other advantages. In the single supply SE configuration a coupling capacitor is required to block the DC offset from reaching the load (unless you are using bipolar supplies). These capacitors can be quite large (in the neighborhood of 40 to 1000 uF) so are expensive. They have the additional drawback of limiting low frequency performance by creating a high pass filter network with the speaker impedance of ½πRC. So a 120 uF cap with a 4 Ω speaker would limit low frequencies to above 330 Hz - no bass drums in that output! The BTL configuration cancels the DC offsets eliminating the need for the blocking caps so low frequency performance is then limited mainly by the speaker itself.

BTL does carry a penalty; internal power dissipation is increased by a factor of four over SE configurations with the same supply voltage.

When calculating power to the load you must have a power supply capable of providing the power to the APA. You must calculate RMS and peak current. In the example above, RMS current would be calculated backwards from the RMS power by $I^2 = P_{RMS} / R$. In this case .79 A RMS at 4.5 V; to translate that to current from the 5 V supply use the voltage ratio, yielding 0.71 A. Peak current is calculated by converting the RMS current to its peak value by multiplying by $2\sqrt{2}$ to get a peak current of 2.2 A in the load or 1.9 A peak from the supply. That means the power supply must deliver almost 4 W of RMS audio power into a monoaural load - not a trivial task.

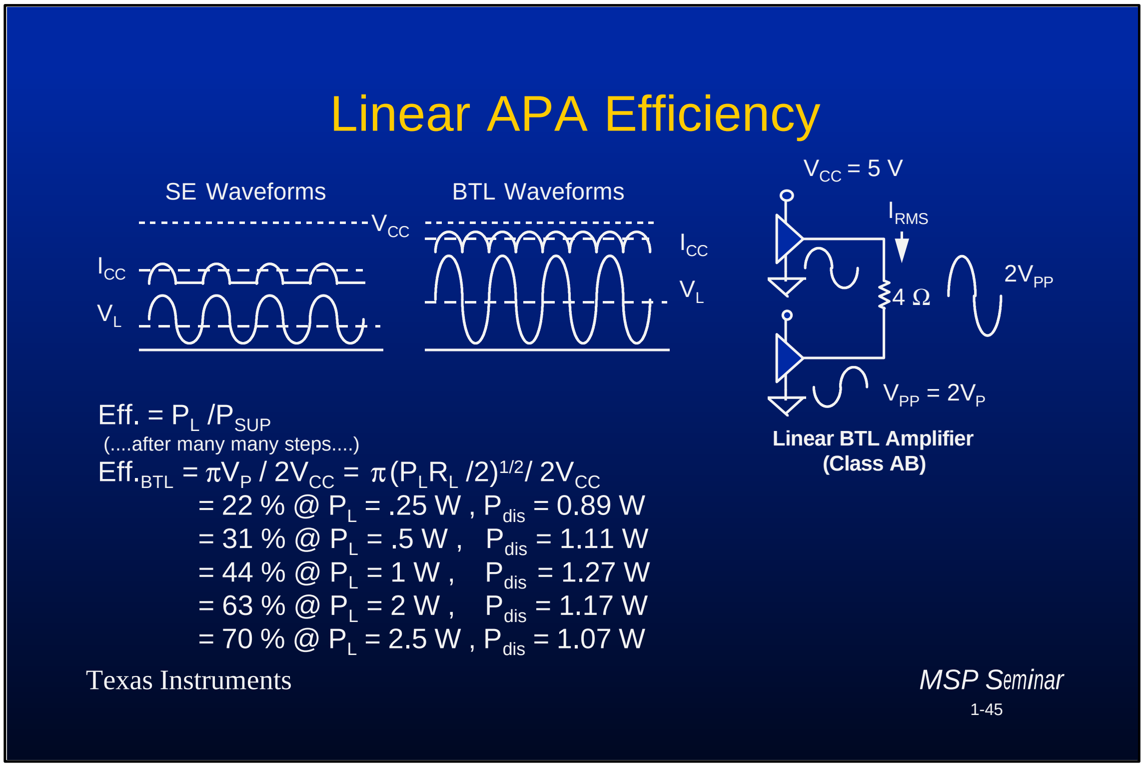


*Figure 1-45 Linear APA Efficiency*

Linear amplifiers are notoriously inefficient. The primary cause of inefficiencies in linear amplifiers is voltage drop across the output stage transistors. The drop occurs for two reasons: one is that even at maximum output swing from a 5 volt supply the output voltage would only swing 4.5 V; the other is due to the sine wave nature of the output waveform. The equation to calculate efficiency starts out simply enough as being equal to the ratio of power from the power supply to the power delivered to the load. To accurately calculate the rms values of power in the load and in the amplifier you must understand the shapes of the current and voltage wave forms as shown above. Although the voltages and currents for SE and BTL are sinusoidal in the load, currents from the supply are very different between SE and BTL configurations. In an SE application the current waveform is a half-wave rectified shape whereas in BTL it is a full wave rectified, this means rms conversion factors are different. Examination of the transitor block diagrams in the previous slide will help clarify the point, keeping in mind that for most of the waveform both the push and pull transistor are not on at the same time.

What we see from the example calculations is that the efficiency is quite horrible for lower power levels resulting in a nearly flat internal power dissipation over the normal operating range. What is a little surprising at first is the fact that the internal dissipation at full output power is less than in the half power range. Also remember that the above example is mono, double everything for stereo! So, for a stereo 2.5 W audio system with a 4 ohm load and 5 V supply the maximum draw on the power supply will be almost 7.25W.

A final “all is not lost” point to remember about linear amplifiers, whether they be SE or BTL configured, is how to manipulate the terms in the efficiency equation to your advantage. Note that in the efficiency equation Vcc is in the denominator. This means that as Vcc goes down, efficiency goes up. Consider this example, if you replaced the 5 V supply with a 12 V supply in the above calculations then efficiency at 2.5 W would fall to 29% and internal power dissipation would rise to 6.12 W. Use the right supply voltage and speaker impedance for your application!


*Figure 1-46 Audio Amplifiers for Notebook Computer, Speakerphone and Handheld Equipment TPA4860 & TPA4861*

Now let us look at some new Audio Power Amplifier products from TI that make practical use of the material we've just covered.

The new TPA4860 and TPA4861 are TI's first releases in a new family, TI Power Amplifiers (TPA), of CMOS and Bipolar Audio Power Amplifiers. These two are CMOS amplifiers designed primarily for bridge mode operation in notebook and desktop PC audio systems. The bridged mode operation, low quiescent currents and power saving shutdown modes make these devices ideal for any low voltage or battery powered application.

The TPA4860 and '61 are drop-in compatible with National Semiconductor's LM4860 and '61 although TI rates the TPA4861 at twice the output power of the LM4861. The TPA4860 is available in a small 16-pin SOIC package and the '61 is in an even smaller 8-pin SOIC. Taking advantage of the BTL configuration eliminates the output coupling caps so the total PCB space required to lay down the solution is small as compared to comparable power SE configurations.

1 K pricing in the $1.25 range makes the TI solution very cost competitive with existing solutions from other suppliers. Next we'll investigate circuit design specifics to keep in mind when using the TPA4860 and '61.

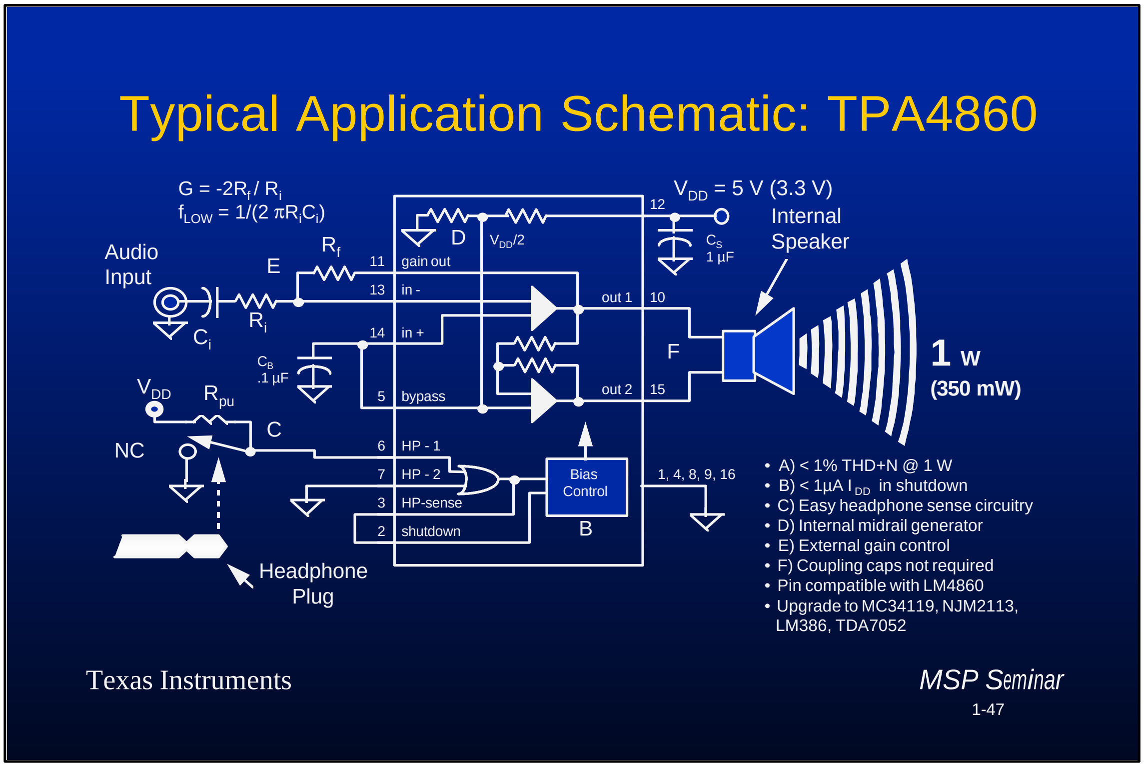


*Figure 1-47 Typical Application Schematic: TPA4860*

Figure 1-47 illustrates in greater detail the typical circuit design requirements for the TPA4860. The gain is set just like a traditional op amp circuit with the exception that in BTL circuits the gain is doubled. So, with two external resistors the Gain equals -2 $R_f / R_i$. The TPA4860 is internally compensated for gains of 1 to 10; higher gains can be used with external compensation, typically a small capacitor in parallel with $R_f$..

The low frequency response of the system is determined by the 1 / 2 π R C product of the input coupling capacitor $C_i$ and the input resistor $R_i$. Typical values of these components are $R_i$ = 10 kΩ and $C_i$ = 1 uF, thus the low frequency response is about 16 Hz, which is better than most headphones or small speakers can reproduce.

An internal midrail generator in the TPA4860 biases the input circuit which eliminates the need for external biasing. $C_s$ in the diagram reduces the power supply noise feed through on the bias circuit. The larger $C_s$ is the better the low frequency power supply rejection is. Better quality caps with very low ESR (equivalent series resistance) also help overall noise performance.

The special headphone sensing circuitry in the TPA4860 is designed to work in concert with the in/out switch in PC headphone jacks. In most PC systems it is desirable to mute the internal speakers when the headphone is plugged in. When the headphone sense goes high the outputs are muted and the HP sense output can be used to signal other circuits that the system is in headphone mode. Looping the HP-sense back into the shutdown pin places the TPA4860 output amplifiers in shutdown mode which reduces quiescent current to around 1 µA from the normal 4.5 mA. A slide of the total system block diagram will be shown later to help clarify the systems approach.

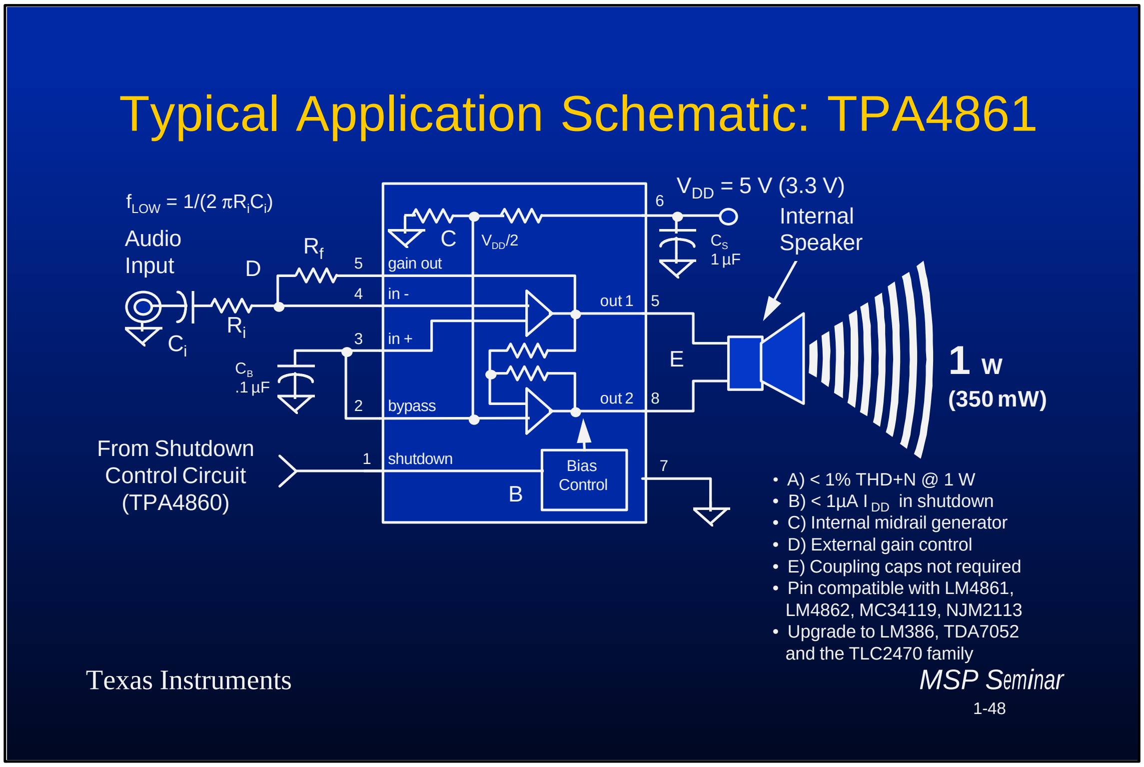


*Figure 1-48   Typical Application Schematic: TPA4861*

The TPA4861 is much like the TPA4860 except it eliminates the headphone sensing circuitry to fit in an 8-pin SOIC package. The internal midrail generation and amplifiers circuits are identical to the TPA4860. As the diagram indicates, the shutdown control for the ‘4861 likely will come from the ‘4860 in a notebook application.

There are several competing devices that are pin compatible to the TPA4861. The LM4861 is a direct second source, the LM4862 is a lower power version but still uses the same pinouts. The MC34119 really was the first of this BTL line of amps although it has less drive capability and is not as simple to use. The NJM2113 is basically a second source of the MC34119. The TLC2470 family of APAs was designed for use with TI’s VBAP (Voice Band Audio Processor) solutions but has been discontinued. In many instances the TPA4861 is a good replacement for it.

The TPA4860 and the TPA4861 can be configured as mono single ended amplifiers with approximately 1/4 of the available output power. In those circuits output coupling caps and damping networks are required for proper operation. The typical application of the single ended mode would be for headphone drive in which case two TPA4861s would be required for stereo operation.

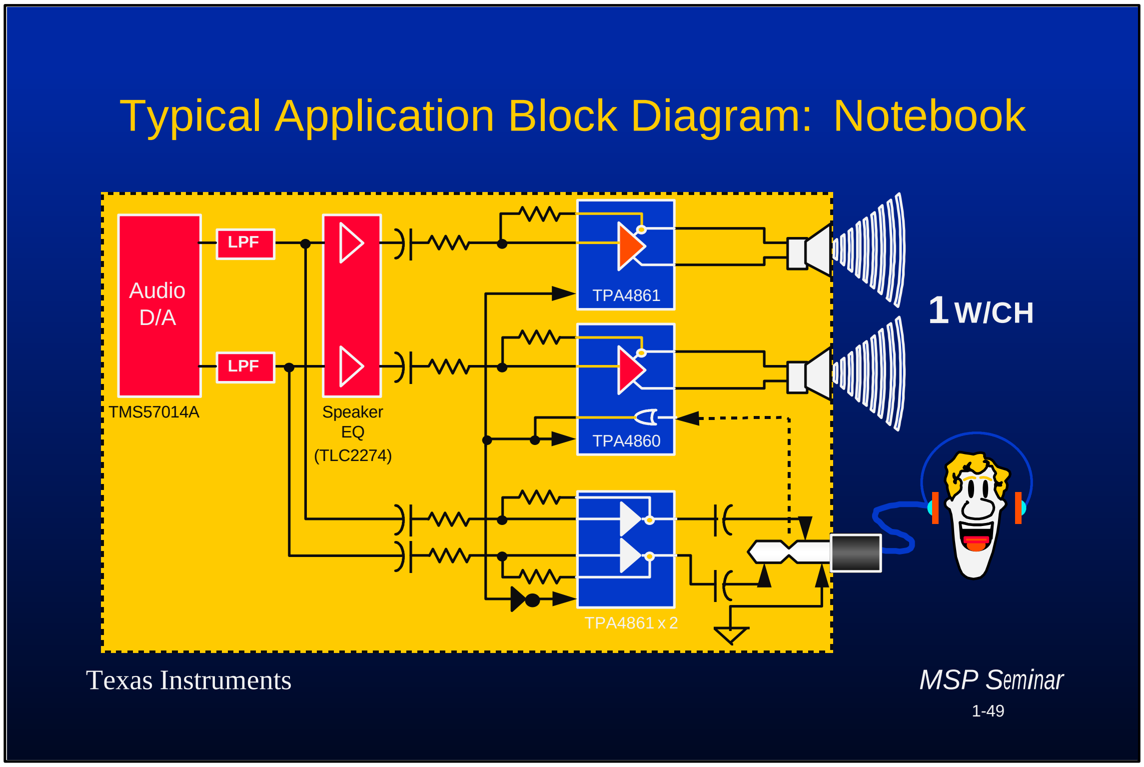


*Figure 1-49 Typical Application Block Diagram: Notebook*

In PC audio systems the digital sound data is placed on the bus, picked up in the sound chip and sent to the output portion of the Audio CODEC shown in the diagram. The D/A in the CODEC converts the digital information into an analog approximation that is filtered to remove the high frequency switching components and provide a smoothed waveform to the analog portion of the audio system. Since most small speakers used in Notebook computers today have limited low and high frequency response it may also be desirable to limit the bandwidth of the audio signals presented to them. Here we show an EQ system that helps compensate for less than ideal speakers. Headphones however typically have wider and flatter response bands so may not need the band limiting or correction provided by the speaker EQ circuit. This is especially true if the output is to drive a more elaborate powered multimedia speaker system or home hi-fi.

The system shown takes advantage of the TPA4860 and the TPA4861 to create a very cost effective solution for notebook audio. Since only one headphone sense network is required, a single ‘4860 can provide that function and then control the other amplifiers with the HP-sense output. Since the ‘4861 is also rated at 1 W the two amps compliment each other well providing the minimum space solution. The second HP-IN input on the ‘4860 would be connected to the docking station jack if that capability was desired.

# Section 1

# Appendix

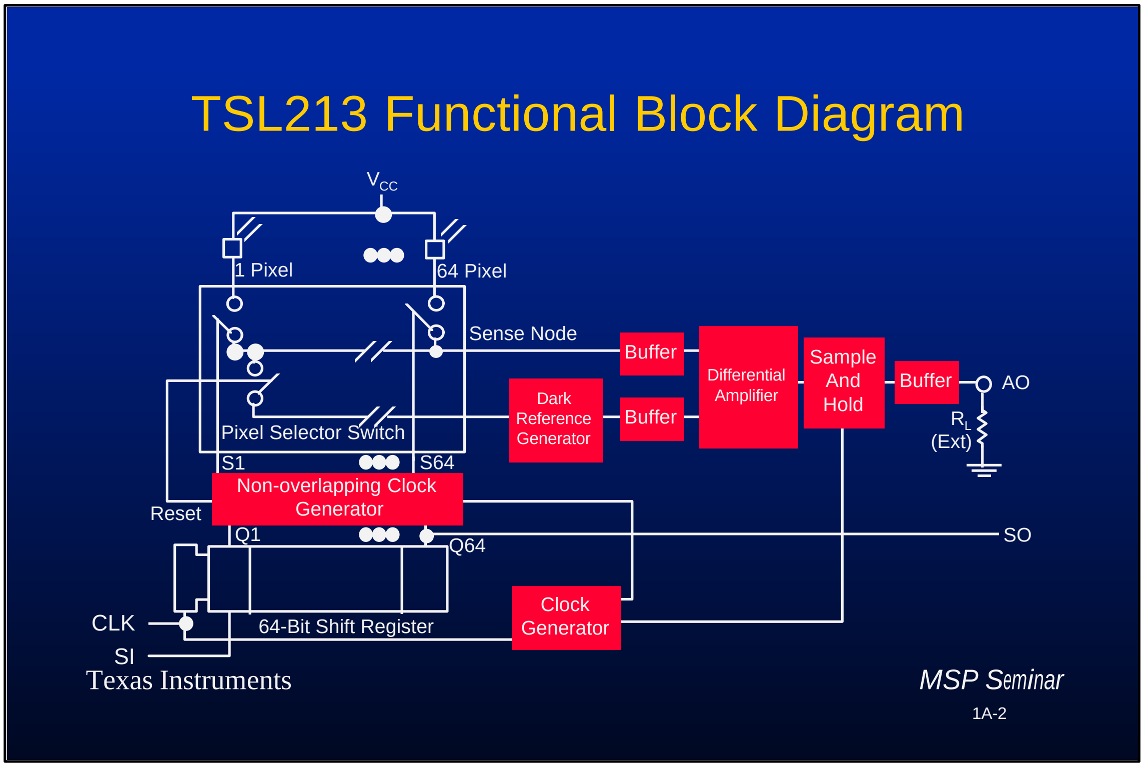


*Figure 1A-2 TSL213 Functional Block Diagram*

## 200 dpi line arrays - TSL213/TSL215/TSL218

The TSL213 array illustrates how a complex sensor, which integrates light-sensing, analog and digital elements, can offer the prospects of low system cost, and ease of design.

The TSL213 is a 64-element line sensor, fabricated from the established Texas Instruments LinCMOS™ mixed-mode volume wafer technology. The pixels have a 125 micron center-to-center spacing. The TSL213 is a charge-mode sensor. That is, during an exposure period, a charge is developed on each pixel proportional to the product of the light intensity and the exposure time (in this it is like a CCD imager, and analogous to photographic film).

On a single TSL213 die are integrated the light-sensing pixels, analog signal conditioning, and digital address and switch elements (equivalent to approximately 2500 gates ).

The internal complexity of the die has been chosen, to make the device easy to use in a microprocessor or digital processing system environment. To operate the TSL213, only a single 5V supply and integration (SI) and pixel output clock pulses are required.

## Characteristics

The TSL213 operates at data rates between 10 kHz and 500 kHz. The relatively large pixel size permits assembly in a high volume low cost 8-pin plastic dual-in-line package.

The TSL213 is recommended as a real alternative to either discrete photo-sensor arrays or to CCD line imagers in sensing systems where more than one sensor is required, and the sensors form part of a digital control system. Typically the pixel size in a line CCD imager is 10 microns, and for a discrete photo-diode or photo-transistor is 1000 microns. At 125 microns pixel size, the TSL213 is appropriate for many applications.

## Function Blocks

The functional structure of the TSL213 is shown in Figure 1.43. There are 64 pixels in a line array, which are addressed individually (unlike CCD where all pixel charges are switched along an analog register simultaneously).

The exposure or integration period is defined as the time between pulses on the Serial Input (SI) pin. The integration period is chosen in each application to give a suitable output level for the light intensity available.

The charge in each pixel is transferred to the output sense node by means of the Clock Pulse (CLK). The sense node generates a signal voltage directly proportional to the charge.

A 64-bit shift register controls the transfer of charges to the output and provides timing signals for the non-overlapping clock generator (NOCG). The NOCG provides internal control for the sensor elements, including charge sensing and reset. The reset establishes a known voltage at the sense node in preparation for the next pixel charge transfer. This voltage is used as a dark reference level for the differential signal amplifier. By means of the NOCG, feed-through clock noise is eliminated at the output. The sample-and-hold signal generated by the NOCG holds the voltage analog output of each pixel constant until the next pixel is clocked out.

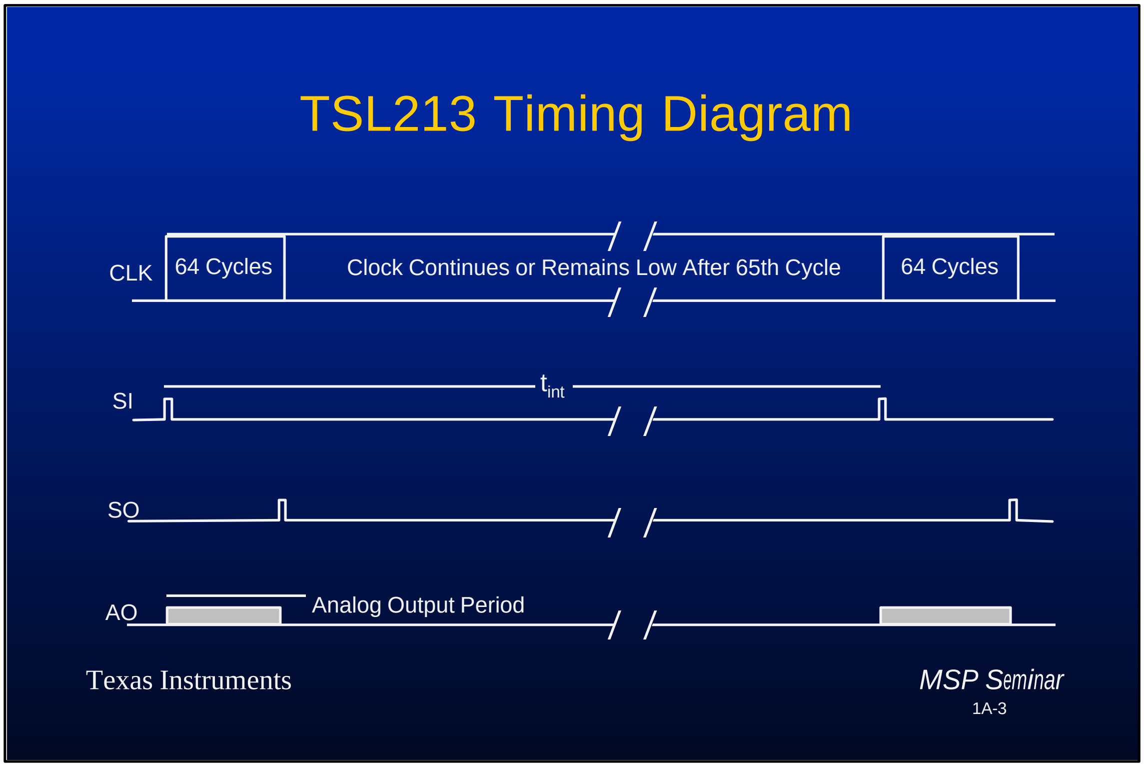


*Figure 1A-3  TSL213 Timing Diagram*

The timing for the TSL213 is quite simple with data output starting on the asssertion of the SI pulse.  64 clocks are required to read out all pixels, a 65th clock is required to shilft the SI pulse completewly out of the shift register in preparation for the next readout cycle.  Two SI pusles cannot reside int he shift register simulataneously.

At power up or after a period of readout  inactivity the sensor may need to be initialized. This is done by performing 15 consecutive output cycles to cleat the pixels of any charge accumulated during output inactivity.

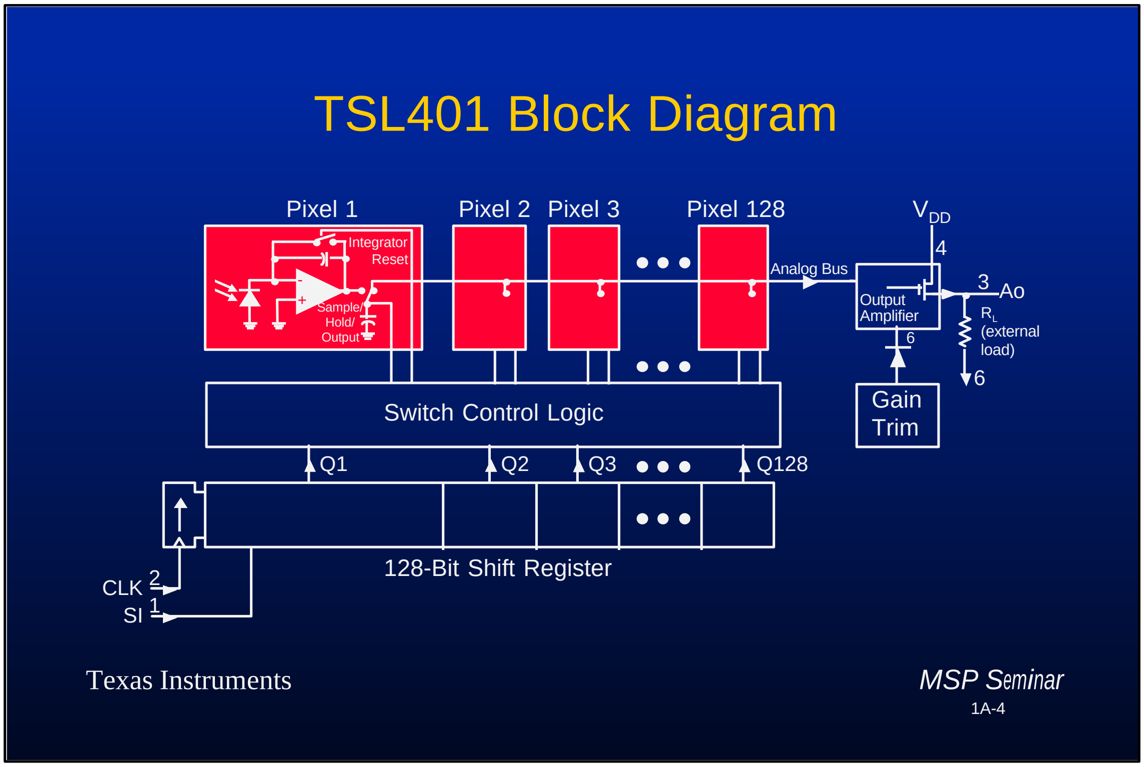


*Figure 1A-4 TSL401 Block Diagram*

## TSL401

A second generation line imager uses a different architecture that places a charge amplifier at each pixel site. This architecture provides better pixel uniformity, offset, improved linearity and a signal to noise ratio that permits 8 bits gray scale resolution. In addition the pixels can be clocked out at a 2Mhz. The TSL401 has an image lag that is typically 0.5%. Image lag is the ratio of signal remaining in a pixel immediately after the light source is turned off, divided by the signal of the previous scan at the pixel site with the light on. The interface to the TSL401 is the same as the TSL213. Also similar to the TSL213 is the capability to generate longer arrays by end butting TSL401 die in a longer package.