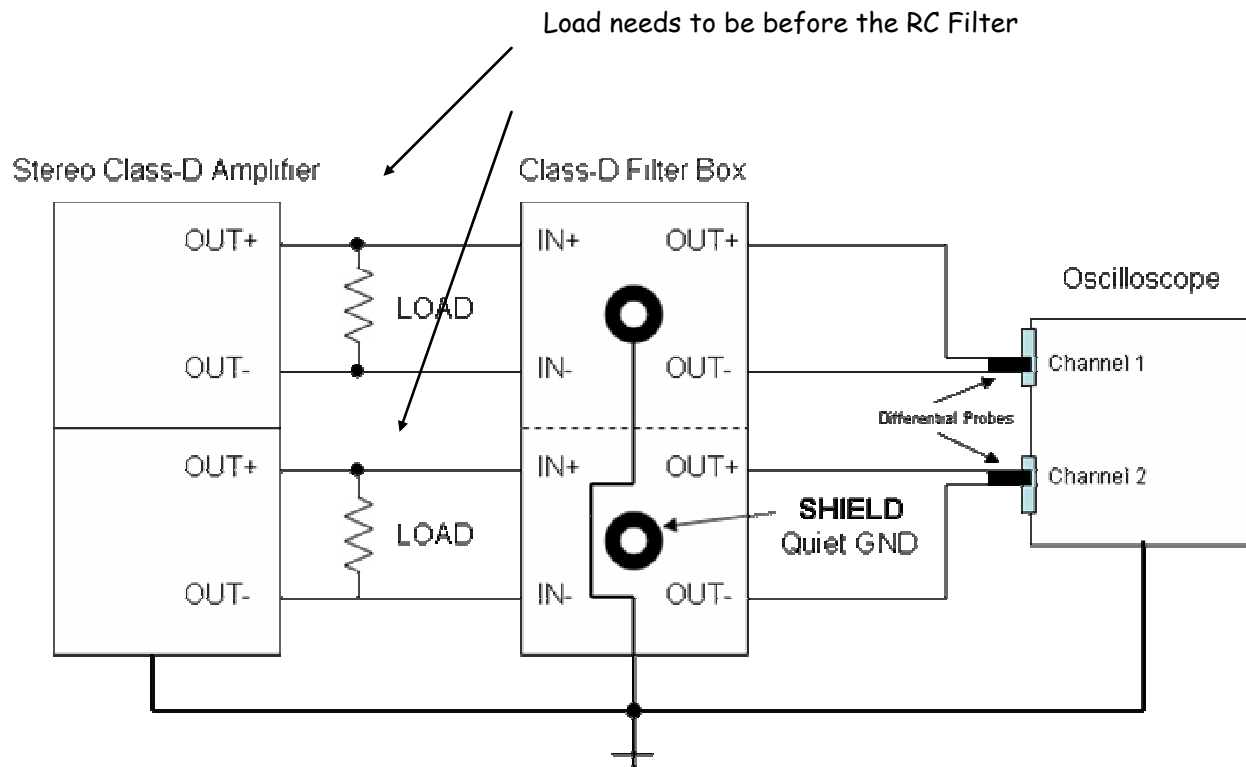




# Class-D Amplifier Output Power Measurement With RC Filter Box

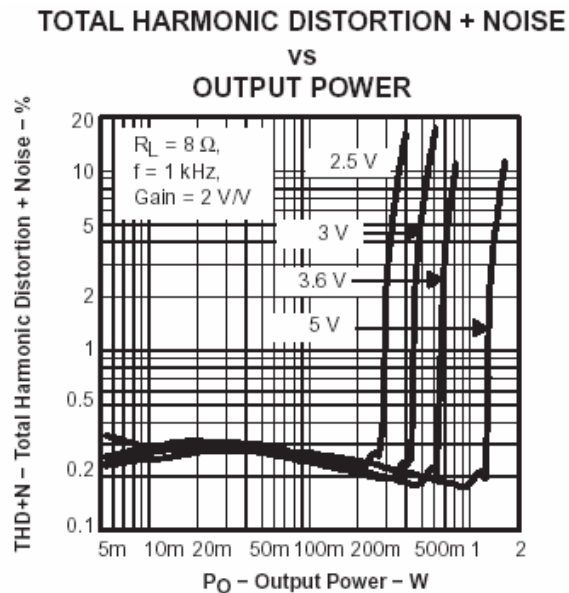


The output waveform on the oscilloscope reflects the audio signal and the output power can be determined through the Peak/RMS Output Voltage and the load impedance using

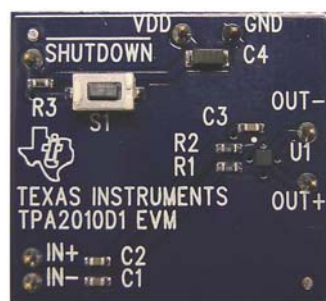
$$P = V^2 / R$$



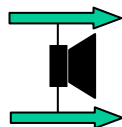
# Class-D Amplifier THD+N Measurement With RC Filter Box - Results @ 1 kHz



Audio  
Precision



TPA2010D1 EVM  
(2 V/V or 6 dB Gain)



RC Filter Box

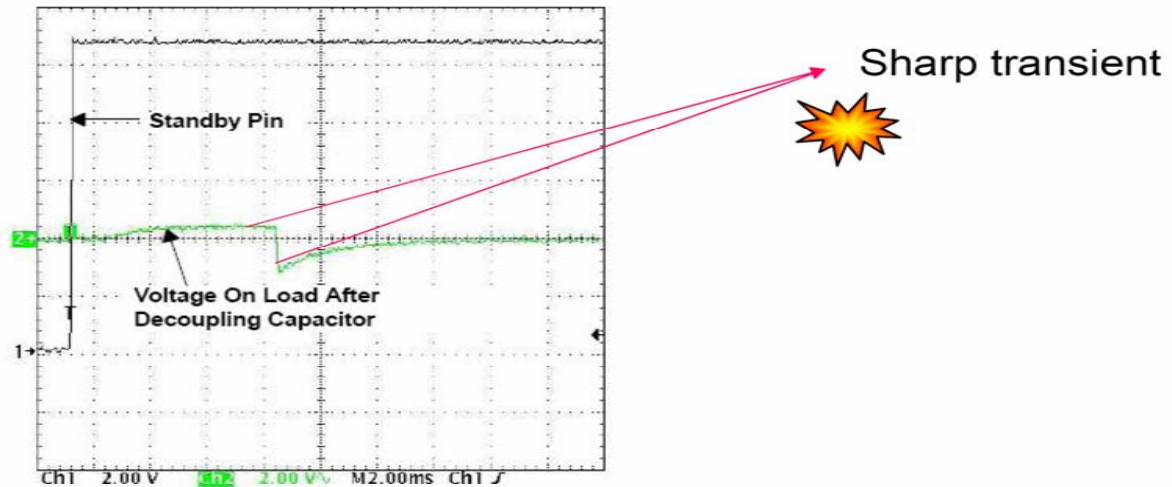
Audio  
Precision

Load is assumed to be  $8\ \Omega$



# How to handle Pop noise

the following figure is the scope capture of what the pop-noise looks like

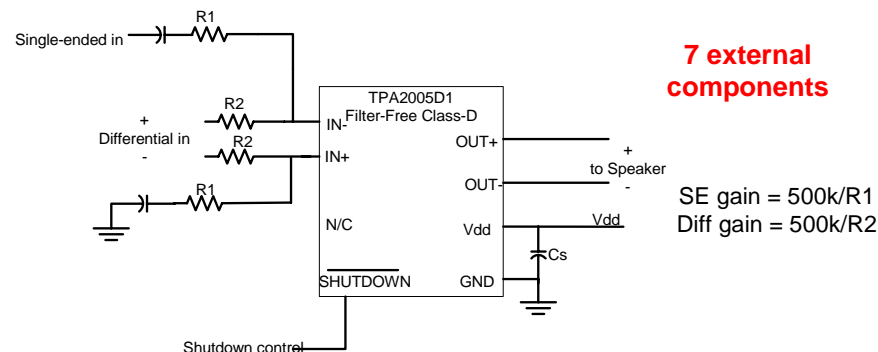
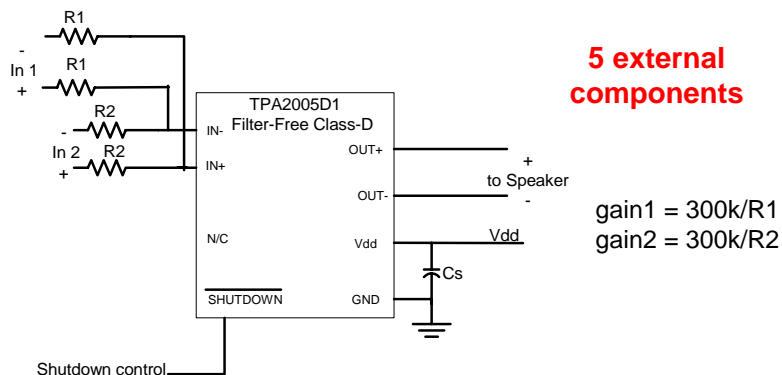


This sharp transient signal is amplified then can be heard.

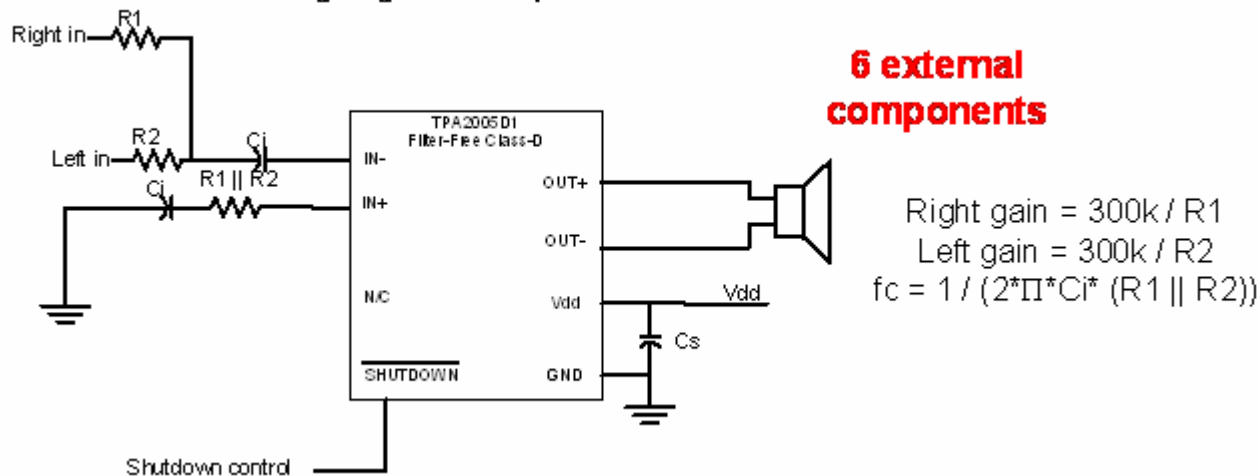
About this situation, sometimes we can try to handle the pop-noise Using the follow ways.

- a: improve the input source signal level as could as possible, then properly reduces the gain of the TPA's amp.  
we can obtain two benefits of better SNR and minimized pop-noise occurred by input DC bias voltage.
- b: add external components to offer a proper DC bias circuitry.

# Full difference AMP update to other application



## Summing single-ended inputs with the TPA2005D1





---

# Digital Audio Interface



# Audio Digital Interface

- ◆ PCM（脉冲编码调制）接口：所有数字信号进行传输都要经过PCM，并且需要仔细参照用于数字电话的单声道机制。PCM接口由时钟脉冲（BCLK）、帧同步信号（FS）及数据队列组成，每个PCM对应一个将要接收或将要发送的数据。在FS信号的上升沿，数据传输从MSB（Most Significant Bit）字开始，FS频率等于采样率。FS信号之后开始数据字的传输，单个的数据位按顺序进行传输，1个时钟周期传输1个数据字。发送MSB时，信号的等级首先降到最低，以避免在不同终端的接口使用不同的数据方案时造成MSB的丢失。
- ◆ I2S接口（Inter-IC Sound）被飞利浦用于消费音频，并在一个称为LRCLK（Left/Right CLOCK）的信号机制中经过多路转换，将两路音频信号成单一的数据队列。当LRCLK为高时，左声道数据被传输；LRCLK为低时，右声道数据被传输。与PCM相比，I2S更适合于立体声系统。对于多通道系统，在同样的BCLK和LRCLK条件下，并行执行几个数据队列也是可能的。
- ◆ AC '97/AC-Link接口：AC '97（音频编码1997）是Intel公司为计算机音频而指定的。他不只是一种数据格式，用于音频编码的内部架构规格，它还具有控制功能。众所周知的AC-Link接口包括位时钟（BITCLK）、同步信号校正（SYNC）和从编码到处理器及从处理器中解码（SDATDIN与SDATAOUT）的数据队列



# Audio Digital Interface Comparison

---

Audio Interface	I <sup>2</sup> S (Consumer/Pro Audio)	AC Link (Computing)	PCM (Telecom)
Sample Rate	192kHz to 2kHz 96k, 48k, 44.1k, 16k, 8k, 2k	Fixed 48kHz	Any rate
I/O	SCK, WS, SDOUT	SYNC, BITCLK SDIN, SDOUT, /RESET	Same as I <sup>2</sup> S
Command write & Status read	Via other interfaces like I <sup>2</sup> C, SPI	AC Link	Same as I <sup>2</sup> S
Power Consumption	Low	Higher	Low



# Audio Digital Interface

## Advantages/Disadvantages

---

- ◆ I<sup>2</sup>S (Originated from High-end Audio market)
  - Advantages
    - ◆ Low Power
    - ◆ Internal PLL allowing flexible clocking scheme
    - ◆ High Quality Audio performance in terms of THD and SNR
  - Disadvantages
    - ◆ Requires two buses i.e. I<sup>2</sup>S for Audio signals and I<sup>2</sup>C for control signals
  
- ◆ AC'97 (Originated from PC market)
  - Advantages
    - ◆ Only uses one bus for audio signals and control signals
    - ◆ Very familiar among design community
  - Disadvantages
    - ◆ Requires S/W drivers
    - ◆ High power consumption (limited power-down mode-bus must be running)
    - ◆ Need 12.288MHz Reference Clock that is not standard in many consumer audio applications
  
- ◆ PCM (Originated from Telephone market)
  - Advantages
    - ◆ Offer H/W Audio compression i.e. A-Law and u-Law
    - ◆ Multi-channel Data capability
  - Disadvantages
    - ◆ Lower audio quality (e.g. used for voiceband)





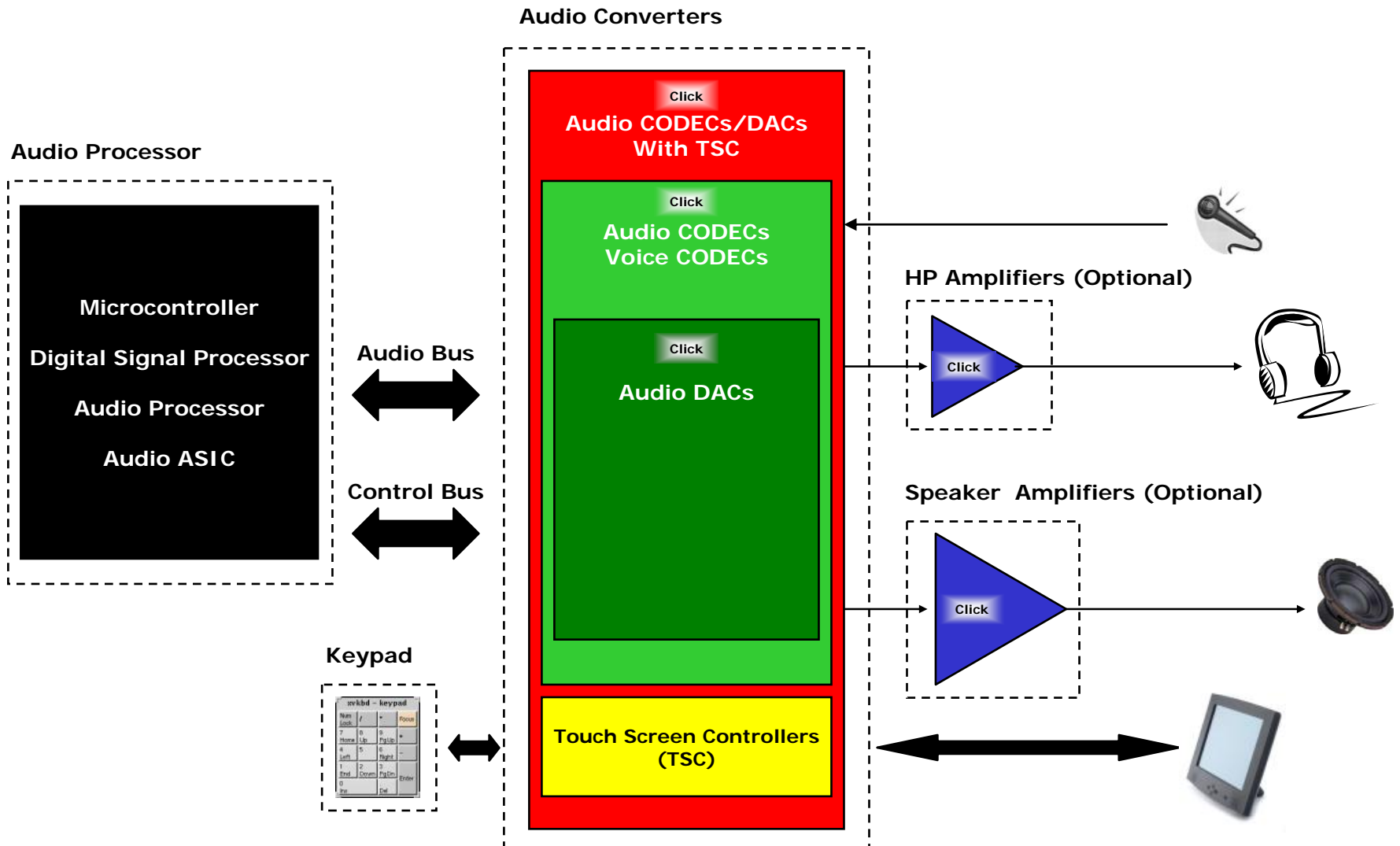
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# Portable Audio Products

The Portable Audio Chain

August 2005

# The Portable Audio Chain





# Audio for Wireless 2006 Roadmap

## Audio Converters CODECs

### Class-AB Integrated Speaker Drivers

TLV320AIC23 - Stereo CODEC  
TLV320AIC26 -> Mono ADC/Stereo DAC  
TLV320AIC28 -> Mono ADC/Stereo DAC  
**TLV320AIC29 -> Mono ADC/Stereo DAC with diff. input**  
TLV320AIC3x -> Music Phones

### + Integrated Touch Screen Controller (TSC)

TSC21xx -> PDA Phones with music  
**TSC2111 -> Diff. input version on TSC2101**  
TSC23xx -> PDA Phones with music (No Speaker Driver)

### Class-D Integrated Speaker Drivers

PCM3792/A -> Stereo Class-D  
**PCM3793 -> Audio Effects / Stereo Class-D**  
**PCM3974 -> Audio Effects (No Speaker Drivers)**

## Audio Converters DACs

### Class-AB Integrated Speaker Drivers

TLV320DAC23 -> DAC version of AIC23  
TLV320DAC26 -> DAC version of AIC26  
**TLV320DAC32 -> DAC only version of AIC3x**  
**TLV320DAC33 -> Higher Performance Burst Mode DAC**

### Class-D Integrated Speaker Drivers

**PCM1775 -> Mono Speaker Driver**  
**PCM1776 -> Stereo Speaker Driver**



## Audio Power Amplifiers Speakers

### Class-AB

TPA6201A1 -> Low-cost (Not public)  
TPA6203A1 -> Mid-end  
TPA6204A1 -> High-power

### Class-D

TPA2005D1 -> Low-cost  
TPA2010D1 -> Mid/High-end  
**TPA203xD1 -> Smallest Solution**  
TPA2012D2 -> Stereo Class-D  
**TPA2013D1 -> Boosted Class-D**

## Audio Power Amplifiers Headphone

### Class-AB

TPA611xA2 -> Low-cost

### Cap-Free

TPA4411 -> Music Phones  
**TPA6130A2 -> Lower Power / Higher Integration**



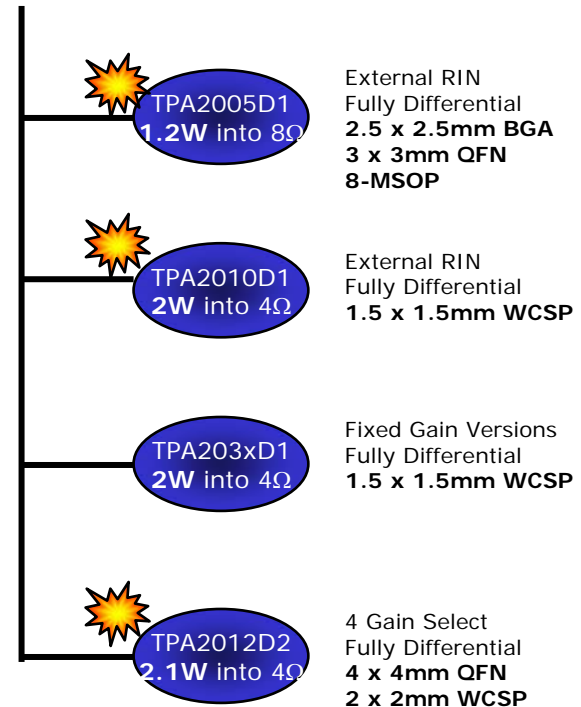
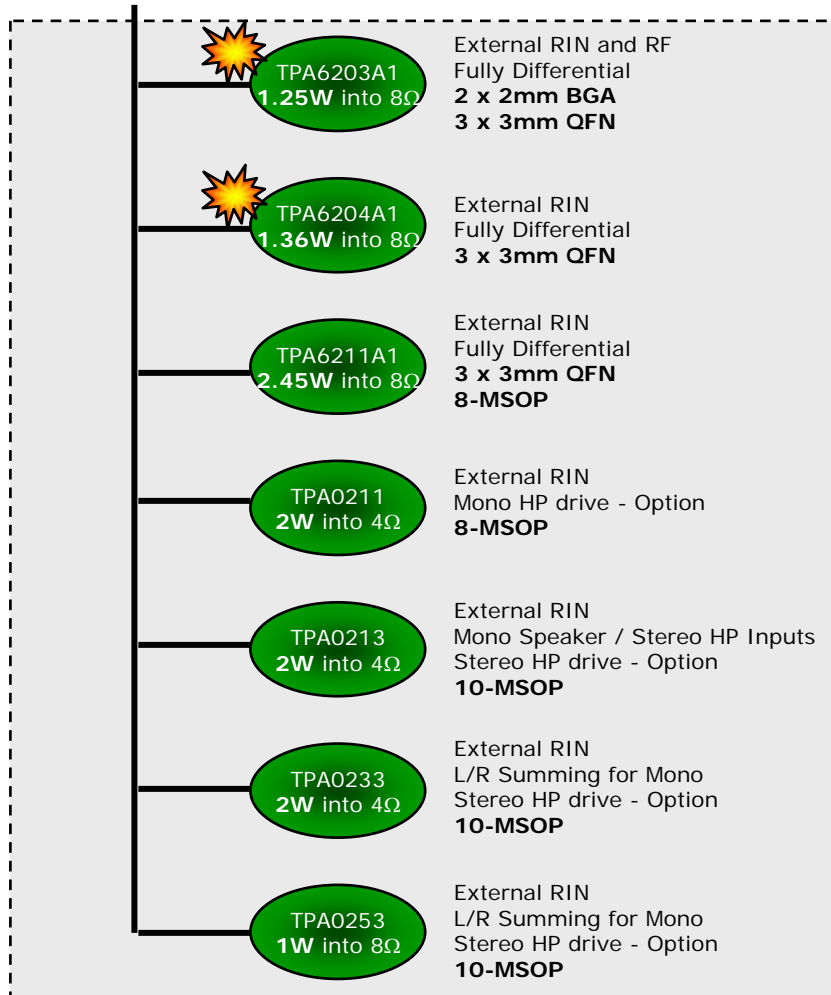
# Portable Audio Products

2.5-5.5V

Supply Voltage

 Hero Product

2.5 – 5.5V



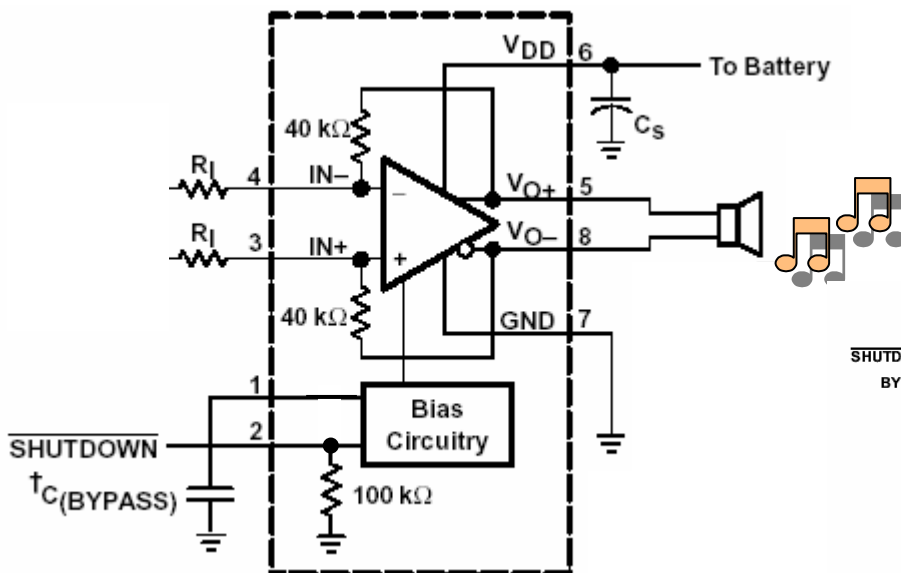
Power Ratings @ 5V (1% THD)

# TPA6201A1

## 1W into 8Ω at 5V Mono Class-AB Amplifier

**ONLY 3  
external  
components!**

1.8V Low-Voltage Logic  
VIH and VIL Levels  
Integrated  
100KΩ Pull-down Resistor

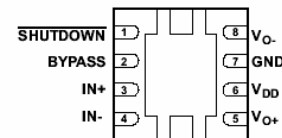


\*\*\* QFN Package pin-to-pin compatible with TPA2005D1

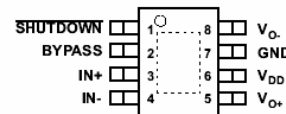
### Packaging

- MSOP-8
- 3x3mm QFN (DRB) [Pb-Free]
- CSP

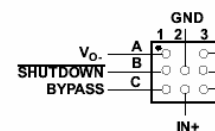
8-Pin QFN (DRB) Package  
(Top View)



8-Pin MSOP (DGN) Package  
(Top View)



MicroStar Junior™ (GQV or ZQV) Package  
(Top View)



### Features

- 500mW into 8Ω at 3.6V (1% THD)
- Supply Voltage: 2.5 to 5.5 V operation ~ PSRR ~ 86dB
- Small package options
- Fully differential amplifier
- No input coupling caps
- <1ms start-up time with pop reduction

### Benefits

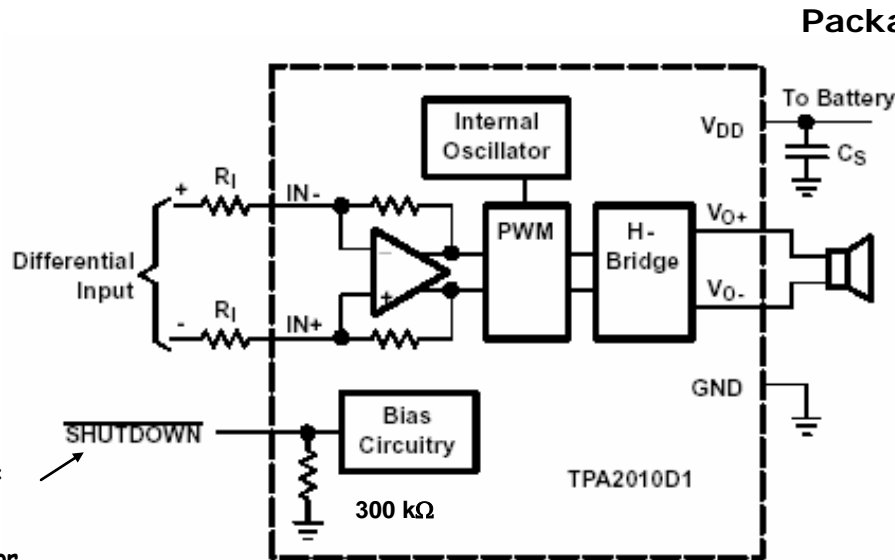
- High power solution for hands-free mode
- Operates directly from battery
- Saves board space
- Eliminates common-mode noise
- Reduces external component count
- Instant start-up for PDA

**ONLY 3  
external  
components!**

# TPA2010D1

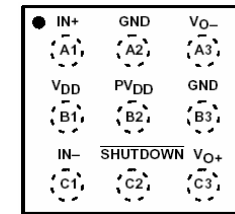
## 2.08W into 4Ω at 5V Mono Class-D Amplifier

1.8V Low-Voltage Logic  
VIH and VIL Levels  
Integrated  
300KΩ Pull-down Resistor



### Packaging

- 1.5x1.5mm WCSP (YEF) [Pb]
- 1.5x1.5mm WCSP (YZF) [Pb-Free]



**WCSP**  
(Top view of PCB)

### Features

- Class-D architecture
- Filter-Free modulation scheme
- **1.06mW into 4Ω at 3.6V (1% THD)**
- Supply Voltage: 2.5 to 5.5 V & ~75dB PSRR
- Smallest available packaging option
- No input coupling caps
- Fully differential amplifier

### Benefits

- Longer battery life compared to class-AB
- No LC Filter required
- Powers hands-free mode
- Direct-Connect to battery
  - ◆ More power
  - ◆ Even higher efficiency
- Saves board space
- Reduces RF rectification

Portable Audio

**ONLY 1 external component!**

# TPA2012D2

## 1.18W into 4Ω at 5V Stereo Class-D Amplifier (QFN)

### Packaging



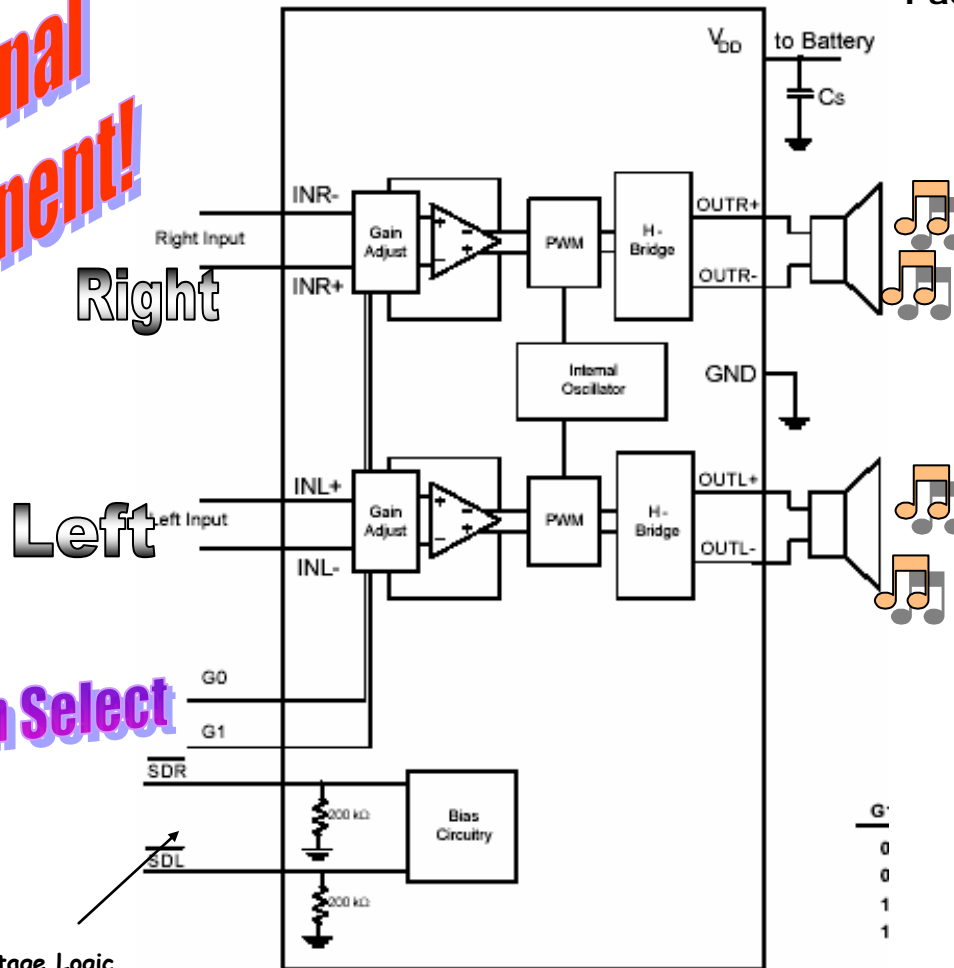
- 2.0mm x 2.0mm WCSP (YZH) [Pb-Free]
- 4mm x 4mm QFN RTJ [Pb-Free]

### Features

Class-D architecture  
 Filter-Free modulation scheme  
**600mW into 8W at 3.6V (1% THD)**  
 Supply Voltage: 2.5 to 5.5 V & ~75dB

### Benefit:

Saves board space  
 Only 1 external component  
 Reduces RF rectification



1.8V Low-Voltage Logic  
 VIH and VIL Levels  
 Integrated  
 200KΩ Pull-down Resistor

### Gain Select

G1	G0	Gain	
		V/V	dB
0	0	2	6
0	1	4	12
1	0	8	18
1	1	16	24

G  
 0  
 0  
 1  
 1

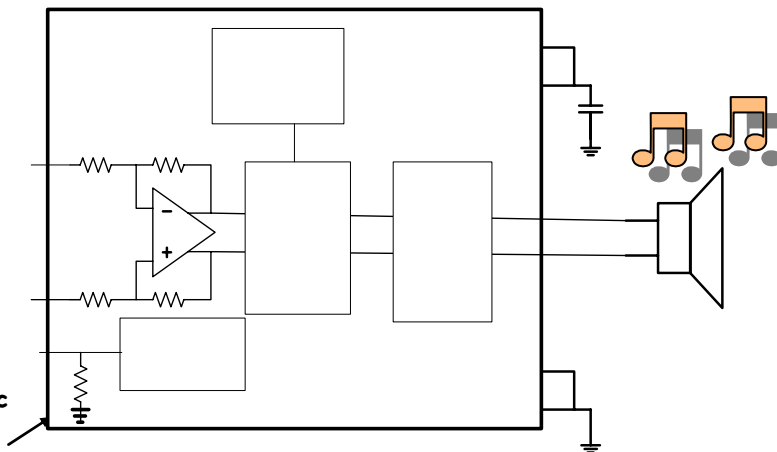


# 3 Fixed Gain (2, 3, & 4V/V) Mono Class-D 2.5W into 4Ω at 5V (10% THD) Mono Class-D Amplifier



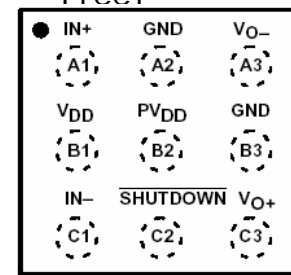
**ONLY 1  
external  
component!**

1.8V Low-Voltage Logic  
VIH and VIL Levels  
Integrated  
300KΩ Pull-down Resistor



## Packaging

- ~1.5x1.5mm  
WCSP (YZF) [Pb-Free]



WCSP  
(Top view of PCB)

## Features

- Fixed Gain of: 2V/V, 3V/V, or 4V/V
- Fully differential, Class-D architecture
- Only 1 external component required
  - No input coupling caps required
  - Filter-Free modulation scheme
- 1.0 W into 4Ω at 3.6V
- Supply Voltage: 2.5 to 5.5 V
- ~87dB PSRR
- ~75dB Ksvr at 217Hz
- Very low noise floor (26uV)
- Audio POP reduction circuitry

## Benefits

- Almost a drop in replacement for TPA2010D1
  - Eliminates external gain setting resistors
- Longer battery life compared to class-AB
- Reduces RF Input
- No LC Filter required
- Direct-Connect to battery
  - More power
  - Higher efficiency
- Saves board space
- Reduces external components



# Fixed Gain Class-D Audio Power Amplifier

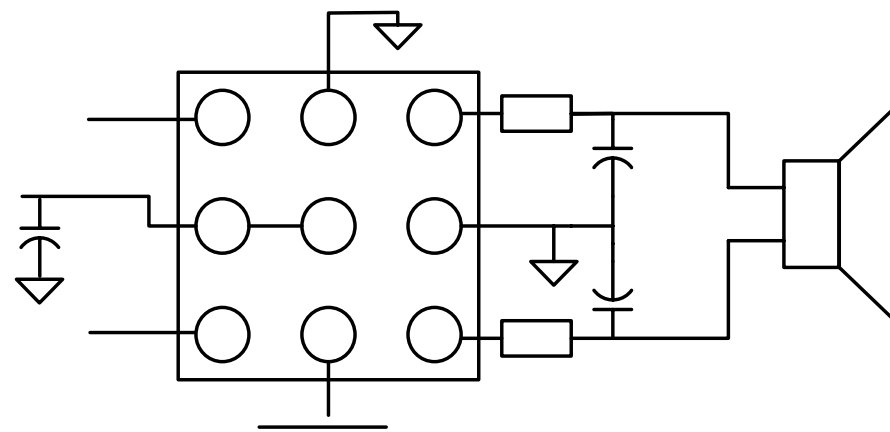
## TPA2032D1, TPA2033D1, TPA2034D1

### Features

- Multiple Gain Versions: 2, 3, or 4V/V
- Integrated Matched Input Resistors
  - Only 1 external component
  - Lower BOM cost
  - Smaller PCB area
- PSRR =  $\sim -87\text{dB}$
- CMRR =  $\sim -73\text{dB}$  (est.)
- Lower input impedance results in less noise coupling to inputs
- Lower Noise Floor: 26 $\mu\text{V}_{\text{rms}}$  un-weighted
- Lower EMI circuitry

### Features

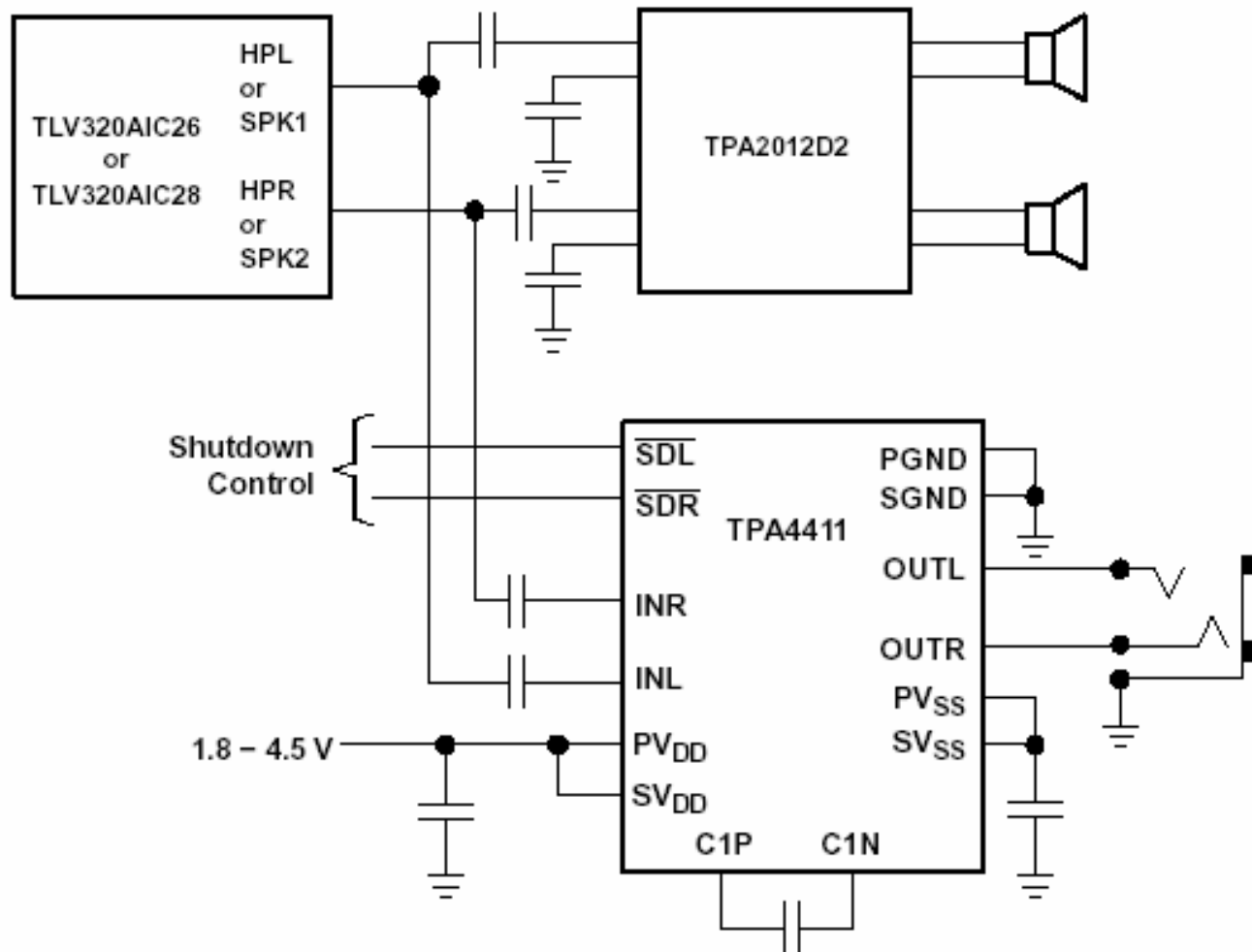
- Ease of design in, extremely close match to TPA2010D1 pinout with better performance
- Audio Pop reduction circuitry
- Very small WCSP Packaging
  - $\sim 1.5\text{mm} \times \sim 1.5\text{mm} \times 0.6\text{mm}$
  - Same package as TPA2010D1





# TPA2012D2

## Portable Audio Reference Solution





# Competitor Analysis

Features	TPA2010D1	TS4962M	LM4671	NCP2820	TPA2032D2	NCP2821
PSRR	75dB	63dB	61dB	62dB	75dB	63dB
CMRR	68dB	57dB	68dB	57dB	69dB	59dB
Vos(mV)	1mV	3mV	5mV	6mV	5mV	6mV
SNR(dB)	97dB	85dB	93dB	-	97dB	-
Pout(THD + N= 1%, f= 1 kHz,RL = 8 Ω)	1.19W(5v)	0.95(4.2v)		1.3W	1.1W	1.3W
	<a href="#">0.59W@3.6V</a>		0.6W	0.7W	0.6W	0.7W
I stdby	4.9mA(max)	3~25mA	6.2mA	2mA	3mA	3mA
Wake up time	1mS	5~10mS	17uS	8mS	3mS	9mS
Vn	36uV	62uV	58uV	65	32uV	63uV
THD+N	0.11%	1%	0.12%	0.10%	0.11%	0.09%



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# Portable Audio Products

## Headphone Amplifiers

August 2005



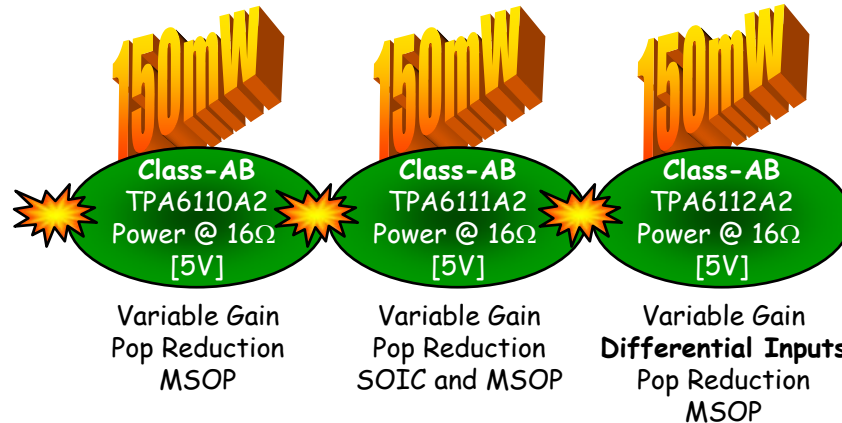
# Stereo Headphone Amplifiers

## Hero Products



Released

### TPA611xA2 Family (2.5 - 5.5V)

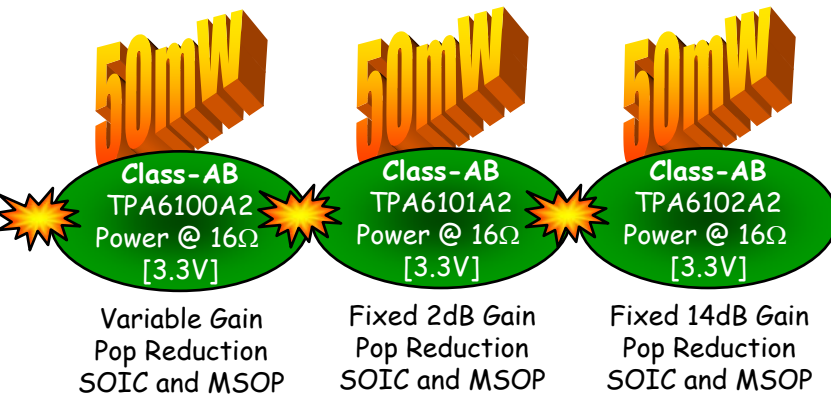


### CapFree HP Amplifier



1.8-4.5V Supply  
Fixed 1.5V/V Gain  
**CapFree** HP Driver  
Pop Reduction  
QFN and **WCSP**

### TPA610xA2 Family (1.6 - 3.6V)



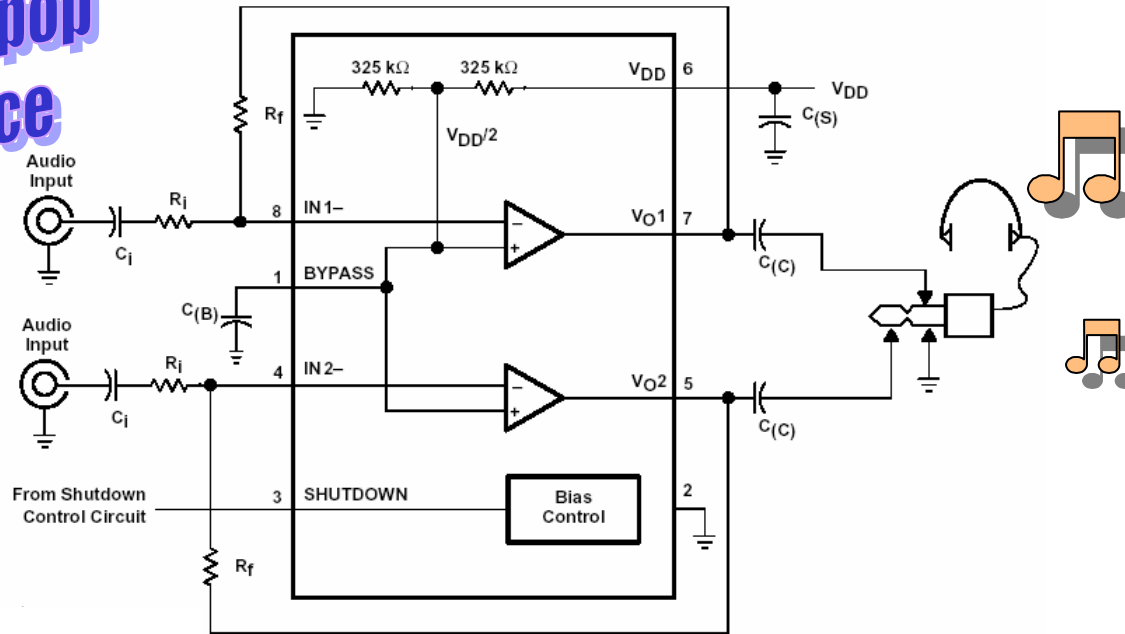


# TPA61xxA2

50mW – 150mW into 16Ω Headphone Drivers



**Excellent Depop  
Performance**



**150mW  
or  
50mW**

## Features

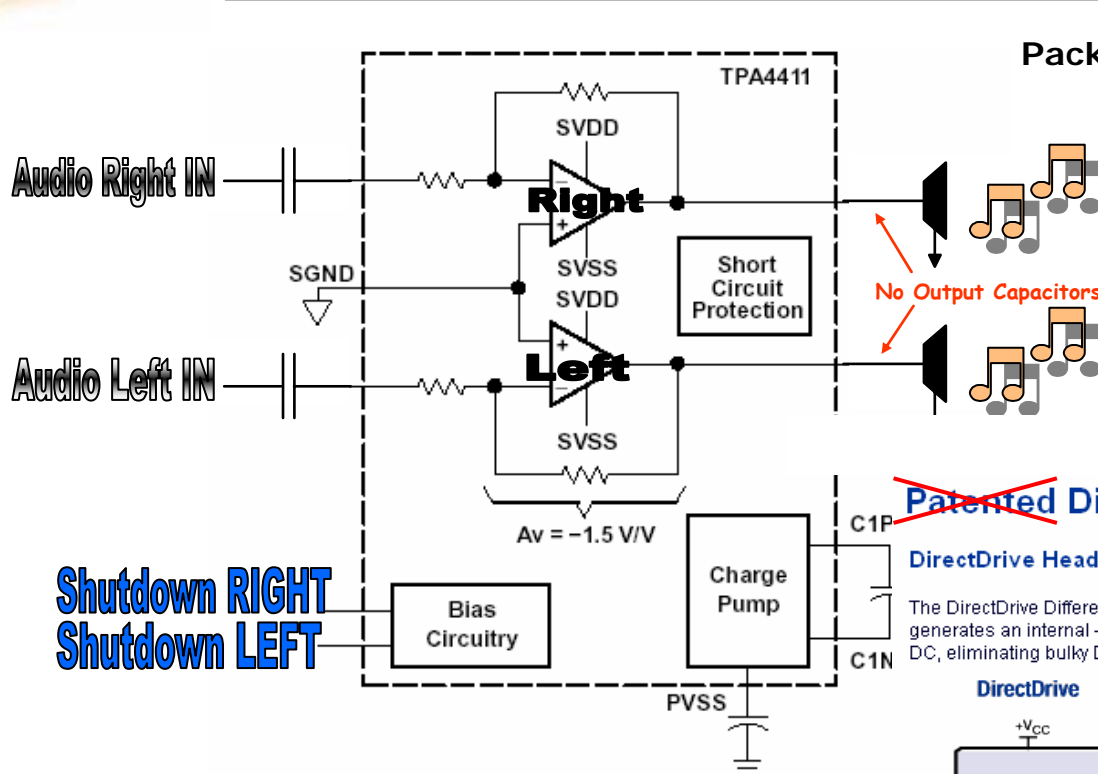
- Low Supply Voltage Option
- 50-mW Stereo Output Power ( $V_{CC}$  1.6-3.6V)
  - ◆ TPA6100A2 = External gain (P/C LM4881)
  - ◆ TPA6101A2 = -1.25 V/V (P/C LM4880, LM4881)
  - ◆ TPA6102A2 = -5 V/V
- 150-mW Stereo Output Power ( $V_{CC}$  2.5-5.5V)
  - ◆ TPA6110A2 = External gain (P/C LM4881)
  - ◆ TPA6111A2 = External gain (P/C LM4880, LM4881)
  - ◆ TPA6112A2 = External gain (*Differential Inputs*)

## Benefits

- Operates from processor power supply
- Powerful output drive with minimum external component count for any headphone application
- Higher power output drive for any headphone application

## TPA4411

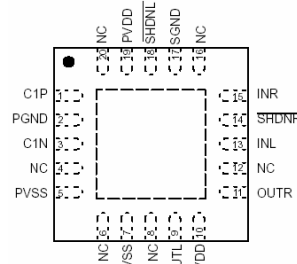
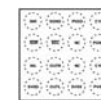
## 40mW into 16Ω at 3V Cap-Free Stereo Headphone Drive



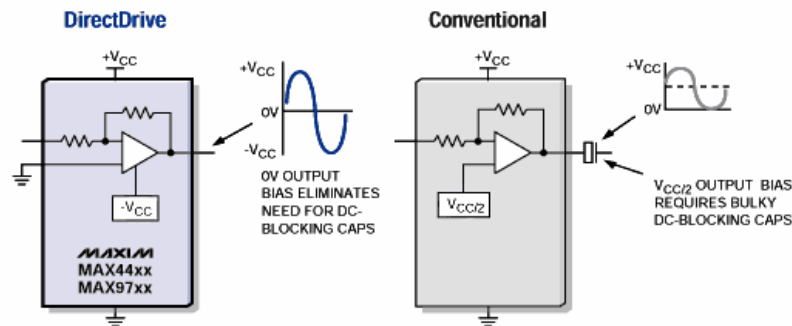
## Packaging



- 2.0mm x 2.0mm WCSP (YZH) [Pb-Free]
- 4mm x 4mm QFN RTJ [Pb-Free]

~~Patented DirectDrive Headphone Amplifiers~~~~DirectDrive Headphone Amplifiers: A Maxim Exclusive!~~

The DirectDrive Difference: Conventional headphone amplifiers bias the output signal at  $V_{CC}/2$ . DirectDrive generates an internal  $-V_{CC}$  from the positive supply. This allows the audio output signal to be biased at 0V DC, eliminating bulky DC-blocking capacitors!



## Features

- 80mW per channel into 16Ω at 4.5V (Max Power)
- Supply Voltage: 1.8 to 4.5V
- No DC output block capacitors
- High PSRR ~ 80dB
- Channel Shutdown option <1uA
- Smallest available packaging option
- Can run directly off the battery
- Reduce current consumption in stand-by
- Reduce board space requirements



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# Portable Audio Products

Low-Power Audio / Voice / USB CODECs

August 2005





# TLV320AIC31

## 16/20/24/32-bit Low-Power Stereo Audio Codec

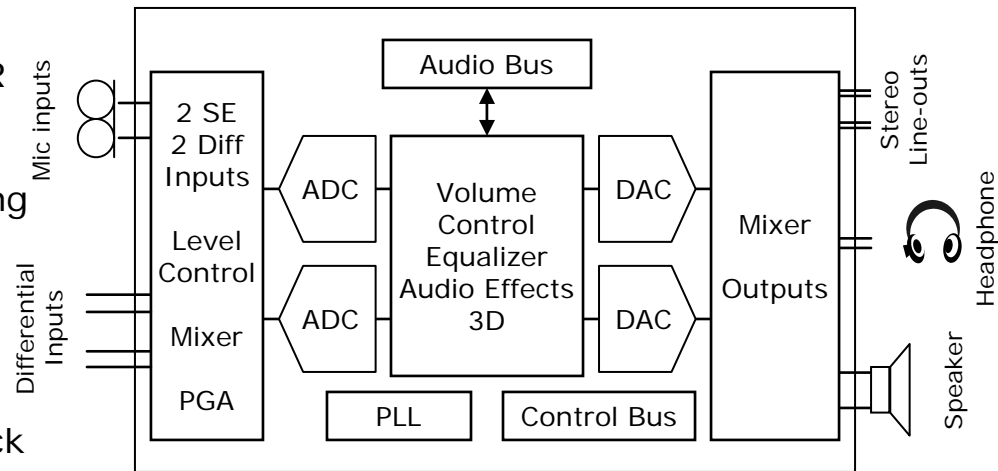


### Key Features

- ◆ Stereo 8-96ksps audio DAC with 100dB SNR  
Stereo 8-96ksps audio ADC with 92dB SNR  
Single End
- ◆ 2 SE & 2 Differential audio inputs with mixing and level control
- ◆ Microphone input with bias, preamp and AGC
- ◆ **Integrated PLL** provides flexible audio clock generation (512KHz to 50MHz input clock)
- ◆ Programmable digital audio  
Bass/Treble/EQ/De-emphasis/**3-D**
- ◆ I<sup>2</sup>C Control and I<sup>2</sup>S/TDM Audio Interfaces
- ◆ **400mW into 8-ohms** stereo speaker driver  
**40mW into 16-ohm** stereo headphones with cap-less output option

### Key Differentiators

- \* **Low-Power:** 14mW stereo 48ksps playback
- \* **Small package:** 5 x 5mm 32-QFN (RHB)



**Power Supply Voltages**  
Analog: 2.7 – 3.6V  
Digital Core: 1.525 – 1.95V  
Digital I/O: 1.1 – 3.6V

**For additional features  
see TLV320AIC33**

### Applications

- Cell phones
- Audio for digital cameras
- Low-Power, portable voice/audio products
- Voice applications with MP3 playback

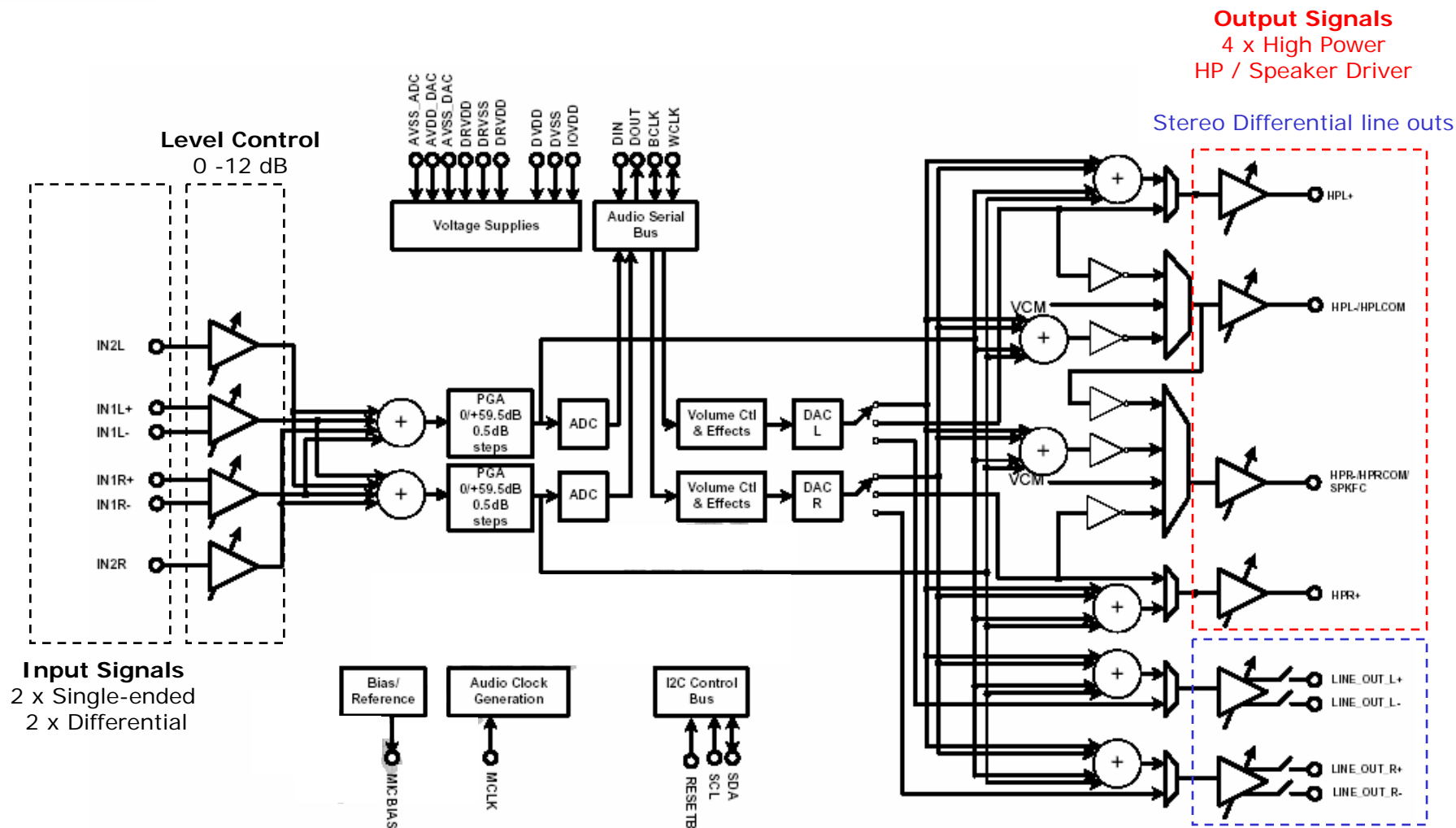
Pin and Software Compatible to TLV320AIC32

REAL WORLD SIGNAL PROCESSING™

 **TEXAS INSTRUMENTS**

# TLV320AIC31

## Block Diagram





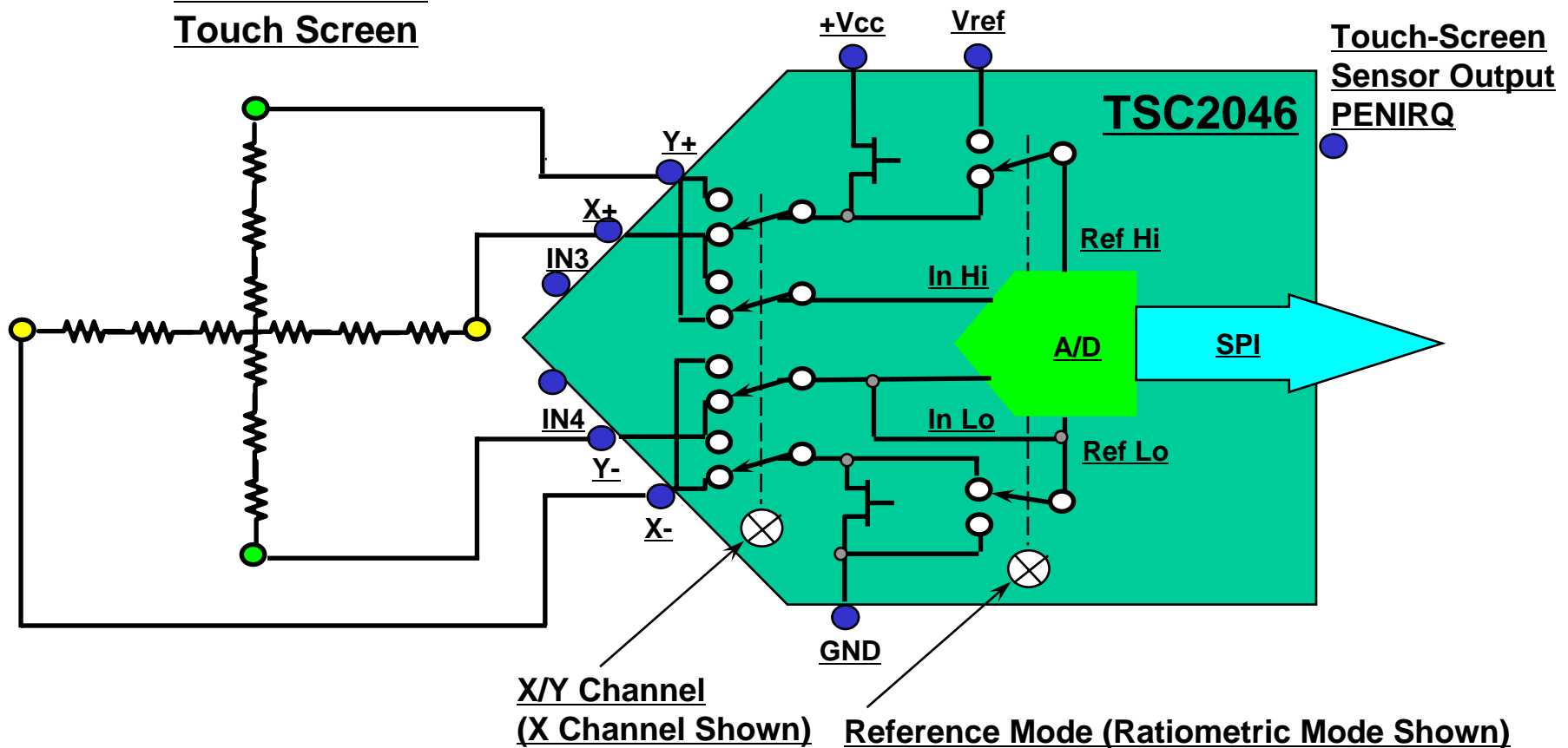
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# Touch Screen



# TSC2046 Functional Block Diagram

LCD Panel  
With Resistive  
Touch Screen





# Simple TSC – Features & Selection Guide

## Features & Advantages

- ◆ Low power consumption increases battery life
- ◆ Differential mode is able to handle touch panel with long settling time without extending acquisition time of ADC
- ◆ Touch screen operation is software-compatible
- ◆ We provide software drivers for touchscreen for selected processors and operating systems

Simple TSC	Res. (bit)	Sample Rate (KSPS)	Touch Panel (wire)	I/F	Aux IN (CH)	TEMP Sensor (CH)	Battery Monitor (CH)	EVM
<a href="#">ADS7843</a>	8/12	Up to 125	4	SPI	2			
<a href="#">ADS7845</a>	8/12	Up to 125	5	SPI	1			
<a href="#">ADS7846</a>	8/12	Up to 125	4	SPI	1	1	1	V
<a href="#">TSC2003</a>	8/12	Up to 125	4	I2C	2	2	2	
<a href="#">TSC2046</a>	8/12	Up to 125	4	SPI	1	1	1	V

# Success Story

## Fujitsu

TPA2005D1

\$200k LNR

Fujitsu W-CDMA Phone

*Won due to better performance compared to LM4666*



## Motorola

TPA2010D1

\$1M LNR

E1000/A1000 UMTS Phone

*Won due to Class-D efficiency and better spec than National LM4667*



E1000 UMTS Phone

## PalmOne ACE/650

TPA6203A1

\$300k LNR

PalmOne GSM/CDMA Phone



Silver

Carbon

screens simulated

Excellent support through TI US (PalmOne) /  
TI Taiwan (HTC) resulting in TI kicking out LM4894!

## Haier

TPA2005D1

About \$100k LNR

V7000/V20 GSM Camera Phone

*Won due to Class-D efficiency*





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**Thank You For Your Time!**