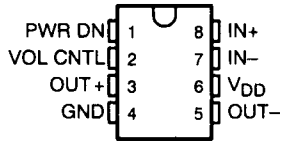
D3986, MARCH 1992–REVISED SEPTEMBER 1992

- **Drives 8-Ω Speaker With 5-V Supply at 1/2-W Peak**
- **Has Automatic Power Down/Power Up Sensed From Inputs**
- **Requires Minimal External Components**
- **Uses Single Pin Volume Control**
- **Has a Three-Pole, Low-Pass Switch-Capacitor Filter Equivalent to a Four-Pole Butterworth Response**
- **Has Low Standby-Mode Current**
- **Has Differential Inputs and Outputs**
- **Gain of the TLC2470I and TLC2471I is Optimized for General-Purpose Audio Applications**
- **Gain of the TLC2472I and TLC2473I is Optimized for Texas Instruments Speech Synthesizers and Other PWM Audio Sources**

P PACKAGE
(TOP VIEW)



description

The TLC2470I, TLC2471I, TLC2472I, and TLC2473I are audio amplifiers with low-pass filtering that directly drive a speaker. The TLC247x consists of an input stage that accepts four different types of input signals, a 50-kHz continuous-time anti-alias low-pass filter, a switched capacitor low-pass filter, and a differential power amplifier. The device also contains automatic power-down and power-up circuitry to reduce power consumption (I_{DD} less than 100 μA typical) when not in use, and a volume control for pulse-width modulated (PWM) input signals. The TLC247x operates from a single 4-V to 6.5-V power supply. The power amplifier differentially produces ±2 V across the speaker. The maximum output power will decrease at a supply voltage of 4 V.

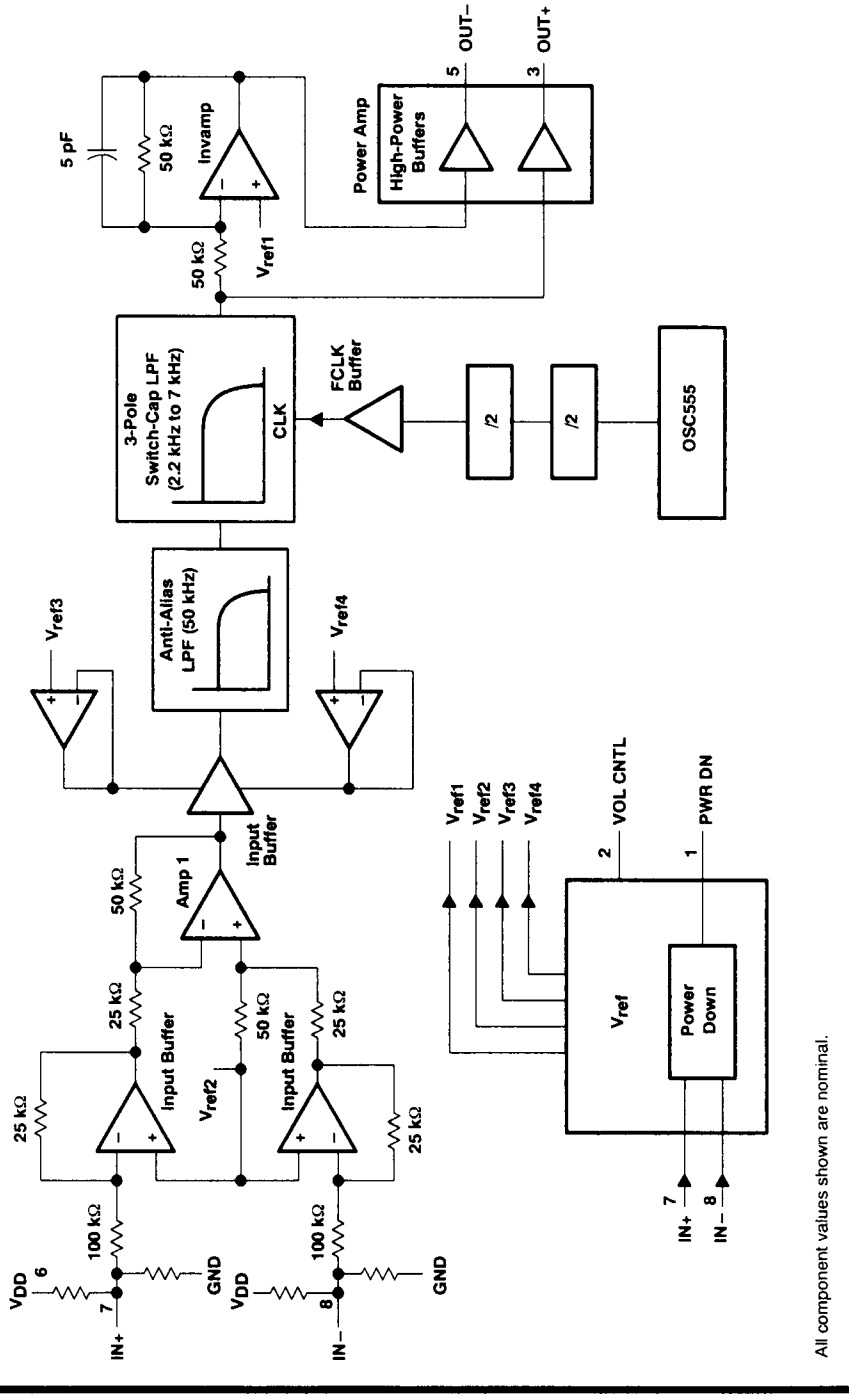
The TLC247x is capable of supplying a peak power of 0.5 W typical into an 8-Ω speaker with the TLC2470I and TLC2472I having a corner frequency of 5 kHz and the TLC2471I and TLC2473I having a corner frequency of 3.5 kHz. It is connected directly to a speaker without the need for any additional components. A 3-μF capacitor is needed to use the optional automatic power-down feature. A volume control for PWM signals can be implemented by using a 1-MΩ potentiometer and a 500-kΩ resistor.

CIRCUIT OPTIONS

CIRCUIT	CORNER FREQUENCY
TLC2470I, TLC2472I	5 kHz
TLC2471I, TLC2473I	3.5 kHz

Caution. These devices have limited built-in gate protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

functional block diagram



All component values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{DD} . . . . . 6.5 V
Differential input voltage (PWM modes), $|V_{IN+} - V_{IN-}|$ . . . . . V_{DD}
Input current, I_I (each input) . . . . . 200 μA
Output current, I_O (differential configuration) . . . . . 175 mA
Supply current, I_{DD} . . . . . 300 mA
Duration of short-circuit current at (or below) 25°C . . . . . 10 ms
Continuous total dissipation . . . . . See Dissipation Rating Table
Operating free-air temperature range, T_A . . . . . −40°C to 85°C
Storage temperature range . . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . . 260°C

DISSIPATION RATING TABLE

PACKAGE	T_A = 25°C POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING
P	1000 mW	8.0 mW/°C	640 mW	520 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V_{DD}	4	6.5	V
Input voltage, V_I	−0.3	V_{DD} +0.3	V
Operating free-air temperature, T_A	−40	85	°C

electrical characteristics, V_{DD} = 5 V, PWR DN = 0 V, VOL CNTL = (2/3) V_{DD}, T_A = 25°C (unless otherwise specified)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OM}	Maximum differential peak output voltage swing (see Note 1)	V_{DD} ≤ 6.5 V,	R_L = 8 Ω		2.1	2.2	V
V_{OM+}	Maximum single-ended positive peak output voltage swing	R_L = 8 Ω			3.6		V
V_{OM-}	Maximum single-ended negative peak output voltage swing				1.4		
A_{VD}	Large-signal differential voltage amplification	Single ended, Output differential	TLC2470I, TLC2471I		2		V/V
			TLC2472I, TLC2473I		1		
I_{DD}	Supply current	V_{DD} = 4 V, Inputs open	No load,		10	15	mA
		V_{DD} = 6.5 V, Inputs open	No load,		13	20	mA
		Power down			50	100	μA
		V_{DD} = 6.5 V,	Power down		50	120	μA
		V_{DD} = 6.5 V, Inputs open	R_L = 8 Ω,		30	50	mA
	Output offset voltage	V_{DD} = 4 V to 6.5 V, Inputs open or both inputs = V_{DD}	R_L = 8 Ω,	−300		300	mV
	Corner frequency	Gain = −3 dB	TLC2470I, TLC2472I		5		kHz
			TLC2471I, TLC2473I		3.5		

NOTE 1: At V_{DD} > 5 V, limit the maximum differential output voltage to 2.2 V max by reducing the PWM volume via the volume control pin or by reducing the amplitude of the analog input to prevent excessive power dissipation.

electrical characteristics, V_{DD} = 5 V, PWR DN = 0 V, VOL CNTL = (2/3) V_{DD}, T_A = 25°C (unless otherwise specified) (continued)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Peak differential output power		V_{DD} = 4 V, $\lvert V_{IN+} - V_{IN-} \rvert$ = 4 V	R_L = 8 Ω,	112	200		mW
		$\lvert V_{IN+} - V_{IN-} \rvert$ = 5 V,	R_L = 8 Ω	320	500		mW
		$\lvert V_{IN+} - V_{IN-} \rvert$ = 5 V, VOL CNTL = 0 V	R_L = 8 Ω,		0.05	8	mW
Volume control current		V_{DD} = 6.5 V, IN – open, VOL CNTL = 0 V	R_L = 8 Ω, IN + open,			3	μA
Input current, V_I	IN+	V_{DD} = 6.5 V, No load	V_{IN+} = 0	–60	–50		μA
			V_{IN+} = 3.25 V	–10		10	
			V_{IN+} = 6.5 V		50	60	
	IN–		V_{IN-} = 0	–60	–50		
			V_{IN-} = 3.25 V	–10		10	
			V_{IN-} = 6.5 V		50	60	

general operation

The input stage of the TLC247x is a modified instrumentation amplifier that accepts three types of pulse-width modulated (PWM) signals or analog signals. If either input is left open (unused), it is internally held at $V_{DD}/2$ by an internal high-impedance voltage divider. For the lowest signal distortion, it is recommended that a 0.2-μF capacitor be connected from the open input to GND. This provides a lower ac impedance at this node. The analog signal type and the three PWM signal types are as follows: Positive output is defined as OUT+ positive with respect to OUT–.

Type 1: Direct analog input

IN– is not connected (for best performance connect a 0.2-μF capacitor from this pin to GND).
IN+ is driven with an analog signal referenced to $V_{DD}/2$.
IN+ driven from 0 V to 1 V (with respect to $V_{DD}/2$) produces 0-V to 2-V output. (TLC2470, TLC2471)
IN+ driven from 0 V to –1 V (with respect to $V_{DD}/2$) produces 0-V to –2-V output. (TLC2470, TLC2471)
IN+ driven for 0 V to 1 V (with respect to $V_{DD}/2$) produces 0-V to 1-V output (TLC2472I, TLC2473I)
IN+ driven for 0 V to –1 V (with respect to $V_{DD}/2$) produces 0-V to –1-V output (TLC2472I, TLC2473I)

For differential analog input, clipping and severe distortion of the speaker output will occur when the difference between the two inputs, $\lvert V_{IN+} - V_{IN-} \rvert$, exceeds 1 V for the TLC2470I and TLC2471I or 2 V for the TLC2472I and TLC2473I.

Type 2: Two-input push-pull PWM operation

Both inputs at logic 1 (V_{DD}) level produce zero output.
IN – at logic 0 produces maximum positive voltage across speaker.
IN + at logic 0 produces maximum negative voltage across speaker.
Pulse-width duration determines output voltage.

Type 3: Single-input, single-ended PWM operation

IN– is not connected (for best performance connect a 0.2-μF capacitor from this pin to GND).
IN+ is pulsed with 50% duty cycle and produces zero output.
IN+ is pulsed with > 50% duty cycle at Logic 1 and produces positive output.
IN+ is pulsed with < 50% duty cycle at Logic 1 and produces negative output.

Type 4: Single-input double-ended PWM operation

IN– pin is not connected (for best performance connect a 0.2-μF capacitor from this pin to GND).
IN+ pin is biased at $V_{DD}/2$ produces zero output.
IN+ pin pulsed positive voltage (with respect to $V_{DD}/2$) produces positive output.
IN+ pin pulsed negative voltage (with respect to $V_{DD}/2$) produces negative output.

input

The input stage has an overall gain of 50%. Internal resistive voltage dividers allow the input signal level to go from V_{DD} to GND without exceeding the input common-mode range of the input operational amplifiers. The output section of the input stage is a unity-gain, limiting amplifier that limits the output signal from the input stage to $V_{DD}/2 \pm 1$ V. This limits the swing of the output power amplifier for PWM signals but allows analog signals of amplitudes less than this to pass through.

A three-pole low-pass continuous-time filter with a typical –3-dB corner frequency of 50 kHz is placed between the input stage and the switched-capacitor filter to prevent aliasing between the PWM input signal and the switched capacitor filter clock that might generate different signals in the audio frequency range.

low-pass filter

A three-pole, inverse-Chebyshev switched-capacitor low-pass filter is used to filter out the high-frequency components of the PWM signal. The output stage of the switched capacitor has a gain of 2X for the TLC2470I and TLC2471I. The output stage of the switch capacitor has a gain of 1X for the TLC2472I and TLC2473I.

output

The audio amplifier with low-pass filtering that differentially drives the speaker consists of two identical power-operational amplifiers connected in noninverting unity-gain configurations. The signal from the switched-capacitor filter is fed directly into the positive-power operational amplifier connected to the OUT+ pin. The signal from the switched-capacitor filter is also fed through a small operational amplifier connected in an inverting unity-gain configuration and then to the negative-power operational amplifier connected to the OUT– pin.

volume control (PWM modes only)

A single-pin volume control is provided for PWM signals. This control reduces the speaker voltage from maximum to zero as the voltage at this pin is varied from 2/3 of the supply voltage to 0 V, respectively. If this pin is left open or connected to a voltage ranging from 2/3 of the supply voltage to the full supply voltage, the voltage across the speaker remains at its maximum value. A 1-MΩ potentiometer is suggested to minimize the current drain across the supply. A 500-kΩ resistor may be placed in series between the positive supply pin and the top of the potentiometer to use the full range of the potentiometer.

This volume control should only be used for PWM input signals and not for analog signals as clipping and severe distortion of the speaker output will result. Volume control of analog signals is accomplished by attenuating these signals before they enter the TLC247x circuit.

auto power down/power up

An automatic power-down feature is also provided for battery applications. This requires a 3-μF capacitor to be connected from PWR DN to GND. If both inputs are held equal to V_{DD}, the circuit will go down into the power-down mode typically in 0.5 seconds. Supply current in the power-down mode is typically 50 μA. The circuit will also power down if both inputs are left open or capacitively coupled to the signal source. For the latter case, internal voltage dividers hold the input pins as $V_{DD}/2$. These voltage dividers draw less than 50-μA input current.

While in the power-down mode, both speaker outputs go to a high-impedance state. An input signal will automatically power up the TLC247x in less than 2 ms.

manual power up

The TLC247x may be manually enabled by externally driving PWR DN to GND. Because of the automatic power-up feature, the device will draw about 4 mA from PWR DN if this pin is held at V_{DD} and an input signal is applied to the inputs. Therefore, no input signal should be present when PWR DN is being held at V_{DD}. Operation of the device with an input signal applied and PWR DN held at V_{DD} is not recommended. PWR DN may be held at GND to keep the device powered up for normal operation with no adverse effects.

TYPICAL CHARACTERISTICS

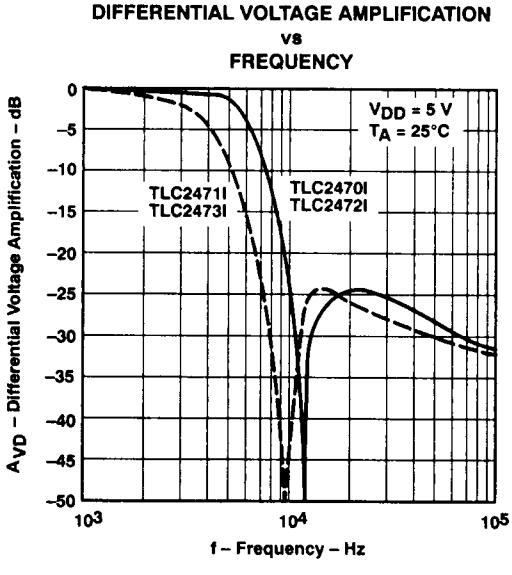


Figure 1

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

APPLICATION INFORMATION

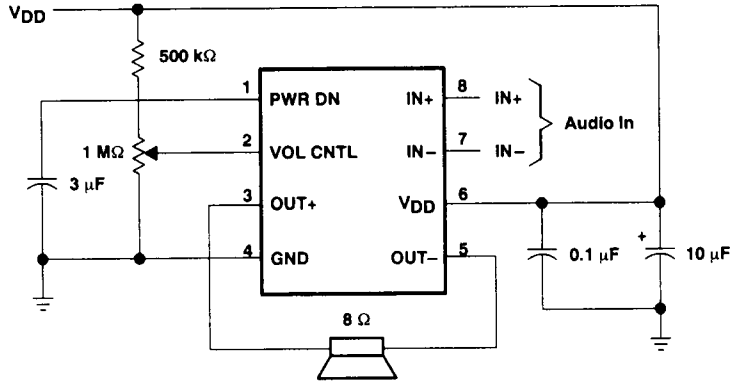


Figure 2. Typical PWM-Audio Configuration

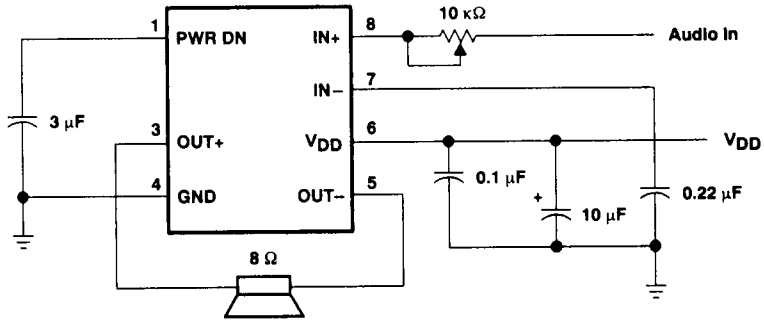


Figure 3. Typical Analog-Audio Configuration