



THS4521 THS4524

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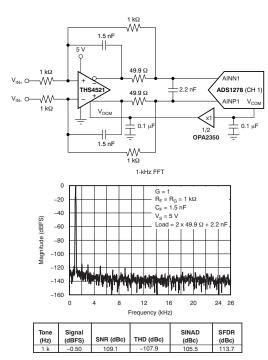
## VERY LOW POWER, NEGATIVE RAIL INPUT, RAIL-TO-RAIL OUTPUT, FULLY DIFFERENTIAL AMPLIFIER

Check for Samples: THS4521, THS4522, THS4524

## FEATURES

- **Fully Differential Architecture**
- Bandwidth: 145 MHz
- Slew Rate: 490 V/µs
- HD<sub>2</sub>: -133 dBc at 10 kHz (1  $V_{RMS}$ , R<sub>L</sub> = 1 k $\Omega$ )
- HD<sub>3</sub>: –140 dBc at 10 kHz (1 V<sub>RMS</sub>, R<sub>L</sub> = 1 k $\Omega$ )
- Input Voltage Noise: 4.6 nV/ $\sqrt{Hz}$  (f = 100 kHz)
- THD+N: -112dBc (0.00025%) at 1 kHz (22-kHz BW, G = 1, 5  $V_{PP}$ )
- Open-Loop Gain: 119 dB
- **NRI—Negative Rail Input**
- **RRO**—Rail-to-Rail Output
- **Output Common-Mode Control (with Low** Offset and Drift)
- **Power Supply:** 
  - Voltage: +2.5 V (±1.25 V) to +5.5 V (±2.75 V)
  - Current: 1.14 mA/ch
- Power-Down Capability: 20 µA (typ)

THS4521 and ADS1278 Combined Performance





Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet. I<sup>2</sup>S is a trademark of NXP Semiconductor.

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## APPLICATIONS

- Low-Power SAR and  $\Delta \Sigma$  ADC Drivers
- Low-Power Differential Drivers
- Low-Power Differential Signal Conditioning
- Low-Power, High-Performance Differential **Audio Amplifiers**

## DESCRIPTION

The THS4521, THS4522, and THS4524 family of devices are very low-power, fully differential op amps with rail-to-rail output and an input common-mode range that includes the negative rail. These amplifiers are designed for low-power data acquisition systems power and high-density applications where dissipation is a critical parameter, and provide exceptional performance in audio applications.

The family includes single (THS4521), dual (THS4522), and quad (THS4524) versions.

These fully differential op amps feature accurate output common-mode control that allows for dc-coupling when driving analog-to-digital converters (ADCs). This control, coupled with an input common-mode range below the negative rail as well as rail-to-rail output, allows for easy interfacing between single-ended, ground-referenced signal sources. Additionally, these devices are ideally suited for driving both successive-approximation register (SAR) and delta-sigma ( $\Delta\Sigma$ ) ADCs using only a single +2.5V to +5V and ground power supply.

The THS4521, THS4522, and THS4524 family of fully differential op amps is characterized for operation over the full industrial temperature range from -40°C to +85°C.

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PRODUCTS							
DEVICE	BW (MHz)	l <sub>Q</sub> (mA)	THD (dBc) at 100 kHz	V <u>N</u> (nV/√Hz)	RAIL- TO-RAIL		
THS4520	570	15.3	-114	2	Out		
THS4121	100	16	-79	5.4	In/Out		
THS4130	150	16	-107	1.3	No		

## THS4521 THS4522 THS4524



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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PRODUCT	PACKAGE- LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA QUANTITY
	0010.0	<b>D</b>		T114504	THS4521ID	Rails, 75
THS4521	SOIC-8	D	4010 1 0510	TH4521	THS4521IDR	Tape and reel, 2500
1054521		DOK	-40°C to +85°C	4521	THS4521IDGKT	Tape and reel, 250
	MSOP-8	DGK			THS4521IDGKR	Tape and reel, 2500
TUO 4500	T000D 10	DW	10°0 to 105°0	THS4522	THS4522IPW	Rails, 90
THS4522	TSSOP-16	PW	–40°C to +85°C		THS4522IPWR	Tape and reel, 2000
TU04504	TOOOD an	DDT	10°0 to 105°0	TU0 (50 (	THS4524IDBT	Rails, 50
THS4524	TSSOP-38	DBT	–40°C to +85°C	THS4524	THS4524IDBTR	Tape and reel, 2000

## PACKAGE/ORDERING INFORMATION<sup>(1)</sup>

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the relevant product folders at www.ti.com.

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

Over operating free-air temperature range (unless otherwise noted).

		THS4521, THS4522. THS4524	UNIT	
Supply V	oltage, $V_{S-}$ to $V_{S+}$	5.5	V	
Input/Out	put Voltage, V <sub>I</sub> (V <sub>IN±</sub> , V <sub>OUT±</sub> , V <sub>OCM</sub> pins)	$(V_{S-}) - 0.7$ to $(V_{S+}) + 0.7V$	V	
Differenti	al Input Voltage, V <sub>ID</sub>	1	V	
Output C	urrent, I <sub>O</sub>	100	mA	
Input Cur	rrent, I <sub>I</sub> (V <sub>IN±</sub> , V <sub>OCM</sub> pins)	10	mA	
Continuous Power Dissipation		See Thermal Characteristic Specifications		
Maximum	n Junction Temperature, T <sub>J</sub>	+150	°C	
Maximum	n Junction Temperature, $T_J$ (continuous operation, long-term reliability)	+125	°C	
Operating	g Free-air Temperature Range, T <sub>A</sub>	-40 to +85	°C	
Storage -	Temperature Range, T <sub>STG</sub>	-65 to +150	°C	
	Human Body Model (HBM)	1300	V	
ESD Rating:	Charge Device Model (CDM)	1000	V	
r tating.	Machine Model (MM)	50	V	

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.



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THS4521

THS4522

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## ELECTRICAL CHARACTERISTICS: $V_{S+} - V_{S-} = 3.3 V$

At  $V_{S+}$  = +3.3 V,  $V_{S-}$  = 0 V,  $V_{OCM}$  = open,  $V_{OUT}$  = 2  $V_{PP}$  (differential),  $R_L$  = 1 k $\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.

		THS4521, THS4522, THS4524				TEST
PARAMETER	CONDITIONS	MIN	ТҮР	MAX	UNIT	LEVEL <sup>(1)</sup>
AC PERFORMANCE						
Small-Signal Bandwidth	$V_{OUT}$ = 100 m $V_{PP}$ , G = 1		135		MHz	С
	$V_{OUT}$ = 100 m $V_{PP}$ , G = 2		49		MHz	С
	$V_{OUT} = 100 \text{ mV}_{PP}, \text{ G} = 5$		18.6		MHz	С
	$V_{OUT} = 100 \text{ mV}_{PP}, \text{ G} = 10$		9.3		MHz	С
Gain Bandwidth Product	$V_{OUT} = 100 \text{ mV}_{PP}, \text{ G} = 10$		93		MHz	С
Large-Signal Bandwidth	$V_{OUT} = 2 V_{PP}, G = 1$		95		MHz	С
Bandwidth for 0.1-dB Flatness	$V_{OUT} = 2 V_{PP}, G = 1$		20		MHz	С
Rising Slew Rate (Differential)	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		420		V/µs	С
Falling Slew Rate (Differential)	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		460		V/µs	С
Overshoot	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		1.2		%	С
Undershoot	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		2.1		%	С
Rise Time	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		4		ns	С
Fall Time	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		3.5		ns	С
Settling Time to 1%	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		13		ns	С
Harmonic Distortion						
2nd harmonic	$ f = 1 \text{ kHz},  \text{V}_{\text{OUT}} = 1  \text{V}_{\text{RMS}},  \text{G} = 1^{(2)}, \\ \text{differential input} $		-122		dBc	С
	$f = 1 \text{ MHz}, V_{OUT} = 2 V_{PP}, G = 1$		-85		dBc	С
3rd harmonic	$ f = 1 \text{ kHz}, \text{ V}_{\text{OUT}} = 1 \text{ V}_{\text{RMS}}, \text{ G} = 1^{(2)}, \\ \text{differential input} $		-141		dBc	С
	$f = 1 \text{ MHz}, V_{OUT} = 2 V_{PP}, G = 1$		-90		dBc	С
Second-Order Intermodulation Distortion	Two-tone, $f_1 = 2 \text{ MHz}$ , $f_2 = 2.2 \text{ MHz}$ , $V_{OUT} = 2 \cdot V_{PP}$ envelope		-83		dBc	С
Third-Order Intermodulation Distortion	Two-tone, $f_1 = 2 \text{ MHz}$ , $f_2 = 2.2 \text{ MHz}$ , $V_{OUT} = 2 \cdot V_{PP}$ envelope		-90		dBc	С
Input Voltage Noise	f > 10 kHz		4.6		nV/√Hz	С
Input Current Noise	f > 100 kHz		0.6		pA/√Hz	С
Overdrive Recovery Time	Overdrive = $\pm 0.5$ V		80		ns	С
Output Balance Error	$V_{OUT}$ = 100 mV, f ≤ 2 MHz (differential input)		-57		dB	С
Closed-Loop Output Impedance	f = 1 MHz (differential)		0.3		Ω	С
Channel-to-Channel Crosstalk (THS4522, THS4524)	f = 10 kHz, measured differentially		-125		dB	С
DC PERFORMANCE						
Open-Loop Voltage Gain (A <sub>OL</sub> )		100	116		dB	А
Input-Referred Offset Voltage	$T_A = +25^{\circ}C$		±0.2	±2	mV	А
	$T_{A} = -40^{\circ}C \text{ to } +85^{\circ}C$		±0.5	±3.5	mV	В
Input offset voltage drift <sup>(3)</sup>	$T_{A} = -40^{\circ}C \text{ to } +85^{\circ}C$		±2		µV/°C	С
Input Bias Current	$T_A = +25^{\circ}C$		0.65	0.85	μA	В
	$T_{A} = -40^{\circ}C \text{ to } +85^{\circ}C$		0.75	0.95	μA	В
Input bias current drift <sup>(3)</sup>	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		±1.75	±2	nA/°C	В
Input Offset Current	$T_A = +25^{\circ}C$		±30	±180	nA	В
	$T_A = -40^{\circ}C \text{ to } +85^{\circ}C$		±30	±215	nA	В
Input offset current drift <sup>(3)</sup>	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		±100	±600	pA/°C	В

(1) Test levels: (A) 100% tested at +25°C. Over temperature limits set by characterization and simulation. (B) Limits set by characterization and simulation. (C) Typical value only for information.

(2) Not directly measureable; calculated using noise gain of 101 as described in the Applications section, Audio Performance.

(3) Input Offset Voltage Drift, Input Bias Current Drift, and Input Offset Current Drift are average values calculated by taking data at -40°C and +85°C, computing the difference, and dividing by 125.

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## ELECTRICAL CHARACTERISTICS: $V_{S+} - V_{S-} = 3.3 V$ (continued)

At  $V_{S+} = +3.3 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.

		THS452	1, THS4522,	THS4524		TEST
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT	LEVEL <sup>(1)</sup>
INPUT						
Common-Mode Input Voltage Low	T <sub>A</sub> = +25°C		-0.2	-0.1	V	А
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		-0.1	0	V	В
Common-Mode Input Voltage High	T <sub>A</sub> = +25°C	1.9	2		V	А
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$	1.8	1.9		V	В
Common-Mode Rejection Ratio (CMRR)		80	100		dB	А
Input Resistance			110  1.5		kΩ∥pF	С
OUTPUT						
Output Voltage Low	$T_A = +25^{\circ}C$		0.08	0.15	V	А
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		0.09	0.2	V	В
Output Voltage High	$T_A = +25^{\circ}C$	3.0	3.1		V	А
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$	2.95	3.05		V	В
Output Current Drive (for linear operation)	$R_L = 50 \ \Omega$		±35		mA	С
POWER SUPPLY						
Specified Operating Voltage		2.5		5.5	V	В
Quiescent Operating Current, per channel	$T_A = +25^{\circ}C$	0.9	1.0	1.2	mA	A
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$	0.85	1.0	1.25	mA	В
Power-Supply Rejection Ratio (±PSRR)		80	100		dB	А
POWER DOWN						
Enable Voltage Threshold	Assured on above 2.1 V		1.6	2.1	V	А
Disable Voltage Threshold	Assured off below 0.7 V	0.7	1.6		V	А
Disable Pin Bias Current			1		μΑ	С
Power Down Quiescent Current			10		μΑ	С
Turn-On Time Delay	Time to V_{OUT} = 90% of final value, V_IN= 2 V, $R_L$ = 200 $\Omega$		108		ns	В
Turn-Off Time Delay	Time to V_{OUT} = 10% of original value, V_IN= 2 V, R_L = 200 $\Omega$		88		ns	В
V <sub>OCM</sub> VOLTAGE CONTROL						
Small-Signal Bandwidth			23		MHz	С
Slew Rate			55		V/µs	С
Gain		0.98	0.99	1.02	V/V	A
Common-Mode Offset Voltage from V <sub>OCM</sub> Input	Measured at V <sub>OUT</sub> with V <sub>OCM</sub> input driven, V <sub>OCM</sub> = 1.65 V ±0.5 V		±2.5	±4	mV	В
Input Bias Current	$V_{OCM} = 1.65 \text{ V} \pm 0.5 \text{ V}$		±5	±8	μΑ	В
V <sub>OCM</sub> Voltage Range		1	0.8 to 2.5	2.3	V	А
Input Impedance			72  1.5		kΩ∥pF	С
Default Output Common-Mode Voltage Offset from $(V_{S+} - V_{S-})/2$	Measured at $V_{\text{OUT}}$ with $V_{\text{OCM}}$ input open		±1.5	±5	mV	А
THERMAL CHARACTERISTICS						
Specified Operating Range, All Packages			-40 to +85		°C	С
Thermal Resistance, $\theta_{JA}$	Junction-to-ambient					
THS4521 D SO-8			194		°C/W	С
DGK MSOP-8			269		°C/W	С
THS4522 PW TSSOP-16			116		°C/W	С
THS4524 DBT TSSOP-38			81		°C/W	С



THS4522 THS4524

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**THS4521** 

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## ELECTRICAL CHARACTERISTICS: $V_{s+} - V_{s-} = 5 V$

At  $V_{S+} = +5 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_F = 1 \text{ k}\Omega$ ,  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, input and output referenced to midsupply, unless otherwise noted.

		THS452	1, THS4522,	THS4524		TEST
PARAMETER	CONDITIONS	MIN	ТҮР	MAX	UNIT	LEVEL <sup>(1)</sup>
AC PERFORMANCE						
Small-Signal Bandwidth	$V_{OUT}$ = 100 m $V_{PP}$ , G = 1		145		MHz	С
	$V_{OUT}$ = 100 m $V_{PP}$ , G = 2		50		MHz	С
	$V_{OUT}$ = 100 m $V_{PP}$ , G = 5		20		MHz	С
	$V_{OUT} = 100 \text{ mV}_{PP}, \text{ G} = 10$		9.5		MHz	С
Gain Bandwidth Product	$V_{OUT} = 100 \text{ mV}_{PP}, \text{ G} = 10$		95		MHz	С
Large-Signal Bandwidth	$V_{OUT} = 2 V_{PP}, G = 1$		145		MHz	С
Bandwidth for 0.1-dB Flatness	$V_{OUT} = 2 V_{PP}, G = 1$		30		MHz	С
Rising Slew Rate (Differential)	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		490		V/µs	С
Falling Slew Rate (Differential)	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		600		V/µs	С
Overshoot	$V_{OUT}$ = 2-V Step, G = 1, R_L = 200 $\Omega$		1		%	С
Undershoot	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		2.6		%	С
Rise Time	$V_{OUT}$ = 2-V Step, G = 1, R_L = 200 $\Omega$		3.4		ns	С
Fall Time	$V_{OUT}$ = 2-V Step, G = 1, R <sub>L</sub> = 200 $\Omega$		3		ns	С
Settling Time to 1%	$V_{OUT}$ = 2-V Step, G = 1, R_L = 200 $\Omega$		10		ns	С
Harmonic Distortion						
2nd harmonic	$ f = 1 \text{ kHz},  V_{\text{OUT}} = 1  V_{\text{RMS}},  \text{G} = 1^{(2)}, \\ \text{differential input} $		-122		dBc	С
	$f = 1 \text{ MHz}, V_{OUT} = 2 V_{PP}, G = 1$		-85		dBc	С
3rd harmonic	$  f = 1 \text{ kHz},  \text{V}_{\text{OUT}} = 1  \text{V}_{\text{RMS}},  \text{G} = 1^{(2)}, \\ \text{differential input} $		-141		dBc	С
	f = 1 MHz, $V_{OUT}$ = 2 $V_{PP}$ , G = 1		-91		dBc	С
Second-Order Intermodulation Distortion	Two-tone, $f_1 = 2 \text{ MHz}$ , $f_2 = 2.2 \text{ MHz}$ , $V_{OUT} = 2 \cdot V_{PP}$ envelope		-86		dBc	С
Third-Order Intermodulation Distortion	Two-tone, $f_1 = 2 \text{ MHz}$ , $f_2 = 2.2 \text{ MHz}$ , $V_{OUT} = 2 \cdot V_{PP}$ envelope		-93		dBc	С
Input Voltage Noise	f > 10 kHz		4.6		nV/√Hz	С
Input Current Noise	f > 100 kHz		0.6		pA/√Hz	С
SNR	$V_{OUT}$ = 5 $V_{PP}$ , 20 Hz to 22 kHz BW, differential input		114		dBc	С
THD+N	$f$ = 1 kHz , $V_{OUT}$ = 5 $V_{PP},$ 20 Hz to 22 kHz BW, differential input		112		dBc	С
Overdrive Recovery Time	Overdrive = $\pm 0.5$ V		75		ns	С
Output Balance Error	$V_{OUT}$ = 100 mV, f < 2 MHz, $V_{IN}$ differential		-57		dB	С
Closed-Loop Output Impedance	f = 1 MHz (differential)		0.3		Ω	С
Channel-to-Channel Crosstalk (THS4522. THS4524)	f = 10 kHz, measured differentially		-125		dB	С
DC PERFORMANCE						
Open-Loop Voltage Gain (A <sub>OL</sub> )		100	119		dB	A
Input-Referred Offset Voltage	$T_A = +25^{\circ}C$		±0.24	±2	mV	А
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		±0.5	±3.5	mV	В
Input offset voltage drift <sup>(3)</sup>	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		±2		μV/°C	С
Input Bias Current	$T_A = +25^{\circ}C$		0.7	0.9	μA	В
	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		0.9	1.1	μA	В
Input bias current drift <sup>(3)</sup>	$T_A = -40^{\circ}C \text{ to } +85^{\circ}C$		±1.8	±2.2	nA/°C	В

(1) Test levels: (A) 100% tested at +25°C. Over temperature limits set by characterization and simulation. (B) Limits set by characterization and simulation. (C) Typical value only for information.

Not directly measureable; calculated using noise gain of 101 as described in the Applications section, Audio Performance. (2)

Input Offset Voltage Drift, Input Bias Current Drift, and Input Offset Current Drift are average values calculated by taking data at -40°C (3)and +85°C, computing the difference, and dividing by 125.

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## ELECTRICAL CHARACTERISTICS: $V_{s+} - V_{s-} = 5 V$ (continued)

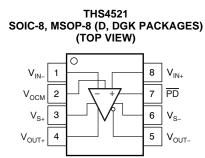
At  $V_{S+} = +5 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_F = 1 \text{ k}\Omega$ ,  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, input and output referenced to midsupply, unless otherwise noted.

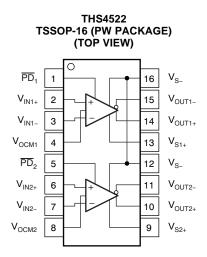
			THS452	1, THS4522,	THS4524		TEST
	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT	LEVEL <sup>(1)</sup>
Input Offset	Current	T <sub>A</sub> = +25°C		±30	±180	nA	В
		$T_A = -40^{\circ}C$ to $+85^{\circ}C$		±30	±215	nA	В
	Input offset current drift <sup>(4)</sup>	$T_A = -40^{\circ}C$ to $+85^{\circ}C$		±100	±600	pA/°C	В
INPUT							
Common-Mc	de Input Voltage Low	T <sub>A</sub> = +25°C		-0.2	-0.1	V	А
		$T_A = -40^{\circ}C$ to $+85^{\circ}C$		-0.1	0	V	В
Common-Mc	de Input Voltage High	T <sub>A</sub> = +25°C	3.6	3.7		V	А
		$T_A = -40^{\circ}C$ to $+85^{\circ}C$	3.5	3.6		V	В
Common-Mc	de Rejection Ratio (CMRR)		80	102		dB	А
Input Impeda	ance			100  0.7		kΩ∥pF	С
OUTPUT							
Output Volta	ge Low	T <sub>A</sub> = +25°C		0.10	0.15	V	А
		$T_A = -40^{\circ}C$ to $+85^{\circ}C$		0.115	0.2	V	В
Output Volta	ge High	$T_A = +25^{\circ}C$	4.7	4.75		V	А
		$T_A = -40^{\circ}C$ to +85°C	4.65	4.7		V	в
Output Curre	ent Drive (for linear operation)	$R_{\rm L} = 50 \ \Omega$		±55		mA	С
POWER SU							
Specified Op	erating Voltage		2.5		5.5	V	В
	perating Current, per channel	T <sub>A</sub> = +25°C	0.95	1.14	1.25	mA	А
	F = = = =	$T_A = -40^\circ C$ to $+85^\circ C$	0.9	1.15	1.3	mA	В
Power-Suppl	y Rejection Ratio (±PSRR)		80	100		dB	A
POWER DO							
	ge Threshold	Ensured <i>on</i> above 2.1 V		1.6	2.1	v	А
	age Threshold	Ensured off below 0.7 V	0.7	1.6		V	A
Disable Pin B	-		0.11	1		μA	C
	Quiescent Current			20		μA	c
		Time to $V_{OUT} = 90\%$ of final value,				μ	
Turn-On Tim	e Delay	$V_{IN}$ = 2 V, $R_L$ = 200 $\Omega$		70		ns	В
Turn-Off Tim		Time to V <sub>OUT</sub> = 10% of original value, V <sub>IN</sub> = 2 V, R <sub>L</sub> = 200 $\Omega$		60		ns	В
VOLTA	AGE CONTROL						
Small-Signal	Bandwidth			23		MHz	С
Slew Rate				55		V/µs	С
Gain			0.98	0.99	1.02	V/V	А
Common-Mc	de Offset Voltage from V <sub>OCM</sub> Input	Measured at V <sub>OUT</sub> with V <sub>OCM</sub> input driven, V <sub>OCM</sub> = 2.5V ±1 V		±5	±9	mV	В
Input Bias C	urrent	$V_{OCM} = 2.5V \pm 1 V$		±20	±25	μA	В
V <sub>OCM</sub> Voltage	e Range		1	0.8 to 4.2	4	V	А
Input Impeda	ance			46  1.5		kΩ∥pF	С
Default Output Common-Mode Voltage Offset from $(V_{S+}-V_{S-})/2$		Measured at $V_{OUT}$ with $V_{OCM}$ input open		±1	±5	mV	A
	HARACTERISTICS						
Specified Operating Range All Packages			-40		+85	°C	С
Thermal Res		Junction-to-ambient					
THS4521	D SO-8			194		°C/W	С
	DGK MSOP-8			269		°C/W	С
THS4522	PW TSSOP-16			116		°C/W	C
THS4524	DBT TSSOP-38			81		°C/W	C

(4) Input Offset Voltage Drift, Input Bias Current Drift, and Input Offset Current Drift are average values calculated by taking data at -40°C and +85°C, computing the difference, and dividing by 125.



### **DEVICE INFORMATION**





#### **TERMINAL FUNCTIONS: THS4521**

SOIC-8,	MSOP-8		
PIN NO.	NAME	DESCRIPTION	
1	V <sub>IN-</sub>	Inverting amplifier input	
2	V <sub>OCM</sub>	Common-mode voltage input	
3	V <sub>S+</sub>	Amplifier positive power-supply input	
4	V <sub>OUT+</sub>	Noninverting amplifier output	
5	V <sub>OUT-</sub>	Inverting amplifier output	
6	V <sub>S-</sub>	Amplifier negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.	
7	PD	Power down. $\overline{PD}$ = logic low puts device into low-power mode. $\overline{PD}$ = logic high or open for normal operation.	
8	V <sub>IN+</sub>	Noninverting amplifier input	

#### **TERMINAL FUNCTIONS: THS4522**

TSSOP-16		
PIN NO.	NAME	DESCRIPTION
1	PD <sub>1</sub>	Power down 1. $\overline{PD}$ = logic low puts device into low-power mode. $\overline{PD}$ = logic high or open for normal operation.
2	V <sub>IN1+</sub>	Noninverting amplifier 1 input
3	V <sub>IN1-</sub>	Inverting amplifier 1 input
4	V <sub>OCM1</sub>	Common-mode voltage input 1
5	PD 2	Power down 2. $\overline{PD}$ = logic low puts device into low-power mode. $\overline{PD}$ = logic high or open for normal operation.
6	V <sub>IN2+</sub>	Noninverting amplifier 2 input
7	V <sub>IN2-</sub>	Inverting amplifier 2 input
8	V <sub>OCM2</sub>	Common-mode voltage input 2
9	V <sub>S+2</sub>	Amplifier 2 positive power-supply input
10	V <sub>OUT2+</sub>	Noninverting amplifier 2 output
11	V <sub>OUT2-</sub>	Inverting amplifier 2 output
12	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
13	V <sub>S+1</sub>	Amplifier 1 positive power-supply input
14	V <sub>OUT1+</sub>	Noninverting amplifier 1 output
15	V <sub>OUT1-</sub>	Inverting amplifier 1 output

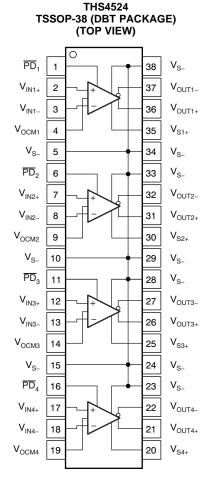
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**THS4521** 

#### TERMINAL FUNCTIONS: THS4522 (continued)

TSSC	DP-16	
PIN NO.	NAME	DESCRIPTION
16	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.



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THS4521

THS4522

**THS4524** 

#### **TERMINAL FUNCTIONS: THS4524**

TSSOP-38		
PIN NO.	NAME	DESCRIPTION
1	PD <sub>1</sub>	Power down 1. $\overline{PD}$ = logic low puts channel into low-power mode. $\overline{PD}$ = logic high or open for normal operation.
2	V <sub>IN1+</sub>	Noninverting amplifier 1 input
3	V <sub>IN1-</sub>	Inverting amplifier 1 input
4	V <sub>OCM1</sub>	Common-mode voltage input 1
5	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
6	PD <sub>2</sub>	Power down 2. $\overline{PD}$ = logic low puts channel into low-power mode. $\overline{PD}$ = logic high or open for normal operation.
7	V <sub>IN2+</sub>	Noninverting amplifier 2 input
8	V <sub>IN2-</sub>	Inverting amplifier 2 input
9	V <sub>OCM2</sub>	Common-mode voltage input 2
10	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
11	$\overline{PD}_3$	Power down 3. $\overline{PD}$ = logic low puts channel into low-power mode. $\overline{PD}$ = logic high or open for normal operation.
12	V <sub>IN3+</sub>	Noninverting amplifier 3 input
13	V <sub>IN3-</sub>	Inverting amplifier 3 input
14	V <sub>OCM3</sub>	Common-mode voltage input 3
15	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
16	PD <sub>4</sub>	Power down 4. $\overline{PD}$ = logic low puts channel into low-power mode. $\overline{PD}$ = logic high or open for normal operation.
17	V <sub>IN4+</sub>	Noninverting amplifier 4 input
18	V <sub>IN4-</sub>	Inverting amplifier 4 input
19	V <sub>OCM4</sub>	Common-mode voltage input 4
20	V <sub>S4+</sub>	Amplifier 4 positive power-supply input
21	V <sub>OUT4+</sub>	Noninverting amplifier 4 output
22	V <sub>OUT4-</sub>	Inverting amplifier 4 output
23	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
24	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
25	V <sub>S3+</sub>	Amplifier 3 positive power-supply input
26	V <sub>OUT3+</sub>	Noninverting amplifier3 output
27	V <sub>OUT3-</sub>	Inverting amplifier3 output
28	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
29	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
30	V <sub>S2+</sub>	Amplifier 2 positive power-supply input
31	V <sub>OUT2+</sub>	Noninverting amplifier 2 output
32	V <sub>OUT2-</sub>	Inverting amplifier 2 output
33	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
34	V <sub>S-</sub>	Negative power-supply input. Note that $V_{S-}$ is tied together on multi-channel devices.
35	V <sub>S1+</sub>	Amplifier 1 positive power-supply input
36	V <sub>OUT1+</sub>	Noninverting amplifier 1 output
37	V <sub>OUT1-</sub>	Inverting amplifier 1 output
38	V <sub>S-</sub>	Negative power-supply input. Note that V <sub>S</sub> is tied together on multi-channel devices.



## **TYPICAL CHARACTERISTICS**

## Table of Graphs: $V_{S+} - V_{S-} = 3.3 V$

TITLE	FIGURE
Small-Signal Frequency Response	Figure 1
Large-Signal Frequency Response	Figure 2
Large- and Small-Signal Pulse Response	Figure 3
Slew Rate vs V <sub>OUT</sub> Step	Figure 4
Overdrive Recovery	Figure 5
10-kHz Output Spectrum on AP Analyzer	Figure 6
Harmonic Distortion vs Frequency	Figure 7
Harmonic Distortion vs Output Voltage at 1 MHz	Figure 8
Harmonic Distortion vs Gain at 1 MHz	Figure 9
Harmonic Distortion vs Load at 1 MHz	Figure 10
Harmonic Distortion vs V <sub>OCM</sub> at 1 MHz	Figure 11
Two-Tone, Second- and Third-Order Intermodulation Distortion vs Frequency	Figure 12
Single-Ended Output Voltage Swing vs Load Resistance	Figure 13
Main Amplifier Differential Output Impedance vs Frequency	Figure 14
Frequency Response vs $C_{LOAD}$ ( $R_{LOAD}$ = 1 k $\Omega$ )	Figure 15
$R_O vs C_{LOAD} (R_{LOAD} = 1 k\Omega)$	Figure 16
Rejection Ratio vs Frequency	Figure 17
THS4522, THS4524 Crosstalk (Measured Differentially)	Figure 18
Turn-on Time	Figure 19
Turn-off Time	Figure 20
Input-Referred Voltage Noise and Current Noise Spectral Density	Figure 21
Main Amplifier Differential Open-Loop Gain and Phase	Figure 22
Output Balance Error vs Frequency	Figure 23
V <sub>OCM</sub> Small-Signal Frequency Response	Figure 24
V <sub>OCM</sub> Large-Signal Frequency Response	Figure 25
V <sub>OCM</sub> Input Impedance vs Frequency	Figure 26



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TITLE	FIGURE
Small-Signal Frequency Response	Figure 27
Large-Signal Frequency Response	Figure 28
Large- and Small-Signal Pulse Response	Figure 29
Slew Rate vs V <sub>OUT</sub> Step	Figure 30
Overdrive Recovery	Figure 31
10-kHz Output Spectrum on AP Analyzer	Figure 32
Harmonic Distortion vs Frequency	Figure 33
Harmonic Distortion vs Output Voltage at 1 MHz	Figure 34
Harmonic Distortion vs Gain at 1 MHz	Figure 35
Harmonic Distortion vs Load at 1 MHz	Figure 36
Harmonic Distortion vs V <sub>OCM</sub> at 1 MHz	Figure 37
Two-Tone, Second- and Third-Order Intermodulation Distortion vs Frequency	Figure 38
Single-Ended Output Voltage Swing vs Load Resistance	Figure 39
Main Amplifier Differential Output Impedance vs Frequency	Figure 40
Frequency Response vs $C_{LOAD}$ ( $R_{LOAD}$ = 1 k $\Omega$ )	Figure 41
$R_O vs C_{LOAD} (R_{LOAD} = 1 k\Omega)$	Figure 42
Rejection Ratio vs Frequency	Figure 43
THS4522, THS4524 Crosstalk (Measured Differentially)	Figure 44
Turn-on Time	Figure 45
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Input-Referred Voltage Noise and Current Noise Spectral Density	Figure 47
Main Amplifier Differential Open-Loop Gain and Phase	Figure 48
Output Balance Error vs Frequency	Figure 49
V <sub>OCM</sub> Small-Signal Frequency Response	Figure 50
V <sub>OCM</sub> Large-Signal Frequency Response	Figure 51
V <sub>OCM</sub> Input Impedance vs Frequency	Figure 52

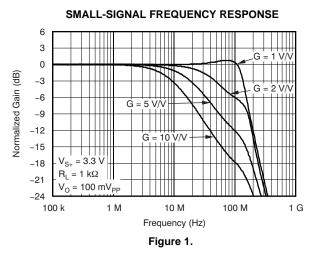
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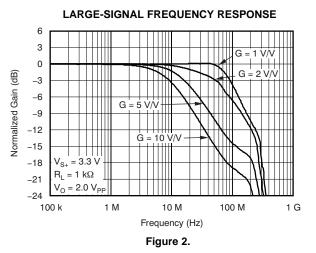


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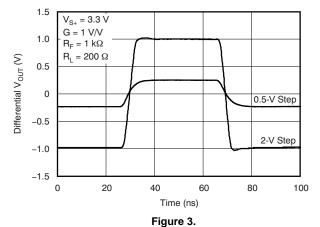
## TYPICAL CHARACTERISTICS: V<sub>S+</sub> - V<sub>S-</sub> = 3.3 V

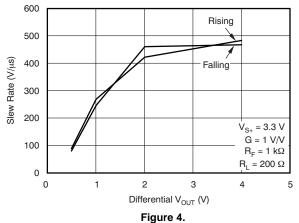
At  $V_{S+} = +3.3 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_{L} = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



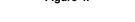


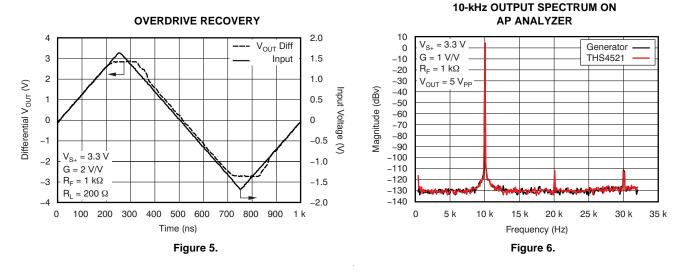






SLEW RATE vs Vout







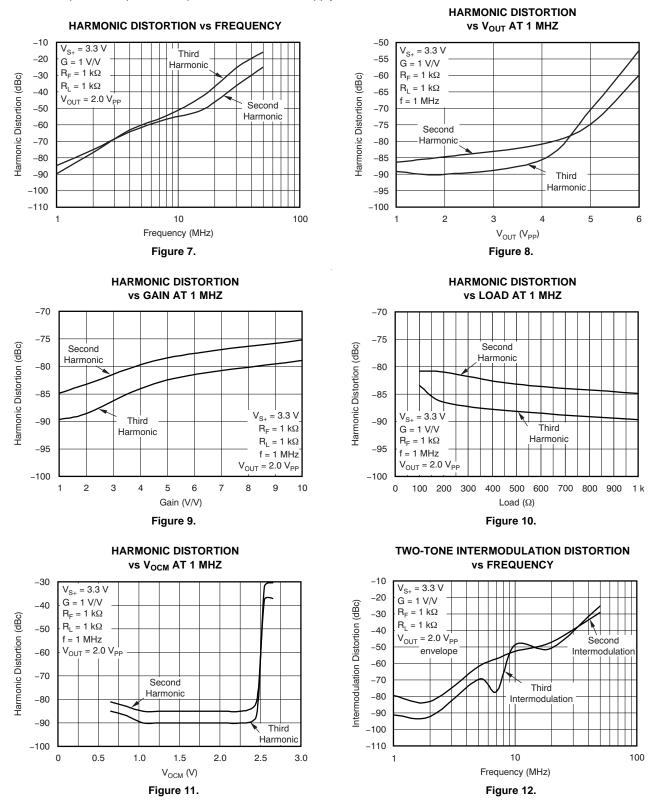
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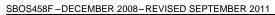
## TYPICAL CHARACTERISTICS: $V_{S+} - V_{S-} = 3.3 V$ (continued)

At  $V_{S+} = +3.3 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



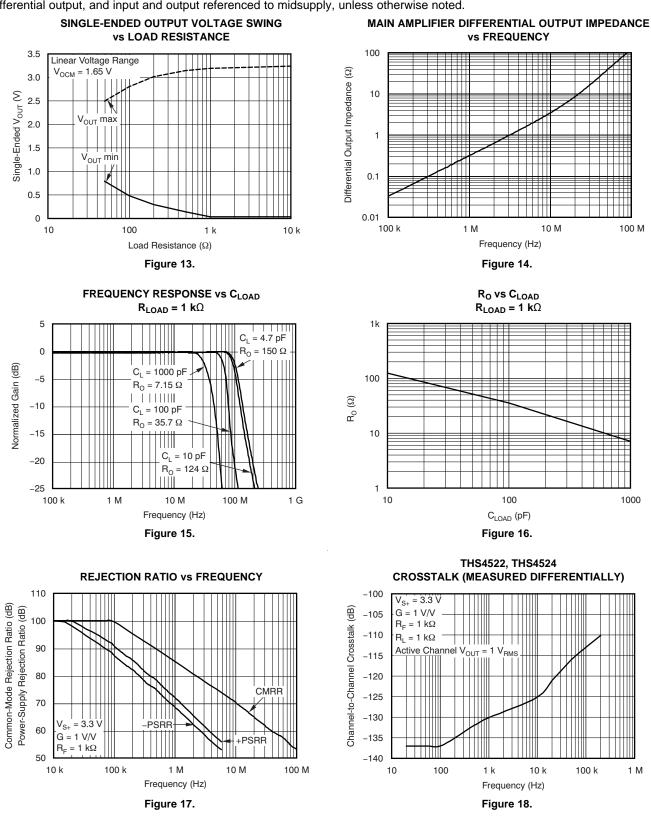
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## TYPICAL CHARACTERISTICS: $V_{S+} - V_{S-} = 3.3 V$ (continued)

At  $V_{S+} = +3.3 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



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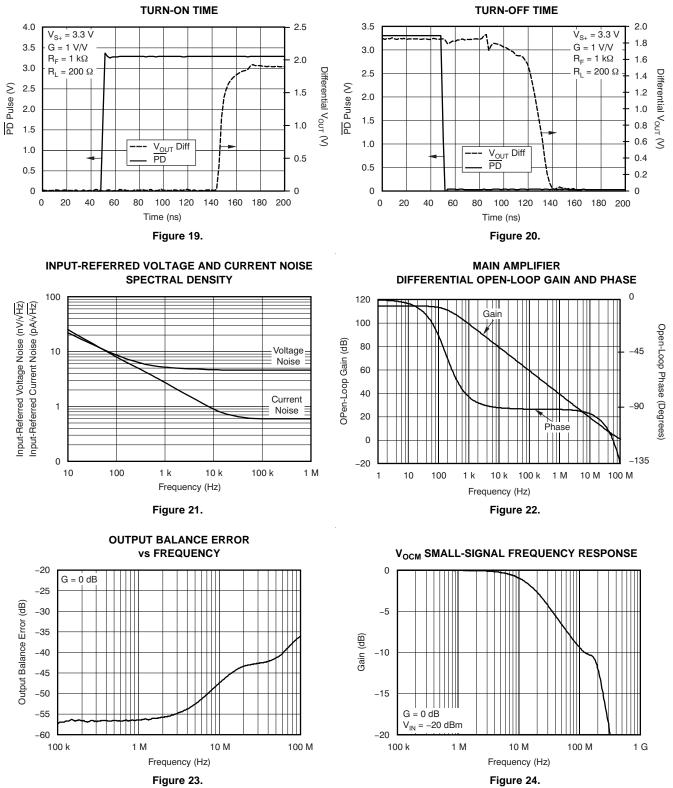
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THS4522

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## TYPICAL CHARACTERISTICS: $V_{S_{+}} - V_{S_{-}} = 3.3 V$ (continued)

At  $V_{S+}$  = +3.3 V,  $V_{S-}$  = 0 V,  $V_{OCM}$  = open,  $V_{OUT}$  = 2  $V_{PP}$  (differential),  $R_L$  = 1 k $\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



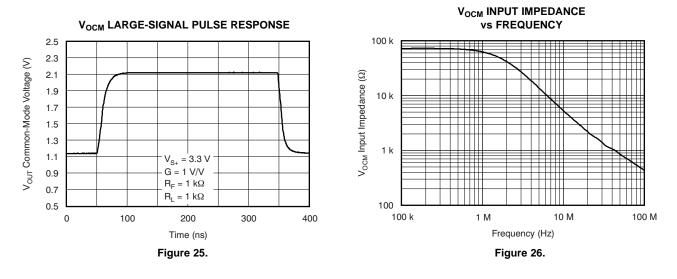
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## TYPICAL CHARACTERISTICS: $V_{s+} - V_{s-} = 3.3 V$ (continued)

At  $V_{S+}$  = +3.3 V,  $V_{S-}$  = 0 V,  $V_{OCM}$  = open,  $V_{OUT}$  = 2  $V_{PP}$  (differential),  $R_L$  = 1 k $\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.





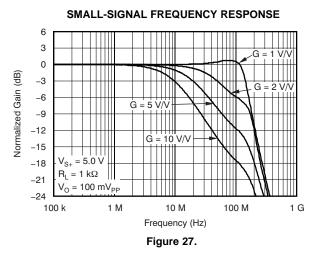
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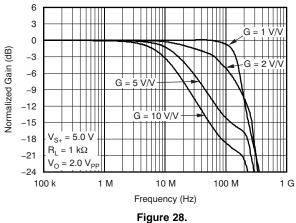
**THS4521** 



### **TYPICAL CHARACTERISTICS: 5 V**

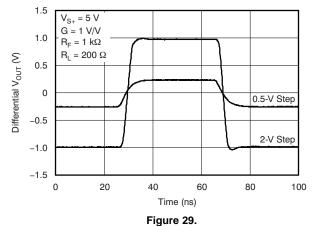
At  $V_{S+} = +5 V$ ,  $V_{S-} = 0 V$ ,  $V_{OCM} = open$ ,  $V_{OUT} = 2 V_{PP}$  (differential),  $R_F = 1 k\Omega$ ,  $R_L = 1 k\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



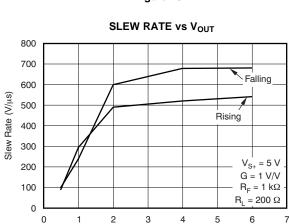


LARGE-SIGNAL FREQUENCY RESPONSE

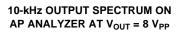


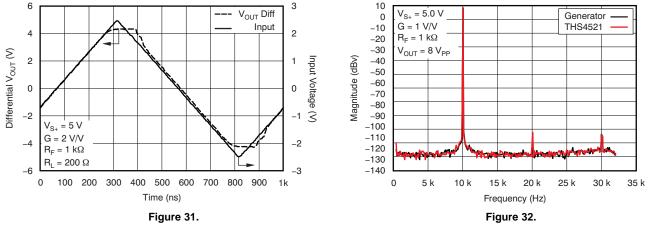


**OVERDRIVE RECOVERY** 









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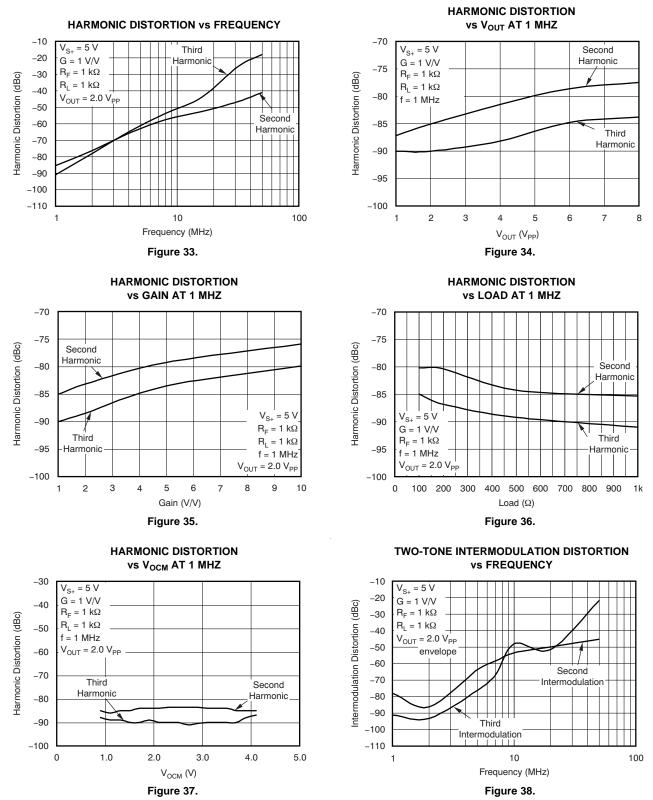
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## **TYPICAL CHARACTERISTICS: 5 V (continued)**

At  $V_{S+} = +5 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_F = 1 \text{ k}\Omega$ ,  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



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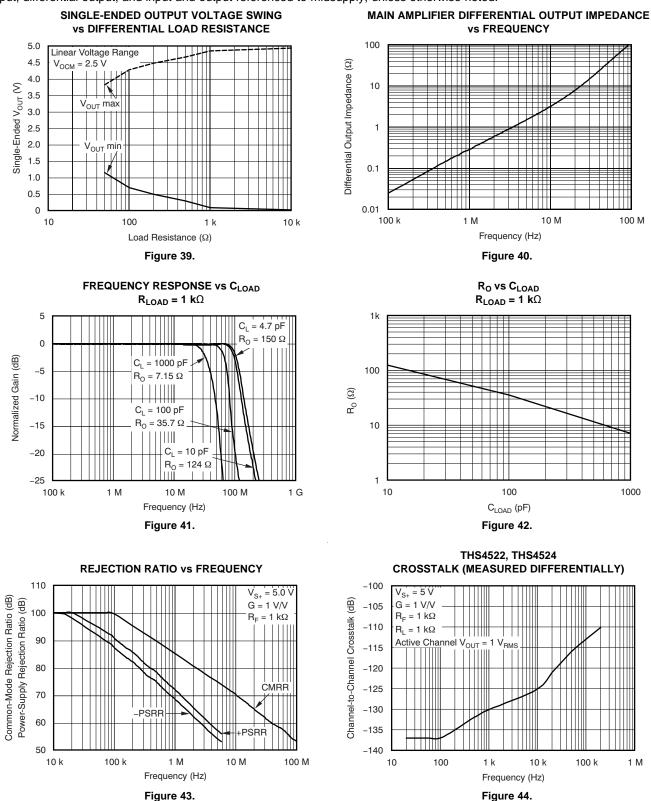
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#### **TYPICAL CHARACTERISTICS: 5 V (continued)**

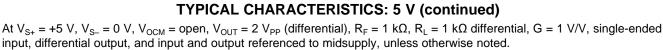
At  $V_{S+} = +5 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_F = 1 \text{ k}\Omega$ ,  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



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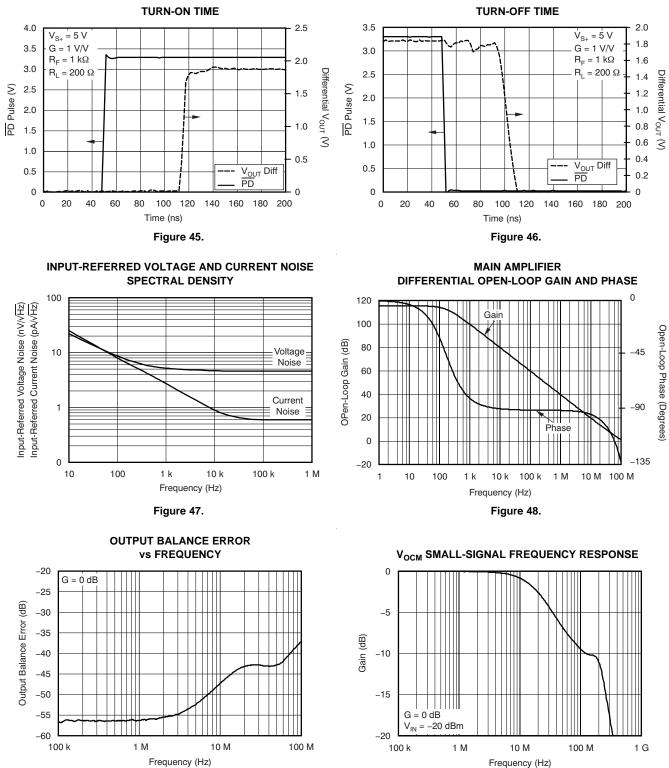


Figure 50.



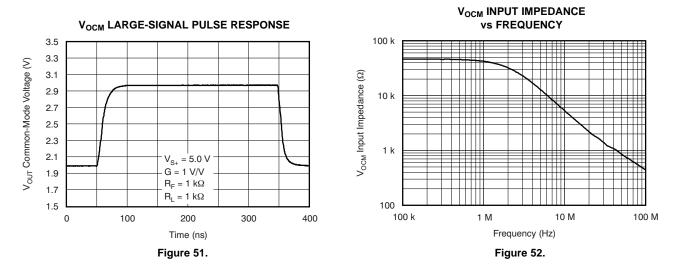
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## **TYPICAL CHARACTERISTICS: 5 V (continued)**

At  $V_{S+} = +5 \text{ V}$ ,  $V_{S-} = 0 \text{ V}$ ,  $V_{OCM} = \text{open}$ ,  $V_{OUT} = 2 \text{ V}_{PP}$  (differential),  $R_F = 1 \text{ k}\Omega$ ,  $R_L = 1 \text{ k}\Omega$  differential, G = 1 V/V, single-ended input, differential output, and input and output referenced to midsupply, unless otherwise noted.



## **TEST CIRCUITS**

#### **Overview**

The THS4521, THS4522, and THS4524 family is tested with the test circuits shown in this section; all circuits are built using the available THS4521 evaluation module (EVM). For simplicity. power-supply decoupling is not shown; see the layout in the Applications section for recommendations. Depending on the test conditions, component values change in accordance with Table 1 and Table 2, or as otherwise noted. In some cases the signal generators used are ac-coupled and in others they dc-coupled 50- $\Omega$  sources. To balance the amplifier when ac-coupled, a  $0.22-\mu F$  capacitor and  $49.9-\Omega$ resistor to ground are inserted across RIT on the alternate input; when dc-coupled, only the  $49.9-\Omega$ resistor to ground is added across RIT. A split power supply is used to ease the interface to common test equipment, but the amplifier can be operated in a single-supply configuration as described in the Applications section with no impact on performance. Also, for most of the tests, except as noted, the devices are tested with single-ended inputs and a transformer on the output to convert the differential output to single-ended because common lab test equipment has single-ended inputs and outputs. Similar or better performance can be expected with differential inputs and outputs.

As a result of the voltage divider on the output formed by the load component values, the amplifier output is attenuated. The **Atten** column in Table 2 shows the attenuation expected from the resistor divider. When using a transformer at the output (as shown in Figure 54), the signal sees slightly more loss because of transformer and line loss; these numbers are approximate.

Table 1. Gain Component Values for Single-Ended Input<sup>(1)</sup>

Gain	R <sub>F</sub>	R <sub>G</sub>	R <sub>IT</sub>
1 V/V	1 kΩ	1 kΩ	52.3 Ω
2 V/V	1 kΩ	487 Ω	53.6 Ω
5 V/V	1 kΩ	187 Ω	59.0 Ω
10 V/V	1 kΩ	86.6 Ω	69.8 Ω

1. Gain setting includes  $50-\Omega$  source impedance. Components are chosen to achieve gain and  $50-\Omega$  input termination.

Table 2. Load Component Values For 1:1			
Differential to Single-Ended Output Transformer <sup>(1)</sup>			

RL	Ro	R <sub>ot</sub>	Atten
100 Ω	24.9 Ω	Open	6 dB
200 Ω	86.6 Ω	69.8 Ω	16.8 dB
499 Ω	237 Ω	56.2 Ω	25.5 dB
1 kΩ	487 Ω	52.3 Ω	31.8 dB

1. Total load includes  $50-\Omega$  termination by the test equipment. Components are chosen to achieve load and  $50-\Omega$  line termination through a 1:1 transformer.

#### Frequency Response

The circuit shown in Figure 53 is used to measure the frequency response of the circuit.

An HP network analyzer is used as the signal source and the measurement device. The output impedance of the HP network analyzer is is dc-coupled and is 50  $\Omega$ . R<sub>IT</sub> and R<sub>G</sub> are chosen to impedance-match to 50  $\Omega$  and maintain the proper gain. To balance the amplifier, a 49.9- $\Omega$  resistor to ground is inserted across R<sub>IT</sub> on the alternate input.

The output is probed using a Tektronix high-impedance differential probe across the  $953-\Omega$  resistor and referred to the amplifier output by adding back the 0.42-dB because of the voltage divider on the output.

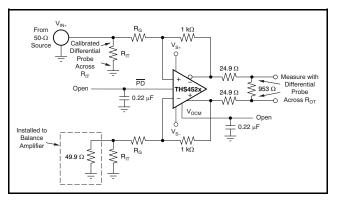


Figure 53. Frequency Response Test Circuit



## Distortion

The circuit shown in Figure 54 is used to measure harmonic and intermodulation distortion of the amplifier.

An HP signal generator is used as the signal source and the output is measured with a Rhode and Schwarz spectrum analyzer. The output impedance of the HP signal generator is ac-coupled and is 50  $\Omega$ . R<sub>IT</sub> and R<sub>G</sub> are chosen to impedance match to 50  $\Omega$ and maintain the proper gain. To balance the amplifier, a 0.22-µF capacitor and 49.9- $\Omega$  resistor to ground are inserted across R<sub>IT</sub> on the alternate input.

A low-pass filter is inserted in series with the input to reduce harmonics generated at the signal source. The level of the fundamental is measured and then a high-pass filter is inserted at the output to reduce the fundamental so it does not generate distortion in the input of the spectrum analyzer.

The transformer used in the output to convert the signal from differential to single-ended is an ADT1–1WT. It limits the frequency response of the circuit so that measurements cannot be made below approximately 1 MHz.

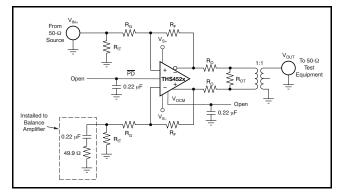


Figure 54. Distortion Test Circuit

### Slew Rate, Transient Response, Settling Time, Output Impedance, Overdrive, Output Voltage, and Turn-On/Turn-Off Time

The circuit shown in Figure 55 is used to measure slew rate, transient response, settling time, output impedance, overdrive recovery, output voltage swing, and amplifier turn-on/turn-off time. Turn-on and turn-off time are measured with the same circuit modified for 50- $\Omega$  input impedance on the PD input by replacing the 0.22- $\mu$ F capacitor with a 49.9- $\Omega$  resistor. For output impedance, the signal is injected at V<sub>OUT</sub> with V<sub>IN</sub> open; the drop across the 2x 49.9- $\Omega$  resistors is then used to calculate the impedance seen looking into the amplifier output.

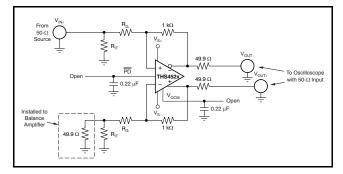


Figure 55. Slew Rate, Transient Response, Settling Time, Output Impedance, Overdrive Recovery, V<sub>OUT</sub> Swing, and Turn-On/Turn-Off Test Circuit



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#### **Common-Mode and Power-Supply Rejection**

The circuit shown in Figure 56 is used to measure the CMRR. The signal from the network analyzer is applied common-mode to the input. Figure 57 is used to measure the PSRR of V<sub>S+</sub> and V<sub>S-</sub>. The power supply under test is applied to the network analyzer dc offset input. For both CMRR and PSRR, the output is probed using a Tektronix high-impedance differential probe across the 953- $\Omega$  resistor and referred to the amplifier output by adding back the 0.42-dB as a result of the voltage divider on the output. For these tests, the resistors are matched for best results.

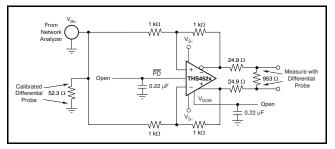


Figure 56. CMRR Test Circuit

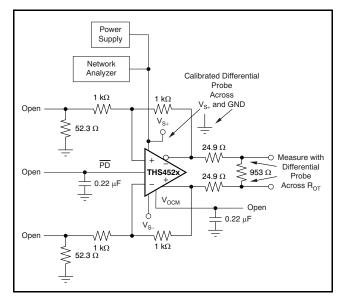


Figure 57. PSRR Test Circuit

## V<sub>OCM</sub> Input

The circuit illustrated in Figure 58 is used to measure the frequency response and input impedance of the  $V_{OCM}$  input. Frequency response is measured using a Tektronix high-impedance differential probe, with  $R_{CM}$  = 0  $\Omega$  at the common point of  $V_{OUT+}$  and  $V_{OUT-}$ , formed at the summing junction of the two matched 499- $\Omega$  resistors, with respect to ground. The input impedance is measured using a Tektronix high-impedance differential probe at the  $V_{OCM}$  input with  $R_{CM}$  = 10 k $\Omega$  and the drop across the 10-k $\Omega$  resistor is used to calculate the impedance seen looking into the amplifier  $V_{OCM}$  input.

The circuit shown in Figure 59 measures the transient response and slew rate of the V<sub>OCM</sub> input. A 1-V step input is applied to the V<sub>OCM</sub> input and the output is measured using a 50- $\Omega$  oscilloscope input referenced back to the amplifier output.

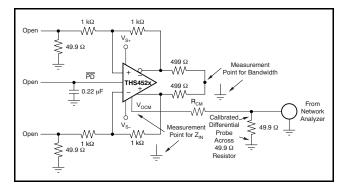


Figure 58. V<sub>OCM</sub> Input Test Circuit

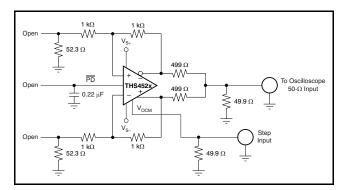


Figure 59. V<sub>OCM</sub> Transient Response and Slew Rate Test Circuit



THS4521 THS4522 THS4524 SBOS458F – DECEMBER 2008 – REVISED SEPTEMBER 2011

### **APPLICATION INFORMATION**

The following circuits show application information for the THS4521, THS4522, and THS4524 family. For simplicity, power-supply decoupling capacitors are not shown in these diagrams; see the *EVM* and *Layout Recommendations* section for suggested guidelines. For more details on the use and operation of fully differential op amps, refer to the Application Report *Fully-Differential Amplifiers* (SLOA054), available for download from the TI web site at www.ti.com.

# Differential Input to Differential Output Amplifier

The THS4521, THS4522, and THS4524 family are fully-differential operational amplifiers that can be used to amplify differential input signals to differential output signals. Figure 60 shows <u>a</u> basic block diagram of the circuit ( $V_{OCM}$  and PD inputs not shown). The gain of the circuit is set by  $R_F$  divided by  $R_G$ .

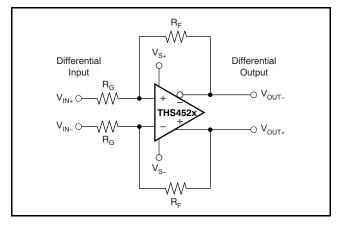
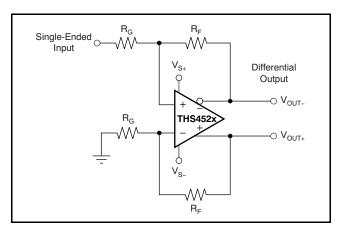


Figure 60. Differential Input to Differential Output Amplifier

# Single-Ended Input to Differential Output Amplifier

The THS4521, THS4522, and THS4524 family can also amplify and convert single-ended input signals to differential output signals. Figure 61 illustrates a basic block diagram of the circuit ( $V_{OCM}$  and  $\overline{PD}$  inputs not shown). The gain of the circuit is again set by  $R_F$  divided by  $R_G$ .



#### Figure 61. Single-Ended Input to Differential Output Amplifier

#### Input Common-Mode Voltage Range

The input common-mode voltage of a fully-differential op amp is the voltage at the + and - input pins of the device.

It is important to not violate the input common-mode voltage range ( $V_{ICR}$ ) of the op amp. Assuming the op amp is in linear operation, the voltage across the input pins is only a few millivolts at most. Therefore, finding the voltage at one input pin determines the input common-mode voltage of the op amp.

Treating the negative input as a summing node, the voltage is given by Equation 1:

$$V_{OUT+} \times \frac{R_{G}}{R_{G} + R_{F}} + \left( V_{IN-} \times \frac{R_{F}}{R_{G} + R_{F}} \right)$$
(1)

To determine the  $V_{ICR}$  of the op amp, the voltage at the negative input is evaluated at the extremes of  $V_{OUT+}$ . As the gain of the op amp increases, the input common-mode voltage becomes closer and closer to the input common-mode voltage of the source.

#### Setting the Output Common-Mode Voltage

The output common-model voltage is set by the voltage at the V<sub>OCM</sub> pin. The internal common-mode control circuit maintains the output common-mode voltage within 5-mV offset (typ) from the set voltage. If left unconnected, the common-mode set point is set to midsupply by internal circuitry, which may be overdriven from an external source.

## THS4521 THS4522 THS4524



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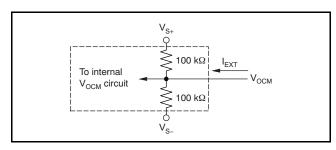
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Figure 62 represents the V<sub>OCM</sub> input. The internal V<sub>OCM</sub> circuit has typically 23 MHz of –3 dB bandwidth, which is required for best performance, but it is intended to be a dc bias input pin. A 0.22- $\mu$ F bypass capacitor is recommended on this pin to reduce noise. The external current required to overdrive the internal resistor divider is given approximately by the formula in Equation 2:

$$I_{EXT} = \frac{2V_{OCM} - (V_{S+} - V_{S-})}{50 \text{ k}\Omega}$$

where:

• V<sub>OCM</sub> is the voltage applied to the V<sub>OCM</sub> pin (2)





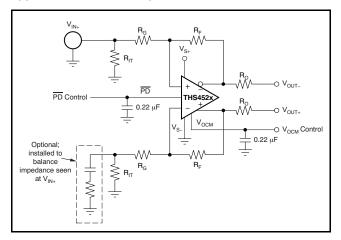
# Typical Performance Variation with Supply Voltage

The THS4521, THS4522, and THS4524 family of devices provide excellent performance across the specified power-supply range of 2.5 V to 5.5 V with only minor variations. The input and output voltage compliance ranges track with the power supply in nearly a 1:1 correlation. Other changes can be observed in slew rate, output current drive, open-loop gain, bandwidth, and distortion. Table 3 shows the typical variation to be expected in these key performance parameters.

### Single-Supply Operation

To facilitate testing with common lab equipment, the THS4521EVM allows for split-supply operation; most of the characterization data presented in this data sheet is measured using split-supply power inputs. The device can easily be used with a single-supply power input without degrading performance.

Figure 63 shows a dc-coupled single-supply circuit with single-ended inputs. This circuit can also be applied to differential input sources.



# Figure 63. THS4521 DC-Coupled Single-Supply with Single-Ended Inputs

The input common-mode voltage range of the THS4521, THS4522, and THS4524 family is designed to include the negative supply voltage. in the circuit shown in Figure 63, the signal source is referenced to ground.  $V_{OCM}$  is set by an external control source or, if left unconnected, the internal circuit defaults to midsupply. Together with the input impedance of the amplifier circuit, R<sub>IT</sub> provides input termination, which is also referenced to ground.

Note that  $R_{IT}$  and optional matching components are added to the alternate input to balance the impedance at signal input.

PARAMETER	V <sub>S</sub> = 5 V	V <sub>S</sub> = 3.3 V	V <sub>S</sub> = 2.5 V
–3-dB Small-signal bandwidth	145 MHz	135 MHz	125 MHz
Slew rate (2-V step)	490 V/µs	420 V/µs	210 V/µs
Harmonic distortion at 1 MHz, 2 V <sub>PP</sub> , $R_L$ = 1 k $\Omega$		·	
harmonic	-85 dBc	-85 dBc	-84 dBc
harmonic	–91 dBc	-90 dBc	-88 dBc
Open-loop gain	119 dB	116 dB	115 dB
Linear output current drive	55 mA	35 mA	24 mA

#### Table 3. Typical Performance Variation versus Power-Supply Voltage

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## Low-Power Applications and the Effects of Resistor Values on Bandwidth

For low-power operation, it may be necessary to increase the gain setting resistors values to limit current consumption and not load the source. Using larger value resistors lowers the bandwidth of the THS4521, THS4522, and THS4524 family as a result of the interactions between the resistors, the device parasitic capacitance, and printed circuit board (PCB) parasitic capacitance. Figure 64 shows the small-signal frequency response with 1-k $\Omega$ , 10-k $\Omega$ , and 100-k $\Omega$  resistors for R<sub>F</sub>, R<sub>G</sub>, and R<sub>L</sub> (impedance is assumed to typically increase for all three resistors in low-power applications).

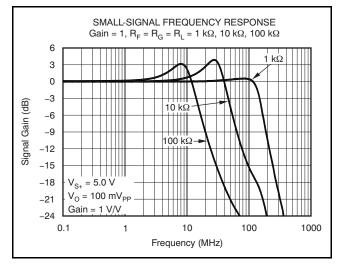


Figure 64. THS4521 Frequency Response with Various Gain Setting and Load Resistor Values

#### Frequency Response Variation due to Package Options

Users can see variations in the small-signal ( $V_{OUT} = 100 \text{ mV}_{PP}$ ) frequency response between the available package options for the THS4521, THS4522, and THS4524 family as a result of parasitic elements associated with each package and board layout changes. Figure 65 shows the variance measured in the lab; this variance is to be expected even when using a good layout.

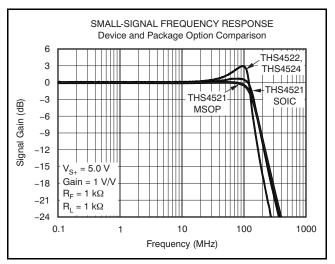


Figure 65. Small-Signal Frequency Response: Package Variations



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#### **Driving Capacitive Loads**

The THS4521, THS4522, and THS4524 family is designed for a nominal capacitive load of 1 pF on each output to ground. When driving capacitive loads greater than 1 pF, it is recommended to use small resistors (R<sub>0</sub>) in series with the output, placed as close to the device as possible. Without Ro, capacitance on the output interacts with the output impedance of the amplifier and causes phase shift in the loop gain of the amplifier that reduces the phase margin. This reduction in phase margin results in frequency response peaking; overshoot, undershoot, and/or ringing when a step or square-wave signal is applied; and may lead to instability or oscillation. Inserting  $R_{\Omega}$  isolates the phase shift from the loop gain path and restores the phase margin, but it also limits bandwidth. Figure 66 shows the recommended values of R<sub>O</sub> versus capacitive loads (C<sub>L</sub>), and Figure 67 shows an illustration of the frequency response with various values.

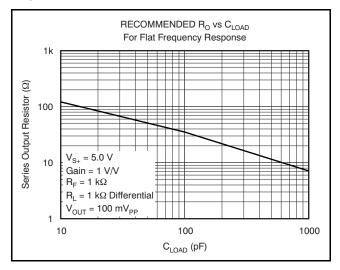
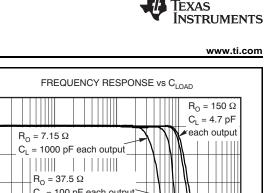
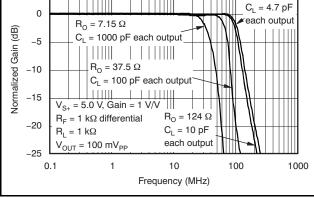
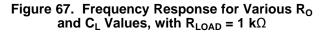


Figure 66. Recommended Series Output Resistor versus Capacitive Load for Flat Frequency Response, with  $R_{LOAD} = 1 \text{ k}\Omega$ 



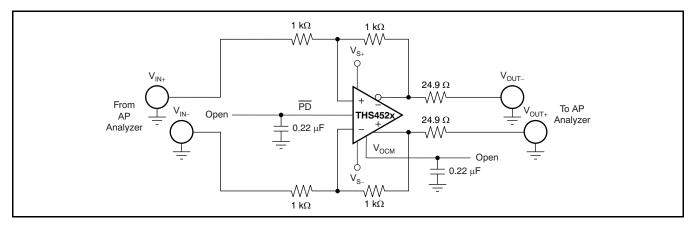




#### **Audio Performance**

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The THS4521, THS4522, and THS4524 family provide excellent audio performance with very low quiescent power. To show performance in the audio band, the device was tested with a SYS-2722 audio analyzer from Audio Precision. THD+N and FFT tests were performed at  $1-V_{RMS}$  output voltage. Performance is the same on both 3.3-V and 5-V supplies. Figure 68 shows the test circuit used; see Figure 69 and Figure 70 for the performance of the analyzer using internal loopback mode (generator) together with the THS4521.







Note that the harmonic distortion performance is very close to the same with and without the device meaning the THS4521 performance is actually much better than can be directly measured by this meathod. The actual device performance can be estimated by placing the device in a large noise gain and using the reduction in loop gain correction. The THS4521 is placed in a noise gain of 101 by adding a 10- $\Omega$  resistor directly across the input terminals of the circuit shown in Figure 68. This test was performed using the AP instrument as both the signal source and the analyzer. The second-order harmonic distortion at 1 kHz is estimated to be -122 dBc with  $V_O = 1V_{RMS}$ ; third-order harmonic distortion is estimated to be -141 dBc. The third-order harmonic distortion result matches exactly with design simulations, but the second-order harmonic distortion is about 10 dB worse. This result is not unexpected second-order distortion because harmonic performance with a differential signal depends heavily on cancellation as a result of the differential nature of the signal, which depends on board layout, bypass capacitors, external cabling, and so forth. Note that the circuit of Figure 68 is also used to measure crosstalk between channels.

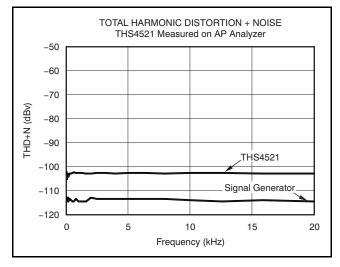


Figure 69. THS4521 1-V<sub>RMS</sub> 20-Hz to 20-kHz THD+N



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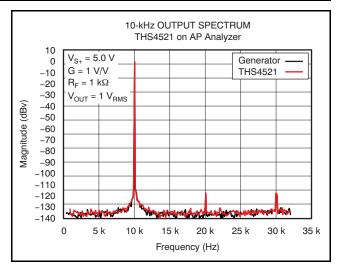


Figure 70. THS4521 1-V<sub>RMS</sub> 10-kHz FFT Plot

The THS4521 shows even better THD+N performance when driving higher amplitude output, such as 5  $V_{PP}$  that is more typical when driving an ADC. To show performance with an extended frequency range, higher gain, and higher amplitude, the device was tested with 5  $V_{PP}$  up to 80 kHz with the AP. Figure 71 shows the resulting THD+N graph with no weighting.

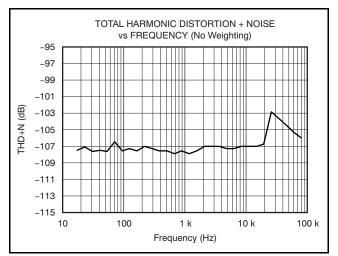


Figure 71. THD+N (No Weighting) on AP, 80-kHz Bandwidth at G = 1 with 5-V<sub>PP</sub> Output

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## TEXAS INSTRUMENTS

#### Audio On/Off Pop Performance

The THS4521 was tested to show on and off pop performance by connecting a speaker between the differential outputs and switching the power supply on and off, and also by using the PD function of the THS4521. Testing was done with and without tones. During these tests, no audible pop could be heard.

With no tone input, Figure 72 shows the pop performance when switching power on to the THS4521 and Figure 73 shows the device performance when turning the power off. The transients during power on and off illustrate that no audible pop should be heard

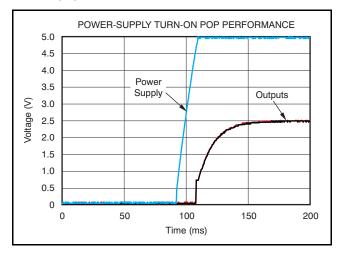


Figure 72. THS4521 Power-Supply Turn-On Pop Performance

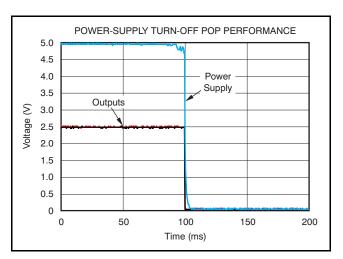


Figure 73. THS4521 Power-Supply Turn-Off Pop Performance

With no tone input, Figure 74 shows the pop performance using the PD pin to enable the THS4521, and Figure 75 shows performance using the PD pin to disable the device. Again, the transients during power on and off show that no audible pop should be heard. It should also be noted that the turn on/off times are faster using the PD pin technique.

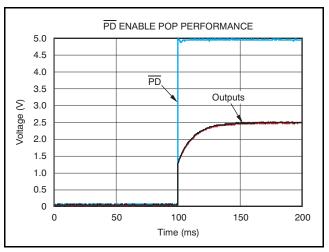


Figure 74. THS4521 PD Pin Enable Pop Performance

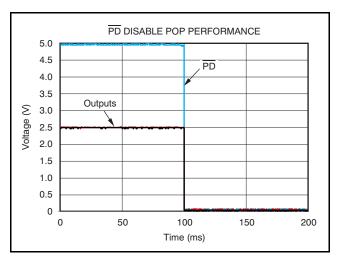


Figure 75. THS4521 PD Pin Disable Pop Performance

The power on/off pop performance of the THS4521, whether by switching the power supply or when using the power-down function built into the chip, shows that no special design should be required to prevent an audible pop.



#### Audio ADC Driver Performance: THS4521 and PCM4204 Combined Performance

То show achievable performance with а high-performance audio ADC, the THS4521 is tested as the drive amplifier for the PCM4204. The PCM4204 is a high-performance, four-channel ADC designed for professional and broadcast audio applications. The PCM4204 architecture uses a 1-bit delta-sigma ( $\Delta\Sigma$ ) modulator per channel that incorporates an advanced dither scheme for improved dynamic performance, and supports PCM output data. The PCM4204 provides a flexible serial port interface and many other advanced features. Refer to the PCM4204 product data sheet for more information.

The PCM4204EVM can test the audio performance of the THS4521 as a drive amplifier. The standard PCM4204EVM is provided with four OPA1632 fully-differential amplifiers, which use the same device pinout as the THS4521. For testing, one of these amplifiers is replaced with a THS4521 device in same package (MSOP), and the power supply changes to a single-supply +5V. Figure 78 shows the modifications made to the circuit. Note the resistor connecting the VOCM input of the THS4521 to the input common-mode drive from the PCM4204 is shown removed and is optional; no performance change was noted with it connected or removed. The THS4521 is operated with a +5-V single-supply so the output common-mode defaults to +2.5 V as required at the input of the PCM4204. The EVM power connections were modified by connecting positive supply inputs,

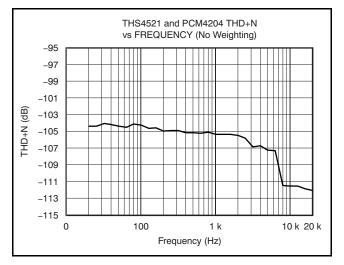


Figure 76. THS4521 and PCM4204: THD+N versus Frequency with No Weighting

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+15 V, +5 VA and +5 VD, to a +5-V external power supply (EXT +3.3 was not used) and connecting –15 V and all ground inputs to ground on the external power supply. Note only one external +5-V supply was needed to power all devices on the EVM.

A SYS-2722 Audio Analyzer from Audio Precision (AP) provides an analog audio input to the EVM; the PCM-formatted digital output is read by the digital input on the AP.

Data were taken using a 256- $f_S$  system clock to achieve  $f_S = 48$ -kHz measurements, and audio output uses PCM format. Other data rates and formats are expected to show similar performance in line with that shown in the product data sheet.

Figure 76 shows the THD+N vs Frequency response with no weighting; Figure 77 shows an FFT of the output with 1-kHz input tone. Input signals to the PCM4204 for these tests is 0.5 dBFS. Dynamic range is also tested at -60 dBFS,  $f_{IN} = 1$  kHz, and A-weighted. Table 4 summarizes testing results using the THS4521 together with the PCM4204 versus typical data sheet performance measurements, and show that it make an excellent drive amplifier for this ADC.

The test circuit shown in Figure 78 has a gain = 0.27 and attenuates the input signal. For applications that require higher gain, the circuit was modified to gains of G = 1, G = 2, and G = 5 by replacing the feedback resistors (R33 and R34) and re-tested to show performance.

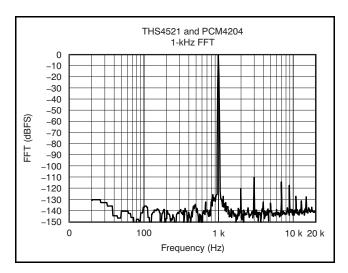


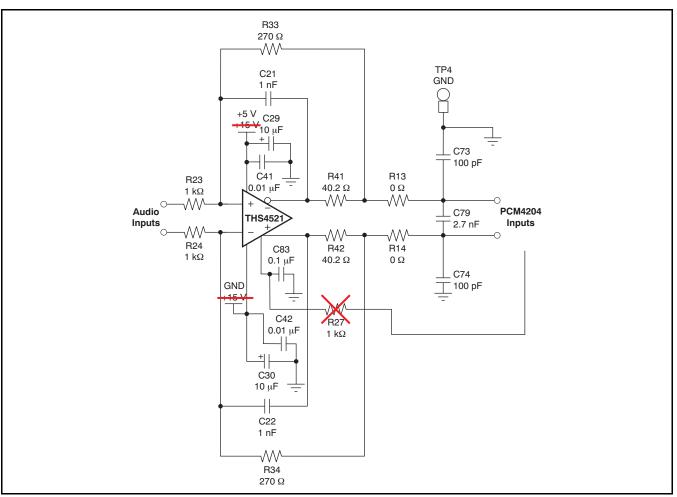
Figure 77. THS4521 and PCM4204 1-kHz FFT

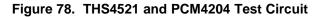
THS4521 THS4522 THS4524



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# Table 4. 1-kHz AC Analysis: Test Circuit versus PCM4204 Data Sheet Typical Specifications ( $f_S = 48 \text{ kSPS}$ )

Configuration	Tone	THD+N	Dynamic Range
THS4521 and PCM4204	1 kHz	–106 dBc	117 dB
PCM4204 Data sheet (typ)	1 kHz	–105 dBc	118 dB



THS4521 THS4522 THS4524

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Figure 79 shows the THS4521 and PCM4204 THD+N versus frequency with no weighting at higher gains.

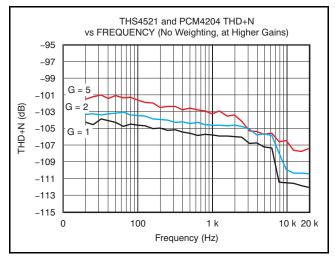


Figure 79. THS4521 and PCM4204: THD+N versus Frequency with No Weighting at Higher Gains

#### Audio ADC Driver Performance: THS4521 and PCM3168 Combined Performance

The THS4521 is also tested as the drive amplifier for the PCM3168A ADC input. The PCM3168A is a high-performance, single-chip, 24-bit, 6-in/8-out, audio coder/decoder (codec) with single-ended and differential selectable analog inputs and differential outputs. The six-channel, 24-bit ADC employs a  $\Delta\Sigma$ modulator and supports 8-kHz to 96-kHz sampling rates and a 16-bit/24-bit width digital audio output word on the audio interface. The eight-channel, 24-bit digital-to-analog converter (DAC) employs a  $\Delta\Sigma$ modulator and supports 8-kHz to 192-kHz sampling rates and a 16-bit/24-bit width digital audio input word on the audio interface. Each audio interface supports I<sup>2</sup>S<sup>™</sup>, left-/right-justified, and DSP formats with 16-bit/24-bit word width. In addition, the PCM3168A supports the time-division-multiplexed (TDM) format.. The PCM3168A provides flexible serial port interface and many other advanced features. Refer to the PCM3168A product data sheet for more information.

The PCM3168A EVM is used to test the audio performance of the THS4521 as a drive amplifier. The standard PCM3168A EVM is provided with OPA2134 op amps that are used to convert single-ended inputs to differential to drive the ADC. For testing, the op amp output series resistors are removed from one of the channels and a THS4521, mounted on its standard EVM, is connected to the ADC inputs via short coaxial cables. The THS4521

SBOS458F – DECEMBER 2008–REVISED SEPTEMBER 2011 EVM is configured for both differential inputs as shown in Figure 60 and for single-ended input as shown in Figure 61 with 1-k $\Omega$  resistors for R<sub>F</sub> and R<sub>G</sub>, and 24.9- $\Omega$  resistors in series with each output to

and 24.9- $\Omega$  resistors in series with each output to isolate the outputs from the reactive load of the coaxial cables. To limit the noise from the external EVM and cables, a 2.7-nF capacitor is placed differentially across the PCM3168A inputs. The THS4521 is operated with a single-supply +5-V supply so the output common-mode of the THS4521 defaults to +2.5 V as required at the input of the PCM3168A. The PCM3168A EVM is configured and operated as described in the PCM3168AEVM User Guide. The ADC was tested with an external THS4521 EVM with both single-ended input and differential inputs. In both configurations, the results are the same. Figure 80 shows the THD+N versus frequency and Table 5 compares the result to the PCM3168 data sheet typical specification at 1 kHz. Both graphs show that it makes an excellent drive amplifier for this ADC. Note: a 2700 series Audio Analyzer from Audio Precision is used to generate the input signals to the THS4521 and to analyze the digital data from the PCM3168.

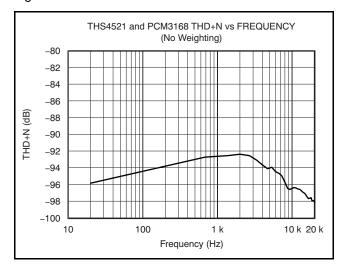


Figure 80. THS4521 and PCM3168: THD+N versus Frequency with No Weighting

Table 5. 1-kHz AC Analysis: Test Circuit vs
PCM3168 Data Sheet Typical Specifications
(f <sub>S</sub> = 48 kSPS)

Configuration	Tone	THD+N		
THS4521 and PCM3168	1 kHz	–92.6 dBc		
PCM3168 Data sheet (typ)	1 kHz	–93 dBc		

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## Texas **INSTRUMENTS**

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#### ADC Driver Performance: THS4521 and ADS1278 Combined Performance

The THS4521 provides excellent performance when high-performance ΔΣ and drivina successive approximation register (SAR) ADCs in audio and industrial applications using a single 3-V to 5-V power supply. To show achievable performance, the THS4521 is tested as the drive amplifier for the ADS1278 24-bit ADC. The ADS1278 offers excellent ac and dc performance, with four selectable operating modes from 10 kSPS to 128 kSPS to enable the user to fine-tune performance and power for specific application needs. The circuit shown in Figure 81 was used to test the performance. Data were taken using the High-Resolution mode (52 kSPS) of the ADS1278 with input frequencies at 1 kHz and 10 kHz and signal levels 1/2 dB below full-scale (-0.5 dBFS). FFT plots showing the spectral performance are given in Figure 82 and Figure 83; tabulated ac analysis results are shown in Table 6 and compared to the ADS1278 data sheet typical performance specifications.

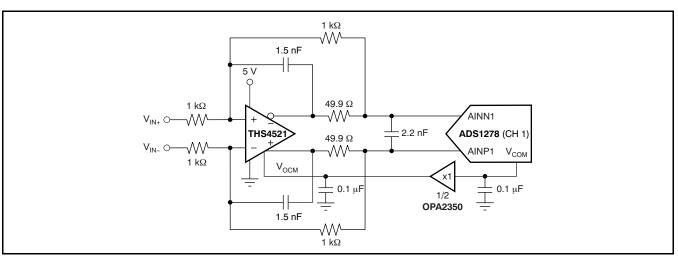


Figure 81. THS4521 and ADS1278 (Ch 1) Test Circuit

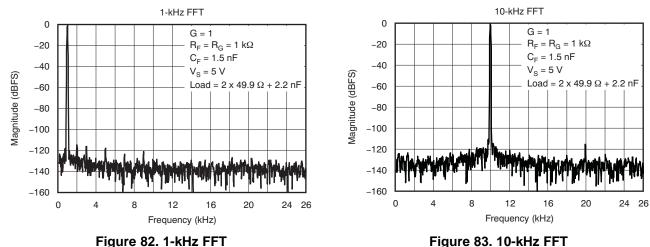


Figure 82. 1-kHz FFT

Table 6. AC Analysis

Configuration	Tone	Signal (dBFS)	SNR (dBc)	THD (dBc)	SINAD (dBc)	SFDR (dBc)
THS4521and	1 kHz	-0.5	109	-108	105	114
ADS1278	10 kHz	-0.5	102	-110	101	110
ADS1278 Data sheet (typ)	1 kHz	-0.5	110	-108	_	109



THS4521 THS4522 THS4524

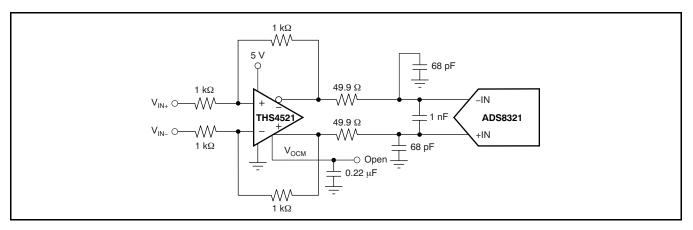
www.ti.com

#### ADC Driver Performance: THS4521 and ADS8321 Combined Performance

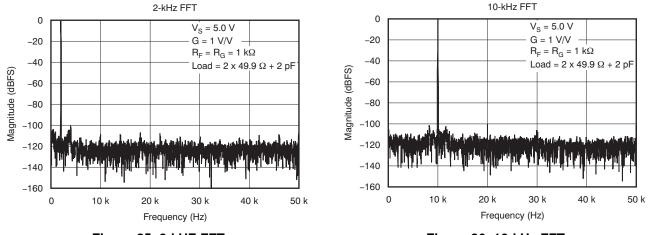
To demonstrate achievable performance, the THS4521 is tested as the drive amplifier for the ADS8321 16-bit SAR ADC. The ADS8321 offers excellent ac and dc performance, with ultra-low power and small size. The circuit shown in Figure 84 was used to test the performance.

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Data were taken using the ADS8321 at 100 kSPS with input frequencies of 2 kHz and 10 kHz and signal levels that were -0.5 dBFS. FFT plots that illustrate the spectral performance are given in Figure 85 and Figure 86. Tabulated ac analysis results are listed in Table 7 and compared to the ADS8321 data sheet typical performance.







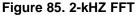


Figure 86. 10-kHz FFT

Table	7.	AC	Analysis
-------	----	----	----------

Configuration	Tone	Signal (dBFS)	SNR (dBc)	THD (dBc)	SINAD (dBc)	SFDR (dBc)
THS4521 and	2 kHz	-0.5	86.7	-97.8	86.4	100.7
ADS8321	10 kHz	-0.5	85.2	-98.1	85.2	102.2
ADS8321 Data sheet (typ)	10 kHz	-0.5	87	-86	84	86



## EVM AND LAYOUT RECOMMENDATIONS

Figure 87 shows the THS4521EVM schematic. PCB layers 1 through 4 are shown in Figure 88; Table 8 lists the bill of materials for the THS4521EVM as supplied from TI. It is recommended to follow the layout of the external components near to the amplifier, ground plane construction, and power routing as closely as possible. Follow these general guidelines:

- 1. Signal routing should be direct and as short as possible into and out of the op amp circuit.
- 2. The feedback path should be short and direct.
- 3. Ground or power planes should be removed from directly under the amplifier input and output pins.
- 4. An output resistor is recommended in each output lead, placed as near to the output pins as possible.
- 5. Two 0.1-µF power-supply decoupling capacitors should be placed as near to the power-supply pins as possible.
- 6. Two 10-μF power-supply decoupling capacitors should be placed within 1 inch of the device and can be shared among multple analog devices.
- A 0.22-µF capacitor should be placed between the V<sub>OCM</sub> input pin and ground near to the pin. This capacitor limits noise coupled into the pin.
- 8. The PD pin uses TTL logic levels; a bypass capacitor is not necessary if actively driven, but can be used for robustness in noisy environments whether driven or not.
- 9. If input termination resistors  $R_{10}$  and  $R_{11}$  are used, a single point connection to ground on L2 is recommended.

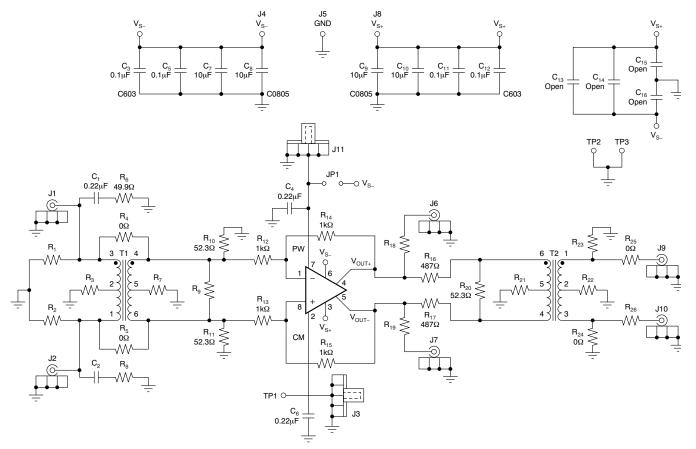


Figure 87. THS4521EVM: Schematic





THS4524 SBOS458F – DECEMBER 2008 – REVISED SEPTEMBER 2011

THS4521

THS4522

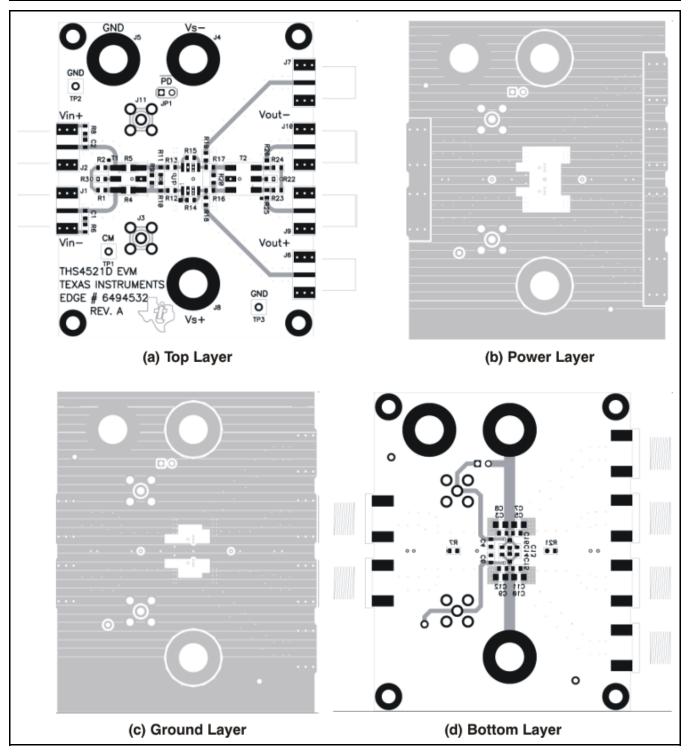


Figure 88. THS4521EVM: Layer 1 to Layer 4 Images



### Table 8. THS4521EVM Parts List

ITEM	DESCRIPTION	SMD SIZE	REFERENCE DESIGNATOR	QTY	MANUFACTURER PART NUMBER
1	Capacitor, 10.0 µF, ceramic, X5R, 6.3 V	0805	C7, C8, C9, C10	4	(AVX) 08056D106KAT2A
2	Capacitor, 0.1 µF, ceramic, X7R, 16 V	0603	C3, C5, C11, C12	4	(AVX) 0603YC104KAT2A
3	Capacitor, 0.22 µF, ceramic, X7R, 10 V	0603	C1, C4, C6	3	(AVX) 0603ZC224KAT2A
4	Open	0603	C2, C13, C14, C15, C16	5	
5	Open	0603	R1, R2, R3, R7, R8, R9, R18, R19, R21, R22, R23, R26	12	
6	Resistor, 0 Ω	0603	R24, R25	2	(ROHM) MCR03EZPJ000
7	Resistor, 49.9 Ω, 1/10W, 1%	0603	R6	1	(ROHM) MCR03EZPFX49R9
8	Resistor, 52.3 Ω, 1/10W, 1%	0603	R10, R11, R20	3	(ROHM) MCR03EZPFX52R3
9	Resistor, 487 Ω, 1/10W, 1%	0603	R16, R17	2	(ROHM) MCR03EZPFX4870
10	Resistor, 1k Ω, 1/10W, 1%	0603	R12, R13, R14, R15	4	(ROHM) MCR03EZPFX1001
11	Resistor, 0 Ω	0805	R4, R5	2	(ROHM) MCR10EZPJ000
12	Open		T1	1	
13	Transformer, RF		T2	1	(MINI-CIRCUITS) ADT1-1WT
14	Jack, Banana receptance, 0.25-in dia. hole		J4, J5, J8	3	(SPC) 813
15	Open		J1, J3, J6, J7, J10, J11	6	
16	Connector, edge, SMA PCB jack		J2, J9	2	(JOHNSON) 142-0701-801
17	Header, 0.1 in CTRS, 0.025-in sq. pins	2 POS.	JP1	1	(SULLINS) PBC36SAAN
18	Shunts		JP1	1	(SULLINS) SSC02SYAN
19	Test point, Red		TP1	1	(KEYSTONE) 5000
20	Test point, Black		TP2, TP3	2	(KEYSTONE) 5001
21	IC, THS4521		U1	1	(TI) THS4521D
22	Standoff, 4-40 hex, 0.625 in length			4	(KEYSTONE) 1808
23	Screw, Phillips, 4-40, .250 in			4	SHR-0440-016-SN
24	Board, printed circuit			1	(TI) EDGE# 6494532



### **REVISION HISTORY**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

C	hanges from Revision E (December 2010) to Revision F Page	ge
•	Changed Input Offset Current values in 3.3 V Electrical Characteristics	3
•	Changed Input Offset Current Drift values in 3.3 V Electrical Characteristics	3
•	Changed Input Offset Current values in 5 V Electrical Characteristics	6
•	Changed Input Offset Current Drift values in 5 V Electrical Characteristics	6
•	Changed R41 and R42 in Figure 78	32

Changes from Revision D (August 2010) to Revision E				
•	Changed test level indication for 5-V input offset voltage drift from B to C	5		

NSTRUMENTS

**EXAS** 

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### **EVM Warnings and Restrictions**

It is important to operate this EVM within the input voltage range of 3 V to 5.5 V and the output voltage range of 3 V to 5.5 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than +85°C. The EVM is designed to operate properly with certain components above +85°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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### **PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
THS4521ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4521IDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4521IDGKT	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4521IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4522IPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4522IPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4524IDBT	ACTIVE	TSSOP	DBT	38	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
THS4524IDBTR	ACTIVE	TSSOP	DBT	38	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	

<sup>(1)</sup> The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.



16-Jan-2012

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#### OTHER QUALIFIED VERSIONS OF THS4521 :

NOTE: Qualified Version Definitions:

# PACKAGE MATERIALS INFORMATION

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### TAPE AND REEL INFORMATION

### REEL DIMENSIONS

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TAPE AND REEL INFORMATION

### TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

*All dimensions are nominal												
Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
THS4521IDGKR	MSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
THS4521IDGKT	MSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
THS4521IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
THS4522IPWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
THS4524IDBTR	TSSOP	DBT	38	2000	330.0	16.4	6.9	10.2	1.8	12.0	16.0	Q1

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# PACKAGE MATERIALS INFORMATION

1-Dec-2011



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
THS4521IDGKR	MSOP	DGK	8	2500	346.0	346.0	29.0
THS4521IDGKT	MSOP	DGK	8	250	210.0	185.0	35.0
THS4521IDR	SOIC	D	8	2500	346.0	346.0	29.0
THS4522IPWR	TSSOP	PW	16	2000	346.0	346.0	29.0
THS4524IDBTR	TSSOP	DBT	38	2000	346.0	346.0	33.0

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



NOTES: A. All linear dimensions are in millimeters.

B. This drawing is subject to change without notice.

Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.

- D Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
- E. Falls within JEDEC MO-187 variation AA, except interlead flash.



PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



NOTES:

A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.  $\beta$ . This drawing is subject to change without notice.

Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.

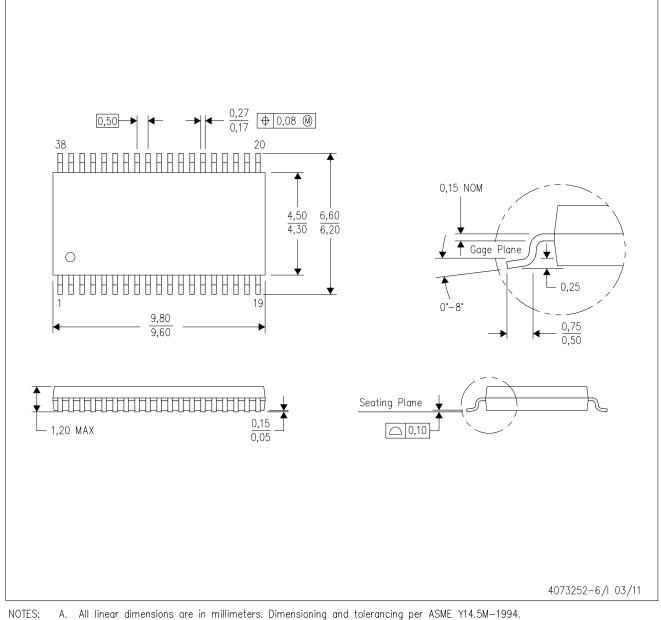
Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.

E. Falls within JEDEC MO-153



DBT (R-PDSO-G38)

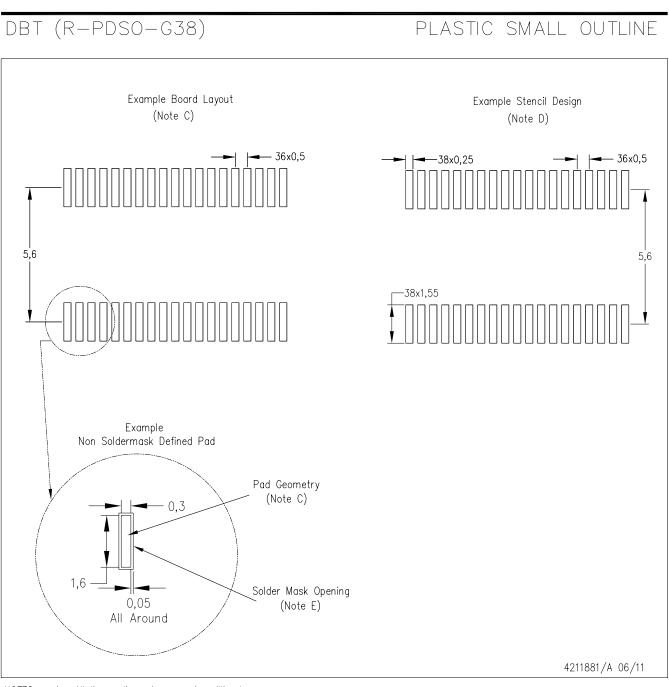
PLASTIC SMALL OUTLINE



B. This drawing is subject to change without notice.

- C. Body dimensions do not include mold flash or protrusion.
- D. Falls within JEDEC MO-153.





- NOTES: A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.



## LAND PATTERN DATA



NOTES: A. All linear dimensions are in millimeters.

- B. This drawing is subject to change without notice.
- C. Publication IPC-7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



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DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
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Interface	interface.ti.com	Medical	www.ti.com/medical
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