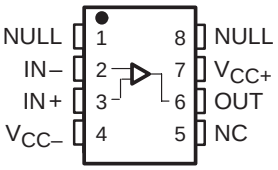
THS4011, THS4012
290-MHz LOW-DISTORTION HIGH-SPEED AMPLIFIERS

SLOS216B – JUNE 1999 – FEBRUARY 2000

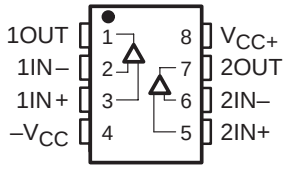
- **Very High Speed**
  - **290 MHz Bandwidth (G = 1, –3 dB)**
  - **310 V/μs Slew Rate**
  - **37 ns Settling Time (0.1%)**
- **Very Low Distortion**
  - **THD = –80 dBc (f = 1 MHz, R_L = 150 Ω)**
- **110 mA Output Current Drive (Typical)**
- **7.5 nV/√Hz Voltage Noise**
- **Excellent Video Performance**
  - **70 MHz Bandwidth (0.1 dB, G = 1)**
  - **0.006% Differential Gain Error**
  - **0.01° Differential Phase Error**
- **±5 V to ±15 V Supply Voltage**
- **Available in Standard SOIC, MSOP PowerPAD, JG, or FK Packages**
- **Evaluation Module Available**

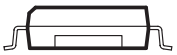
THS4011
JG, D AND DGN PACKAGE
(TOP VIEW)



NC – No internal connection

THS4012
D AND DGN† PACKAGE
(TOP VIEW)

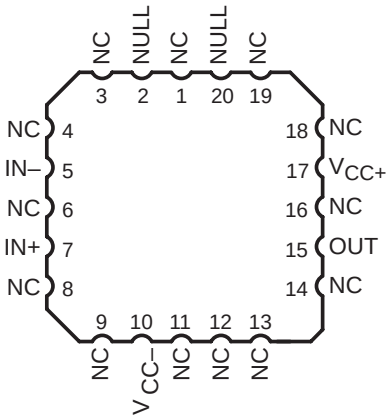




Cross Section View Showing
PowerPAD Option (DGN)

† This device is in the Product Preview stage of development. Please contact your local TI sales office for availability.

THS4011
FK PACKAGE
(TOP VIEW)



description

The THS4011 and THS4012 are very high speed, single/dual, voltage feedback amplifiers ideal for a wide range of applications. The devices offer very good ac performance with 290-MHz bandwidth, 310-V/μs slew rate, and 37-ns settling time (0.1%). These amplifiers have a high output drive capability of 110 mA and draw only 7.8-mA supply current per channel. For applications requiring low distortion, the THS4011/12 operate with a total harmonic distortion (THD) of –80 dBc at f = 1 MHz. For video applications, the THS4011/12 offer 0.1 dB gain flatness to 70-MHz, 0.006% differential gain error, and 0.01° differential phase error.

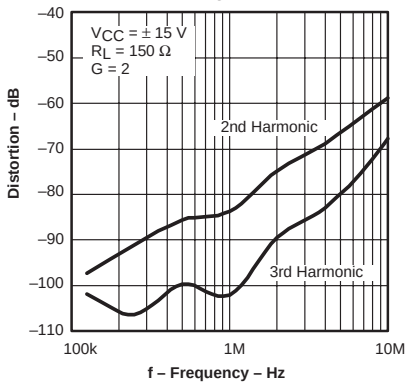
RELATED DEVICES	
DEVICE	**DESCRIPTION**
THS4011/2	290-MHz Low Distortion High-Speed Amplifiers
THS4031/2	100-MHz Low Noise High Speed-Amplifiers
THS4061/2	180-MHz High-Speed Amplifiers

CAUTION: THE THS4011 AND THS4012 provide ESD protection circuitry. However, permanent damage can still occur if this device is subjected to high-energy electrostatic discharges. Proper ESD precautions are recommended to avoid any performance degradation or loss of functionality.

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.

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

DISTORTION vs FREQUENCY



AVAILABLE OPTIONS

T_A	NUMBER OF CHANNELS	PACKAGED DEVICES				MSOP SYMBOL	EVALUATION MODULE
		PLASTIC SMALL OUTLINE† (D)	PLASTIC MSOP† (DGN)	CERAMIC DIP (JG)	CHIP CARRIER (FK)		
0°C to 70°C	1	THS4011CD	THS4011CDGN	—	—	TIACM	THS4011EVM
	2	THS4012CD	THS4012CDGN‡	—	—	TIABD	THS4012EVM
–40°C to 85°C	1	THS4011ID	THS4011IDGN	—	—	TIACN	—
	2	THS4012ID	THS4012IDGN‡	—	—	TIABZ	—
–55°C to 125°C	1	—	—	THS4011MJG	THS4011MFK	—	—

† The D and DGN packages are available taped and reeled. Add an R suffix to the device type (i.e., THS4011CDGNR).
‡ This device is in the Product Preview stage of development. Please contact your local TI sales office for availability.

functional block diagram

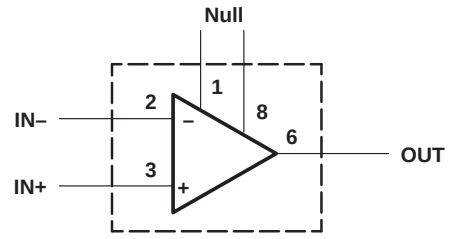


Figure 1. THS4011 – Single Channel

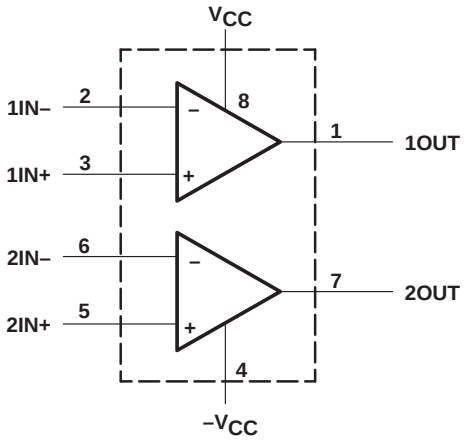


Figure 2. THS4012 – Dual Channel

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

Supply voltage, V_{CC} . . . . . ±16.5 V
Input voltage, V_I . . . . . $\pm V_{CC}$
Output current, I_O . . . . . 175 mA
Differential input voltage, V_{ID} . . . . . ±4 V
Continuous total power dissipation . . . . . See Dissipation Rating Table
Maximum junction temperature, T_J . . . . . 150°C
Operating free-air temperature, T_A, THS401xC . . . . . 0°C to 70°C
THS401xI . . . . . –40°C to 85°C
THS4011M . . . . . –55°C to 125°C
Storage temperature, T_{stg} . . . . . –65°C to 150°C
Lead temperature, 1,6 mm (1/16 inch) from case for 10 seconds, D, DGN package . . . . . 300°C
Lead temperature, 1,6 mm (1/16 inch) from case for 60 seconds, JG package . . . . . 300°C
Case temperature for 60 seconds, FK package . . . . . 260°C

† 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 under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

DISSIPATION RATING TABLE

PACKAGE	θ_{JA} (°C/W)	θ_{JC} (°C/W)	T_A = 25°C POWER RATING
D	167†	38.3	740 mW
DGN‡	58.4	4.7	2.14 W
JG	119	28	1050 mW
FK	87.7	20	1375 mW

† This data was taken using the JEDEC standard Low-K test PCB. For the JEDEC Proposed High-K test PCB, the θ_{JA} is 95°C/W with a power rating at T_A = 25°C of 1.32 W.
‡ This data was taken using 2 oz. trace and copper pad that is soldered directly to a 3 in. × 3 in. PC. For further information, refer to *Application Information* section of this data sheet.

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}	Split supply	±4.5		±16	V
	Single supply	9		32	
Operating free-air temperature, T_A	C suffix	0		70	°C
	I suffix	–40		85	
	M suffix	–55		125	

electrical characteristics, V_{CC} = ±15 V, R_L = 150 Ω, T_A = 25°C, (unless otherwise noted)

dynamic performance

PARAMETER		TEST CONDITIONS†		THS4011C/I, THS4012C/I			UNIT
				MIN	TYP	MAX	
BW	Unity-gain bandwidth (–3 dB)	Gain = 1	V_{CC} = ±15 V		290		MHz
			V_{CC} = ±5 V		270		
	Bandwidth for 0.1 dB flatness	Gain = 1	V_{CC} = ±15 V		70		MHz
			V_{CC} = ±5 V		35		
	Full power bandwidth (see Note 2)	V_{CC} = ±15 V, R_L = 150 Ω	$V_{O(PP)}$ = 20 V,		4.9		MHz
		V_{CC} = ±5 V, R_L = 150 Ω,	$V_{O(PP)}$ = 5 V,		16		
SR	Slew rate	Gain = –1, R_L = 150 Ω	V_{CC} = ±15 V		310		V/µs
			V_{CC} = ±5 V		260		
t_s	Settling time to 0.1%	V_I = –2.5 V to 2.5 V, Gain = –1	V_{CC} = ±15 V		37		ns
			V_{CC} = ±5 V		35		
	Settling time to 0.01%	V_I = –2.5 V to 2.5 V, Gain = –1	V_{CC} = ±15 V		90		ns
			V_{CC} = ±5 V		70		

† Full range = 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix.

noise/distortion performance

PARAMETER		TEST CONDITIONS†		THS4011C/I, THS4012C/I			UNIT
				MIN	TYP	MAX	
THD	Total harmonic distortion	V_{CC} = ±15 V, $V_{O(PP)}$ = 2 V	f_c = 1 MHz,		–80		dBc
V_n	Input voltage noise	V_{CC} = ±5 V or ±15 V,	f = 10 kHz		7.5		nV/√Hz
I_n	Input current noise	V_{CC} = ±5 V or ±15 V,	f = 10 kHz		1		pA/√Hz
	Differential gain error	Gain = 2, R_L = 150 Ω, NTSC	V_{CC} = ±15 V		0.01%		
			V_{CC} = ±5 V		0.01%		
	Differential phase error	Gain = 2, R_L = 150 Ω, NTSC	V_{CC} = ±15 V		0.01°		
			V_{CC} = ±5 V		0.001°		

† Full range = 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix.

electrical characteristics at T_A = 25°C, V_{CC} = ±15 V, R_L = 150 Ω (unless otherwise noted) (continued)

dc performance

PARAMETER		TEST CONDITIONS†		THS4011C/I, THS4012C/I			UNIT
				MIN	TYP	MAX	
	Open loop gain	V_{CC} = ±15 V, V_O = ±10 V, R_L = 1 kΩ	T_A = 25°C	10	25		V/mV
			T_A = full range	8			
		V_{CC} = ±5 V, V_O = ±2.5 V, R_L = 250 Ω	T_A = 25°C	7	12		V/mV
			T_A = full range	5			
V_{IO}	Input offset voltage	V_{CC} = ±5 V or ±15 V	T_A = 25°C		1	6	mV
			T_A = full range			8	
	Input offset voltage drift					15	µV/°C
I_{IB}	Input bias current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		2	6	µA
			T_A = full range			8	
I_{IO}	Input offset current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		25	250	nA
			T_A = full range			400	
	Offset current drift	V_{CC} = ±5 V or ±15 V			0.3		nA/°C

† Full range = 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix.

input characteristics

PARAMETER		TEST CONDITIONS†		THS4011C/I, THS4012C/I			UNIT
				MIN	TYP	MAX	
V_{ICR}	Common-mode input voltage range	V_{CC} = ±15 V		±13	±14.1		V
		V_{CC} = ±5 V		±3.8	±4.3		
CMRR	Common-mode rejection ratio	V_{CC} = ±15 V, V_{IC} = ±12 V	T_A = 25°C	82	110		dB
			T_A = full range	77			dB
		V_{CC} = ±5 V, V_{IC} = ±2.5 V	T_A = 25°C	90	95		dB
			T_A = full range	83			
R_I	Input resistance				2		MΩ
C_I	Input capacitance				1.2		pF

† Full range = 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix.

output characteristics

PARAMETER		TEST CONDITIONS†		THS4011C/I, THS4012C/I			UNIT
				MIN	TYP	MAX	
V_O	Output voltage swing	V_{CC} = ±15 V	R_L = 1 kΩ	±13	±13.5		V
		V_{CC} = ±5 V		±3.4	±3.7		
		V_{CC} = ±15 V	R_L = 250 Ω	±12	±13		
		V_{CC} = ±5 V	R_L = 150 Ω	±3	±3.4		
I_O	Output current	R_L = 20 Ω,	V_{CC} = ±15 V	70	110		mA
			V_{CC} = ±5 V	50	75		
I_{OS}	Short-circuit output current	V_{CC} = ±15 V			150		mA
R_O	Output resistance	Open loop			12		Ω

† Full range = 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix.

electrical characteristics at T_A = 25°C, V_{CC} = ±15 V, R_L = 150 Ω (unless otherwise noted) (continued)

power supply

PARAMETER		TEST CONDITIONS†		THS4011C/I, THS4012C/I			UNIT
				MIN	TYP	MAX	
V_{CC}	Supply voltage	Dual supply		±4.5		±16.5	V
		Single supply		9		33	
I_{CC}	Supply current (each amplifier)	V_{CC} = ±15 V	T_A = 25°C		7.8	9.5	mA
			T_A = full range			11	
		V_{CC} = ±5 V	T_A = 25°C		6.9	8.5	
			T_A = full range			10	
PSRR	Power supply rejection ratio	V_{CC} = ±5 V to ±15 V	T_A = 25°C	75	83		dB
			T_A = full range	68			

† Full range = 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix.

electrical characteristics, V_{CC} = ±15 V, R_L = 150 Ω, T_A = 25°C, (unless otherwise noted)

dynamic performance

PARAMETER		TEST CONDITIONS†		THS4011M			UNIT
				MIN	TYP	MAX	
BW	Unity-gain bandwidth	Closed loop, R_L = 1 kΩ	V_{CC} = ±15 V	*160	200		MHz
	Bandwidth for 0.1 dB flatness	Gain = 1	V_{CC} = ±15 V		70		MHz
			V_{CC} = ±5 V		35		
			V_{CC} = ±2.5 V		30		
	Full power bandwidth (see Note 1)	V_{CC} = ±15 V, R_L = 150 Ω,	$V_{O(PP)}$ = 20 V		2.5		MHz
		V_{CC} = ±5 V, R_L = 150 Ω,	$V_{O(PP)}$ = 20 V		8		
SR	Slew rate	V_{CC} = ±15 V, R_L = 1 kΩ		*300	400		V/µs
t_s	Settling time to 0.1%	V_I = –2.5 V to 2.5 V, Gain = –1	V_{CC} = ±15 V		37		ns
			V_{CC} = ±5 V		35		
	Settling time to 0.01%	V_I = –2.5 V to 2.5 V, Gain = –1	V_{CC} = ±15 V		90		ns
			V_{CC} = ±5 V		70		

† Full range = –55°C to 125°C for the M suffix.
*This parameter is not tested.
NOTE 1: Full pwer bandwidth = slew rate/2π $V_{(PP)}$.

noise/distortion performance

PARAMETER		TEST CONDITIONS†		THS4011M			UNIT
				MIN	TYP	MAX	
THD	Total harmonic distortion	V_{CC} = ±15 V, $V_{O(PP)}$ = 1 V	f_c = 1 MHz,		–80		dBc
V_n	Input voltage noise	V_{CC} = ±5 V or ±15 V,	f = 10 kHz		7.5		nV/√Hz
I_n	Input current noise	V_{CC} = ±5 V or ±15 V,	f = 10 kHz		1		pA/√Hz
	Differential gain error	Gain = 2, R_L = 150 Ω, NTSC	V_{CC} = ±15 V		0.006		%
			V_{CC} = ±5 V		0.001		
	Differential phase error	Gain = 2, R_L = 150 Ω, NTSC	V_{CC} = ±15 V		0.01°		
			V_{CC} = ±5 V		0.002°		

† Full range = –55°C to 125°C for the M suffix.

electrical characteristics at T_A = full range, V_{CC} = ±15 V, R_L = 1 kΩ (unless otherwise noted) (continued)

dc performance

PARAMETER		TEST CONDITIONS†		THS4011M			UNIT
				MIN	TYP	MAX	
	Open loop gain	V_{CC} = ±15 V, V_O = ±10 V, R_L = 1 kΩ	T_A = full range	6	14		V/mV
		V_{CC} = ±5 V, V_O = ±2.5 V, R_L = 1 kΩ	T_A = full range	5	10		V/mV
V_{IO}	Input offset voltage	V_{CC} = ±5 V or ±15 V	T_A = 25°C		2	6	mV
			T_A = full range		2	8	
	Input offset voltage drift	V_{CC} = ±5 V or ±15 V			15		µV/°C
I_{IB}	Input bias current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		2	6	µA
			T_A = full range		4	8	
I_{IO}	Input offset current	V_{CC} = ±5 V or ±15 V			25	250	nA
	Offset current drift	V_{CC} = ±5 V or ±15 V	T_A = 25°C		0.3		nA/°C

† Full range = –55°C to 125°C for the M suffix.

input characteristics

PARAMETER		TEST CONDITIONS†		THS4011M			UNIT
				MIN	TYP	MAX	
V_{ICR}	Common-mode input voltage range	V_{CC} = ±15 V		±13	±14.1		V
		V_{CC} = ±5 V		±3.8	±4.3		
CMRR	Common-mode rejection ratio	V_{CC} = ±15 V,	V_{IC} = ±12 V	75	90		dB
		V_{CC} = ±5 V,	V_{IC} = ±2.5 V	84	95		
R_I	Input resistance				2		MΩ
C_I	Input capacitance				1.2		pF

† Full range = –55°C to 125°C for the M suffix.

output characteristics

PARAMETER		TEST CONDITIONS†		THS4011M			UNIT
				MIN	TYP	MAX	
V_O	Output voltage swing	V_{CC} = ±15 V	R_L = 1 kΩ	±13	±13.5		V
		V_{CC} = ±5 V		±3.4	±3.7		
		V_{CC} = ±15 V	R_L = 250 Ω	±12	±13		
		V_{CC} = ±5 V	R_L = 150 Ω	±3	±3.4		
I_O	Output current	V_{CC} = ±15 V	R_L = 20 Ω	70	115		mA
		V_{CC} = ±5 V		50	75		
I_{OS}	Short-circuit output current	V_{CC} = ±15 V	T_A = 25°C		150		mA
R_O	Output resistance	Open loop			12		Ω

† Full range = –55°C to 125°C for the M suffix.

electrical characteristics at T_A = full range, V_{CC} = ±15 V, R_L = 1 kΩ (unless otherwise noted) (continued)

power supply

PARAMETER		TEST CONDITIONS†		THS4011M			UNIT
				MIN	TYP	MAX	
V_{CC}	Supply voltage	Dual supply		±4.5		±16.5	V
		Single supply		9		33	
I_{CC}	Quiescent current	V_{CC} = ±15 V	T_A = 25°C		7.8	9.5	mA
			T_A = full range			11	
		V_{CC} = ±5 V	T_A = 25°C		6.9	8.5	
			T_A = full range			10	
PSRR	Power supply rejection ratio	V_{CC} = ±5 V to ±15 V	T_A = 25°C	80	86		dB
			T_A = full range	78	83		

† Full range = –55°C to 125°C for the M suffix.

PARAMETER MEASUREMENT INFORMATION

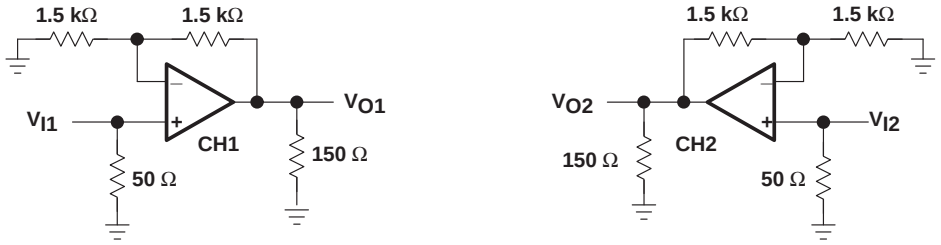


Figure 3. THS4012 Crosstalk Test Circuit

TYPICAL CHARACTERISTICS

INPUT OFFSET VOLTAGE vs FREE-AIR TEMPERATURE

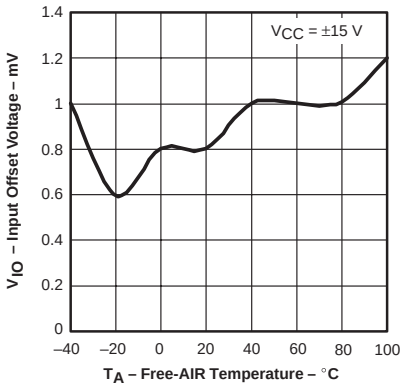


Figure 4

INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE

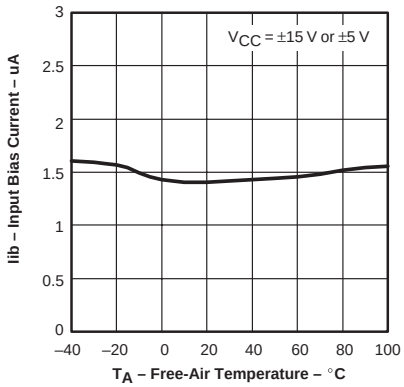


Figure 5

OUPUT VOLTAGE vs SUPPLY VOLTAGE

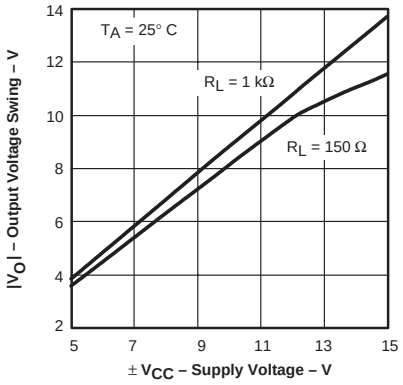


Figure 6

MAXIMUM OUTPUT VOLTAGE SWING vs FREE-AIR TEMPERATURE

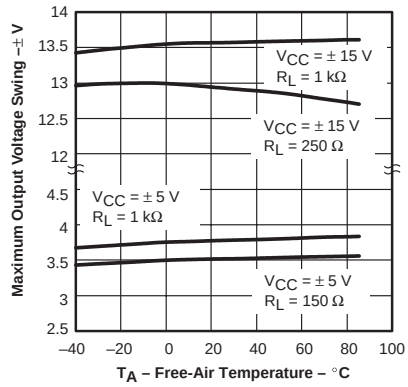


Figure 7

COMMON-MODE INPUT VOLTAGE vs SUPPLY VOLTAGE

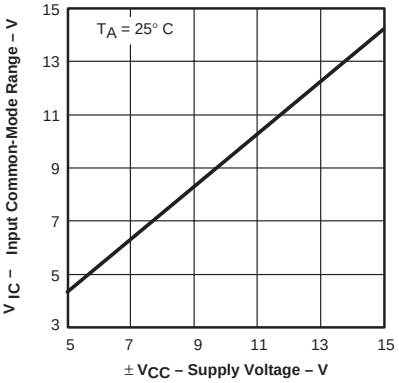


Figure 8

PSRR vs FREQUENCY

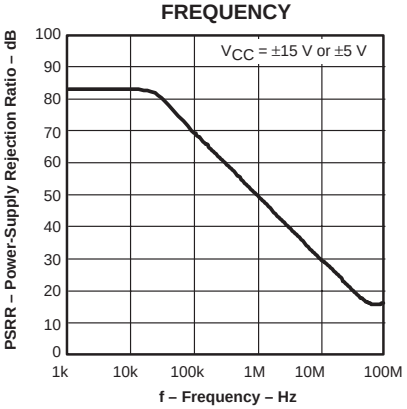


Figure 9

CMRR vs FREQUENCY

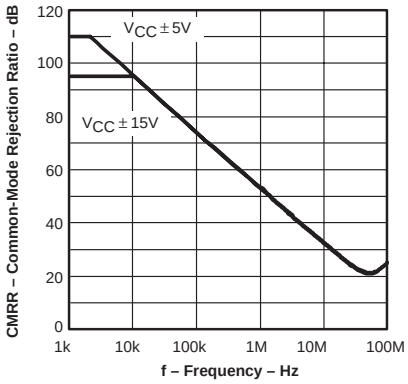


Figure 10

CROSSTALK vs FREQUENCY

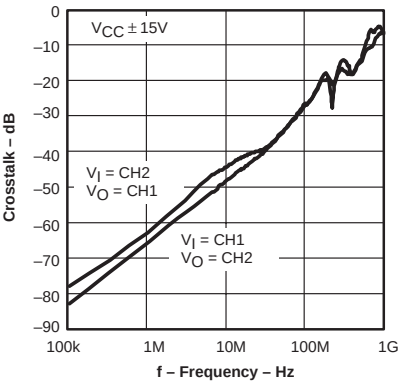


Figure 11

OPEN-LOOP GAIN RESPONSE

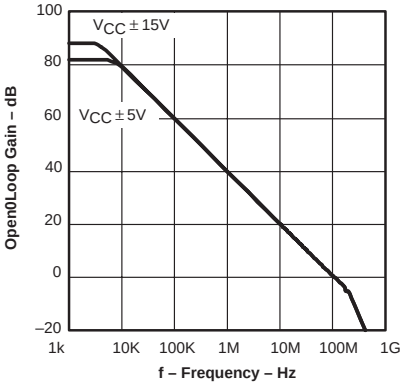


Figure 12

TYPICAL CHARACTERISTICS

DISTORTION vs FREQUENCY

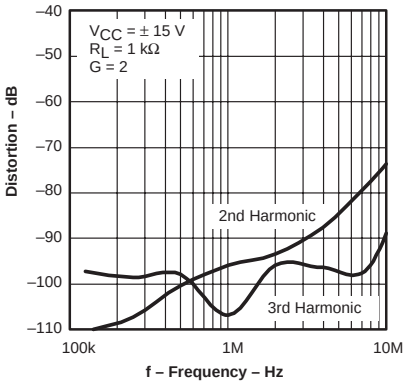


Figure 13

DISTORTION vs FREQUENCY

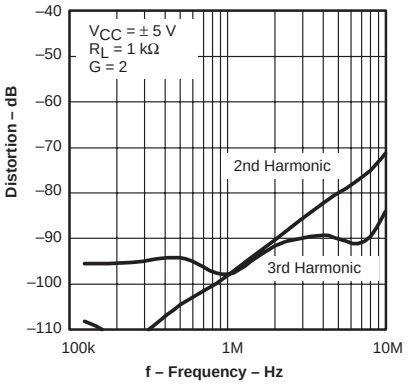


Figure 14

DISTORTION vs FREQUENCY

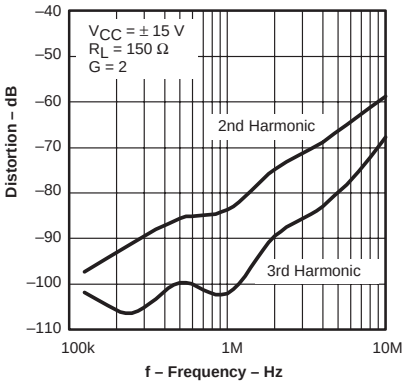


Figure 15

DISTORTION vs FREQUENCY

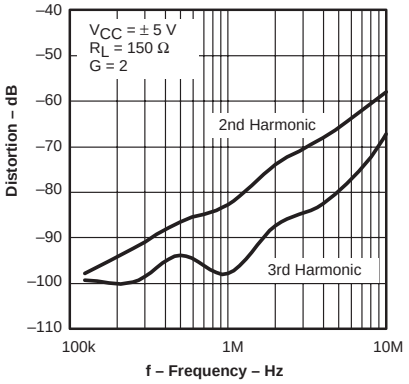


Figure 16

OUTPUT AMPLITUDE vs FREQUENCY

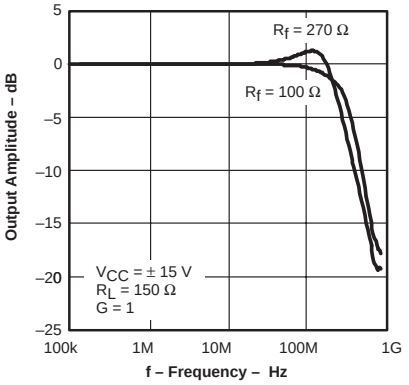


Figure 17

OUTPUT AMPLITUDE vs FREQUENCY

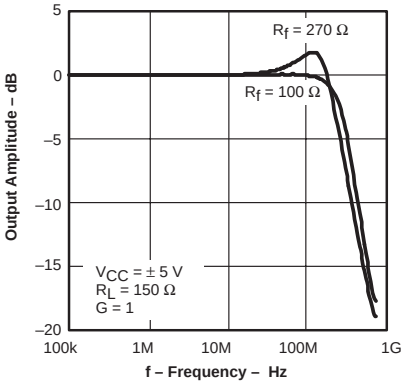


Figure 18

NOISE SPECTRAL DENSITY vs FREQUENCY

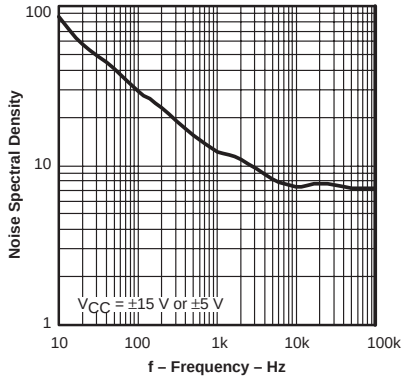


Figure 19

DIFFERENTIAL PHASE vs NUMBER OF 150-Ω LOADS

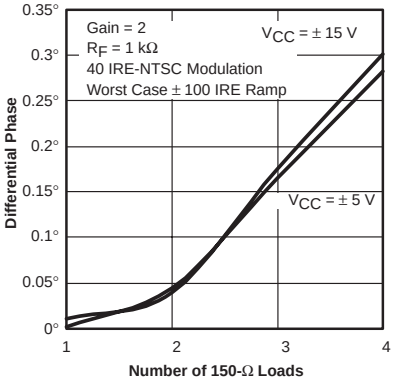


Figure 20

TYPICAL CHARACTERISTICS

DIFFERENTIAL PHASE vs NUMBER OF 150-Ω LOADS

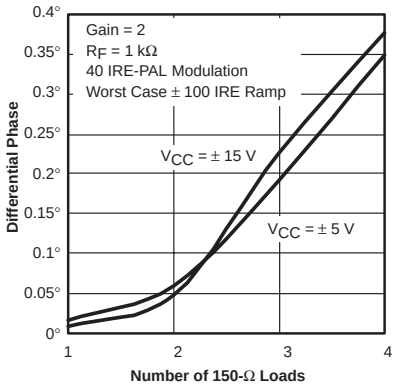


Figure 21

DIFFERENTIAL GAIN vs NUMBER OF 150-Ω LOADS

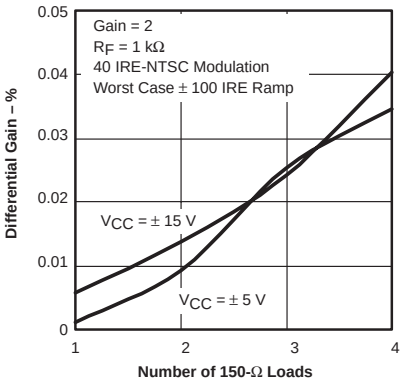


Figure 22

DIFFERENTIAL GAIN vs NUMBER OF 150-Ω LOADS

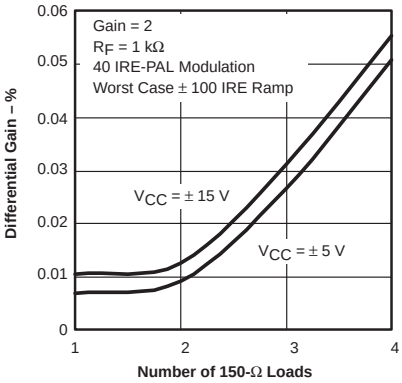


Figure 23

APPLICATION INFORMATION

theory of operation

The THS401x is a high-speed, operational amplifier configured in a voltage feedback architecture. It is built using a 30-V, dielectrically isolated, complementary bipolar process with NPN and PNP transistors possessing f_Ts of several GHz. This results in an exceptionally high performance amplifier that has a wide bandwidth, high slew rate, fast settling time, and low distortion. A simplified schematic is shown in Figure 24.

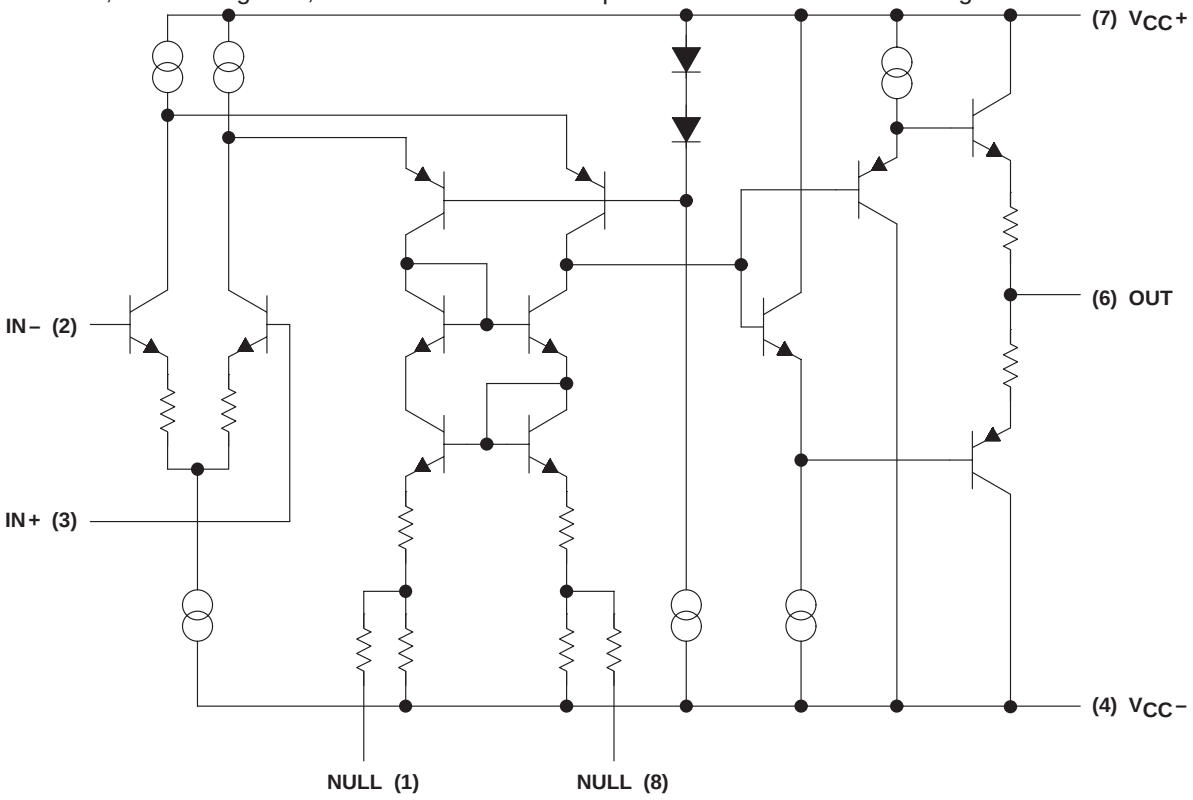


Figure 24. THS4011 Simplified Schematic

noise calculations and noise figure

Noise can cause errors on very small signals. This is especially true when amplifying small signals. The noise model for the THS401x is shown in Figure 25. This model includes all of the noise sources as follows:

- e_n = Amplifier internal voltage noise (nV/$\sqrt{Hz}$)
- IN+ = Noninverting current noise (pA/$\sqrt{Hz}$)
- IN– = Inverting current noise (pA/$\sqrt{Hz}$)
- e_{Rx} = Thermal voltage noise associated with each resistor (e_{Rx} = 4 kTR_x)

APPLICATION INFORMATION

noise calculations and noise figure (continued)

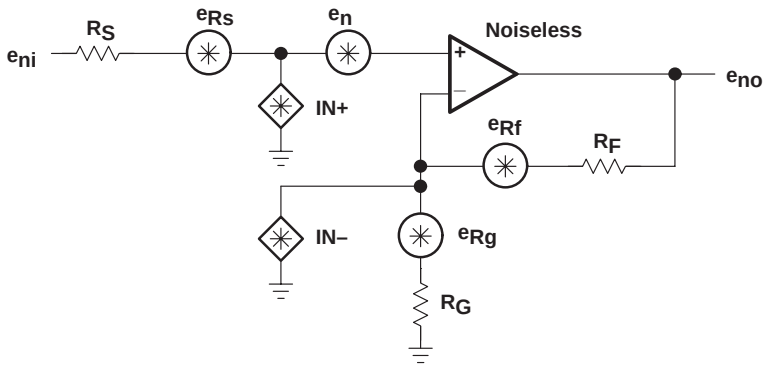


Figure 25. Noise Model

The total equivalent input noise density (e_{ni}) is calculated by using the following equation:

$$e_{ni} = \sqrt{(e_n)^2 + \left(IN + \times R_S\right)^2 + \left(IN- \times \left(R_F \parallel R_G\right)\right)^2 + 4\ kTR_S + 4\ kT\left(R_F \parallel R_G\right)}$$

Where:

k = Boltzmann's constant = 1.380658×10^{-23}
T = Temperature in degrees Kelvin (273 +°C)
$R_F \parallel R_G$ = Parallel resistance of R_F and R_G

To get the equivalent output noise of the amplifier, just multiply the equivalent input noise density (e_{ni}) by the overall amplifier gain (A_V).

$$e_{no} = e_{ni}\ A_V = e_{ni}\left(1 + \frac{R_F}{R_G}\right) \text{ (noninverting case)}$$

As the previous equations show, to keep noise at a minimum, small value resistors should be used. As the closed-loop gain is increased (by reducing R_G), the input noise is reduced considerably because of the parallel resistance term. This leads to the general conclusion that the most dominant noise sources are the source resistor (R_S) and the internal amplifier noise voltage (e_n). Because noise is summed in a root-mean-squares method, noise sources smaller than 25% of the largest noise source can be effectively ignored. This can greatly simplify the formula and make noise calculations much easier to calculate.

For more information on noise analysis, please refer to the *Noise Analysis* section in *Operational Amplifier Circuits Applications Report* (literature number SLVA043).

APPLICATION INFORMATION

noise calculations and noise figure (continued)

This brings up another noise measurement usually preferred in RF applications, the noise figure (NF). Noise figure is a measure of noise degradation caused by the amplifier. The value of the source resistance must be defined and is typically 50 Ω in RF applications.

$$NF = 10\log\left[\frac{e_{ni}^2}{\left(e_{Rs}\right)^2}\right]$$

Because the dominant noise components are generally the source resistance and the internal amplifier noise voltage, we can approximate noise figure as:

$$NF = 10\log\left[1 + \frac{\left[\left(e_n\right)^2 + \left(IN + \times R_S\right)^2\right]}{4\ kTR_S}\right]$$

Figure 26 shows the noise figure graph for the THS401x.

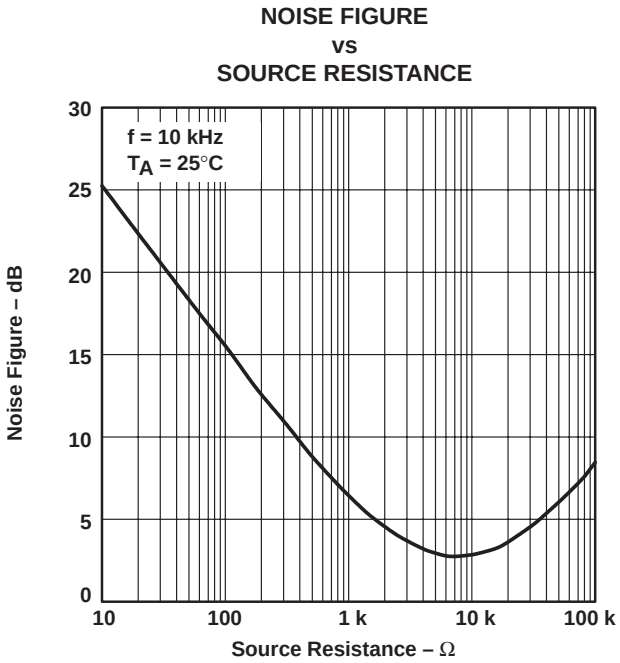


Figure 26. Noise Figure vs Source Resistance

APPLICATION INFORMATION

driving a capacitive load

Driving capacitive loads with high performance amplifiers is not a problem as long as certain precautions are taken. The first is to realize that the THS401x has been internally compensated to maximize its bandwidth and slew rate performance. When the amplifier is compensated in this manner, capacitive loading directly on the output will decrease the device's phase margin leading to high frequency ringing or oscillations. Therefore, for capacitive loads of greater than 10 pF, it is recommended that a resistor be placed in series with the output of the amplifier, as shown in Figure 27. A minimum value of 20 Ω should work well for most applications. For example, in 75-Ω transmission systems, setting the series resistor value to 75 Ω both isolates any capacitance loading and provides the proper line impedance matching at the source end.

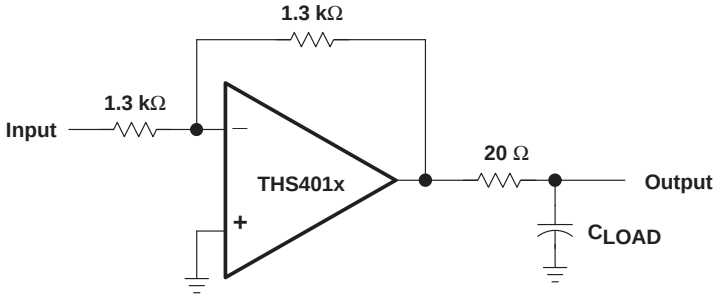


Figure 27. Driving a Capacitive Load

offset nulling

The THS401x has very low input offset voltage for a high-speed amplifier. However, if additional correction is required, an offset nulling function has been provided on the THS4011. The input offset can be adjusted by placing a potentiometer between terminals 1 and 8 of the device and tying the wiper to the negative supply. This is shown in Figure 28.

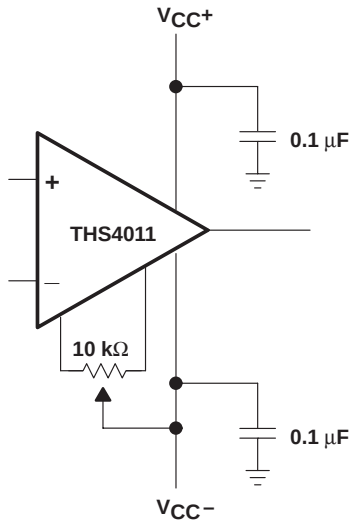
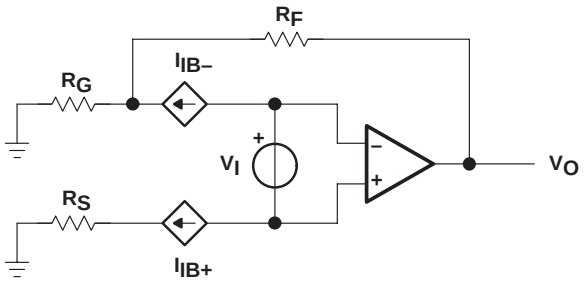


Figure 28. Offset Nulling Schematic

APPLICATION INFORMATION

offset voltage

The output offset voltage, (V_{OO}) is the sum of the input offset voltage (V_{IO}) and both input bias currents (I_{IB}) times the corresponding gains. The following schematic and formula can be used to calculate the output offset voltage:



$$V_{OO} = V_{IO}\left(1 + \left(\frac{R_F}{R_G}\right)\right) \pm I_{IB+}\ R_S\left(1 + \left(\frac{R_F}{R_G}\right)\right) \pm I_{IB-}\ R_F$$

Figure 29. Output Offset Voltage Model

optimizing unity gain response

Internal frequency compensation of the THS401x was selected to provide very wideband performance yet still maintain stability when operated in a noninverting unity gain configuration. When amplifiers are compensated in this manner there is usually peaking in the closed loop response and some ringing in the step response for very fast input edges, depending upon the application. This is because a minimum phase margin is maintained for the G=+1 configuration. For optimum settling time and minimum ringing, a feedback resistor of 100 Ω should be used as shown in Figure 30. Additional capacitance can also be used in parallel with the feedback resistance if even finer optimization is required.

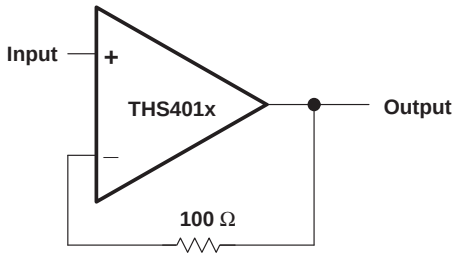


Figure 30. Noninverting, Unity Gain Schematic

APPLICATION INFORMATION

general configurations

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. The simplest way to accomplish this is to place an RC filter at the noninverting terminal of the amplifer (see Figure 31).

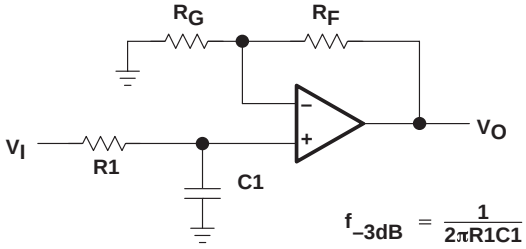


Figure 31. Single-Pole Low-Pass Filter

If even more attenuation is needed, a multiple pole filter is required. The Sallen-Key filter can be used for this task. For best results, the amplifier should have a bandwidth that is 8 to 10 times the filter frequency bandwidth. Failure to do this can result in phase shift of the amplifier.

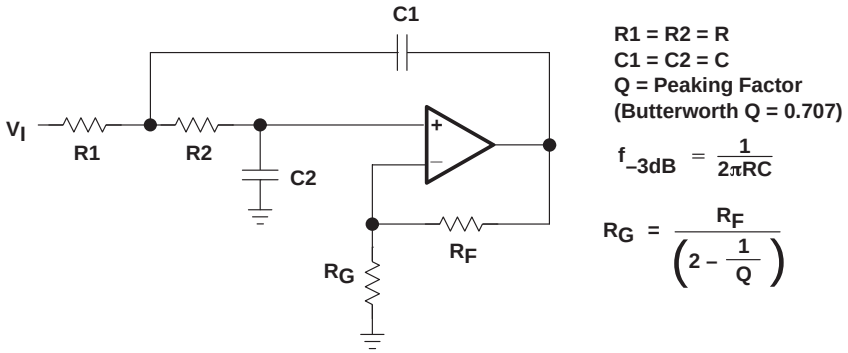


Figure 32. 2-Pole Low-Pass Sallen-Key Filter

APPLICATION INFORMATION

circuit layout considerations

To achieve the levels of high frequency performance of the THS401x, follow proper printed-circuit board high frequency design techniques. A general set of guidelines is given below. In addition, a THS401x evaluation board is available to use as a guide for layout or for evaluating the device performance.

- Ground planes – It is highly recommended that a ground plane be used on the board to provide all components with a low inductive ground connection. However, in the areas of the amplifier inputs and output, the ground plane can be removed to minimize the stray capacitance.
- Proper power supply decoupling – Use a 6.8-μF tantalum capacitor in parallel with a 0.1-μF ceramic capacitor on each supply terminal. It may be possible to share the tantalum among several amplifiers depending on the application, but a 0.1-μF ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1-μF capacitor should be placed as close as possible to the supply terminal. As this distance increases, the inductance in the connecting trace makes the capacitor less effective. The designer should strive for distances of less than 0.1 inches between the device power terminals and the ceramic capacitors.
- Sockets – Sockets are not recommended for high-speed operational amplifiers. The additional lead inductance in the socket pins will often lead to stability problems. Surface-mount packages soldered directly to the printed-circuit board is the best implementation.
- Short trace runs/compact part placements – Optimum high frequency performance is achieved when stray series inductance has been minimized. To realize this, the circuit layout should be made as compact as possible, thereby minimizing the length of all trace runs. Particular attention should be paid to the inverting input of the amplifier. Its length should be kept as short as possible. This will help to minimize stray capacitance at the input of the amplifier.
- Surface-mount passive components – Using surface-mount passive components is recommended for high frequency amplifier circuits for several reasons. First, because of the extremely low lead inductance of surface-mount components, the problem with stray series inductance is greatly reduced. Second, the small size of surface-mount components naturally leads to a more compact layout thereby minimizing both stray inductance and capacitance. If leaded components are used, it is recommended that the lead lengths be kept as short as possible.

general PowerPAD design considerations

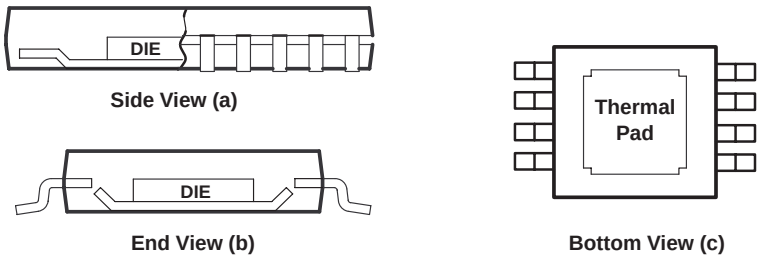
The THS401x is available packaged in a thermally-enhanced DGN package, which is a member of the PowerPAD family of packages. This package is constructed using a downset leadframe upon which the die is mounted [see Figure 33(a) and Figure 33(b)]. This arrangement results in the lead frame being exposed as a thermal pad on the underside of the package [see Figure 33(c)]. Because this thermal pad has direct thermal contact with the die, excellent thermal performance can be achieved by providing a good thermal path away from the thermal pad.

The PowerPAD package allows for both assembly and thermal management in one manufacturing operation. During the surface-mount solder operation (when the leads are being soldered), the thermal pad can also be soldered to a copper area underneath the package. Through the use of thermal paths within this copper area, heat can be conducted away from the package into either a ground plane or other heat dissipating device.

The PowerPAD package represents a breakthrough in combining the small area and ease of assembly of surface mount with the, heretofore, awkward mechanical methods of heatsinking.

APPLICATION INFORMATION

general PowerPAD design considerations (continued)



NOTE A: The thermal pad is electrically isolated from all terminals in the package.

Figure 33. Views of Thermally Enhanced DGN Package

Although there are many ways to properly heatsink this device, the following steps illustrate the recommended approach.

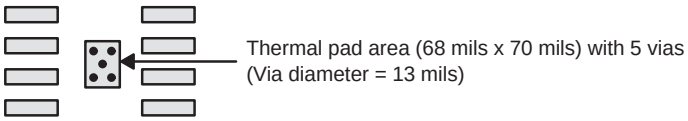


Figure 34. PowerPAD PCB Etch and Via Pattern

1. Prepare the PCB with a top side etch pattern as shown in Figure 34. There should be etch for the leads as well as etch for the thermal pad.
2. Place five holes in the area of the thermal pad. These holes should be 13 mils in diameter. Keep them small so that solder wicking through the holes is not a problem during reflow.
3. Additional vias may be placed anywhere along the thermal plane outside of the thermal pad area. This helps dissipate the heat generated by the THS401xDGN IC. These additional vias may be larger than the 13-mil diameter vias directly under the thermal pad. They can be larger because they are not in the thermal pad area to be soldered so that wicking is not a problem.
4. Connect all holes to the internal ground plane.
5. When connecting these holes to the ground plane, **do not** use the typical web or spoke via connection methodology. Web connections have a high thermal resistance connection that is useful for slowing the heat transfer during soldering operations. This makes the soldering of vias that have plane connections easier. In this application, however, low thermal resistance is desired for the most efficient heat transfer. Therefore, the holes under the THS401xDGN package should make their connection to the internal ground plane with a complete connection around the entire circumference of the plated-through hole.
6. The top-side solder mask should leave the terminals of the package and the thermal pad area with its five holes exposed. The bottom-side solder mask should cover the five holes of the thermal pad area. This prevents solder from being pulled away from the thermal pad area during the reflow process.
7. Apply solder paste to the exposed thermal pad area and all of the IC terminals.
8. With these preparatory steps in place, the THS401xDGN IC is simply placed in position and run through the solder reflow operation as any standard surface-mount component. This results in a part that is properly installed.

APPLICATION INFORMATION

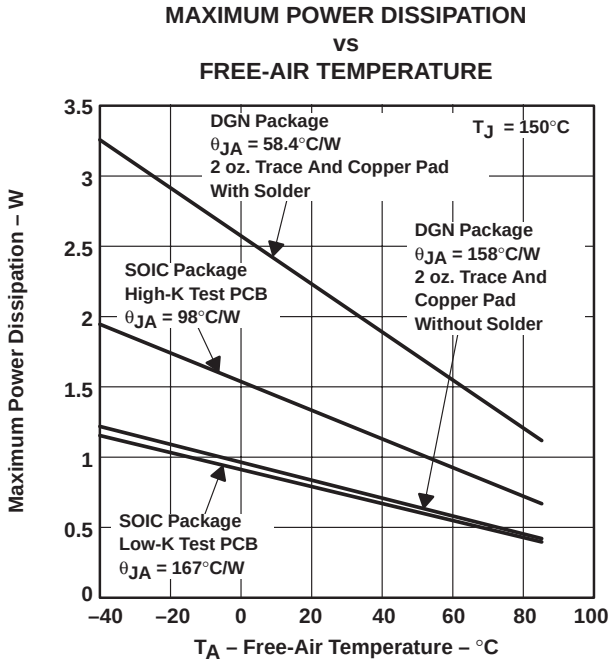
general PowerPAD design considerations (continued)

The actual thermal performance achieved with the THS401xDGN in its PowerPAD package depends on the application. In the example above, if the size of the internal ground plane is approximately 3 inches × 3 inches, then the expected thermal coefficient, θ_{JA}, is about 58.4°C/W. For comparison, the non-PowerPAD version of the THS401x IC (SOIC) is shown. For a given θ_{JA}, the maximum power dissipation is shown in Figure 35 and is calculated by the following formula:

$$P_D = \left(\frac{T_{MAX} - T_A}{\theta_{JA}} \right)$$

Where:

P_D = Maximum power dissipation of THS401x IC (watts)
T_{MAX} = Absolute maximum junction temperature (150°C)
T_A = Free-ambient air temperature (°C)
$\theta_{JA} = \theta_{JC} + \theta_{CA}$
θ_{JC} = Thermal coefficient from junction to case
θ_{CA} = Thermal coefficient from case to ambient air (°C/W)



NOTE A: Results are with no air flow and PCB size = 3”× 3”

Figure 35. Maximum Power Dissipation vs Free-Air Temperature

More complete details of the PowerPAD installation process and thermal management techniques can be found in the Texas Instruments Technical Brief, *PowerPAD Thermally Enhanced Package.* This document can be found at the TI web site (www.ti.com) by searching on the key word PowerPAD. The document can also be ordered through your local TI sales office. Refer to literature number SLMA002 when ordering.

APPLICATION INFORMATION

general PowerPAD design considerations (continued)

The next consideration is the package constraints. The two sources of heat within an amplifier are quiescent power and output power. The designer should never forget about the quiescent heat generated within the device, especially muti-amplifier devices. Because these devices have linear output stages (Class A-B), most of the heat dissipation is at low output voltages with high output currents. Figure 36 to Figure 39 show this effect, along with the quiescent heat, with an ambient air temperature of 50°C. When using V_{CC} = ±5 V, there is generally not a heat problem, even with SOIC packages. But, when using V_{CC} = ±15 V, the SOIC package is severely limited in the amount of heat it can dissipate. The other key factor when looking at these graphs is how the devices are mounted on the PCB. The PowerPAD devices are extremely useful for heat dissipation. But, the device should always be soldered to a copper plane to fully use the heat dissipation properties of the PowerPAD. The SOIC package, on the other hand, is highly dependent on how it is mounted on the PCB. As more trace and copper area is placed around the device, θ_{JA} decreases and the heat dissipation capability increases. The currents and voltages shown in these graphs are for the total package. For the dual amplifier package (THS4012), the sum of the RMS output currents and voltages should be used to choose the proper package.

THS4011
MAXIMUM RMS OUTPUT CURRENT
vs
RMS OUTPUT VOLTAGE DUE TO THERMAL LIMITS

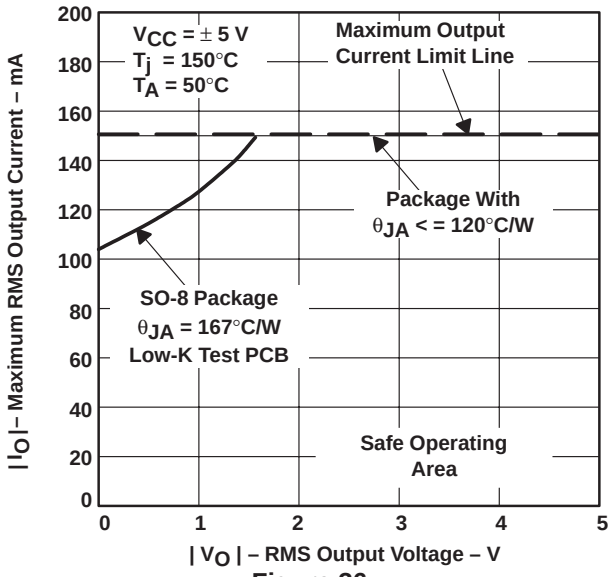


Figure 36

THS4011
MAXIMUM RMS OUTPUT CURRENT
vs
RMS OUTPUT VOLTAGE DUE TO THERMAL LIMITS

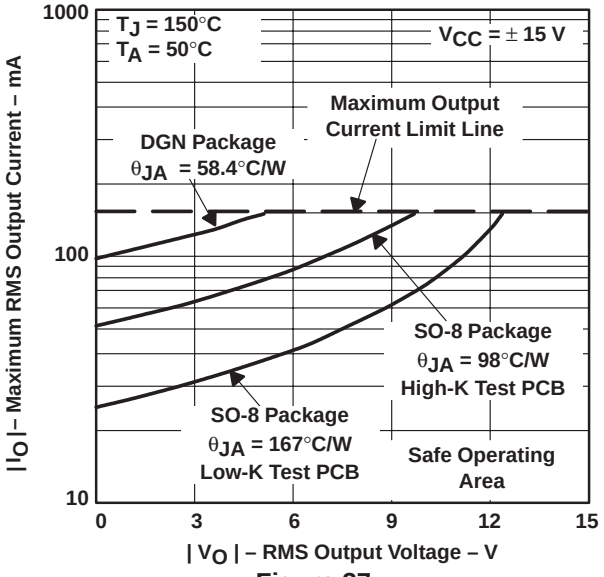


Figure 37

APPLICATION INFORMATION

general PowerPAD design considerations (continued)

THS4012
MAXIMUM RMS OUTPUT CURRENT
vs
RMS OUTPUT VOLTAGE DUE TO THERMAL LIMITS

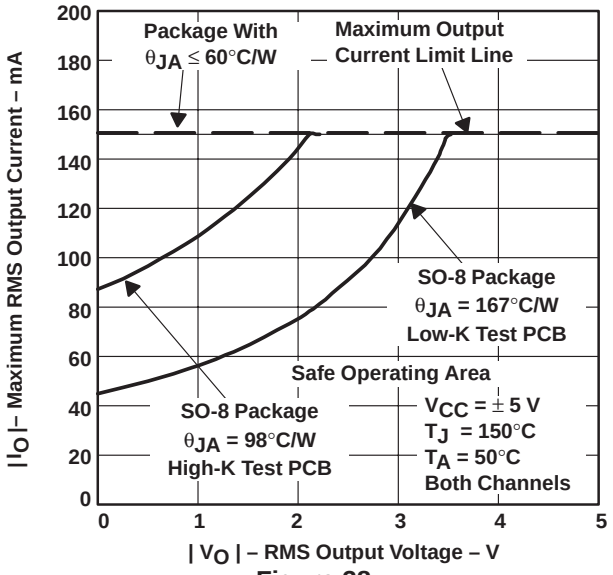


Figure 38

THS4012
MAXIMUM RMS OUTPUT CURRENT
vs
RMS OUTPUT VOLTAGE DUE TO THERMAL LIMITS

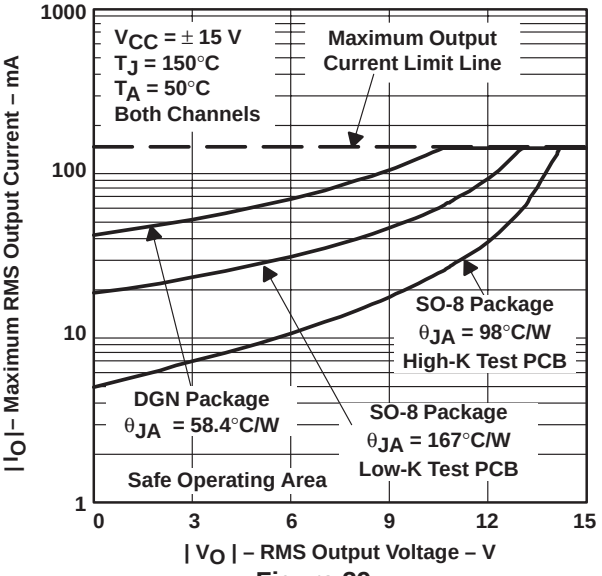


Figure 39

APPLICATION INFORMATION

evaluation board

An evaluation board is available for the THS4011 (literature number SLOP128) and THS4012 (literature number SLOP230). This board has been configured for very low parasitic capacitance in order to realize the full performance of the amplifier. A schematic of the THS4011 evaluation board is shown in Figure 40. The circuitry has been designed so that the amplifier may be used in either an inverting or noninverting configuration. For more information, please refer to the *THS4011 EVM User's Guide* (literature number SLOU028) or the *THS4012 EVM User's Guide* (literature number SLOU041) To order the evaluation board contact your local TI sales office or distributor.

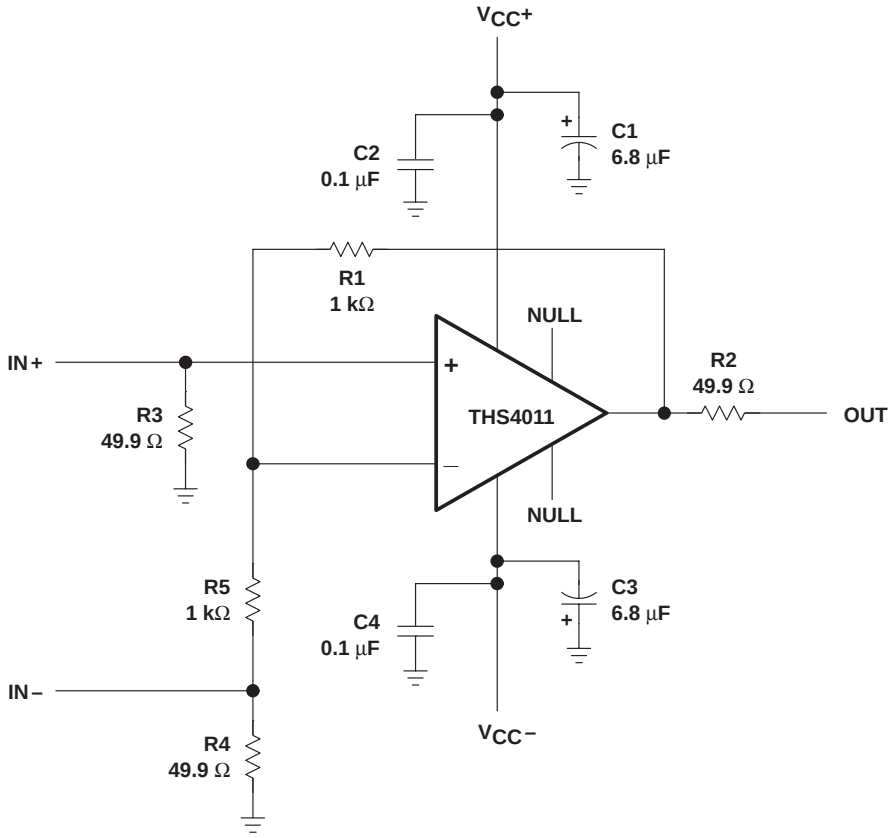
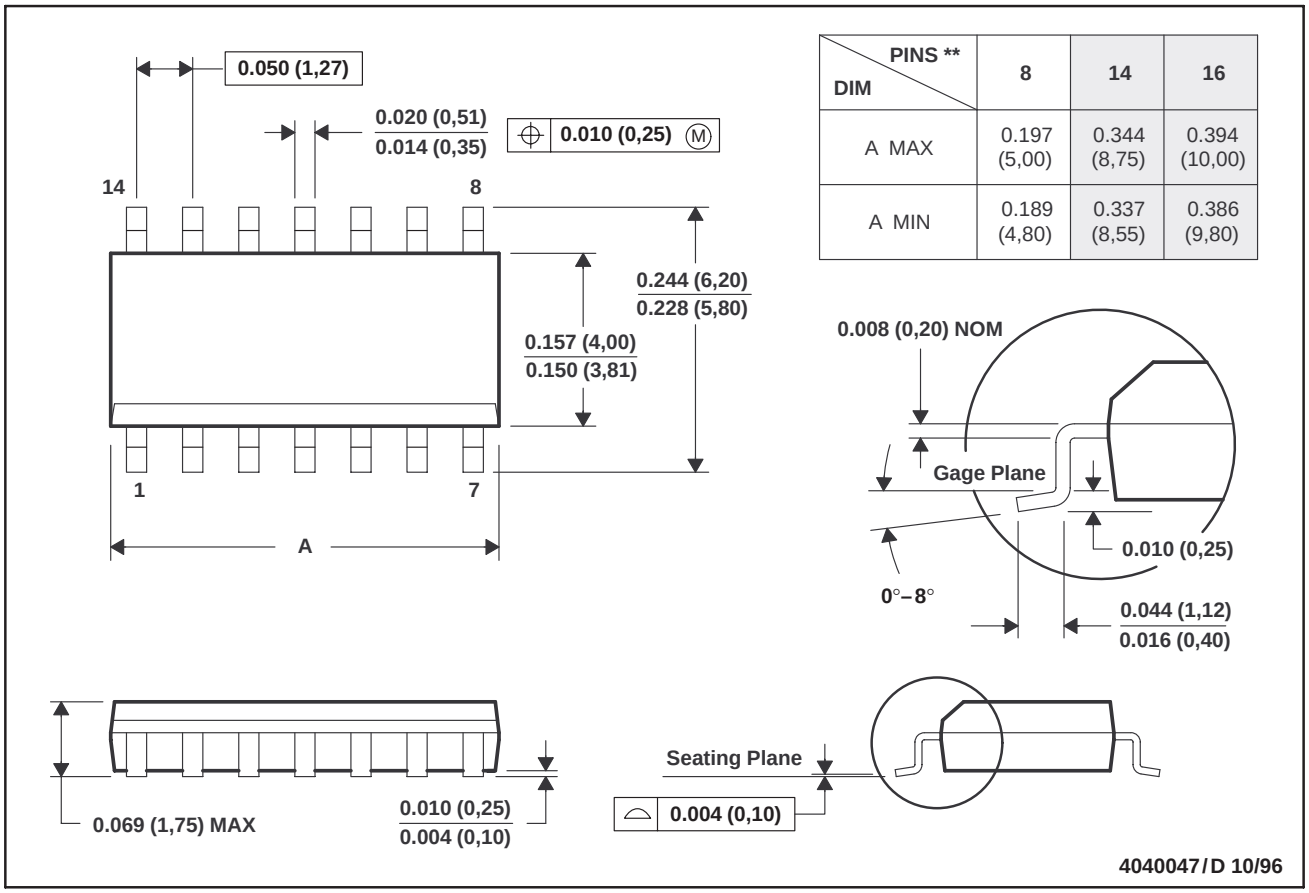


Figure 40. THS4011 Evaluation Board

MECHANICAL INFORMATION

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN

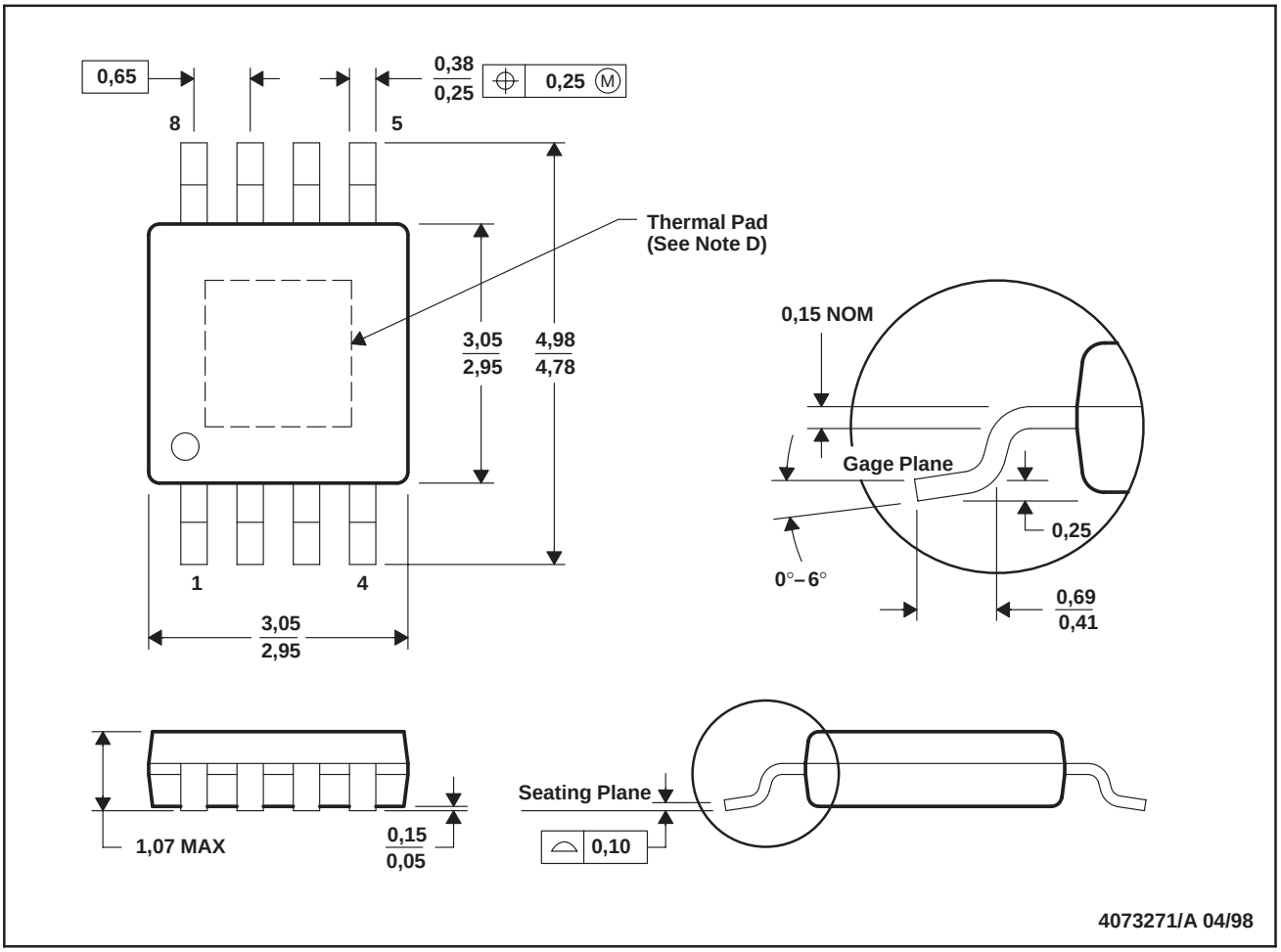


DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

MECHANICAL INFORMATION

DGN (S-PDSO-G8) **PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE**



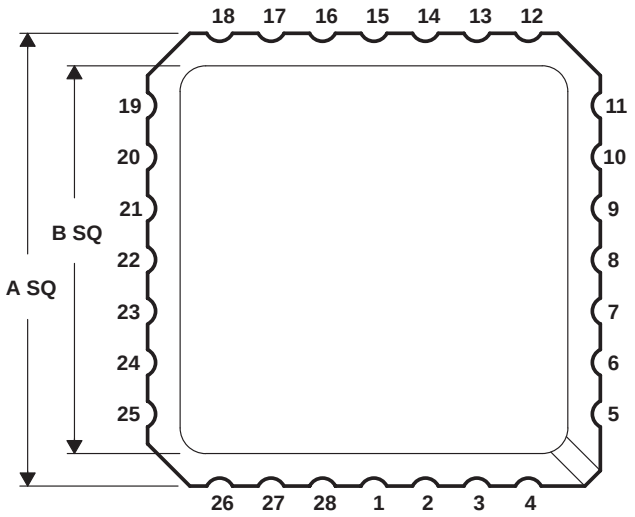
NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions include mold flash or protrusions.
D. The package thermal performance may be enhanced by attaching an external heat sink to the thermal pad. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.
E. Falls within JEDEC MO-187

PowerPAD is a trademark of Texas Instruments Incorporated.

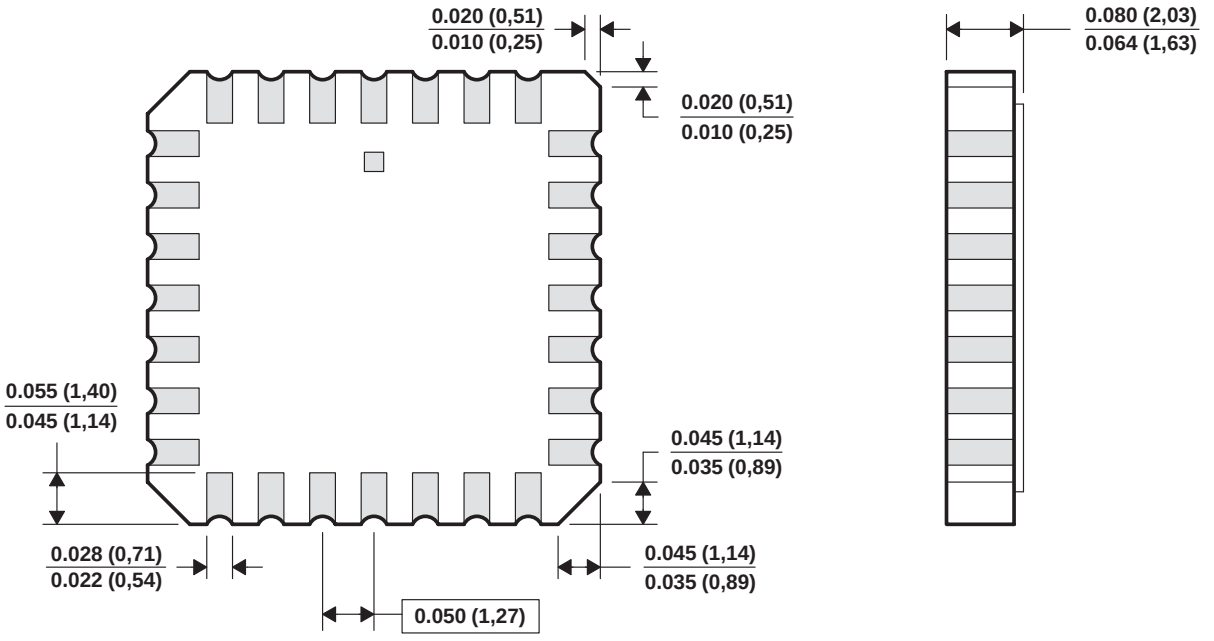
MECHANICAL INFORMATION

FK (S-CQCC-N)** **LEADLESS CERAMIC CHIP CARRIER**

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)

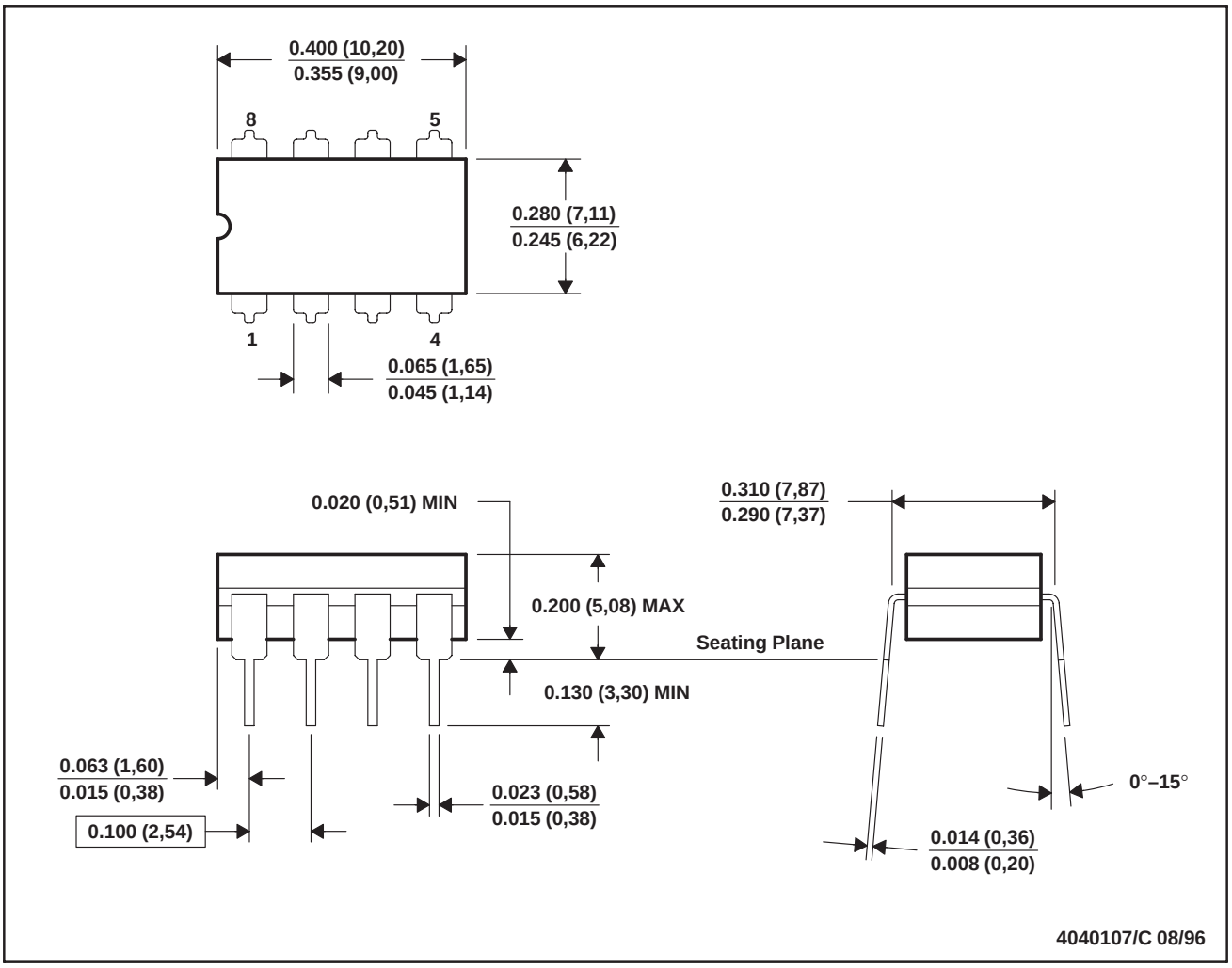


4040140/D 10/96

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

MECHANICAL INFORMATION

JG (R-GDIP-T8) **CERAMIC DUAL-IN-LINE PACKAGE**



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
E. Falls within MIL-STD-1835 GDIP1-T8

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