HIGH-SPEED, FULLY DIFFERENTIAL, CONTINUOUSLY VARIABLE GAIN AMPLIFIER

FEATURES

- **Low Noise: V_n = 1.1 nV/$\sqrt{\text{Hz}}$, Noise Figure = 9 dB**
- **Low Distortion:**
  - **HD_2 = –65 dBc, HD_3 = –61 dBc at 32 MHz**
  - **IMD_3 = –62 dBc, OIP_3 = 21 dBm at 70 MHz**
- **300 MHz Bandwidth**
- **Continuously Variable Gain Range: 11.6 dB to 46.5 dB**
- **Gain Slope: 38.8 dB/V**
- **Fully Differential Input and Output**
- **Output Common-Mode Voltage Control**
- **Output Voltage Limiting**

APPLICATIONS

- **Time Gain Amplifiers in Ultra Sound, Sonar, and Radar**
- **Automatic Gain Control in Communication and Video**
- **System Gain Calibration in Communications**
- **Variable Gain in Instrumentation**

DESCRIPTION

The THS7530 is fabricated using Texas Instruments' state-of-the-art BiCom III SiGe complementary bipolar process. The THS7530 is a dc-coupled wide bandwidth amplifier with voltage-controlled gain. The amplifier has high impedance differential inputs and low impedance differential outputs with high bandwidth gain control, output common mode control, and output voltage clamping.

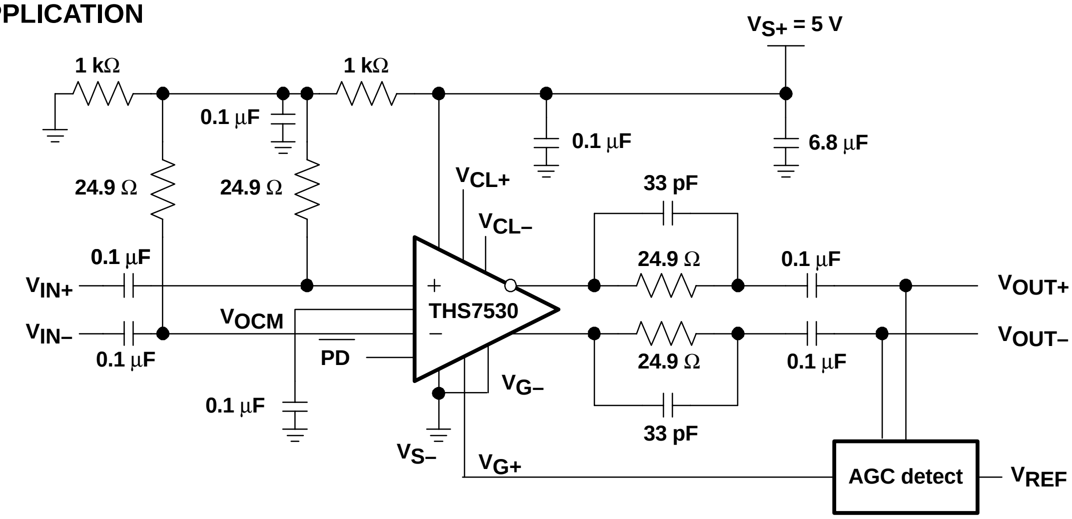
Signal channel performance is exceptional with 300-MHz bandwidth, and third harmonic distortion of –61 dBc at 32 MHz with 1 V_{PP} output into 400 Ω.

Gain control is linear in dB with 0 V to 0.9 V varying the gain from 11.6 dB to 46.5 dB with 38.8-dB/V gain slope.

Output voltage limiting is provided to limit the output voltage swing, and prevent saturating following stages.

The device is characterized for operation over the industrial temperature range: –40°C to 85°C.

AGC APPLICATION



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.

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.

PACKAGING/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE DESIGNATOR	SYMBOL	TEMPERATURE RANGE, T_A	ORDERING NUMBER	TRANSPORT MEDIA
THS7530	TSSOP PowerPAD	PWP-14	THS7530	–40°C to 85°C	THS7530PWP	Tube
					THS7530PWPR	Tape and reel

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted[(1)]

		THS7530
Supply voltage, $V_{S+} – V_{S–}$		5.5 V
Input voltage, V_I		$\pm V_S$
Output current, I_O [(2)]		65 mA
Differential input voltage, V_{ID}		±4 V
Continuous power dissipation		See Dissipation Rating Table
Maximum junction temperature, T_J		150°C
Maximum junction temperature for long term stability, T_J		125°C
Operating free-air temperature range, T_A		–40°C to 85°C
Storage temperature range, T_{stg}		–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		300°C
ESD	HBM	3000 V
	CDM	1500 V
	MM	200 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 under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) The THS7530 incorporates a PowerPAD™ on the underside of the chip. This acts as a heatsink and must be connected to a thermally dissipative plane for proper power dissipation. Failure to do so may result in exceeding the maximum junction temperature which could permanently damage the device. See TI technical brief SLMA002 and SLMA004 for more information about utilizing the PowerPAD thermally enhanced package.

RECOMMENDED OPERATING CONDITIONS

	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply voltage, [$V_{S–}$ to V_{S+}]		4.5	5	5.5	V
Operating free–air temperature, T_A		–40		85	°C
Input common mode voltage	[$V_{S–}$ to V_{S+}] = 5 V		2.5		V
Output common mode voltage	[$V_{S–}$ to V_{S+}] = 5 V		2.5		V

PACKAGE THERMAL DATA

PACKAGE	PCB	Θ_{JA} (C/W)	Θ_{JC} (C/W)	T_A = 25°C POWER RATING
14PWP	See *Layout Considerations* in the application section of this data sheet.	37.5	2.07	3 W

PowerPAD is a trademark of Texas Instruments.

SPECIFICATIONS: MAIN AMPLIFIER

V_{S+} = 5 V, V_{S-} = 0 V, V_{OCM} = 2.5 V, V_{ICM} = 2.5 V, V_{G-} = 0 V, V_{G+} = 1 V (maximum gain), T_A = 25°C, ac performance measured using the ac test circuit shown in Figure 1 (unless otherwise noted). DC performance is measured using the dc test circuit shown in Figure 2 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TYP	OVER TEMPERATURE			
		25 C	25 C	–40 C to 85 C	UNITS	MIN/ MAX
AC PERFORMANCE (See Figure 1)						
Small-signal bandwidth	All gains, P_{IN} = –45 dBm	300			MHz	Typ
Slew rate(1)	1 V_{PP} Step, 25% to 75%, minimum gain	1250			V/µs	Typ
Settling time to 1%(1)	1 V_{PP} Step, minimum gain	11			ns	Typ
Harmonic distortion	$V_{O(PP)}$ = 1 V, $R_{L(diff)}$= 400 Ω					
2nd Harmonic	f = 32 MHz	–65			dBc	Typ
3rd Harmonic	f = 32 MHz	–61			dBc	Typ
Third-order intermodulation distortion	P_O = –10 dBm each tone, f_C=70 MHz, 200 kHz tone spacing	–62			dBc	Typ
Third-order output intercept point	f_C=70 MHz, 200 kHz tone spacing	21			dBm	Typ
Noise figure (with input termination)	Source impedance: 50 Ω	9			dB	Typ
Total input voltage noise	f > 100 kHz	1.1			$nV/\sqrt{Hz}$	Typ
DC PERFORMANCE—INPUTS (See Figure 2)						
Input bias current		20	39	40	µA	Max
Input bias current offset		<150			pA	Typ
Minimum input voltage	Minimum gain	1.5	1.6	1.7	V	Max
Maximum input voltage	Minimum gain	3.5	3.35	3.2	V	Min
Common-mode rejection ratio		114	56	44	dB	Min
Differential input impedance		8.5 || 3.0			kΩ || pF	Typ
DC PERFORMANCE—OUTPUTS (See Figure 2)						
Output offset voltage	All gains	±100	±340	±480	mV	Max
Maximum output voltage high		3.5	3.275	3.25	V	Min
Minimum output voltage low		1.5	1.7	1.8	V	Max
Output current		±37	±16	±16	mA	Min
Output impedance		15			Ω	Typ
OUTPUT COMMON-MODE VOLTAGE CONTROL (See Figure 2)						
Small-signal bandwidth		32			MHz	Typ
Gain		1.00			V/V	Typ
Common-mode offset voltage		4.5	12	13.8	mV	Max
Minimum input voltage		1.75			V	Typ
Maximum input voltage		3.25			V	Typ
Input impedance		25 || 1			kΩ || pF	Typ
Default voltage, with no connect		2.5			V	Typ
Input bias current		<1			µA	Typ

(1) Slew rate and settling time measured at amplifier output.

SPECIFICATIONS: MAIN AMPLIFIER (CONTINUED)

V_{S+} = 5 V, V_{S-} = 0 V, V_{OCM} = 2.5 V, V_{ICM} = 2.5 V, V_{G-} = 0 V, V_{G+} = 1 V (maximum gain), T_A = 25°C, ac performance measured using the ac test circuit shown in Figure 1 (unless otherwise noted). DC performance is measured using the dc test circuit shown in Figure 2 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TYP	OVER TEMPERATURE			
		25 C	25 C	–40 C to 85 C	UNITS	MIN/ MAX
GAIN CONTROL (See Figure 2)						
Gain control differential voltage range	V_{G+}	0 to 1			V	Typ
Minus gain control voltage	$V_{G-} - V_{S-}$	–0.6 to 0.8			V	Typ
Minimum gain	V_{G+} = 0 V	11.6			dB	Typ
Maximum gain	V_{G+} = 0.9 V	46.5			dB	Typ
Gain slope	V_{G+} = 0 V to 0.9 V	38.8			dB/V	Typ
Gain slope variation	V_{G+} = 0 V to 0.9 V	±1.5			dB/V	Typ
Gain error	V_{G+} = 0 V to 0.15 V	±4			dB	Typ
	V_{G+} = 0.15 V to 0.9 V	±2.25			dB	Typ
Gain control input bias current		<1			µA	Typ
Gain control input resistance		40			kΩ	Typ
Gain control bandwith	Small signal –3 dB	15			MHz	Typ
VOLTAGE CLAMPING (See Figure 2)						
Output voltages ($V_{OUT\pm}$) relative to clamp voltages ($V_{CL\pm}$)	In voltage limiting mode	±25	±38	±60	mV	Max
$V_{CL\pm}$ input resistance		3.3			kΩ	Typ
$V_{CL\pm}$ voltage limits		V_{S-} to V_{S+}			V	Typ
POWER SUPPLY (See Figure 2)						
Specified operating voltage		5	5.5	5.5	V	Max
Maximum quiescent current		40	48	49	mA	Max
Power supply rejection (±PSRR)		77	70	45	dB	Min
POWERDOWN (See Figure 2)						
Enable voltage threshold	TTL low = normal operation	1.4		1.0	V	Min
Disable voltage threshold	TTL high = shut down	1.4		1.65	V	Max
Power-down quiescent current		0.35	0.4	0.45	mA	Max
Input current high		9	16	19	µA	Max
Input current low		109	116	119	µA	Max
Input impedance		50 || 1			kΩ || pF	Typ
Turnon time delay	Measured to 50% quiescent current	820			ns	Typ
Turnoff time delay		500			ns	Typ
Forward isolation in power down		80			dB	Typ
Input resistance in power down		> 1			MΩ	Typ
Output resistance in power down		16			kΩ	Typ

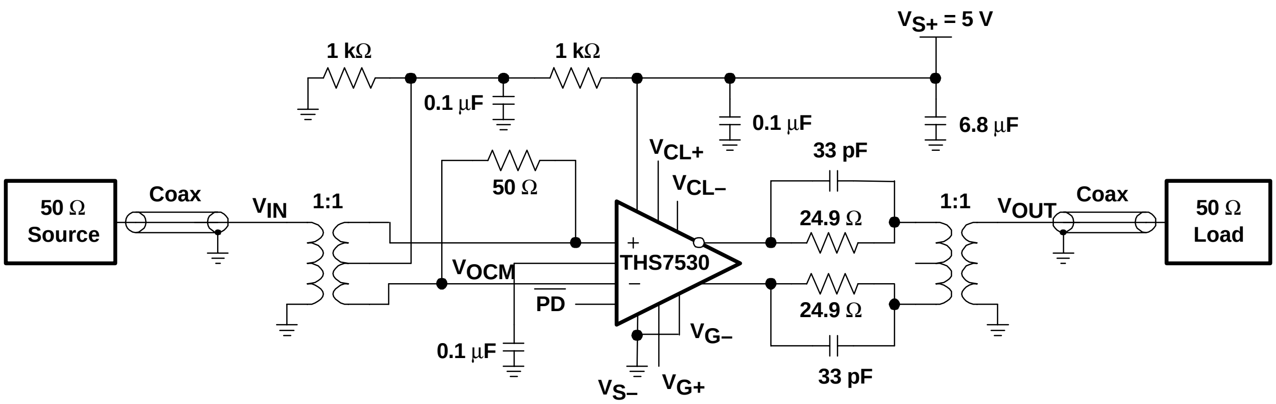


Figure 1. AC Test Circuit

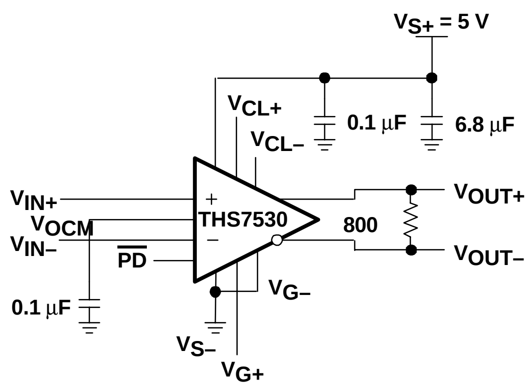
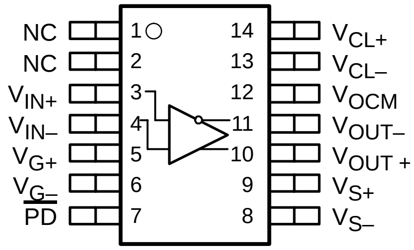


Figure 2. DC Test Circuit

PIN ASSIGNMENTS

THD7530PWP
(TOP VIEW)



NC – No internal connection

Terminal Functions

TERMINAL		DESCRIPTION
NO.	**NAME**	
1	NC	No internal connection
2	NC	No internal connection
3	V_{IN+}	Noninverting amplifier input
4	V_{IN-}	Inverting amplifier input
5	V_{G+}	Gain setting positive input
6	V_{G-}	Gain setting negative input
7	$\overline{PD}$	Powerdown, $\overline{PD}$ = logic low puts part into low power mode, $\overline{PD}$ = logic high or open for normal operation
8	V_{S-}	Negative amplifier power supply input
9	V_{S+}	Positive amplifier power supply input
10	V_{OUT+}	Noninverted amplifier output
11	V_{OUT-}	Inverted amplifier output
12	V_{OCM}	Output common-mode voltage input
13	V_{CL-}	Output negative clamp voltage input
14	V_{CL+}	Output positive clamp voltage input

TYPICAL CHARACTERISTICS

TABLE OF GRAPHS

Measured using the ac test circuit shown in Figure 1 (unless otherwise noted).

		FIGURE
Voltage Gain to Load	vs Frequency (Input at 45 dBm)	3
Gain and Gain Error	vs V_{G+}	4
Noise Figure	vs Frequency	5
Output Intercept Point	vs Frequency	6
1-dB Compression Point	vs Frequency	7
Total Input Voltage Noise	vs Frequency	8
Intermodulation Distortion	vs Frequency	9
Harmonic Distortion	vs Frequency	10
S–Parameters	vs Frequency	11
Differential Input Impedance of Main Amplifier	vs Frequency	12
Differential Output Impedance of Main Amplifier	vs Frequency	13
V_{G+} Input Impedance	vs Frequency	14
V_{OCM} Input Impedance	vs Frequency	15
Common-Mode Rejection Ratio	vs Frequency	16
Step Response – 2 V_{PP}	vs Time	17
Step Response – Rising Edge	vs Time	18
Step Response – Falling Edge	vs Time	19

VOLTAGE GAIN TO LOAD vs FREQUENCY (P_{IN} = –45 dBm)

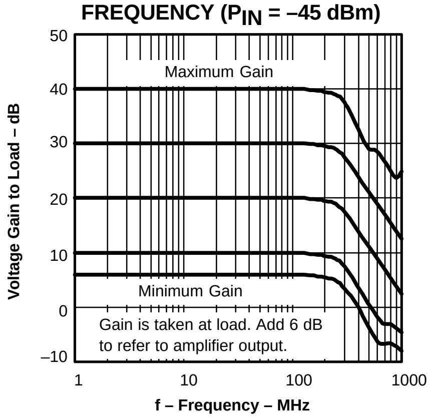


Figure 3

GAIN AND GAIN ERROR vs V_{G+}

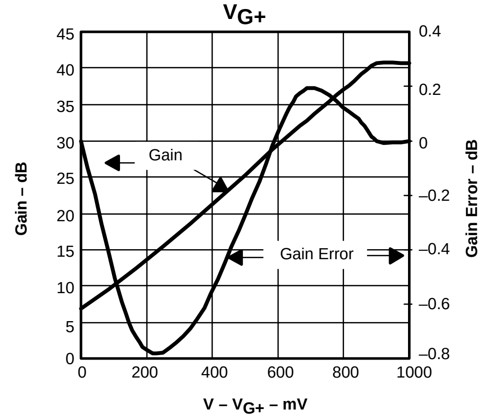


Figure 4

NOISE FIGURE vs FREQUENCY

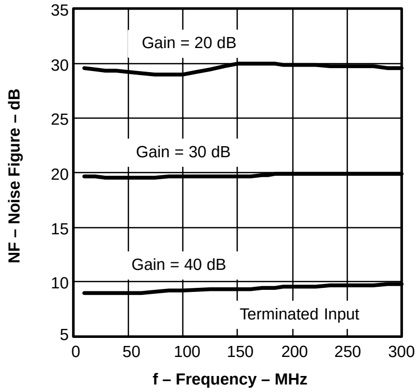


Figure 5

OUTPUT INTERCEPT POINT vs FREQUENCY

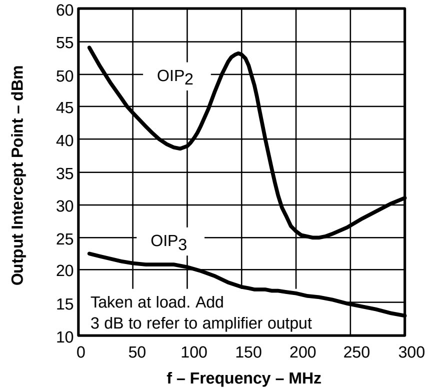


Figure 6

1 dB COMPRESSION POINT vs FREQUENCY

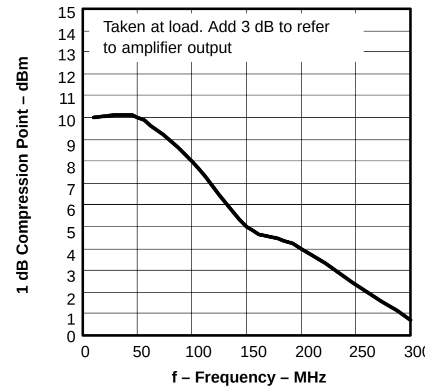


Figure 7

TOTAL INPUT VOLTAGE NOISE vs FREQUENCY

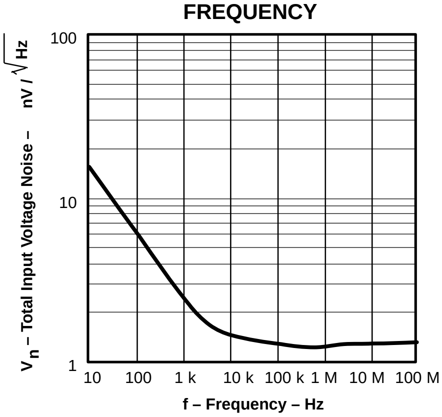


Figure 8

INTERMODULATION DISTORTION vs FREQUENCY

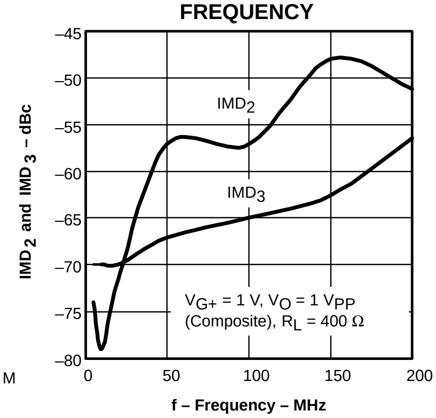


Figure 9

HARMONIC DISTORTION vs FREQUENCY

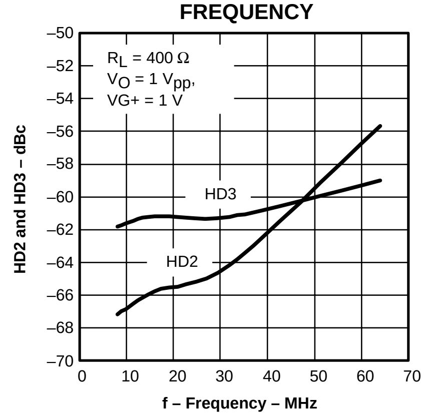


Figure 10

S-PARAMETERS vs FREQUENCY

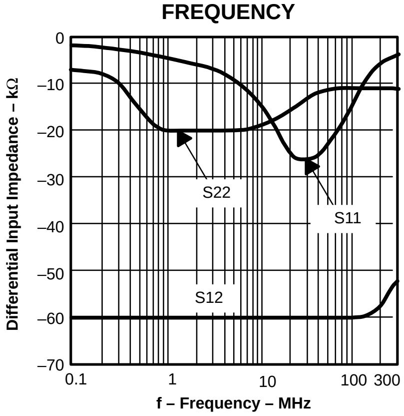


Figure 11

DIFFERENTIAL INPUT IMPEDANCE OF MAIN AMPLIFIER vs FREQUENCY

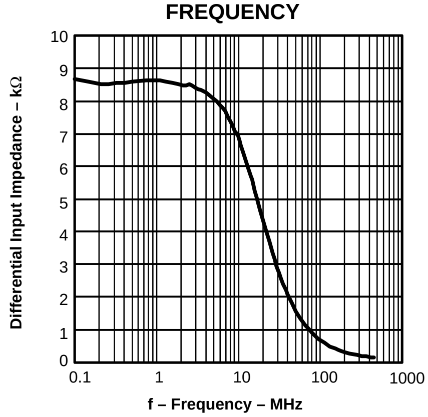


Figure 12

DIFFERENTIAL OUTPUT IMPEDANCE OF MAIN AMPLIFIER vs FREQUENCY

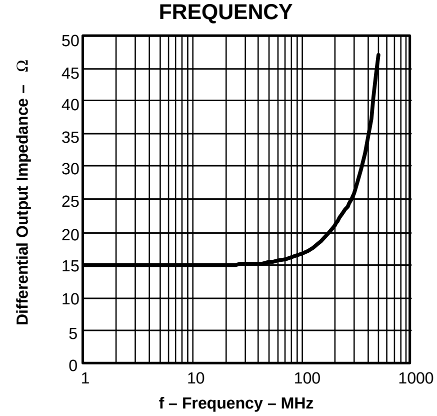


Figure 13

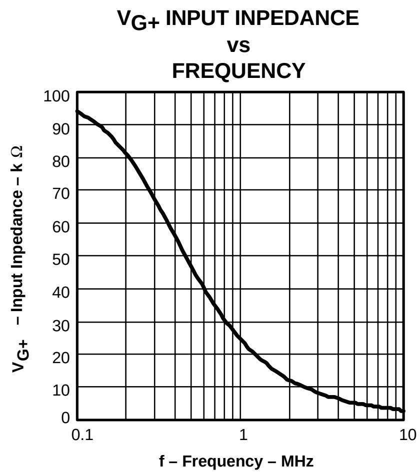


Figure 14

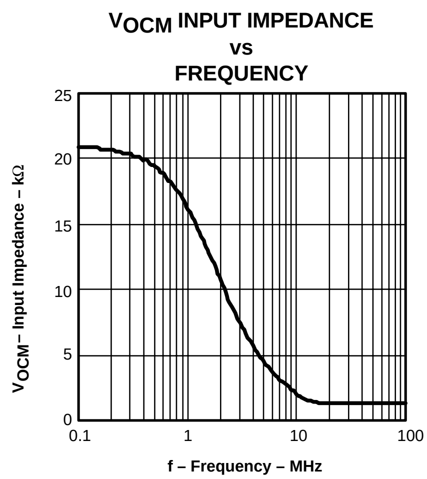


Figure 15

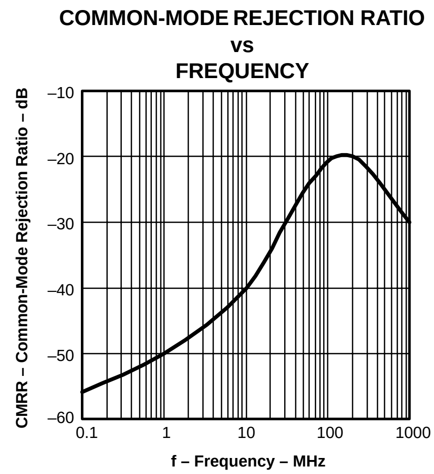


Figure 16

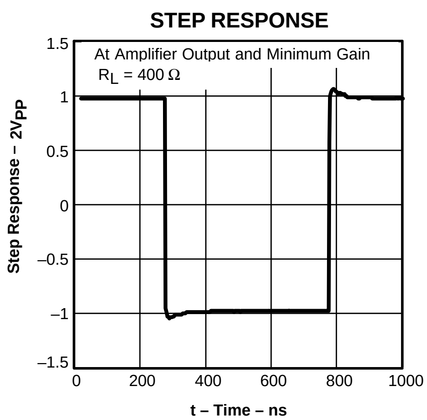


Figure 17

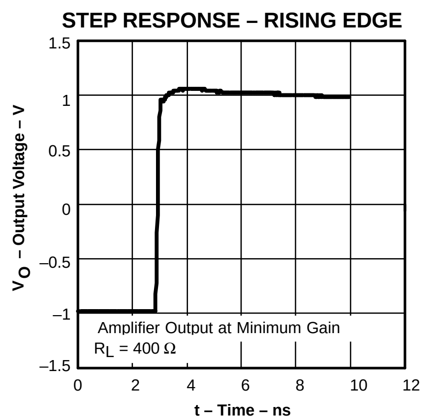


Figure 18

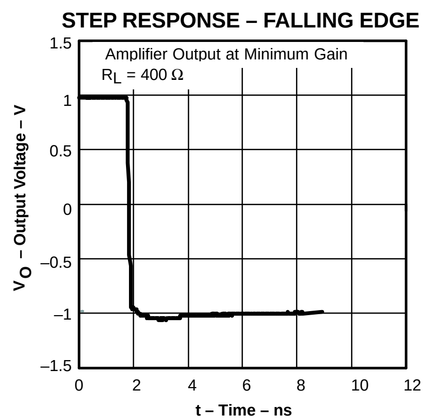


Figure 19

APPLICATION INFORMATION

The THS7530 is designed for nominal 5-V power supply from V_{S+} to V_{S-}.

The amplifier has fully differential inputs, V_{IN+} and V_{IN-}, and fully differential outputs, V_{OUT+} and V_{OUT-} The inputs are high impedance and outputs are low impedance. External resistors are recommended for impedance matching and termination purposes.

The inputs and outputs can be dc-coupled, but for best performance, the input and output common-mode voltage should be maintained at the midpoint between the two supply pins. The output common-mode voltage is controlled by the voltage applied to V_{OCM}. Left unterminated, V_{OCM} is set to midsupply by internal resistors. A 0.1-µF bypass capacitor should be placed between V_{OCM} and ground to reduce common-mode noise. The input common-mode voltage defaults to midrail when left unconnected. For voltages other than midrail, V_{OCM} must be biased by external means. V_{IN+} and V_{IN-} both require a nominal 30-µA bias current for proper operation. Therefore, insure equal input impedance at each input to avoid generating an offset voltage that varies with gain.

Voltage applied from V_{G-} to V_{G+} controls the gain of the part with 38.8-dB/V gain slope. The input can be differential or single ended. V_{G-} must be maintained within –0.6 V and +0.8 V of V_{S-} for proper operation. The negative gain input should typically be tied directly to the negative power supply.

V_{CL+} and V_{CL-} are inputs that limit the output voltage swing of the amplifier. The voltages applied set an absolute limit on the voltages at the output. Input voltages at V_{CL+} and V_{CL-} clamp the output insuring that neither output exceeds those values.

The power-down input is a TTL compatible input, referenced to the negative supply voltage. A logic low puts the THS7530 in power savings mode. In power-down mode the part consumes less than 1-mA current, the output goes high impedance, and a high amount of isolation is maintained between the input and output.

Power supply bypass capacitors are required for proper operation. A 6.8-µF tantalum bulk capacitor is recommended if the amplifier is located far from the power supply and may be shared among other devices. A ceramic 0.1-µF capacitor is recommended within 0.1” of the device power pin. The ceramic capacitors should be located on the same layer as the amplifier to eliminate the use of vias between the capacitors and the power pin.

The following circuits show some basic circuit configurations.

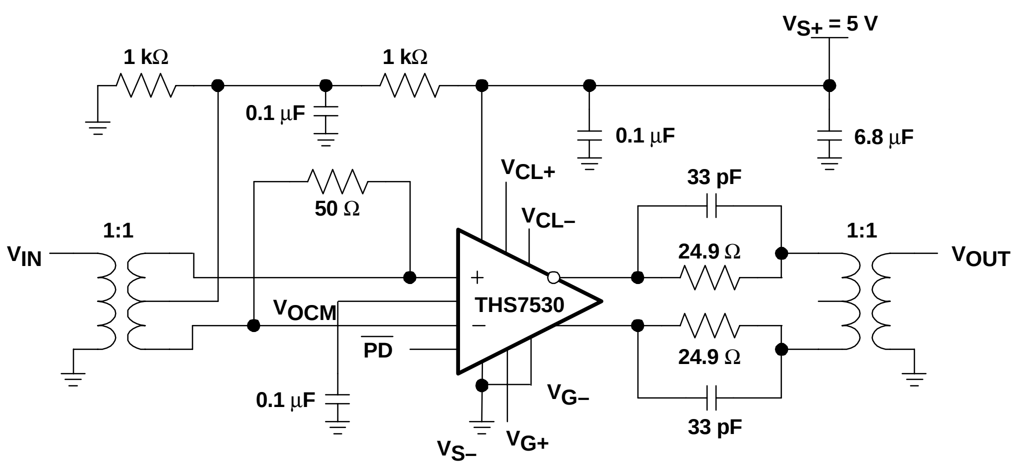


Figure 20. EVM Schematic: Designed for Use With Typical 50-   RF Test Equipment

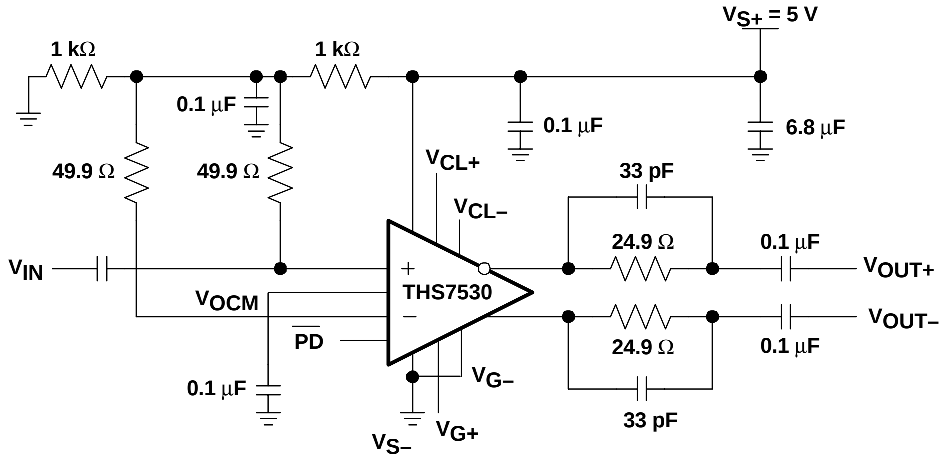


Figure 21. AC-Coupled Single-Ended Input With AC-Coupled Differential Output

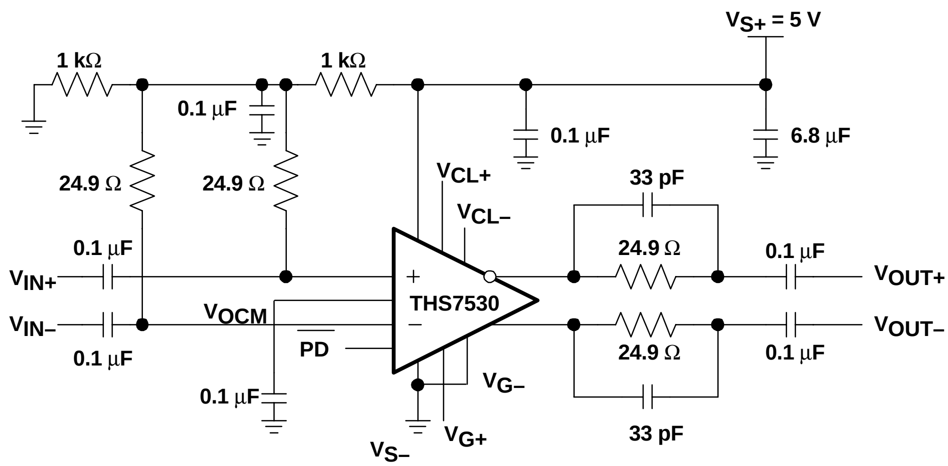


Figure 22. AC-Coupled Diferential Input With AC-Coupled Differential Output

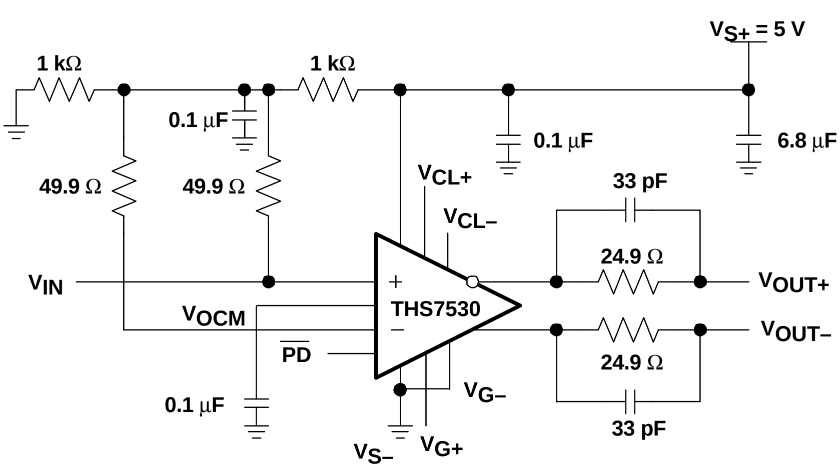


Figure 23. DC-Coupled Single-Ended Input With DC-Coupled Differential Output

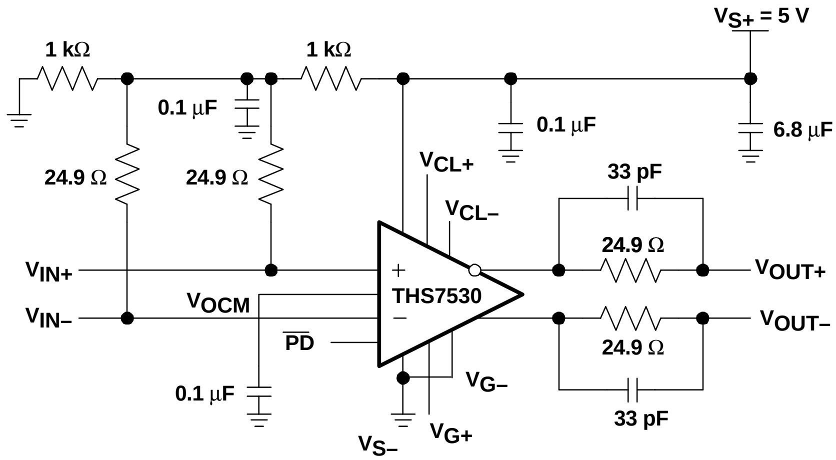


Figure 24. DC-Coupled Differential Input With DC-Coupled Differential Output

LAYOUT CONSIDERATIONS

The THS7530 comes in a thermally enhance PowerPAD™ package. Figure 25 shows the recommended number of vias and thermal land size recommended for best performance. Thermal vias connect the thermal land to internal or external copper planes and should have a drill diameter sufficiently small so that the via hole is effectively plugged when the barrel of the via is plated with copper. This plug is needed to prevent wicking the solder away from the interface between the package body and the thermal land on the surface of the board during solder reflow. The experiments conducted jointly with Solectron Texas indicate that a via drill diameter of 0.33mm (13 mils) or smaller works well when 1 ounce copper is plated at the surface of the board and simultaneously plating the barrel of the via. If the thermal vias are not plugged when the copper plating is performed, then a solder mask material should be used to cap the vias with a dimension equal to the via diameter + 0,1 mm minimum. This prevents the solder from being wicked through the thermal via and potentially creating a solder void in the region between the package bottom and the thermal land on the surface of the PCB.

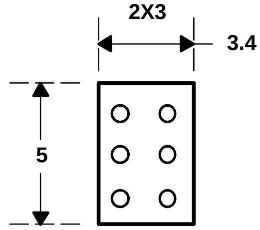


Figure 25. Recommended Thermal Land Size and Thermal Via Patterns (dimensions in mm)

See TI's Technical Brief titled PowerPAD™ Thermally Enhanced Package (SLMA002) for a detailed discussion of the PowerPAD™ package, its dimensions, and recommended use.

THEORY OF OPERATION

Figure 26 shows a simplified schematic of the THS7530.

The input architecture is a modified Gilbert Cell. The output from the Gilbert Cell is converted to a voltage and buffered to the output as a fully-differential signal. A summing node between the outputs is used to compare the output common-mode voltage to the V_{OCM} input. The V_{OCM} error amplifier then servos the output common-mode voltage to maintain it equal to the V_{OCM} input. Left unterminated, V_{OCM} is set to midsupply by internal resistors.

The gain control input is conditioned to give linear in dB gain control (block H). The gain control input is a differential signal from 0 V to 0.9 V which varies the gain from 11.6 dB to 46.5 dB.

V_{CL+} and V_{CL-} provide inputs that limit the output voltage swing of the amplifier.

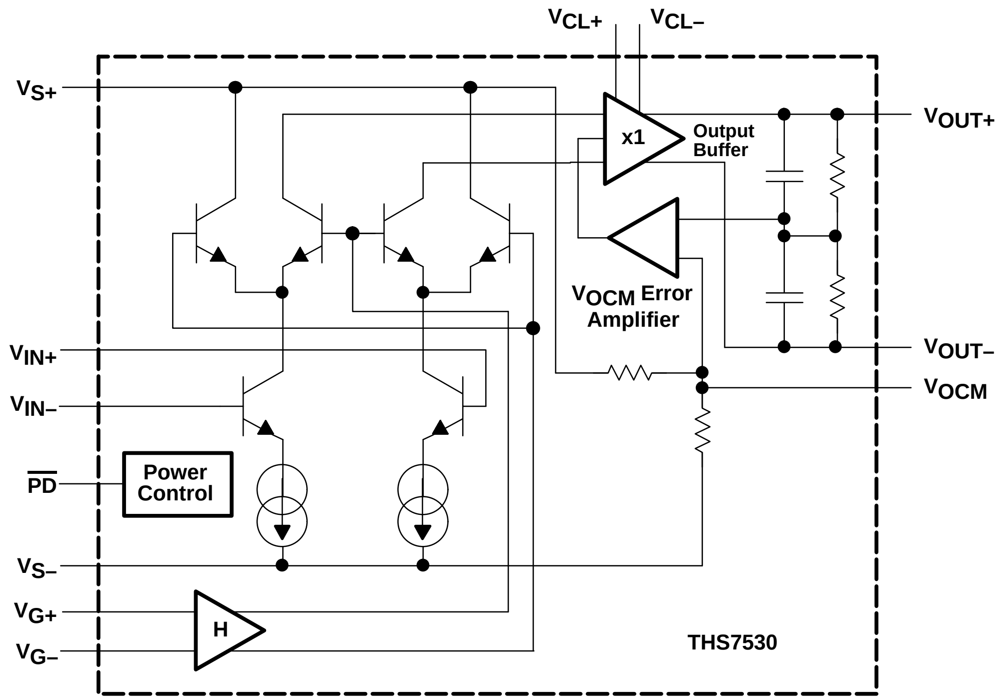


Figure 26. THS7530 Simplified Schematic

SPICE MODEL

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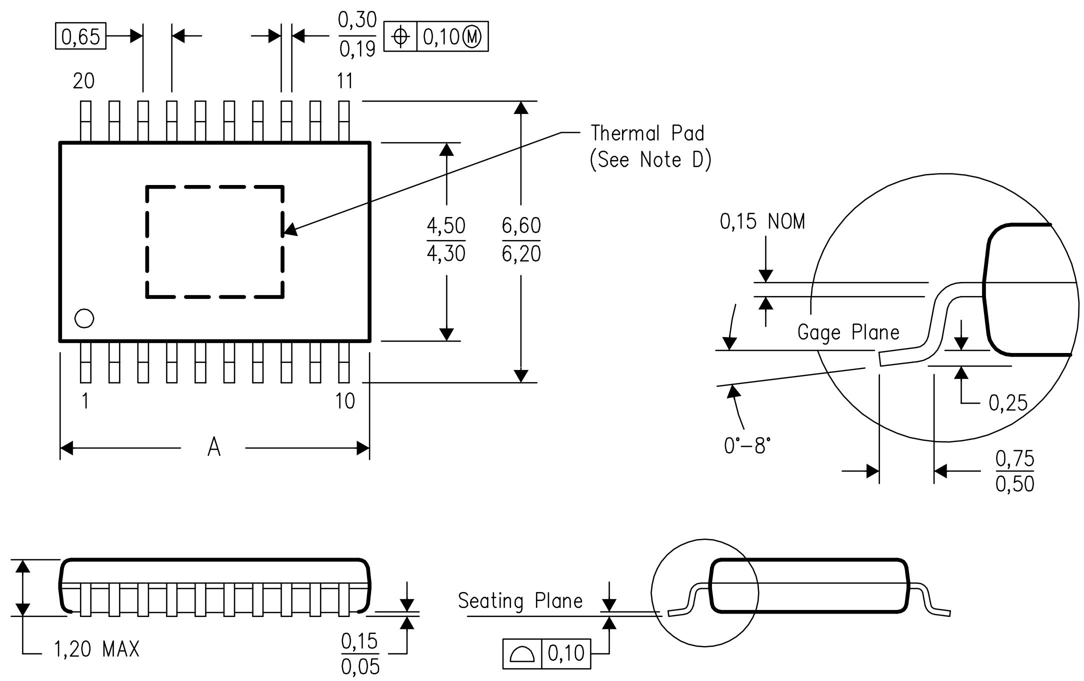
*
* THS7530 SUBCIRCUIT
* HIGH SPEED FULLY DIFFERENTIAL VARIABLE AMPLIFIER
* WRITTEN 11/26/02
* VG– is tied to VS– and output clamping is not modeled
* CONNECTIONS:   IN+
*                |      IN–
*                |       |      VS+
*                |       |      |      VS–
*                |       |      |      |    OUT–
*                |       |      |      |     |    OUT+
*                |       |      |      |     |     |    VOCM
*                |       |      |      |     |     |     |     VG+
*                |       |      |      |     |     |     |      |
.SUBCKT THS7530  1       2      3      4     5     6     7      8
*
*INPUT*
Q1          122 1 101 NPN_IN  16
Q2          123 2 102 NPN_IN  16
R1          102 101  25
I1          101 4 DC 4.85e–3
I2          102 4 DC 4.85e–3
```

```
*QUAD*
Q3          132 120 122 NPN  16
Q4          121 119 122 NPN  16
Q5          132 119 123 NPN  16
Q6          121 120 123 NPN  16
R2          132 3  250
R3          121 3  250
*CURRENT AMP*
F1          128 129 VF1 6
VF1         132 121 0V
*Z NODE*
R4          128 129  2k
I3          129 4 DC 0.75e–3
I4          128 4 DC 0.75e–3
V9          128 328 0.7
V10         129 329 0.7
*FREQUENCY SHAPING*
E3          131 0 329 0 1
R5          131 140  30
L3          140 133  7.5n
C6          133 0  24p
E4          130 0 328 0 1
R9          130 141  30
L4          141 125  10n
C7          125 0  27p
*OUTPUT BUFFER*
Q9            4 133 117 PNP  5.12
Q10           3 133 127 NPN  5.12
Q11           3 117 134 NPN  81.92
Q12           4 127 135 PNP  81.92
Q13           4 125 116 PNP  5.12
Q14           3 125 126 NPN  5.12
Q15           3 116 136 NPN  81.92
Q16           4 126 137 PNP  81.92
R6                  138 134  5
R7                  135 138  5
R10                 139 136  5
R11             137 139  5
I5              3 117 DC 0.4e–3
I6              127 4 DC 0.4e–3
I7              3 116 DC 0.4e–3
I8              126 4 DC 0.4e–3
```

```
*OUTPUT Z*
R8            113 138  2
R12           115 139  2
L1          113 5  4n
L2          115 6  4n
C1            6 5  2p
*VOCM
Rcm1         115 114  8k
Ccm1         115 114  0.1p
Rcm2         114 113  8k
Ccm2         114 113  0.1p
E1               118 0 114 7 1e3
Rtop               3 7  50k
Rbot               4 7  50k
Q7               128 118 3 PNP  16
Q8               129 118 3 PNP  16
*GAIN CONTROL*
V8         235 8 0.454
E5         231 0 235 4 0.51
E6         232 0 POLY(1) 231 0 0.0 1 1 0.5 3.5
E7         233 0 232 0 0.115
E8         234 0 POLY(1) 233 0 0.0 0 1 0 0.333
E9         120 119 234 0 0.42
V7         3 120 1.6
Rsupply 3 4 310
.MODEL NPN_IN NPN
+  KF=1E–12
.MODEL NPN NPN
.MODEL PNP PNP
.ENDS
```

PWP (R-PDSO-G**) PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE

20 PIN SHOWN



PINS ** / DIM	14	16	20	24	28
A MAX	5,10	5,10	6,60	7,90	9,80
A MIN	4,90	4,90	6,40	7,70	9,60

4073225/G 08/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusions.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <http: //www.ti.com>.
E. Falls within JEDEC MO-153

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