

# THS6101 UPSTREAM CABLE DRIVER FOR DOCSIS-COMPLIANT CABLE COMMUNICATIONS

SLOS257 – AUGUST 2000

- **Low Noise and Distortion**
  - Exceeds all DOCSIS Requirements
  - – 64 dB HD3 at 29.3 MHz,  $V_O = 56$  dBmV
  - 83 dBmV IP3 at 65MHz
  - – 47 dBmV Noise Level at Minimum Gain
- **Wide Range of Output Power Levels**
  - 62 dBmV RMS Output Power Drive
  - 54 dB Range of Programmable Gain
  - 6 dB Gain Steps
- **Low Power Solution**
  - 15 mW Disable-Mode Power Consumption
  - Power Consumption Scales With Gain
- **Single-Supply 5 V Operation**

## description

The THS6101 is a Class-A amplifier designed specifically for driving the upstream data path in Data Over Cable System Interface Specification (DOCSIS)-compliant cable modem applications. The DOCSIS places demanding constraints on the upstream drive amplifier, and the THS6101 is designed for full compliance with this industry standard.

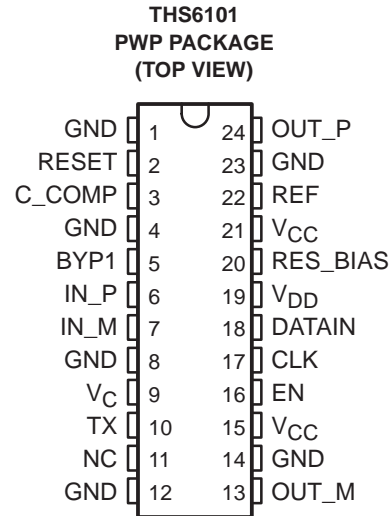
Using only a single 5-V power supply, the THS6101 meets all of the DOCSIS distortion requirements. Differential signal paths throughout the device maintain signal integrity. An external 2:1 balun transformer converts the differential output signal to a single-ended output signal.

The THS6101 architecture results in a very low third-harmonic distortion of  $-64$  dBc at 29.3 MHz and an output power level of 56 dBmV. Signal linearity is maintained at maximum output levels, providing a third-harmonic distortion of  $-58$  dBc at 29.3 MHz and an output power level of 62 dBmV. The device also exhibits an IP3 of 83 dBmV at a frequency of 65 MHz and an output power level of 60 dBmV, for two-tone intermodulation effects.

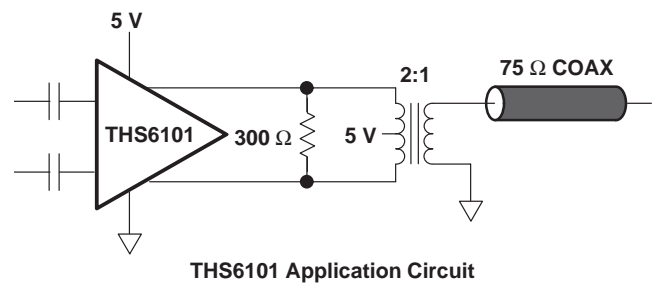
Output noise from the THS6101 is very low. At minimum gain, the device produces less than  $10$  nV/ $\sqrt{\text{Hz}}$  of noise at its output. This translates to a level of  $-47$  dBmV at the lowest symbol rate, which is lower than that required by DOCSIS. The THS6101 exhibits a disable-mode output noise of  $2$  nV/ $\sqrt{\text{Hz}}$  or  $-61$  dBmV.

The THS6101 output power level range exceeds the 58 dBmV required by DOCSIS. Its 62-dBmV RMS drive readily compensates for typical losses associated with the output transformer and tuner duplexer. The THS6101 provides a gain range of 54 dB, from 32 dB down to  $-22$  dB in 6-dB steps. The gain is programmable through an SPI-compatible serial interface with a 4-bit control word.

The stringent power requirements of cable telephony and VOIP systems will greatly benefit from the low, industry-leading power consumption of the THS6101. With a typical 10% transmit duty-cycle, the 15-mW disable-mode power consumption of the THS6101 results in an average power consumption of 94 mW. Furthermore, the advanced architecture of the THS6101 reduces this average power consumption to 15 mW when transmitting at minimum gain.



NC – No internal connection



**PRODUCT PREVIEW**



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PRODUCT PREVIEW information concerns products in the formative or design phase of development. Characteristic data and other specifications are design goals. Texas Instruments reserves the right to change or discontinue these products without notice.



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## AVAILABLE OPTIONS

PACKAGED DEVICES	
$T_A$	TSSOP† (PWP) PowerPAD™
0°C to 70°C	THS6101CPWP
-40°C to 85°C	THS6101IPWP

† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., THS6101CPWPR).

## Absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Supply voltage, $V_{CC}$	13.2 V
Supply voltage, $V_{DD}$	5.5 V
Input voltage, $V_I$	$V_{CC}$
Output current, $I_O$	250 mA
Differential input voltage, $V_{ID}$	$\pm 5$ V
Continuous total power dissipation	See Dissipation Rating Table
Operating free air temperature, $T_A$ : C suffix	0°C to 70°C
I suffix	-40°C to 85°C
Maximum junction temperature	150°C
Storage temperature, $T_{stg}$	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	300°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	$\theta_{JA}$ † (°C/W)	$\theta_{JC}$ (°C/W)	$T_A = 25^\circ\text{C}$ POWER RATING
PWP(24)	30.1	0.92	3.32 W

§ This data was taken using 2 oz. Trace and copper pad that is soldered directly to a 3 in. × 3 in. PCB.

¶ The data shown for  $\theta_{JA}$  was taken using the recommended PowerPAD™ PCB guidelines.

## recommended operating conditions

		MIN	TYP	MAX	UNIT
Operating free-air temperature, $T_A$	C suffix	0		70	°C
	I suffix	-40		85	

## power supply

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{CC}$ Analog supply voltage		4.5	5	5.5	V
$V_{DD}$ Logic supply voltage		4.5	5	5.5	V
$I_{CC}$ Quiescent current	Transmit mode, G = 32 dB (Gain code = 9)		186		mA
	Transmit mode, G = 26 dB (Gain code = 8)		125		
	Transmit mode, G = 20 dB (Gain code = 7)		68		
	Transmit mode, G = 14 dB (Gain code = 6)		40		
	Transmit mode, G = 8 dB (Gain code = 5)		30		
	Transmit mode, G = 2 dB (Gain code = 4)		22		



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**recommended operating conditions (continued)**

**power supply**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I <sub>CC</sub>	Quiescent current	Transmit mode, G = -4 dB (Gain code = 3)		20		mA
		Transmit mode, G = -10 dB (Gain code = 1)		16		
		Transmit mode, G = -16 dB (Gain code = 1)		16		
		Transmit mode, G = -22 dB (Gain code = 0)		15		
		Disable mode (TX = 0)		3		

**electrical characteristics, V<sub>CC</sub> = V<sub>DD</sub> = 5 V, V<sub>IN</sub> = 0.25 V<sub>p-p</sub>, R<sub>L</sub> = 75 Ω, T<sub>A</sub> = 25°C (unless otherwise noted)**

**input characteristics**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Z <sub>IN</sub>	Input impedance	Single-ended		750		W
V <sub>IN</sub>	Input voltage range	Differential		62.5	250	mV
CMR <sub>IN</sub>	Common mode rejection	V <sub>IN,CM</sub> = 1 V, f <sub>IN</sub> = 10 MHz, Gain = 2		60		dB
	Gain range		-22		32	dB
	Absolute gain accuracy		-1		1	dB
	Gain step width		5.8	6	6.2	dB

**output characteristics**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Output voltage range	V <sub>CC</sub> = 5 V		6.32		V <sub>p-p</sub>
	Output impedance	Transmit mode		75		W
		Disable mode		75		W
	Output noise spectral density	Gain = 32 dB, TX = 1		94.5		nV/√Hz
		Gain = -22 dB, TX = 1		10		
		All gain codes, TX = 0		2		

**dynamic performance**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
	Full power bandwidth	Gain code = 9, V <sub>in</sub> = 35 dBmV sine wave, Gain code < 9, V <sub>in</sub> = 39 dBmV sine wave		100		MHz
2 <sup>nd</sup>	Harmonic distortion	f <sub>in</sub> = 44 MHz	V <sub>OUT</sub> = 56 dBmV		-62	dBc
			V <sub>OUT</sub> = 62 dBmV		-57	
3 <sup>rd</sup>	Harmonic distortion	f <sub>in</sub> = 29.3 MHz	V <sub>OUT</sub> = 56 dBmV		-64	dBc
			V <sub>OUT</sub> = 62 dBmV		-58	
	3 <sup>rd</sup> Order intercept	f <sub>in</sub> = 29.3 MHz		83		dBmV
	Two-tone 3 <sup>rd</sup> order distortion	f <sub>in1</sub> = 42 MHz, f <sub>in2</sub> = 42.2 MHz, Gain code = 9 (G = 32 dB)	V <sub>OUT</sub> = 60dBmV, V <sub>IN</sub> = 30dBmV,		-65	dBc
		f <sub>in1</sub> = 65 MHz, V <sub>OUT</sub> = 60 dBmV, Gain code = 9 (G = 32 dB)	f <sub>in2</sub> = 65.2 MHz, V <sub>IN</sub> = 30 dBmV,		-62.5	dBc
	Spurious-free dynamic range	f <sub>in</sub> = 65 MHz, Gain code = 9 (G = 32 dB)		TBD		dBc
	Signal feedthrough and spurious emissions	f <sub>in</sub> = 65 MHz, Disable mode		TBD		dBmV

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electrical characteristics,  $V_{CC} = V_{DD} = 5\text{ V}$ ,  $V_{IN} = 0.25\text{ V}_{p-p}$ ,  $R_L = 75\ \Omega$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted) (continued)

## power control

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Turn on/turn off time			TBD		ms
Enable/disable output transient voltage	Gain code = 9			100	mV
	Gain code $\leq 5$			7	
Transient slew rate	All gain codes		TBD		V/ $\mu\text{s}$
Gain code 0	$G = -22\text{ dB}$ (min gain)		10000000		
Gain code 1	$G = -16\text{ dB}$		10000001		
Gain code 2	$G = -10\text{ dB}$		10000010		
Gain code 3	$G = -4\text{ dB}$		10000011		
Gain code 4	$G = 2\text{ dB}$		10000100		
Gain code 5	$G = 8\text{ dB}$		10000101		
Gain code 6	$G = 14\text{ dB}$		10000110		
Gain code 7	$G = 20\text{ dB}$		10000111		
Gain code 8	$G = 26\text{ dB}$		10001000		
Gain code 9	$G = 32\text{ dB}$ (max gain)		10001001		

## device

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	Units
<b>LOGIC INPUT LEVELS</b>					
$V_{IH}$ High-level input voltage	Relative to GND		2		V
$V_{IL}$ Low-level input voltage	Relative to GND			0.8	V
$I_{IH}$ High-level input current	$V_{IH} = 5\text{ V}$		20	100	nA
$I_{IL}$ Low-level input current	$V_{IL} = 0.5\text{ V}$		0.9	2	mA
<b>SERIAL INTERFACE TIMING</b>					
$t_c(\text{CLK})$ Clock cycle time		20			ns
$t_{su}(\text{DS})$ DATAIN to CLK setup time		5			ns
$t_h(\text{DH})$ DATAIN to CLK hold time		5			ns
$t_{su}(\text{ENS})$ EN to CLK setup time		10			ns
$t_h(\text{ENH})$ EN to CLK hold time		10			ns

## PARAMETER MEASUREMENT INFORMATION

The THS6101 is a multistage amplifier specifically designed to drive the return path in DOCSIS-compliant cable modems. The device is designed to comply with the DOCSIS requirements, providing sufficient output power, low output noise and distortion, and a clean transition to the low-power mode.

The THS6101 has a current-mode open collector output stage. A 2:1 balun transformer provides power from the 5-V connection at its primary center tap and converts the THS6101 differential output to a single-ended output for driving a coaxial cable. An external 300- $\Omega$  resistor across the device outputs provides proper termination of the line.



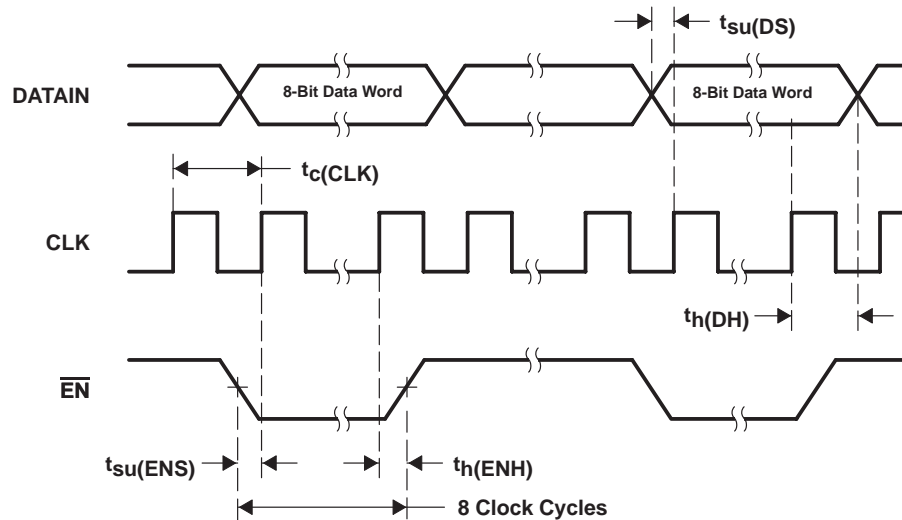
## PRINCIPLES OF OPERATION

The gain of the THS6101 ranges from  $-22$  dB at the minimum setting to  $32$  dB at the maximum setting. A serial SPI-compatible interface provides control over the gain setting. Figure 1 illustrates the required timing of the serial interface.

The following table matches gain code with its corresponding gain value.

CODE	GAIN
10000000	$-22$ dB
10000001	$-16$ dB
10000010	$-10$ dB
10000011	$-4$ dB
10000100	$2$ dB
10000101	$8$ dB
10000110	$14$ dB
10000111	$20$ dB
10001000	$26$ dB
10001001	$32$ dB

The last four bits of the code represents the THS6101 gain setting.



**Figure 1. Serial Interface Timing**

The THS6101 provides 9 coarse gain steps of  $6$  dB, for a full gain range of  $54$  dB. Variable attenuation incorporated into many DOCSIS-compliant cable modem solutions provides the fine gain control required by DOCSIS. To produce the correct output power levels, the THS6101 requires a nominal input power level of  $25$  dBmV to  $30$  dBmV. These input levels correctly interpolate between the  $6$ -dB steps produced by the THS6101.

Since cable modem transmissions are burst-mode in nature, the THS6101 is equipped with both a transmit and a disable mode. The TX input pin controls this functionality. With the TX pin pulled high, the THS6101 is powered-up and ready to transmit. Pulling the TX pin low reduces the quiescent current of the THS6101 to  $2$  mA and shuts down the output stage of the amplifier, isolating it from the line.

**THS6101**  
**UPSTREAM CABLE DRIVER FOR DOCSIS-COMPLIANT**  
**CABLE COMMUNICATIONS**

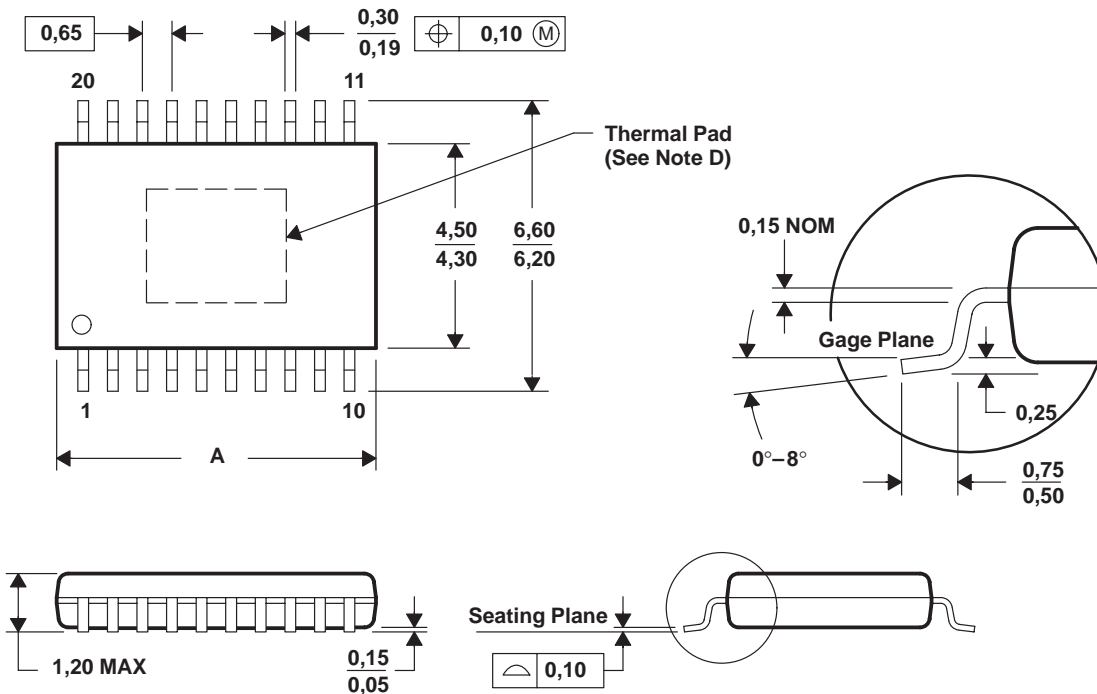
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**MECHANICAL DATA**

**PWP (R-PDSO-G\*\*)**

**PowerPAD™ PLASTIC SMALL-OUTLINE**

20 PINS SHOWN



DIM \ PINS **	PINS **				
	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/F 10/98

- 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. The package thermal performance may be enhanced by bonding the thermal pad to an external thermal plane. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.  
 E. Falls within JEDEC MO-153

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