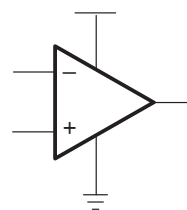


TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

- Wide Bandwidth . . . 10 MHz
- High Output Drive
 - I_{OH} . . . 57 mA at $V_{DD} - 1.5$ V
 - I_{OL} . . . 55 mA at 0.5 V
- High Slew Rate
 - $SR+$. . . 16 V/ μ s
 - $SR-$. . . 19 V/ μ s
- Wide Supply Range . . . 4.5 V to 16 V
- Supply Current . . . 1.9 mA/Channel
- Ultralow Power Shutdown Mode
 - I_{DD} . . . 125 μ A/Channel
- Low Input Noise Voltage . . . 7 nV/ $\sqrt{\text{Hz}}$
- Input Offset Voltage . . . 60 μ V
- Ultra-Small Packages
 - 8 or 10 Pin MSOP (TLC070/1/2/3)

Operational Amplifier



description

The first members of TI's new BiMOS general-purpose operational amplifier family are the TLC07x. The BiMOS family concept is simple: provide an upgrade path for BiFET users who are moving away from dual-supply to single-supply systems and demand higher ac and dc performance. With performance rated from 4.5 V to 16 V across commercial (0°C to 70°C) and an extended industrial temperature range (–40°C to 125°C), BiMOS suits a wide range of audio, automotive, industrial and instrumentation applications. Familiar features like offset nulling pins, and new features like MSOP PowerPAD™ packages and shutdown modes, enable higher levels of performance in a variety of applications.

Developed in TI's patented LBC3 BiCMOS process, the new BiMOS amplifiers combine a very high input impedance low-noise CMOS front end with a high-drive bipolar output stage, thus providing the optimum performance features of both. AC performance improvements over the TL07x BiFET predecessors include a bandwidth of 10 MHz (an increase of 300%) and voltage noise of 7 nV/ $\sqrt{\text{Hz}}$ (an improvement of 60%). DC improvements include a factor of 4 reduction in input offset voltage down to 1.5 mV (maximum) in the standard grade, and a power supply rejection improvement of greater than 40 dB to 130 dB. Added to this list of impressive features is the ability to drive ± 50 -mA loads comfortably from an ultrasmall-footprint MSOP PowerPAD package, which positions the TLC07x as the ideal high-performance general-purpose operational amplifier family.

FAMILY PACKAGE TABLE

DEVICE	NO. OF CHANNELS	PACKAGE TYPES				SHUTDOWN	UNIVERSAL EVM BOARD
		MSOP	PDIP	SOIC	TSSOP		
TLC070	1	8	8	8	—	Yes	Refer to the EVM Selection Guide (Lit# SLOU060)
TLC071	1	8	8	8	—	—	
TLC072	2	8	8	8	—	—	
TLC073	2	10	14	14	—	Yes	
TLC074	4	—	14	14	20	—	
TLC075	4	—	16	16	20	Yes	



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.

PowerPAD is a trademark of Texas Instruments.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TLC070 and TLC071 AVAILABLE OPTIONS

T_A	PACKAGED DEVICES			
	SMALL OUTLINE (D) [†]	SMALL OUTLINE (DGN) [†]	SYMBOL	PLASTIC DIP (P)
0°C to 70°C	TLC070CD TLC071CD	TLC070CDGN TLC071CDGN	xxTIACS xxTIACU	TLC070CP TLC071CP
–40°C to 125°C	TLC070ID TLC071ID	TLC070IDGN TLC071IDGN	xxTIACT xxTIACV	TLC070IP TLC071IP
	TLC070AID TLC071AID	— —	— —	TLC070AIP TLC071AIP

[†] This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLC070CDR).

TLC072 and TLC073 AVAILABLE OPTIONS

T_A	PACKAGED DEVICES						
	SMALL OUTLINE (D) [†]	MSOP				PLASTIC DIP (N)	PLASTIC DIP (P)
		(DGN) [†]	SYMBOL [‡]	(DGQ) [†]	SYMBOL [‡]		
0°C to 70°C	TLC072CD TLC073CD	TLC072CDGN —	xxTIADV —	— TLC073CDGQ	— xxTIADX	— TLC073CN	TLC072CP —
–40°C to 125°C	TLC072ID TLC073ID	TLC072IDGN —	xxTIADW —	— TLC073IDGQ	— xxTIADY	— TLC073IN	TLC072IP —
	TLC072AID TLC073AID	— —	— —	— —	— —	— TLC073AIN	TLC072AIP —

[†] This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLC072CDR).

[‡] xx represents the device date code.

TLC074 and TLC075 AVAILABLE OPTIONS

T_A	PACKAGED DEVICES		
	SMALL OUTLINE (D) [†]	PLASTIC DIP (N)	TSSOP (PWP) [†]
0°C to 70°C	TLC074CD TLC075CD	TLC074CN TLC075CN	TLC074CPWP TLC075CPWP
–40°C to 125°C	TLC074ID TLC075ID	TLC074IN TLC075IN	TLC074IPWP TLC075IPWP
	TLC074AID TLC075AID	TLC074AIN TLC075AIN	TLC074AIPWP TLC075AIPWP

[†] This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLC074CDR).



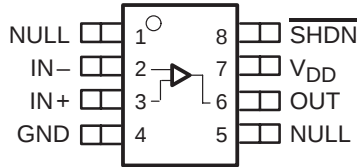
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TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

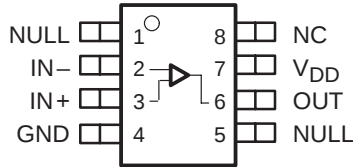
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TLC07x PACKAGE PINOUTS

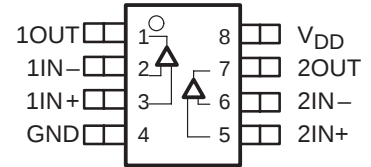
TLC070
D, DGN OR P PACKAGE
(TOP VIEW)



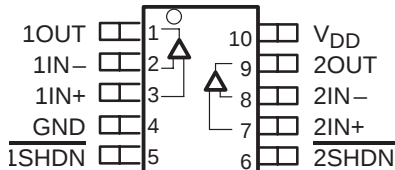
TLC071
D, DGN OR P PACKAGE
(TOP VIEW)



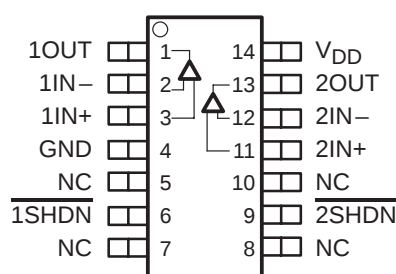
TLC072
D, DGN, OR P PACKAGE
(TOP VIEW)



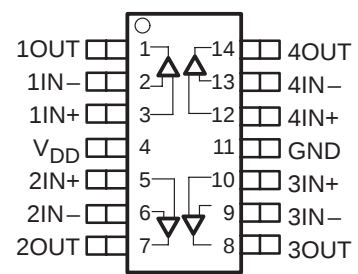
TLC073
DGQ PACKAGE
(TOP VIEW)



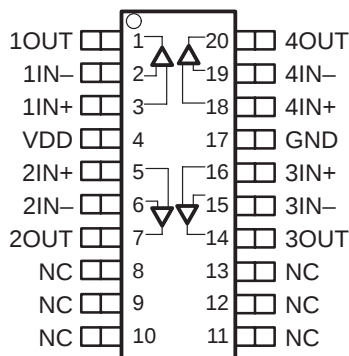
TLC073
D OR N PACKAGE
(TOP VIEW)



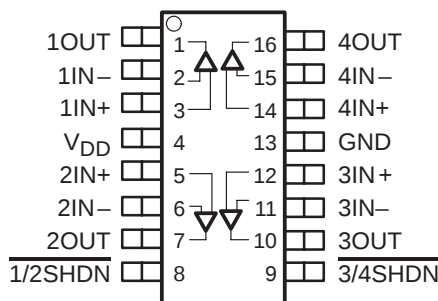
TLC074
D OR N PACKAGE
(TOP VIEW)



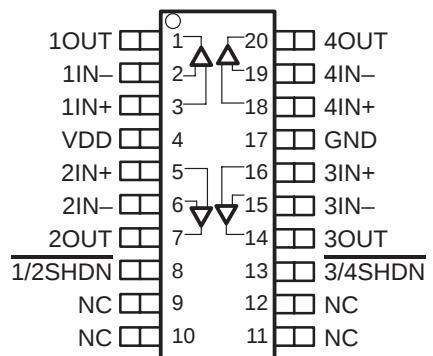
TLC074
PWP PACKAGE
(TOP VIEW)



TLC075
D OR N PACKAGE
(TOP VIEW)



TLC075
PWP PACKAGE
(TOP VIEW)



NC – No internal connection

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA

FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

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

Supply voltage, V_{DD} (see Note 1)	17 V
Differential input voltage range, V_{ID}	$\pm V_{DD}$
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : C suffix	0°C to 70°C
I suffix	–40°C to 125°C
Maximum junction temperature, T_J	150°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	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.

NOTE 1: All voltage values, except differential voltages, are with respect to GND.

DISSIPATION RATING TABLE

PACKAGE	θ_{JC} (°C/W)	θ_{JA} (°C/W)	$T_A \leq 25^\circ\text{C}$ POWER RATING
D (8)	38.3	176	710 mW
D (14)	26.9	122.3	1022 mW
D (16)	25.7	114.7	1090 mW
DGN (8)	4.7	52.7	2.37 W
DGQ (10)	4.7	52.3	2.39 W
N (14, 16)	32	78	1600 mW
P (8)	41	104	1200 mW
PWP (20)	1.40	26.1	4.79 W

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{DD}	Single supply	4.5	16	V
	Split supply	± 2.25	± 8	
Common-mode input voltage, V_{ICR}		+0.5	$V_{DD}-0.8$	V
Shutdown on/off voltage level [‡]	V_{IH}	2		V
	V_{OL}		0.8	
Operating free-air temperature, T_A	C-suffix	0	70	°C
	I-suffix	–40	125	

[‡] Relative to the voltage on the GND terminal of the device.



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA
FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY
OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A [†]	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	V _{DD} = 5 V, V _{IC} = 2.5 V, V _O = 2.5 V, R _S = 50 Ω	TLC070/1/2/3	25°C		60	1000	μV
				Full range			1500	
			TLC070/1/2/3A	25°C		20	750	
				Full range			1000	
			TLC074/5	25°C		390	1900	
				Full range			3000	
			TLC074/5A	25°C		390	1400	
				Full range			2000	
α _{VIO}	Temperature coefficient of input offset voltage					1.2		μV/°C
I _{IO}	Input offset current	V _{DD} = 5 V, V _{IC} = 2.5 V, V _O = 2.5 V, R _S = 50 Ω		25°C		0.7	50	pA
			TLC07XC	Full range			100	
			TLC07XI				700	
I _{IB}	Input bias current			25°C		1.5	50	pA
			TLC07XC	Full range			100	
			TLC07XI				700	
V _{ICR}	Common-mode input voltage	CMRR > 70 dB, R _S = 50 Ω		25°C		0.5 to 4.2		V
		CMRR > 52 dB, R _S = 50 Ω		Full range		0.5 to 4.2		
V _{OH}	High-level output voltage	V _{IC} = 2.5 V	I _{OH} = −1 mA	25°C		4.1	4.3	V
				Full range			3.9	
			I _{OH} = −20 mA	25°C		3.7	4	
				Full range			3.5	
			I _{OH} = −35 mA	25°C		3.4	3.8	
				Full range			3.2	
			I _{OH} = −50 mA	25°C		3.2	3.6	
				−40°C to 85°C			3	
V _{OL}	Low-level output voltage	V _{IC} = 2.5 V	I _{OL} = 1 mA	25°C		0.18	0.25	V
				Full range			0.35	
			I _{OL} = 20 mA	25°C		0.35	0.39	
				Full range			0.45	
			I _{OL} = 35 mA	25°C		0.43	0.55	
				Full range			0.7	
			I _{OL} = 50 mA	25°C		0.48	0.63	
				−40°C to 85°C			0.7	
I _{OS}	Short-circuit output current	Sourcing		25°C		100		mA
		Sinking		25°C		100		
I _O	Output current	V _{OH} = 1.5 V from positive rail		25°C		57		mA
		V _{OL} = 0.5 V from negative rail		25°C		55		

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA

FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)
(continued)

PARAMETER		TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
A_{VD}	Large-signal differential voltage amplification	$V_{O(PP)} = 3\text{ V}$, $R_L = 10\text{ k}\Omega$	25°C	100	120		dB
			Full range	100			
$r_{i(d)}$	Differential input resistance		25°C		1000		$G\Omega$
C_{IC}	Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		22.9		pF
z_o	Closed-loop output impedance	$f = 10\text{ kHz}$, $A_V = 10$	25°C		0.25		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 1\text{ to }3\text{ V}$, $R_S = 50\text{ }\Omega$	25°C	100	140		dB
			Full range	100			
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$)	$V_{DD} = 4.5\text{ V to }16\text{ V}$, No load $V_{IC} = V_{DD}/2$	25°C	95	130		dB
			Full range	95			
I_{DD}	Supply current (per channel)	$V_O = 2.5\text{ V}$, No load	25°C		1.9	2.5	mA
			Full range			3.5	
$I_{DD(SHDN)}$	Supply current in shutdown mode (per channel) (TLC070, TLC073, TLC075)	$\overline{SHDN} \leq 0.8\text{ V}$	25°C		125	200	μA
			Full range			250	

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA
FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY
OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A [†]	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain	V _{O(PP)} = 0.8 V, R _L = 10 kΩ		C _L = 50 pF,	25°C	10	16	V/μs
					Full range	9.5		
SR−	Negative slew rate at unity gain	V _{O(PP)} = 0.8 V, R _L = 10 kΩ		C _L = 50 pF,	25°C	12.5	19	V/μs
					Full range	10		
V _n	Equivalent input noise voltage	f = 100 Hz		C _L = 50 pF,	25°C	12		nV/√Hz
		f = 1 kHz			25°C	7		
I _n	Equivalent input noise current	f = 1 kHz		C _L = 50 pF,	25°C	0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	V _{O(PP)} = 3 V, R _L = 10 kΩ and 250 Ω, f = 1 kHz	A _V = 1		25°C	0.002%		
			A _V = 10	0.012%				
			A _V = 100	0.085%				
t _(on)	Amplifier turnon time‡	R _L = 10 kΩ		25°C	0.15		μs	
t _(off)	Amplifier turnoff time‡			25°C	1.3		μs	
Gain-bandwidth product		f = 10 kHz,	R _L = 10 kΩ	25°C	10		MHz	
t _s	Settling time	V(STEP) _{PP} = 1 V, A _V = −1, C _L = 10 pF, R _L = 10 kΩ	0.1%	25°C	0.18		μs	
			0.01%		0.39			
		V(STEP) _{PP} = 1 V, A _V = −1, C _L = 47 pF, R _L = 10 kΩ	0.1%		0.18			
			0.01%		0.39			
φ _m	Phase margin	R _L = 10 kΩ,	C _L = 50 pF	25°C	32°			
		R _L = 10 kΩ,	C _L = 0 pF		40°			
	Gain margin	R _L = 10 kΩ,	C _L = 50 pF	25°C	2.2		dB	
		R _L = 10 kΩ,	C _L = 0 pF		3.3			

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.

‡ Disable time and enable time are defined as the interval between application of the logic signal to SHDN and the point at which the supply current has reached half its final value.

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA
FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY
OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

electrical characteristics at specified free-air temperature, $V_{DD} = 12\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
V_{IO} Input offset voltage	$V_{DD} = 12\text{ V}$ $V_{IC} = 6\text{ V}$, $V_O = 6\text{ V}$, $R_S = 50\ \Omega$	TLC070/1/2/3	25°C	60	1000	μV
			Full range		1500	
		TLC070/1/2/3A	25°C	20	750	
			Full range		1000	
		TLC074/5	25°C	390	1900	
			Full range		3000	
		TLC074/5A	25°C	390	1400	
			Full range		2000	
α_{VIO} Temperature coefficient of input offset voltage				1.2		$\mu\text{V}/^\circ\text{C}$
I_{IO} Input offset current	$V_{DD} = 12\text{ V}$ $V_{IC} = 6\text{ V}$, $V_O = 6\text{ V}$, $R_S = 50\ \Omega$		25°C	0.7	50	pA
		TLC07xC	Full range		100	
		TLC07xI			700	
I_{IB} Input bias current	$V_{DD} = 12\text{ V}$ $V_{IC} = 6\text{ V}$, $V_O = 6\text{ V}$, $R_S = 50\ \Omega$		25°C	1.5	50	pA
		TLC07xC	Full range		100	
		TLC07xI			700	
V_{ICR} Common-mode input voltage	CMRR > 70 dB, $R_S = 50\ \Omega$	25°C	0.5 to 11.2			V
	CMRR > 52 dB, $R_S = 50\ \Omega$	Full range	0.5 to 11.2			
V_{OH} High-level output voltage	$V_{IC} = 6\text{ V}$	$I_{OH} = -1\text{ mA}$	25°C	11.1	11.2	V
			Full range		11	
		$I_{OH} = -20\text{ mA}$	25°C	10.8	10.9	
			Full range		10.7	
		$I_{OH} = -35\text{ mA}$	25°C	10.6	10.7	
			Full range		10.3	
		$I_{OH} = -50\text{ mA}$	25°C	10.4	10.5	
			-40°C to 85°C		10.3	
V_{OL} Low-level output voltage	$V_{IC} = 6\text{ V}$	$I_{OL} = 1\text{ mA}$	25°C	0.17	0.25	V
			Full range		0.35	
		$I_{OL} = 20\text{ mA}$	25°C	0.35	0.45	
			Full range		0.5	
		$I_{OL} = 35\text{ mA}$	25°C	0.4	0.52	
			Full range		0.6	
		$I_{OL} = 50\text{ mA}$	25°C	0.45	0.6	
			-40°C to 85°C		0.65	
I_{OS} Short-circuit output current	Sourcing	25°C		150		mA
	Sinking	25°C		150		
I_O Output current	$V_{OH} = 1.5\text{ V}$ from positive rail	25°C		57		mA
	$V_{OL} = 0.5\text{ V}$ from negative rail	25°C		55		

† Full range is 0°C to 70°C for C suffix and -40°C to 125°C for I suffix. If not specified, full range is -40°C to 125°C.



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA
FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY
OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

electrical characteristics at specified free-air temperature, $V_{DD} = 12\text{ V}$ (unless otherwise noted)
(continued)

PARAMETER		TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
A_{VD}	Large-signal differential voltage amplification	$V_{O(PP)} = 8\text{ V}$, $R_L = 10\text{ k}\Omega$	25°C	120	140		dB
			Full range	120			
$r_{i(d)}$	Differential input resistance		25°C		1000		G Ω
C_{iC}	Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		21.6		pF
z_o	Closed-loop output impedance	$f = 10\text{ kHz}$, $A_V = 10$	25°C		0.25		Ω
CMRR	Common-mode rejection ratio	$V_{iC} = 1\text{ to }10\text{ V}$, $R_S = 50\text{ }\Omega$	25°C	100	140		dB
			Full range	100			
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD} / \Delta V_{iO}$)	$V_{DD} = 4.5\text{ V to }16\text{ V}$, No load $V_{iC} = V_{DD}/2$	25°C	95	130		dB
			Full range	95			
I_{DD}	Supply current (per channel)	$V_O = 7.5\text{ V}$, No load	25°C		2.1	2.9	mA
			Full range			3.5	
$I_{DD(SHDN)}$	Supply current in shutdown mode (TLC070, TLC073, TLC075) (per channel)	$\overline{SHDN} \leq 0.8\text{ V}$	25°C		125	200	μA
			Full range			250	

[†] Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA

FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

operating characteristics at specified free-air temperature, $V_{DD} = 12\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A [†]	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain	V _{O(PP)} = 2 V, R _L = 10 kΩ	C _L = 50 pF,	25°C	10	16		V/μs
				Full range	9.5			
SR−	Negative slew rate at unity gain	V _{O(PP)} = 2 V, R _L = 10 kΩ	C _L = 50 pF,	25°C	12.5	19		V/μs
				Full range	10			
V _n	Equivalent input noise voltage	f = 100 Hz		25°C		12		nV/√Hz
		f = 1 kHz		25°C		7		
I _n	Equivalent input noise current	f = 1 kHz		25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	V _{O(PP)} = 8 V, R _L = 10 kΩ and 250 Ω, f = 1 kHz	A _V = 1	25°C		0.002%		
			A _V = 10			0.005%		
			A _V = 100			0.022%		
t _(on)	Amplifier turnon time [‡]	R _L = 10 kΩ		25°C		0.47		μs
t _(off)	Amplifier turnoff time [‡]			25°C		2.5		μs
Gain-bandwidth product		f = 10 kHz,	R _L = 10 kΩ	25°C		10		MHz
t _s	Settling time	V _{(STEP)PP} = 1 V, A _V = −1, C _L = 10 pF, R _L = 10 kΩ	0.1%	25°C		0.17		μs
			0.01%			0.22		
		V _{(STEP)PP} = 1 V, A _V = −1, C _L = 47 pF, R _L = 10 kΩ	0.1%			0.17		
			0.01%			0.29		
φ _m	Phase margin	R _L = 10 kΩ,	C _L = 50 pF	25°C		37°		
		R _L = 10 kΩ,	C _L = 0 pF			42°		
	Gain margin	R _L = 10 kΩ,	C _L = 50 pF	25°C		3.1		dB
		R _L = 10 kΩ,	C _L = 0 pF			4		

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.

‡ Disable time and enable time are defined as the interval between application of the logic signal to SHDN and the point at which the supply current has reached half its final value.

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA
FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY
OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	vs Common-mode input voltage	1, 2
I_{IO}	Input offset current	vs Free-air temperature	3, 4
I_{IB}	Input bias current	vs Free-air temperature	3, 4
V_{OH}	High-level output voltage	vs High-level output current	5, 7
V_{OL}	Low-level output voltage	vs Low-level output current	6, 8
Z_o	Output impedance	vs Frequency	9
I_{DD}	Supply current	vs Supply voltage	10
PSRR	Power supply rejection ratio	vs Frequency	11
CMRR	Common-mode rejection ratio	vs Frequency	12
V_n	Equivalent input noise voltage	vs Frequency	13
$V_{O(PP)}$	Peak-to-peak output voltage	vs Frequency	14, 15
	Crosstalk	vs Frequency	16
	Differential voltage gain	vs Frequency	17, 18
	Phase	vs Frequency	17, 18
ϕ_m	Phase margin	vs Load capacitance	19, 20
	Gain margin	vs Load capacitance	21, 22
	Gain-bandwidth product	vs Supply voltage	23
SR	Slew rate	vs Supply voltage	24
		vs Free-air temperature	25, 26
THD + N	Total harmonic distortion plus noise	vs Frequency	27, 28
		vs Peak-to-peak output voltage	29, 30
	Large-signal follower pulse response		31, 32
	Small-signal follower pulse response		33
	Large-signal inverting pulse response		34, 35
	Small-signal inverting pulse response		36
	Shutdown forward isolation	vs Frequency	37, 38
	Shutdown reverse isolation	vs Frequency	39, 40
	Shutdown supply current	vs Supply voltage	41
		vs Free-air temperature	42
	Shutdown pulse		43, 44



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS

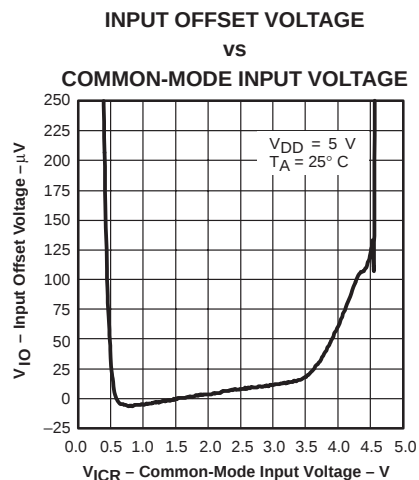


Figure 1

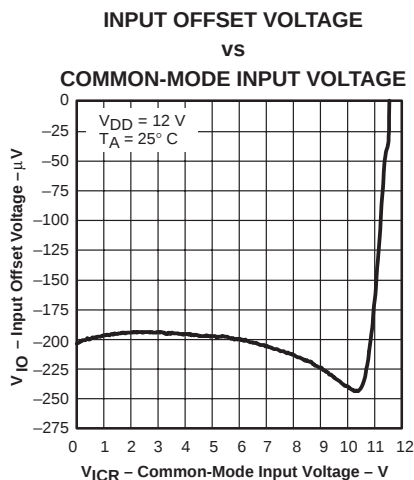


Figure 2

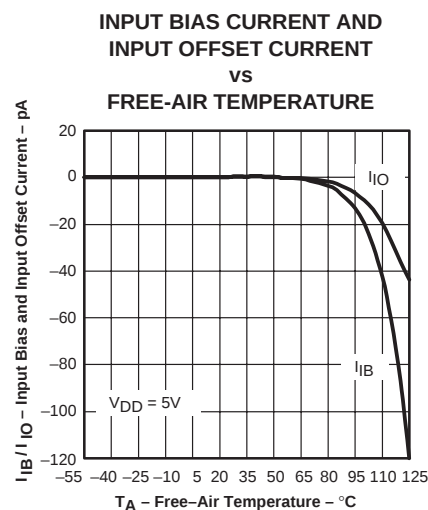


Figure 3

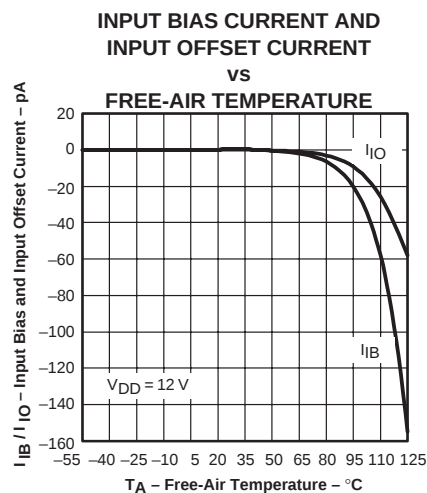


Figure 4

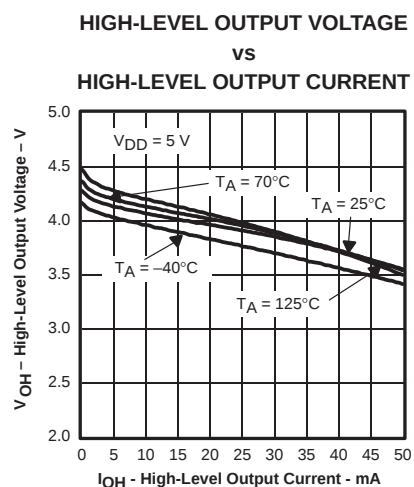


Figure 5

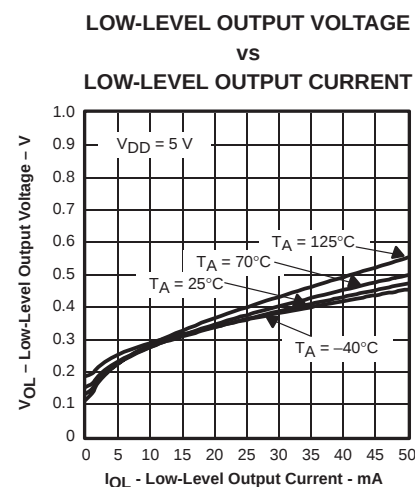


Figure 6

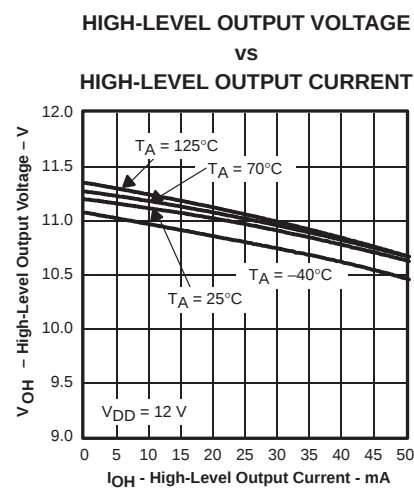


Figure 7

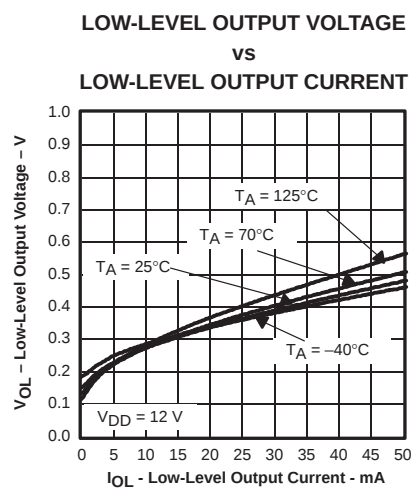


Figure 8

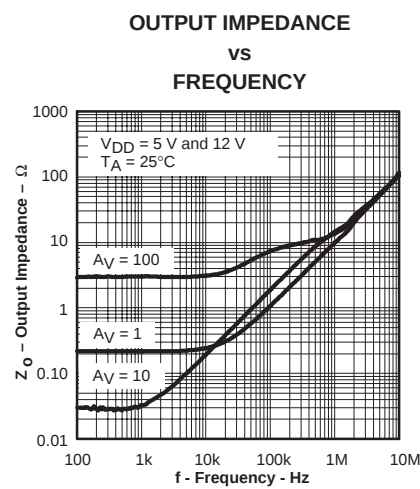


Figure 9

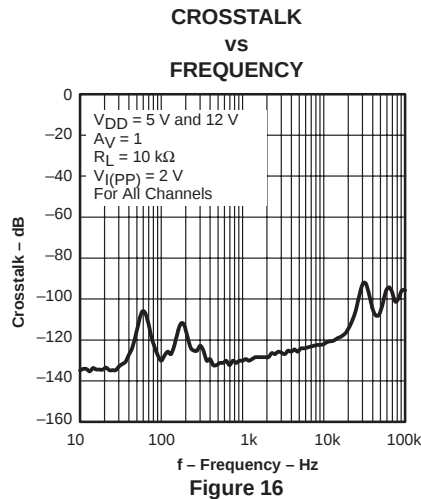
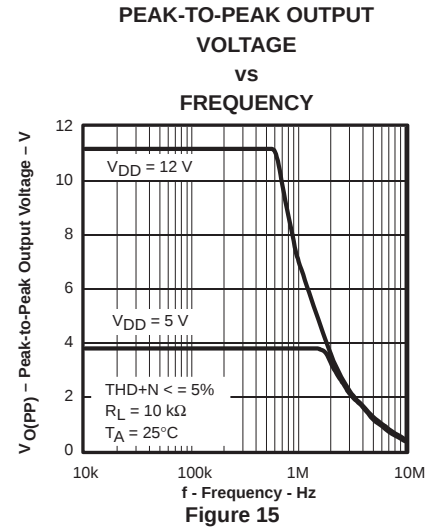
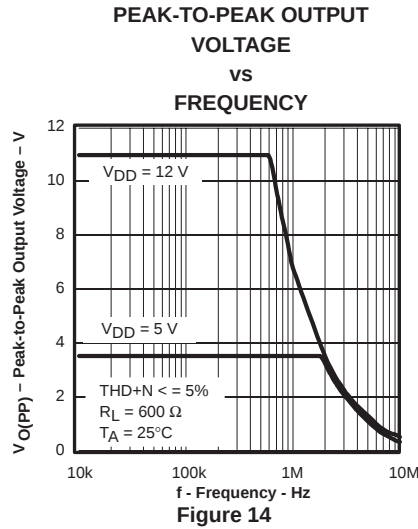
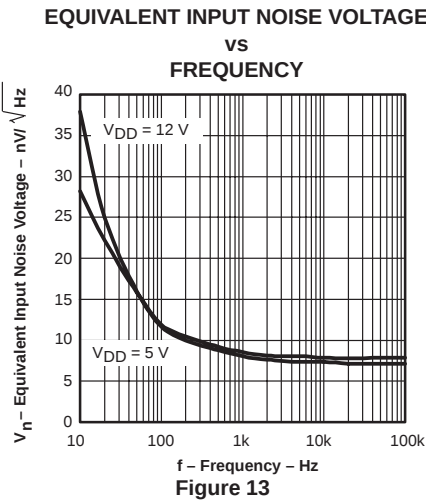
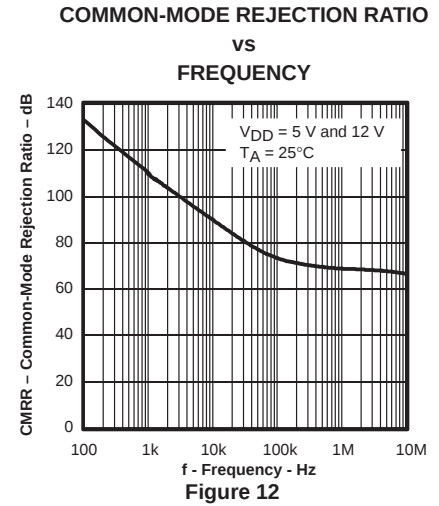
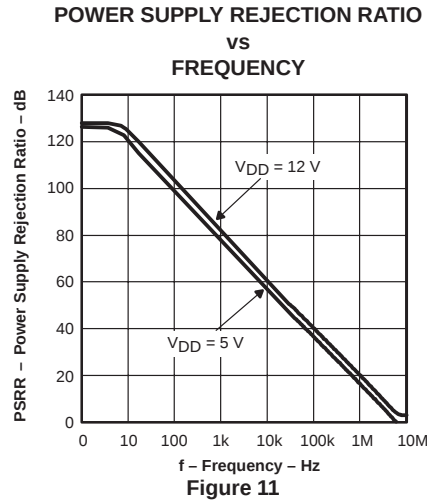
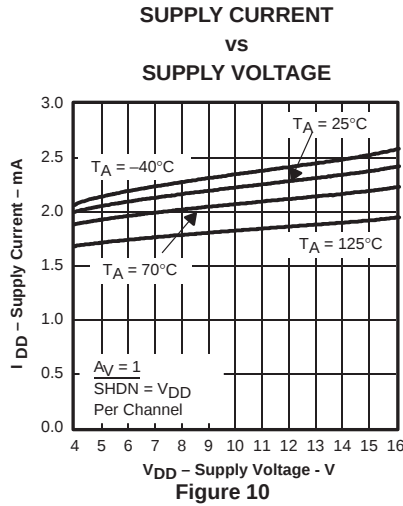


POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS

DIFFERENTIAL VOLTAGE GAIN AND
PHASE

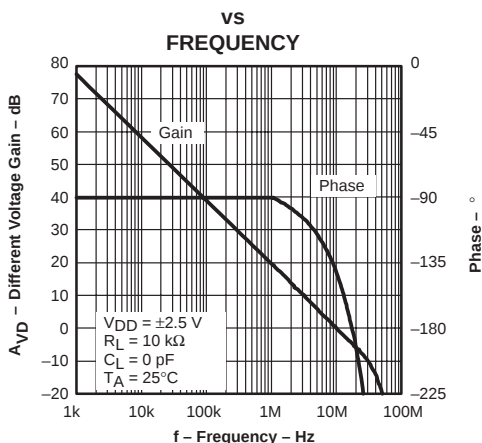


Figure 17

DIFFERENTIAL VOLTAGE GAIN AND
PHASE

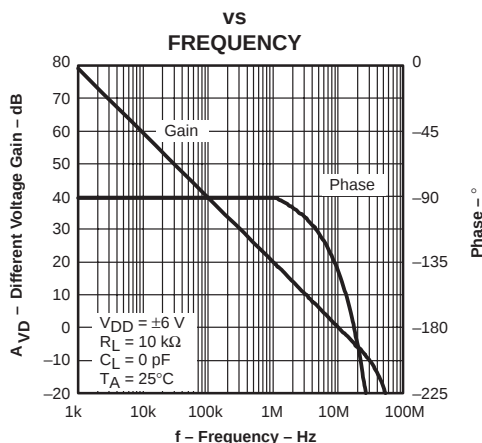


Figure 18

PHASE MARGIN
VS
LOAD CAPACITANCE

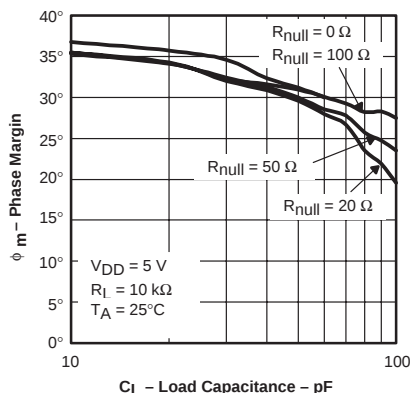


Figure 19

PHASE MARGIN
VS
LOAD CAPACITANCE

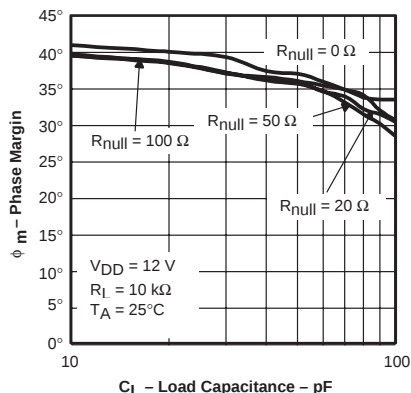


Figure 20

GAIN MARGIN
VS
LOAD CAPACITANCE

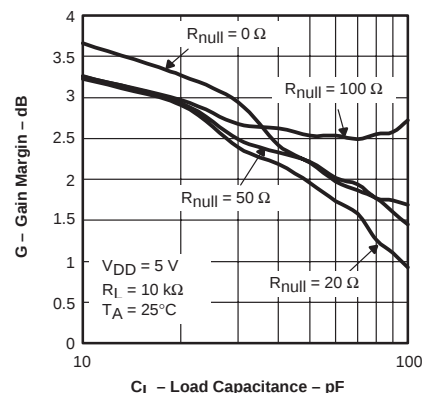


Figure 21

GAIN MARGIN
VS
LOAD CAPACITANCE

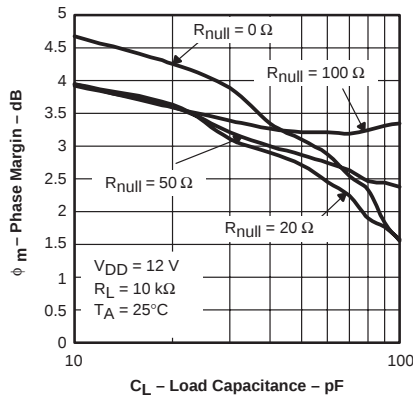


Figure 22

GAIN BANDWIDTH PRODUCT
VS
SUPPLY VOLTAGE

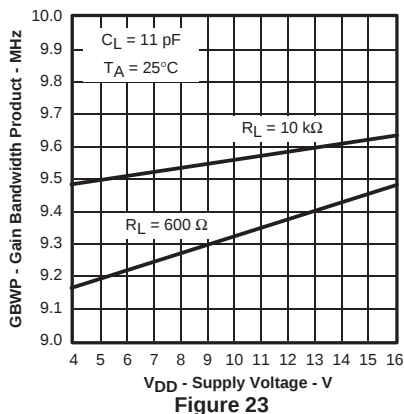


Figure 23

SLEW RATE
VS
SUPPLY VOLTAGE

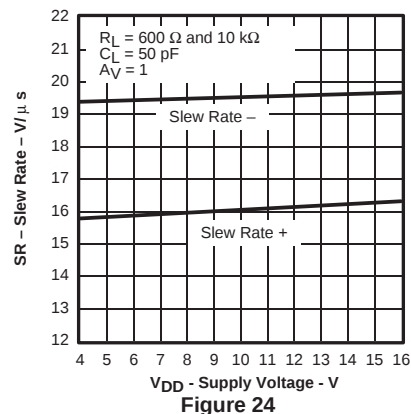


Figure 24



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS

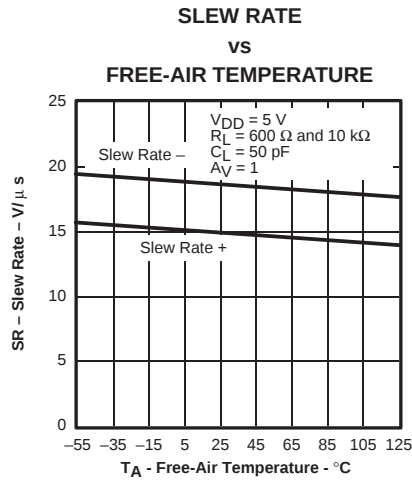


Figure 25

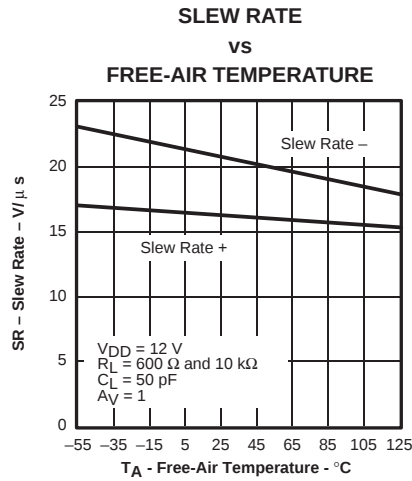


Figure 26

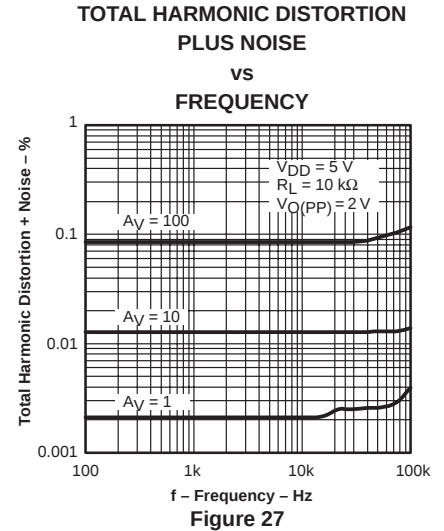


Figure 27

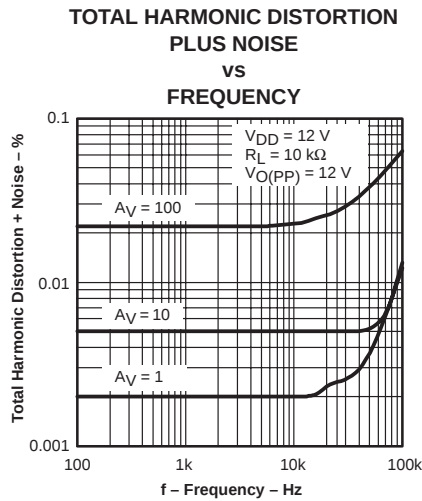


Figure 28

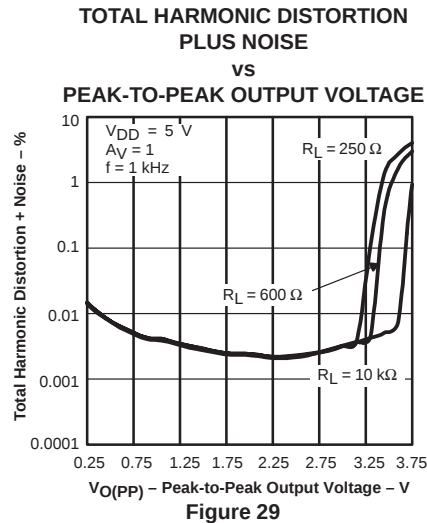


Figure 29

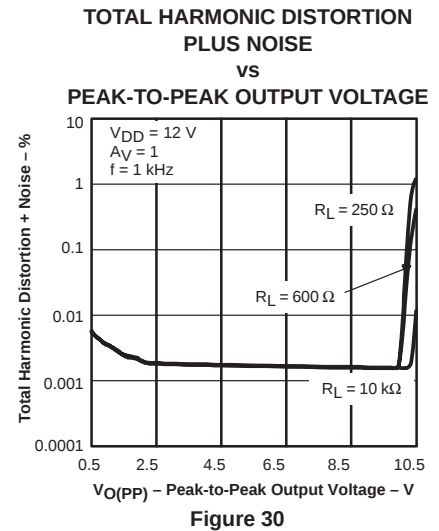


Figure 30

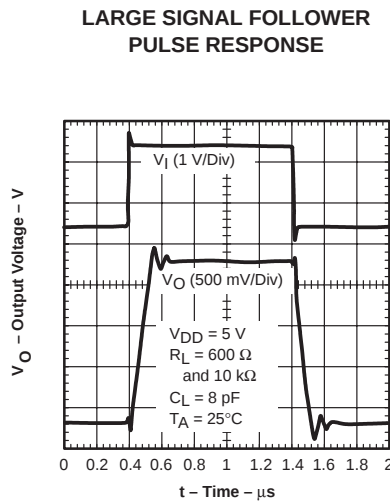


Figure 31

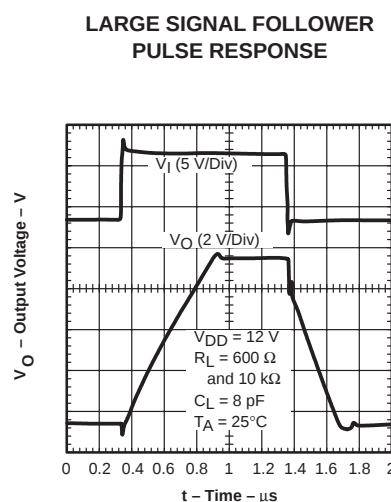


Figure 32

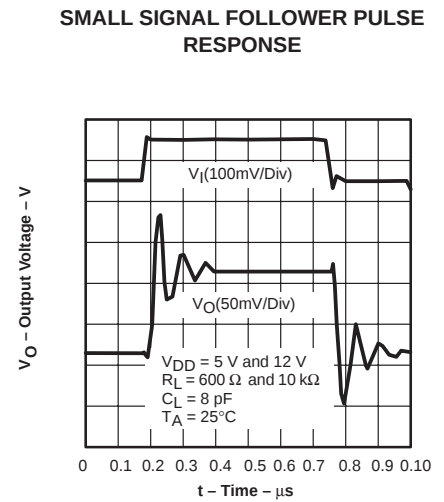


Figure 33



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS

**LARGE SIGNAL INVERTING
PULSE RESPONSE**

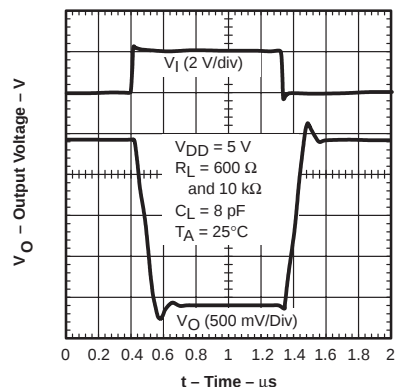


Figure 34

**LARGE SIGNAL INVERTING
PULSE RESPONSE**

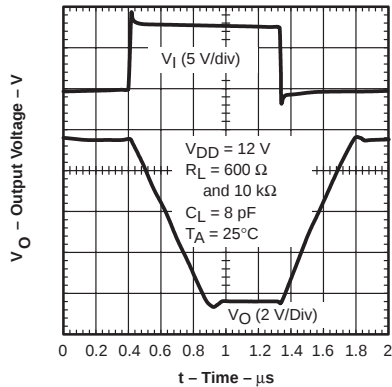


Figure 35

**SMALL SIGNAL INVERTING
PULSE RESPONSE**

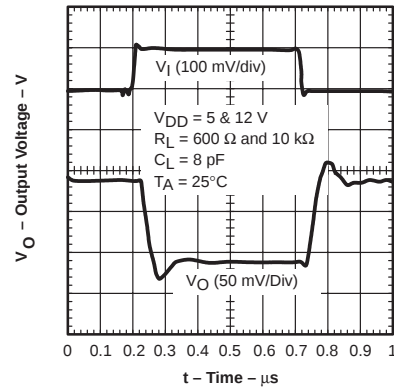


Figure 36

**SHUTDOWN FORWARD
ISOLATION
VS
FREQUENCY**

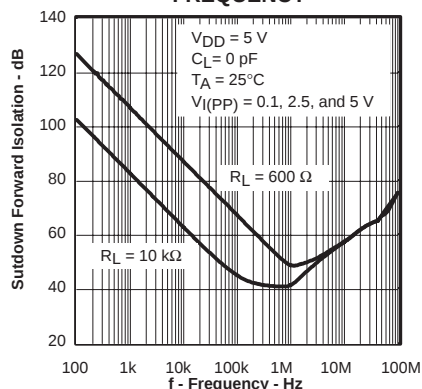


Figure 37

**SHUTDOWN FORWARD
ISOLATION
VS
FREQUENCY**

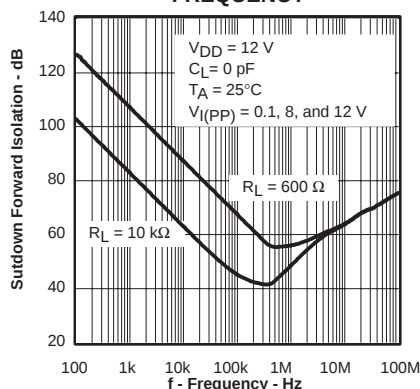


Figure 38

**SHUTDOWN REVERSE
ISOLATION
VS
FREQUENCY**

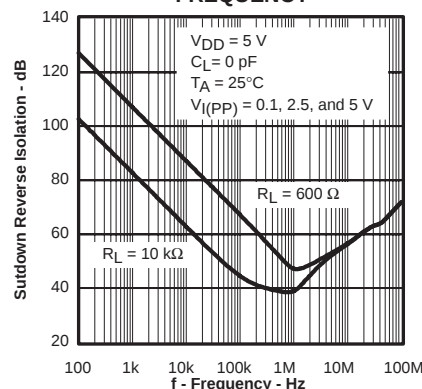


Figure 39

**SHUTDOWN REVERSE
ISOLATION
VS
FREQUENCY**

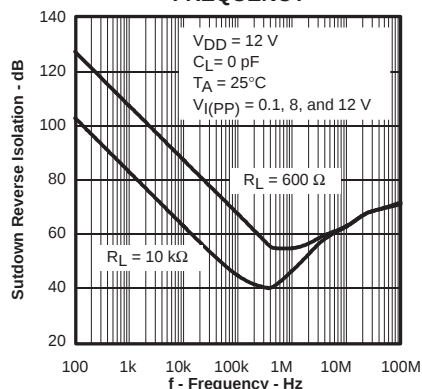


Figure 40

**SHUTDOWN SUPPLY CURRENT
VS
SUPPLY VOLTAGE**

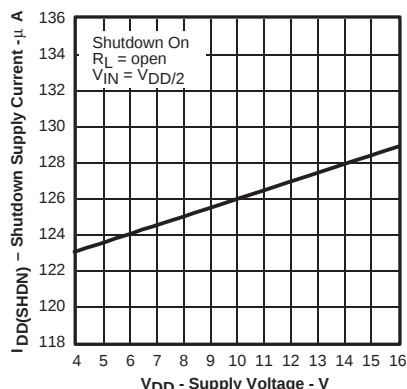


Figure 41

**SHUTDOWN SUPPLY CURRENT
VS
FREE-AIR TEMPERATURE**

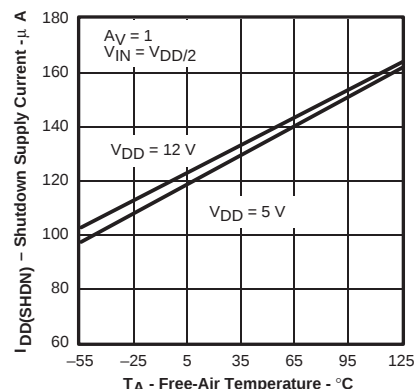
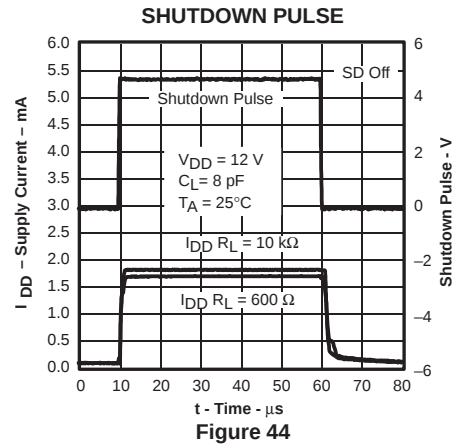
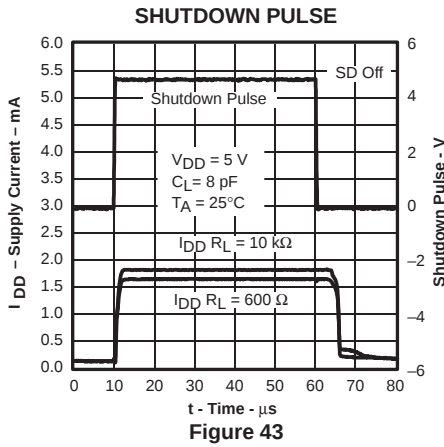


Figure 42

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

TYPICAL CHARACTERISTICS



PARAMETER MEASUREMENT INFORMATION

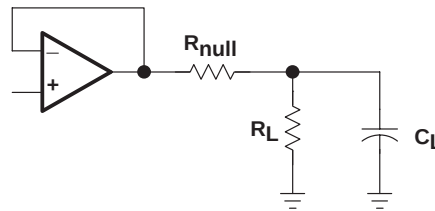
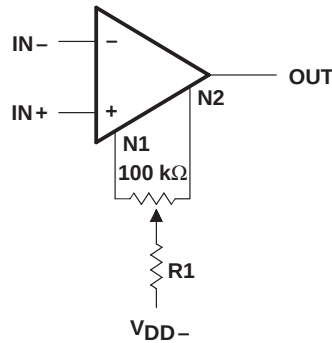


Figure 45

APPLICATION INFORMATION

input offset voltage null circuit

The TLC070 and TLC071 has an input offset nulling function. Refer to Figure 46 for the diagram.



NOTE A: R1 = 5.6 kΩ for offset voltage adjustment of ± 10 mV.
R1 = 20 kΩ for offset voltage adjustment of ± 3 mV.

Figure 46. Input Offset Voltage Null Circuit

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

APPLICATION INFORMATION

driving a capacitive load

When the amplifier is configured 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 (R_{NULL}) with the output of the amplifier, as shown in Figure 47. A minimum value of 20 Ω should work well for most applications.

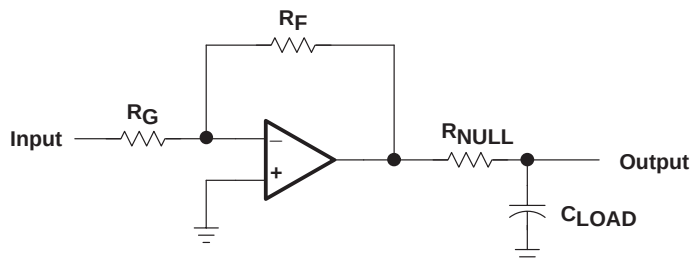


Figure 47. Driving a Capacitive Load

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:

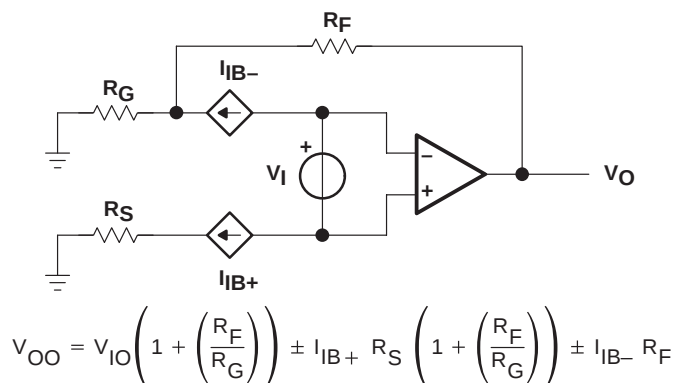


Figure 48. Output Offset Voltage Model

APPLICATION INFORMATION

high speed CMOS input amplifiers

The TLC07x is a family of high-speed low-noise CMOS input operational amplifiers that has an input capacitance of the order of 20 pF. Any resistor used in the feedback path adds a pole in the transfer function equivalent to the input capacitance multiplied by the combination of source resistance and feedback resistance. For example, a gain of -10 , a source resistance of $1\text{ k}\Omega$, and a feedback resistance of $10\text{ k}\Omega$ add an additional pole at approximately 8 MHz. This is more apparent with CMOS amplifiers than bipolar amplifiers due to their greater input capacitance.

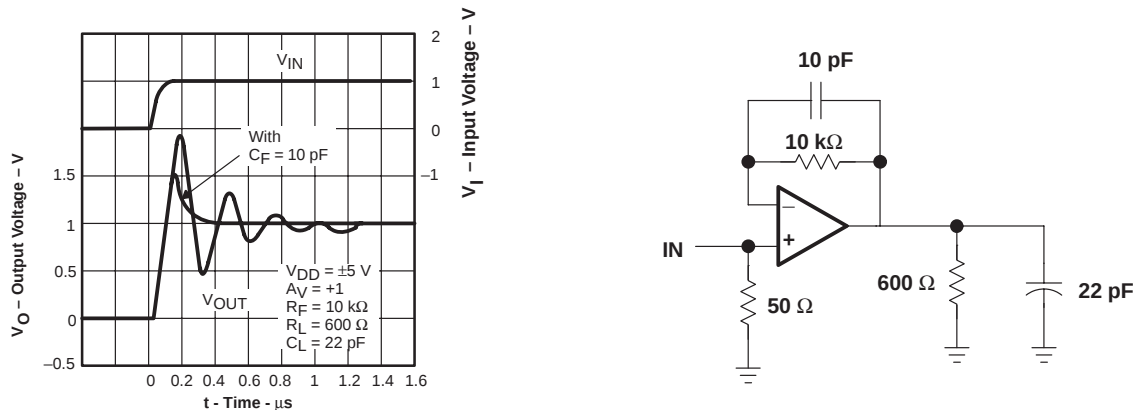
This is of little consequence on slower CMOS amplifiers, as this pole normally occurs at frequencies above their unity-gain bandwidth. However, the TLC07x with its 10-MHz bandwidth means that this pole normally occurs at frequencies where there is on the order of 5 dB gain left and the phase shift adds considerably.

The effect of this pole is the strongest with large feedback resistances at small closed loop gains. As the feedback resistance is increased, the gain peaking increases at a lower frequency and the 180° phase shift crossover point also moves down in frequency, decreasing the phase margin.

For the TLC07x, the maximum feedback resistor recommended is $5\text{ k}\Omega$; larger resistances can be used but a capacitor in parallel with the feedback resistor is recommended to counter the effects of the input capacitance pole.

The TLC073 with a 1-V step response has an 80% overshoot with a natural frequency of 3.5 MHz when configured as a unity gain buffer and with a $10\text{-k}\Omega$ feedback resistor. By adding a 10-pF capacitor in parallel with the feedback resistor, the overshoot is reduced to 40% and eliminates the natural frequency, resulting in a much faster settling time (see Figure 49). The 10-pF capacitor was chosen for convenience only.

Load capacitance had little effect on these measurements due to the excellent output drive capability of the TLC07x.



TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

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 amplifier (see Figure 50).

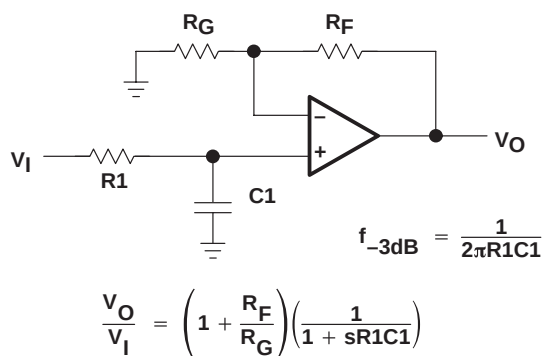


Figure 50. Single-Pole Low-Pass Filter

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.

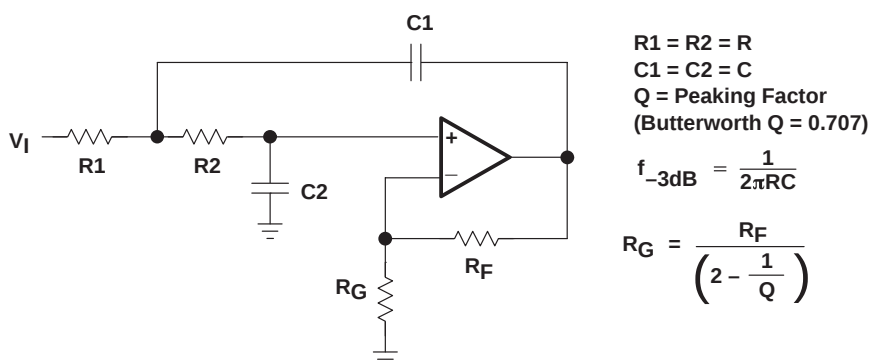


Figure 51. 2-Pole Low-Pass Sallen-Key Filter

APPLICATION INFORMATION

shutdown function

Three members of the TLC07x family (TLC070/3/5) have a shutdown terminal ($\overline{\text{SHDN}}$) for conserving battery life in portable applications. When the shutdown terminal is tied low, the supply current is reduced to 125 $\mu\text{A}/\text{channel}$, the amplifier is disabled, and the outputs are placed in a high-impedance mode. To enable the amplifier, the shutdown terminal can either be left floating or pulled high. When the shutdown terminal is left floating, care should be taken to ensure that parasitic leakage current at the shutdown terminal does not inadvertently place the operational amplifier into shutdown. The shutdown terminal threshold is always referenced to the voltage on the GND terminal of the device. Therefore, when operating the device with split supply voltages (e.g. $\pm 2.5\text{ V}$), the shutdown terminal needs to be pulled to $V_{\text{DD-}}$ (not system ground) to disable the operational amplifier.

The amplifier's output with a shutdown pulse is shown in Figures 43 and 44. The amplifier is powered with a single 5-V supply and is configured as noninverting with a gain of 5. The amplifier turnon and turnoff times are measured from the 50% point of the shutdown pulse to the 50% point of the output waveform. The times for the single, dual, and quad are listed in the data tables.

Figures 37, 38, 39, and 40 show the amplifier's forward and reverse isolation in shutdown. The operational amplifier is configured as a voltage follower ($A_V = 1$). The isolation performance is plotted across frequency using 0.1 V_{PP} , 2.5 V_{PP} , and 5 V_{PP} input signals at $\pm 2.5\text{ V}$ supplies and 0.1 V_{PP} , 8 V_{PP} , and 12 V_{PP} input signals at $\pm 6\text{ V}$ supplies.

circuit layout considerations

To achieve the levels of high performance of the TLC07x, follow proper printed-circuit board design techniques. A general set of guidelines is given in the following.

- 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 can be used but are not recommended. 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 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 performance 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.

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

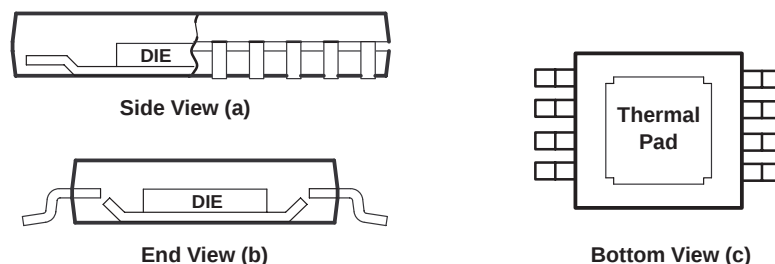
APPLICATION INFORMATION

general PowerPAD design considerations

The TLC07x is available in a thermally-enhanced PowerPAD family of packages. These packages are constructed using a downset leadframe upon which the die is mounted [see Figure 52(a) and Figure 52(b)]. This arrangement results in the lead frame being exposed as a thermal pad on the underside of the package [see Figure 52(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.



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

Figure 52. Views of Thermally Enhanced DGN Package

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

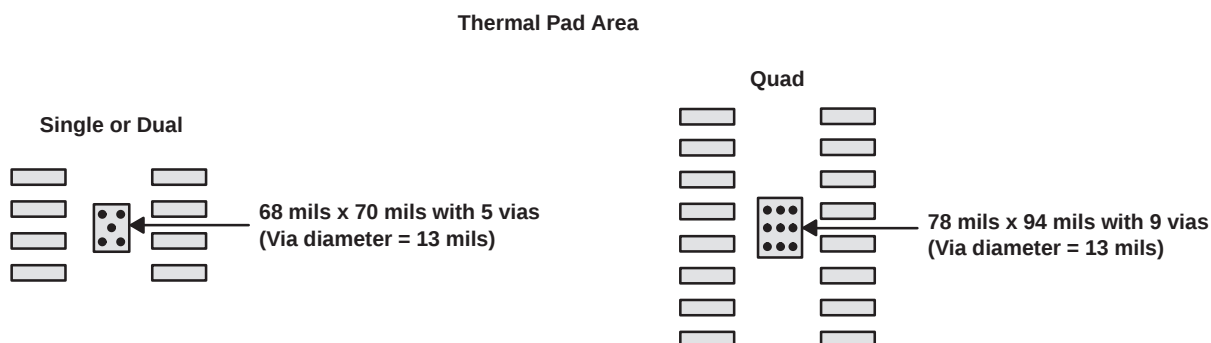


Figure 53. PowerPAD PCB Etch and Via Pattern

APPLICATION INFORMATION

general PowerPAD design considerations (continued)

1. Prepare the PCB with a top side etch pattern as shown in Figure 53. There should be etch for the leads as well as etch for the thermal pad.
2. Place five holes (dual) or nine holes (quad) 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 TLC07x 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 TLC07x PowerPAD 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 (dual) or nine holes (quad) exposed. The bottom-side solder mask should cover the five or nine 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 TLC07x 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.

For a given θ_{JA} , the maximum power dissipation is shown in Figure 54 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 TLC07x IC (watts)

T_{MAX} = Absolute maximum junction temperature (150°C)

T_A = Free-ambient air temperature (°C)

θ_{JA} = $\theta_{JC} + \theta_{CA}$

θ_{JC} = Thermal coefficient from junction to case

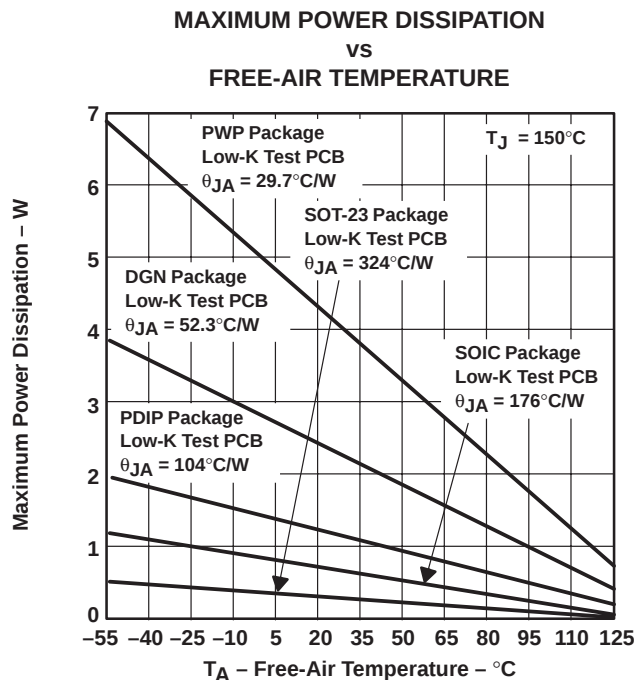
θ_{CA} = Thermal coefficient from case to ambient air (°C/W)

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SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

APPLICATION INFORMATION

general PowerPAD design considerations (continued)



NOTE A: Results are with no air flow and using JEDEC Standard Low-K test PCB.

Figure 54. Maximum Power Dissipation vs Free-Air Temperature

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 multi-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.

The other key factor when dealing with power dissipation 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 or quad amplifier packages, the sum of the RMS output currents and voltages should be used to choose the proper package.

TLC070, TLC071, TLC072, TLC073, TLC074, TLC075, TLC07xA
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OPERATIONAL AMPLIFIERS

SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 1) and subcircuit in Figure 55 are generated using the TLC07x typical electrical and operating characteristics at $T_A = 25^\circ\text{C}$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 2: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers," *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

PSpice and *Parts* are trademarks of MicroSim Corporation.

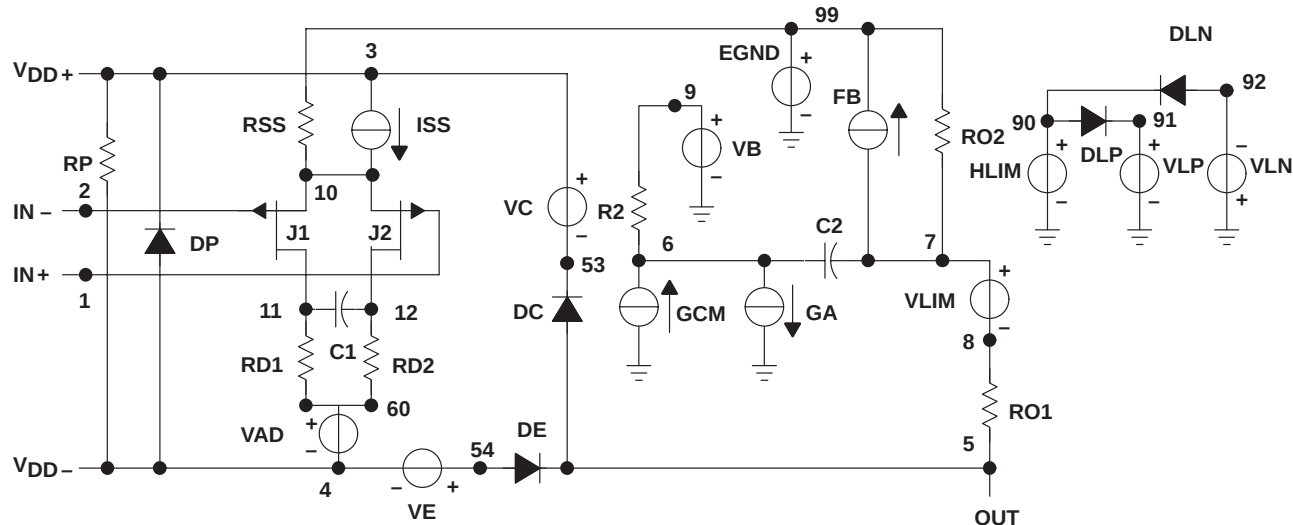


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SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

APPLICATION INFORMATION



*DEVICE=TLC07X_5V, OPAMP, PJF, INT

* TLC07X – 5V operational amplifier "macromodel" subcircuit

* created using Parts release 8.0 on 12/16/99 at 08:38

* Parts is a MicroSim product.

* connections:

* non-inverting input
* inverting input
* positive power supply
* negative power supply
* output

.subckt TLC07X_5V 1 2 3 4 5

```
*
c1 11 12 4.8697E-12
c2 6 7 8.0000E-12
css 10 99 4.0063E-12
dc 5 53 dy
de 54 5 dy
dln 92 90 dx
dln 92 90 dx
dp 4 3 dx
egnd 99 0 poly(2) (3,0) (4,0) 0 .5 .5
fb 7 99 poly(5) vb vc ve vlp vln 0 6.9132E6 -1E3 1E3
6E6 -6E6
```

```
ga 6 0 11 12 457.42E-6
gcm 0 6 10 99 1.1293E-6
iss 3 10 dc 183.67E-6
ioff 0 6 dc .806E-6
hlim 90 0 vlim 1K
j1 11 2 10 jx1
j2 12 1 10 jx2
r2 6 9 100.00E3
rd1 4 11 2.1862E3
rd2 4 12 2.1862E3
ro1 8 5 10
ro2 7 99 10
rp 3 4 2.4728E3
rss 10 99 1.0889E6
vb 9 0 dc 0
vc 3 53 dc 1.5410
ve 54 4 dc .84403
vlim 7 8 dc 0
vlp 91 0 dc 119
vln 0 92 dc 119
.model dx D(Is=800.00E-18)
.model dy D(Is=800.00E-18 Rs=1m Cjo=10p)
.model jx1 PJF(Is=117.50E-15 Beta=1.1391E-3 Vto=-1)
.model jx2 PJF(Is=117.50E-15 Beta=1.1391E-3 Vto=-1)
.ends
```

Figure 55. Boyle Macromodel and Subcircuit

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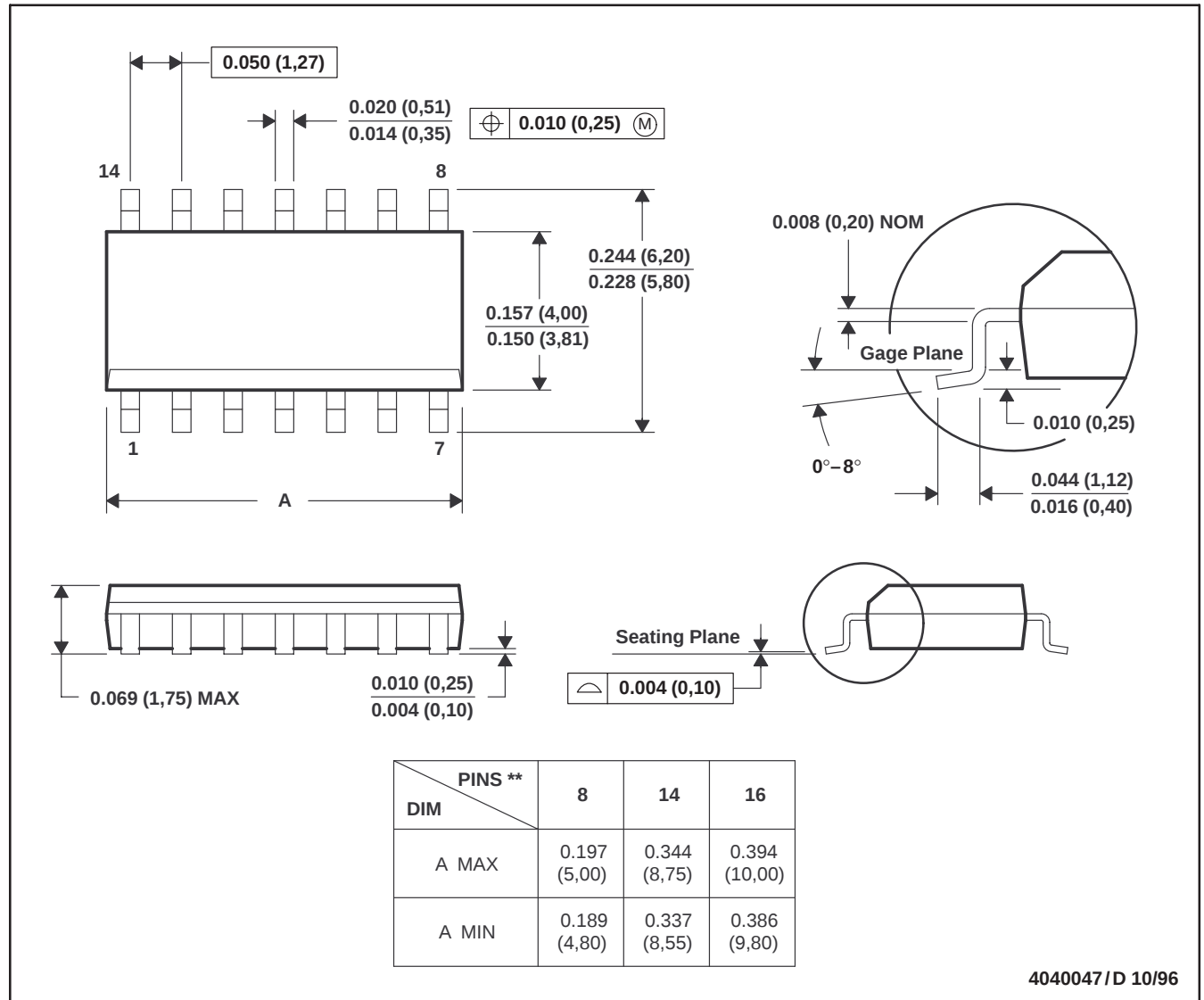
SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

MECHANICAL DATA

D (R-PDSO-G)**

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



- 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

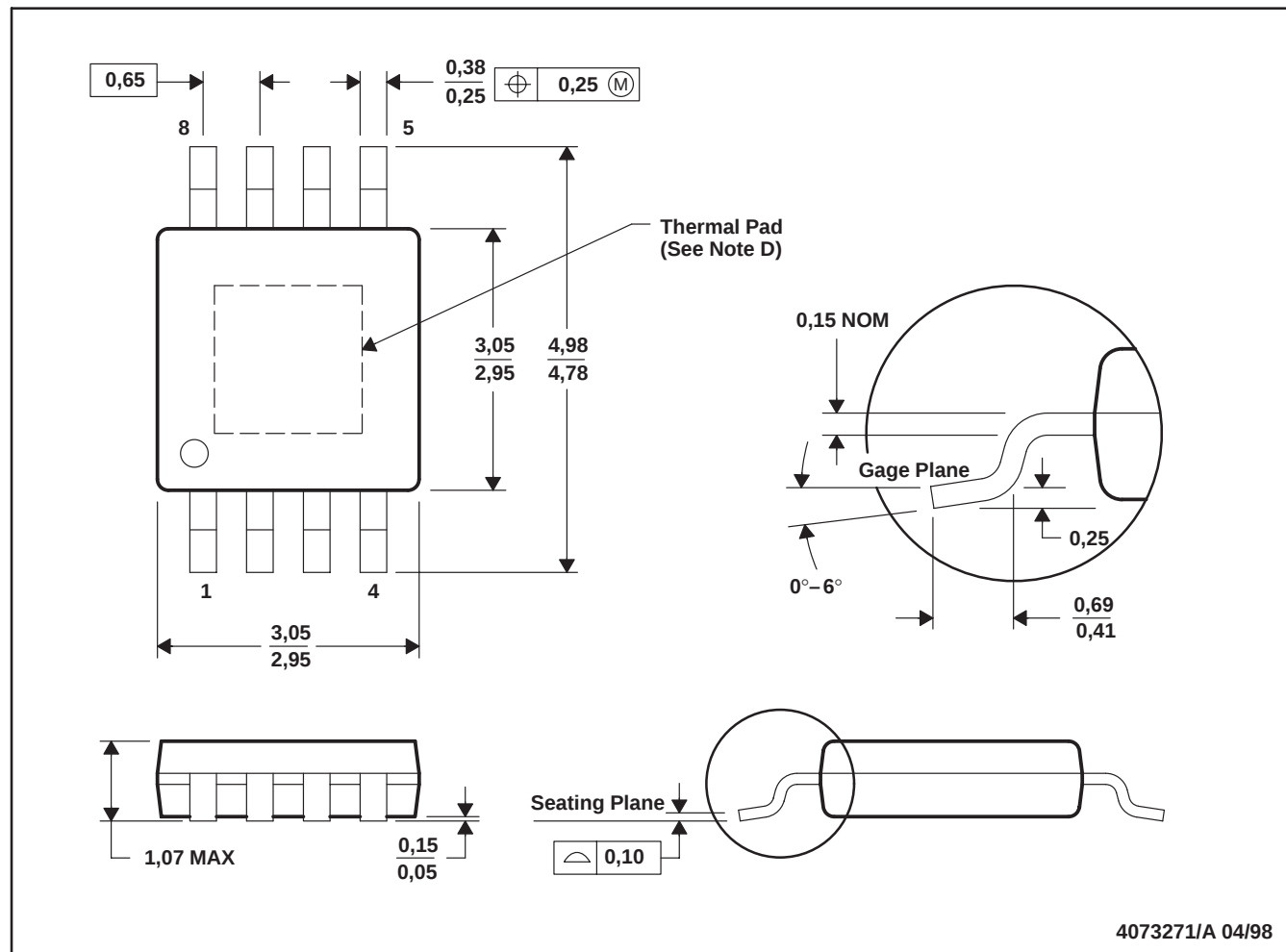
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SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

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. The dimension of the thermal pad is 68 mils (height as illustrated) × 70 mils (width as illustrated) (maximum). The pad is centered on the bottom of the package.

E. Falls within JEDEC MO-187

PowerPAD is a trademark of Texas Instruments.



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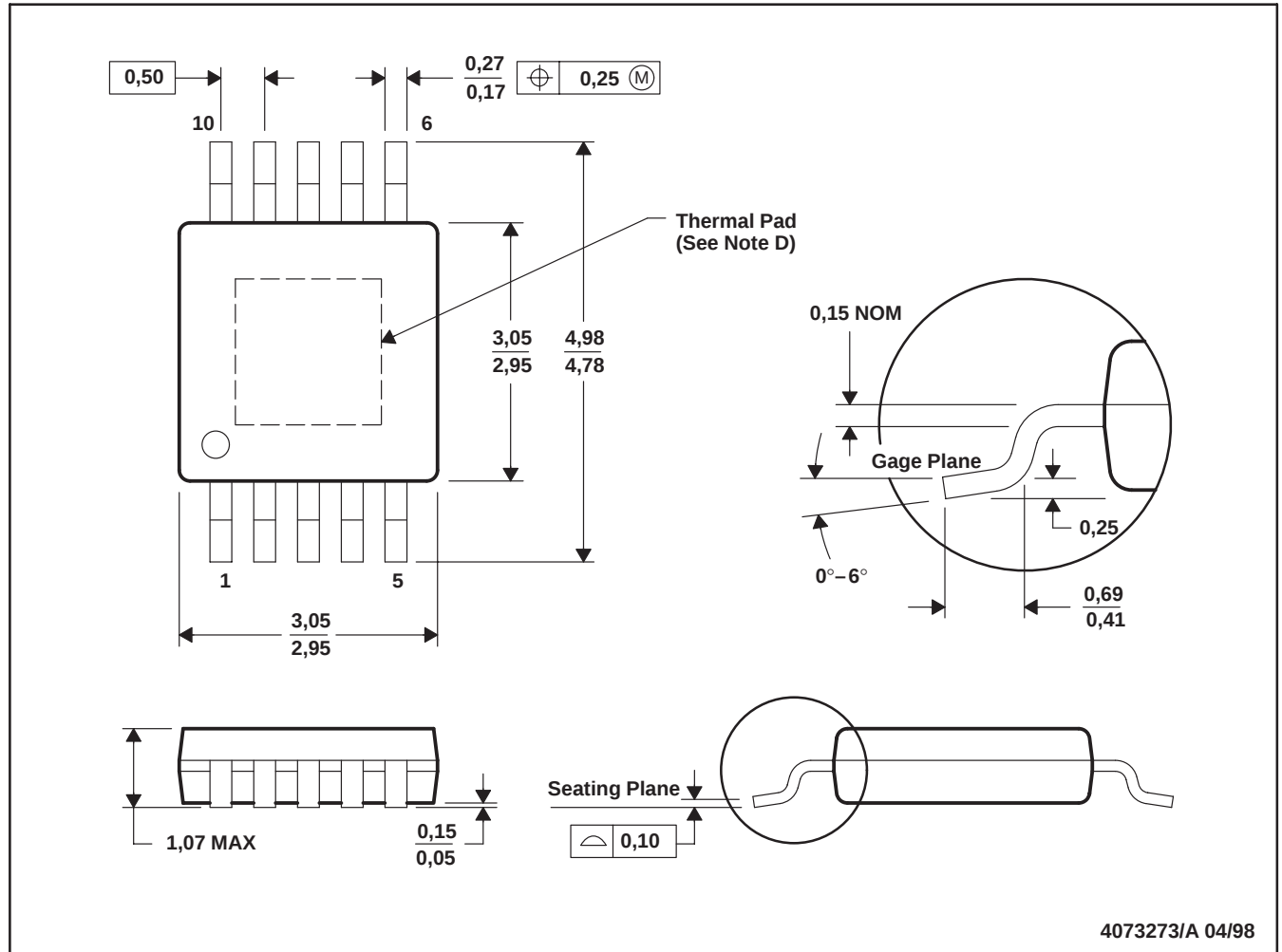
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SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

MECHANICAL INFORMATION

DGQ (S-PDSO-G10)

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 do not include mold flash or protrusion.
 - 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. The dimension of the thermal pad is 68 mils (height as illustrated) × 70 mils (width as illustrated) (maximum). The pad is centered on the bottom of the package.

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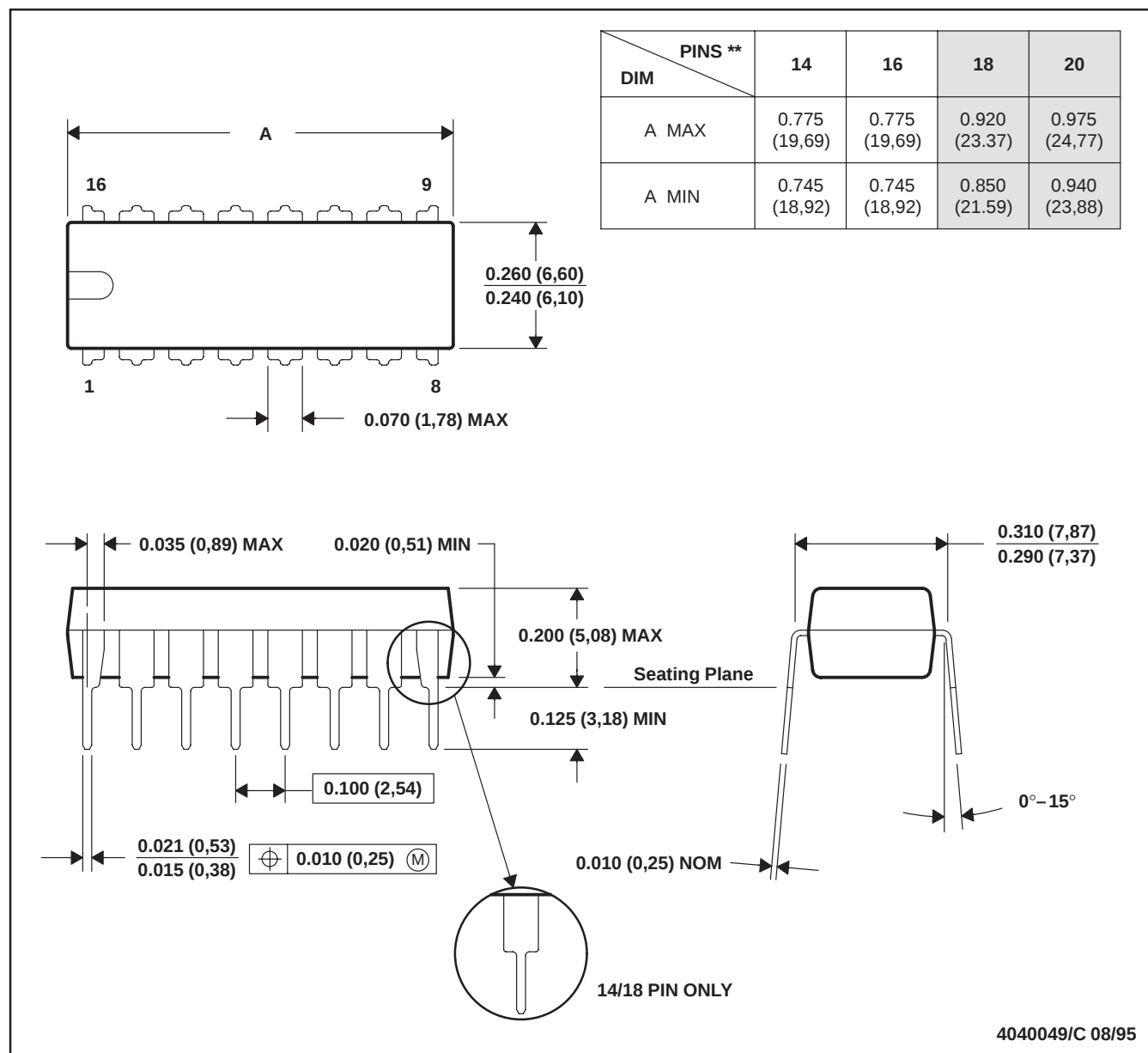
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MECHANICAL INFORMATION

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PIN SHOWN



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001 (20 pin package is shorter than MS-001.)

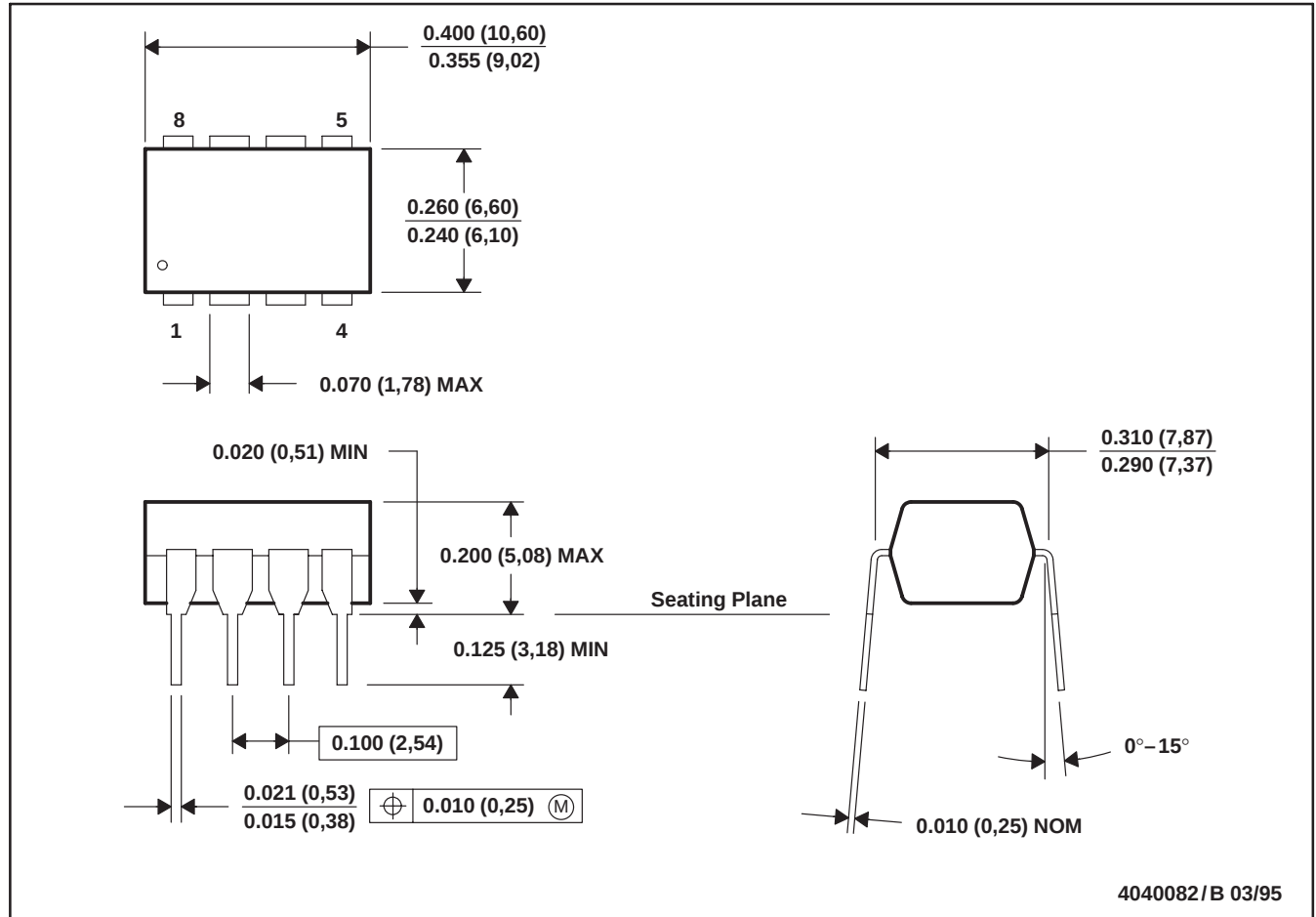
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SLOS219C – JUNE 1999 – REVISED NOVEMBER 2000

MECHANICAL INFORMATION

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-001

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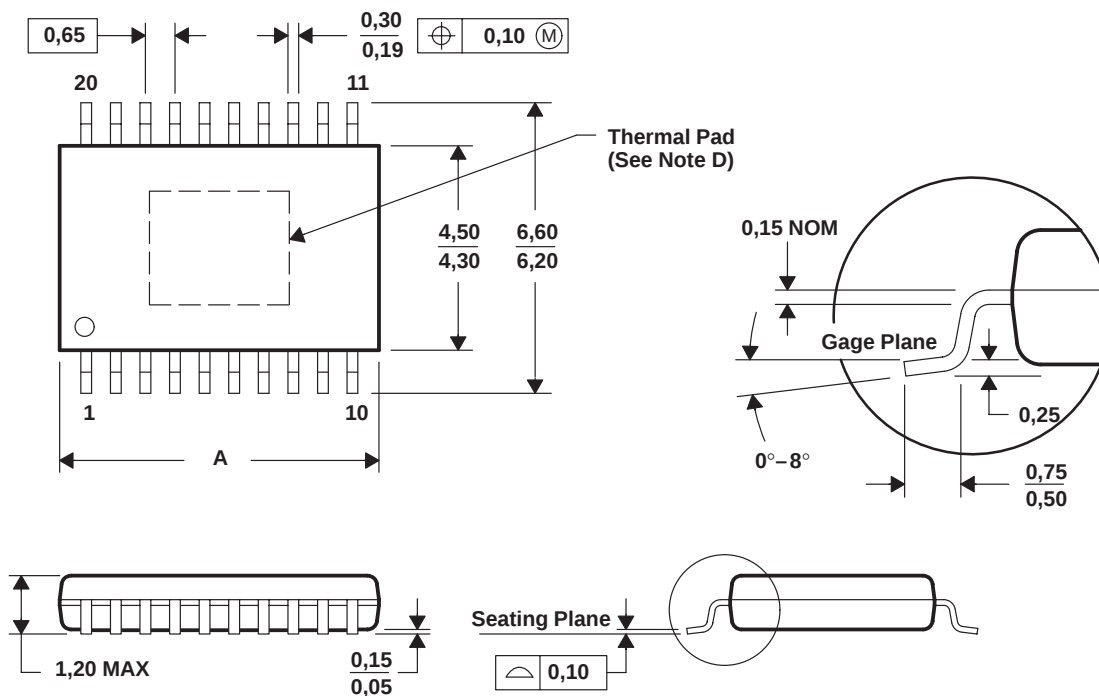
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MECHANICAL INFORMATION

PWP (R-PDSO-G**)

PowerPAD™ PLASTIC SMALL-OUTLINE

20 PINS SHOWN



4073225/F 10/98

- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Body dimensions do not include mold flash or protrusions.
 - 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. The dimension of the thermal pad is 78 mils (height as illustrated) × 94 mils (width as illustrated) (maximum). The pad is centered on the bottom of the package.
 - Falls within JEDEC MO-153

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