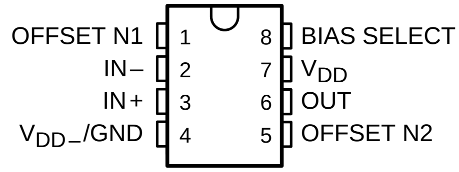
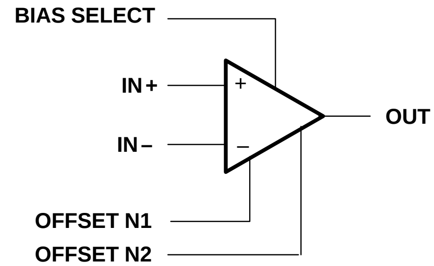
- **Wide Range of Supply Voltages 1.4-V to 16-V**
- **True Single-Supply Operation**
- **Common-Mode Input Voltage Range Includes the Negative Rail**
- **Low Noise . . . 30 nV/√Hz Typ at 1-kHz (High Bias)**
- **ESD Protection Exceeds 2000 V Per MIL-STD-833C, Method 3015.1**

D OR P PACKAGE
(TOP VIEW)



symbol



description

The TLC251C, TLC251AC, and TLC251BC are low-cost, low-power programmable operational amplifiers designed to operate with single or dual supplies. Unlike traditional metal-gate CMOS operational amplifiers, these devices utilize Texas Instruments silicon-gate LinCMOS™ process, giving them stable input offset voltages without sacrificing the advantages of metal-gate CMOS. This series of parts is available in selected grades of input offset voltage and can be nulled with one external potentiometer. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this family is ideally suited for battery-powered or energy-conserving applications. A bias-select pin can be used to program one of three ac performance and power-dissipation levels to suit the application. The series features operation down to a 1.4-V supply and is stable at unity gain.

These devices have internal electrostatic-discharge (ESD) protection circuits that prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC251C series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOS™ operational amplifiers without the power penalties of traditional bipolar devices. Remote and inaccessible equipment applications are possible using the low-voltage and low-power capabilities of the TLC251C series.

In addition, by driving the bias-select input with a logic signal from a microprocessor, these operational amplifiers can have software-controlled performance and power consumption. The TLC251C series is well suited to solve the difficult problems associated with single battery and solar cell-powered applications.

The TLC251C series is characterized for operation from 0°C to 70°C.

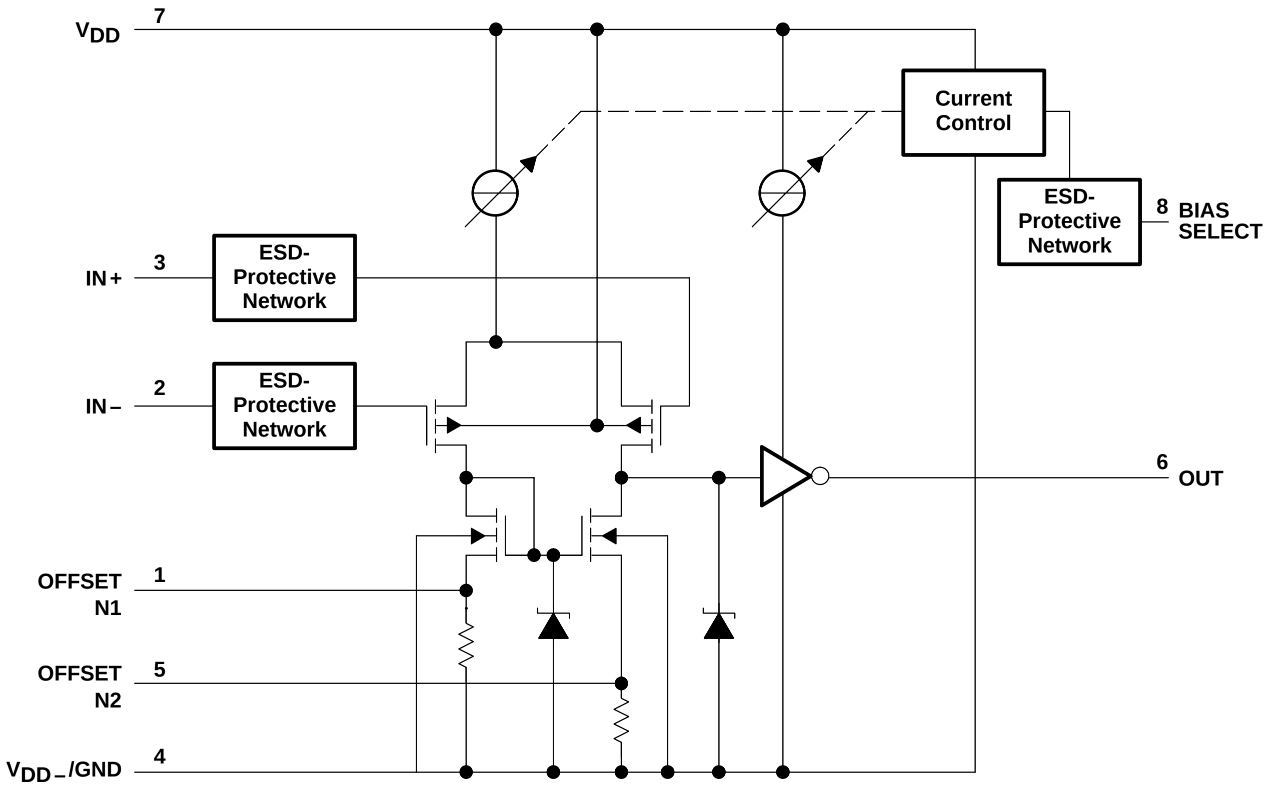
AVAILABLE OPTIONS

T_A	V_{IO}max AT 25°C	PACKAGED DEVICES		CHIP FORM (Y)
		SMALL OUTLINE (D)	PLASTIC DIP (P)	
0°C to 70°C	10 mV 5 mV 2 mV	TLC251CD TLC251ACD TLC251BCD	TLC251CP TLC251ACP TLC251BCP	TLC251Y — —

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC251CDR). Chips are tested at 25°C.

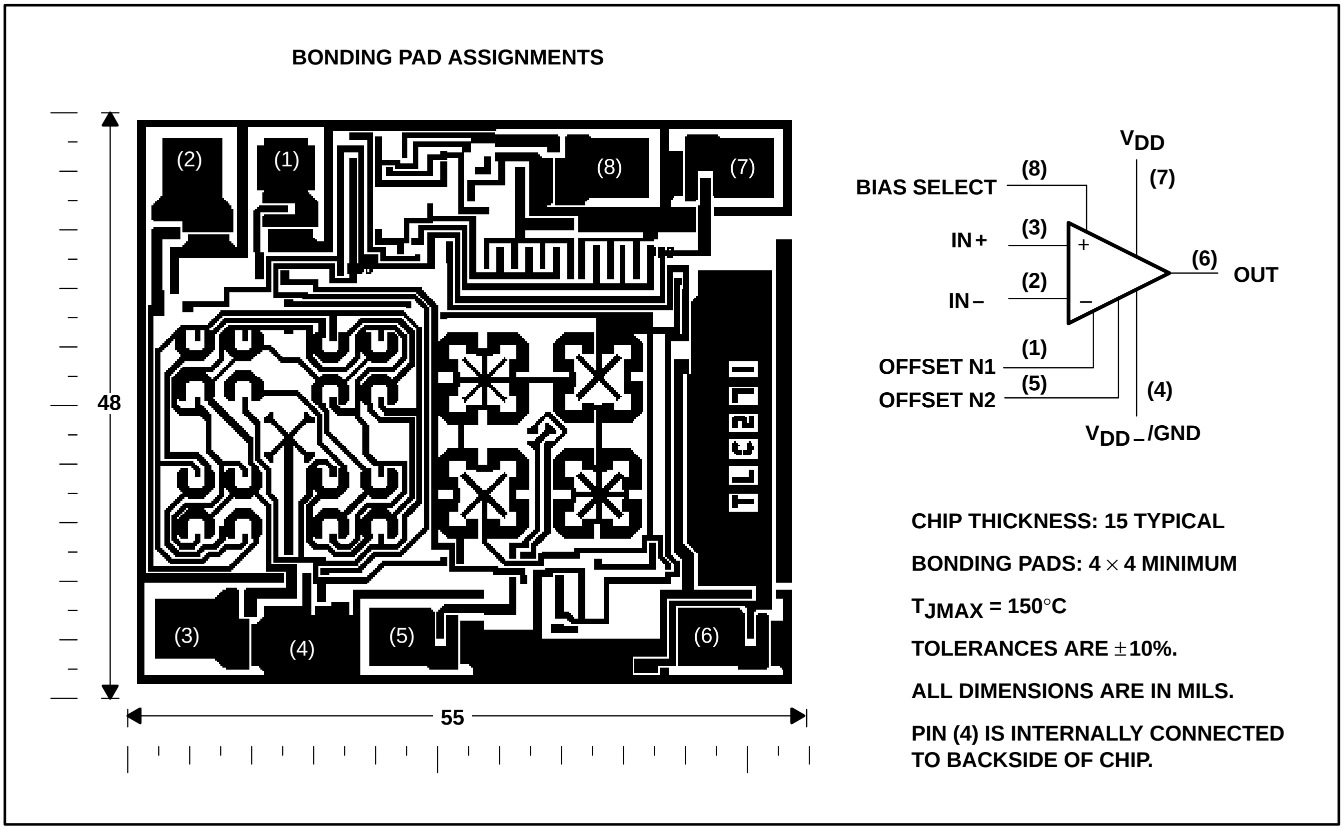
LinCMOS is a trademark of Texas Instruments.

schematic


VDD
7
Current Control
ESD- Protective Network
8
BIAS SELECT
IN+
3
ESD- Protective Network
IN–
2
ESD- Protective Network
6
OUT
OFFSET N1
1
OFFSET N2
5
VDD–/GND
4

TLC251Y chip information

These chips, properly assembled, display characteristics similar to the TLC251C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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

Supply voltage, V_{DD} (see Note 1) . . . . 18 V
Differential input voltage, V_{ID} (see Note 2) . . . . ±18 V
Input voltage range, V_I (any input) . . . . –0.3 V to 18 V
Duration of short circuit at (or below) 25°C free-air temperature (see Note 3) . . . . unlimited
Continuous total dissipation . . . . See Dissipation Rating Table
Operating free-air temperature range, T_A . . . . 0°C to 70°C
Storage temperature range . . . . –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.

NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD-}/GND.
2. Differential voltages are at IN+ with respect to IN–.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{DD}		1.4	16	V
Common-mode input voltage, V_{IC}	V_{DD} = 1.4 V	0	0.2	V
	V_{DD} = 5 V	–0.2	4	
	V_{DD} = 10 V	–0.2	9	
	V_{DD} = 16 V	–0.2	14	
Operating free-air temperature, T_A		0	70	°C
Bias-select voltage		See Application Information		

HIGH-BIAS MODE

electrical characteristics at specified free-air temperature

PARAMETER			TEST CONDITIONS	T_A†	TLC251C, TLC251AC, TLC251BC						UNIT
					V_{DD} = 5 V			V_{DD} = 10 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC251C	V_O = 1.4 V, V_{IC} = 0 V, R_S = 50 Ω, R_L = 10 kΩ	25°C		1.1	10		1.1	10	mV
				Full range			12			12	
		TLC251AC		25°C		0.9	5		0.9	5	
				Full range			6.5			6.5	
		TLC251BC		25°C		0.34	2		0.39	2	
				Full range			3			3	
α_{VIO}	Average temperature coefficient of input offset voltage			25°C to 70°C		1.8			2		μV/°C
I_{IO}	Input offset current (see Note 4)		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.1	60		0.1	60	pA
				70°C		7	300		7	300	
I_{IB}	Input bias current (see Note 4)		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.6	60		0.7	60	pA
				70°C		40	600		50	600	
V_{ICR}	Common-mode input voltage range (see Note 5)			25°C	−0.2 to 4	−0.3 to 4.2		−0.2 to 9	−0.3 to 9.2		V
				Full range	−0.2 to 3.5			−0.2 to 8.5			V
V_{OH}	High-level output voltage		V_{ID} = 100 mV, R_L = 10 kΩ	25°C	3.2	3.8		8	8.5		V
				0°C	3	3.8		7.8	8.5		
				70°C	3	3.8		7.8	8.4		
V_{OL}	Low-level output voltage		V_{ID} = −100 mV, I_{OL} = 0	25°C		0	50		0	50	mV
				0°C		0	50		0	50	
				70°C		0	50		0	50	
A_{VD}	Large-signal differential voltage amplification		R_L = 10 kΩ, See Note 6	25°C	5	23		10	36		V/mV
				0°C	4	27		7.5	42		
				70°C	4	20		7.5	32		
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}min$	25°C	65	80		65	85		dB
				0°C	60	84		60	88		
				70°C	60	85		60	88		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)		V_{DD} = 5 V to 10 V, V_O = 1.4 V	25°C	65	95		65	95		dB
				0°C	60	94		60	94		
				70°C	60	96		60	96		
$I_{I(SEL)}$	Input current (BIAS SELECT)		$V_{I(SEL)}$ = 0	25°C		−1.4			−1.9		μA
I_{DD}	Supply current		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	25°C		675	1600		950	2000	μA
				0°C		775	1800		1125	2200	
				70°C		575	1300		750	1700	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

HIGH-BIAS MODE

operating characteristics, V_{DD} = 5 V

PARAMETER		TEST CONDITIONS		T_A	TLC251C, TLC251AC, TLC251BC			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L = 10 kΩ, C_L = 20 pF	$V_{I(PP)}$ = 1 V	25°C		3.6		V/µs
				0°C		4		
				70°C		3		
			$V_{I(PP)}$ = 2.5 V	25°C		2.9		
				0°C		3.1		
				70°C		2.5		
V_n	Equivalent input noise voltage	f = 1 kHz, R_S = 20 Ω		25°C		25		nV/√Hz
B_{OM}	Maximum output-swing bandwidth	$V_O = V_{OH}$, C_L = 20 pF, R_L = 10 kΩ		25°C		320		kHz
				0°C		340		
				70°C		260		
B_1	Unity-gain bandwidth	V_I = 10 mV, C_L = 20 pF		25°C		1.7		MHz
				0°C		2		
				70°C		1.3		
ϕ_m	Phase margin	V_I = 10 mV, f = B_1, C_L = 20 pF		25°C		46°		
				0°C		47°		
				70°C		44°		

operating characteristics, V_{DD} = 10 V

PARAMETER		TEST CONDITIONS		T_A	TLC251C, TLC251AC, TLC251BC			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L = 10 kΩ, C_L = 20 pF	$V_{I(PP)}$ = 1 V	25°C		5.3		V/µs
				0°C		5.9		
				70°C		4.3		
			$V_{I(PP)}$ = 5.5 V	25°C		4.6		
				0°C		5.1		
				70°C		3.8		
V_n	Equivalent input noise voltage	f = 1 kHz, R_S = 20 Ω		25°C		25		nV/√Hz
B_{OM}	Maximum output-swing bandwidth	$V_O = V_{OH}$, C_L = 20 pF, R_L = 10 kΩ		25°C		200		kHz
				0°C		220		
				70°C		140		
B_1	Unity-gain bandwidth	V_I = 10 mV, C_L = 20 pF		25°C		2.2		MHz
				0°C		2.5		
				70°C		1.8		
ϕ_m	Phase margin	V_I = 10 mV, f = B_1, C_L = 20 pF		25°C		49°		
				0°C		50°		
				70°C		46°		

MEDIUM-BIAS MODE

electrical characteristics at specified free-air temperature

PARAMETER			TEST CONDITIONS	T_A†	TLC251C, TLC251AC, TLC251BC						UNIT
					V_{DD} = 5 V			V_{DD} = 10 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC251C	V_O = 1.4 V, V_{IC} = 0 V, R_S = 50 Ω, R_L = 10 kΩ	25°C		1.1	10		1.1	10	mV
				Full range			12			12	
		TLC251AC		25°C		0.9	5		0.9	5	
				Full range			6.5			6.5	
		TLC251BC		25°C		0.34	2		0.39	2	
				Full range			3			3	
α_{VIO}	Average temperature coefficient of input offset voltage			25°C to 70°C		1.7			2.1		μV/°C
I_{IO}	Input offset current (see Note 4)		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.1	60		0.1	60	pA
				70°C		7	300		7	300	
I_{IB}	Input bias current (see Note 4)		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.6	60		0.7	60	pA
				70°C		40	600		50	600	
V_{ICR}	Common-mode input voltage range (see Note 5)			25°C	–0.2 to 4	–0.3 to 4.2		–0.2 to 9	–0.3 to 9.2		V
				Full range	–0.2 to 3.5			–0.2 to 8.5			V
V_{OH}	High-level output voltage		V_{ID} = 100 mV, R_L = 10 kΩ	25°C	3.2	3.9		8	8.7		V
				0°C	3	3.9		7.8	8.7		
				70°C	3	4		7.8	8.7		
V_{OL}	Low-level output voltage		V_{ID} = –100 mV, I_{OL} = 0	25°C		0	50		0	50	mV
				0°C		0	50		0	50	
				70°C		0	50		0	50	
A_{VD}	Large-signal differential voltage amplification		R_L = 10 kΩ, See Note 6	25°C	25	170		25	275		V/mV
				0°C	15	200		15	320		
				70°C	15	140		15	230		
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}min$	25°C	65	91		65	94		dB
				0°C	60	91		60	94		
				70°C	60	92		60	94		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)		V_{DD} = 5 V to 10 V, V_O = 1.4 V	25°C	70	93		70	93		dB
				0°C	60	92		60	92		
				70°C	60	94		60	94		
$I_{I(SEL)}$	Input current (BIAS SELECT)		$V_{I(SEL)} = V_{DD}/2$	25°C		–130			–160		nA
I_{DD}	Supply current		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	25°C		105	280		143	300	μA
				0°C		125	320		173	400	
				70°C		85	220		110	280	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

MEDIUM-BIAS MODE

operating characteristics, V_{DD} = 5 V

PARAMETER		TEST CONDITIONS		T_A	TLC251C, TLC251AC, TLC251BC MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	R_L = 100 kΩ, C_L = 20 pF	$V_{I(PP)}$ = 1 V	25°C		0.43		V/µs
				0°C		0.46		
				70°C		0.36		
			$V_{I(PP)}$ = 2.5 V	25°C		0.40		
				0°C		0.43		
				70°C		0.34		
V_n	Equivalent input noise voltage	f = 1 kHz, R_S = 20 Ω		25°C		32		nV/√Hz
B_{OM}	Maximum output-swing bandwidth	V_O = V_{OH}, C_L = 20 pF, R_L = 100 kΩ		25°C		55		kHz
				0°C		60		
				70°C		50		
B_1	Unity-gain bandwidth	V_I = 10 mV, C_L = 20 pF		25°C		525		kHz
				0°C		600		
				70°C		400		
ϕ_m	Phase margin	V_I = 10 mV, f = B_1, C_L = 20 pF		25°C		40°		
				0°C		41°		
				70°C		39°		

operating characteristics, V_{DD} = 10 V

PARAMETER		TEST CONDITIONS		T_A	TLC251C, TLC251AC, TLC251BC MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	R_L = 100 kΩ, C_L = 20 pF	$V_{I(PP)}$ = 1 V	25°C		0.62		V/µs
				0°C		0.67		
				70°C		0.51		
			$V_{I(PP)}$ = 5.5 V	25°C		0.56		
				0°C		0.61		
				70°C		0.46		
V_n	Equivalent input noise voltage	f = 1 kHz, R_S = 20 Ω		25°C		32		nV/√Hz
B_{OM}	Maximum output-swing bandwidth	V_O = V_{OH}, C_L = 20 pF, R_L = 100 kΩ		25°C		35		kHz
				0°C		40		
				70°C		30		
B_1	Unity-gain bandwidth	V_I = 10 mV, C_L = 20 pF		25°C		635		kHz
				0°C		710		
				70°C		510		
ϕ_m	Phase margin	V_I = 10 mV, f = B_1, C_L = 20 pF		25°C		43°		
				0°C		44°		
				70°C		42°		

LOW-BIAS MODE

electrical characteristics at specified free-air temperature

PARAMETER			TEST CONDITIONS	T_A†	TLC251C, TLC251AC, TLC251BC						UNIT
					V_{DD} = 5 V			V_{DD} = 10 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC251C	V_O = 1.4 V, V_{IC} = 0 V, R_S = 50 Ω, R_L = 10 MΩ	25°C		1.1	10		1.1	10	mV
				Full range			12			12	
		TLC251AC		25°C		0.9	5		0.9	5	
				Full range			6.5			6.5	
		TLC251BC		25°C		0.24	2		0.26	2	
				Full range			3			3	
α_{VIO}	Average temperature coefficient of input offset voltage			25°C to 70°C		1.1			1		μV/°C
I_{IO}	Input offset current (see Note 4)		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.1	60		0.1	60	pA
				70°C		7	300		7	300	
I_{IB}	Input bias current (see Note 4)		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.6	60		0.7	60	pA
				70°C		40	600		50	600	
V_{ICR}	Common-mode input voltage range (see Note 5)			25°C	–0.2 to 4	–0.3 to 4.2		–0.2 to 9	–0.3 to 9.2		V
				Full range	–0.2 to 3.5			–0.2 to 8.5			V
V_{OH}	High-level output voltage		V_{ID} = 100 mV, R_L = 1 MΩ	25°C	3.2	4.1		8	8.9		V
				0°C	3	4.1		7.8	8.9		
				70°C	3	4.2		7.8	8.9		
V_{OL}	Low-level output voltage		V_{ID} = –100 mV, I_{OL} = 0	25°C		0	50		0	50	mV
				0°C		0	50		0	50	
				70°C		0	50		0	50	
A_{VD}	Large-signal differential voltage amplification		R_L = 1 MΩ, See Note 6	25°C	50	520		50	870		V/mV
				0°C	50	700		50	1030		
				70°C	50	380		50	660		
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}min$	25°C	65	94		65	97		dB
				0°C	60	95		60	97		
				70°C	60	95		60	97		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)		V_{DD} = 5 V to 10 V, V_O = 1.4 V	25°C	70	97		70	97		dB
				0°C	60	97		60	97		
				70°C	60	98		60	98		
$I_{I(SEL)}$	Input current (BIAS SELECT)		$V_{I(SEL)} = V_{DD}$	25°C		65			95		nA
I_{DD}	Supply current		$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	25°C		10	17		14	23	μA
				0°C		12	21		18	33	
				70°C		8	14		11	20	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

LOW-BIAS MODE

operating characteristics, V_{DD} = 5 V

PARAMETER		TEST CONDITIONS		T_A	TLC251C, TLC251AC, TLC251BC MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	R_L = 1 MΩ, C_L = 20 pF	$V_{I(PP)}$ = 1 V	25°C		0.03		V/μs
				0°C		0.04		
				70°C		0.03		
			$V_{I(PP)}$ = 2.5 V	25°C		0.03		
				0°C		0.03		
				70°C		0.02		
V_n	Equivalent input noise voltage	f = 1 kHz, R_S = 20 Ω		25°C		68		nV/√Hz
B_{OM}	Maximum output-swing bandwidth	$V_O = V_{OH}$, C_L = 20 pF, R_L = 1 MΩ		25°C		5		kHz
				0°C		6		
				70°C		4.5		
B_1	Unity-gain bandwidth	V_I = 10 mV, C_L = 20 pF		25°C		85		kHz
				0°C		100		
				70°C		65		
ϕ_m	Phase margin	V_I = 10 mV, f = B_1, C_L = 20 pF		25°C		34°		
				0°C		36°		
				70°C		30°		

operating characteristics, V_{DD} = 10 V

PARAMETER		TEST CONDITIONS		T_A	TLC251C, TLC251AC, TLC251BC MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	R_L = 1 MΩ, C_L = 20 pF	$V_{I(PP)}$ = 1 V	25°C		0.05		V/μs
				0°C		0.05		
				70°C		0.04		
			$V_{I(PP)}$ = 5.5 V	25°C		0.04		
				0°C		0.05		
				70°C		0.04		
V_n	Equivalent input noise voltage	f = 1 kHz, R_S = 20 Ω		25°C		68		nV/√Hz
B_{OM}	Maximum output-swing bandwidth	$V_O = V_{OH}$, C_L = 20 pF, R_L = 1 MΩ		25°C		1		kHz
				0°C		1.3		
				70°C		0.9		
B_1	Unity-gain bandwidth	V_I = 10 mV, C_L = 20 pF		25°C		110		kHz
				0°C		125		
				70°C		90		
ϕ_m	Phase margin	V_I = 10 mV, f = B_1, C_L = 20 pF		25°C		38°		
				0°C		40°		
				70°C		34°		

electrical characteristics at specified free-air temperature, V_{DD} = 1.4 V

PARAMETER			TEST CONDITIONS†	T_A‡	BIAS	TLC251C, TLC251AC, TLC251BC			UNIT
						MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC251C	V_O = 0.2 V, R_S = 50 Ω	25°C	Any			10	mV
				Full range				12	
		TLC251AC		25°C	Any			5	
				Full range				6.5	
		TLC251BC		25°C	Any			2	
				Full range				3	
α_{VIO}	Average temperature coefficient of input offset voltage			25°C to 70°C	Any		1		μV/°C
I_{IO}	Input offset current		V_O = 0.2 V	25°C	Any		1	60	pA
				Full range				300	
I_{IB}	Input bias current		V_O = 0.2 V	25°C	Any		1	60	pA
				Full range				600	
V_{ICR}	Common-mode input voltage range			25°C	Any	0 to 0.2			V
V_{OM}	Peak output voltage swing§		V_{ID} = 100 mV	25°C	Any	450	700		mV
A_{VD}	Large-signal differential voltage amplification		V_O = 100 to 300 mV, R_S = 50 Ω	25°C	Low		20		
					High		10		
CMRR	Common-mode rejection ratio		R_S = 50 Ω, V_O = 0.2 V, $V_{IC} = V_{ICR}min$	25°C	Any	60	77		dB
I_{DD}	Supply current		V_O = 0.2 V, No load	25°C	Low		5	17	μA
					High		150	190	

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following values: for low bias, R_L = 1 MΩ, for medium bias, R_L = 100 kΩ, and for high bias, R_L = 10 kΩ.
‡ Full range is 0°C to 70°C.
§ The output swings to the potential of V_{DD-}/GND.

operating characteristics, V_{DD} = 1.4 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	BIAS	TLC251C, TLC251AC, TLC251BC			UNIT
				MIN	TYP	MAX	
B_1	Unity-gain bandwidth	C_L = 100 pF	Low		12		kHz
			High		12		
SR	Slew rate at unity gain	See Figure 1	Low		0.001		V/μs
			High		0.1		
	Overshoot factor	See Figure 1	Low		35%		
			High		30%		

electrical characteristics, V_{DD} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	TLC251Y HIGH-BIAS MODE			MEDIUM-BIAS MODE			LOW-BIAS MODE			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 1.4 V, V_{IC} = 0 V, R_S = 50 Ω, R_L†		1.1	10		1.1	10		1.1	10	mV
α_{VIO}	Average temperature coefficient of input offset voltage			1.8			1.7			1.1		µV/°C
I_{IO}	Input offset current (see Note 4)	V_O = V_{DD}/2, V_{IC} = V_{DD}/2		0.1	60		0.1	60		0.1	60	pA
I_{IB}	Input bias current (see Note 4)	V_O = V_{DD}/2, V_{IC} = V_{DD}/2		0.6	60		0.6	60		0.6	60	pA
V_{ICR}	Common-mode input voltage range (see Note 5)		–0.2 to 4	–0.3 to 4.2		–0.2 to 4	–0.3 to 4.2		–0.2 to 4	–0.3 to 4.2		V
V_{OH}	High-level output voltage	V_{ID} = 100 mV, R_L†	3.2	3.8		3.2	3.9		3.2	4.1		V
V_{OL}	Low-level output voltage	V_{ID} = –100 mV, I_{OL} = 0		0	50		0	50		0	50	mV
A_{VD}	Large-signal differential voltage amplification	V_O = 0.25 V, R_L†	5	23		25	170		50	480		V/mV
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min	65	80		65	91		65	94		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_{DD} = 5 V to 10 V, V_O = 1.4 V	65	95		70	93		70	97		dB
$I_{I(SEL)}$	Input current (BIAS SELECT)	$V_{I(SEL)}$ = V_{DD}/2		–1.4			–0.13			0.065		µA
I_{DD}	Supply current	V_O = V_{DD}/2, V_{IC} = V_{DD}/2, No load		675	1600		105	280		10	17	µA

† For high-bias mode, R_L = 10 kΩ; for medium-bias mode, R_L = 100 kΩ; and for low-bias mode, R_L = 1 MΩ.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.

operating characteristics, V_{DD} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS		TLC251Y HIGH-BIAS MODE MIN	TYP	MAX	MEDIUM-BIAS MODE MIN	TYP	MAX	LOW-BIAS MODE MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	R_L†, C_L = 20 pF	$V_{I(PP)}$ = 1 V		3.6			0.43			0.03		V/µs
			$V_{I(PP)}$ = 2.5 V		2.9			0.40			0.03		
V_n	Equivalent input noise voltage	f = 1 kHz,	R_S = 20 Ω		25			32			68		nV/√Hz
B_{OM}	Maximum output swing bandwidth	V_O = V_{OH}, R_L = 10 kΩ	C_L = 20 pF,		320			55			4.5		kHz
B_1	Unity-gain bandwidth	V_I = 10 mV,	C_L = 20 pF		1700			525			65		kHz
ϕ_m	Phase margin	f = B_1, C_L = 20 pF	V_I = 10 mV,		46°			40°			34°		

† For high-bias mode, R_L = 10 kΩ; for medium-bias mode, R_L = 100 kΩ; and for low-bias mode, R_L = 1 MΩ.

PARAMETER MEASUREMENT INFORMATION

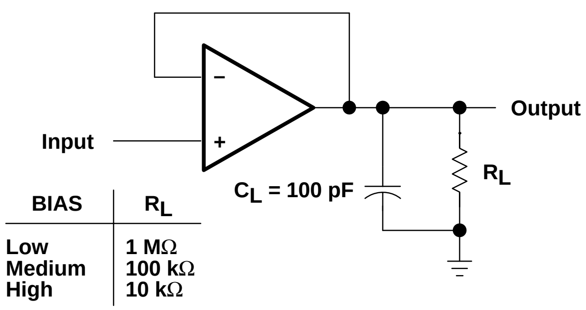


Figure 1. Unity-Gain Amplifier

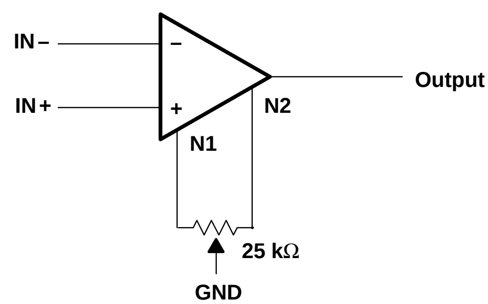


Figure 2. Input Offset Voltage Null Circuit

TYPICAL CHARACTERISTICS

Table of Graphs

				FIGURE
I_{DD}	Supply current		vs Bias-select voltage vs Supply voltage vs Free-air temperature	3 4 5
A_{VD}	Large-signal differential voltage amplification	Low bias	vs Frequency	6
		Medium bias	vs Frequency	7
		High bias	vs Frequency	8
	Phase shift	Low bias	vs Frequency	6
		Medium bias	vs Frequency	7
		High bias	vs Frequency	8

TYPICAL CHARACTERISTICS

SUPPLY CURRENT vs BIAS-SELECT VOLTAGE

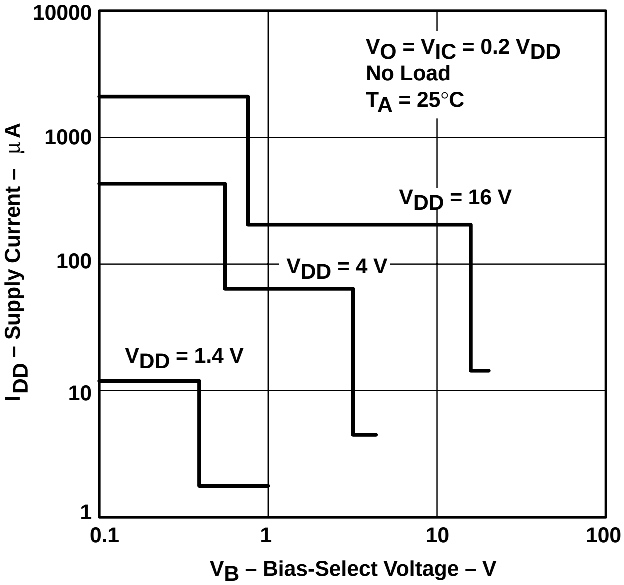


Figure 3

SUPPLY CURRENT vs SUPPLY VOLTAGE

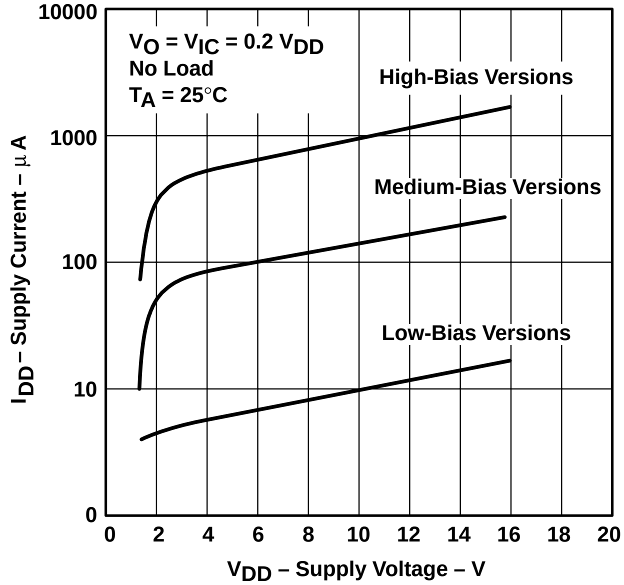


Figure 4

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

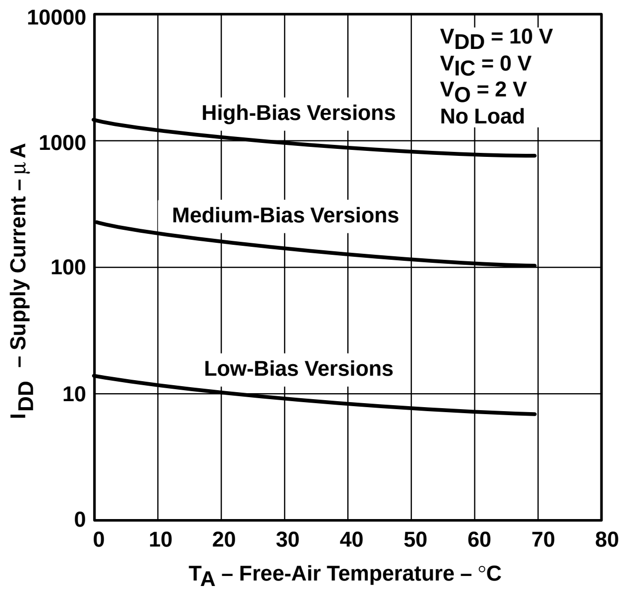


Figure 5

TYPICAL CHARACTERISTICS

LOW-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

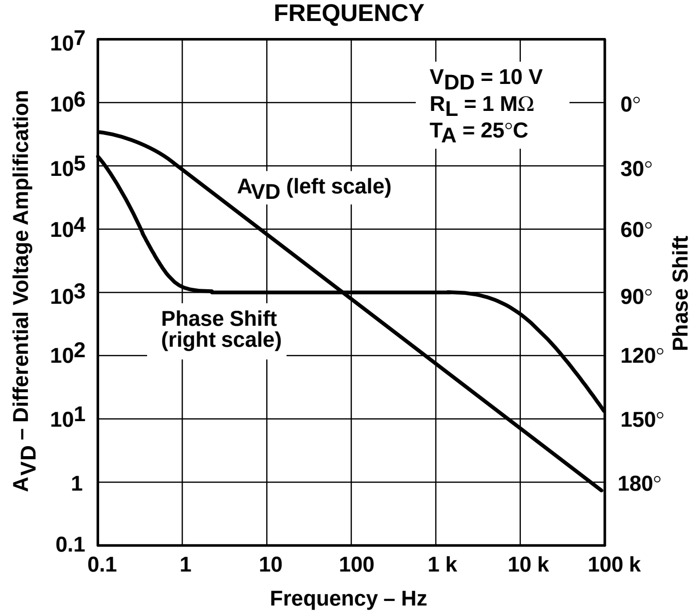


Figure 6

MEDIUM-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

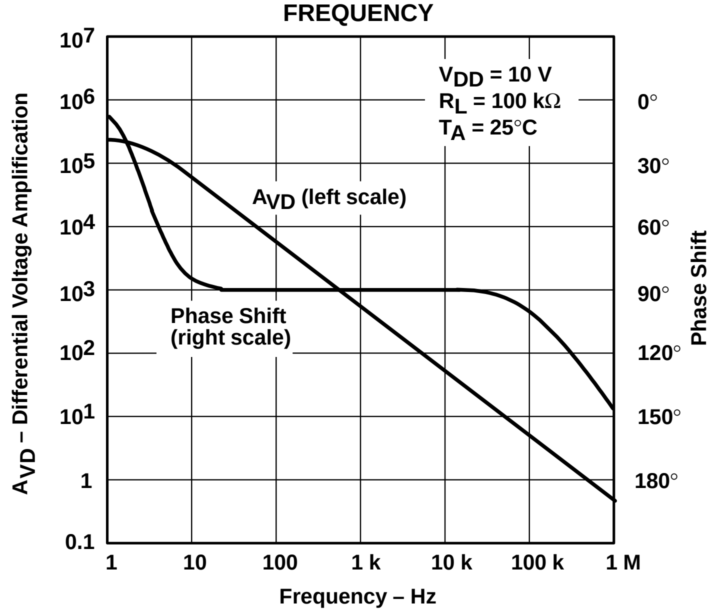


Figure 7

TYPICAL CHARACTERISTICS

HIGH-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

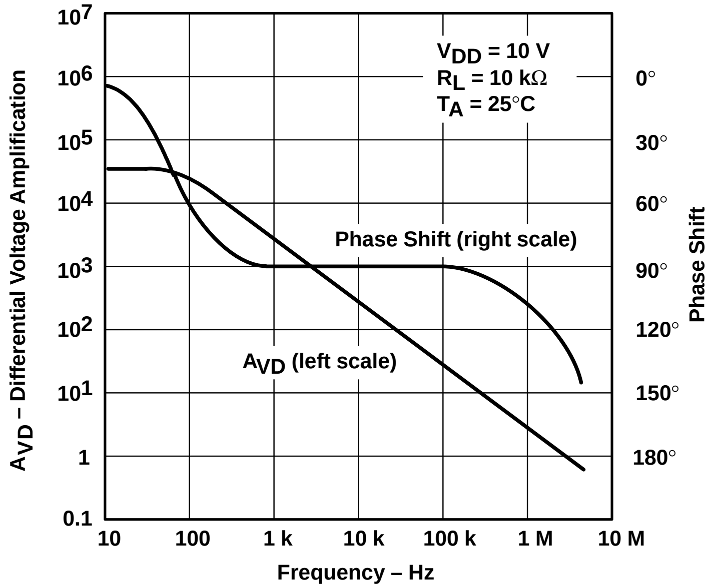


Figure 8

APPLICATION INFORMATION

latch-up avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNPN structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the operational amplifier supplies should be applied simultaneously with, or before, application of any input signals.

APPLICATION INFORMATION

using BIAS SELECT

The TLC251 has a terminal called BIAS SELECT that allows the selection of one of three I_{DD} conditions (10, 150, and 1000 µA typical). This allows the user to trade-off power and ac performance. As shown in the typical supply current (I_{DD}) versus supply voltage (V_{DD}) curves (Figure 4), the I_{DD} varies only slightly from 4 V to 16 V. Below 4 V, the I_{DD} varies more significantly. Note that the I_{DD} values in the medium- and low-bias modes at V_{DD} = 1.4 V are typically 2 µA, and in the high mode are typically 12 µA. The following table shows the recommended BIAS SELECT connections at V_{DD} = 10 V.

BIAS MODE	AC PERFORMANCE	BIAS SELECT CONNECTION†	TYPICAL I_{DD}‡
Low	Low	V_{DD}	10 µA
Medium	Medium	0.8 V to 9.2 V	150 µA
High	High	Ground pin	1000 µA

† Bias selection may also be controlled by external circuitry to conserve power, etc. For information regarding BIAS SELECT, see Figure 3 in the typical characteristics curves.
‡ For I_{DD} characteristics at voltages other than 10 V, see Figure 4 in the typical characteristics curves.

output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage (V_{OH}) is virtually independent of the I_{DD} selection and increases with higher values of V_{DD} and reduced output loading. The low-level output voltage (V_{OL}) decreases with reduced output current and higher input common-mode voltage. With no load, V_{OL} is essentially equal to the potential of V_{DD-}/GND.

input offset nulling

The TLC251C series offers external offset null control. Nulling may be achieved by adjusting a 25-kΩ potentiometer connected between the offset null terminals with the wiper connected to the device V_{DD-}/GND pin as shown in Figure 2. The amount of nulling range varies with the bias selection. At an I_{DD} setting of 1000 µA (high bias), the nulling range allows the maximum offset specified to be trimmed to zero. In low or medium bias or when the amplifier is used below 4 V, total nulling may not be possible for all units.

supply configurations

Even though the TLC251C series is characterized for single-supply operation, it can be used effectively in a split-supply configuration when the input common-mode voltage (V_{ICR}), output swing (V_{OL} and V_{OH}), and supply voltage limits are not exceeded.

circuit layout precautions

The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive dc leakages.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
TLC251ACD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TLC251ACDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TLC251ACP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	
TLC251ACPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	
TLC251BCP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	
TLC251BCPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	
TLC251CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TLC251CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TLC251CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TLC251CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TLC251CP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	
TLC251CPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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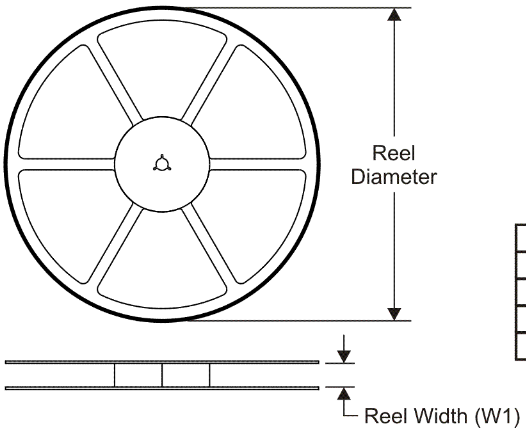
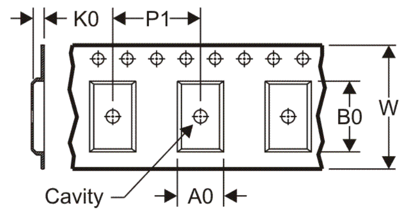
TAPE AND REEL INFORMATION

REEL DIMENSIONS

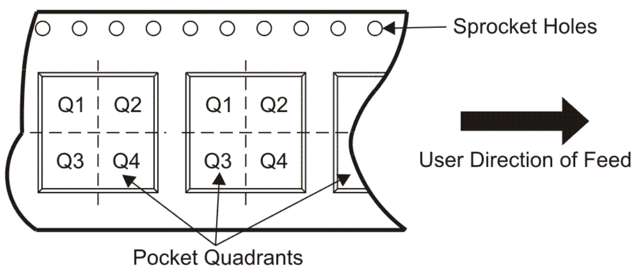


TAPE DIMENSIONS



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

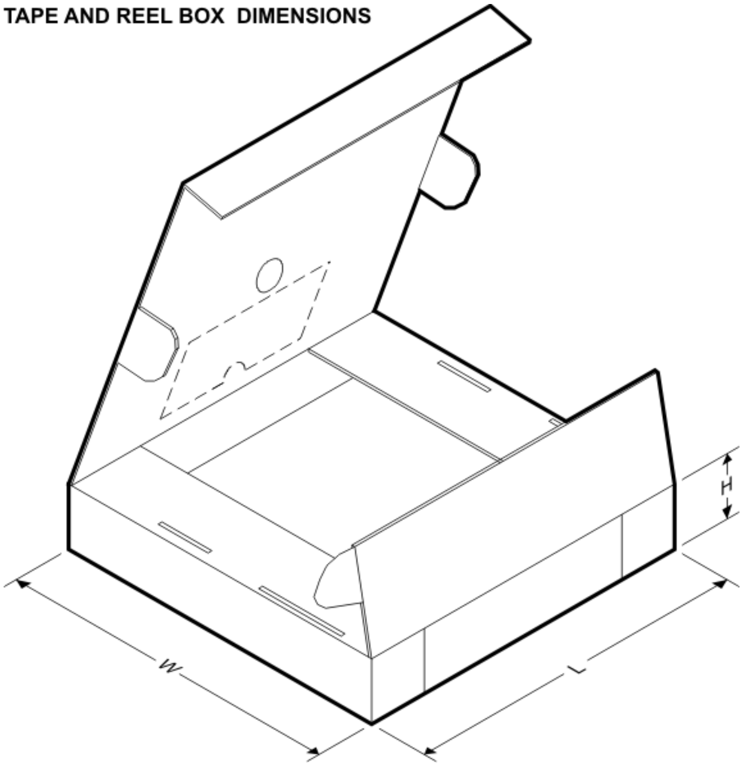
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC251CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC251CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC251CDR	SOIC	D	8	2500	346.0	346.0	29.0
TLC251CDR	SOIC	D	8	2500	340.5	338.1	20.6